bias and accidental errors from inspection of the difference of average values. It shows that bias of each elements expecting Ni and Cu which having a little high values.

Taking these results into consideration, we can judge that the analysis on the vessel are suitable for practical use on the whole.

4-8 Manganese Nodules

Sampling of Manganese nodules using FG and SC was done at a total of 180 sampling points (60 stations). The sampled manganese nodules were measured and observed in many different ways on the vessel. On shore, chemical and mineral analysis was performed on some representative samples.

1) Physical properties (Morphology and granular size - characteristics by external appearance)

(1) Morphology

Classification of manganese nodules morphology is 8 as follows;

1 Spheroidal type

2 Ellipsoidal type

3 Ellipsoidal fat type

4 Pebble thin type

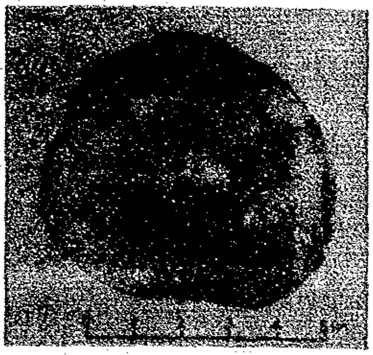
5 Pebble type

6 Massive type

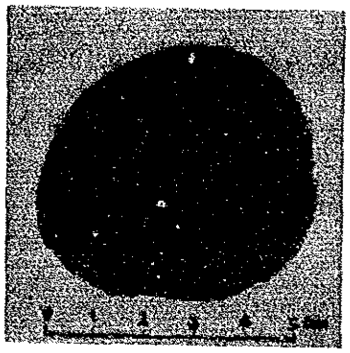
7 Plate type

8 Other type

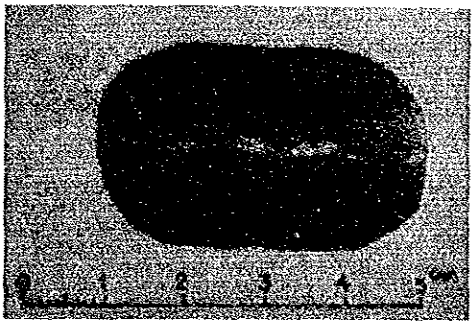
General explanations about each manganese nodule morphology is as follows (cf. Fig. 4-8-1). Tab. 4-8-1 shows physical properties of each morphology.



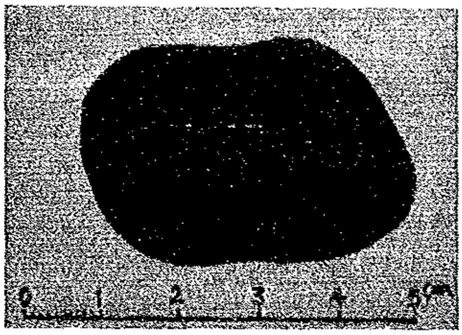
86S1336FG05(Section)
Spheroidal



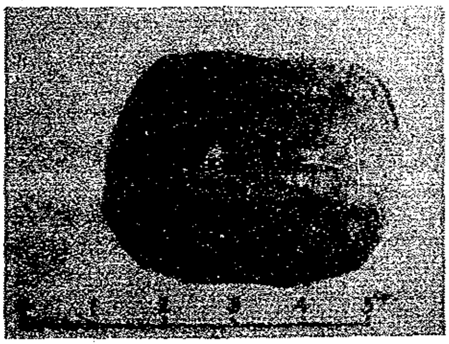
(Upper surface)



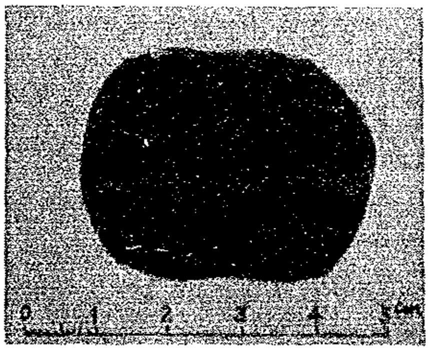
86S1736FG08(Section)
Massive



(Upper surface)

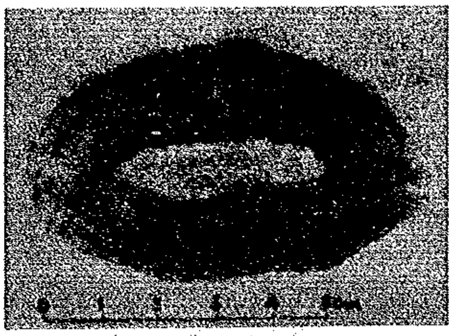


86S1436FG01（断面）
Massive

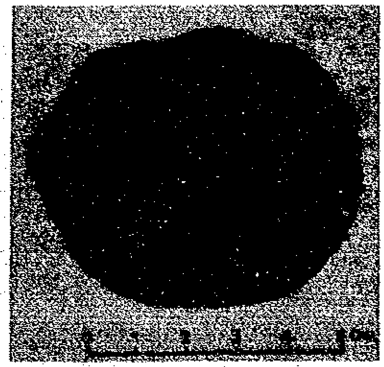


(Upper surface)

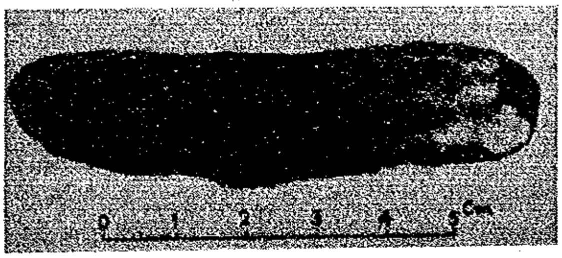
Fig. 4-8-1 Morphology of Manganese Nodules (No. 1)



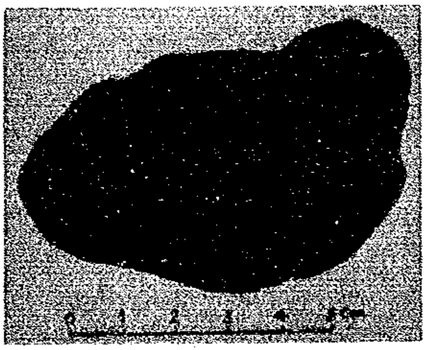
8 6 S 1 7 3 6 F G 0 6 (Section)
Ellipthoidal



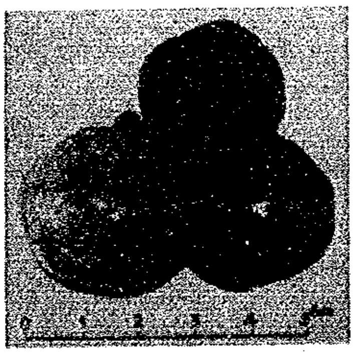
(Lower surface)



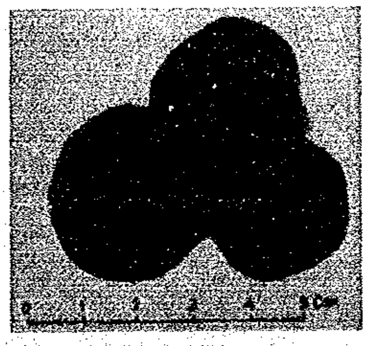
8 6 S 1 5 3 7 F G 0 1(Section)
Platy



(Upper surface)



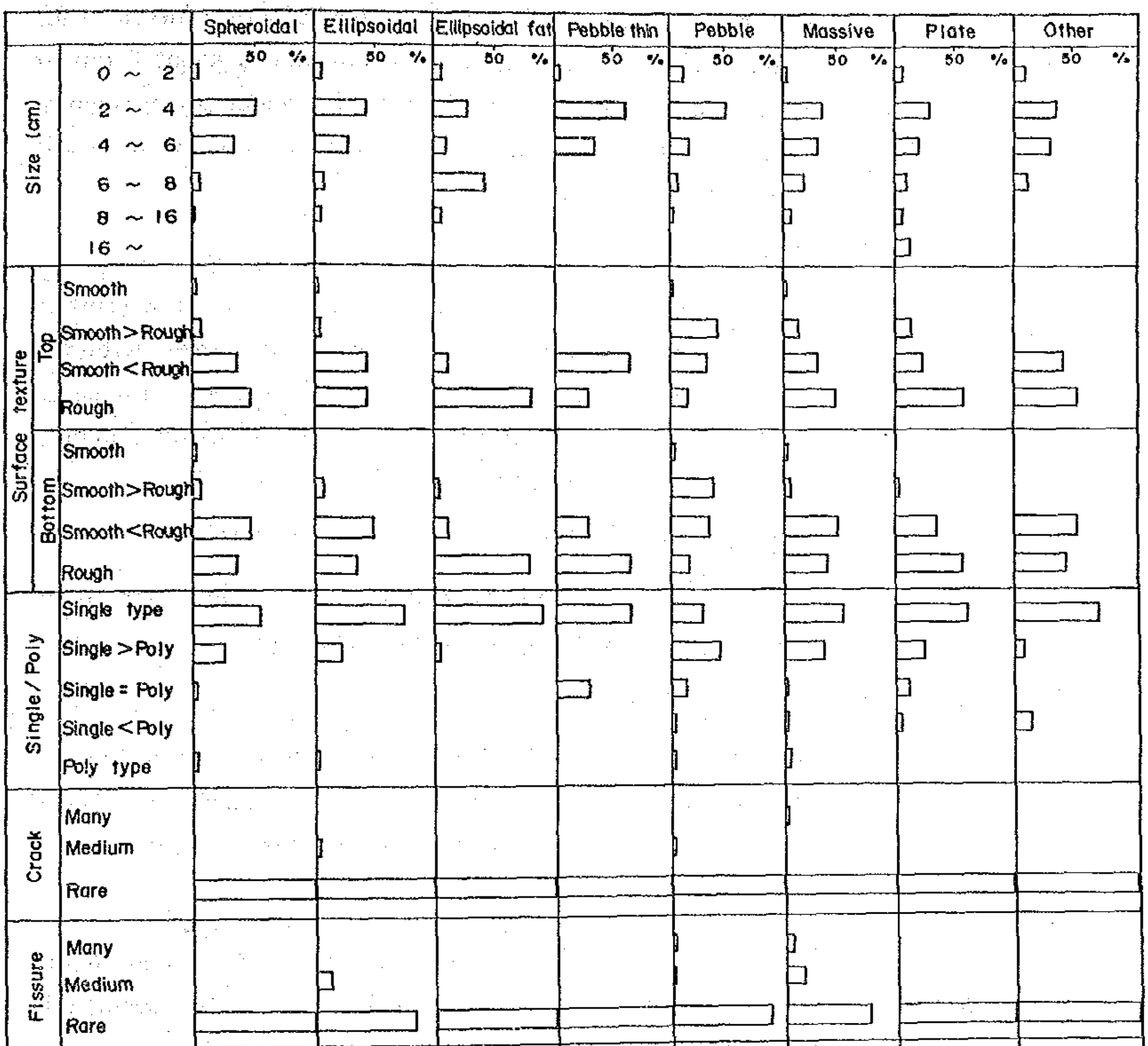
8 6 S 1 1 3 7 F G 0 2(Section)
Poligonal and Spheroidal



(Lower surface)

Fig. 4-8-1 Morphology of Manganese Nodules (No. 2)

Table 4-8-1 Physical Properties Associated with Morphology of Manganese Noduels



		Spheroidal	Ellipsoidal	Ellipsoidal fat	Pebble thin	Pebble	Massive	Plate	Other
Moisture content (%)	Mean	29.61	29.70	29.29	29.50	29.52	28.93	29.99	34.10
	Standard deviation	1.96	1.42	——	2.52	2.03	1.97	3.96	1.25
	Maximum	36.36	36.36	29.29	32.65	31.91	31.43	34.81	34.79
	Minimum	23.40	27.30	29.29	27.27	20.83	6.25	24.30	31.58
Specific gravity (wet)	Mean	1.99	2.00	1.97	1.98	2.01	1.99	2.00	1.97
	Standard deviation	0.04	0.02	——	0.03	0.03	0.05	0.10	0.03
	Maximum	2.13	2.20	1.97	2.00	2.15	2.67	2.12	2.00
	Minimum	1.90	1.98	1.97	1.92	1.97	1.88	1.76	1.93

1 Spheroidal type

The shape of this type is mainly perfect sphere. The diameter is generally less than about 3 - 6 cm and is about 8 cm at maximum. this type has various surface appearance; smooth, rough etc. This is mainly a single type, but combined type is also observed rare as it may be.

2 Ellipsoidal type

This type has a hamburger like external form and a crushed spheroidal form full of fine concaves and convexes, with the rough surface and is mainly manganese nodules with small cracks. Manganese nodules in the surveyed areas have mainly small coated fragments.

3 Ellipsoidal fat type

This type is one of the variations of the spheroidal type and is more irregular and larger than ellipsoidal type.

4 Pebble thin type

This type is usually a small manganese nodule with a thin and round or oval shape like small stones on the sea shore or like a discus with a relatively smooth surface without irregularity.

5 Pebble type

Nodules of this type look like a gravel on shore and on the river bed. Its diameter is mainly 2 - 4 cm. The surface is smoother than the other types.

6 Massive type

This type is similar to the spheroidal and the ellipsoidal thin type, however, the nodules of this type present various shapes such as irregular angular shape and a plate shape and its diameter varies enormously. the surface appearance is also various.

7 Plate type

This type has a relatively rough surface. It is thin and round like a tile or a rice cake. Its size is various.

8 Other type

In this type, are classified small nodules whose shape is difficult to be determined, stick shaped ones etc.

(2) Size distribution

Fig. 4-8-2 shows the size distribution of manganese nodules. This Fig. indicates clearly that there are mainly medium size manganese nodules with 2 - 8 cm in diameter in this area.

(3) Characteristics of outward form

The characteristics of outward form are shown in the Tab. 4-8-1. the overwhelming majority of manganese nodules found in the surveyed areas are spheroidal type and small stone shape and massive shape follow it (Fig. 4-8-2). The surface is various, in general, varying from relatively rough to smooth. It is to be remarked that there are a few cracks or fragmentation. Combinated forms are found in considerable quantities in some places.

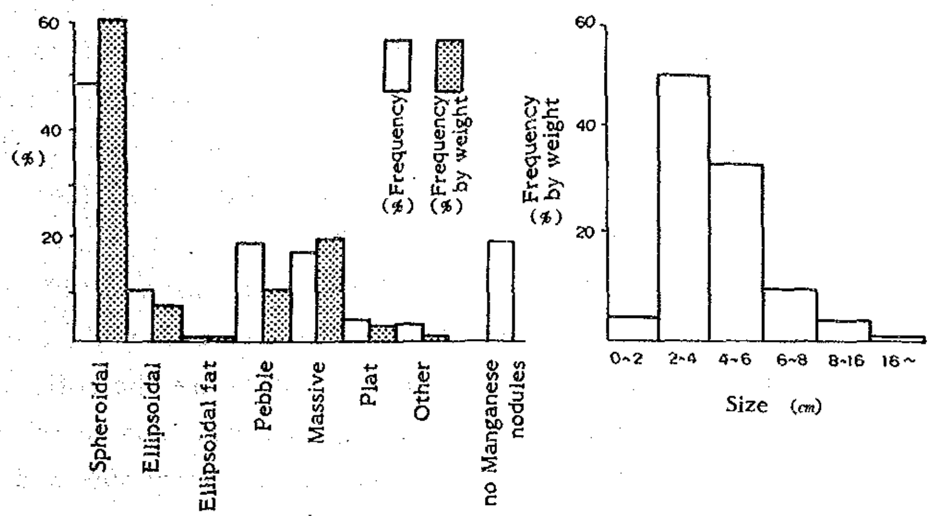


Fig. 4-8-2 Morphology, Size and Sampling Weight of Manganese Nodules

Nodules in this area are classified into S type (smooth surface type) in the ordinary classificaiton although there exists some difference in the smoothness.

2) Chemical properties

(5 principal components and total analysis, minor element analysis, and chemical properties of section)

Fluorescent X-ray analysis for 5 components (Ni, Cu, Co, Mn and Fe) of each category of granular size distribution was done on the vessel. Analysis of accessary components of representative samples selected from the foresaid samples was done on shore. Some manganese nodules were divided into several pieces considering their section structure and each of these pieces was analyzed by fluorescent X-ray. the chemical properties of manganese nodules will be described according to these results. (Statistical consequences should be considered in the light of small number of samples.)

(1) 5 principal components

1 Grade variation of manganese nodules in the surveyed area

Fig. 4-8-3 shows the frequency distribution of the 5 principal components of manganese nodules in the surveyed areas. Fig. 4-8-4 and Tab. 4-8-2 show a scatter diagram of each component and statistics of the average grade of manganese nodules respectively. The weighted averages of Ni, Cu and Co indicate low values; 0.24%, 0.14% and 0.47% respectively, but that of Co is high in comparison with the others. The weighted averages of Mn and Fe are 16.12% and 17.78% respectively, having 0.91 of Mn/Fe ratio based on teh average values. It made clear that surveyed sea area is the area with high Fe content. These average grades are the reflection of the above-mentioned grades of spheroidal and massive type nodules whose volume represents respectively 50% and 15.6% of collected amount.

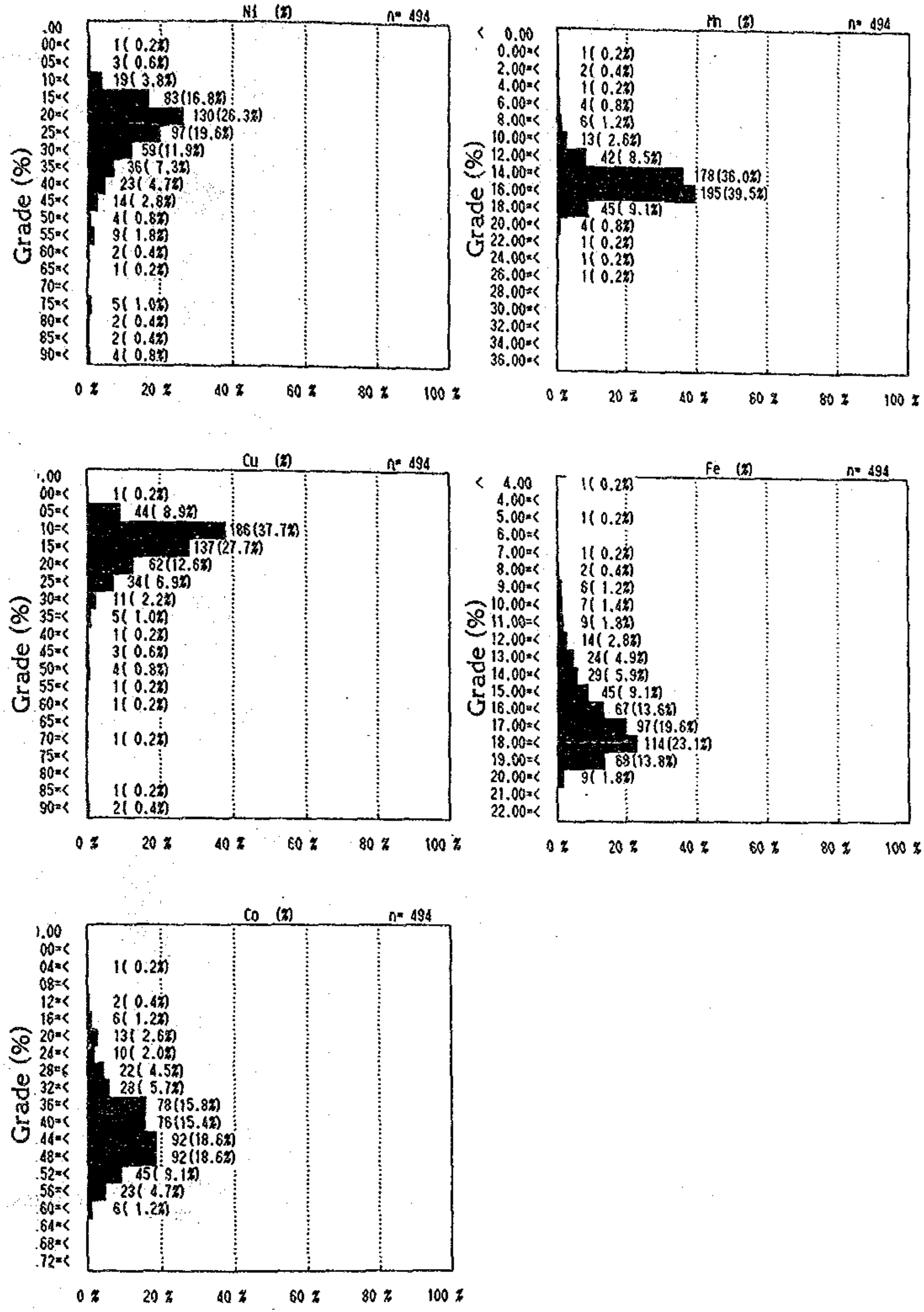
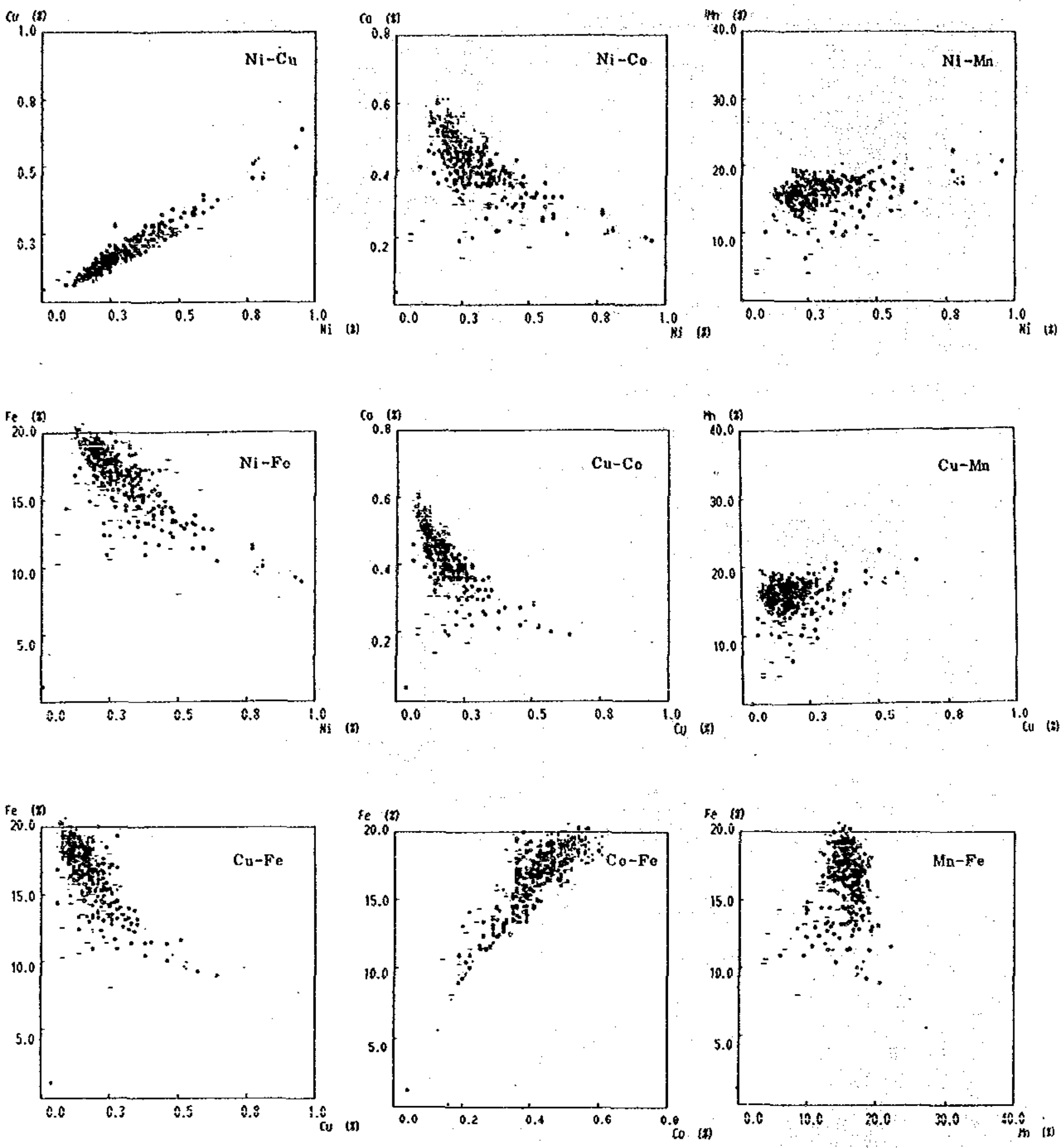


Fig. 4-8-3 Frequency Distribution of 5 Principal Components



Legend · Spheroidal · Ellipsoidal ∘ Ellipsoidal fat · Ellipsoidal pebble ▪ Massive
– Platy – Other

Fig. 4-8-4 Scatter Diagram Among Respective Components

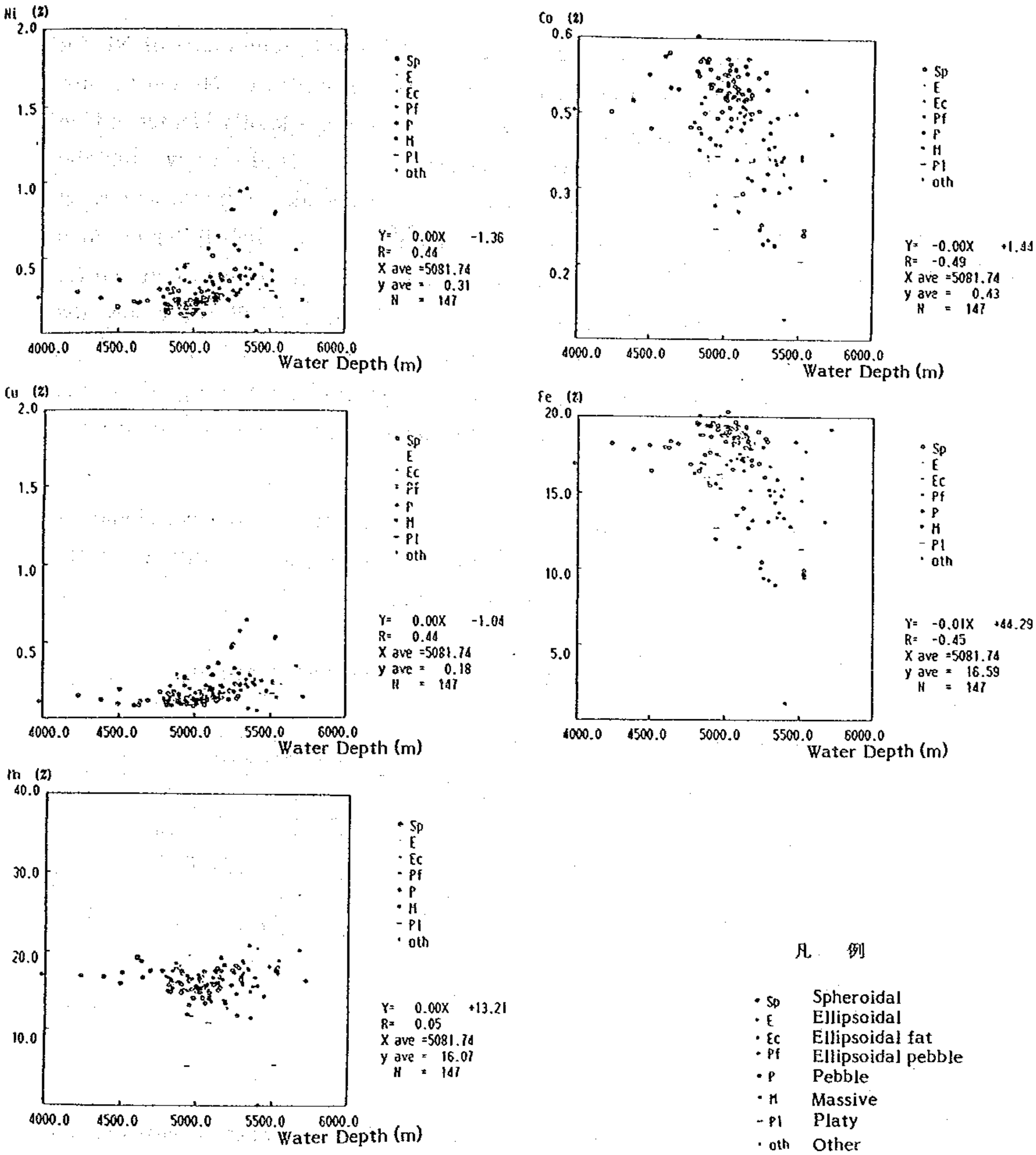


Fig. 4-8-5 Relation between Major Components and Water Depth

Annexed figure 8 - 10 shows the equal-grade chart of Ni, Cu and Co. This figure shows that the grades of Ni and Cu are higher than its average grade in the sea knolls located int he north-western part in the surveyed sea. It also shows that the grades of Ni and Co in the high abundance zone, spreading over the zone between 10°S and 11°S, are slightly higher than the average grades. On the contrary, the grades of Ni and Cu in the high abundance zone of 15°S - 16°30' are below the average grades. The Co grade in the zone of 10°S - 11°S is almost at the level of the average grade, but the grade in the zone of 15°S - 16°30'S shows the heighest value among the surveyed area.

Tab. 4-8-2 shows the correlation coefficient of five elements. It is evident that the correlations are positive within the Ni-Cu-Mn system and Co-Fe system.

Table 4-8-2 Chemical Properties of Manganese Nodules

	Statistics (%)				Correlation coeffucient				
	Average	Standard deviation	Maximum	Minimum	Fe	Mn	Co	Cu	Ni
Ni	0.29	0.14	1.45	0.01	−0.71	0.37	−0.67	0.95	1.00
Cu	0.17	0.11	1.14	0.04	−0.69	0.32	−0.69	1.00	
Co	0.43	0.09	0.62	0.04	0.84	0.28	1.00		
Mn	15.8,1	2.49	27.19	0.00	0.13	1.00			
Fe	16.79	2.53	20.57	1.06	1.00				

It is also evident that the correlation is negative between the former system and the latter system.

Fig. 4-8-5 shows the relation between the grades of five elements and depth of water. the grades of Ni and Cu increase gradually in proportion to the depth of water so far as the level of 5,300 m and decrease under 5,300 m level. The grade of Co and Fe decrease in proportion to the depth of water under 5,000 m level.

2 Grade difference according to the morphology of manganese nodules.

Tab. 4-8-3 shows the grade properties classified by the shape of manganese nodules. The contents are summarized in the following three points.

(a) Spheroidal and ellipsoidal types show a similar tendency of grades. Ni and Cu are low relatively, Co and Fe are high. The Cu/Ni ratio and Mn/Fe ratio are low.

(b) Ellipsoidal fat, pebble and massive type nodules have similar tendency, namely Ni and Cu are high, Co is low and, Cu/Ni and Mn/Fe ratio are high. this is the reverse tendency of (a).

(c) The plate type is a little different from (a) and (b); Ni and Cu are medium level; Co, Mn and Fe are low.

3 Grade difference according to grain size of manganese nodules (Tab. 4-8-4)

An evident tendency is observed that the grades of Ni and Cu and the ratio of Mn/Fe are getting higher as the granular size is becoming smaller. It is observed that the grdes of Co, Mn and Fe are high in the medium sized nodules (4 - 6 cm).

4 Grade difference according to topography (Tab. 4-8-5)

The grade of Ni and Cu are low and sea knolls, while the grades of Co, Mn and Fe are high in the flat area. On the other hand, Ni grade and Cu grade are high and Cu grade, Mn grade and Fe grade are low in the channel. All the elements show medium grades in platforms and sea knolls.

Table 4-8-3 Morphology and Chemical Properties of Manganese Nodules

Morphology	n	Ni (%)				Cu (%)				Co (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
Spheroidal	165	0.25	0.14	1.45	0.12	0.14	0.11	1.14	0.07	0.48	0.07	0.61	0.13
Ellipsoidal	58	0.28	0.17	0.91	0.11	0.19	0.17	0.94	0.06	0.43	0.10	0.62	0.17
Ellipsoidal fat	21	0.23	0.08	0.48	0.14	0.13	0.04	0.25	0.08	0.47	0.07	0.60	0.34
Pebble thin	2	0.31	0.10	0.38	0.24	0.19	0.06	0.23	0.14	0.31	0.02	0.32	0.29
Pebble	132	0.34	0.15	0.95	0.09	0.33	0.09	0.64	0.06	0.38	0.07	0.52	0.19
Massive	76	0.27	0.08	0.51	0.01	0.16	0.05	0.31	0.04	0.43	0.09	0.57	0.04
Plate	30	0.30	0.13	0.58	0.06	0.18	0.06	0.27	0.08	0.33	0.09	0.51	0.14
Other	10	0.34	0.09	0.47	0.23	0.20	0.05	0.29	0.14	0.37	0.05	0.45	0.29

Morphology	n	Mn (%)				Fe (%)				Cu/Ni ratio	Mn/Fe ratio
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum		
Spheroidal	165	16.48	1.48	27.19	13.44	18.09	1.94	20.57	5.61	0.57	0.94
Ellipsoidal	58	16.00	2.44	24.96	7.68	16.67	2.69	19.98	7.77	0.63	1.01
Ellipsoidal fat	21	15.89	1.94	19.11	11.88	17.19	1.76	19.30	12.39	0.56	0.93
Pebble thin	2	15.94	4.53	19.14	12.74	13.76	2.78	15.72	11.79	0.59	1.15
Pebble	132	15.51	2.19	22.13	6.16	15.86	2.51	20.00	8.90	0.64	1.01
Massive	76	16.03	2.82	19.60	0.00	16.41	2.51	20.21	1.06	0.63	0.97
Plate	30	12.43	4.31	17.83	3.74	15.10	2.65	19.18	8.11	0.66	0.81
Other	10	15.85	2.77	20.26	11.98	16.01	2.08	18.63	11.34	0.60	1.01

Table 4-8-4 Size and Chemical Properties of Manganese Nodules

Size (cm)	n	Ni (%)				Cu (%)				Co (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
0 – 2	126	0.36	0.20	1.45	0.10	0.24	0.14	1.14	0.06	0.38	0.08	0.50	0.13
2 – 4	135	0.28	0.13	0.91	0.06	0.17	0.09	0.88	0.06	0.44	0.08	0.61	0.17
4 – 6	126	0.25	0.10	0.87	0.01	0.15	0.09	0.94	0.04	0.46	0.09	0.61	0.04
6 – 8	79	0.24	0.08	0.58	0.06	0.14	0.05	0.29	0.06	0.45	0.08	0.62	0.19
8 – 16	26	0.25	0.06	0.36	0.13	0.15	0.05	0.29	0.09	0.41	0.10	0.56	0.14
16 –	2	0.19	0.09	0.25	0.13	0.12	0.05	0.15	0.08	0.40	0.14	0.50	0.30

Size (cm)	n	Mn (%)				Fe (%)				Cu/Ni ratio	Mn/Fe ratio
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum		
0 – 2	126	15.48	2.48	27.19	6.05	15.82	2.88	19.29	5.61	0.67	1.04
2 – 4	135	16.09	2.16	21.77	4.33	17.37	2.38	20.57	8.11	0.59	0.95
4 – 6	126	16.21	2.47	24.96	0.00	17.27	2.48	20.21	1.06	0.60	0.95
6 – 8	79	15.85	2.45	19.50	3.74	17.03	1.74	19.81	10.23	0.59	0.94
8 – 16	26	14.24	3.38	19.11	3.91	15.47	2.09	19.98	10.61	0.60	0.92
16 –	2	11.56	0.30	11.77	11.35	14.86	1.91	16.21	13.51	0.61	0.78

Table 4-8-5 Sea Floor Topography and Chemical Properties of Manganese Nodules

Topography	n	Ni (%)				Cu (%)				Co (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
Flat	93	0.23	0.07	0.95	0.13	0.13	0.05	0.88	0.08	0.48	0.06	0.61	0.19
Hollow	2	0.43	0.00	1.45	0.11	0.32	0.00	1.14	0.06	0.37	0.00	0.44	0.13
Platform	9	0.32	0.08	0.55	0.01	0.18	0.05	0.33	0.04	0.42	0.07	0.51	0.04
Knoll	16	0.28	0.08	0.54	0.10	0.17	0.05	0.29	0.08	0.42	0.08	0.53	0.16
Sea-mount	4	0.25	0.06	0.35	0.20	0.13	0.04	0.19	0.08	0.48	0.06	0.56	0.42

Topography	n	Mn (%)				Fe (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
Flat	93	15.91	1.39	22.16	10.87	18.14	1.57	20.28	8.90
Hollow	2	15.18	0.00	27.19	11.47	13.43	0.00	15.85	5.61
Platform	9	16.78	1.86	20.26	0.00	15.87	1.94	17.66	1.06
Knoll	16	16.54	3.03	18.87	5.16	16.63	1.93	19.95	11.34
Sea-mount	4	17.76	1.00	19.28	16.75	17.42	0.83	18.37	16.40

5 Grade difference according to bottom materials (Tab. 4-8-6)

The grade of Ni and Cu are low while the grades of Co, Mn and Fe are comparatively high in brown clay, calcareous - siliceous clay and faraminifera ooze.

On the other hand, every element except Mn has reverse tendency in siliceous clay and insoluble brown clay mentioned above.

(2) Auxiliary components

Total analysis and minor element analysis were done on 4 samples selected from samples used for the 5 principal components analysis on the vessel, considering its shapes, sea bottom topography and areas, in order to investigate the auxiliary componet properties of manganese nodules. Tab. 4-8-7 shows both the total and small quantity analysis values along with the 5 principal components values analyzed on the vessel. The SiO_2, TiO_2, Al_2O_3, CaO, K_2O, Pb, V, B and Y components of manganese nodules in the surveyed areas have a higher grade than the average grade (*1) in the Clarion-Clipperton Prime area by Mckelvey et al (1979). On the contrary, MgO_2, BaO, Na_2O, P_2O_5, Sr, Mo and Zn have a lower grade than the average grade in the Clarion-Clipperton Prime area.

(*1) Si 7.81%, Ti 0.61%, Al 2.84%, Mg 1.80%, Ca 1.47%, Ba 0.32%, Na 1.87%, K_2O 82%, P 0.32%, Pb 0.048%, Sr 0.066%, Mo 0.048%, V 0.03%, B 0.016%, Zn 0.13%, Y 0.01%

Table 4-8-6 Bottom Sediments and Chemical Properties of Manganese Nodules

Sediment	n	Ni (%)				Cu (%)				Co (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
Brown clay	82	0.25	0.09	1.45	0.01	0.15	0.05	1.14	0.04	0.46	0.07	0.56	0.04
Siliceous clay	1	0.37	—	—	—	0.25	—	—	—	0.33	—	—	—
Calc-siliceous clay	23	0.22	0.06	0.58	0.10	0.13	0.04	0.33	0.81	0.46	0.07	0.56	0.19
Foraminifera ooze	9	0.24	0.07	0.35	0.15	0.14	0.04	0.20	0.08	0.49	0.06	0.61	0.41
Sticky brown clay	3	0.79	0.00	0.79	0.78	0.53	0.00	0.53	0.52	0.21	0.00	0.22	0.21

Sediment	n	Mn (%)				Fe (%)			
		Average	Standard deviation	Maximum	Minimum	Average	Standard deviation	Maximum	Minimum
Brown clay	82	15.98	1.55	27.19	0.00	17.69	1.84	20.28	1.06
Siliceous clay	1	20.20	—	—	—	15.18	—	—	—
Calc-siliceous	23	15.75	2.21	18.16	5.16	17.94	1.83	20.04	9.37
Foraminifera ooze	9	16.98	1.09	18.52	14.91	17.88	1.20	19.59	16.40
Sticky brown clay	3	17.58	0.00	18.09	17.23	9.68	0.00	9.93	9.47

Table 4-8-7 Chemical Composition of Manganese Nodules

	Sampling No.	86S1137FG03	86S1636FG02	86S1537FG02	86S1735FG09
Topography		(Hilly) Flat	(Quasi-Plain) Flat	(Plain) Flat	(Quasi-Plain) Knoll
Depth (m)		5132	4962	5183	4498
Morphology		Ellipsoidal fat	Plate	Plate	Spheroidal
Size (cm)		8 – 16	16–	6 – 8	6 – 8
Analysis (%)	Ni	0.25	0.13	0.26	0.17
	Cu	0.15	0.08	0.16	0.09
	Co	0.44	0.50	0.35	0.53
	Mn	17.51	11.77	13.87	15.90
	Fe	16.42	16.21	17.87	18.08
Major elements (%)	SiO_2	15.74	22.98	23.34	13.62
	TiO_2	1.56	1.99	1.90	2.18
	Al_2O_3	4.68	6.83	6.24	4.10
	Fe_2O_3	20.56	22.30	21.39	25.41
	FeO	<0.05	<0.05	<0.05	<0.05
	MnO_2	21.98	17.54	17.53	23.42
	MgO	2.22	2.66	3.04	2.21
	CaO	2.56	2.03	1.94	2.72
	BaO	0.12	0.10	0.10	0.14
	Na_2O	2.61	2.28	2.28	2.17
	K_2O	1.24	1.58	1.77	0.94
	P_2O_5	0.46	0.42	0.40	0.54
	Ig–loss	22.03	17.73	17.34	19.52
Minor elements (%)	Pb	0.096	0.103	0.084	0.123
	Sr	0.024	0.018	0.018	0.029
	Mo	0.022	0.016	0.012	0.022
	V	0.047	0.043	0.044	0.056
	As	0.015	0.015	0.013	0.018
	B	0.039	0.045	0.042	0.047
	Zn	0.043	0.041	0.047	0.050
	Y	0.015	0.013	0.012	0.018
	Pt	<0.0001	<0.0001	<0.0001	<0.0001

The plate shape nodules of 86S1636FG02 and 86S1537FG02 are remarkably higher in SiO_2 and Al_2O_3. The reason for the higher grade of SiO_2 and Al_2O_3 might be that relatively large externeous materials (such as rock fragments) are contained. the above mentioned results approximately correspond to the results of SOPAC Investigation of 1985. they are considered to represent the area characteristics of the present surveyed area.

(3) Chemical properties variation in section of manganese nodules

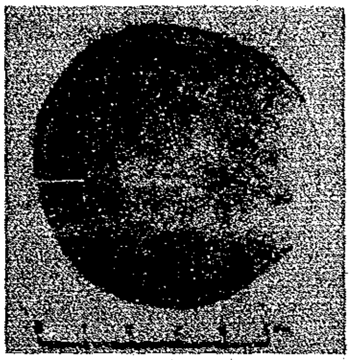
It is useful to investigate the chemical properties (distribution of metal elements) of the sectional surface of the manganese nodules in order to understand the grade variation according to the above mentioned factors (shape, granular size, topography and bottom materials etc.) and to elucidate for solution to historical process, especially its relation to sedimentation, of the growth of manganese nodules. (Akira Nishimura 1986).

Representative samples of spheroidal type, massive type, plate type and ellipsoidal type nodules were selected. Fluorescent X-ray analysis on these samples were carried out about the five principal elements on the surveying vessel. The samples, for analysis, separated into groups of severed layers by the naked eyes, were collected by a hand picking method using a small chisel.

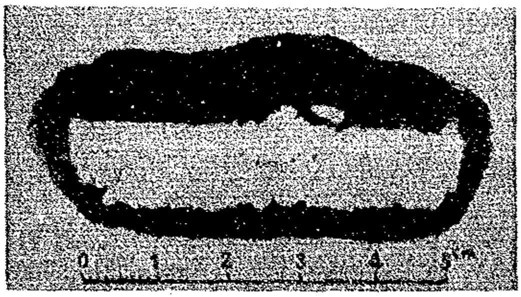
Fig. 4-8-6 and Fig. 4-8-7 show the sampling positions. Tab. 4-8-8, Tab. 4-8-9, Fig. 4-8-8 and Fig. 4-8-9 show the results of analyses.

1 The distinct elementary distribution considered as typical one is observed on the surface of the section of spheroidal nodules having the zonal structure wih perfect concentrical circles. The other shapes of nodules show a little disordered distribution though having the same tendency with the spheroidal nodules.

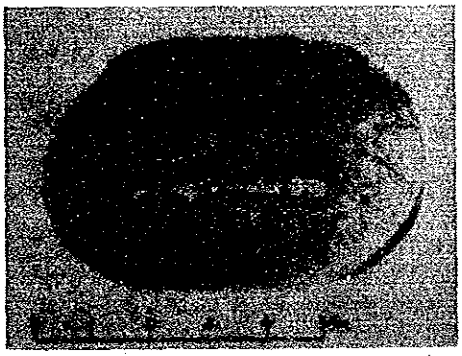
2 It is the most remarkable point in the elementary distribution that Fe grade decreases and Ni grade increases in proportion to progress from the exterior to the center of the nodules.



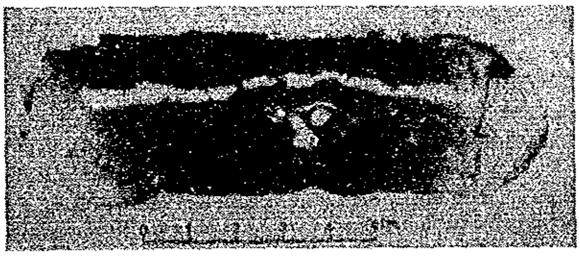
86S1735FG09
Spheroidal



86S1537FG02
Platy



86S1636FG07
Massive



86S1137FG03
Ellipsoidal

Fig. 4-8-6 Photos of Manganese Nodules Used for Section Analysis

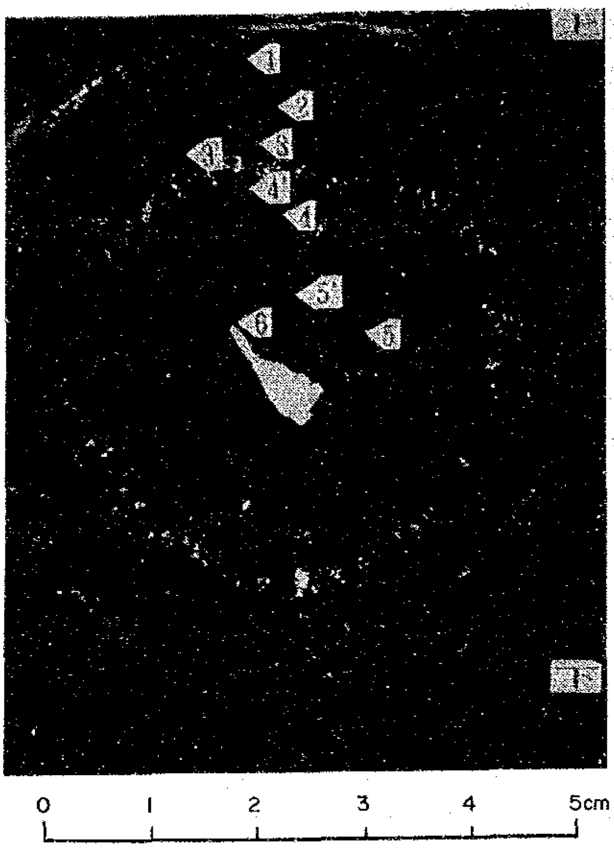
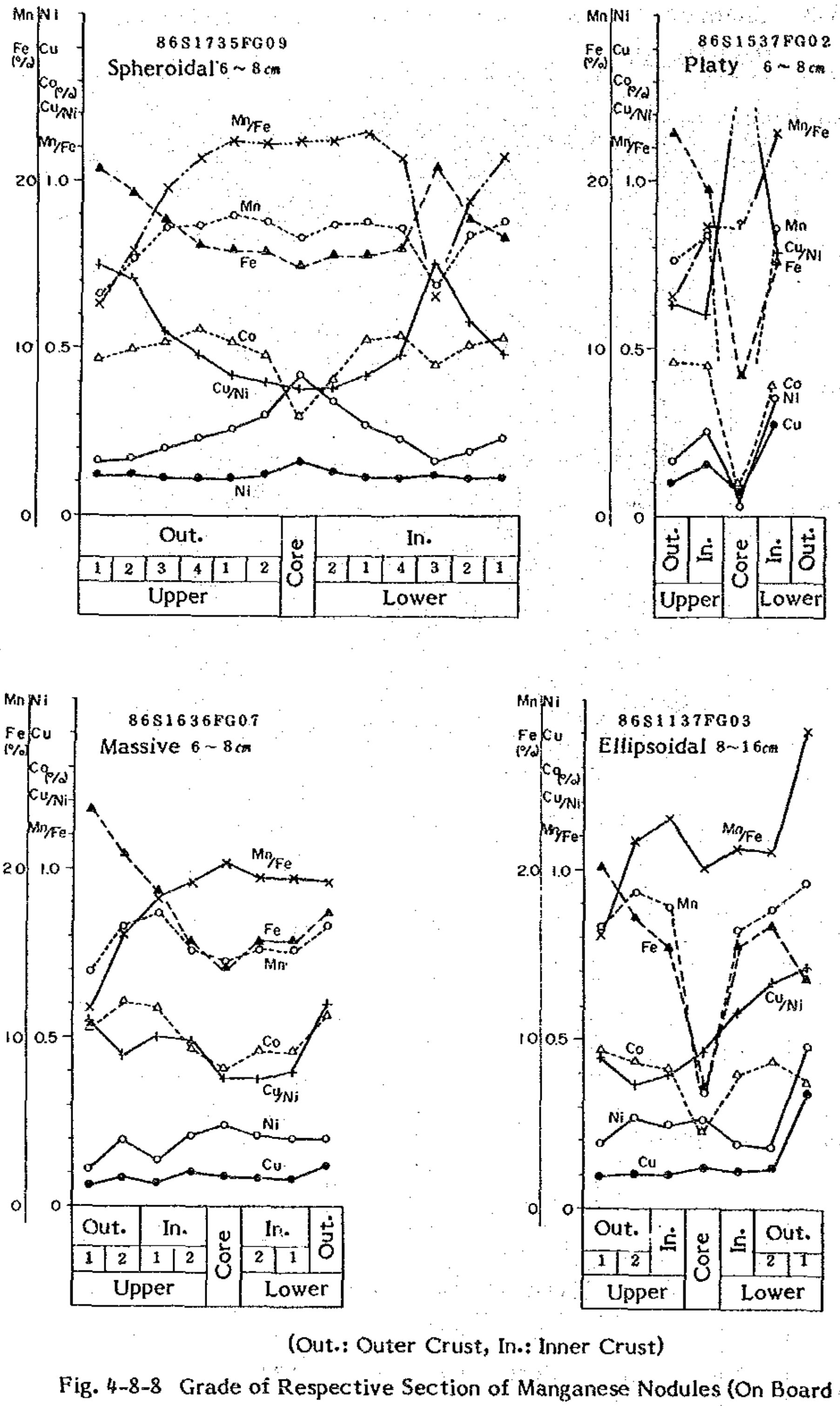


Fig. 4-8-7 Photos of Manganese Nodules Used for EPMA Analysis

Table 4-8-8 Chemical Compositional Difference between Surface and Inner Part Nodules

Sample No.	Size (cm)	Morphology	Analysed position		XRF Analyses (%)					Cu/Ni	Mn/Fe
					Ni	Cu	Co	Mn	Fe		
86S 1735FG09	6−8	Spheroidal	Upper	Out. 1	0.16	0.12	0.47	13.11	20.76	0.75	0.63
				Out. 2	0.17	0.12	0.50	15.29	19.26	0.71	0.79
				Out. 3	0.20	0.11	0.52	17.21	17.54	0.55	0.98
				Out. 4	0.23	0.11	0.56	17.31	16.13	0.48	1.07
				In. 1	0.26	0.11	0.52	17.93	15.99	0.42	1.12
				In. 2	0.30	0.12	0.48	17.50	15.74	0.40	1.11
			Core		0.42	0.16	0.30	16.60	14.84	0.38	1.12
			Lower	In. 2	0.34	0.13	0.41	17.37	15.50	0.38	1.12
				In. 1	0.27	0.11	0.53	17.55	15.42	0.41	1.14
				Out. 4	0.23	0.11	0.54	17.05	15.95	0.48	1.07
				Out. 3	0.16	0.12	0.45	13.69	20.98	0.75	0.65
				Out. 2	0.19	0.11	0.51	16.66	17.75	0.58	0.94
				Out. 1	0.23	0.11	0.53	17.58	16.46	0.48	1.07
86S 1636FG07	6−8	Massive	Upper	Out. 1	0.11	0.06	0.53	13.94	23.46	0.55	0.59
				Out. 2	0.20	0.09	0.61	16.54	20.42	0.45	0.81
				In. 1	0.14	0.07	0.59	17.24	18.64	0.50	0.92
				In. 2	0.21	0.10	0.47	15.08	15.70	0.48	0.96
			Core		0.24	0.09	0.41	14.43	14.25	0.38	1.01
			Lower	In. 2	0.21	0.08	0.46	15.20	15.69	0.38	0.97
				In. 1	0.20	0.08	0.46	15.17	15.66	0.40	0.97
				Out.	0.20	0.12	0.57	16.55	17.28	0.60	0.96
86S 1537FG02	6−8	Plate	Upper	Out.	0.16	0.10	0.46	14.61	22.86	0.63	0.64
				In.	0.25	0.15	0.45	16.75	19.50	0.60	0.86
			Core		0.03	0.07	0.07	Tr	8.36	2.33	−
			Lower	In.	0.35	0.27	0.39	17.16	15.09	0.77	1.14
				Out.	−	−	−	−	−	−	−
86G 1137FG03	8−16	Ellipsoidal	Upper	Out. 1	0.19	0.09	0.47	16.24	20.10	0.47	0.81
				Out. 2	0.27	0.10	0.44	18.67	17.19	0.37	1.09
				In.	0.25	0.10	0.42	17.81	15.41	0.40	1.16
			Core		0.26	0.12	0.23	6.86	6.89	0.46	1.00
			Lower	In.	0.19	0.11	0.40	16.37	15.42	0.58	1.06
				Out. 2	0.18	0.12	0.44	17.63	16.65	0.67	1.06
				Out. 1	0.48	0.34	0.37	19.11	13.52	0.71	1.41

(Out.: Outer crust, In.: Inner Crust)



(Out.: Outer Crust, In.: Inner Crust)

Fig. 4-8-8 Grade of Respective Section of Manganese Nodules (On Board Analysis)

Table 4-8-9 Results of EPMA Analysis of the Manganese Nodules

(wt %)

	Outer crust 1				Outer crust 2				Outer crust 3							Outer crust 4				
	1−1	1−2	1−3	Aver.	2−1	2−2	2−3	Aver.	3′−1	3′−2	Aver.	3−1	3−2	3−3	Aver.	4′−1	4−1	4−2	4−3	Aver.
Ni	0.160	1.406	1.648	1.071	0.263	0.163	0.151	0.192	0.176	0.462	0.319	0.194	0.277	0.366	0.279	0.352	0.426	0.365	0.299	0.363
Cu	0.066	0.293	0.419	0.259	0.099	0.142	0.126	0.122	0.145	0.117	0.131	0.158	0.114	0.125	0.132	0.093	0.113	0.093	0.078	0.095
Co	0.649	0.353	0.268	0.423	0.791	0.243	0.289	0.041	0.283	0.818	0.551	0.299	1.024	0.902	0.742	0.642	0.624	0.477	0.647	0.583
Mn	18.804	27.867	30.008	25.560	23.088	20.710	20.223	21.340	19.434	22.598	21.026	21.211	24.075	23.815	23.034	22.610	24.511	23.693	21.298	23.167
Fe	13.822	8.813	6.909	9.848	13.072	18.065	19.230	16.789	17.303	10.158	13.731	17.183	14.026	10.471	13.893	10.582	10.272	12.847	13.338	12.152
Total	33.501	38.732	39.252	37.161	37.313	39.323	40.019	38.884	37.341	34.153	35.748	39.045	39.516	35.679	38.080	34.279	35.946	37.475	35.660	36.360

(wt %)

	Inner crust 1							Inner crust 2							
	5′−1	5′−2	Aver.	5−1	5−2	5−3	Aver.	6-1-1	6-1-2	6-1-3	6-2-1	6-2-2	6-3-1	6-3-2	Aver.
Ni	0.605	0.411	0.508	0.039	0.141	1.176	0.452	0.562	0.777	1.228	0.303	0.356	0.780	0.826	0.690
Cu	0.127	0.149	0.138	0.231	0.046	0.600	0.292	0.156	0.220	0.326	0.118	0.123	0.199	0.202	0.192
Co	0.296	0.330	0.313	0.052	0.212	0.136	0.133	0.000	0.000	0.281	0.369	0.006	0.580	0.313	0.221
Mn	26.237	24.927	25.582	1.345	12.846	22.293	12.161	19.708	19.339	20.876	19.739	19.317	23.870	23.723	20.939
Fe	9.052	12.231	10.642	39.048	18.476	10.234	22.586	15.726	13.237	10.792	12.042	12.830	9.954	9.244	11.975
Total	36.317	38.048	37.183	40.715	31.721	34.439	35.624	36.152	33.573	33.503	32.571	32.632	35.383	34.308	34.017

(Aver.: Average)

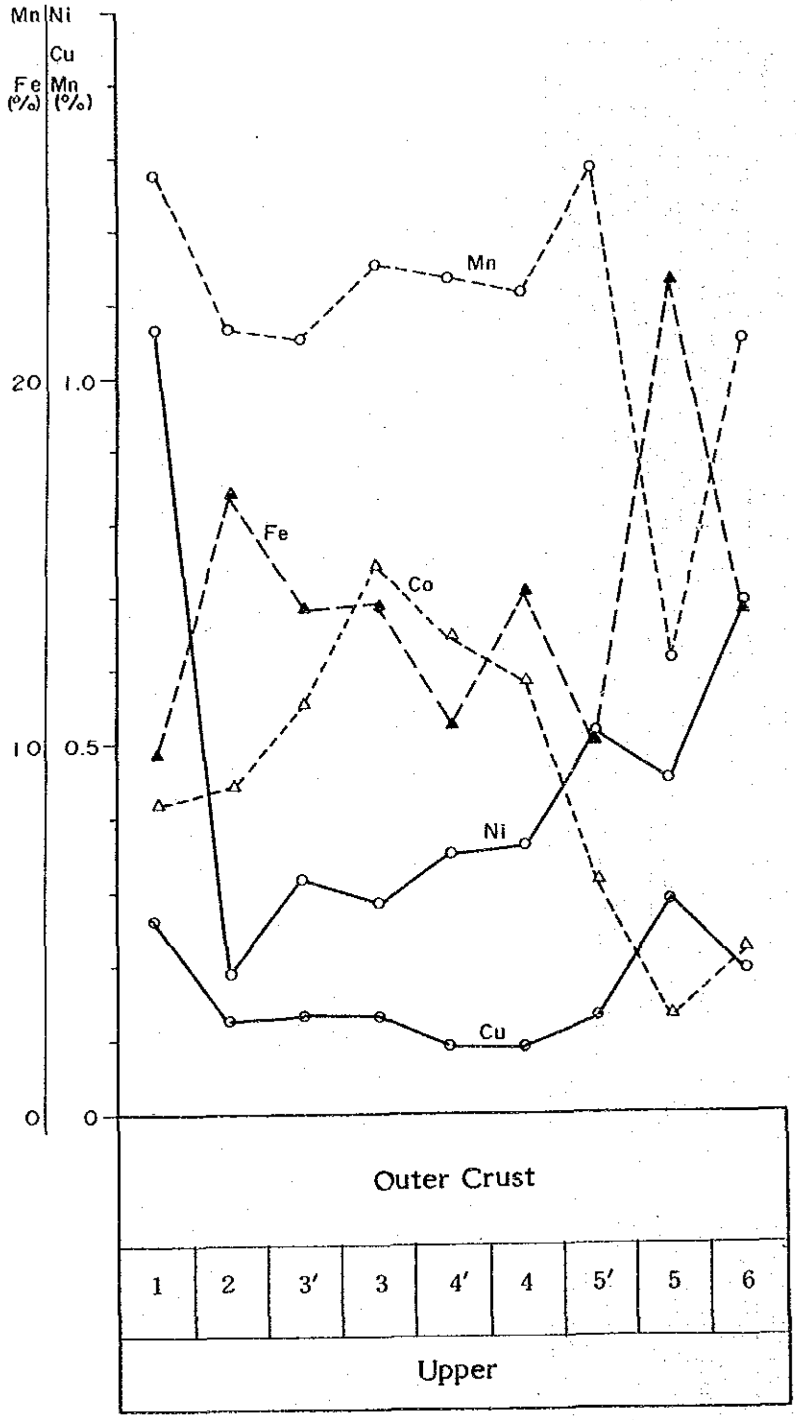


Fig. 4-8-9 Grade of Respective Section of Manganese Nodules (EPMA Analysis)

3 Co and Mn have similar tendency in grades. The grades decrease in the center of nodules as same as Fe, however what differs is the fact that the grade is decreasing on the surface of nodules.

4 Although the Cu grade is a little increasing at the core of spheroidal nodules, it has not a marked change.

5 The tendency mentioned above is more clearly by checking the ratio of Mn/Fe and Cu/Ni.

3) Mineral properties

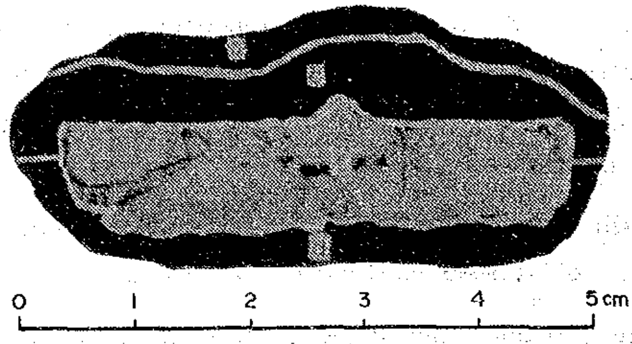
Concerning the representative samples, X-ray diffraction analysis and observation of polished thin sections by microscope were done in order to investigate the mineral composition and inner structure of manganese nodules.

(1) X-ray diffraction analysis

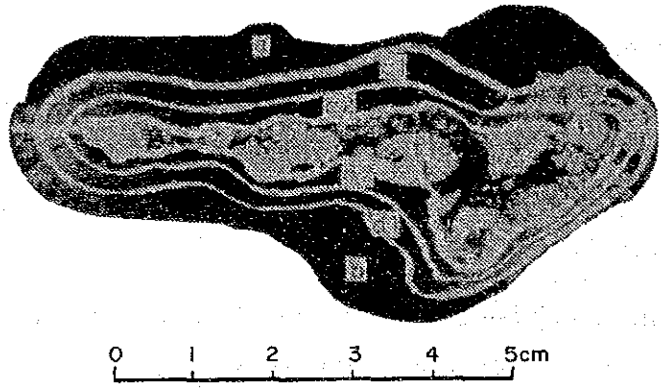
Manganese nodules were roughly divided into the outer crust, inner crust and core; moreover, each of the samples shown in Fig. 4-8-10 was divided into several smaller parts on which X-ray diffraction analysis was executed. The results of analysis are in Tab. 4-8-10 and the X-ray diffraction patterns are in Fig. 4-8-11.

Detected minerals are 10 Å manganite, δ-MnO_2 manganese mineral (*1), quartz, plagioclase, smectite, phillipsite etc. Almost all the manganese minerals are characteristically composed of δMnO_2 and 10 Å manganite is detected in very small quantities. This is backed up by the microscopic observation. Generally speaking, the grade of Co and Fe is high and the grade of Ni, Cu and Mn is low in the δMnO_2 comparing with 10 Å manganite. The above mentioned results coincide with the description in the paragraph of "chemical properties" (the grade of Co and Fe is high

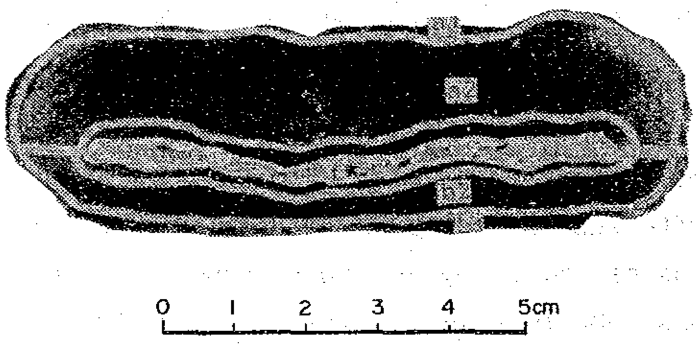
(*1) 7Å manganite, the other manganese material, could not be identified in the present analysis because its peak overlapped with that of phillipsite.



86S1537FG02(6~8cm)
Platy



86S1636FG02(16cm~)
Platy



86S1137FG03(8~16cm)
Ellipsoidal

a : Outer Crust (Upper) b : Outer Crust (Lower) c : Inner Crust (Upper) d : Inner Crust (Lower) f : Core

Fig. 4-8-10 Photos of Manganese Nodules Used for X-ray Diffraction Analysis

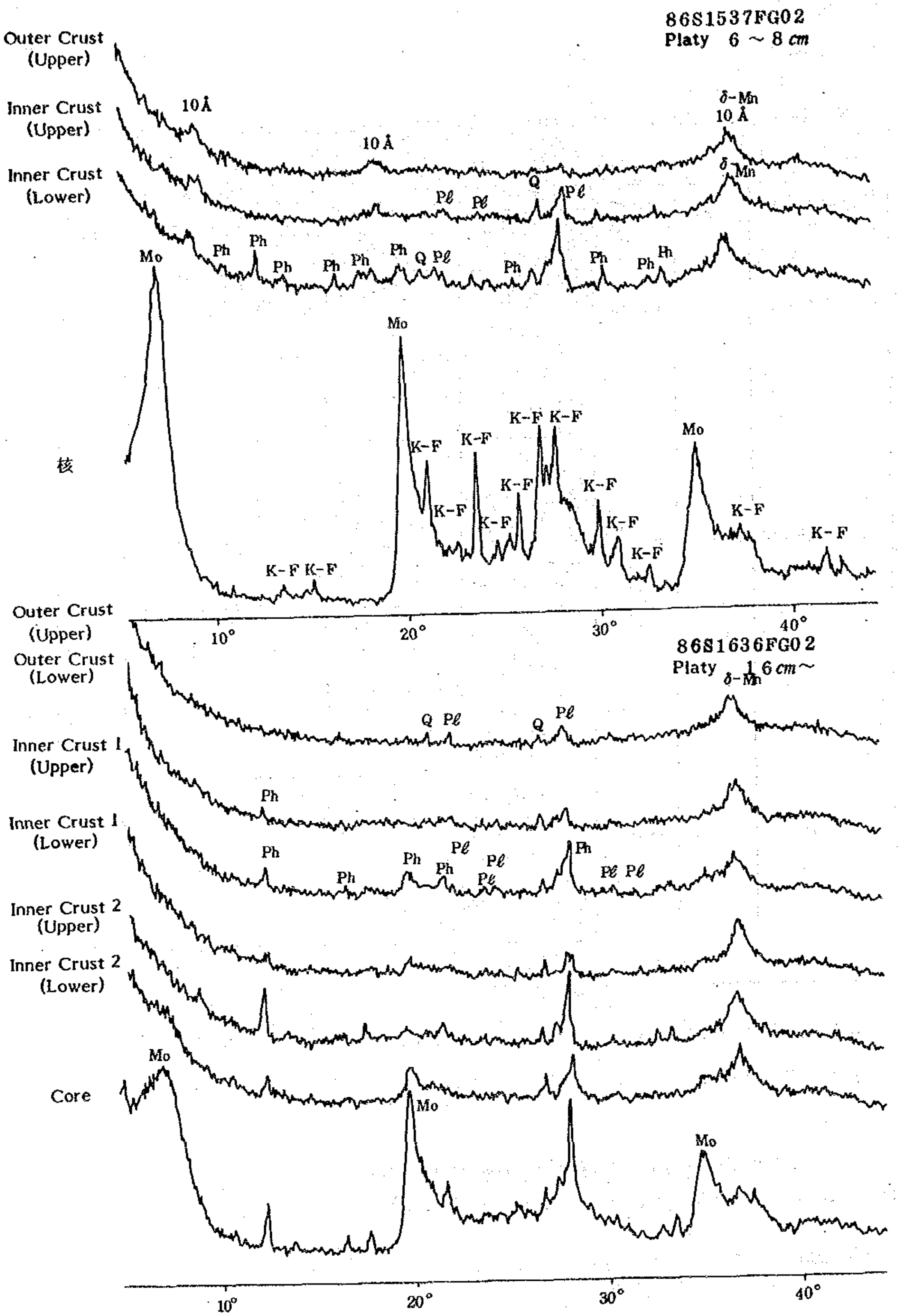
Table 4-8-10 Results of X-ray Diffraction Analysis of the Manganese Nodules

Sample No.	Size (cm)	Morphology	Analysed position			10 Å	δ-Mn	Q	Pℓ	Mo	K-F	Ph
86S1537FG02	6 – 8	Plate	Out. Upper			+	++					
			In.		Upper	±	++	±	+			
			In.		Lower	±	++	±	±			+
			Core							+++	++	
86S1636FG02	16–	Plate	Out.		Upper		++	±	±			
			Out.		Lower		++	±	±			±
			In.	1	Upper		++	±	±			+
			In.	1	Lower		++	±	±			±
			In.	2	Upper		++	±	±			+
			In.	2	Lower		++	±	±	+		±
			Core							+++		+
86S1137FG03	8 – 16	Ellipsoidal	Out.	1	Upper	±	++	±				
			Out.	1	Lower		++	±	±			+
			Out.	2	Upper		++	+	±			±
			Out.	2	Lower		++	+	+	±		++
			In.		Upper		++	+	+			+
			In.		Lower		++	+	+			++
			Core				+	+	+	+		+++

10 Å : 10 Å manganite   δ-Mn : δ-MnO_2 Q : Quartz

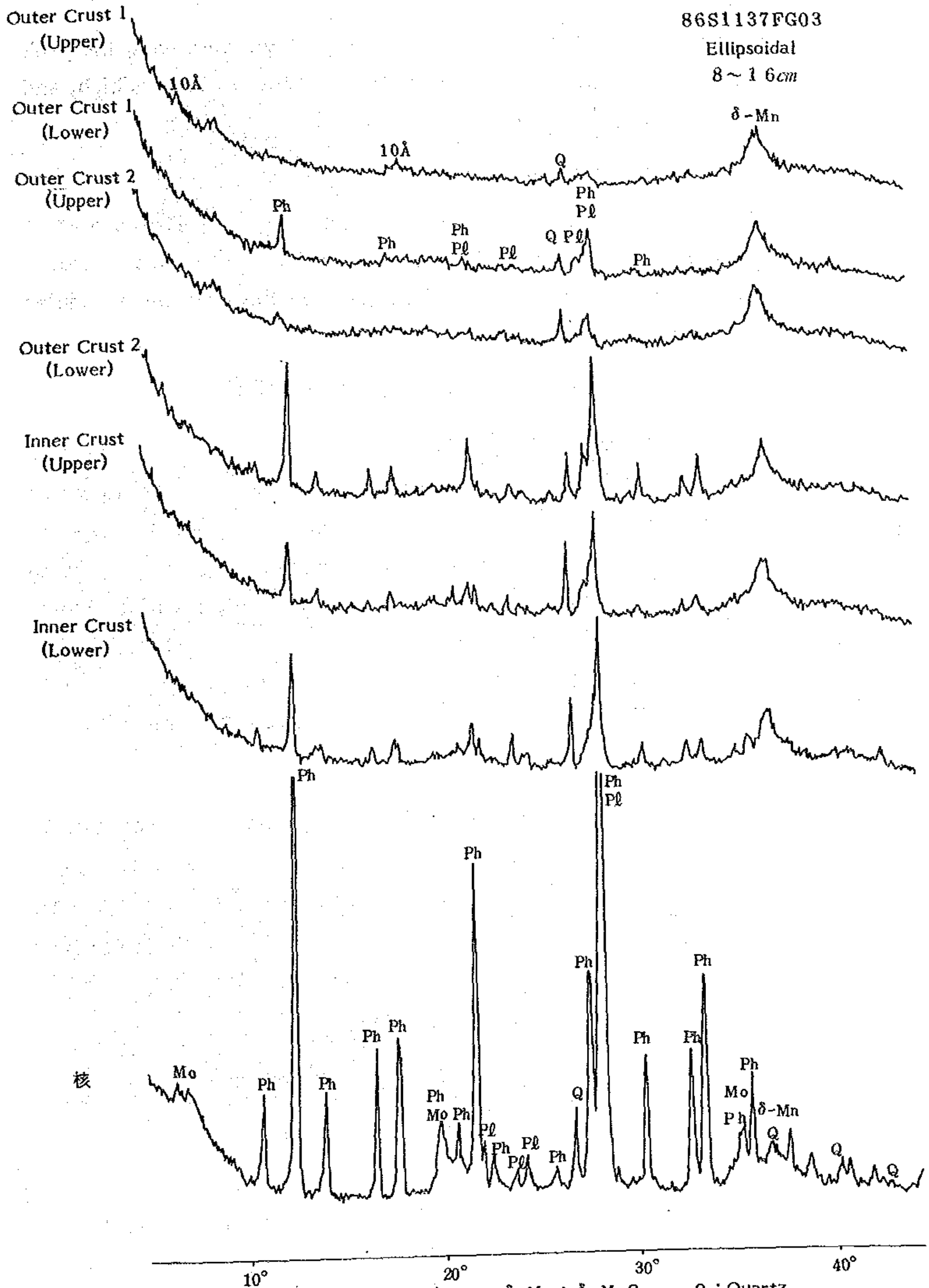
Pℓ : Plagioclase   Mo : Montmorillonite   K-F : K-feldsper   Ph : Phillipsite

+++, ++, +, ± indicate intensity of diffraction peaks,
(+++: high, ++: moderate, +: weak, ±: very weak)



凡例 10Å : 10Å Manganite · δ-Mn : δ-MnO_2 Q : Quartz
Pℓ :Plagioclase Mo : Montmollironite K-F : K-feldsper Ph : Phillipsite

Fig. 4-8-11 X-ray Diffraction Pattern of the Manganese Nodules (No. 1)



凡例　10Å：10Å Manganite　δ-Mn：δ-MnO_2　Q：Quartz
Pℓ：Plagioclase Mo：Montmollironite　K-F：K-Feldsper Ph：Phillipsite

Fig. 4-8-11 X-ray Diffraction Pattern of the Manganese Nodules (No. 2) and the grade of Ni, Cu and Mn is low). In the core part, the peak of diffraction chart line of smectite and phillipsite etc. is high, and this indicates a mixture of extraneous.

(2) Observation by microscope

Polished thin sections were prepared for the representative samples of manganese nodules and observation was done by a reflex microscope. Explanations will be made on the manganese nodules of spheroidal and plate types.

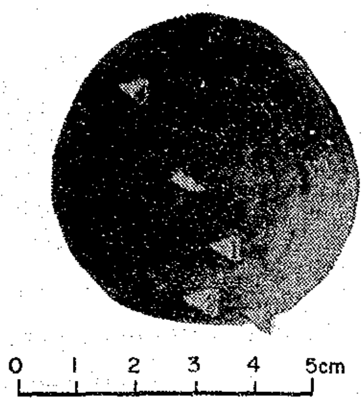
1 Spheroidal type (86S1735FG09, Fig. 4-8-12-(1))

(Observation by naked eyes)

The external appearance is almost spheroidal and the aspect of surface both absence and reverse is coarse and this type of manganese nodules occurs characteristically in the surveyed area. The section is divided into the outer crust and the core. the outer crust is further divided into 4 parts by the sandwiched thin seam of clay. the core having a concentricly circled structure is composed of the extraneous materials.

(Observation by microscope)

The outer crust has a dense stratiform texture composed of δ-MnO_2 a branch like texture and variola like texture. And in the thin seam of clay sandwitched between the outer crusts, there are white clay materials, round pebble clastic grains and zeolitic authigenic minerals and branch shaped MnO_2 observed.



861735FG09

Spheroidal

1. Section

Number of this photo shows micro-photo's position

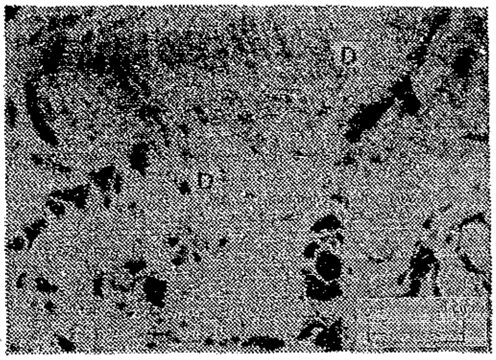
2. 1 ~ 4 Microscopic photo

D : 10 Å Manganite

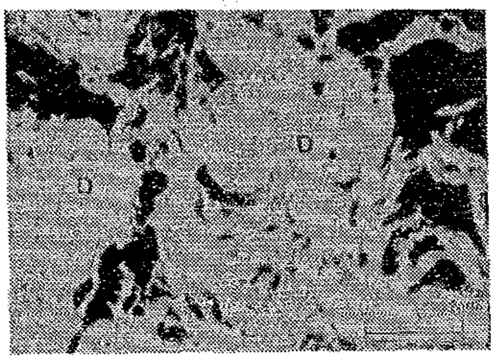
Zeo : Zeolite

Clay : Clay minerals

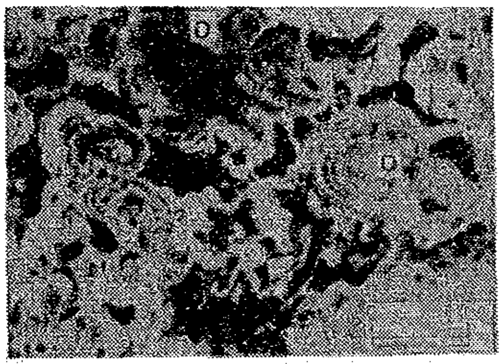
Rf : Rock fragment



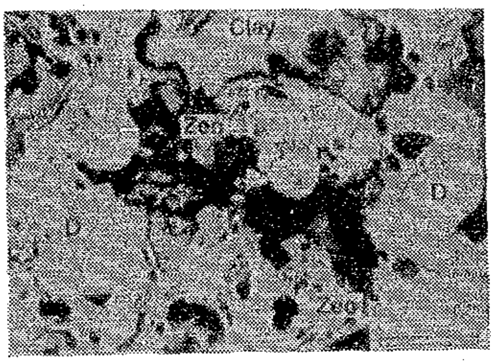
2 — 1 (reflected light)



2 — 2 (reflected light)



2 — 3 (reflected light)



2 — 4 (reflected light)

Fig. 4-8-12 Macro-Photo and Microscopic Photos of Polished Thin Section of Manganese Nodules (No. 1)

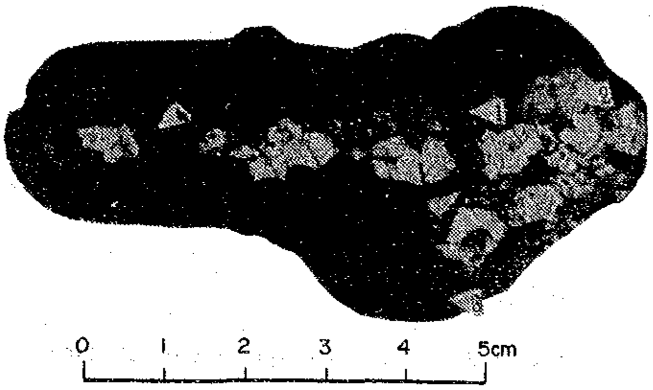
2 Plate type (86S31636FG02, Fig. 4-8-12-(2))

(Observation by naked eyes)

External appearance presents a disk shape, the obverse is relatively smooth and forms a plain curved surface, whereas the reverse is full of convex concave and shows irregular hangings. The section is divided into an outer crust and a core. the outer crust is separated into the inner part and the outer part by the thin seam of clay sandwitched between them. the inner part is dense. Its upper part is thick and the lower part is thin. the thickness of the seam is 2 - 9 mm. reversely, the upper part of the outer crust is thin and the lower part is thick. The thickness of the seam is about 2 - 7 mm. The core is mainly composed of the crushed rock fragments.

(Observation by microscope)

The inner crust is uniform and is mainly composed of δ-MnO_2 and are developed a beded structure, branch like and nipple like texture. the outer crust is porous and incorporation of many clastic grains is observed in relatively large quantities. The core in which branch-nipple like textures develop is mainly occupied by clastic rock fragments. A few δ-MnO_2 surround the rock fragments.



86S1636FG02

Platy

1'. Section

Number of this photo shows micro-photo's position

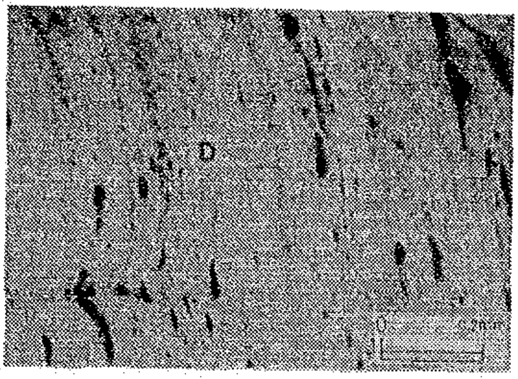
2'. 1 ~ 4 Microscopic photo

D : 10 Å Manganite

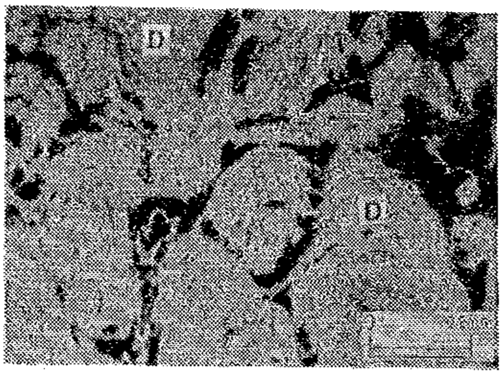
Zeo : Zeolite

Clay : Clay minerals

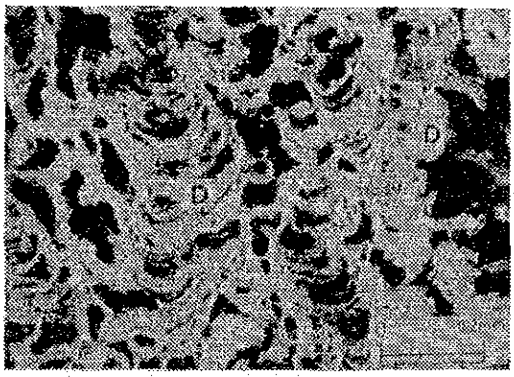
Rf : Rock fragment



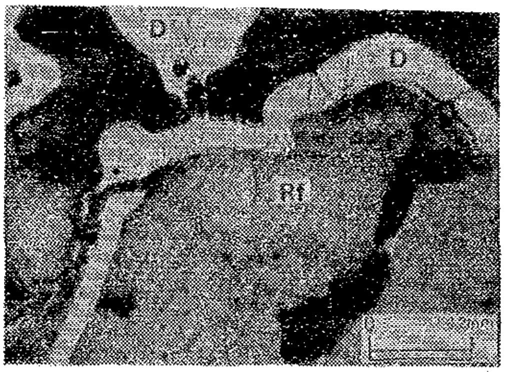
2'－1 (reflected light)



2'－2 (reflected light)



2'－3 (reflected light)



2'－4 (reflected light)

Fig. 4-8-12 Macro-Photo and Microscopic Photos of Polished Thin Section of Manganese Nodules (No. 2)

4) Distribution of manganese nodules

(1) Morphology distribution of manganese nodules

The morphology distribution of manganese nodules was classified into 4 zones having a difference character as follows and it is shown in Fig. 4-8-13.

(a) zone where spheroidal type is superior

(b) zone where pebble, pebble thin and plate types are superior

(c) zone where the main type of manganese nodules is ellipsoidal and the other type is gravel, massive and plate type which is more than 20% in the whole.

(d) zone where massive type is superior

The distribution of (a) and (b) is wide, while that of (c) and (d) generally limited.

(2) Size distribution of manganese nodules

Fig. 4-8-14 shows the size distribution of manganese nodules. Judging from this figure, the size distribution does not have a marked tendency.

(3) Granular size and morphology

The morphorogical classification ratio of manganese nodules by respective granular size is shown in Fig. 4-8-15. As for spheroidal type, the peak of distribution ratio is at 4 - 6 cm. As for ellipsoidal and massive types, the distribution ratio is nearly constant up to about 6 cm, and it increases as the size becomes larger up to 16 cm. Above 16 cm, only plate type appears.

(4) Local topography and morphology

Morphology distribution of manganese nodules is concordant with that of topography (and the depth of water). (a) of previous paragraph (a) lies mainly in plain, quasi-plain and partly in sea mount, where the water depth mostly measures shallower than 5,200 m. (b) lies in the area of many sea knolls and channels, where the water depth mostly measures deeper than 5,200 m.

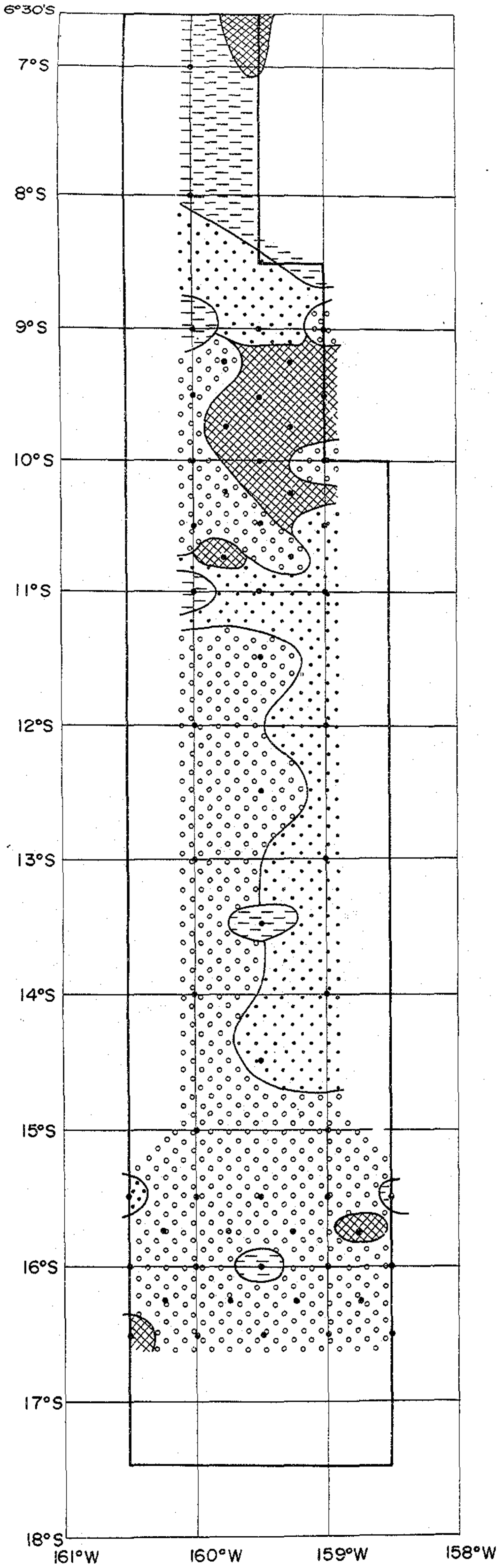


Fig. 4-8-13 Morphology Distribution of Manganese Nodules

Legend

- Main is spheroidal.
- Main is pebble, pebble thin and platy.
- Main is ellipsoidal, and sub is over 20% of pebble, massive and platy.
- Main is massive.
- • Sampling station

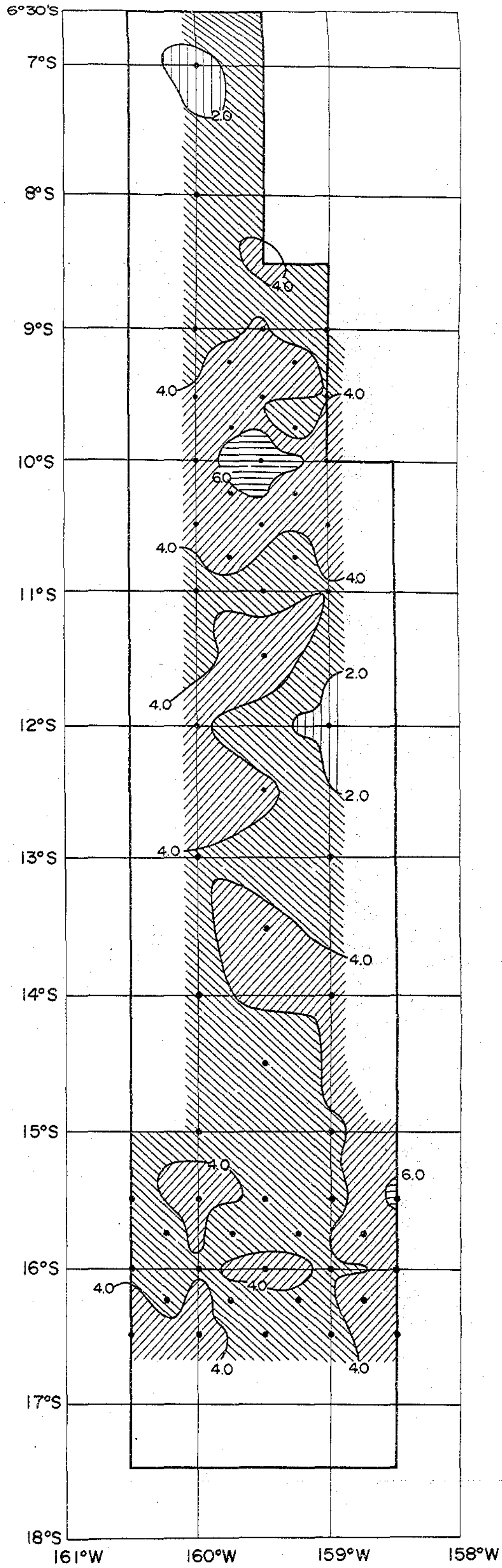


Fig. 4-8-14 Size Distribution of Manganese Nodules

Legend

- 6 ~ 8 cm
- 4 ~ 6 cm
- 2 ~ 4 cm
- 0 ~ 2 cm
- • Sampling station

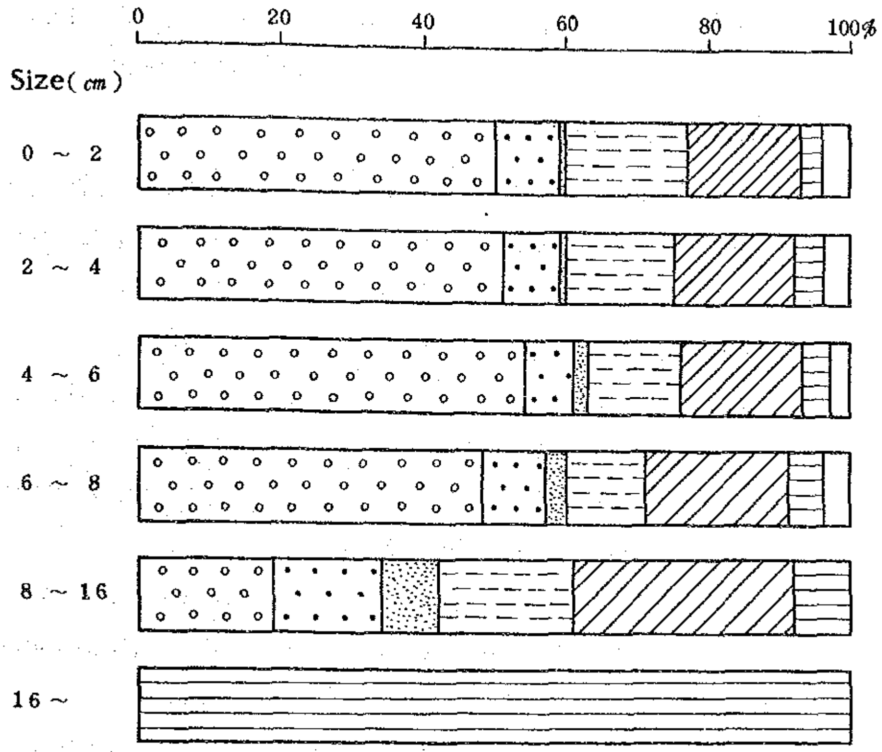
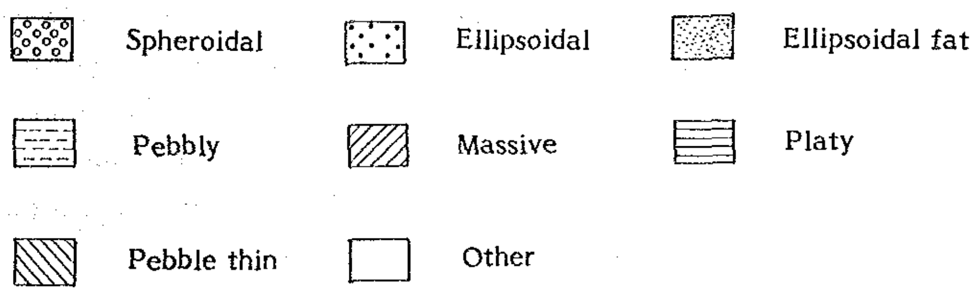


Fig. 4-8-15 Relation between Size and Morphology



It is difficult to point out recognizable distribution relations in (c) but its distribution seems similar to (b). (d) lies mainly in platform where sea-knoll develops and the water depth mostly measures deeper than 5,300 m.

The above tendency is also noted in Fig. 4-8-16 which is the relationship between local topography and morphology.

(5) SBP type and morphology

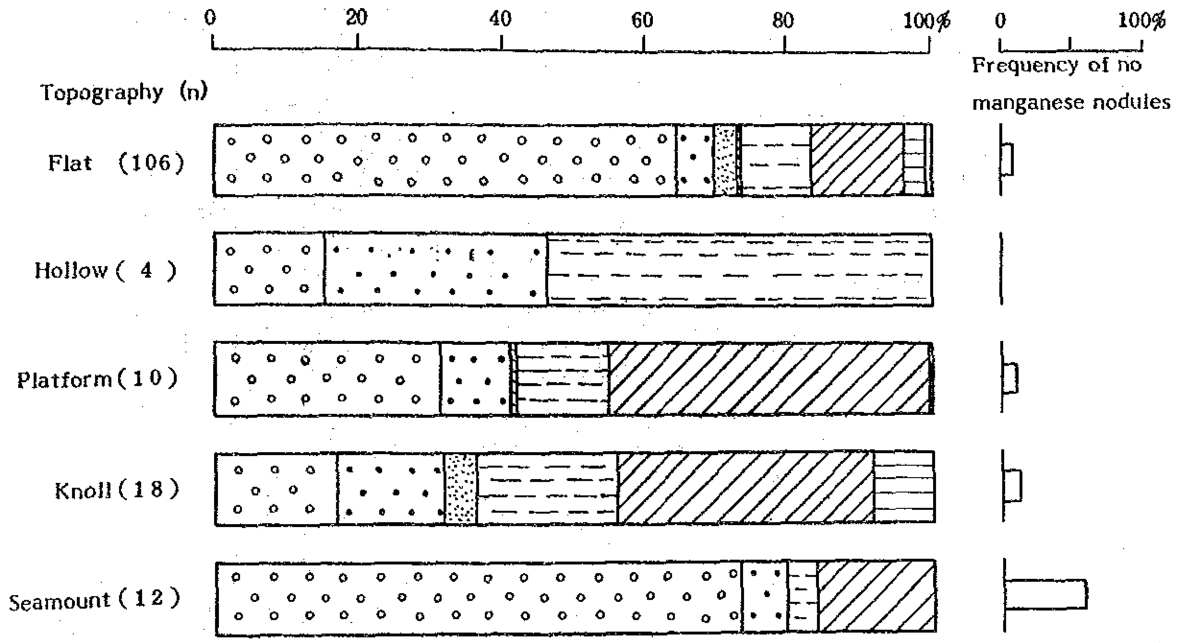
The morphological classification by respective SBP type and thickness of upper transparent layers are shown respectively in Fig. 4-8-17 and Fig. 4-8-18.

It is not easy to derive some significance from these figures, but the following points can be pointed out. the distribution ratio of spheroidal type is high in types a, b and t_s with clearly transparent layers and that of pebble and ellipsoidal types is high in types c, d_1, d_2 and d_s without transparent layers.

As for the thickness of transparent layers, distribution peak of spheroidal type lies at about 30 - 40 cm thick, while pebble and ellipsoidal types are highly distributed in thinner layers. About massive and plate types, general conclusion cannot be drawn.

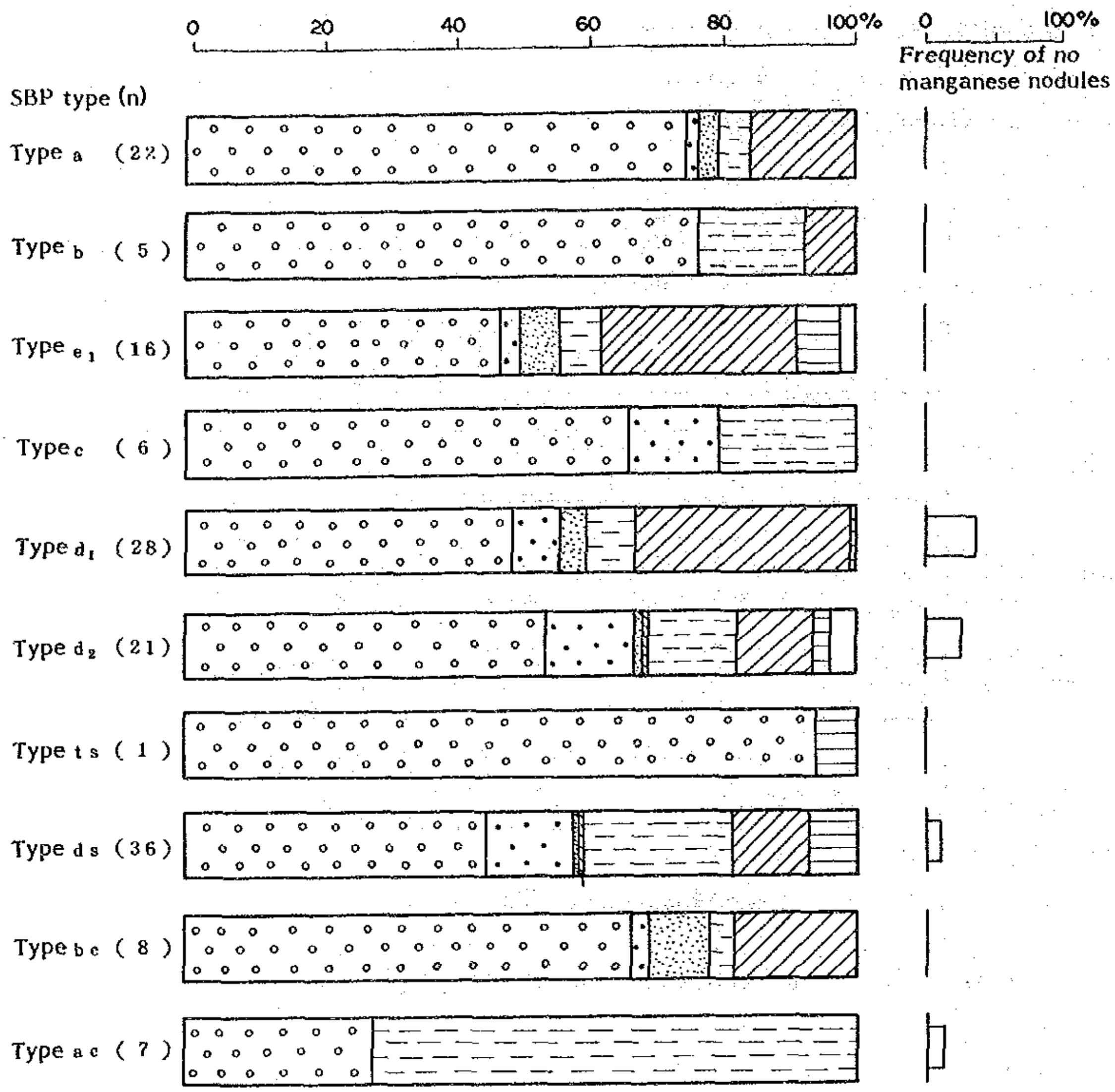
(6) Bottom materials and morphology

Fig. 4-8-19 shows morphological classification ratio by respective bottom materials. In brown clays and calcareous - siliceous clays, all the types are found. In calcareous - siliceous clays, the ratio of spheroidal type is higher, while that of pebble and massive types is lower, compared with brown clays. Ellipsoidal and plate types don't appear in foraminifera ooze, while in insoluble brown clays, only spheroidal and pebble types appear.



Legend is same as Fig. 4-8-15.

Fig. 4-8-16 Relation between Local Topography and Morphology



Legend is same as Fig. 15.

Fig. 4-8-17 Relation between SBP Type and Morphology

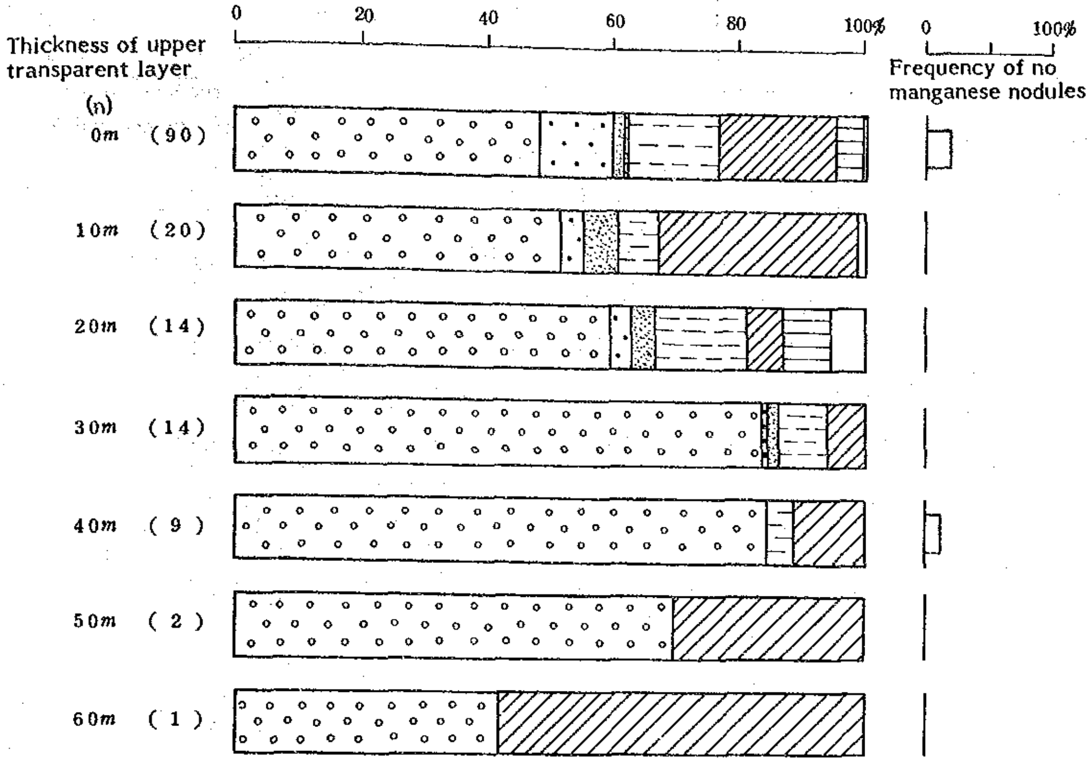


Fig. 4-8-18 Relation between Upper Transparent Layer Thickness and Morphology

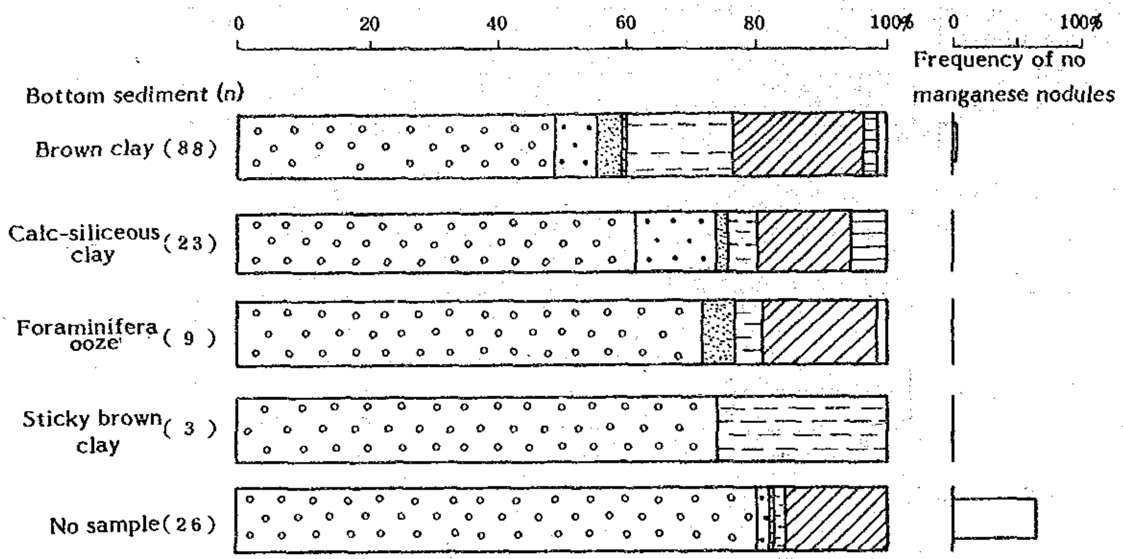


Fig. 4-8-19 Relation between Bottom Sediments and Morphology

5) Sea bottom condition and abundance

(1) Morphology and abundance of manganese nodules

Fig. 4-8-20 shows the average abundance and occurrence ratio of abundance by respective morphology. Except for one sampling point with a ellipsoidal fat, average abundance for spheroidal and massive types are high, respectively 24.89 kg/m^2 and 22.00 kg/m^2. Both types have a similar tendency in frequency distribution and occurrence ratio of more than 25 kg/m^2 exceeds 50%. Following these, ellipsoidal and plate types indicate relatively high abundance (around 14 kg/m^2). These occurrence ratio of abundance is high below 7.5 kg/m^2 and the deviation is also large.

Pebble type indicates the lowest average abundance (9.78 kg/m^2) and its frequency distribution has a peak at 0 - 2.5 kg/m^2. Over 2.5 kg/m^2, it is evenly distributed at round 10%.

(2) Sea floor topography and abundance

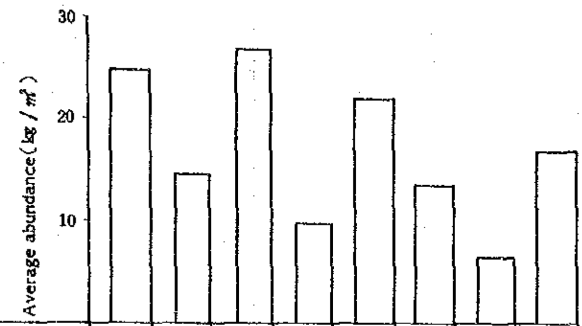
At each sampling points, the relation between the sea bottom and the abundance of manganese nodules is shown in Tab. 4-8-11.

The surveyed areas are divided, from macroscopic point of view, into 4 parts as being shown in Tab. 4-8-11.

From this table, the average abundance of manganese nodules for mountains is low (6.07 kg/m^2) and the occurrence ratio of more than 20 kg/m^2 is also low (18.8%). On the other side, three areas of hills, quasi-plains indicate high average abundance (more than 10 kg/m^2). Particularly in the southmost quasi-plains, the average abundance is 22.74 kg/m^2 and the occurrence ratio of more than 20 kg/m^2 indicates the highest value of 75.9%. the weight factor for quasi-plains is larger than the rest of the areas, which means that the granular size of manganese nodules is large.

By reference to the collecting efficiency of each area, the efficiency is poor in mountains (53.7%) probably due to the influence of its topography but it is relatively good in hills, quasi-plains and plains. Particularly in plains, it shows a satisfactory value of 94.1%.

The statistical results of sea floor topography observed microscopically are shown in Tab. 4-8-12.



Morphology	A	B	C	D	E	F	G	H
Average Abundance	24.89	14.59	26.65	9.78	22.00	13.81	6.25	17.22
Standard deviation	11.01	13.41	—	9.08	11.24	7.38	8.89	13.31
Number of samples	63	12	1	24	22	5	4	150

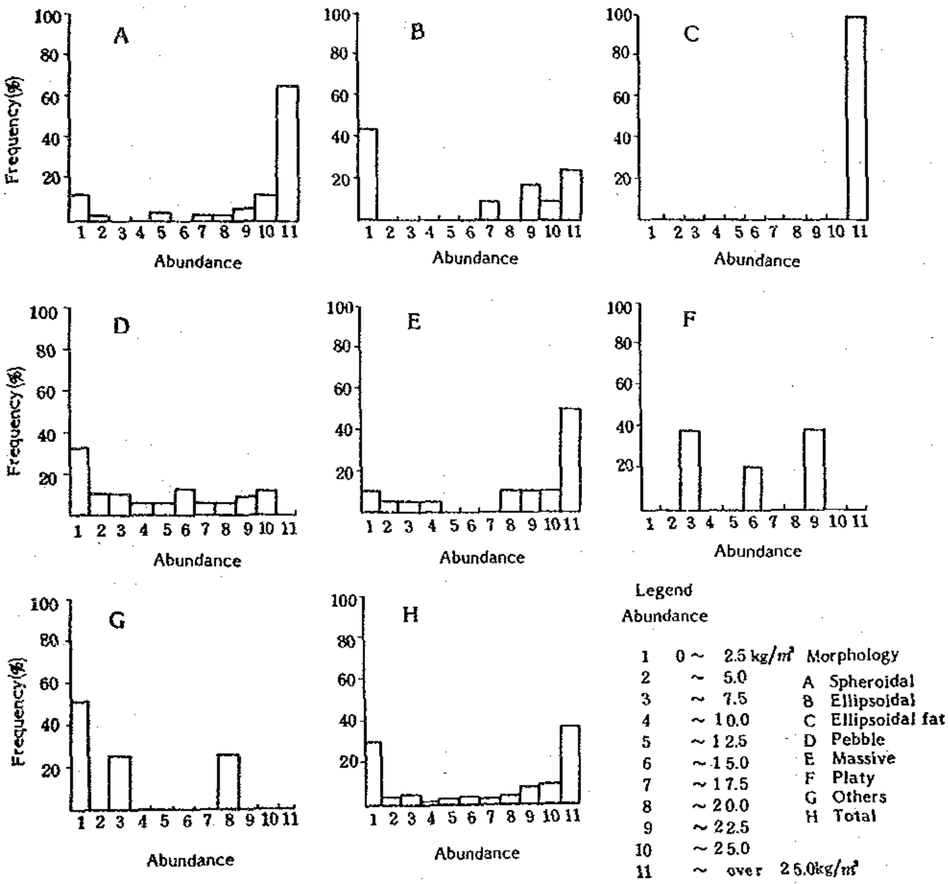


Fig. 4-8-20 Average Abundance by Respective Morphology and Occurrence Ratio by Respective Abundance of Manganese Nodules

Table 4-8-11 Macroscopic Topography and Abundance of Manganese Nodules

Topography	Number of Sampling point	Average abundance	Appearance ratio of ≧ 20 kg/m^2	Weight coefficient	Collection (*1) efficiency
Plain	32	14.14 kg/m^2	37.5%	31.5 kg/m^2	91.4%
Hill	44	16.23 "	32.1 "	32.1 "	84.6 "
Mountain	16	6.07 "	32.0 "	32.0 "	53.7 "
Quasi-plain	58	22.74 "	39.1 "	39.1 "	77.7 "

(*1) Collection efficiency = re-collecting surface ratio/photographic surface ratio X 100(%)

Table 4-8-12 Microscopic Topography and Abundance of Manganese Nodules

Topography	Number of sampling points	Average abundance	Appearance ratio of $\geqq 20\ kg/m^2$	Weight coefficient
Flat	104	18.68 kg/m^2	57.7%	34.8 kg/m^2
Channel	4	0.17 "	0.0 "	19.1 "
Plat form	10	12.73 "	50.0 "	34.1 "
Sea knoll	23	18.10 "	52.2 "	35.5 "
Sea mount	9	10.56 "	33.3 "	51.7 "

Number of sampling points for flat is prominent, while that of the other area is very low, so the relation between topography and abundance cannot be discussed with same accuracy. But as for tendency, the abundance for flat and that of sea knoll are high respectively 18.68 kg/m^2 and 18.18 kg/m^2. It decreases in the following order, platform, sea mount and channel (only 0.17 kg/m^2).

Noticeable fact about weight factor is as follows. It shows intermediate value in flat, platform and sea knoll, but is very low in channel (19.1 kg/m^2) and on the contrary, high in sea amount (51.7 kg/m^2). Looking back on the results of macroscopic division, weight factor of mountainous area which contains many sea mounts indicates a mean value of 32.1 kg/m^2, which seems contradictive. This is due to leveling the weight factor with low values of channel and flat.

(3) SBP type and abundance

The relationship between the SBP type and abundance is shown in Fig. 4-8-21. The average abundance of type a is the highest (26.86 kg/m^2). Its standard deviation is little, so this is what is called a stable and high abundance area.

On the other side, low average abundance is shown in types c and b_C. Type c is nearly sterile in particular. As for the rest of the types, the average abundance is relatively large (13 - 18 kg/m^2) but the deviation of these seem to be also large and the differences by respective types are not recognized.

The weight factor of type b_C is the largest (49.3 kg/m^2) and that of type a_C is low.

(4) Upper transparent layers and abundance

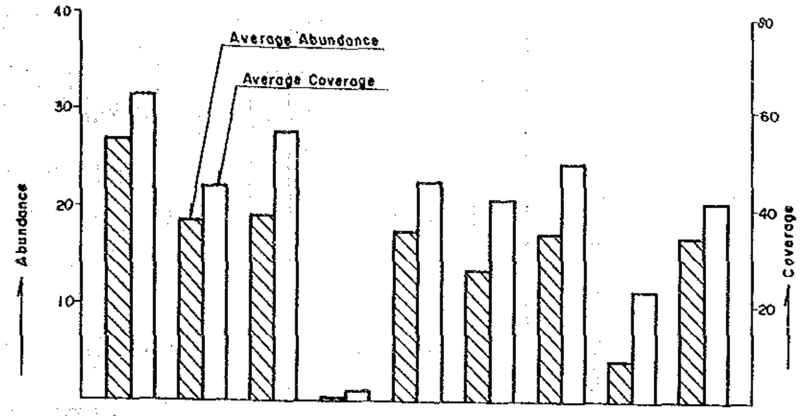
The relation between upper transparent layers and abundance is shown in Fig. 4-8-22. the data on layer thickness of over 50 m is limited. Excepting this data, distinct correlation between the thickness and abundance cannot be found out. But abundance has some tendency to become lower, as the thickness of the upper layers increases.

Abundance variation for thickness of 10 - 20 m is little, and that for thickness of 30 - 40 m is large.

The relationship with SBP type, as mentioned in the previous section, being taken into account, it may be said that this is a relatively stable and high abundance area where SBP type shows type a and the layer thickness is 10 - 20 m.

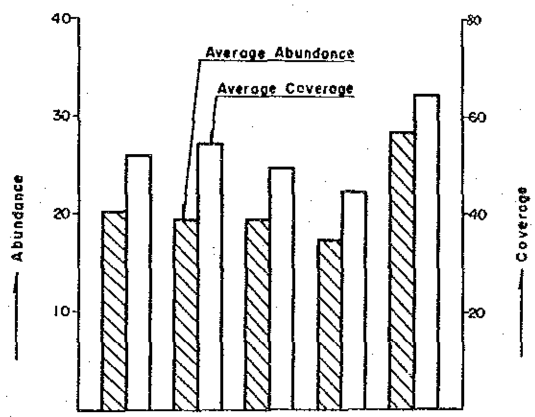
(5) Bottom materials and abundance

Fig. 4-8-23 shows the relation between bottom materials and abundance. Abundance for the calcareous - siliceous clays and the calcareous sediment is high. Its average value is about 28 kg/m^2 and these frequency distribution shows similar trend; mostly more than 20 kg/m^2 and below 10 kg/m^2 is rare.



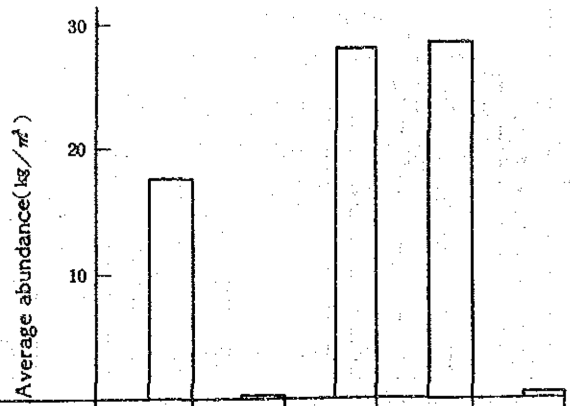
SBP Type	a	b	e₁	c	d₁	d₂	ds	ac	bc
Average Abundance	26.86	18.47	19.15	0.26	17.55	13.63	17.39	4.21	17.09
Average Coverage	62.7	44.0	55.3	2.1	42.7	41.7	49.3	22.9	41.6
Weight Coefficient	40.2	40.1	34.1	12.3	41.5	30.9	32.7	14.6	49.3
Number of Samples	22	5	16	6	28	21	46	7	8

Fig. 4-8-21 Relation between SBP Type and Abundance of Manganese Nodules



Transparent Layer	10	20	30	40	50<
Average Abundance	20.31	19.52	19.51	17.43	28.59
Average Coverage	51.9	54.7	49.6	44.7	64.3
Weight Coefficient	41.2	31.1	36.7	32.5	44.1
Number of Samples	20	14	14	9	2

Fig. 4-8-22 Relation between Upper Transparent Layer Thickenss and Abundance of Manganese Nodules



Bottom sediment	A	B	C	D	E
Average Abundance	17.57	0.15	28.28	28.85	0.42
Standard deviation	11.70	—	9.25	4.51	0.01
Number of samples	88	1	23	9	3

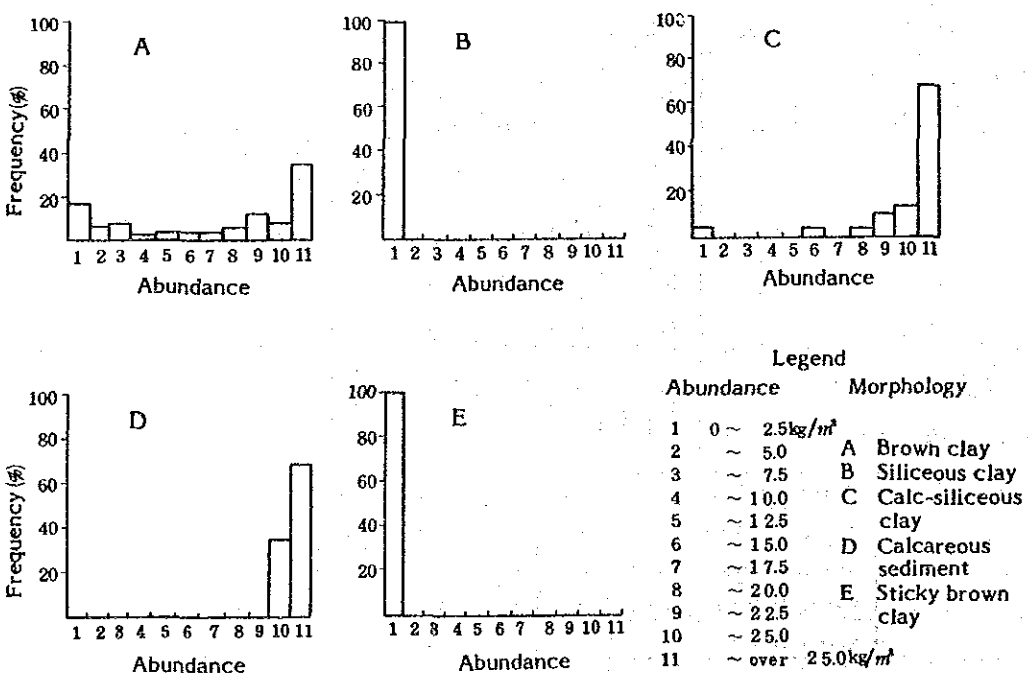


Fig. 4-8-23 Average Abundance by Respective Bottom Sediments and Occurrence Ratio by Respective Abundance of Manganese Nodules

In brown clays, occurrence ratio of over 20 kg/m^2 is relatively high but it has a shape of reversed normal distribution. therefore, the ratio for brown clays is somewhat lower than that of calcareous sediment. Insoluble brown clays, number of sampling points is only three, so any conclusion cannot be drawn, but the abundance seems to be low.

4-9 Bearing Situation of manganese nodules

1) Abundance of the manganese nodules

The abundance of the manganese nodules in this surveyed area is 17.14 kg/m^2 in the average of 60 stations, and its maximum value indicates extremely high value of 34.75 kg/m^2. The abundance of manganese nodules is, as a whole, low in the northern area and high in the southern area. The area of extremely high value in this area is the following 2 areas (Tab. 4-9-1). The abundance of the manganese nodules is high from 11°S to 15°S, but the abundance in the surveyed stations may be less than in the above mentioned areas. In these two areas, the direction of the zone of the high abundance of the manganese nodules seems to be NE-SW. The west part adjacent to the high abundance area near the point of 7°45'S and 159°15'W observed in the survey of the fiscal 1985 is all sterile zone according to the result of this survey.

In order to access to the real abundance of manganese nodules, its value must be corrected toward higher value on the whole, because in the part of the mountain district, there is the precedent that the collecting efficiency of manganese nodules was low.

2) Grade distribution

The characteristic of the grade distribution of manganese nodules in this surveyed area is, in the whole: high Ni-Co grade and low Co grade in the north area, and high Co grade and low Ni-Cu grade in the south area (Annexed figures 8 ~12).

Table 4-9-1 High Abundance Zone of Manganese Nodule

	Northern Part	Southern Part
Sphere	10° S - 11° S	15°S - 16° 30'S
Direction of high abundance zone	NE-SW	NE-SW
Area	about 6,200 km^2	about 12,300 km^2
Abundance: Average	20.53 kg/m^2	24.68 kg/m^2
Abundance: Maximum	34.11 kg/m^2	34.57 kg/m^2
Number of sampling point	9	13

The Ni grade indicates high value of 1.5% - 0.75% in the north-west edge lying from north of 9°00'S. The Ni grade changes between 0.75 - 0.2% from 9°00'S to 15°00'S, but it is a low grade zone of less than about 0.25% in the area south to 15°00'S. The Cu grade indicates high value of 1.25% - 0.75% in the north-west edge to north of 9°00'S in response to Ni grade distribution, but it indicates low value of around 0.1% in the part south of 14°00'S passing through the medium zone of the level of 0.75% - 0.2%. Co grade is reversely less than 0.20% in the north-west edge lying to north of 9°00'S, but it becomes gradually high southward direction and the high grade zone of more than 0.5% come to cover more than 50% of the area in the part south of 15°00'S.

Mn grade indicates high value of more than 20% in the north-west edge, but it becomes gradually low in the southward direction and its value becomes less than of 15% in the part south of 15°S.

Contrary to Mn, Fe grade indicates a low value of less than 10% in the north-west edge, but it becomes high southward and becomes more than 18% from the south of 15°S.

3) Distribution of metal quantity

Considering manganese nodules as useful ore reserve, it is necessary to consider not only the quantity of the manganese nodules per unit area, that is, high coverage but also the metal quantity included in the manganese nodules (specially Ni, Cu and Co that are useful metals).

For Ni, Cu and Co, the metal quantity per unit area is calculated for each sampling as in the following formulas with metal content value, and the results are described in annexed figures 13～15.

- Ni metal quantity per unit area = abundance x (1-water content ratio) x Ni grade
- Cu = abundance x (1-water content ratio) x Cu Grade.
- Co = abundance x (1-water content ratio) x Co grade.

In this case, a cut off grade for each metal is not used. The caracteristics of distribution of metal quantity in the surveyed area is that primarily, the abundance of Ni, Cu and Co coincides with the distribution of abundance of manganese nodules. this caracteristics become more remarkable in Co whose distribution of abundance and grade tend to be identical.

In order to compare with the last year's result, distribution sphere and average abundance of Ni, Cu and Co of more than 20 g/m^2 are shown in Tab. 4-9-2.

Table 4-9-2 Comparison of Metal Contents Distribution

	1985 Survey Area		1986 Survey Area	
	Distribution Area (*1) (km^2)	Average Content Density (g/m^2)	Distribution Area (km^2)	Average Content Density (g/m^2)
Ni	7,500	29.2	96,270	38.4
Cu	630	23.2	41,590	27.0
Co	4,700 (*2)	31.5	102,140	74.7

*1) For Ni and Cu, shown the limit of each content density more than 20 g/m^2; For Co that of more than 10 g/m^2.

*2) Estimated from '85 report. Cf. 8,340 km^2 of distribution limit more than 10 g/m^2.

4) Geological factors and abundance of manganese nodules

The results of studies, clarified by various geological analysis, are summarized in Fig. 4-9-1.

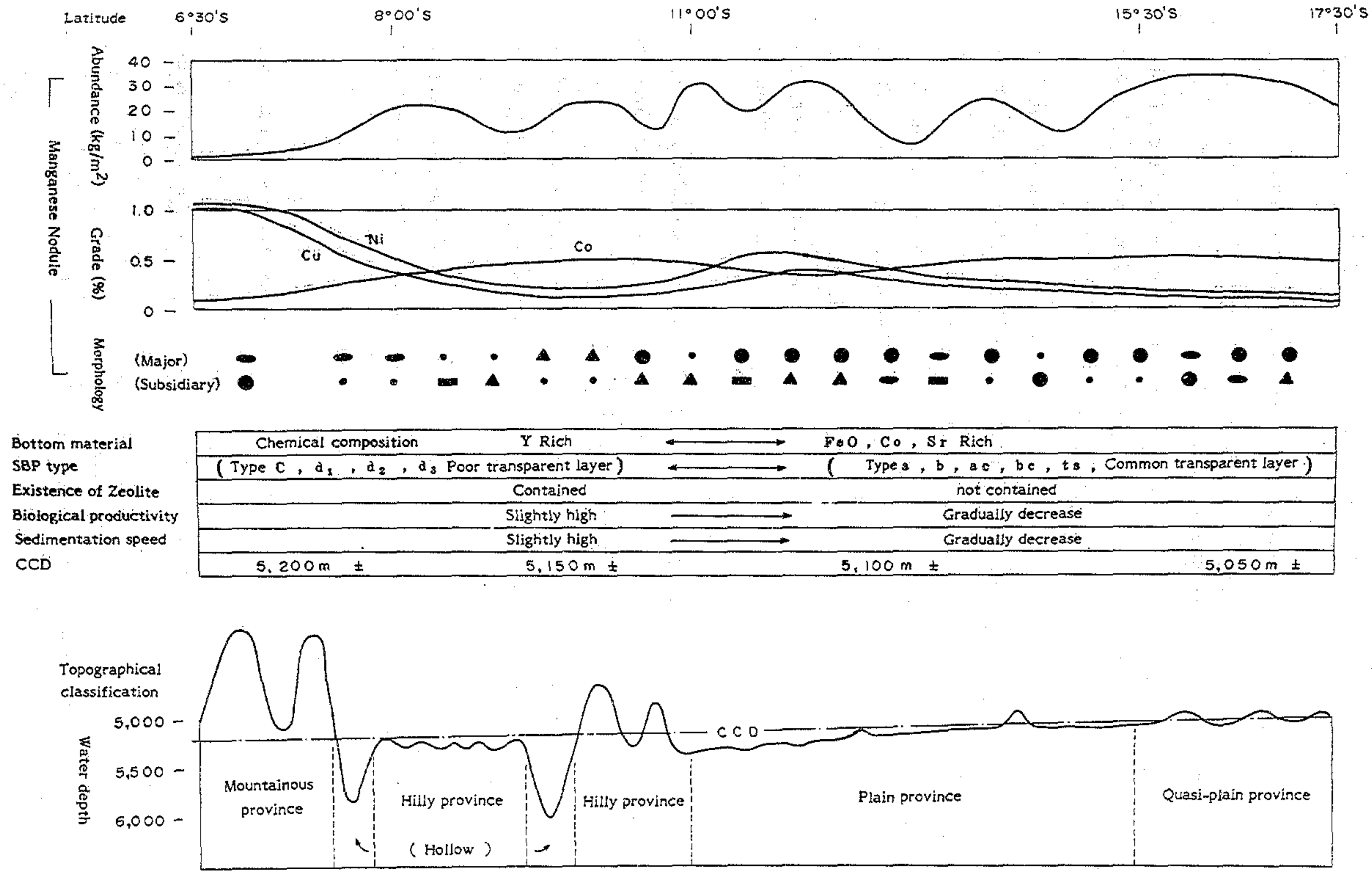
The abundance and grade characteristic of manganese nodules show significant difference between the north and the south in teh surveyed area, and in addition, it seems to have a very close corresponding relation with some basic geological factors.

As previously mentioned, the geological factors indicating the most remarkable difference between the north and the south are topography and water depth and bottom matrials and SBP type and the thickness of transparent layer compoundly related with above three. the change of CCD presumed by this survey and the so-called biological productivity and difference of sedimentation speed (Cronan D. S. 1984) can be added to the factors.

It is difficult to prove originally what kind of relation the above mentioned factors concretely have with the distribution of manganese nodules and how they regulate correctly its distribution. For the time being, this survey result is summarized from the phenomenal aspect as follows.

The zone of high abundance of manganese nodules represented in the south of survey area is topographically flat or semi-flat and the knolls of about hundreds of meters are found. the southern part of the survey area is almost 5,000 m to 5,200 m deep and it can be said that the depth corresponds to the estimated CCD (Carbonate compensation depth). The bottom materials consist mainly of brown clay. But calcareous sediments such as calc-siliceous are also observed in a large quantity. The SBP types characterized by the development of upper transparent layers such as type a, b, bc, ac and ts have a wider distribution. the transparent layers are 10 to 40 m thick. According to Cronan D. S. (1984), the sedimentation speed might be slower in the southern part than in the northern part. The data obtained in 4-5-8 seem to indicate the same tendency, although they are not decisive. It is to be remarked that the zeolites are found in the superficial bottom materials in the northern part whereas they are not found in the southern part. Because of these factors, the southern part abound in spheroidal nodules with similar granular size of 2 to 6 cm, consequently this area forms a high abundance zone.

The phenomena such as the north-south difference found in the metal composition of manganese nodules (high Cu, high Ni and low Co in the northern part and high Co, low Ni and low Cu in the southern part) and the north-south difference found in the chemical composition of the bottom materials (increase in FeO, Co and Sr contents and decrease in Y content southward) might be considered from the same point of view.



(cf. Explanatory notes of types of manganese nodules are shown in figure 4-6-1.

Fig. 4-9-1 Summary figure of the Characteristics of geological factor and distribution of manganese nodule

Chapter 5. Summary

1) Water depth, sea bottom topography and geology

1 11°S latitude makes a border line between the northern part and the southern part having different situations of sea floor topography and geology.

2 Seamounts, knolls and hills abound in the northern part. On the contrary, the southern part is flat or semi-flat from macroscopic point of view.

3 The area is deep in general. It is around 5,200 m deep in the northern hilly area, and tends to be shallower as around 5,100 m in the southern flat area.

4 The north-western part of the area abounds in sea mounts higher than 1,000 m, and corresponds to a part of eastern rim of the Manihiki plateau.

5 Sediments are composed mainly of brown clay and subsidiary of calc-siliceous clay and foraminifera ooze. No remarkable difference is observed between the northern and the southern parts.

6 Distribution of SBP types, and variation of thickness of echo-sounding transparent layer denote more common development of transparent layer in the southern part.

7 CCD (Carbonate compensation depth) estimated by the deepest level of existence of calcareous sediments is between 5,050 m - 5,150 m and has a slight trend of deepening toward north.

2) Characteristics of manganese nodules.

The caracteristics of manganese nodules yielded in this area are summarized as follows;

1 They belong to the so called S (Smooth) type in the usual type-classification (A. Usui 1985, etc.)

2 Almost all of them are exposed on the surface of sea bottom and embedding ratio of manganese nodules is extremely low.

3 Most of manganese nodules is spheroidal type: Massive type and gravel type are secondary. It is observed a difference between northern and southern part.

4 It is observed that clastic type and combined type are dominant in sea knolls and in the hilly province, and that combined together, they are gradually transformed to pavement type and clastic type.

5 Mineral fase is mostly composed of δ-MnO_2, and very rare todorokite.

6 The chemical composition of manganese nodules is mostly low in Ni and Cu and high in Co. Mn/Fe ratio is small. A difference of values between the northern and southern parts is observed as mentioned in the next.

3) Abundance, grade and metal contents distribution of manganese nodules

(1) Abundance of manganese nodules is extremely high.

In all of the 180 sampling points,

the abundance exceeded 20 kg/m^2 in 97 points;

the abundance exceeded 30 kg/m^2 in 32 points;

the abundance exceeded 40 kg/m^2 in 2 points;

And the average abundance on the whole surveyed area of 237,700 km^2 shows an extremely high value of 17.1 kg/m^2.

(2) The continuity of manganese nodule distribution is extremely high.

The high abundance zone (ex. more than 7.5 kg/m^2) of manganese nodules is about 50% of the whole surveyed area. The results of the sea bottom observation performed by FDC along 2 lines denotes that the high abundance zones continue without break.

(3) Cobalt content is very high

The Co grade of manganese nodules distributed in the central to southern part in the surveyed area, is fairly high, compared with that (*1) of the Northern Pacific region.

(*1) In the zone of Northern Pacific, Co-grade is ordinary about 0.31%.

In all of th sampling points;

Co-grade exceeds 0.4% in 69% of sampling points.

Co-grade exceeds 0.5% in 31% of sampling points.

Co-grade reaches a maximum value of 0.61%.

(4) North-south variation is distinct

The abundance and Co grade are generally high in the southern part, and Ni grade and Cu grade are high in the northern part. Fe grade is high in the southern part and Mn grade is high in the northern part. The metal grade distribution is high throughout the area under the influence of manganese nodules abundance which is high throughout the area.

As for the Co content, it is apparent that it shows a higher value in the southern part. Tab. 4-9-2 shows the comparison of the high abundance of manganese nodules in the area sureyed this year with the abundance observed last year. Incidentally, the distribution area with Co metal content of more than 20 g/m^2 are 22 times larger than that of the last year's area.

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List of the Survey Results

Data file around the Cook Islands

(No. 1)

Sample No. (Station)	Location: Latitude	Longitude	Depth (m)	Topography	Manganese Nodules — Size distribution (%): 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%): Ni	Cu	Co	Mn	Fe	Geology — Sediment	sil%	cal%	T.P.L.* type	thick (m)	Remarks
86S0836FG01	07° 00.00'S	159° 59.93'W	5.610	(Mount) Channel	21	79					0.11	E.Sp	—	—	—	—	—	—	—	BC	2	0	c	0	
86S0836FG02	06° 59.00'S	160° 00.89'W	5.521	(Mount) Channel	100						0.08	E.Sp	—	—	—	—	—	—	—	BC	5	0	c	0	
86S0836FG03	06° 58.90'S	159° 58.80'W	5.677	(Mount) Channel	65	35					0.13	E.Sp	2.00	38.4	1.45	1.14	0.13	27.19	5.61	BC	8	0	c	0	
(86401) Average			5.603		59	41					0.11	E.Sp	2.00	36.4	1.45	1.14	0.13	27.19	5.61						
86S0936FG01	08° 00.00'S	160° 00.00'W	3.751	(Mount) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
86S0936FG02	07° 58.90'S	160° 01.00'W	3.475	(Mount) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
86S0936FG03	07° 58.69'S	159° 59.04'W	3.755	(Mount) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
(86402) Average			3.660								0.00	—	—	—	—	—	—	—	—						
86S1036FG01	08° 59.98'S	159° 59.92'W	5.572	(Mount) Flat							0.00	—	—	—	—	—	—	—	—	BC	4	0	d2	0	
86S1036FG02	08° 58.97'S	160° 00.87'W	5.490	(Mount) Flat							0.00	—	—	—	—	—	—	—	—	BC	4	0	ds	0	
86S1036FG03	08° 58.88'S	159° 58.80'W	5.368	(Mount) Flat	19	45	36				1.42	E.P	2.15	28.6	0.89	0.88	0.19	22.16	8.93	BC	5	0	ds	0	
(86403) Average			5.477		19	45	36				0.47	E.P	2.15	28.6	0.89	0.88	0.19	22.16	8.93						
86S1136FG01	09° 59.92'S	160° 00.13'W	4.603	(Mount) Seamoun	1	5	84	10			35.00	Sp	2.01	28.1	0.20	0.08	0.56	19.28	17.99	-	-	-	ds	0	
86S1136FG02	09° 58.92'S	160° 01.22'W	4.630	(Mount) Seamoun	9	43	43	5			(16.82)	Sp.E	2.08	28.1	0.19	0.08	0.57	18.86	17.90	FO	0	70	ds	0	
86S1136FG03	09° 58.79'S	159° 59.35'W	5.350	(Mount) Channel	56	44					0.37	P	2.09	27.7	0.11	0.06	0.44	11.47	15.85	-	-	-	ds	0	
(86404) Average			4.861		2	5	83	10			17.69	Sp	2.01	28.1	0.20	0.08	0.56	19.20	17.97						
86S1236FG01	10° 59.98'S	159° 59.88'W	4.948	(Hilly) Seaknol	26	53	16	5			14.15	Pl.M	2.05	24.3	0.10	0.10	0.22	5.16	12.67	CSC	2	10	ds	0	
86S1236FG02	10° 59.01'S	160° 00.92'W	5.432	(Hilly) Seaknol	2	75	21	2			28.87	E.Sp	1.99	31.8	0.28	0.18	0.45	17.36	19.15	CSC	2	5	d2	0	
86S1236FG03	10° 58.84'S	159° 58.98'W	4.911	(Hilly) Seaknol	1	13	53	33			(30.21)	Sp	2.02	31.0	0.17	0.09	0.50	17.25	18.70	-	-	-	ds	0	
(86405) Average			5.097		10	68	19	3			21.41	E.Pl	2.01	29.3	0.22	0.14	0.37	13.04	16.85						
86S1336FG01	11° 59.89'S	160° 00.30'W	4.920	(Plain) Flat	100						0.02	Sp	—	—	—	—	—	—	—	BC	2	0	ds	0	
86S1336FG02	11° 58.90'S	160° 01.39'W	4.955	(Plain) Flat	42	58					0.15	E	2.20	36.4	0.68	0.38	0.29	19.45	12.47	BC	3	0	el	0	
86S1336FG03	11° 58.78'S	159° 59.53'W	4.833	(Plain) Flat	0	40	54	6			31.60	Sp.E	2.00	29.5	0.29	0.16	0.42	16.48	16.40	CSC	3	5	ds	0	
(86406) Average			4.903		0	40	54	6			10.59	Sp.E	2.01	29.5	0.29	0.16	0.42	16.49	16.38						

* sil% : siliceous fossil %   cal% : calcareous fossil %   T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 2)

Sample No. (Station)	Location: Latitude	Location: Longitude	Location: Depth (m)	Location: Topography	Manganese Nodules: Size distribution (%) 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%) Ni	Cu	Co	Mn	Fe	Geology: Sediment	sil%	cal%	T.P.L.* type	thick (m)	Remarks
86S1436FG01	13° 00.00'S	160° 00.02'W	5.275	(Plain)Flat	2	45	49	4			29.41	Sp	1.95	33.1	0.25	0.13	0.53	17.95	18.60	BC	3	0	bc	0	
86S1436FG02	12° 59.07'S	160° 01.08'W	5.244	(Plain)Flat	100						0.01	Sp.P	—	—	—	—	—	—	—	-	-	-	bc	0	
86S1436FG03	12° 58.99'S	159° 59.07'W	5.284	(Plain)Flat	3	70	20	7			28.51	Sp.E	2.04	30.8	0.26	0.14	0.50	16.55	18.35	-	-	-	bc	0	
(86407) Average			5.268		3	57	35	5			19.31	Sp.E	1.99	32.0	0.25	0.13	0.51	17.25	18.47						
86S1536FG01	14° 00.12'S	160° 00.03'W	5.127	(Plain)Flat	1	61	34	4			35.53	Sp.E	1.94	30.3	0.22	0.13	0.48	16.09	18.60	BC	2	0	a	0	
86S1536FG02	13° 59.17'S	160° 01.08'W	5.161	(Plain)Flat	1	61	38				32.22	Sp	1.98	30.3	0.22	0.12	0.50	16.32	18.40	BC	2	0	a	0	
86S1536FG03	13° 59.14'S	159° 59.11'W	4.960	(Plain)Flat							(0.00)	—	—	—	—	—	—	—	—	-	-	-	ds	0	
(86408) Average			5.083		1	61	36	2			33.88	Sp	1.96	30.3	0.22	0.13	0.49	16.20	18.50						
86S1636FG01	14° 59.97'S	159° 59.98'W	5.158	(Quasi)Flat	3	55	39	3			28.95	Sp.P	1.97	32.4	0.24	0.12	0.56	17.57	18.06	BC	2	0	e1	0	
86S1636FG02	14° 58.97'S	160° 01.00'W	4.962	(Quasi)Flat						100	(6.09)	Pl	1.89	32.9	0.13	0.08	0.50	11.77	16.21	-	-	-	d1	0	
86S1636FG03	14° 58.83'S	159° 59.01'W	5.180	(Quasi)Flat	100						0.12	P	—	—	—	—	—	—	—	BC	2	0	e1	0	
(86409) Average			5.100		3	55	39	3		0	15.04	Sp.P	1.97	32.4	0.24	0.12	0.56	17.57	18.06						
86S1736FG01	15° 59.97'S	159° 59.94'W	4.822	(Quasi)Flat	2	25	67	6			43.88	Sp.Ef	1.98	31.1	0.14	0.08	0.53	15.77	19.46	CSC	2	10	d1	0	
86S1736FG02	15° 58.99'S	160° 00.89'W	5.039	(Quasi)Flat	1	64	35				26.62	Sp.Ef	2.03	26.2	0.20	0.12	0.44	14.11	19.23	BC	3	0	d2	0	
86S1736FG03	15° 58.91'S	159° 58.89'W	5.030	(Quasi)Flat	1	92	7				28.78	Sp.P	2.04	25.2	0.20	0.12	0.46	14.67	19.30	BC	2	0	d2	0	
(86410) Average			4.964		1	55	41	3			33.09	Sp.Ef	2.01	28.1	0.17	0.10	0.49	14.98	19.35						
86S1737FG01	15° 59.95'S	159° 00.15'W	5.025	(Quasi)Flat	1	64	35				32.20	Sp.Ef	2.00	30.6	0.20	0.12	0.49	15.54	19.03	CSC	2	5	a	0	
86S1737FG02	15° 58.88'S	159° 01.17'W	5.013	(Quasi)Flat	1	48	51				20.04	Sp	1.97	30.5	0.18	0.11	0.48	15.21	18.89	CSC	3	5	a	0	
86S1737FG03	15° 58.86'S	158° 59.26'W	5.004	(Quasi)Flat	3	27	58	12			11.95	Sp.Ef	2.09	28.8	0.21	0.12	0.46	15.37	18.35	BC	2	0	a	0	
(86411) Average			5.014		1	52	44	2			21.40	Sp.Ef	2.01	30.2	0.20	0.12	0.48	15.41	18.85						
86S1637FG01	15° 00.03'S	159° 00.06'W	5.147	(Quasi)Flat	1	42	57				28.62	Sp.P	1.97	29.4	0.21	0.11	0.53	16.85	18.70	BC	1	0	d2	0	
86S1637FG02	14° 59.10'S	159° 01.11'W	5.135	(Quasi)Flat	0	54	46				31.84	Sp.P	1.97	28.3	0.23	0.12	0.54	17.85	17.86	BC	1	0	a	0	
86S1637FG03	14° 59.23'S	158° 58.23'W	5.171	(Quasi)Flat	15	61	16	4	4		13.23	P.Sp	2.00	30.4	0.29	0.17	0.48	16.45	17.87	BC	1	0	d2	0	
(86412) Average			5.151		3	51	45	1	1		24.56	Sp.P	1.97	29.1	0.23	0.12	0.53	17.26	18.23						

* sil% : siliceous fossil %　　cal% : calcareous fossil %　　T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 3)

Sample No. (Station)	Location				Manganese Nodules															Geology					Remarks
					Size distribution (%)						Abundance	Shape	S.G. wet	H2O	XRF Analyses (%)					Sediment			T.P.L.*		
	Latitude	Longitude	Depth (m)	Topography	0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	(Kg/m2)			(%)	Ni	Cu	Co	Mn	Fe		sil%	cal%	type	thick (m)	
86S1537FG01	13° 59.81'S	158° 59.97'W	5.196	(Plain)Flat	5	33	45	17			18.93	Ot.P	1.99	34.8	0.24	0.16	0.36	12.76	18.23	BC	1	0	d2	0	
86S1537FG02	13° 58.94'S	159° 00.98'W	5.183	(Plain)Flat	0	31	34	30	5		20.24	Pl	2.07	29.2	0.26	0.16	0.35	13.87	17.87	BC	1	0	el	0	
86S1537FG03	13° 59.00'S	158° 58.97'W	5.261	(Plain)Flat	6	53	31	10			22.16	P.Sp	1.97	30.4	0.28	0.17	0.40	14.83	17.99	BC	1	0	b	0	
(86413) Average			5.213		4	40	36	19	2		20.44	Pl.P	2.01	31.4	0.26	0.16	0.37	13.82	18.02						
86S1437FG01	13° 00.29'S	158° 59.64'W	5.270	(Plain)Flat	4		96				0.65	Sp	1.91	36.4	0.42	0.22	0.30	18.11	16.02	BC	2	0	b	0	
86S1437FG02	12° 59.42'S	159° 00.50'W	5.265	(Plain)Flat	53	47					1.11	P.Pl	2.00	31.0	0.58	0.33	0.19	11.84	9.37	CSC	3	5	ds	0	
86S1437FG03	12° 59.47'S	158° 58.39'W	5.157	(Plain)Flat	36	27	37				2.05	P.Ef	2.06	30.0	0.63	0.36	0.32	19.19	12.67	BC	2	0	ds	0	
(86414) Average			5.231		35	28	36				1.27	P.Ef	2.02	31.4	0.58	0.33	0.28	16.87	12.23						
86S1337FG01	12° 00.00'S	158° 59.96'W	5.253	(Plain)Flat	92	8					0.28	Sp.P	2.13	30.3	0.81	0.48	0.23	18.25	10.45	BC	3	0	ac	0	
86S1337FG02	11° 59.05'S	159° 00.95'W	5.242	(Plain)Flat	100						0.22	P.Sp	2.15	26.1	0.81	0.46	0.22	17.87	10.04	BC	3	0	ac	0	
86S1337FG03	11° 58.96'S	158° 58.98'W	5.298	(Plain)Flat	100						0.25	P.Sp	2.14	20.8	0.98	0.57	0.20	18.85	9.26	BC	5	0	ac	0	
(86415) Average			5.264		97	3					0.28	P.Sp	2.14	25.3	0.86	0.51	0.21	18.29	9.83						
86S1237FG01	11° 00.11'S	158° 59.79'W	5.341	(Plain)Flat	3	64	33				5.59	M.P	1.97	28.5	0.42	0.25	0.36	17.62	14.38	BC	2	0	bc	0	
86S1237FG02	10° 59.80'S	159° 00.68'W	5.339	(Plain)Flat	100						0.18	P.Sp	2.00	23.5	0.85	0.64	0.19	20.69	8.90	BC	2	0	bc	0	
86S1237FG03	10° 58.44'S	158° 58.44'W	5.184	(Plain)Flat	25	41	14	7	13		17.32	P.Ef	2.04	28.7	0.35	0.20	0.82	13.34	13.22	BC	2	0	ds	0	
(86416) Average			5.288		20	46	18	5	10		7.70	P.M	2.02	28.6	0.37	0.21	0.28	14.44	13.46						
86S1137FG01	09° 59.88'S	159° 00.09'W	5.180	(Hilly)Flat	1	24	44	31			34.58	Sp.M	2.00	28.8	0.24	0.13	0.49	18.16	16.83	CSC	2	3	x	0	
86S1137FG02	09° 58.82'S	159° 01.13'W	5.148	(Hilly)Flat	1	57	29	13			35.62	Sp.M	2.00	29.9	0.23	0.13	0.48	17.68	17.30	CSC	3	5	d2	0	
86S1137FG03	09° 58.74'S	158° 59.13'W	5.132	(Hilly)Flat	1	31	22	22	24		32.12	M.E	1.87	30.1	0.26	0.15	0.44	17.51	16.42	CSC	3	5	a	0	
(86417) Average			5.153		1	38	32	22	8		34.11	Sp.M	1.99	29.5	0.25	0.14	0.47	17.79	16.87						
86S1037FG01	09° 00.02'S	159° 00.06'W	5.532	(Hilly)Flat	89	11					0.43	Sp.P	2.00	32.5	0.78	0.52	0.21	17.46	9.66	IBC	4	0	c	0	
86S1037FG02	08° 59.09'S	159° 01.01'W	5.534	(Hilly)Flat	87	13					0.41	Sp.P	2.00	28.5	0.79	0.58	0.22	18.08	9.83	IBC	5	0	c	0	
86S1037FG03	08° 59.01'S	158° 58.99'W	5.536	(Hilly)Flat	100						0.43	Sp.P	2.00	23.4	0.79	0.58	0.21	17.23	9.47	IBC	5	0	c	0	
(86418) Average			5.534		92	8					0.42	Sp.P	2.00	27.5	0.79	0.53	0.21	17.58	9.68						

* sil% : siliceous fossil %　　cal% : calcareous fossil %　　T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 4)

Sample No. (Station)	Location				Manganese Nodules															Geology					Remarks
					Size distribution (%)						Abundance	Shape	S.G. wet	H2O	XRF Analyses (%)					Sediment			T.P.L.*		
	Latitude	Longitude	Depth (m)	Topography	0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	(Kg/m2)			(%)	Ni	Cu	Co	Mn	Fe		sil%	cal%	type	thick. (m)	
86S1036SC04	09° 31.43'S	159° 29.29'W	5.680	(Hilly)Flat	4	41	55				3.60	M.P	1.98	29.3	0.54	0.33	0.32	20.01	13.07	BC	4	0	d2	0	
86S1036FG05	09° 29.87'S	159° 30.87'W	5.518	(Hilly)Seamoul	11	35	43	11			7.74	M.P	1.99	29.1	0.41	0.24	0.38	17.71	14.50	BC	5	0	a	0	
86S1036FG06	09° 29.75'S	159° 28.85'W	5.055	(Hilly)Seamoul	4	48	35	13			29.38	Sp.M	2.00	31.9	0.27	0.15	0.48	17.45	16.55	BC	5	0	d1	0	
(86419) Average			5.418		5	45	38	11			13.57	M.Sp	2.00	31.1	0.32	0.18	0.44	17.73	15.83						
86S1136FG04	10° 29.92'S	159° 30.00'W	4.773	(Hilly)Flat	0	59	41				23.42	Sp	1.92	27.6	0.29	0.17	0.42	17.58	16.86	FO	1	70	ds	0	
86S1136FG05	10° 28.88'S	159° 31.02'W	4.878	(Hilly)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	ds	0	
86S1136FG06	10° 28.82'S	159° 29.03'W	4.890	(Hilly)Flat		13	85	2			35.28	Sp.M	2.00	28.9	0.21	0.11	0.50	17.58	18.20	-	-	-	ds	0	
(86420) Average			4.780		0	31	67	1			19.57	Sp	1.97	28.4	0.24	0.14	0.47	17.58	17.66						
86S1236SC04	11° 29.67'S	159° 30.19'W	4.900	(Plain)Flat	3	25	36	36			24.67	Sp.M	1.97	23.8	0.27	0.15	0.40	14.72	15.45	CSC	4	5	ds	0	
86S1236FG05	11° 28.70'S	159° 30.81'W	5.080	(Plain)Flat	6	23	12	1		58	21.90	Pl	1.93	34.8	0.33	0.19	0.29	10.86	13.64	CSC	2	5	ds	0	
86S1236FG06	11° 28.96'S	159° 28.95'W	4.950	(Plain)Flat	15	85					37.62	Sp.P	2.06	34.3	0.17	0.08	0.52	16.27	19.15	BC	3	0	ds	0	
(86421) Average			4.977		8	51	14	11		15	28.06	Sp.Pl	2.00	32.8	0.24	0.13	0.42	14.42	16.61						
86S1336FG04	12° 29.95'S	159° 28.92'W	5.232	(Plain)Flat	8	70	16	5			17.59	Sp.P	2.05	31.9	0.34	0.18	0.45	17.68	16.90	BC	3	0	bc	0	
86S1336FG05	12° 28.87'S	159° 30.88'W	4.901	(Plain)Platfor	1	8	42	49			31.82	Sp.M	1.95	29.8	0.22	0.12	0.51	17.57	17.86	CSC	2	5	dI	0	
86S1336FG06	12° 28.82'S	159° 28.87'W	5.181	(Plain)Flat	2	83	15				28.62	Sp.M	1.99	29.9	0.37	0.21	0.45	18.44	17.17	BC	4	0	dI	0	
(86422) Average			5.105		3	49	26	21			26.01	Sp.M	1.99	30.2	0.30	0.16	0.47	17.82	17.31						
86S1436FG04	13° 29.89'S	159° 29.96'W	5.102	(Plain)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	ac	0	
86S1436FG05	13° 29.04'S	159° 30.97'W	5.116	(Plain)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	d2	0	
86S1436SC06	13° 28.83'S	159° 29.11'W	5.140	(Plain)Flat	4	35	53	8			15.00	E.Pl	2.04	28.2	0.33	0.20	0.39	15.73	19.13	BC	3	0	ds	0	
(86423) Average			5.119		4	35	53	8			5.00	E.Pl	2.04	28.2	0.33	0.20	0.39	15.73	19.13						
86S1536FG04	14° 29.99'S	159° 30.01'W	5.126	(Plain)Flat	64	36					2.52	Sp.P	2.01	30.0	0.51	0.28	0.29	15.78	14.04	BC	2	0	ac	0	
86S1536FG05	14° 28.88'S	159° 31.04'W	5.111	(Plain)Flat	49	37	2	12			11.77	P.Sp	2.08	25.4	0.37	0.20	0.42	16.68	17.15	BC	2	0	ac	0	
86S1536FG06	14° 28.80'S	159° 29.10'W	5.119	(Plain)Flat	17	75	8				14.31	P.Sp	2.07	29.9	0.38	0.18	0.48	17.65	17.29	BC	2	0	ac	0	
(86424) Average			5.119		34	56	5	5			9.53	P.Sp	2.07	28.0	0.36	0.19	0.43	17.08	16.95						

* sil% : siliceous fossil %   cal% : calcareous fossil %   T.P.L : Transparent Layer

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(No. 5)

Sample No. (Station)	Location				Manganese Nodules: Size distribution (%)						Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%)					Geology: Sediment			T.P.L.*		Remarks
	Latitude	Longitude	Depth (m)	Topography	0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm					Ni	Cu	Co	Mn	Fe		sil%	cal%	type	thick (m)	
86S1636FG04	15° 29.86'S	159° 30.07'W	4.919	(Quasi)Flat	2	40	58				38.16	Sp.P	1.97	28.6	0.13	0.08	0.51	15.11	19.57	CSC	2	5	ds	0	
86S1696FG05	15° 28.88'S	159° 31.15'W	5.140	(Quasi)Flat	1	63	36				30.93	M.Sp	2.03	31.4	0.20	0.13	0.46	16.00	18.89	BC	2	0	el	0	
86S1636SC06	15° 29.05'S	159° 29.02'W	5.140	(Quasi)Flat	2	60	38				34.61	Sp	2.00	27.0	0.20	0.12	0.47	15.72	19.35	BC	3	0	b	0	
(86425) Average			5.066		2	54	45				34.57	Sp.M	2.00	28.9	0.17	0.11	0.48	15.57	19.30						
86S1636FG07	15° 30.22'S	160° 00.07'W	5.055	(Quasi)Flat	7	30	12	44	7		28.65	Ef.P	1.97	29.3	0.18	0.10	0.52	15.58	18.55	BC	2	0	el	0	
86S1636FG08	15° 29.26'S	160° 01.10'W	5.070	(Quasi)Flat	4	54	38	4			27.51	Sp.E	1.93	31.3	0.13	0.08	0.54	15.22	19.63	BC	2	0	el	0	
86S1636FG09	15° 28.26'S	159° 59.14'W	5.067	(Quasi)Flat	1	63	36				25.92	Sp.M	1.95	28.7	0.18	0.11	0.54	15.89	19.22	BC	2	0	bc	0	
(86426) Average			5.064		4	49	29	16	2		26.69	Sp.Ef	1.95	30.1	0.17	0.10	0.53	15.56	19.13						
86S1635FG01	15° 29.97'S	160° 29.96'W	4.953	(Quasi)Flat	8	55	25	12			6.22	Pl.P	2.12	26.7	0.46	0.25	0.37	16.72	17.42	BC	2	0	d2	0	
86S1635FG02	15° 28.99'S	160° 30.90'W	4.885	(Quasi)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	d2	0	
86S1635FG03	15° 28.92'S	160° 28.81'W	4.929	(Quasi)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	d2	0	
(86427) Average			4.916		8	55	25	12			2.07	Pl.P	2.12	26.7	0.46	0.25	0.37	16.72	17.42						
86S1635FG04	15° 44.93'S	160° 14.96'W	5.017	(Quasi)Flat	9	63	9	19			11.95	Sp.E	1.99	30.4	0.21	0.12	0.51	14.80	19.21	BC	1	0	d2	0	
86S1635FG05	15° 43.83'S	160° 16.00'W	5.005	(Quasi)Flat							(0.00)	—	—	—	—	—	—	—	—	-	-	-	d2	0	
86S1635FG06	15° 43.70'S	160° 14.02'W	4.830	(Quasi)Flat	17	74	6	3			20.60	Sp.P	1.98	30.3	0.18	0.11	0.52	14.83	19.50	BC	1	0	ds	0	
(86428) Average			4.951		14	70	7	9			16.28	Sp.P	1.98	30.3	0.19	0.11	0.52	14.82	19.40						
86S1735FG01	16° 00.00'S	160° 29.53'W	4.821	(Quasi)Flat	3	84	13				28.77	Sp.P	1.97	31.5	0.15	0.08	0.60	16.66	19.47	FO	0	50	a	0	
86S1735FG02	15° 58.99'S	160° 30.41'W	4.812	(Quasi)Flat	4	21	55	16	4		33.77	Sp.M	1.98	29.6	0.19	0.10	0.53	14.91	18.59	FO	0	60	a	0	
86S1735FG03	15° 58.98'S	160° 28.30'W	4.854	(Quasi)Flat	7	85	5	3			30.47	Sp.P	1.87	30.8	0.16	0.08	0.56	15.95	18.78	FO	0	40	a	0	
(86429) Average			4.829		5	61	26	7	1		31.00	Sp.P	1.97	30.6	0.17	0.09	0.56	15.78	19.29						
86S1736FG04	16° 30.19'S	159° 59.85'W	5.058	(Quasi)Flat	9	41	34	10	6		22.95	Sp.M	1.99	29.2	0.20	0.12	0.48	13.44	18.25	BC	1	0	a	0	
86S1736FG05	16° 29.23'S	160° 00.83'W	5.020	(Quasi)Flat	3	43	54				(14.28)	Sp.M	2.02	28.9	0.20	0.12	0.53	15.21	18.82	BC	1	0	a	0	
86S1736FG06	16° 29.29'S	159° 58.80'W	5.087	(Quasi)Flat	6	37	32	19	6		26.64	Sp.M	1.99	29.7	0.19	0.11	0.49	14.13	18.63	BC	1	0	a	0	
(86430) Average			5.055		7	39	33	15	6		24.80	Sp.M	1.98	29.5	0.19	0.11	0.49	13.81	18.46						

* sil% : siliceous fossil %   cal% : calcareous fossil %   T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 6)

Sample No. (Station)	Location: Latitude	Location: Longitude	Location: Depth (m)	Location: Topography	Manganese Nodules: Size distribution (%) 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%) Ni	Cu	Co	Mn	Fe	Geology: Sediment	sil%	cal%	T.P.L.* type	thick (m)	Remarks
86S1735FG04	16° 14.76'S	160° 15.02'W	4.890	(Quasi)Flat	5	61	34				29.02	Sp	1.93	28.1	0.20	0.10	0.56	16.03	19.40	CSC	1	3	a	0	
86S1735FG05	16° 13.73'S	160° 16.02'W	4.882	(Quasi)Flat	8	89	3				(18.35)	Sp.P	2.01	28.6	0.21	0.11	0.55	16.00	19.44	CSC	1	5	el	0	
86S1735FG06	16° 13.53'S	160° 14.05'W	4.901	(Quasi)Flat	4	90	6				(8.75)	Sp.P	2.03	28.5	0.20	0.11	0.54	15.85	19.34	CSC	1	6	a	0	
(86431) Average			4.891		5	61	34				29.02	Sp	1.93	28.1	0.20	0.10	0.56	16.03	19.40						
86S1735FG07	16° 30.00'S	160° 30.03'W	4.730	(Quasi)Seaknol							0.00	—	—	—	—	—	—	—	—	-	-	-	dl	0	
86S1735FG08	16° 29.02'S	160° 31.13'W	4.845	(Quasi)Flat	0	8	22	52	18		31.24	M.Sp	1.98	25.4	0.25	0.13	0.47	15.27	16.91	BC	2	0	el	0	
86S1735FG09	16° 28.96'S	160° 29.24'W	4.498	(Quasi)Seaknol	1	1	7	91			(28.35)	Sp	1.93	25.2	0.17	0.09	0.53	15.90	18.08	-	-	-	dl	0	
(86432) Average			4.691		0	8	22	52	18		15.62	M.Sp	1.98	25.4	0.25	0.13	0.47	15.27	16.91						
86S1736FG07	16° 14.78'S	159° 45.11'W	4.773	(Quasi)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	dl	0	
86S1736FG08	16° 13.75'S	159° 46.14'W	4.836	(Quasi)Flat	6	87	7				32.25	Sp.P	2.09	31.5	0.13	0.08	0.55	16.00	20.04	CSC	1	5	dl	0	
86S1736FG09	16° 13.67'S	159° 44.15'W	4.998	(Quasi)Seaknol	19	74	2	5			23.95	Sp.P	1.90	32.4	0.13	0.07	0.53	15.52	19.95	BC	1	0	dl	0	
(86433) Average			4.869		12	81	5	2			18.73	Sp.P	2.01	31.9	0.13	0.08	0.54	15.80	20.01						
86S1736FG10	16° 29.98'S	159° 29.88'W	5.082	(Quasi)Flat	23	56	8	13			5.92	Ot.P	1.93	31.9	0.27	0.14	0.44	14.15	17.21	BC	1	0	el	0	
86S1736FG11	16° 29.07'S	159° 30.78'W	4.911	(Quasi)Seaknol							0.00	—	—	—	—	—	—	—	—	-	-	-	dl	0	
86S1736FG12	16° 29.03'S	159° 28.71'W	4.951	(Quasi)Flat	12	83	22	3			23.95	Sp.E	2.00	30.6	0.19	0.13	0.44	13.12	19.43	CSC	1	5	dl	0	
(86434) Average			4.981		14	62	19	5			9.98	Sp.E	1.99	30.9	0.21	0.13	0.44	13.32	18.99						
86S1736FG13	16° 14.82'S	159° 14.67'W	5.139	(Quasi)Flat	4	89	7				21.35	Sp.P	2.10	28.4	0.21	0.13	0.48	15.05	19.30	BC	1	0	ts	0	
86S1736FG14	16° 13.88'S	159° 15.62'W	5.225	(Quasi)Flat	6	40	48	6			16.33	Sp.M	1.97	30.5	0.22	0.12	0.52	15.76	19.04	BC	2	0	el	0	
86S1736FG15	16° 13.72'S	159° 13.60'W	5.084	(Quasi)Flat	4	50	30	5	11		26.85	Sp.M	1.98	28.8	0.22	0.13	0.48	14.68	18.30	BC	1	0	ds	0	
(86435) Average			5.149		5	60	27	4	5		21.51	Sp.M	2.02	29.1	0.22	0.13	0.49	15.07	18.82						
86S1736FG16	15° 58.93'S	159° 30.08'W	5.018	(Quasi)Flat	9	68	23				22.07	Sp.M	1.97	30.8	0.15	0.09	0.51	14.74	20.28	BC	1	0	el	0	
86S1736FG17	15° 58.97'S	159° 31.17'W	4.796	(Quasi)Flat	3	44	45	8			33.81	E.Sp	2.01	29.3	0.19	0.11	0.53	15.81	18.41	CSC	1	3	ds	0	
86S1736FG18	15° 58.92'S	159° 29.21'W	4.978	(Quasi)Flat	7	23	26	26	18		22.38	E.M	1.98	29.0	0.18	0.11	0.51	15.76	16.25	BC	1	0	ds	0	
(86436) Average			4.931		6	45	33	11	5		26.09	E.Sp	1.99	29.7	0.17	0.10	0.52	15.50	18.74						

* sil% : siliceous fossil %　　cal% : calcareous fossil %　　T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 7)

Sample No. (Station)	Location: Latitude	Location: Longitude	Location: Depth (m)	Location: Topography	Manganese Nodules: Size distribution (%) 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H20 (%)	XRF Analyses (%) Ni	Cu	Co	Mn	Fe	Geology: Sediment	sil%	cal%	T.P.L.* type	thick (m)	Remarks
86S1737FG04	16° 30.03'S	159° 00.10'W	5.150	(Quasi)Flat	3	86	11				(12.79)	Sp.M	2.04	25.6	0.25	0.14	0.45	15.41	18.35	BC	1	0	a	0	
86S1737FG05	16° 29.13'S	159° 01.13'W	5.087	(Quasi)Flat	2	71	27				31.37	Sp	2.13	28.1	0.21	0.12	0.52	15.83	18.87	BC	1	0	a	0	
86S1737FG06	16° 29.10'S	158° 59.23'W	5.114	(Quasi)Flat	2	83	13	2			25.01	Sp.M	2.06	25.2	0.23	0.13	0.49	15.67	18.94	BC	1	0	a	0	
(86437) Average			5.117		2	76	21	1			28.44	Sp.M	2.10	26.9	0.22	0.12	0.51	15.79	18.79						
86S1737FG07	16° 15.04'S	158° 45.04'W	5.065	(Quasi)Flat	2	75	23				(12.88)	Sp	2.00	30.7	0.23	0.13	0.50	15.64	18.65	BC	1	0	a	0	
86S1737FG08	16° 14.11'S	158° 46.06'W	5.050	(Quasi)Flat	2	40	58				(19.18)	Sp	2.05	31.4	0.20	0.11	0.51	15.60	18.65	BC	1	0	a	0	
86S1737FG09	16° 14.12'S	158° 44.15'W	5.050	(Quasi)Flat	1	23	31	41	4		(22.98)	Ef.Sp	1.95	28.2	0.21	0.12	0.50	15.25	18.05	BC	1	0	a	0	
(86438) Average			5.055		0	0	0	0	0		0.00	—	—	—	—	—	—	—	—						
86S1737FG10	16° 29.94'S	158° 30.04'W	4.236	(Quasi) Seamoun	4	65	27	4			(17.57)	Sp.M	2.02	28.6	0.27	0.15	0.45	16.90	18.19	FO	0	90	d1	0	
86S1737FG11	16° 29.03'S	158° 30.95'W	4.386	(Quasi) Seamoun	1	9	25	65			(22.37)	Sp	1.96	29.0	0.23	0.12	0.47	16.88	17.78	-	-	-	d1	0	
86S1737FG12	16° 28.99'S	158° 28.95'W	4.508	(Quasi) Seamoun	1	8	75	16			29.57	Sp	1.97	31.7	0.35	0.18	0.42	17.39	16.39	FO	0	90	d1	0	
(86439) Average			4.377		1	8	75	16			29.57	Sp	1.97	31.7	0.35	0.18	0.42	17.39	16.39						
86S1737FG13	15° 59.99'S	158° 30.16'W	5.002	(Quasi)Flat	6	94					23.46	Sp	1.98	25.7	0.17	0.11	0.48	14.34	19.36	BC	1	0	e1	0	
86S1737FG14	15° 59.07'S	158° 31.21'W	4.834	(Quasi)Flat	21	57	6	16			23.20	P.Pt	1.87	30.4	0.16	0.11	0.38	16.37	16.81	BC	2	0	ds	0	
86S1737FG15	15° 58.98'S	158° 29.32'W	4.949	(Quasi)Flat	8	20	21	37	14		29.39	M.Sp	1.98	26.2	0.19	0.11	0.49	14.90	17.51	BC	1	0	d1	0	
(86440) Average			4.928		11	54	10	19	5		25.35	Sp.P	1.98	27.3	0.18	0.11	0.45	15.35	18.47						
86S1636FG10	15° 45.05'S	159° 45.00'W	4.980	(Quasi)Flat	5	52	38	4	6		(20.88)	Sp.M	2.01	30.8	0.21	0.14	0.45	14.00	18.88	BC	1	0	ds	0	
86S1636FG11	15° 44.11'S	159° 46.02'W	4.988	(Quasi)Flat	100						0.01	Ot	—	—	—	—	—	—	—	-	-	-	ds	0	
86S1636FG12	15° 44.16'S	159° 44.03'W	4.969	(Quasi)Flat	6	91	3				27.89	Sp.P	2.00	28.9	0.18	0.11	0.50	15.17	19.96	CSC	1	3	d2	0	
(86441) Average			4.979		6	91	3	0	0		13.95	Sp	2.00	28.9	0.18	0.11	0.50	15.17	19.96						
86S1636FG13	15° 44.97'S	159° 15.12'W	5.038	(Quasi)Flat		77	21	2			31.97	Sp	2.02	31.0	0.19	0.10	0.55	16.85	19.02	BC	1	0	a	0	
86S1636FG14	15° 43.91'S	159° 16.25'W	5.048	(Quasi)Flat							(0.00)	—	—	—	—	—	—	—	—	-	-	-	b	0	
86S1636FG15	15° 42.81'S	159° 14.48'W	5.022	(Quasi)Flat	0	84	16				31.10	Sp.P	2.05	30.5	0.16	0.09	0.56	16.80	19.38	BC	1	0	a	0	
(86442) Average			5.035		0	80	19	1			31.54	Sp.P	2.03	30.7	0.17	0.09	0.55	16.73	19.20						

* sil% : siliceous fossil % cal% : calcareous fossil % T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 8)

Sample No. (Station)	Location: Latitude	Longitude	Depth (m)	Topography	Manganese Nodules: Size distribution (%) 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H_2O (%)	XRF Analyses (%) Ni	Cu	Co	Mn	Fe	Geology: Sediment	sil%	cal%	T.P.L.* type	thick (m)	Remarks
86S1637FG04	15° 30.11'S	158° 28.95'W	4.895	(Quasi)Flat	5	19	23	30	23		22.58	E.P	1.98	30.0	0.27	0.26	0.36	15.13	17.94	CSC	1	2	ds	0	
86S1637FG05	15° 29.24'S	158° 30.98'W	4.896	(Quasi)Flat	1	9	19		71		(5.15)	E.Sp	1.98	28.9	0.21	0.14	0.45	14.97	18.04	-	-	-	ds	0	
86S1637FG06	15° 29.38'S	158° 28.98'W	4.789	(Quasi)Flat							0.00	—	—	—	—	—	—	—	—	-	-	-	ds	0	
(86443) Average			4.860		5	19	23	30	23		11.30	E.P	1.98	30.0	0.27	0.25	0.38	15.13	17.94						
86S1637FG07	15° 44.98'S	158° 45.10'W	5.105	(Quasi)Flat	5	48	41	6			26.21	M.Ef	1.96	30.1	0.27	0.17	0.45	15.89	17.55	BC	1	0	a	0	
86S1637FG08	15° 43.97'S	158° 46.00'W	5.088	(Quasi)Flat	3	26	65	6			(21.78)	Sp.M	1.97	30.3	0.19	0.11	0.50	16.00	19.37	BC	1	0	a	0	
86S1637FG09	15° 43.83'S	158° 44.02'W	5.040	(Quasi)Flat	3	26	41	30			29.55	M.Ef	2.02	30.2	0.29	0.17	0.42	15.29	17.09	BC	1	0	bc	0	
(86444) Average			5.078		4	36	41	19			27.88	M.Ef	1.99	30.1	0.28	0.17	0.44	15.57	17.31						
86S1637FG10	15° 30.88'S	159° 00.56'W	5.022	(Quasi)Flat	2	89	9				(17.18)	Sp.P	2.03	26.4	0.22	0.12	0.51	16.55	18.73	BC	1	1	a	0	
86S1637FG11	15° 28.91'S	159° 01.59'W	5.032	(Quasi)Flat	1	47	52				34.22	Sp.M	1.88	25.2	0.16	0.09	0.54	16.16	18.93	BC	1	1	b	0	
86S1637FG12	15° 29.95'S	158° 59.61'W	5.007	(Quasi)Flat	2	84	14				31.63	Sp.P	2.00	29.0	0.21	0.13	0.48	15.59	18.98	CSC	1	2	a	0	
(86445) Average			5.020		1	65	34				32.93	Sp.M	1.99	27.0	0.19	0.11	0.51	15.89	18.95						
86S1137FG04	10° 30.06'S	158° 59.95'W	5.078	(Hilly)Flat	32	28	3		37		13.42	P.M	1.99	27.1	0.34	0.21	0.36	13.99	13.55	BC	1	0	d2	0	
86S1137FG05	10° 29.17'S	159° 00.91'W	4.941	(Hilly)Flat	84	16					2.85	P	1.99	26.2	0.44	0.27	0.27	11.82	11.95	BC	2	0	e1	0	
86S1137FG06	10° 29.15'S	158° 58.92'W	4.940	(Hilly)Flat	4	36	33	27			18.81	P.E	2.01	31.0	0.35	0.21	0.39	16.91	15.59	CSC	1	3	ds	0	
(86446) Average			4.986		21	31	19	14	14		11.69	P.E	2.00	29.1	0.35	0.21	0.37	15.34	14.48						
86S1136FG07	10° 14.98'S	159° 14.75'W	5.048	(Hilly)Seaknol	2	71	25	2			30.00	E.P	2.00	30.8	0.30	0.18	0.42	17.57	16.89	BC	5	1	d1	0	
86S1136FG08	10° 14.03'S	159° 15.67'W	5.334	(Hilly)Seaknol	2	48	50				19.55	M.E	2.07	27.3	0.37	0.21	0.38	17.80	15.11	BC	2	0	d2	0	
86S1136FG09	10° 13.99'S	159° 13.59'W	4.867	(Hilly)Seaknol	3	28	44	25			35.52	M.Ef	1.99	27.7	0.26	0.14	0.48	18.52	16.87	FO	2	40	d1	0	
(86447) Average			5.083		2	48	39	11			28.86	M.E	2.01	28.7	0.30	0.17	0.44	18.03	16.46						
86S1136FG10	10° 00.37'S	159° 30.34'W	4.802	(Hilly)Platfor	1	3	7	15	74		(46.68)	M.Sp	1.96	27.9	0.23	0.12	0.43	16.86	16.26	-	-	-	d1	0	
86S1136FG11	09° 59.47'S	159° 31.41'W	5.095	(Hilly)Platfor	86	14					3.35	P	2.04	21.4	0.55	0.33	0.26	13.65	11.50	BC	1	0	a	0	
86S1136FG12	09° 59.54'S	159° 29.52'W	4.973	(Hilly)Platfor	5	9			86		21.85	M.P	1.88	31.1	0.33	0.18	0.39	16.51	15.24	BC	1	0	e1	0	
(86448) Average			4.957		16	10	0	0	75		12.60	M.P	1.90	29.8	0.36	0.21	0.37	16.09	14.68						

* sil% : siliceous fossil % cal% : calcareous fossil % T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 9)

Sample No. (Station)	Location: Latitude	Location: Longitude	Location: Depth (m)	Location: Topography	Manganese Nodules: Size distribution (%) 0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm	Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%) Ni	Cu	Co	Mn	Fe	Geology: Sediment	silt%	cal%	T.P.L.* type	thick (m)	Remarks
86S1136FG13	10° 45.01'S	159° 45.12'W	5.290	(Hilly) Platfor	4	28	31	15	22		20.71	E.P	1.98	27.3	0.38	0.22	0.37	15.32	14.85	BC	1	0	d2	0	
86S1136FG14	10° 43.96'S	159° 46.18'W	5.133	(Hilly) Platfor	1	66	33				25.63	M.P	2.02	28.3	0.31	0.18	0.43	17.24	17.02	BC	1	0	d1	0	
86S1136FG15	10° 43.92'S	159° 44.16'W	5.176	(Hilly) Platfor	7	26	31	30	6		20.87	M.P	1.98	30.6	0.39	0.21	0.44	18.31	15.14	BC	1	0	d1	0	
(86449) Average			5.200		4	42	32	14	9		22.40	M.P	2.00	28.9	0.35	0.20	0.41	16.96	15.77						
86S1236FG07	10° 59.91'S	159° 30.00'W	3.325	(Hilly) Seamoun		100					0.05	P	—	—	—	—	—	—	—	-	-	-	d1	0	
86S1236FG08	10° 58.97'S	159° 31.06'W	3.342	(Hilly) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
86S1236FG09	10° 58.92'S	159° 29.08'W	3.981	(Hilly) Seamoun	61	39					(0.82)	P	2.08	30.6	0.24	0.11	0.45	17.09	16.87	FO	0	90	d1	0	
(86450) Average			3.549		0	100					0.03	P	—	—	—	—	—	—	—						
86S1136FG16	10° 45.01'S	159° 15.05'W	4.868	(Hilly) Flat	1	85	11	3			23.80	Sp.Ot	1.95	28.7	0.29	0.17	0.45	17.87	17.45	FO	0	70	e1	0	
86S1136FG17	10° 44.04'S	159° 16.04'W	4.846	(Hilly) Flat	2	68	27	3			23.29	M.Sp	2.00	28.1	0.33	0.20	0.41	17.48	16.60	FO	2	60	e1	0	
86S1136FG18	10° 44.05'S	159° 14.13'W	4.894	(Hilly) Flat	2	89	9				(2.18)	Ot.P	2.03	26.3	0.42	0.28	0.36	18.12	15.61	FO	5	60	e1	0	
(86451) Average			4.869		1	77	19	3			23.55	Sp.M	1.97	28.4	0.31	0.19	0.43	17.88	17.03						
86S1136FG19	10° 30.38'S	159° 59.29'W	4.639	(Mount) Seamoun	1	38	56	5			31.02	Sp.P	2.01	28.4	0.20	0.11	0.50	16.75	18.37	FO	3	70	d1	0	
86S1136FG20	10° 29.45'S	160° 00.22'W	5.306	(Mount) Seamoun	0	34	43	12	11		29.02	M.E	1.95	30.9	0.28	0.18	0.43	17.32	16.70	BC	1	80	d1	0	
86S1136FG21	10° 29.45'S	159° 58.13'W	4.633	(Mount) Seamoun							(0.00)	—	—	—	—	—	—	—	—	-	-	-	d1	0	
(86452) Average			4.859		1	38	50	8	5		30.02	Sp.M	1.98	29.6	0.23	0.14	0.47	17.02	17.57						
86S1136FG22	10° 15.04'S	159° 44.81'W	5.509	(Hilly) Channel							(0.00)	—	—	—	—	—	—	—	—	-	-	-	ds	0	
86S1136FG23	10° 13.97'S	159° 45.55'W	5.476	(Hilly) Channel	17	59	24				(6.01)	P.Ot	2.01	33.3	0.31	0.17	0.45	18.22	18.37	-	-	-	ds	0	
86S1136FG24	10° 13.92'S	159° 43.17'W	5.505	(Hilly) Channel							(0.00)	—	—	—	—	—	—	—	—	-	-	-	ds	0	
(86453) Average			5.497		0	0	0				0.00	—	—	—	—	—	—	—	—						
86S1036FG07	09° 00.06'S	159° 28.86'W	5.522	(Hilly) Seaknol	1	56	43				19.08	M.P	2.02	28.3	0.34	0.22	0.37	17.50	15.84	BC	5	0	ds	0	
86S1036FG08	08° 59.11'S	159° 30.86'W	5.299	(Hilly) Seaknol	4	47	35	7	7		24.27	P.E	1.98	30.0	0.37	0.21	0.38	15.95	15.18	BC	3	0	ds	0	
86S1036FG09	08° 59.06'S	159° 28.85'W	5.380	(Hilly) Seaknol	1	50	33	12	4		22.42	P.Pl	2.02	28.8	0.36	0.23	0.38	16.69	14.81	BC	5	0	ds	0	
(86454) Average			5.400		2	51	37	7	4		21.92	P.M	2.01	29.5	0.36	0.22	0.37	16.68	15.28						

* sil% : siliceous fossil %　　cal% : calcareous fossil %　　T.P.L : Transparent Layer

Data file around the Cook Islands

(No. 10)

Sample No. (Station)	Location				Manganese Nodules: Size distribution (%)						Abundance (Kg/m2)	Shape	S.G. wet	H2O (%)	XRF Analyses (%)					Geology: Sediment			T.P.L.*		Remarks
	Latitude	Longitude	Depth (m)	Topography	0-2 cm	2-4 cm	4-6 cm	6-8 cm	8-16 cm	16- cm					Ni	Cu	Co	Mn	Fe		sil%	cal%	type	thick (m)	
86S1036FG10	09° 15.02'S	159° 44.92'W	5.549	(Hilly) Seaknol	2	7	50	34	7		23.55	M.Sp	1.94	27.9	0.23	0.13	0.50	18.87	17.69	-	-	-	ds	0	
86S1036FG11	09° 14.04'S	159° 45.89'W	5.720	(Hilly) Seaknol	4	73	19	4			23.73	P.Sp	2.01	31.9	0.22	0.14	0.41	16.30	19.21	BC	3	0	ds	0	
86S1036FG12	09° 14.00'S	159° 43.92'W	5.633	(Hilly) Seaknol							(0.00)	—	—	—	—	—	—	—	—	-	-	-	ds	0	
(86455) Average			5.634		3	40	34	19	3		23.64	Sp.M	1.98	29.9	0.22	0.13	0.45	17.62	18.43						
86S1036FG13	09° 30.00'S	160° 00.03'W	2.859	(Mount) Seamoun-							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
86S1036FG14	09° 29.01'S	160° 01.07'W	2.823	(Mount) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
86S1036FG15	09° 28.98'S	159° 59.10'W	3.479	(Mount) Seamoun							0.00	—	—	—	—	—	—	—	—	-	-	-	d1	0	
(86456) Average			3.054								0.00	—	—	—	—	—	—	—	—						
86S1036FG16	09° 45.10'S	159° 15.21'W	5.412	(Hilly) Platfor	19	12	69				0.72	M.P	2.67	6.2	0.01	0.04	0.04	0.00	1.06	BC	3	0	h	0	
86S1036FG17	09° 44.13'S	159° 16.24'W	5.397	(Hilly) Platfor	100						0.15	Ot	2.00	31.6	0.37	0.25	0.33	20.26	15.18	SC	15	0	d2	0	
86S1036FG18	09° 44.13'S	159° 14.35'W	5.255	(Hilly) Platfor							0.00	—	—	—	—	—	—	—	—	-	-	-	d2	0	
(86457) Average			5.355		33	10	57				0.29	M.P	2.55	10.6	0.37	0.25	0.33	20.26	15.18						
86S1036FG19	09° 44.99'S	159° 44.63'W	5.290	(Hilly) Seaknol	36	53	11				6.05	P.M	1.97	29.1	0.54	0.29	0.33	16.95	13.16	BC	3	0	ds	0	
86S1036FG20	09° 44.00'S	159° 45.63'W	5.513	(Hilly) Seaknol	1	7	15		77		6.52	Pl.M	1.76	31.7	0.28	0.16	0.16	5.27	11.34	BC	2	0	d1	0	
86S1036FG21	09° 43.98'S	159° 43.56'W	5.014	(Hilly) Seaknol	0	22	29	49			39.88	M.Ef	1.99	28.3	0.25	0.16	0.41	17.06	16.79	SCC	10	5	d1	0	
(86458) Average			5.272		4	24	25	37	10		17.46	M.Pl	1.96	28.8	0.29	0.17	0.37	15.64	15.72						
86S1036FG22	09° 14.99'S	159° 14.96'W	5.352	(Hilly) Platfor	10	17	3	70			2.25	M.Pt	1.96	26.5	0.31	0.20	0.35	14.85	13.34	-	-	-	d2	0	
86S1036FG23	09° 13.98'S	159° 15.89'W	5.305	(Hilly) Platfor	4	37	37	22			(8.57)	Ot.P	1.96	29.3	0.35	0.22	0.36	15.56	14.88	BC	8	0	ds	0	
86S1036FG24	09° 13.81'S	159° 13.92'W	5.372	(Hilly) Platfor	13	41	24	22			(4.15)	M.P	2.01	25.8	0.42	0.27	0.29	15.48	13.58	BC	5	0	d2	0	
(86459) Average			5.343		10	17	3	70			2.25	M.Pt	1.96	26.5	0.31	0.20	0.35	14.85	13.34						
86S1037FG04	09° 30.03'S	159° 00.03'W	5.397	(Hilly) Flat	13	67	20				8.25	P.E	2.01	25.7	0.38	0.21	0.36	15.66	13.36	BC	5	0	ds	0	
86S1037FG05	09° 28.89'S	159° 01.03'W	5.309	(Hilly) Flat	1	47	39	13			25.32	M.Sp	2.02	31.0	0.38	0.21	0.41	18.49	14.80	BC	3	0	ds	0	
86S1037FG06	09° 28.69'S	158° 59.10'W	5.439	(Hilly) Flat	24	60	16				5.22	P.Ot	1.99	31.1	0.45	0.24	0.30	14.32	12.81	BC	1	0	ds	0	
(86460) Average			5.382		7	53	32	9			13.26	M.P	2.01	29.9	0.39	0.22	0.39	17.33	14.23						

* sil% : siliceous fossil %　　cal% : calcareous fossil %　　T.P.L : Transparent Layer

Monthly Frequency Distribution of Wind Velocity in 1986

(W.V: m/sec)

W.V / Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
September	10	1	12	9	25	47	103	82	85	31	33	15	15	12	0	0	480
%	2.08	0.21	2.50	1.88	5.21	9.79	21.46	17.08	17.71	6.46	6.88	3.13	3.13	2.50	0	0	
October	4	0	3	14	20	33	32	44	47	32	34	26	18	5	0	0	312
%	1.28	0	0.96	4.49	6.41	10.58	10.26	14.10	15.06	10.26	10.90	8.33	5.77	1.60	0	0	

Monthly Frequency Distribution of Wind Direction in 1986

W.D. / Month	CALM	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
September	10	27	10	33	28	195	83	41	2	8	0	3	1	1	9	16	13	480
%	2.08	5.63	2.08	6.88	5.83	40.63	17.29	8.54	0.42	1.67	0	0.63	0.21	0.21	1.88	3.33	2.71	
October	4	31	24	37	31	73	40	40	11	4	0	0	0	1	1	10	5	312
%	1.28	9.94	7.69	11.86	9.94	23.40	12.82	12.82	3.53	1.28	0	0	0	0.32	0.32	3.21	1.60	

Monthly Frequency Distribution of Weather in 1986

Weather / Month	Fine	Cloudy	Rain	Total	Light rain
September	16	2	2	20	8
%	80	10	10		(40)
October	10	0	3	13	2
%	76.92	0	23.08		(15.38)

Monthly Frequency Distribution of Atmospheric Pressure (daily average) in 1986

(A.P: mb)

A.P / Month	1007.1 ~ 1008.0	1008.1 ~ 1009.0	1009.1 ~ 1010.0	1010.1 ~ 1011.0	1011.1 ~ 1012.0	1012.1 ~ 1013.0	1013.1 ~ 1014.0	1014.1 ~ 1015.0	1015.1 ~ 1016.0	1016.1 ~ 1017.0	1017.1 ~ 1018.0	1018.1 ~ 1019.0	Total
September	2	4	24	39	66	85	80	85	43	33	14	5	480
%	0.42	0.83	5.00	8.13	13.75	17.71	16.67	17.71	8.96	6.88	2.92	1.04	
October	0	0	14	26	39	52	63	61	41	16	0	0	312
%	0	0	4.49	8.33	12.50	16.67	20.19	19.55	13.14	5.13	0	0	

Monthly Frequency Distribution of Swell Direction in 1986

S.D / Month	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Not clear	Total
September	0	0	6	4	16	10	15	5	4	0	0	0	0	0	0	0	60	120
%	0	0	5.00	3.33	13.33	8.33	12.50	4.17	3.33	0	0	0	0	0	0	0	50.00	
October	0	3	0	3	6	3	3	6	15	0	0	0	0	0	0	0	39	78
%	0	3.85	0	3.85	7.69	3.85	3.85	7.69	19.23	0	0	0	0	0	0	0	50.00	

Monthly Frequency Distribution of Swell Cycle in 1986

(S.C: sec)

S.C / Month	5	6	7	8	9	10	11	12	13	14	15	Not clear	Total
September	0	24	6	21	0	3	0	6	0	0	0	60	120
%	0	20.00	5.00	17.50	0	2.50	0	5.00	0	0	0	50.00	
October	0	6	0	21	0	6	0	6	0	0	0	39	78
%	0	7.69	0	26.92	0	7.69	0	7.69	0	0	0	50.00	

Monthly Frequency Distribution of Swell Height in 1986

(S.H: m)

S.H / Month	1	2	3	4	5	Not clear	Total
September	21	28	8	3	0	60	120
%	17.50	23.33	6.67	2.50	0	50.00	
October	6	12	15	6	0	39	78
%	7.69	15.38	19.23	7.69	0	50.00	

Monthly Frequency Distribution of Degree of Cloudiness in 1986

D.C / Month	0	1	2	3	4	5	6	7	8	9	Total
September	0	11	31	89	105	146	14	38	33	13	480
%	0	2.29	6.46	18.54	21.88	30.42	2.92	7.92	6.88	2.71	
October	0	0	39	46	55	68	16	34	17	17	312
%	0	0	12.50	14.74	17.63	21.79	5.13	10.90	11.86	5.45	