4-5 Bottom Materials

1) Distribution of Bottom Materials

Bottom materials in the survey area are mainly composed of brown clay materials and calcareous sediments.

Calcareous sediments are scattered in the relatively shallow sea area adjacent to the sea mounts and to the sea knolls, while brown clay materials are distributed in most of parts of the area. The sampling ratio is shown in Tab. 4-5-1. Although this sampling ratio does not always indicate the coverage ratio, the fact that the calcareous sediment ratio indicating a high value of 27.2% differs greatly from last year's study area (5.6%).

As shown in Fig. 4-5-1, calcareous sediments are widely recognized in both of the sea areas: 10°S - 11°S and 15°0' - 16°0'S. These areas are almost sea knolls.

As for the distribution of zeolite (phillipsite), there is a difference between the north and the south areas as described later.

Table 4-5-1 Sampling Ratio of Bottom Materials

Age	Classification	Sample number	Ratio (%)	
Quaternary	Brown clay	98	70.0	
	Siliceous clay	1	0.7	
	Calc-siliceous clay	24	17.2	97.9
	Silic-calcareous clay	1	0.7	
	Foraminifera	13	9.3	
Former	Insoluble brown clay	3	2.1	2.1

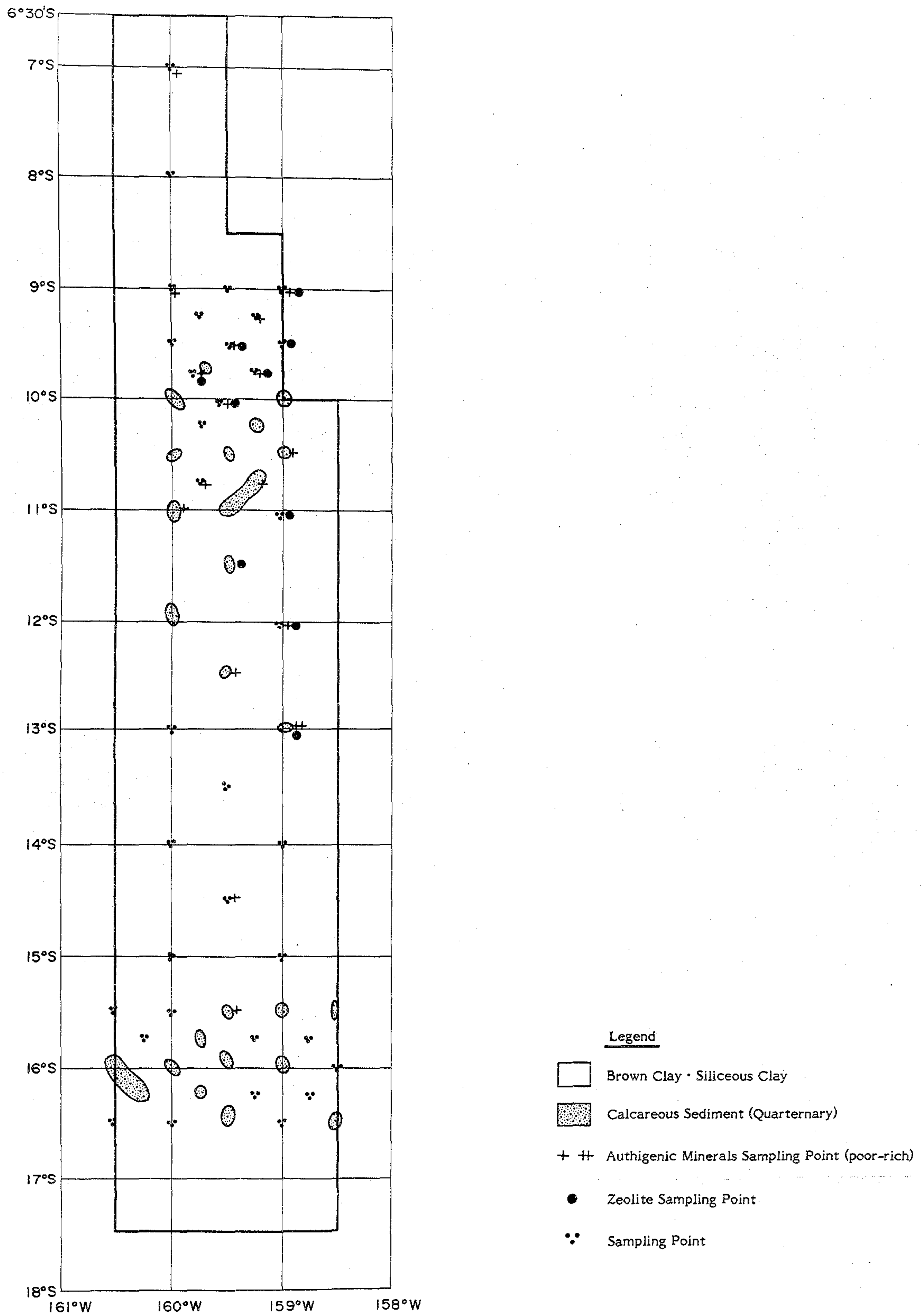


Fig. 4.5.1 Distribution of Bottom Materials

2) Classification of Bottom Materials

Classification of bottom materials is done according to the classification criteria of bottom materials shown in Tab. 4-5-2.

Quantitative analysis of each composition was made by the microscope observation using smear slide (x100).

Table 4-5-2 Classification Criteria of Bottom Materials

	Fossil	Siliceous	Calcareous (*1)	Remarks (*2)
Brown clay	< 10			
Insoluble brown clay	< 10			Imperiable
Silic-calcareous clay	10 - 30		> 5	Siliceous fossil > Calcareous fossil >
Calc-siliceous clay	10 - 30	> 5		Calcareous fossil Siliceous fossil
Foraminifera clay	> 30			Mainly foramini-fera dominant

*1 Radiolaria, Diatons, Silicoflagellate, Sponge spicule

*2 Foraminifera, Calcareous Nannoplankton

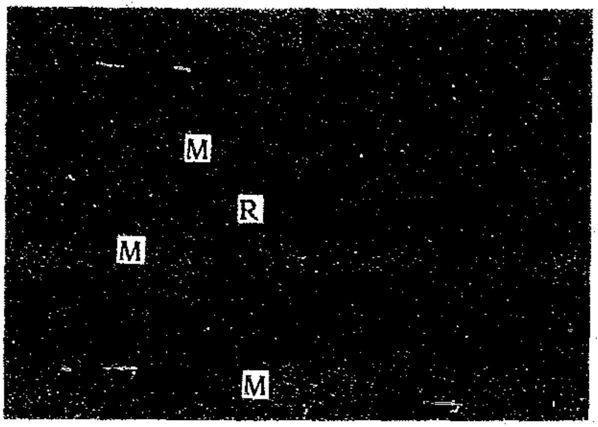
3) Properties of bottom materials

Fig. 4-5-2 shows major microscope pictures of each bottom materials. Properties of bottom materials are generally described in this section.

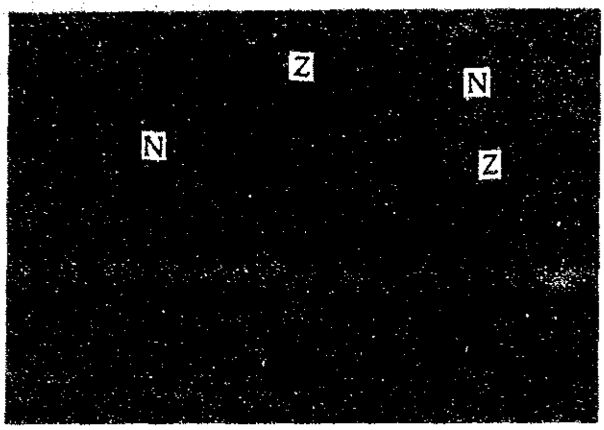
(1) Brown clay materials

1 Brown clay

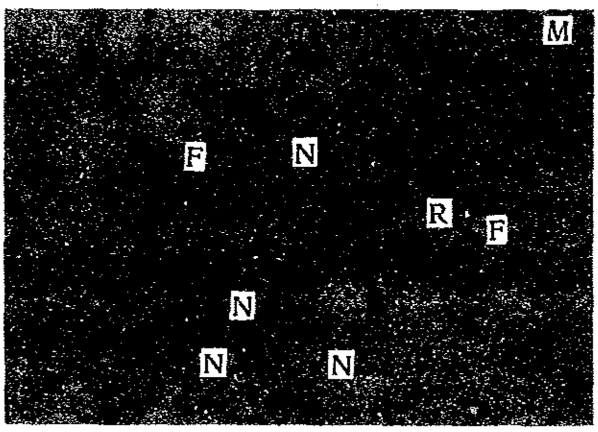
The main component minerals of brown clay in the survey area are clay minerals, siliceous creature shells and a small amount of amorphous material, phyroclastic material, zeolites, barite, ichthyolith and micro-nodule.



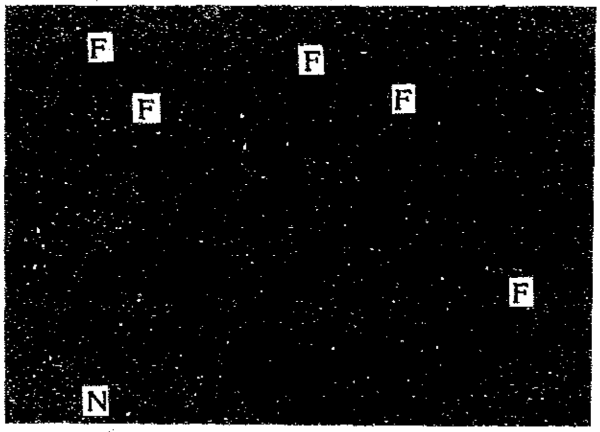
Brown clay (86S1736FG10)



Brown clay (86S1337HG02)



Calc-siliceous clay (86S1636FG04)



Foraminifera ooze (86S1136FG17)

Index R : Radiolaria S : Sponge spicule F : Foraminifera fragment
Z : Zeolite M : Mud fragment N : Micro-nodule

Fig. 4.5.2 Smear Slide Photos of Bottom Sediments

Siliceous creature shells are generally small amount, composing of small amount of radiolaria and silicoflagellate. The content of radiolaria are generally low, less than 5% in most cases and average content of whole sampling points is about 2%. But there is some difference between the northern part of 12°S and the southern part of 12°S. The content of north part indicates about 3% and that of south part indicates twice of the north value. Its color is generally dark brownish red to dark brown and its size is fine. But the brown clay sampled from the sea area (9°S to 12°S) is coarse because of bearing of zeolites.

2 Insoluble brown clay

It is almost same mineral composition as brown clay's composition. It is characterized by brownish and yellow color, high viscosity (as sticky as birdlime), and water-insolubility. In the survey area, insoluble brown clay is sampled only at three sampling points.

3 Calcareous sediments

Calcareous sediments are classified according to the quantitative ratio of calcareous biogenic debris and siliceous biogenic debris. In the survey area, foraminifera ooze, calcareous-siliceous clay and siliceous-calcareous clay are recognized. All of them mainly consists of foraminifera debris and contained a small amount of radiolaria, a extremely small amount of sponge spicule, micronodule and zeolites. Its color is brownish yellow or brownish black. Its grain size is fine to medium.

4) Composing minerals of bottom materials

Samples of the sea bottom materials taken by spade corer (SC) were taken from 6 points of different depth of core samples, and were examined by X-ray diffraction analysis to study the mineral composition. Tab. 4-5-3 and Fig. 4-5-3 shows the results of analysis.

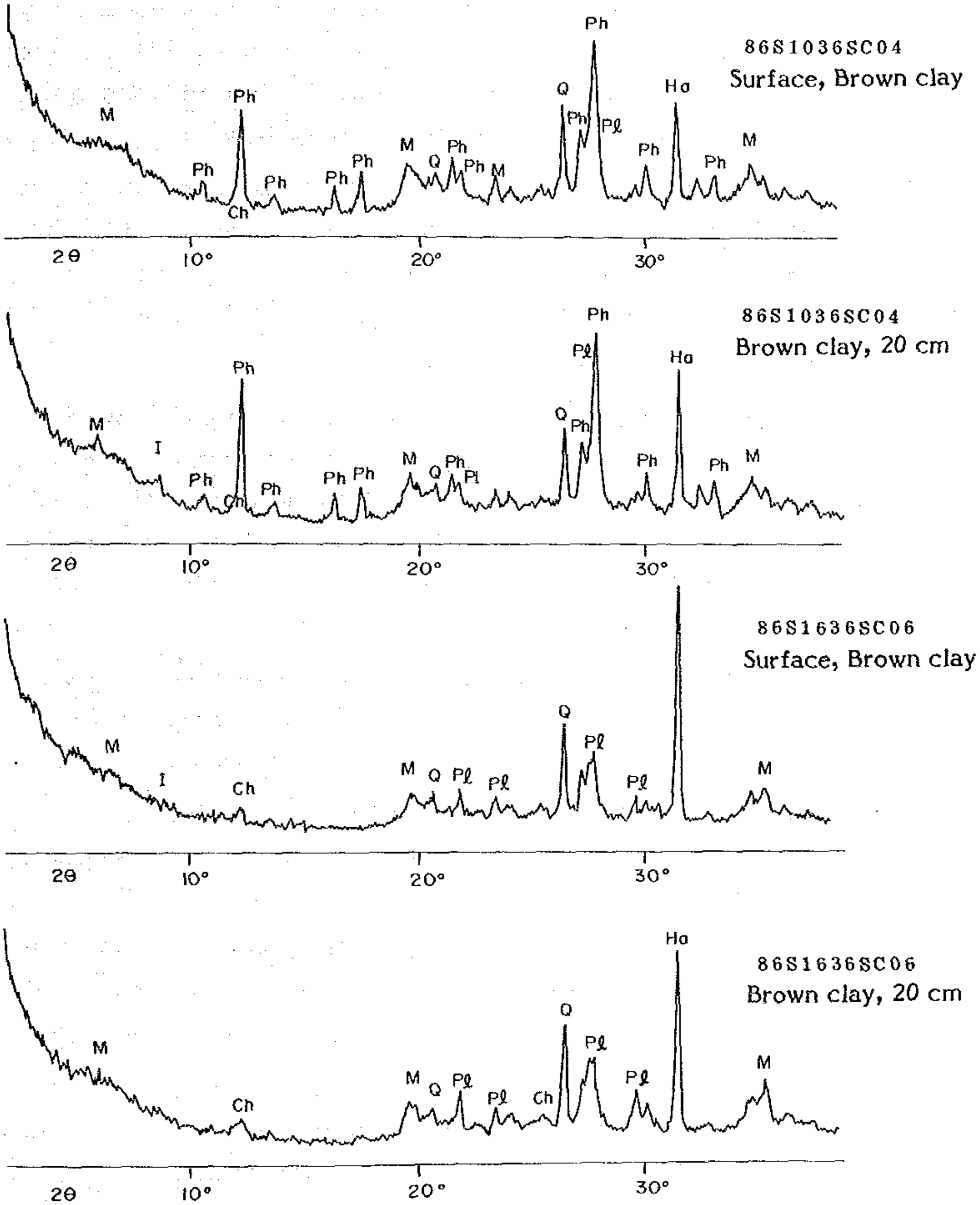
Table 4.5.3 Results of X-ray Diffraction Analysis of Bottom Materials

Sample No. \ Minerals	Qtz	Pl	Mont	Il	Chl	Phil	Ha
86S1036SC04 0cm (Brown Clay)	±	±	±	±	±	+	++
〃 5cm (〃)	±	±	±	±	±	+	+
〃 10cm (〃)	±	±	±	±	±	+	+
〃 20cm (〃)	±	±	±		±	+	+
〃 30cm (〃)	±	±	±		±	+	±
〃 40cm (〃)	±	±	±	±	±	+	+
86S163SC06 0cm (Brown Clay)	+	+	±	±	±		++
〃 5cm (〃)	+	+	±	±	±		+
〃 10cm (〃)	+	+	±		±		++
〃 20cm (〃)	+	+	±	±	±		++
〃 30cm (〃)	+	+	±		±		+
〃 40cm (〃)	+	+	±		±		+

Legend: ++, +, ± indicate intencity of diffraction peaks, (++: moderate, + weak, ± very weak)

Qtz: Quartz, Pl: Plagioclase, Mont: Montmorillonite

Il: Illite, Chl: Chlorite, Phil: Phillipsite, Ha: Halite



Index Q : Quartz Pl : Plagioclase M : Montmorillonite I : Illite
Ch : Chrolite Ph : Phillipsite Ha : Halite

Fig. 4.5.3 Typical Pattern of the X-ray Diffraction of Bottom Sediment

All samples are brown in color. Quartz, plagioclase, phillipsite and clay materials were detected. Clay minerals are illite, chlorite and montmorillonite, and halite. It exhibits variation of mineral composition caused by the difference in depth from the sea bottom.

It is worth noticing that phillipsite is widely observed in the representative sample (SC04) from the northern area and not in the representative sample (SC06) from the southern area, along with the area distribution of minerals in the whole area as shown in Fig. 4-5-1.

5) Chemical composition of bottom materials

Samples of the sea bottom materials taken by spade corer (SC) were taken from 6 points of different depth, and were examined by chemical analysis. Tab. 4-5-4 shows the results of the analysis. This analysis prevailed the content variations from upper to lower layer of the bottom materials, and between the north and the south areas in this area, which had been obscure in the last year's survey.

1 To compare upper and lower layer, upper bottom materials have higher content of Fe_2O_3, FeO and Na_2O. On the other hand, lower bottom materials have a higher content of SiO_2 and CaO.

2 Components as MnO, Ni, Cu Co and Sr indicate a different content between the upper and the lower layer, but is not uniform between the north and the south areas.

3 In the comparison between the north area (SC04) and the south area (SC06), the north area has a higher content of SiO_2 and Y, whereas the south area has a higher content of Fe_2O_3, FeO, MnO, Co and Sr.

4 In comparison with the last year's survey results, a north-south difference is more clear in the following components.

FeO: '85 area < north area < south area

Y: '85 area > north area > south area

Co: '85 area < north area < south area

Sr: '85 area < north area < south area

Table 4-5-4 Chemical Composition of the Bottom Materials

(%)

No.	Sample No.		SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	BaO	Na_2O	K_2O	P_2O_5	Ig-loss
1	86S1036SC04	Surface	44.73	0.96	14.21	9.65	0.19	1.80	3.01	3.28	0.05	5.84	2.55	1.62	11.21
2		5cm	44.69	0.92	14.80	9.99	0.06	1.75	2.98	3.12	0.04	5.42	2.73	1.34	11.14
3		10cm	44.85	1.05	14.56	10.08	0.03	1.76	2.92	3.37	0.05	5.13	2.67	1.34	11.25
4		20cm	45.06	1.07	14.42	10.22	0.04	1.74	2.93	3.35	0.05	5.07	2.70	1.35	10.92
5		30cm	45.92	0.84	13.92	8.54	0.03	2.10	3.03	3.87	0.04	5.17	2.66	1.84	10.95
6		40cm	45.57	0.88	14.06	8.85	0.04	2.21	3.00	3.75	0.04	4.96	2.63	1.77	11.31
7	86S1636SC06	Surface	36.38	1.61	13.13	12.25	0.58	2.59	3.63	3.12	0.36	7.04	1.71	0.68	16.54
8		5cm	38.09	1.62	13.52	11.87	0.32	2.35	3.70	3.07	0.36	6.89	1.78	0.77	15.40
9		10cm	39.13	1.65	13.73	11.82	0.32	2.30	3.70	3.13	0.37	5.87	1.82	0.78	15.00
10		20cm	39.89	1.69	13.75	11.81	0.19	2.13	3.65	3.14	0.35	5.43	1.84	0.69	14.40
11		30cm	40.40	1.77	13.72	11.95	0.03	2.13	3.69	3.52	0.36	5.36	1.90	0.70	13.37
12		40cm	40.38	1.87	13.85	11.41	0.06	1.99	3.70	3.81	0.30	5.50	1.93	0.63	13.98
	X		44.08	0.92	13.59	10.04	<0.01	1.81	3.46	3.46	3.10	0.05	3.97	2.14	10.84
	Y		51.5	0.59	12.5	5.4	–	0.53	1.5	3.0	1.5	–	5.7	3.3	11.2

(%)

No.	Sample No.		Pb	V	B	Zn	Y	Ni	Cu	Co	As	Sr	Mo		合 計
1	86S1036SC04	Surface	0.011	0.011	0.011	0.016	0.024	0.025	0.04	0.019	0.003	0.029	0.001		99.29
2		5cm	0.010	0.009	0.013	0.028	0.023	0.028	0.04	0.019	0.003	0.027	0.001		99.19
3		10cm	0.011	0.008	0.011	0.016	0.025	0.026	0.04	0.019	0.003	0.030	0.002		99.26
4		20cm	0.010	0.013	0.010	0.015	0.026	0.026	0.04	0.019	0.003	0.028	0.002		99.12
5		30cm	0.010	0.006	0.010	0.017	0.037	0.045	0.05	0.022	0.002	0.028	0.004		99.14
6		40cm	0.009	0.011	0.010	0.017	0.035	0.046	0.05	0.023	0.002	0.028	0.004		99.31
7	86S1636SC06	Surface	0.017	0.011	0.013	0.020	0.011	0.027	0.04	0.036	0.004	0.043	0.002		99.85
8		5cm	0.013	0.011	0.012	0.020	0.011	0.027	0.04	0.025	0.003	0.041	0.002		99.95
9		10cm	0.013	0.009	0.013	0.023	0.011	0.025	0.04	0.024	0.003	0.042	0.002		99.83
10		20cm	0.011	0.013	0.011	0.019	0.011	0.023	0.04	0.022	0.003	0.043	0.002		99.16
11		30cm	0.013	0.013	0.011	0.019	0.011	0.024	0.04	0.023	0.003	0.046	0.003		99.11
12		40cm	0.011	0.017	0.010	0.017	0.010	0.022	0.03	0.022	0.003	0.048	0.002		99.61
	X		0.007	0.010	0.032	0.016	0.032	0.032	0.05	0.017	0.002	0.024	0.004		95.63
	Y		–	–	0.17	–	–	–	–	–	–	–	–		–

No.1 12 : Results of this survey

X : Results of the last year's

Y : DOMES Site-B (Bischoff J.L. et.al., 1979)

5 To compare with bottom materials of DOMES site-B*1, bottom materials in this area have higher content of TiO_2, Fe_2O_3, MnO, CaO and P_2O_5. On the other hand, bottom materials in this survey area have a lower content of SiO_2, Na_2O, and K_2O.

6 Table 4-5-5 shows the correlation coefficients of chemical components. MnO_2 indicates positive correlation with FeO, Pb and Co, and negative one with SiO_2. And Al_2O_3, Fe_2O_3 indicates a positive correlation with Pb, As and Sr, and negative with Ni, Cu and Y. Ni indicates a positive correlation with P_2O_5, Cu, Mo and Y, and a negative one with Fe_2O_3 and TiO_2

Table 4-5-5 Mutual Relations among Metal Content in the Bottom Materials

	SiO2	TiO2	Al2O3	Fe2O3	FeO	MnO2	MgO	CaO	BaO	Na2O	K2O	P2O5	LOI	Pb	V	B	Zn	Y	Ni	Cu	Co	As	Sr	Mo
SiO2	1.00	-0.69	0.83	-0.93	-0.78	-0.76	-0.93	0.47	-0.95	-0.79	0.87	0.91	-0.99	-0.85	-0.37	-0.55	-0.28	0.90	0.52	0.38	-0.74	-0.68	-0.88	0.21
TiO2		1.00	-0.69	0.93	0.43	0.52	0.96	-0.22	0.95	0.47	-0.94	-0.96	0.85	0.62	0.62	0.25	0.12	-0.94	-0.63	-0.64	0.48	0.54	0.93	-0.15
Al2O3			1.00	-0.63	-0.72	-0.92	-0.80	0.09	-0.81	-0.69	0.85	0.80	-0.85	-0.76	-0.24	-0.21	0.06	0.56	0.07	0.00	-0.84	-0.33	-0.74	-0.25
Fe2O3				1.00	0.61	0.52	0.89	-0.54	0.93	0.62	-0.81	-0.88	0.89	0.76	0.43	0.51	0.28	-0.97	-0.74	-0.60	0.83	0.75	0.89	-0.36
FeO					1.00	0.74	0.54	-0.62	0.80	0.81	-0.86	-0.50	0.81	0.86	-0.02	0.89	0.26	-0.54	-0.26	0.00	0.83	0.68	0.43	-0.50
MnO2						1.00	0.69	-0.15	0.70	0.67	-0.75	-0.47	0.81	0.71	0.01	0.38	0.16	-0.42	0.15	0.26	0.89	0.23	0.58	0.34
MgO							1.00	-0.24	0.99	0.57	-0.93	-0.91	0.91	0.65	0.47	0.34	0.23	-0.89	-0.48	-0.48	-0.56	0.45	0.97	-0.06
CaO								1.00	-0.35	-0.59	0.34	0.41	-0.44	-0.48	0.10	-0.79	-0.52	0.51	0.57	0.24	-0.22	-0.68	-0.13	0.72
BaO									1.00	0.80	-0.99	-0.93	0.94	0.72	0.43	0.41	0.23	-0.91	-0.52	-0.46	0.60	0.53	0.95	-0.10
Na2O										1.00	-0.67	-0.53	0.79	0.83	0.04	0.65	0.27	-0.59	-0.32	-0.10	0.75	0.66	0.46	-0.35
K2O											1.00	0.93	-0.96	-0.75	-0.43	-0.40	-0.19	0.89	0.49	0.43	-0.65	-0.54	-0.94	0.10
P2O5												1.00	-0.86	-0.67	-0.56	-0.42	-0.27	0.97	0.73	0.66	-0.47	-0.69	-0.83	0.32
LOI													1.00	0.83	0.32	0.54	0.25	-0.85	-0.43	-0.30	0.78	0.82	0.85	-0.15
Pb														1.00	0.07	0.63	0.20	-0.68	-0.41	-0.19	0.86	0.79	0.63	-0.21
V															1.00	-0.29	-0.24	-0.55	-0.52	-0.58	0.05	0.31	0.59	-0.20
B																1.00	0.81	-0.49	-0.35	-0.12	0.46	0.62	0.22	-0.52
Zn																	1.00	-0.31	-0.15	-0.07	0.14	0.24	0.10	-0.86
Y																		1.00	0.81	0.73	-0.42	-0.73	-0.90	0.46
Ni																			1.00	0.91	0.01	-0.77	-0.55	0.78
Cu																				1.00	0.21	-0.51	-0.59	0.63
Co																					1.00	0.52	0.51	0.14
As																						1.00	0.49	-0.69
Sr																							1.00	-0.07
Mo																								

6) Authigenic minerals in bottom materials

The 1985 report shows that mineral componnts of authigenic minerals are mainly zeolite (phillipsite) with accompanying clay mineral, mineral fragments and biogenic debris.

This survey shows that the authigenic minerals are mainly recognized in the survey area north of 13°S, and especially concentrated in the sea area 9°S to 11°S.

(*1) SiO_2 51.5%, TiO_2 0.59%, Al_2O_3 2.5%, Fe_2O_3 5.4%, MnO 0.53%, MgO 3.0%, CaO 1.5%, Na_2O .57%, K_2O 3.3%, P_2O_5 0.51%, B 0.17%, Ig-loss 11.2% (Bischoff, J.L et. al., 1979)

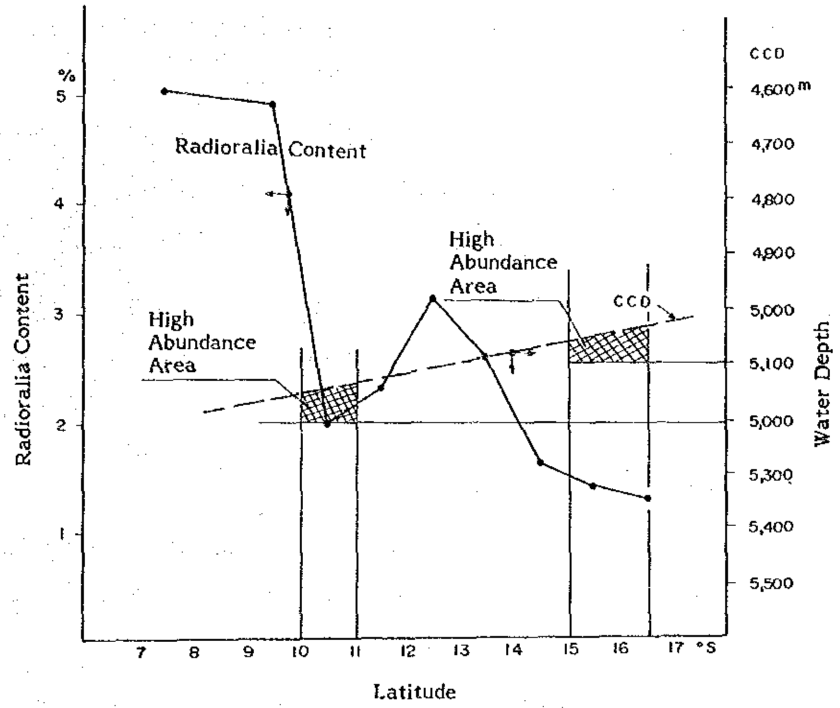


Fig. 4-5-4 Variation Diagram of CCD (Carbonate Compensation Depth) in the Surveyed Area

Observation by smear slide from 4 samples taken by spade corer, which is made to clarify vertical variation of zeolite content, shows that some samples from north of 13°S contain zeolites at the 40 cm deep, whereas samples from south of 13°S do not contain zeolites at all.

7) CCD (Calcium carbonate compensation depth)

Maximum water depth in which calcium carbonate minerals (CCD) are not recognized through observation by microscope increases gradually from southern area to the northern area in this area. The depth of CCD is about 5,050 m in the area 15°S - 16°30' and 5,150 m in 10°S - 11°S. (Fig. 4-5-4)

8) Identification of micro-fossils in bottom materials

Through identification of fossils (Radiolaria, Foraminifera) in the bottom materials sampled by spade corer, sedimentary environment were examined.

Two samples were selected, one in the northern part in the investigated sea area, and another in the southern part.

The sample numbers, sampling positions, water depth, and types of bottom sediments are as follows;

Sample No.	Sample Position	Sea deapth	Type
86S1036SC04	09°31.43'S, 159°29.29'W	5,680 m	Brown clay
86S1636SC06	15°29.05'S, 159°29.02'W	5,140 m	Brown clay

(1) Radiolaria

1 Method of assaying

Samples of 100 cc was selected on board from 2 samples collected by a spade corer at each of: the surface, 5 cm, 10 cm, 20 cm, 30 cm, and 40 cm.

In the laboratory on shore, samples of 20 cc were taken, and were washed with water on a screen with a opening diameter of 62μm to concentrate the Radiolarias. The samples cleaned by HCl, H_2O_3, were further washed on a screen of the same diameter.

Radiolarian occurrence list was made by observing and identifying with an optical microscope the dried samples packed into slide glass.

2 Occurrence of fossiles (cf. Tab. 4-5-6, Fig. 4-5-5 and Fig. 4-5-6)

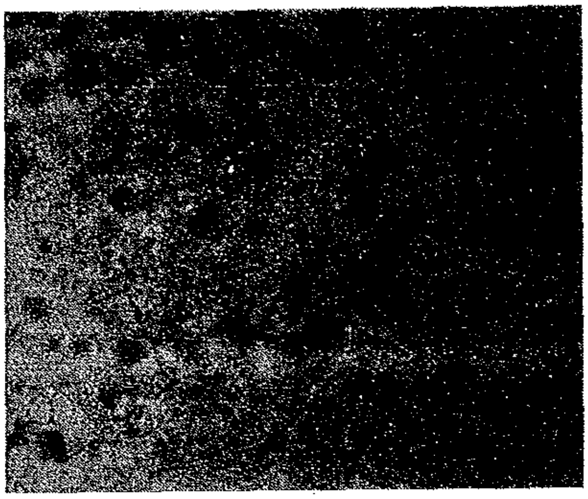
(a) 86S1036SC04

The surface: Many fossils as well as many different species in a good state of preservation were found with a small amount of the radiolaria with frame melt.

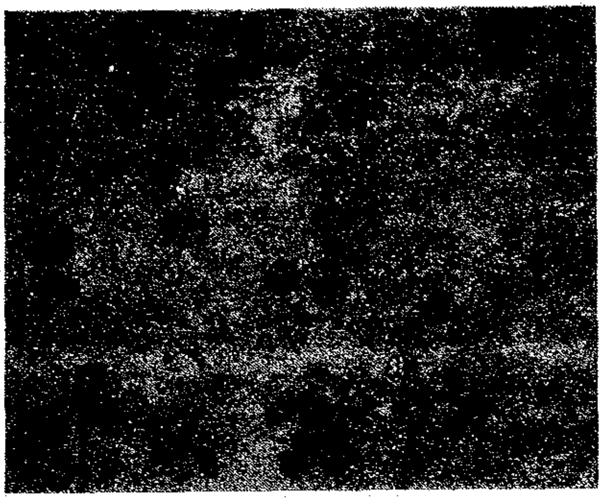
5 cm: Many fossils as well as many different species in a good state of preservation were found.

Table 4-5-6 List of the Collected Radiolarias

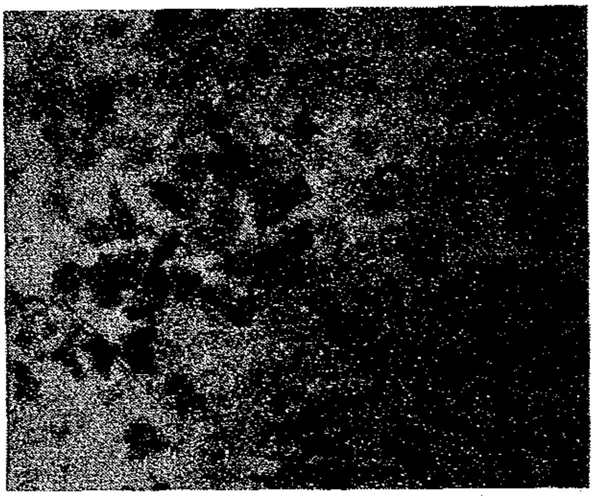
Species \ Sample	Surface	86S1036SC04 5cm	10cm	20cm	30cm	40cm	Surface	86S1636SC06 5cm	10cm	20cm	30cm	40cm
Acrosphaera flammabunda (Haeckel)	x	x	x				x	x	x			
A. lappacea (Haeckel)	x	x	x				x	x				
A. murrayana (Haeckel)	x	x	x				x	x				
A. spinosa Haeckel	x	x	x				x	x	x			
Buccinosohaera invaginata Haeckel	x	x					x					
Collosphaera huxleyi Muller	x	x	x				x	x				
C. tuberosa Haeckel	x	x	x				x	x				
Otosphaera polymorpha Haeckel	x	x	x				x					
Siphonosphaera socialis Haeckel	x	x	x				x	x	x			
Acanthosphaera capillaris Haeckel	x	x	x				x	x	x			
Actinomma archadophorum Haeckel	x	x					x					
A. spp.	x	x	x				x	x	x			
Actinosphaera capillacea (Haeckel)	x	x	x				x					
Amphisphaera cf. palliatum (Haeckel)	x	x	x				x	x	x			
Druppatructus spp.	x	x	x				x	x	x	x		
Hexacontium elegans (Haeckel)		x					x					
H. heracliti (Haeckel)	x	x	x				x	x				
H. hostile Cleve	x	x					x					
H. hexacanthum (Muller)	x	x	x				x	x				
H. sp.	x						x					
Hexacontarium sp.	x	x	x				x	x				
Stylatractus melpomene (Haeckel)	x	x	x				x	x				
S. cf. neptunus Haeckel	x	x	x				x	x	x			
Thecosphaera radianus Holland et Enjumet		x					x					
Xiphatractus sp.	x	x	x				x					
Ommatartus tetrathalamus tetrathalamus (Haeckel)	x	x	x				x	x				
Heliodiscus asteriscus Haeckel	x	x	x				x	x				
Amphirhopalum ypsilon Haeckel	x	x	x				x	x				
Eucitonia elegans Ehrenberg	x	x	x				x					
E. frucata Ehrenberg	x	x	x				x	x	x			
Dictyocoryne profunda Ehrenberg	x	x	x				x	x	x			
D. truncatum (Ehrenberg)	x	x	x				x	x				
Spongaster tetras tetras Ehrenberg	x	x	x				x	x				
Spongodiscus biconcavus Ehrenberg	x	x	x				x	x				
Stylodictia spp.	x	x	x				x	x				
Xiphospira spp.	x	x	x				x					
Larcospira quadrangura Haeckel	x	x	x				x					
Tetrapyle octacantha Muller	x	x					x					
OROSPHAERIDAE (fragments)	x	x	x				x	x	x	x	x	x
Clathromitra pentacantha Haeckel	x	x	x				x					
Clathrocanium reginae Haeckel	x	x	x				x					
Pseudodictyophimus glacilipes (Bailey)	x	x	x				x					
Lampromitra butschlii (haeckel)	x	x	x				x	x				
Botryocyrtis scutum (Harting)	x	x					x					
Carpocanium spp.	x	x	x				x					
Eucecryphalus elizabethae (Haeckel)	x	x	x				x					
Eucyrtidium acuminatum Ehrenberg	x	x	x				x	x				
E. anomalum (Haeckel)	x	x	x				x	x	x			
E. dictyopodium (Haeckel)	x	x	x				x	x				
Lipmanella bombus (Haeckel)	x	x	x				x					
L. virchowi (Haeckel)	x	x	x				x	x				
Dictyophimus infabricatus Nigrini	x	x	x				x					
Pterocanium charibdeum (Muller)	x	x	x				x					
P. praetextum (Ehrenberg)	x	x	x				x	x				
P. trilobium (Haeckel)	x	x	x				x					
Anthocyrtidium ophirense (Ehrenberg)	x	x	x				x					
A. zanguebaricum (Ehrenberg)	x	x	x				x					
Lamprocyclas maritalis Haeckel	x	x	x				x	x				
Lamplocyrtis gamphonycha (Jorgensen)	x	x	x				x					
Pterocorys hertwigii (Haeckel)		x					x					
P. macroceras (Popofsky)	x	x	x				x					
P. zancleus (Muller)	x	x	x				x					
Theocorythium trachelium (Ehrenberg)	x	x	x				x					
Botryostrobus aquilonaris (Bailey)	x	x	x				x	x				
B. auritus (Ehrenberg)	x	x	x				x					
Phrmostichoartus corbula (Harting)	x	x					x					
Spirocyrtis scalaris Haeckel	x	x	x				x					
S. subscalaris Nigrini	x	x	x				x	x				
Tholospyris ramosa Haeckel	x	x	x				x	x				
T. acuminata (Hertwig)	x	x	x				x	x				
Acanthodesmia vuniculata (Muller)	x	x	x				x					
Liriospyris reticulata (Ehrenberg)	x	x	x				x					
Nephrospyris renilla Haeckel	x	x					x					
Zigocircus capulosus Popofsky	x	x	x				x					
Z. productus (Hertwig)	x	x	x				x	x	x			
魚の歯		x		x		x	x					



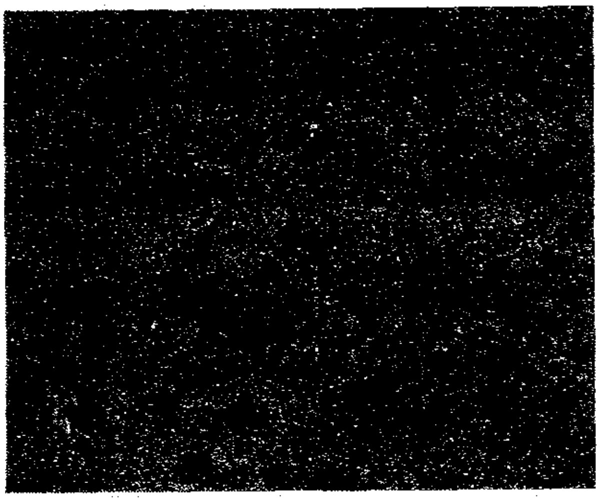
86S1636 SC06 Surface



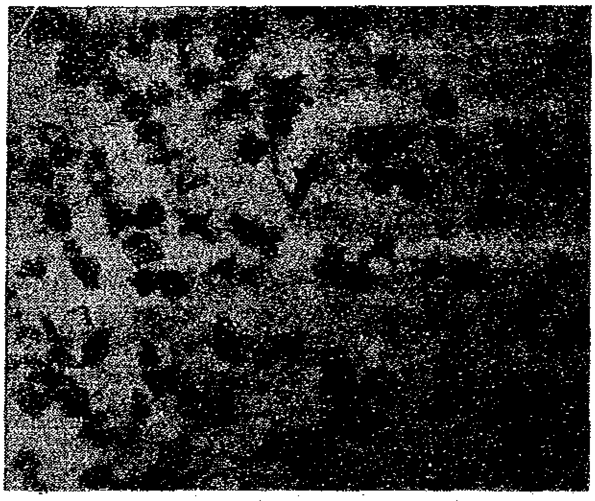
86S1036 SC04 Surface



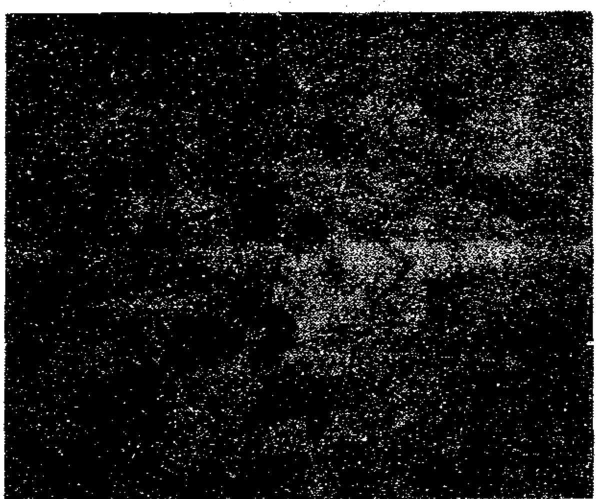
86S1636 SC06 5cm



86S1036 SC04 10cm

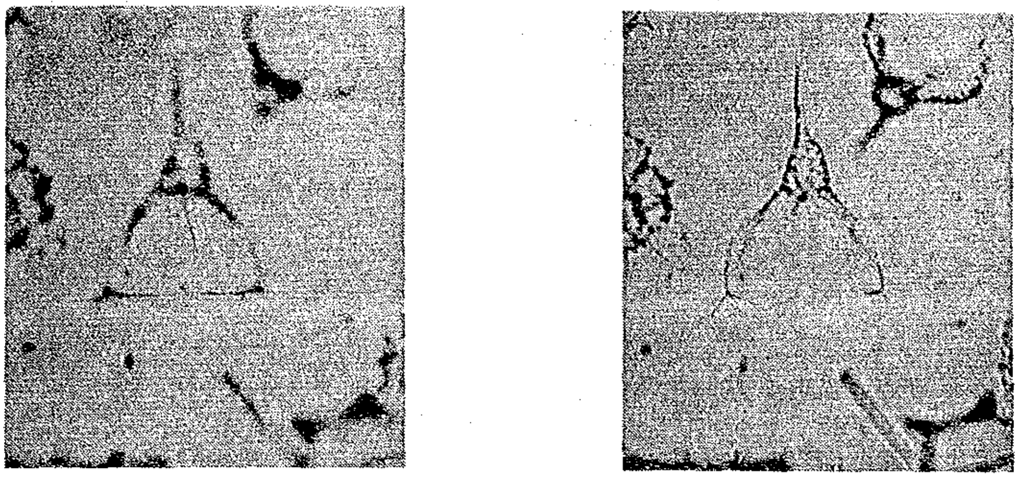


86S1636 SC06 20cm

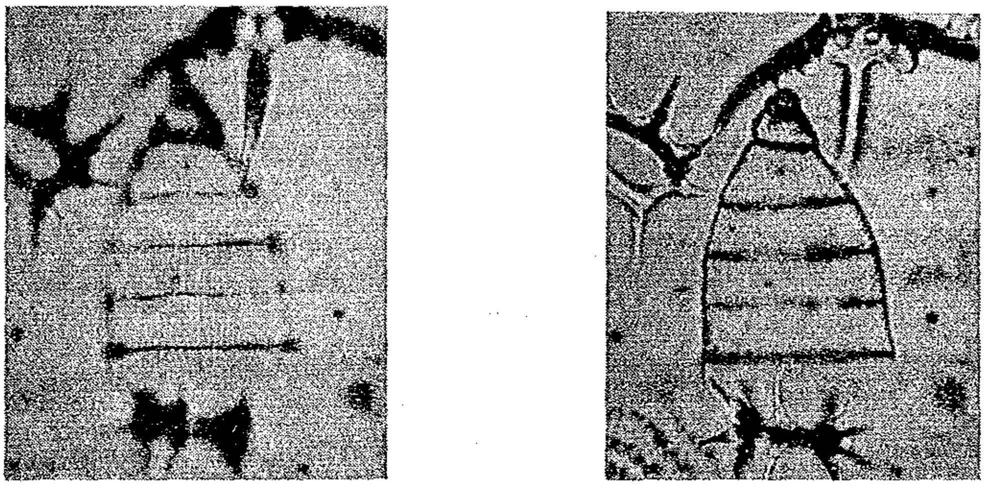


86S1036 SC04 20cm

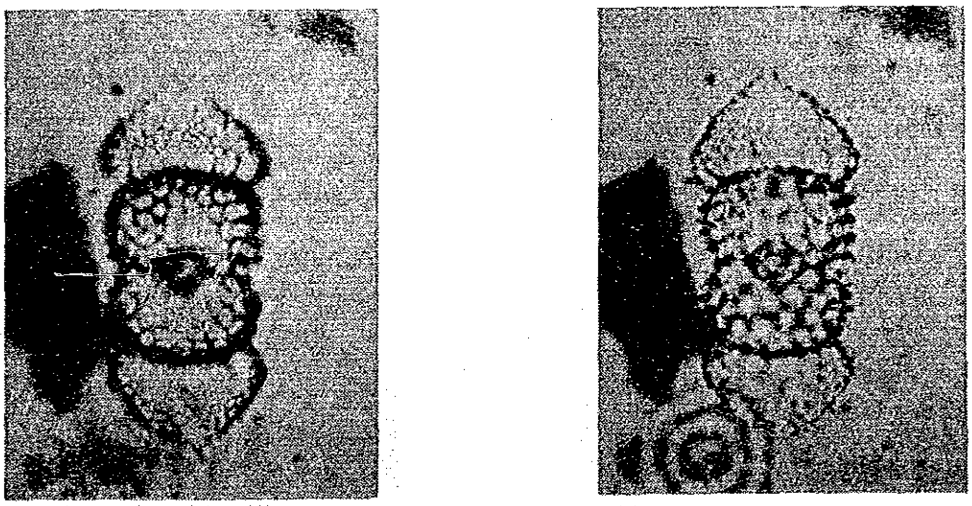
Fig. 4-5-5 Microscopic Photos of Bottom Sediment



Pterocorys hertwigii

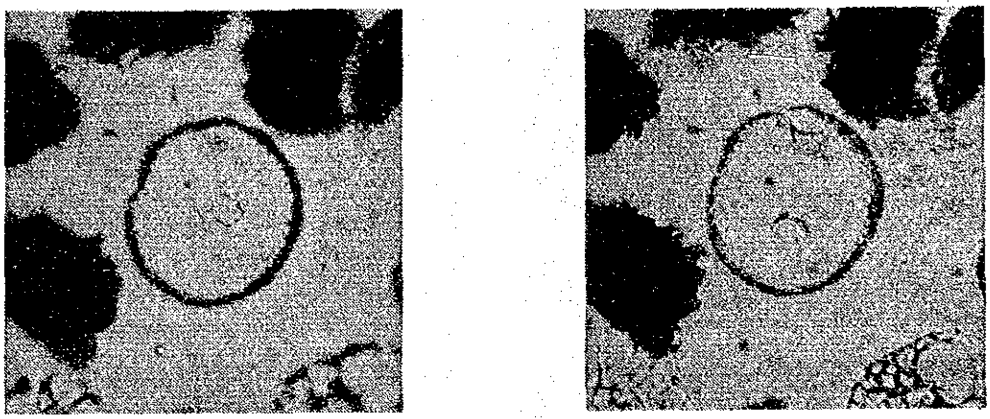


Eucytidium dictyopodium

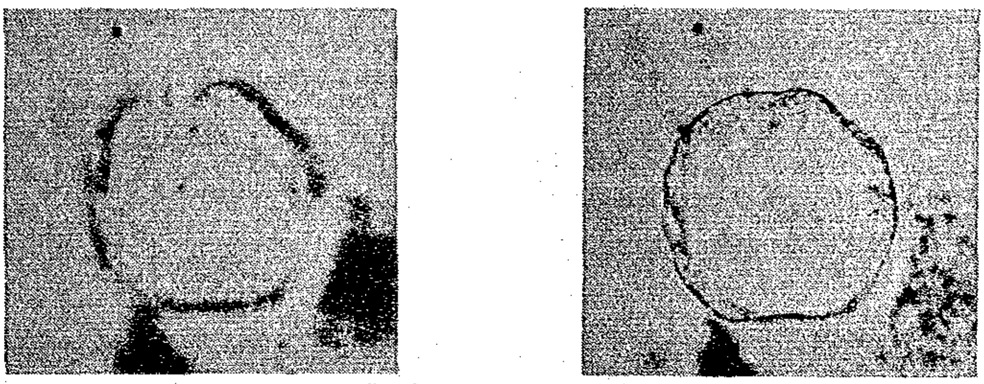


Ommatartus tetrathalamus

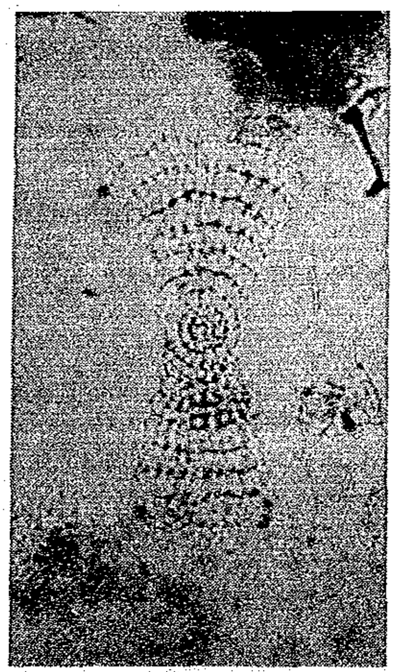
Fig. 4-5-6 Species of the Typical Radiolarian Fossil (No.1)



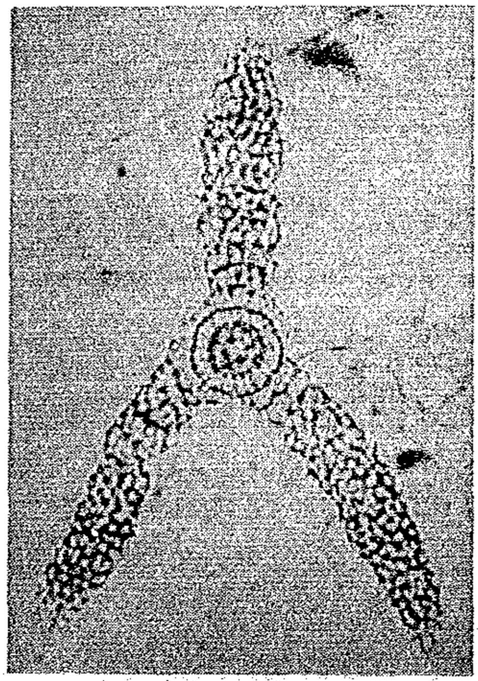
Buccinosphaera invaginata



Collosphaera tuberosa



Amphirhopalum ypsilon



Eucitonja elegans

Fig. 4-5-6 Species of the Typical Radiolarian Fossil (No. 2)

10 cm: Many fossils as well as many different species in a good stage of preservation were found with a small amount of radiolaria with frame melt.

20 cm: Small pieces of radiolaria frames, small amount of fish-tooth fossils and many crystals of zeolitic materials are found.

30 cm: No occurence of Radiolaria. Small amount of fish-tooth fossils and many crystals of zeolitic materials are found.

40 cm: No occurence of radiolaria. Small amount of fish-tooth fossils and many crystals of zeolitic materials are found.

(b) 86S1636SC06

The surface: Many fossils as well as many different species in a good stae of preservation were found with a small amount of the Radiolaria with frame melt.

5 cm: Many fossils as well as many different species in a bad stage of preservation were found with mostly melted and fractured radiolarian frame.

10 cm: A small amount of Radiolaria and many fish-tooth fossils are found, which are melted and fractured.

20 cm: Small pieces of Radiolarian frames, and many fish-tooth fossils are found.

30 cm: Small pieces of radiolarian frames and fish-tooth fossils are found.

40 cm: Small pieces of Radiolarian frames and fish-tooth fossils are found.

3 Geological age

All species found in 5 samples bearing abundant radiolaria belong to present period, that is such as Collosphaera tuberosa Haeckel and Ampherhoalum ypsilon Haeckel which appeared in the later part of Quarternary period (about 400,000 years ago). In the samples, there appear no Stilacontarium acquilonium (Hays), Axoplunum angelinum (Campbell et Clark), and Amphirhopalum praeypsilon Sakai which extinguished at the same period with above mentioned two species. Buccinosphera in vaginata Hoeckel which made its appearance about 200,000 years ago, is found in the surface and 5 cm level of 86S1036SC04 as well as in the surface of 86S1636SC06. According to these facts, the part upper to 5 cm level in 86S1036SC04 is younger than 200,000 years, and the age of the 10 cm level is between 200,000 and 400,000 years ago, but its age below 20 cm level cannot be made clear. It is to be added that there is a possibility that the 10 cm level bears no B invaginata, a species more soluble than the others, as a result of melting. (i.e. newer than 200,000 years ago)

The age of the sample No. 86SC1636SC06 in the surface level is younger than 200,000 years ago, but as for the age in the 5 cm level it can only be said that it may be younger than 400,000 years as it is most probable that all B. invaginatas has been melted. the age below 5 cm level cannot be made clear.

4 Sedimentation speed

86S1036SC04: the sedimentation speed is 0.25 - 0.5 mm per thousand years supposing that the 10 cm level is 200,000 - 400,000 years ago. In case of melting of invaginata in the 10 cm level, its speed must be more than 0.5 mm per thousand years.

86S1636SC06: the sedimentation speed is more than 0.13 mm per thousand years.

5 Paleo-environment

Observed radiolaria are mainly of species which generally live in the equatorial Pacific ocean. Compared to the sample No. 86S1036SC04, the sample No. 86S1636SC06 seems to abound in species which indicates warmer water environment, such as Euchitonia elegans Ehrenberg, Eucyrtidiumdictyopodium (Haeckel), Pterocorys hertwigii (Haeckel), and so on. However, according to the present data concerning with species distribution, there is no significant difference between the environment of these two samples, sites and the Equatorial sea area.

It is necessary for more strict study of the environmental analysis to increase the number of samples and to make statistical analysis. There is no established theory about the environment which makes the radiolarian melting.

However, it can be estimated that there might have been a situation in which radiolaria, located in the several tens of centimeters beneath the surface level, underwent melting, in case there had been a distribution of ooze without fossil (which has normally to produce fossils) beneath the fossil bearing stratum and that there have been an unconformity (or no sediments situation) or in case that the sedimentation speed had been kept at 10^{-1} mm per one thousand years.

(a) Sample No. 86S1036SC04

Between the surface and 10 cm level where many radiolarias are found, there are many zeolitic materials which are the same kind found in the samples of the 20 cm and below level. These zeolitic materials derive from the lower layers. (Preservation condition is strikingly worse in the environment where the large crystals of zeolitic materials were formed.)

According to these facts, it is possible that there is an unconformity in between 10 cm and 20 cm level. The drastic change in radiolarian preservation situation between 10 cm and 20 cm level also indicates the possible existence of the unconformity.

(b) Sample No. 86S1636SC06

As the melting condition of the surface toward the underneath layer changes continuously, it can be said properly that these samples are continuous sediments.

(c) Comparison between 86S1036SC04 and 86S1636SC06

Judging from the radiolaria occurrence, there are no differences between these two samples except for the condition of preservation.

86S1036SC04 has probably an unconformity judging from the preservation condition and the zeoritic materials occurrence, and it is proper to consider 86S1636SC06 as continuous sediments.

(2) Foraminifera (cf. Tab. 4-5-7 and Fig. 4-5-7)

1 Analysis method

The above mentioned two core-samples were taken on board by incerting a plastic tube (6 cm in bore and 50 cm in length) into the bottom materials' sample collected by spade corer. Both sides of the plastic tube containing sea bottom materials were cut vertically by an electric buzz saw in the laboratory on shore. The core contained was cut vertically into two portions by a knife. From one of the two portions obtained from the two cores were obtained the undermentioned six samples. Each sample was watered and left as it was for several days. It was agitated to be dissolved and dried after being washed on a screen of 250 mesh (63).

All forminifera contained in each sample were examined under the microscope. As the core A (A-1 to A-3) contained relatively many foraminefera, we divided it into 8 portions

Table 4-5-7 List of the Collected Foraminifera

	86S1036SC04			86S1636SC06		
	0- 8	17-22	32-37	0- 8	19-24	36-41
Placopsilinella aurantiacea Earland	2					
Rhabdammina cornuta (Brady)	5					
Bathysiphon? sp.					4	8
Psammosphaera sp. A	5	2				
P. sp. B	31	13	6			
Lagenammina cf. atlantica (Cushman)	1					
L. diffulugiformis (Brady)	16	10	1	1		
Technitella sp.			4			
Hyperammina elongata Brady				5		
H. spp.	3		1			
Ammodiscus gullmarensis Höglund				10		
A. sp. A	1		2	1		
A. sp. indet.		1				
Glomospira charoides (Jones & Parker)	1	2	21	2		
Ashemonella? sp.				10	4	
Hormosina ovicula Brady	4			5		
H. sp. indet.		3	1		2	2
Nodosinum gaussicum (Rhumbler)			3			
Reophax pauciloculatus Rhumbler	5					
R. spiculifer Brady		2		2		
Haplophragmoides cf. sphaeriloculum Cushman	1	1	3			
H. sp. indet.	1		6	8		11
Ammobaculites filiformis Earland	29	5	4	5		3
A. sp. A			6			
Adercotryma glomerata (Brady)				2		
A.? sp.	1					
Recurvoides trochamminiformis Saidova	4	1				
"Alveolophragmium subglobosum (G.O. Sars)"	1					
Spiroplectammina cf. biformis Brady				3		7
S. filiformis Earland	35	14	22	14	3	17
S. filiformis Earland?	57	62	19			
Trochammina discorbis Earland						58
T. globigeriniformis (Parker & Jones)				3		
T. sp. A	1			6		
T. spp.	3			1	4	
T.? spp.		3				
Pseudobolivina? sp.	7	1				
Dorothia? sp.	4		5			
Eggerella? subconica Parr				1		
E. sp.				3		10
Agglutinated Foraminifera gen. sp. indet.						10
Foraminiferal numbers counted	218	120	104	83	17	126

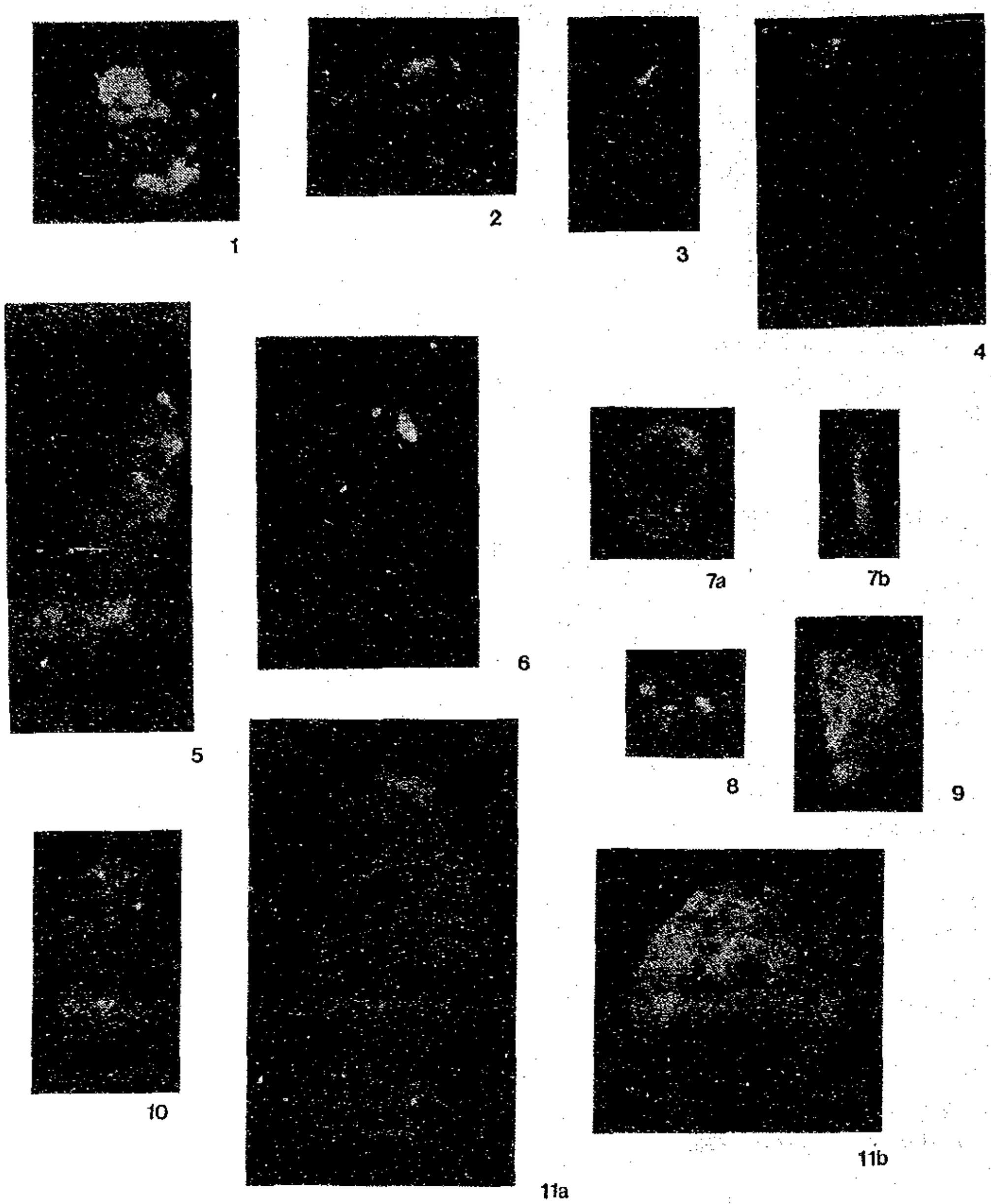


Fig. 4-5-7 Species of the Typical Foraminifera Fossil (No. 1)

1 Psammosphaera sp. A
86S1036SC04, 0-8cm, X33

2 Psammosphaera sp. B
86S1036SC04, 0-8cm, X53

3 Lagenammina diffulugiformis (Brady)
86S1036SC04, 0-8cm, X66

4 Lagenammina cf. atlantica (Cushman)
86S1036SC04, 0-8cm, X53

5 Technitella sp.
86S1036SC04, 32-37cm, X53

6 Hyperammina elongata Brady
86S1636SC06, 0-8cm, X53

7a,b Ammodiscus gullmarensis Höglund
86S1636SC06, 0-8cm, X117

8 Glomospira charoides (Parker & Jones)
86S1036SC04, 32-37cm, X117

9 Ashemonella? sp.
86S1636SC06, 0-8cm, X66

10 Hormosina ovicula Brady
86S1036SC04, 0-8cm, X66

11a,b Nodosinum gaussicum (Rhumbler)
86S1036SC04, 32-37cm, X53

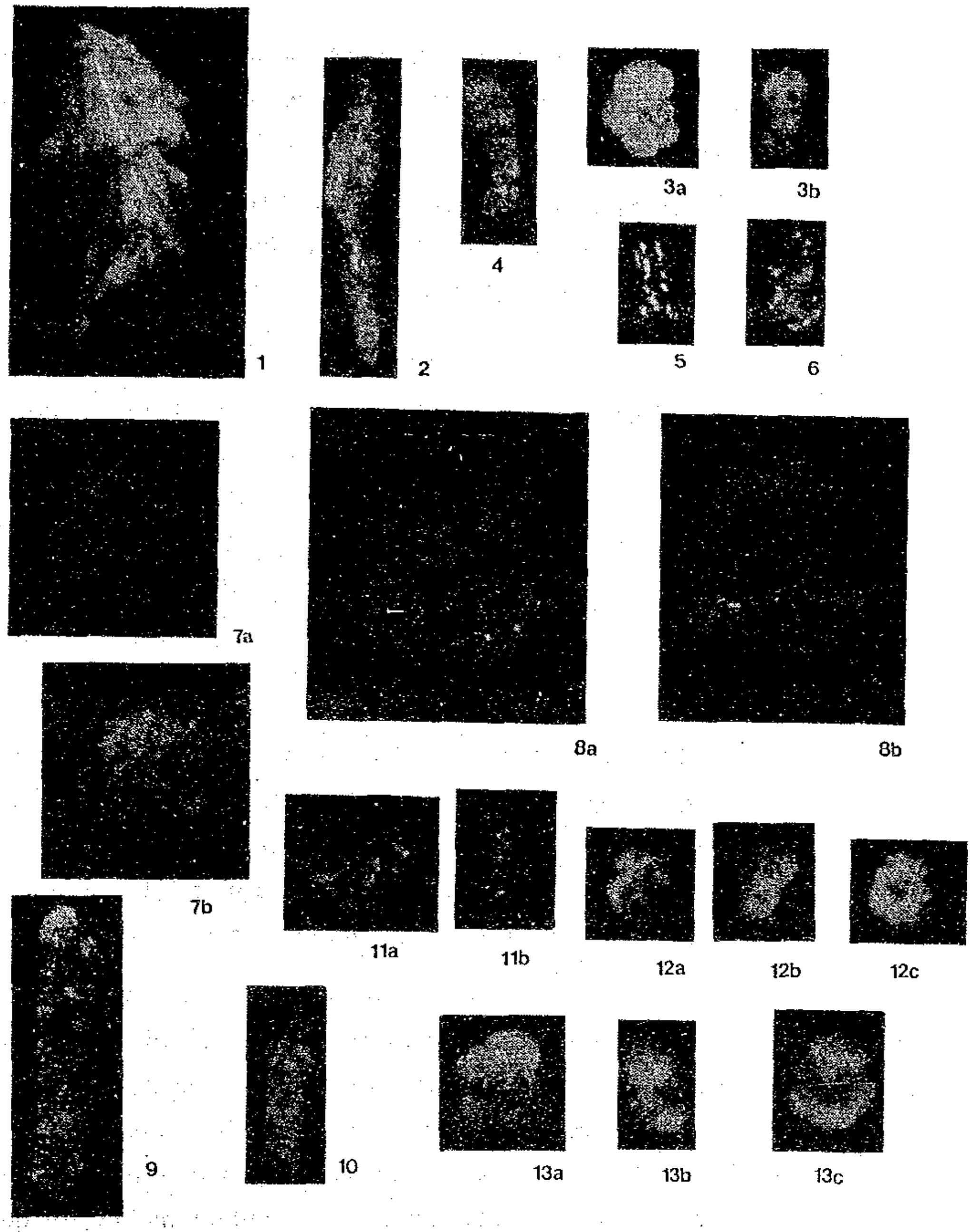


Fig. 4-5-7 Species of the Typical Foraminifera Fossil (No. 2)

1 Reophax pauciloculatus Rhumbler
86S1036SC04, 0-8cm, X33

2 Reophax spiculifer Brady
86S1036SC04, 17-22cm, X117

3a,b Haplophragmoides cf. sphaeriloculum Cushman
86S1036SC04, 0-8cm, X71

4 Ammobaculites filiformis Earland
86S1036SC04, 0-8cm, X117

5, 6 Ammobaculites sp. A
86S1036SC04, 32-37cm, X117

7a,b Recurvoides trochamminiformis Saidova
86S1036SC04, 0-8cm, X33

8a,b "Alveolophragmium subglobosum (G.O. Sars)"
86S1036SC04, 0-8cm, X53

9 Spiroplectammina filiformis Earland
86S1036SC04, 0-8cm, X117

10 Spiroplectammina cf. biformis Brady
86S1636SC06, 0-8cm, X117

11a,b Trochammina discorbis Earland
86S1636SC06, 36-41cm, X117

12a-c Trochammina globigeriniformis (Parker & Jones)
86S1636SC06, 0-8cm, X71

13a-c Trochammina sp. A
86S1636SC06, 0-8cm, X117

from one of which were gathered forminifera (the core B was divided into two portions from one of which were gathered forminifera.)

34 species of forminifera were identified in the 6 samples, the results being given in Tab. 4-5-7. Microscopic photos of 23 species were shown in Fig. 4-5-7.

	Core length	Depth and sample No.	
A. 86S1036SC04	37 cm	0 - 8 cm	A-1
		17 - 22 cm	A-2
		32 - 37 cm	A-3
B. 86S1636SC06	41 cm	0 - 8 cm	B-1
		19 - 24 cm	B-2
		36 - 41 cm	B-3

2 Fossil occurrence

The foraminifera contained in the two cores were all benthos having sandy shell. Neither calcareous bentic foraminifera nor floating foraminifera was found. The reason may be that the two cores were obtained from the depth of 5,140 m and 5,680 m both of which were located lower than that of CCD.

Sediments of core B which remained on the screen of 250 mesh were of very small quantity and contained radiolaria and sponge spicules as well as a very small quantity of manganese micro-nodules and foraminifera. On the other hand, core A sediments left a fairly abundant sand-size portion on the screen which consists of zeolitic particles mainly, of quite a lot of manganese micro-nodules and radiolaria, and of a small quantity of foraminifera. For the same cubic content, core A contained about 5 times number of foraminifera of core B. But, in the sandy-particle portion remaining on the 250 mesh screen, only a few foraminifera were contained.

Most of the foraminifera in the 6 samples of the two cores were transformed into manganeses compound and became black foraminifera. There existed some but not many normal foraminifera and some were intermediate. Because of this fact, structual morphology was not known in many cases and therefore it was difficult to identify the species.

As for the bearing difference between the upper layer of core and the lower layer, the upmost sample, for both cores, contained more foraminifera both in species and quantity and was in a better state of preservation than lower layer samples. One of the reasons is probably that the upmost layer's sample contained newly died foraminifera. It arrives very often that the shell of dead forminifera have been destroyed or have undergone an alternation of quality before they were embeded by sediments. But it is also possible that there might have existed an environmental difference between the upmost layer's sample and the lower layer's samples.

3 Geological age

Nothing accurate was known about the sediments' age because there was no floating foraminifera contained. Even the benthic foraminifera were all of sandy species, whose habitat age is not known and contained no calcareous species. But, judging from the fact that all the identified species were existing at present and from the shell preservation condition as mentioned above, the upmost layers for both cores are of the present period. As for the lower layers it may be possible to correlate the community's changes with the great changes of oceanic environment such as post glacial period, galcial period and interglacial period etc. But the samples are not sufficient to do so.

4 Paleo-environment

All the species identified being of the species reported in the deep-sea and in the Antarctic ocean, they may well be found in around 5,000 m deep in the central part of the Pacific ocean. Although it is not possible to demonstrate concretly, some observations will be made about the community changes in both cores.

(a) Core A (86S1036SC04)

In the Core A, the species found in A-2 are in most cases found in A-1. But considering that some species were found only in A-1 and the shells of them are not all fragil, there might have been some environmental changes between the two samples. It can be a change in sea-bottom environment in the period glacial-postglacial period.

On the other hand, some species were found commonly in both A-1 and A-2 but not in A-3. Inversely several were found only in A-3 but not in A-1 and A-2. There were also some species found commonly in A-1, A-2, and A-3 but with a big difference in the frequency between A-2 and A-3. Consequently, the difference of community is relatively apparent between A-2 and A-3.

(b) Core B (86S1036SC06)

As for core B, differences of community can be observed between B-1 and B-2 and between B-2 and B-3, although they are not apparent because there were insufficient communities contained in the intermediate sample B-2. The difference of community between B-1 and B-3 is fairly apparent.

(c) difference of community between core A and core B

There is a difference of community between core A and core B although both are of 5,000 m deep level. There are some species found in core A and not in core B, some found on core B and not in Core A reversely. The difference is not only in the upmost layer's samples but exists for the two entire cores.

This means that the environmental difference has continued to exist within the limits of the time span that the two cores represent.

No sample was obtained which enabled us to decide which environmental difference it was. Especially, when the communities consist of only the sandy foraminifera, it is difficult to determine as each secies has a wider range of distribution in geography and in period. Before everything, there are too many unknown factors about the deep-sea ecology of foraminifera.

(3) Summary

Results which have been argued in the preceeding paragraphs are summarized in Tab. 4-5-8. It can be said that the estimated value of sedimentation speed (0.5 mm/1000 years) is slower than that of the manganese abundant sea area in Clarion-clipper zone (1 - 3 mm/1000 years). It is possible that strata unconformity or the change in sedimental environment in around 20 cm deep level from the surface which is found in the sample point 86S1036SC04, is in correlation with the change of chemical analysis data of the same sample. (Values for SiO_2, MnO_2, P_2O_5, Y, Ni and Cu have tend to be slightly higher below 30 cm deep level.)

Table 4-5-8 Summary of Geological Environmental Analysis Based on Fossils in the Bottom Materials

		Radiolaria	Foraminifera
86S1036SC04 Bearing situation	- 10 cm	Rich in number and species slight frame melting is found contains a few frame debis	Contains benthic foraminifera with sandy-shell, but bears no calcereous benthic foraminifera nor floating foraminifera.
	20 cm	Contains many zeolite No radioralia	Contains 5 times the number of foraminifera contained in 86S1636SC06. Most of the foraminifera are transformed into manganese oxide and its color is black.
	30 cm	Contains a few fossils of fish tooth rich in zeolite	The upmost layer sample present a better preservation condition and contains more foraminifera and rich in species.
Geological period	Upper than 5 cm level	Newer than 200 Thousands years ago	
	10 cm	200-400 thousands years ago	The upmost layer is of present period.
	20 cm	Not known	Lower part's period is unknown
Sedimentation speed		Farther than 0.5 mm/1000 years	
Paleo-Environment		Unconformity can be predicted in between 10 cm and 20 cm levels	Some difference is predicted between 17-20 cm and 32-37 cm.

(Continue)

86S1636SC	The surface	Rich in the number and species	
Bearing	5 cm	Rich in the number and species most of the fame is melted and destroyed	The same situation as in 86S1036SC04
	10 cm	Contains melted and destroyed fossils pour in the number presents a few frame debris	
	20 cm	Presents many fish tooth fossils	
Geological period	The surface	Newer than 200 thuosand years ago	The surface layer is of present period Lower layer = Not known
	5 cm	Newer than 400 thousand years ago	
	10 cm	Not known	
Sedimentation speed		Faster than 0.13 mm/1000 years	
Paleo-environment		Presents continuous sediments	There may be some difference between 0-8 cm 36-41 cm

4-6 Sea bottom observation

As mentioned above, sea bottom observation in this survey was done by photographing and observing the sea bottom by FDC intermittently and photographing the sea bottom by deep-sea cameras mounted on FG and SC.

288 photos and 174 deep-sea photos could be obtained for respective observation.

1) Observations by FDC

Tab. 4-6-1 shows the covering ratio (%) and abundance (kg/m^2) obtained from the deep-sea photos for each observation station.

Fig. 4-6-1 shows schematically values of abundance, shapes, granular sizes, as well as estimated distribution continuation along the track lines. Further details of occurrence in some typical observation stations are given in Fig. 4-6-2 and Fig. 4-6-3.

These data as well as the FG sampling data indicating fairly different sea bottom conditions between the northern part (Track Lines 03 and 04) and the southern part (Track Lines 01 and 02), further description will be given for each part as follows.

(1) Northern part

With the 159°20' as the dividing line, this part is divided into two zones: eastern zone with higher abundance and western zone with lower abundance.

In the eastern zone, the morphology of manganese nodules is mainly massive type and spheroidal type but some of them are ellipsoidal, plate and pebble type. The granular size is big in general. the change in size and shape is gradual in an observation station. Judging from the tendency of change and stable abundance of distribution, the nodule distribution in the eastern zone might be generally continuous.

In a strictly limited part (observation station 04 - 07, depth 5,290 m), development of the basement rock covered with crust was

Table 4-6-1 Coverage and Abundance of Manganese Nodules at Each Stations of FDC-Survey

Track line 01-02			Track line 03-04		
Station	Covering ratio	Abundance	Station	Covering ratio	Abundance
01-01	89.4	37.8	03-01	68.0	26.8
-02	78.5	18.5	-02	3.5	2.4
-03	91.8	36.6	-03	64.6	25.7
-04	94.9	33.5	-04	0.4	0.1
-05	95.0	36.2	-05	0.2	0.04
-06	97.5	39.3	-06	0.7	0.1
-07	36.5	36.5	-07	28.0	7.9
-08	88.9	31.1	-08	4.8	0.5
-09	97.3	29.1	04-01	87.0	36.6
-10	96.7	34.4	-02	54.4	20.1
-11	22.3	7.2	-03	69.0	28.9
-12	47.8	23.1	-04	5.2	0.4
-13	44.1	17.2	-05	0.5	0.1
-14	47.5	18.4	-06	94.0	32.6
-15	83.2	38.9	-07	59.2	18.9
02-01	47.0	17.9	-08	95.3	36.1
-02	93.6	38.2	-09	45.0	21.0
-03	91.7	43.7	-10	91.1	46.8
-04	14.6	14.0	-11	67.5	29.4
-05	74.0	33.1	-12	88.8	35.3
-06	93.6	35.5	-13	45.5	16.3
-07	95.7	37.3	-14	72.3	31.8
-08	92.8	41.0	-15	79.1	29.3
-09	95.6	34.6	-16	87.9	40.5
			-17	89.4	42.1
			-18	90.0	41.5
			-19	83.2	30.8
Average	75.4%	30.5 kg/m^2	Average	54.6%	22.3 kg/m^2

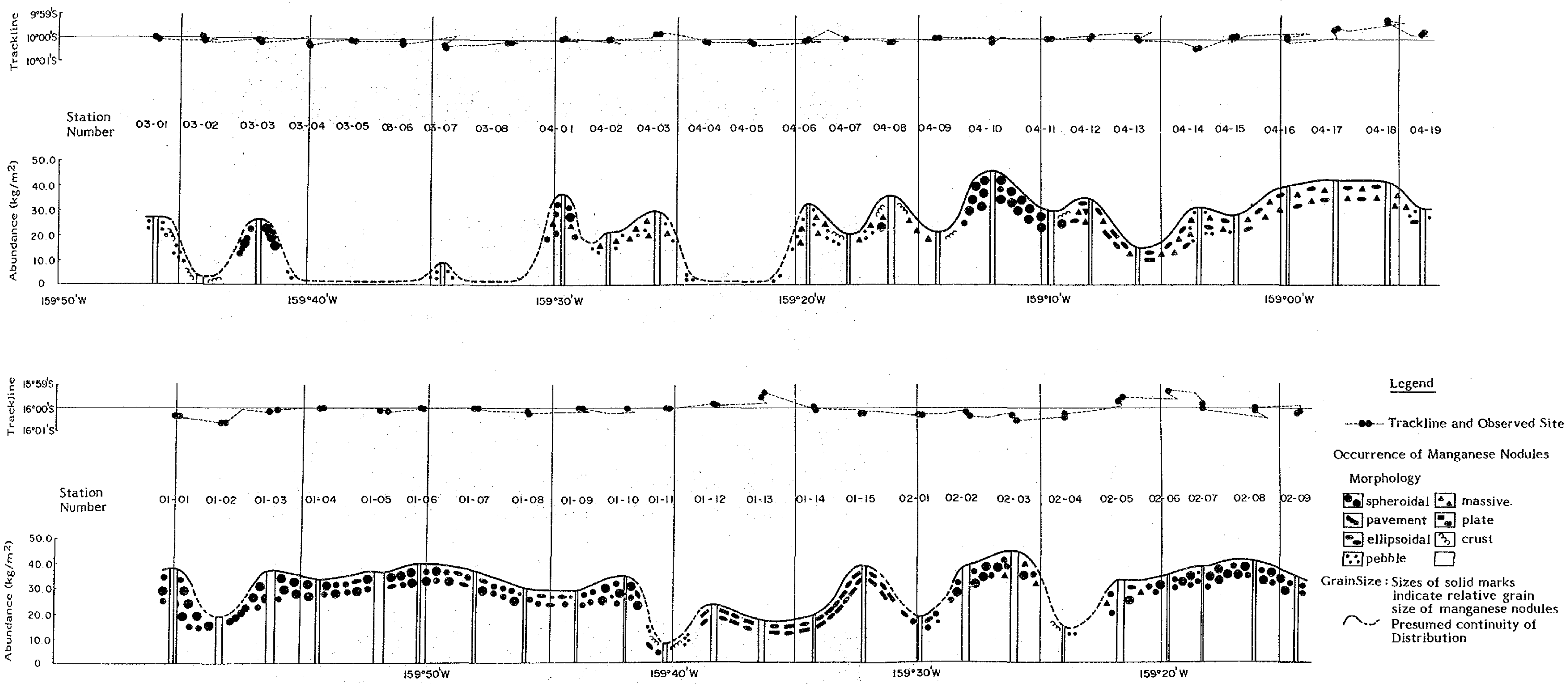
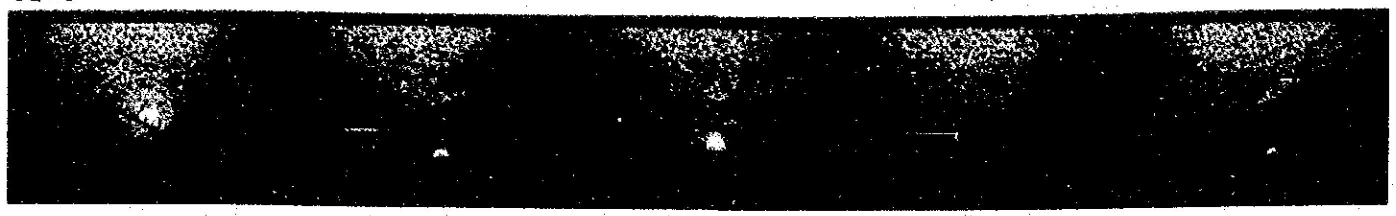


Fig. 4-6-1 Modified Occurrence of Manganese Nodules Obtained by FDC Survey

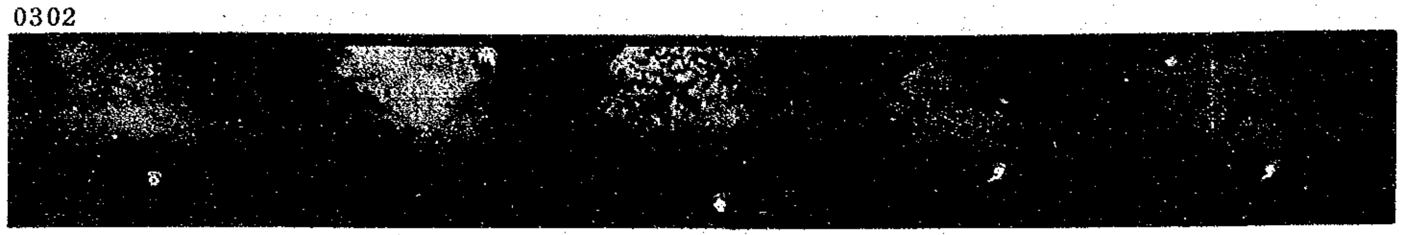
0103



36.8(91.6)	36.5(91.8)	36.3(92.1)	35.3(92.8)	37.1(94.5)

Continuous distribution of spheroidal nodules. Grain size is about 4.5 cm.

0302



0 (0)	0 (0)	11.6(16.4)	0.4(0.9)	0 (0)

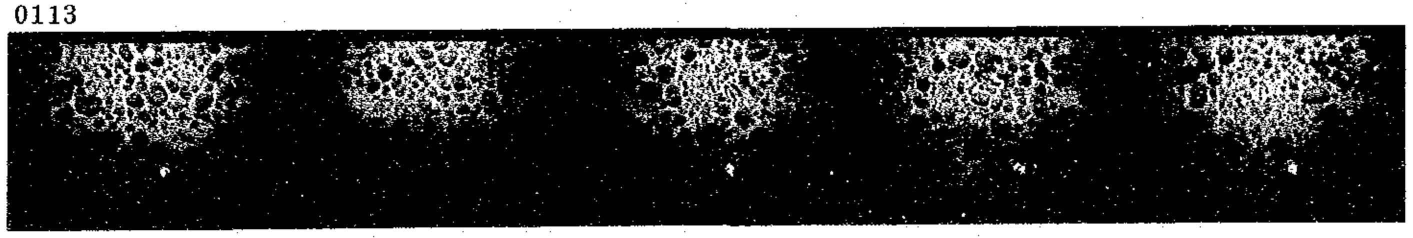
Exposed bedrock covered by thin manganese crust in hilly area.

0301

28.3(82.9)	22.7(64.6)	28.2(81.7)	21.9(67.0)	33.3(44.1)

Massive and spheroidal, partially crust. Mud-mound formed by benthic animals.

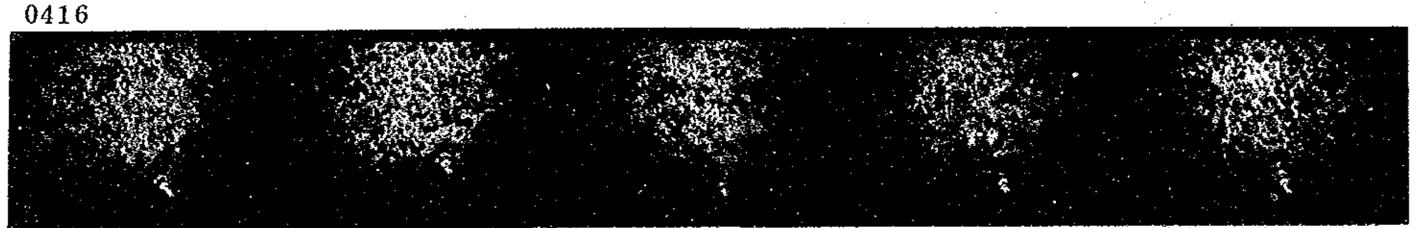
0113



17.1(44.9)	17.1(40.2)	16.0(45.0)	19.1(46.9)	16.5(43.6)

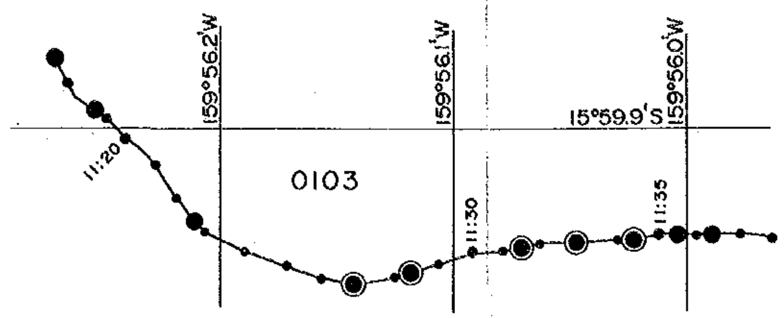
Ellipthoidal nodules with maximum diameter of about 20 cm.

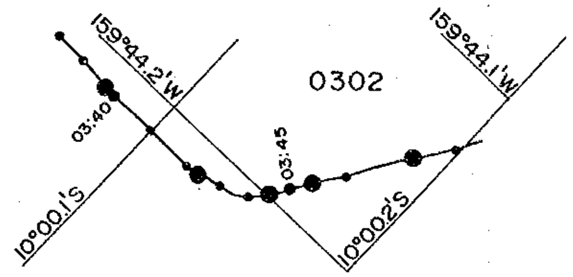
0416

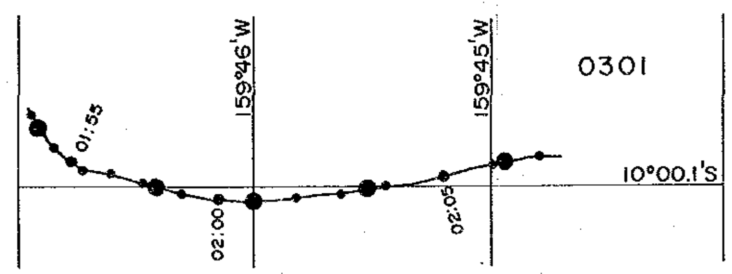


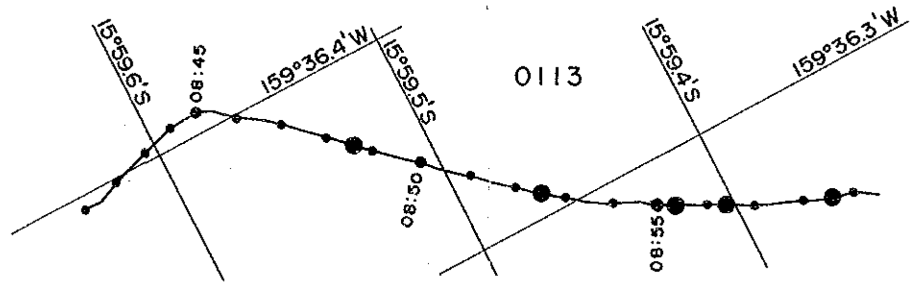
36.8(87.3)	41.4(86.1)	46.4(88.0)	45.3(89.3)	32.6(88.6)

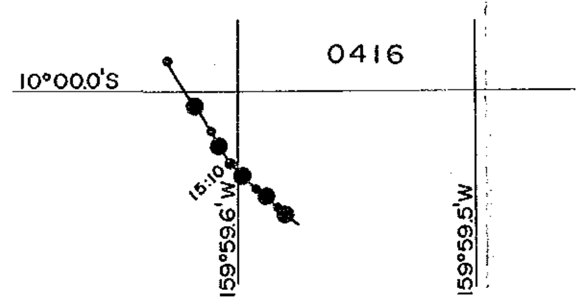
Many types (ellipthoidal, massive, spheroidal).

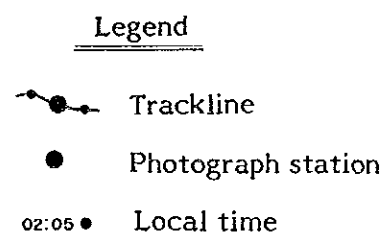






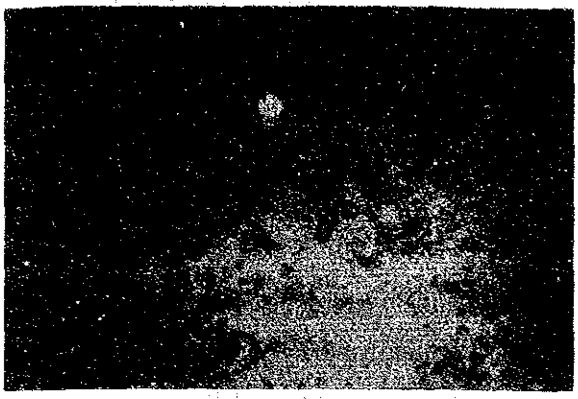




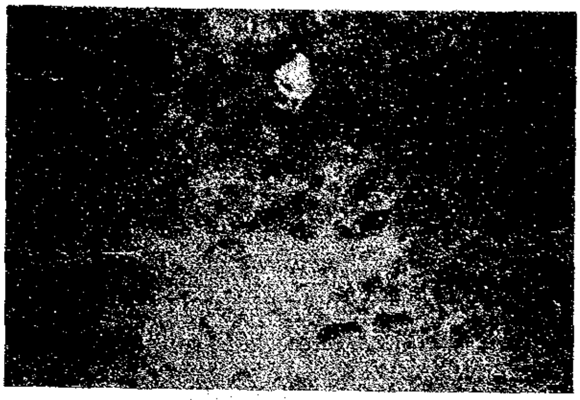


[Numbers at leftside-up: Station number, at bottom left: abundance and bottom right: coverage]

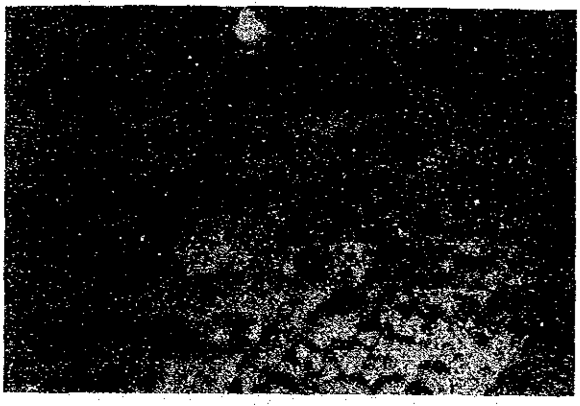
Fig. 4-6-2 Examples of Continuous Photos by FDC



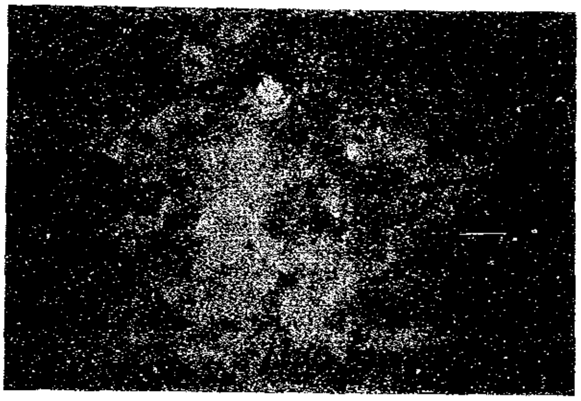
86SFDC0301
Pebble and massive. Mud-mound formed by benthic animals



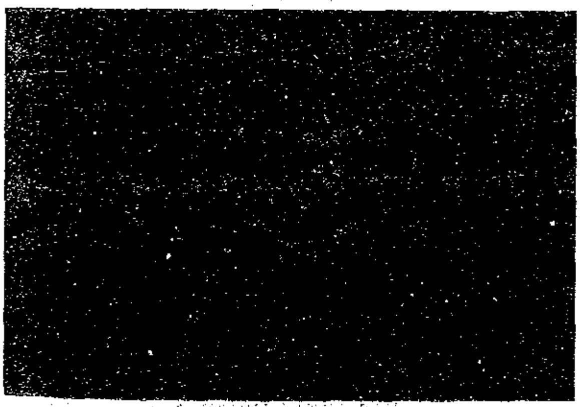
86SFDC0402
Ellipthoidal and plate
Abundance: 12.7 kg/m^2



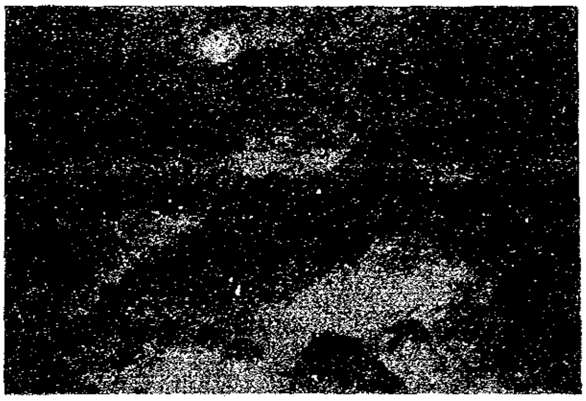
86SFDC0302
Transitional part from massive to crust



86SFDC0405
Crust . Mud at hollows.



86SFDC0303
Spheroidal . Abundance: 56.5 kg/m^2



86SFDC0407
Bedrock with crust?

Fig. 4-6-3 Examples of Photos by FDC

observed but it turned into massive-type and pebble-shaped nodules int he same station. In the adjacent station 04 - 08 (depth 5,660 m) there were signs that it turned gradually into massive-type, spheroidal-type and pebble type.

The variation of occurrence in each station can be understood as representative of the variation caused by a topographic transition from sea knoll slope to sea knoll plain. A transition from crust or pavement-type to spheroidal-type or massive-type was also observed in other observation stations (04 - 09 to 04 - 10).

The abundance in the eastern zone ranges from 20 to 40 kg/m^2.

On the other hand, the western zone has a wider mud-predominant-zone and its nodule distribution is intermittent.

In the mud prevailing zone were observed many traces indicating sea bottom creatures' activities; mud mound, orifices that seem to have served as passage of creatures living in the mud, winded irregular traces like a scrawl of earthworm, and creatures' excrements in form of the paste pushed out from a tube whose diameter is about 5 mm to 1 cm.

Most of the nodules in the mud prevailing zone are pebble-type and hense low in abundance.

Nodules in the intermittent-distribution zones are in most cases, massive and pebble type. In a part (station 03 - 03) were observed spheroidal nodules that underwent a transition in form to clastics and pavement-type in the observation station and in the adjacent observation station (03 - 02).

The characteristics common in eastern and western zones of the Northern part is the abundance of massive and pebble shape of nodules.

Average abundance throughout the track line is 22.3 kg/m^2.

(2) Southern part

There is a continuous distribution of nodules with high abundance along almost all track line. Only four stations (stations 01 - 02, 01 -11, 02 - 01 and 02 - 04) left somewhat discontinuous impression because of their low abundance. The abundance for each observation station except for the above-mentioned four stations, is higher than 20 kg/m^2. One of them (02 - 08) excess 40 kg/m^2. Average abundance throughout the soutehrn part is 30 kg/m^2.

Shapes of the nodules in a higher-distribution zone are spheroidal (8 cm max.) followed by ellipsoidal (10 cm and more max.) and plate-types. Massive and ellipsoidal types are few. Int he observation station or in the zone delimited by the station and the adjacent station we observed a transition from spheroidal type to plate type passing through ellipsoidal type, but the transition is very gradual. Granular size as well as the shapes varies gradually and the bearing situation is stable in general.

Among theses observation stations there are two zones where the abundance is more than 30 kg/m^2 continuously (observation stations 01 - 03 to 01 - 10 and 02 - 05 to 02 - 09) but the variation in these stations is so slight that in most cases it is appropriate to call it homogenious.

But a slight variation in shape and granular size is obviously observed from an observation station to another (2 miles apart from it.).

In some parts (observation stations 01 - 02 and 01 - 05), spheroidal nodules agglutinated into pavement-type nodules. the bearing situation in the above-mentioned four stations is (1) coexistence of mud and black portion which can not precisely be identified as basement rock covered with crust in two observation stations (02 - 01 and 02 - 04), (2) pavement-type in a station (01 - 02), (3) predominance of mud mound produced by creatures etc.

These bearing characteristics observed in the intensely undulated areas in southern part, as well as in the northern part seem to be fairly universal.

2) Observation by Deep Sea Cameras

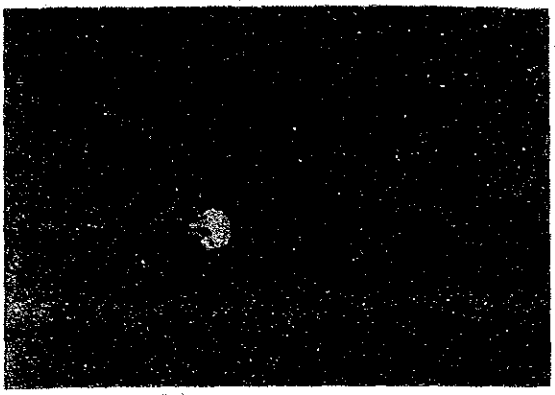
174 photos successfully taken represent well occurrence in teh area, and provide us informations which support or supplement the sampling data in its content concerning the nature and abundance of bottom materials and of manganeses nodules.

They helped to seize exactly (1 the bottom materials at rock exposed zone and calcareous sediments zone in sea mount and sea mound where sampling was often impossible and (2) the distribution and embedded degree of manganese nodules. Further details will be discussed in the following paragraphs. Typical examples are shown in Fig. 4-6-4.

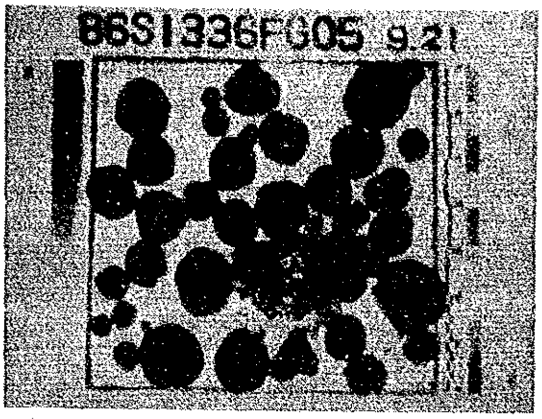
3) Comparison with the results of FG sampling

Comparison is made between the abundance obtained by this survey and that of FG sampling. Three observation stations were selected as representative of FDC survey area corresponding to the area of FG sampling delimited by three sampling stations (equilateral area with 2.1 mile long side and 1.4 mile short sides). In the survey the comparison was possible in 4 stations whose results are shown in Tab. 4-6-2.

This table shows that both values are, in average, fairly similar, the difference being around ±20%.

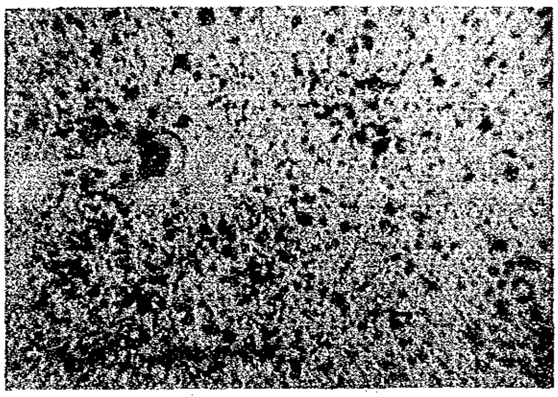


8 6 S 1 3 3 6 F G 0 5 (Sea Bottom)

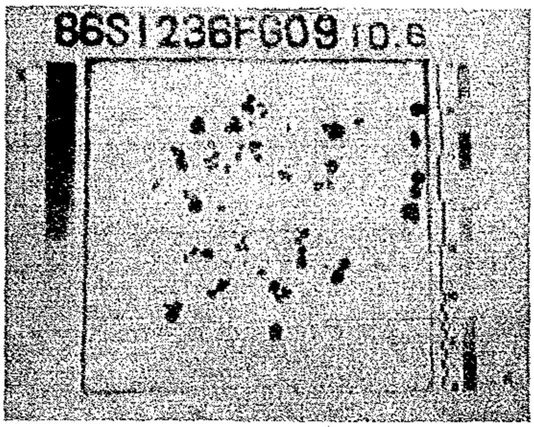


(Collected)

(Spheroidal . Coverage: 76.9%. Abundance: 31.82 kg/m²)

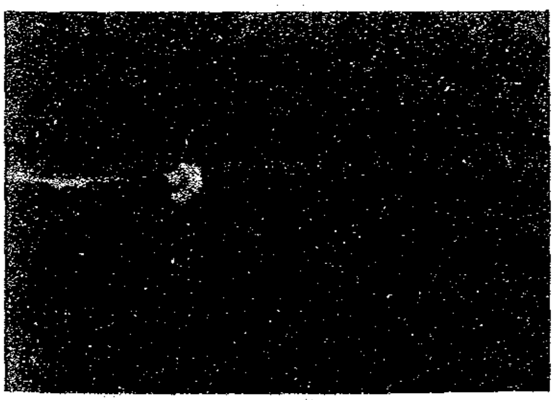


8 6 S 1 2 3 6 F G 0 9 (Sea Bottom)

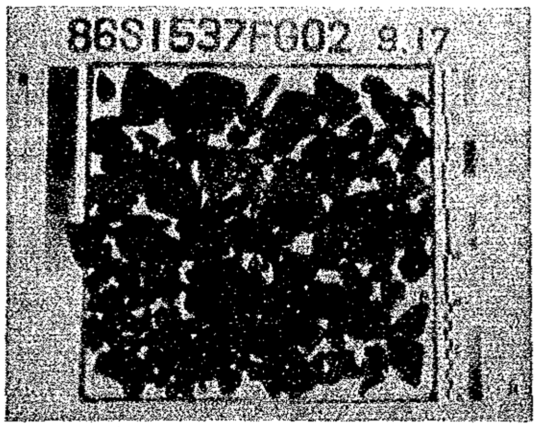


(Collected)

(Pebble . Coverage: 20.2% . Abundance: 0.82 kg/m²)



8 6 S 1 5 3 7 F G 0 2 (Sea Bottom)



(Collected)

(Plate . Coverage 95.4% . Abundance: 20.24 kg/m²)

Fig. 4-6-4 Examples of Deep-Sea Bottom Photos and of Re-collected Photos

Table 4-6-2 Comparison of Abundance Obtained by FG Sampling and FDC Survey

(kg/m²)

FG sampling			FDC survey		
Station	Value of sampling point	Average	Average	Value of sampling point	Station
86410	43.88			37.8	01-01
	16.62	33.09	28.15	18.5	02-02
	28.78				
86436	22.07			38.9	01-15
	33.81	26.09	31.67	17.9	02-01
	22.38			38.2	02-02
86448	46.68			0.5	03-08
	3.35	23.96	19.05	36.6	04-01
	21.85			20.1	04-02
86417	34.58			29.3	04-15
	35.62	34.11	37.30	40.5	04-06
	32.12			42.1	04-17

4-7 Assaying

The equipment of fluorescent X-ray analysis functioned normally.

For the 5 elements: Ni, Cu, Co, Mn and Fe that are principal components of the collected manganese nodules, the fluorescent X-ray analysis was executed on board. It totaled 590 cases, made up as follows:

- manganese nodules: 494
- manganese nodules sections: 85
- bottom materials: 8
- special cases: 3

50 samples were used for the wet chemical analysis (analysis on shore) for the purpose of inspection on the bias.

The results of inspection on bias and accidental errors are described below:

1) Inspection on the bias

Scatter diagram of metal grade assayed on bord and on shore showed quasi-linear distribution, and regression coefficient estimated by the diagram was nearly 1. Therefore, inspection on the bias and accidental errors was examined by means of regression analysis considering the results of inspection on the difference of average values by means of t-test.

The following are the upper and lower values of the calibration curve.

Metal	Upper grade	Lower grade	Number of samples
Ni	1.25	0.13	24
Cu	0.99	0.08	30
Co	0.48	0.66	35
Mn	28.97	4.57	35
Fe	18.44	6.04	43

(1) Methods by regression analysis

The regression equation: Y = aX + B was utilized.

Y: value of the wet chemical analysis

X: fluorescent X-ray analysis on board

a: regression coefficient

b: constant term

The results of the t-test relating to the estimated values of a and b of the regression equation and to the values of regression coefficient are shown in Tab. 4-7-1.

Further, the correlation coefficients between the analysis values on board and the chemical analysis values are given together. The estimated values of bias and accidental errors are also shown in Tab. 4-7-2.

(2) Test on the difference of average values

Tab. 4-7-3 shows the estimated values of bias and accidental errors obtained from the results of the t-test on the difference between respective mean values of the analysis on board and the chemical analysis.

2) Examination of the results

As shown in Tab. 4-7-1, it could be considered that the analysis values on board and those t-tested ashore had a very close correlationship.

It is easily concluded for the reason that even though a slight difference is observed on the regression coefficients and constant terms of each elements, the both values of analysis in the dispersion figure are distributed along a straight line for each element and all the regression coefficients are close to 1.

As shown in Tab. 4-7-2, according to the results of bias and accidental errors assumed by regression analysis, although they show a little high values in the low grade area of Ni, Cu and Mn, they show good values about the other elements. Furthermore, Tab. 4-7-3 shows the results of

Table 4-7-1 Estimated Values of a, b and Correlation Coefficients

	a	b	t: calculated	t	Correlation coefficient
Ni	1. 0934	−0. 0904	3. 0607	2. 704	0. 9855
Cu	0. 9967	−0. 0341	0. 1771	〃	0. 9929
Co	0. 9212	0. 0287	3. 1267	〃	0. 9861
Mn	0. 9829	−0. 9457	0. 5226	〃	0. 9795
Fe	0. 9242	1. 2253	5. 1978	〃	0. 9953

t: degree of freedom 4 and 5, significant level ±1%

Table 4-7-2 Examination of the Bias and the Accidental Errors by Regression Analysis

	Average grade assayed on board	Bias estimated	Accidental error estimated	Relative bias
Ni	0.300%	−0.062%	±0.020%	−20 %
	0.800%	−0.016%	±0.036%	− 2 %
Cu	0.300%	−0.035%	±0.011%	−12 %
	0.800%	−0.037%	±0.030%	− 5 %
Co	0.300%	0.005%	±0.013%	0.2 %
	0.600%	−0.019%	±0.015%	− 3 %
Mn	13.000%	−1.168%	±0.521%	− 9 %
	20.000%	−1.288%	±0.298%	− 6 %
Fe	10.000%	0.467%	±0.276%	5 %
	20.000%	−0.291%	±0.226%	− 1 %

Table 4-7-3 Bias and Accidental Errors Resulting from Inspection of the Difference of Average Values

	Average grade assayed on board	Bias estimated	Accidental error estimated	Relative bias	t calculated	t
Ni	0.3592%	−0.052%	±0.020%	−14%	7.144	2.704
Cu	0.2305%	−0.035%	±0.011%	−15%	8.814	〃
Co	0.4232%	−0.005%	±0.011%	− 1%	1.275	〃
Mn	16.9195%	−1.257%	±0.249%	− 7%	13.545	〃
Fe	15.8417%	0.026%	±0.200%	0.2%	0.349	〃

t: degree of freedom 4 and 5, significant level ±1%

Accidental error of the data assayed on board means provability 95%