

## **XV. MINOR CHEMICAL COMPOSITION OF BOTTOM SEDIMENTS FROM THE CENTRAL PACIFIC WAKE-TAHITI TRANSECT**

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### **Introduction**

The moisture content and the minor element contents were determined for 115 sediment samples collected from the GH80-1 survey traverses of the Central Pacific Wake-Tahiti Transect. The minor elements determined were Mn, Fe, Co, Ni, Cu, Zn, and Pb. The data for evaluating the distribution of these components in the ocean floor of the Central Pacific Basin and its northern and southern vicinities were obtained. These sediment samples comprises 24 surface sediment samples and 91 segments from core samples ranging in depth to several meters below the sea bottom.

Principal characteristics of the concentration and horizontal distribution of each component in the gross sediment samples are described in this chapter, as well as the relations among the elements. More detailed discussions of the behavior of the minor elements in regard to the sedimentary facies, depth below the sea bottom, etc. will be presented elsewhere.

### **Method**

#### *Preparation of samples*

Raw sediment samples were stored in polystyrene bottles. Supernatant water of the sediment samples was removed from each bottle. Samples were mixed well, then transferred to paper bags respectively, and were dried in the sun for a few days. After drying enough, samples were rough-crushed over the bags with a wooden hammer. Crushed samples were transferred and spread on clean papers. The crushed samples of about 10 g selected by the quartering method were stored in small paper bags. Coarse grains such as tiny manganese nodules (coarser than 2 mm) were removed and transferred to polyethylene bags from the selected samples.

The selected samples were ground under the size of 150 mesh. The ground samples were stored in paper bags and then allowed to stand for a week in the atmosphere. After standing, the samples were stored in polyethylene bags and these samples were used for analysis.

For the analysis, we weighed out the samples for the determination of moisture and of minor elements almost at the same time, in order that the minor element contents must be converted to a dry basis by separate moisture determination on the samples.

#### *Determination of moisture content ( $-H_2O$ )*

About 0.5 g of the sample in the weighing bottle whose weight was known was weighed exactly. The bottle containing the sample was dried for 3 hours at 110°C to constant weight. The weight of the weighing bottle with the sample was weighed after cooling

in a desiccator. The weight of the dried sample was calculated through subtracting the weight of the bottle from that mentioned above. The moisture content was calculated from the loss in weight.

#### *Determination of minor element contents*

About 0.25 g of the sample was weighed out exactly into a platinum dish (75 ml). A small amount of water was added and moistened. Two ml of nitric acid, 5 ml of perchloric acid and 10 ml of hydrofluoric acid were added and then mixed well. The dish was heated to dryness on a sand bath. After dried, the dish was cooled. The inside of the dish was washed with a small amount of water. Then, 3 ml of perchloric acid was added and the dish was heated to dryness. After cooled, 2.5 ml of hydrochloric acid (6N) were added. The dish was heated on a hot plate weakly until the salts were dissolved. After cooling, a small amount of water was added and the dish was heated to dissolve the salts and then cooled. The solution was transferred into a volumetric flask (50 ml) washing with water. The solution was diluted to the mark with water. The minor elements (Mn, Fe, Co, Ni, Cu, Zn, and Pb) were determined by the atomic absorption spectroscopy, following the method by TERASHIMA (1971) after some modifications which concern the elimination of diverse interferences.

#### **Results and discussions**

The contents of the minor elements (Mn, Fe, Co, Ni, Cu, Zn, and Pb) and the moisture ( $-H_2O$ ) for the 115 sediment samples are shown in Appendix XV-1, which also shows the metal contents of manganese nodules determined by USUI and MOCHIZUKI (Chap. XVI, this cruise report) for convenience. The data in the appendix are analytical values of air-dried samples. Since the moisture content of the air-dried sample is changeable depending of the humidity of air, the minor element contents must be converted to a dry basis ( $110^\circ C$ ) by separate moisture determination on the sample. The following results and discussion are described on a dry basis.

#### *The contents of each components and the characteristics of their horizontal distributions*

The average, the minimum, and the maximum contents of each component are shown in Table XV-1. The histograms of each component are shown in Fig. XV-1. The dotted curves drawn with the histograms are normal distribution curves by the average and standard deviation.

As can be seen from the histograms, the contents of each component are widely distributed in the bottom sediments. Three types of the distribution of each component are obtained by comparing their histograms with normal distribution curves. One is

Table XV-1 Average, minimum, and maximum chemical composition of the bottom sediments. The value was recalculated for 115 samples on the basis of dried state ( $110^\circ C$ ).

	H <sub>2</sub> O-(%)	Mn(%)	Fe(%)	Cu(ppm)	Ni(ppm)	Co(ppm)	Zn(ppm)	Pb(ppm)
Average	11.99	0.78	4.36	399	214	111	147	39
Minimum	1.46	0.04	0.10	12	0	4	9	0
Maximum	16.04	2.22	8.81	1134	727	373	626	128

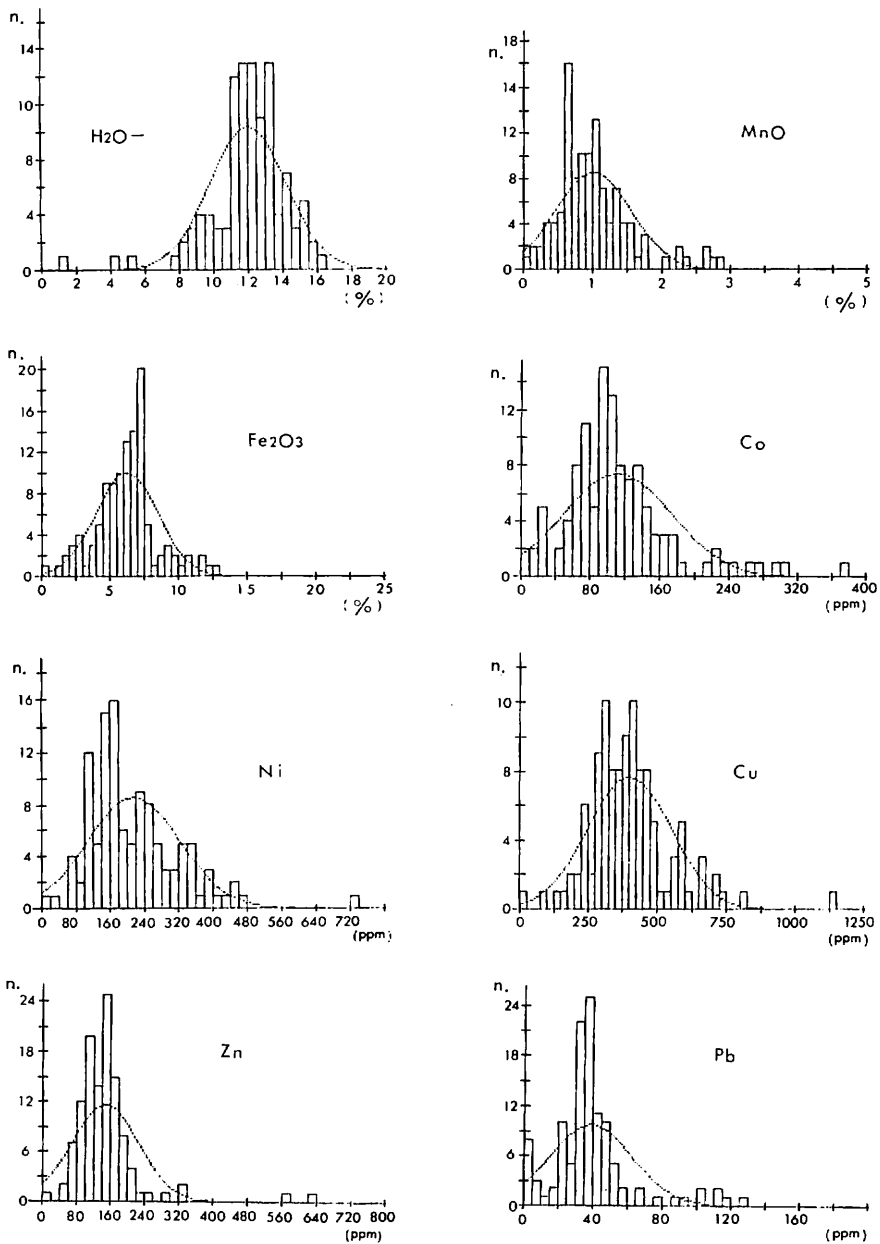


Fig. XV-1 The histograms of the minor element and the moisture contents in the bottom sediments.

almost identical type and the others are right or left skewed type as follows.

- 1) The distributions of Cu and Zn contents are almost identical types comparing their histograms with normal distribution curves.
- 2) The distributions of Mn, Co, Ni, and Pb contents are left skewed in comparison with normal distribution curves. Especially, the strong tendency of skewness as to the



are obtained as follows.

- 1) A correlation between moisture content and the others is scarcely observed.
- 2) A correlation between Zn content and the others is not appreciably observed.
- 3) A strong correlation is observed between Mn and Fe, Co, Ni, or Pb (correlation coefficient,  $r \geq 0.7$ ).
- 4) Among Mn, Fe, Co, and Pb, a strong correlation is observed to each other ( $r \geq 0.7$ ).
- 5) A strong correlation is observed between Ni and Mn or Co ( $r \geq 0.7$ ).
- 6) A medium correlation is observed between Cu and Mn or Ni ( $0.5 \leq r < 0.7$ ).

The metallic elements such as Mn, Fe, Co, Ni, Cu, Zn, and Pb will be present at various states in the sediments. The particles which constitute the deep-sea sediments are classified as terrigenous, volcanogenic, biogenic, and chemogenic ones and furthermore diagenetic one originated from these. According to NAKAO and KATO, and NAKAO *et al.* (both in preparation), it has been considered that at least the majority of manganese (about 90%) exist as the diagenetic and the chemical origin particles (manganese micronodules) which can be easily dissolved or extracted by the mixed solution of acetic acid and hydroxylamine hydrochloride. While their works show only ca. 20% of total Fe and ca. 50% of total Cu do in the extractive states in deep-sea sediments. In other words, 80% of total Fe should be in the crystal structure of minerals which cannot be destroyed by that solution. Therefore, it seems that different factors control the concentration of Mn and especially Fe. Present results, however, show rather intimate relations among those elements including Fe, suggesting the presence of some common factors controlling their distribution in sediments. Further study is required to solve this problem, though maybe the presence of iron-manganese mineral (AOKI, this cruise report) is one of the relating aspects.

#### References

- NAKAO, S. and KATO, K. Major partitioning of some transition elements in deep-sea sediments related to manganese nodules (*in prep.*).
- , MELLIN, T., and FISK, M. Preliminary study on manganese micronodules (*in prep.*).
- TERASHIMA, S. (1971) Atomic absorption analysis of minor elements in silicate. *Bunseki Kagaku*, vol. 20, p. 321–326.

Appendix XV-1 Chemical composition of bottom sediments

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
1590	B2	15°23.31'N 178°43.79'E	5287	0 cm	9.35	.60	4.35	116
	FG192-1	15°23.67'N 178°44.00'E	5306	*	*	*	*	*
	FG192-2	15°23.61'N 178°44.01'E	5306	*	*	*	*	*
1591	FG193-1	14°03.09'N 179°45.80'E	5569	*	*	*	*	*
	FG193-2	14°02.97'N 179°45.83'E	5571	*	*	*	*	*
1592	FG194-1	13°14.65'N 179°37.55'W	5596	*	*	*	*	*
	FG194-2	13°14.56'N 179°37.51'W	5596	*	*	*	*	*
1593	FG195-1	11°54.16'N 178°36.28'W	5491	*	*	*	*	*
	FG195-2	11°54.06'N 178°36.24'W	5489	*	*	*	*	*
1594	FG196-1 in	11°06.91'N 178°00.01'W	5729	*	*	*	*	*
	FG196-1 out			*	*	*	*	*
	FG196-2 in	11°06.19'N 177°59.45'W	5736	*	*	*	*	*
	FG196-2 out			*	*	*	*	*
	FG196-3	11°05.47'N 177°58.45'W	5814	*	*	*	*	*
	FG196-4 in	11°04.77'N 177°58.28'W	5870	*	*	*	*	*
	FG196-4 out			*	*	*	*	*
	FG196-5 in	11°04.03'N 177°57.59'W	5886	*	*	*	*	*
	FG196-5 out			*	*	*	*	*
1595	FG197-1	9°46.68'N 176°59.02'W	6298	*	*	*	*	*
	FG197-2	9°45.93'N 176°58.33'W	6293	*	*	*	*	*
	FG197-3	9°45.19'N 176°57.68'W	5855	*	*	*	*	*

and manganese nodules from GH80-1 cruise.

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
210	347	219	33	DPs/IDPs	10.83	20.59	13.86	.45	.52	.29	670	1227	
*	*	*	*	IDPs/Ds	12.85	19.51	10.66	.34	.78	.43	757	1287	
*	*	*	*	Ss/Ds	10.89	12.35	8.69	.20	.54	.27	568	851	
*	*	*	*	Sr	11.23	22.09	7.60	.22	.86	.76	1023	406	
*	*	*	*	Sr/SEr	?	18.61	6.99	.20	.86	.68	757	624	
*	*	*	*	DPs/IDPs, (SEr)	12.80	23.46	8.16	.25	.89	.79	893	900	
*	*	*	*	DPs/(Sr)	12.18	26.88	7.34	.23	1.06	.97	1196	610	
*	*	*	*	Sr/SEr, (DPr)	12.68	23.96	7.22	.26	.98	.85	1059	583	
*	*	*	*	DPs/(Sr)	11.73	22.70	6.84	.23	.95	.81	1020	595	
*	*	*	*	IDPs/DPs/(V)	11.28	20.11	13.94	.37	.44	.36	542	1234	
*	*	*	*	"	14.70	20.09	16.49	.42	.44	.33	551	1244	
*	*	*	*	DPs/IDPs	13.67	22.16	14.88	.47	.51	.36	556	1233	
*	*	*	*	"	13.64	19.88	16.09	.45	.43	.30	543	1214	
*	*	*	*	V*	13.16	20.29	11.44	.36	.41	.30	546	856	
*	*	*	*	DPs/IDPs	14.55	20.20	16.42	.39	.45	.33	565	1139	
*	*	*	*	DPs	14.34	20.59	13.34	.34	.52	.43	555	1002	
*	*	*	*	DPs	13.43	19.85	12.28	.31	.53	.45	528	797	
*	*	*	*	"	14.30	20.34	16.94	.41	.40	.30	548	1154	
*	*	*	*	IDPs/DPs	13.62	22.95	10.30	.29	.76	.78	748	724	
*	*	*	*	IDPs/DPs/(SEr)	13.80	18.15	14.08	.31	.48	.32	509	984	
*	*	*	*	IDPs	9.11	7.33	10.69	.12	.26	.18	333	360	

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
1596	FG198-1	8°57.56'N 176°23.96'W	6009	*	*	*	*	*
	FG198-2	8°56.76'N 176°23.44'W	6129	*	*	*	*	*
	FG198-3	8°55.96'N 176°22.94'W	6120	*	*	*	*	*
	FG198-4	8°55.14'N 176°22.43'W	6068	*	*	*	*	*
1597	FG199-1	7°38.13'N 175°14.54'W	5945	*	*	*	*	*
	FG199-2	7°38.21'N 175°14.43'W	5936	*	*	*	*	*
1598	B4	6°49.67'N 174°47.63'W	5962	0 cm	13.58	.45	3.55	80
1599	FG201-2	5°28.35'N 173°47.05'W	5179	*	*	*	*	*
	FG201-3	5°27.52'N 173°46.44'W	5245	*	*	*	*	*
	FG201-4	5°26.66'N 173°45.82'W	5277	*	*	*	*	*
1600	B5	4°41.39'N 173°11.89'W	5584	0 cm	14.44	.40	3.26	72
1601	B6	3°17.83'N 172°10.51'W	5350	0 cm	14.91	.80	3.33	75
	FG203-1	3°17.45'N 172°10.38'W	5349	*	*	*	*	*
	FG203-2	3°17.24'N 172°10.34'W	5335	*	*	*	*	*
1602	B7	2°33.26'N 171°37.69'W	5389	0 cm	15.54	.40	3.31	66
1603	P159	1°17.22'N 170°42.28'W	5479	pilot 0-15	13.38	.42	3.22	58
				0-15 cm				
				II 70-80	12.92	.29	2.41	42
				57- 67 cm				
				IV 50-60	12.24	.20	1.79	25
				237-247 cm				
	VI 50-60	12.40	.29	2.47	35			
437-447 cm								
VIII 50-60	11.22	.11	1.33	18				
637-647 cm								
	FG205-1	1°17.60'N 170°42.01'W	5511	*	*	*	*	*



(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
*	*	*	*	IDPs	12.83	16.67	12.10	.27	.50	.19	512	640	
*	*	*	*	IDPs	10.83	14.33	9.80	.17	.57	.39	497	498	
*	*	*	*	IDPs	12.25	14.57	12.18	.22	.50	.38	501	595	
*	*	*	*	IDPs	9.83	13.45	10.83	.20	.44	.33	458	620	
*	*	*	*	SPr/Sr	11.20	21.84	6.93	.21	1.04	1.05	855	566	
*	*	*	*	SPr/Sr	13.17	22.35	6.31	.18	1.08	1.16	899	481	
109	293	95	28	*	*	*	*	*	*	*	*	*	
*	*	*	*	Sr	12.31	14.47	9.35	.15	.75	.73	766	430	
*	*	*	*	Sr	?	8.76	6.31	.07	.48	.50	589	207	
*	*	*	*	Sr/SPr	12.23	21.55	7.95	.14	1.19	1.09	941	396	
126	305	91	20	*	*	*	*	*	*	*	*	*	
252	409	116	26	Sr	11.97	26.74	4.75	.13	1.79	1.69	1313	358	
*	*	*	*	Sr	12.58	26.66	4.91	.14	1.67	1.66	1215	330	
*	*	*	*	Sr	15.21	28.33	5.21	.12	1.67	1.77	1312	268	
115	285	88	20	*	*	*	*	*	*	*	*	*	
180	331	101	19	*	*	*	*	*	*	*	*	*	
165	284	82	0	*	*	*	*	*	*	*	*	*	
130	206	55	0	*	*	*	*	*	*	*	*	*	
194	272	71	17	*	*	*	*	*	*	*	*	*	
100	157	41	2	*	*	*	*	*	*	*	*	*	
*	*	*	*	Sr	13.32	26.84	5.93	.09	1.75	1.40	1102	399	

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
	FG205-2	1°17.46'N 170°42.05'W	5509	*	*	*	*	*
1604	B8	0°24.23'N 170°02.51'W	5457	0 cm	16.04	.35	3.01	47
	FG206-2	0°24.74'N 170°02.71'W	5457	*	*	*	*	*
1605	P160	0°57.91'S 169°01.69'W	5455	pilot 6-16 6-16 cm	9.82	.45	3.29	53
				II 60-70 162-172 cm	11.86	.56	4.03	62
				IV 60-70 362-372 cm	12.25	.55	3.93	65
				VI 60-70 562-572 cm	11.99	.69	4.32	88
				VIII 39-50 741-752 cm	12.65	.39	3.07	49
1606	B9	1°45.07'S 168°26.20'W	5230	*	*	*	*	*
	FG208-2	1°44.92'S 168°25.79'W	5215	*	*	*	*	*
1607	P161	3°02.12'S 167°29.91'W	5698	pilot 15-30 15-30 cm	10.40	.97	5.69	83
				I 60-70 26-36 cm	11.80	.97	5.95	96
				III 60-70 226-236 cm	11.37	.91	5.56	93
				VI 50-60 516-526 cm	12.47	1.15	6.68	112
				VIII 50-60 716-726 cm	12.51	.35	2.84	120
	FG209-1	3°02.21'S 167°29.09'W	5690	*	*	*	*	*
	FG209-2	3°02.13'S 167°29.16'W	5692	*	*	*	*	*
1609	FG211-2	3°52.06'S 166°51.87'W	5434	*	*	*	*	*
1611	B11	7°20.88'S 164°17.60'W	4155	*	*	*	*	*
	FG213-1	7°20.47'S 164°17.41'W	4156	*	*	*	*	*
1613	B12	9°29.32'S 162°41.40'W	2944	0 cm	1.46	.04	.09	10

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
					H <sub>2</sub> O(±) (%)	Mn (%)	Fe (%)	Co (%)				
*	*	*	*	SPr/Sr	13.30	25.95	6.17	.09	1.65	1.44	1097	445
100	272	74	28	*	*	*	*	*	*	*	*	*
*	*	*	*	Sr	13.47	19.65	8.63	.13	1.14	.92	804	497
110	225	85	43	*	*	*	*	*	*	*	*	*
70	268	92	21	*	*	*	*	*	*	*	*	*
94	275	95	34	*	*	*	*	*	*	*	*	*
216	337	121	42	*	*	*	*	*	*	*	*	*
78	285	78	29	*	*	*	*	*	*	*	*	*
*	*	*	*	DPs	12.56	20.12	16.81	.36	.41	.26	624	1029
*	*	*	*	Sr/SrEr	15.06	4.85	4.38	.07	.19	.15	275	304
100	260	121	49	DPs/SPs	12.27	19.64	12.42	.33	.74	.44	667	985
161	398	142	49	*	*	*	*	*	*	*	*	*
143	340	140	41	*	*	*	*	*	*	*	*	*
298	279	288	27	*	*	*	*	*	*	*	*	*
289	360	184	33	*	*	*	*	*	*	*	*	*
*	*	*	*	IDPs	11.09	14.57	12.16	.15	.41	.31	520	652
*	*	*	*	IDPs	12.23	14.90	11.83	.20	.50	.37	556	496
*	*	*	*	DPs	16.09	19.43	16.05	.40	.45	.27	630	847
*	*	*	*	Vs	9.83	5.76	6.32	.09	.26	.18	321	283
*	*	*	*	Vs	11.76	6.85	6.50	.10	.26	.20	360	365
0	12	16	23	*	*	*	*	*	*	*	*	*

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
1616	B14	12°20.07'S 160°30.89'W	5690	0 cm	10.61	1.53	7.45	192
	FG218-2	12°20.46'S 160°31.27'W	5637	*	*	*	*	*
1617	B15 in	13°47.40'S 159°28.35'W	5162	0 cm	11.22	1.91	7.61	220
	B15 out			*	*	*	*	*
	FG219-1 in	13°47.03'S 159°28.25'W	5148	*	*	*	*	*
	FG219-1 out			*	*	*	*	*
	FG219-2 in (#1)	13°47.15'S 159°28.26'W	5147	*	*	*	*	*
	FG219-2 in (#2) FG219-2 out			*	*	*	*	*
1618	B16 irregular	14°29.61'S 158°52.98'W	5453	0 cm	10.79	1.98	7.86	197
	B16 sphere			*	*	*	*	*
	FG220-2	14°29.69'S 158°53.13'W	5438	*	*	*	*	*
1618-A	FG221-1 sphere	14°29.49'S 158°52.59'W	5484	*	*	*	*	*
	FG221-1 irregular			*	*	*	*	*
	FG221-2	14°29.37'S 158°52.53'W	5484	*	*	*	*	*
1619	B17	13°34.29'S 157°05.16'W	5111	0 cm	11.07	1.60	7.45	206
	FG222-1	13°34.39'S 157°05.31'W	5110	*	*	*	*	*
	FG222-2	13°34.28'S 157°05.42'W	5110	*	*	*	*	*
1620	B18	12°26.44'S 157°57.20'W	5285	0 cm	11.39	1.82	6.41	231
	FG223-1	12°26.09'S 157°57.15'W	5263	*	*	*	*	*
	FG223-2	12°26.17'S 157°57.10'W	5265	*	*	*	*	*

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
223	383	143	105	Ss/Ls/(SPs)	11.83	19.29	16.27	.44	.51	.30	679	1240	
*	*	*	*	Ss/DPs/Fs	12.07	13.66	12.19	.27	.50	.24	581	508	
249	392	147	99	Ss	11.15	18.67	17.05	.50	.33	.18	553	1285	
*	*	*	*	"	11.97	15.56	21.53	.50	.20	.15	498	1863	
*	*	*	*	Ss/DPs/IDPs	12.59	17.58	16.62	.46	.34	.19	541	1370	
*	*	*	*	"	15.82	13.00	19.30	.41	.28	.19	539	1485	
*	*	*	*	Ss	15.52	18.61	16.69	.50	.34	.17	529	1110	
*	*	*	*	"	13.57	17.46	16.50	.45	.34	.18	519	1058	
*	*	*	*	"	12.76	15.67	21.32	.49	.20	.14	517	1638	
244	349	146	92	Ss/SPs/ISs	12.11	11.16	12.66	.16	.36	.27	451	589	
*	*	*	*	Ss	10.77	20.59	9.75	.20	.93	.68	808	840	
*	*	*	*	Ss/ISs	14.12	18.66	8.51	.18	.90	.69	761	532	
*	*	*	*	ISs/DPs/Ss	13.76	20.13	11.33	.26	.78	.55	732	657	
*	*	*	*	ISs	12.74	9.57	13.87	.14	.34	.25	441	522	
*	*	*	*	ISs/DPs	12.79	18.08	13.42	.34	.55	.35	643	919	
267	367	139	99	DPs/IDPs	11.54	21.94	12.02	.36	.82	.52	695	928	
*	*	*	*	DPs/Lr+s	12.04	18.74	12.91	.35	.57	.34	633	967	
*	*	*	*	DPs/SPs/ISs	12.28	20.05	13.18	.36	.59	.36	638	1005	
347	412	145	113	Ds	10.90	20.25	15.04	.44	.60	.36	661	1439	
*	*	*	*	Ss/SEs	10.73	19.18	13.30	.43	.45	.25	558	993	
*	*	*	*	Ss/SEs	11.62	19.33	13.87	.40	.51	.30	585	1067	

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
1621	B19	11°35.38'S 158°34.91'W	5312	0 cm	11.33	1.83	6.60	248
	FG224-1	11°35.57'S 158°34.72'W	5317	*	*	*	*	*
	FG224-2	11°35.47'S 158°34.78'W	5318	*	*	*	*	*
1622	P167	10°16.35'S 159°35.57'W	5235	pilot 5-20	11.59	.94	5.96	144
				5- 20 cm				
				III 10-20a	12.02	.72	5.04	159
				33- 43 cm				
				IV 60-70	12.34	.97	5.78	327
	178-188 cm							
V 60-70	11.64	.77	5.33	267				
	375-385 cm							
VIII 60-70	12.02	.91	5.69	256				
575-585 cm								
FG225-1	10°16.03'S 159°35.45'W	5221	*	*	*	*	*	
1623	B20	9°26.14'S 160°14.83'W	4561	0 cm	4.43	.46	1.71	59
	surface B20 burr			*	*	*	*	*
1625	B21	7°06.72'S 161°56.68'W	4650	0 cm	9.00	.32	2.56	87
	FG228-1	7°06.54'S 161°55.93'W	4648	*	*	*	*	*
1627	B22	5°27.32'S 163°46.01'W	4995	0 cm	15.44	.45	3.57	104
1628	P170	3°30.50'S 164°09.94'W	4947	pilot 10-25	8.62	.47	2.24	58
				10- 25 cm				
				V 40-50	14.02	.88	4.18	104
				59- 69 cm				
				VI 35-45	13.33	1.01	4.45	119
	152-162 cm							
VII 60-70	12.24	1.08	4.69	131				
243-253 cm								
VIII 60-70	13.06	1.53	4.48	152				
343-353 cm								
FG231-2	3°30.63'S 164°09.44'W	4981	*	*	*	*	*	
1629	B23	2°53.00'S 164°57.31'W	5261	0 cm	15.23	.40	3.41	72

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
358	412	149	92	Ds	10.73	18.57	16.28	.47	.27	.18	535	1380	
*	*	*	*	Ss/Ds	14.08	18.63	14.58	.46	.45	.26	573	1196	
*	*	*	*	DPs/Ls	13.16	18.91	14.75	.43	.48	.25	564	1051	
214	363	118	60	*	*	*	*	*	*	*	*	*	
298	428	128	58	*	*	*	*	*	*	*	*	*	
402	312	129	81	*	*	*	*	*	*	*	*	*	
318	290	188	70	*	*	*	*	*	*	*	*	*	
389	328	147	74	*	*	*	*	*	*	*	*	*	
*	*	*	*	Ss/Ds	13.08	18.08	7.53	.19	.87	.64	745	657	
58	130	50	36	Ss/SPs	13.41	18.98	17.23	.48	.30	.16	550	1354	
*	*	*	*	Ss	11.06	14.67	6.28	.17	.57	.51	604	516	
144	233	67	47	DPs/Ds	11.54	10.29	5.99	.12	.53	.40	623	348	
*	*	*	*	Ss/Is	?	7.62	6.07	.11	.35	.33	400	259	
182	343	88	44	*	*	*	*	*	*	*	*	*	
100	189	64	37	*	*	*	*	*	*	*	*	*	
216	390	121	42	*	*	*	*	*	*	*	*	*	
297	575	132	46	*	*	*	*	*	*	*	*	*	
334	702	160	51	*	*	*	*	*	*	*	*	*	
632	986	198	33	*	*	*	*	*	*	*	*	*	
*	*	*	*	Ir	12.18	26.39	5.34	.11	1.36	1.48	1351	282	
140	260	86	33	Ir/IDPr/Sr/Ls+r	10.77	18.04	6.00	.15	1.01	.75	837	441	

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
	FG232-1	2°52.99'S 164°56.56'W	5212	*	*	*	*	*
	FG232-2	2°52.92'S 164°56.72'W	5211	*	*	*	*	*
1630	P171	1°30.45'S 165°52.52'W	5537	pilot 15-34 15- 34 cm	13.98	.60	4.27	77
				I 60-70 36- 46 cm	13.12	.71	4.61	88
				II 60-70 136-146 cm	12.59	.61	4.47	88
				III 60-70 231-241 cm	12.66	.84	4.78	106
				IV 70-80 338-348 cm	12.79	.85	4.65	101
				V 60-70 423-433 cm	13.38	.74	4.34	90
				VI 60-70 523-533 cm	13.39	.65	4.04	82
				VII 50-60 613-623 cm	13.36	.76	3.99	90
				VIII 60-70 723-733 cm	11.98	.74	4.42	98
1631	B24	0°58.61'S 166°20.89'W	5342	0 cm	14.76	.39	3.38	53
	FG234-1	0°59.02'S 166°20.41'W	5390	*	*	*	*	*
	FG234-2	0°58.94'S 166°20.49'W	5355	*	*	*	*	*
1632	P172	0°26.16'N 167°33.83'W	5255	I 20-30 20- 30 cm	11.21	.46	2.75	54
				II 60-70 122-132 cm	15.10	.44	3.32	59
				III 40-50 202-212 cm	15.12	.43	3.49	63
				IV 50-60 312-322 cm	13.83	.72	3.83	80
				V 60-70 422-432 cm	14.40	.69	3.85	86
				VI 60-70 522-532 cm	15.06	.56	3.22	63
				VII 40-50 602-612 cm	14.14	.53	2.94	60
				VIII 60-70 722-732 cm	14.60	.64	2.89	62
	FG235-2	0°25.99'N 167°33.63'W	5251	*	*	*	*	*



(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
*	*	*	*	Sr/Ds/r/Ls+r	13.16	21.23	12.55	.30	.70	.57	726	765	
*	*	*	*	Sr/SEr	11.71	27.00	5.45	.10	1.49	1.45	1190	310	
110	242	123	32	*	*	*	*	*	*	*	*	*	
121	260	122	41	*	*	*	*	*	*	*	*	*	
99	212	116	44	*	*	*	*	*	*	*	*	*	
197	361	132	38	*	*	*	*	*	*	*	*	*	
214	303	125	42	*	*	*	*	*	*	*	*	*	
154	329	112	38	*	*	*	*	*	*	*	*	*	
127	280	98	31	*	*	*	*	*	*	*	*	*	
165	304	102	38	*	*	*	*	*	*	*	*	*	
159	281	114	34	*	*	*	*	*	*	*	*	*	
100	231	81	28	Sr	11.44	24.72	6.93	.15	1.55	1.18	1033	462	
*	*	*	*	SPs/r/Ss/r	12.56	23.78	8.63	.16	1.31	1.06	962	375	
*	*	*	*	SPs/r/Ss/r	12.07	22.46	9.18	.17	1.21	.93	900	613	
89	280	97	27	*	*	*	*	*	*	*	*	*	
130	337	95	26	*	*	*	*	*	*	*	*	*	
106	315	97	26	*	*	*	*	*	*	*	*	*	
149	373	252	28	*	*	*	*	*	*	*	*	*	
220	399	536	26	*	*	*	*	*	*	*	*	*	
143	346	93	24	*	*	*	*	*	*	*	*	*	
130	346	84	23	*	*	*	*	*	*	*	*	*	
183	346	87	22	*	*	*	*	*	*	*	*	*	
*	*	*	*	Sr	?	10.89	9.21	.06	.44	.49	535	288	

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(-) (%)	Bottom sediment					
						Mn (%)	Fe (%)	Co (ppm)			
1633	B25	1°16.04'N 168°09.97'W	5359	0 cm	15.92	.33	2.90	56			
1634	P173	2°32.13'N 169°06.07'W	5087	I 30-40 50-60 cm	11.73	.49	3.01	51			
				II 60-70 138-148 cm	13.37	.60	3.69	80			
				III 60-70 238-248 cm	12.82	.61	3.71	88			
				IV 40-50 318-328 cm	13.56	.70	3.05	70			
				V 60-70 438-448 cm	9.05	.22	1.18	17			
				VI 60-70 535-545 cm	8.16	.28	1.36	22			
				VII 60-70 635-645 cm	8.79	.18	1.02	5			
				VIII 60-70 735-745 cm	5.42	.10	.69	4			
				FG237-1	2°31.48'N 169°05.67'W	5082	*	*	*	*	*
				FG237-2	2°31.51'N 169°05.59'W	5060	*	*	*	*	*
1635	B26	3°16.42'N 169°40.10'W	5351	0 cm	14.14	.31	2.72	7			
	FG238-1	3°16.46'N 169°40.22'W	5374	*	*	*	*	*			
	FG238-2	3°16.36'N 169°40.22'W	5352	*	*	*	*	*			
1635-A	P174	3°16.31'N 169°40.25'W	5350	I 50-60 50-60 cm	11.75	.24	1.57	22			
				VIII 60-70 731-741 cm	12.05	.25	1.38	22			
	FG239-1	3°16.29'N 169°41.35'W	5349	*	*	*	*				
	FG239-2	3°16.30'N 169°41.29'W	5358	*	*	*	*				
	D377 from to from to	3°16.08'N 3°16.16'N 169°39.41'W 169°41.16'W	from 5396 to 5373	*	*	*	*	*			
1636	P175	4°43.37'N 170°42.88'W	5747	pilot 5-20 5-20 cm	14.04	.43	3.52	80			
				II 50-60 116-126 cm	13.32	.60	3.77	79			

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
124	250	72	21	*	*	*	*	*	*	*	*	*	
126	293	88	32	*	*	*	*	*	*	*	*	*	
144	340	492	29	*	*	*	*	*	*	*	*	*	
199	387	116	25	*	*	*	*	*	*	*	*	*	
260	418	169	21	*	*	*	*	*	*	*	*	*	
98	218	67	4	*	*	*	*	*	*	*	*	*	
155	281	128	1	*	*	*	*	*	*	*	*	*	
65	163	104	0	*	*	*	*	*	*	*	*	*	
21	92	57	3	*	*	*	*	*	*	*	*	*	
*	*	*	*	IDPs/r/DPs/r	13.34	22.51	12.33	.24	.87	.81	858	828	
*	*	*	*	IDPs/r/DPs/r	13.59	23.32	13.13	.14	.86	.78	874	644	
153	308	8	16	Sr/Dr	10.83	29.38	4.92	.12	1.61	1.85	1461	367	
*	*	*	*	Sr/Dr	13.04	26.59	6.04	.15	1.61	1.66	1159	409	
*	*	*	*	Sr/Dr	12.80	28.86	5.49	.13	1.68	1.71	1265	214	
86	181	60	6	*	*	*	*	*	*	*	*	*	
52	206	92	3	*	*	*	*	*	*	*	*	*	
*	*	*	*	IDPs/r/DPs/r	13.71	15.99	12.27	.19	.76	.44	753	511	
*	*	*	*	IDPr/Dr	11.46	9.58	10.21	.15	.58	.37	774	260	
*	*	*	*	Ir/Vr/Sr	11.40	7.14	4.49	.09	.38	.33	434	393	
124	264	81	20	*	*	*	*	*	*	*	*	*	
133	289	166	36	*	*	*	*	*	*	*	*	*	

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(—) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
				III 60-70 226-236 cm	13.00	.75	3.74	87
				IV 50-60 316-326 cm	12.04	.70	4.76	98
				V 50-60 416-426 cm	11.66	.70	4.68	100
				VI 50-60 514-524 cm	12.20	.73	4.35	96
				VII 60-70 624-634 cm	12.77	.57	3.62	80
				VIII 50-60 714-724 cm	14.21	.45	3.33	62
1638	P176	6°48.65'N 172°15.46'W		I 10-20 10- 20 cm	11.59	.82	4.53	130
				II 60-70 124-134 cm	12.38	.88	4.14	116
				III 60-70 224-234 cm	11.98	.74	3.63	99
				IV 60-70 324-334 cm	11.41	.60	3.08	84
				V 60-70 424-434 cm	9.85	.50	2.13	66
				VI 60-70 522-532 cm	11.04	.42	1.72	54
				VII 40-50 602-612 cm	10.90	.56	2.29	76
				VIII 45-55 697-707 cm	11.64	.52	2.50	66
	FG242-1	6°48.95'N 172°15.53'W	5836	*	*	*	*	*
	FG242-2	6°48.86'N 172°15.44'W	5839	*	*	*	*	*
1639	B28	7°40.26'N 172°56.77'W	5926	0 cm	13.07	.46	3.71	84
	FG243-1	7°40.17'N 172°56.35'W	5907	*	*	*	*	*
	FG243-2	7°40.28'N 172°56.45'W	5913	*	*	*	*	*
1640	P177	8°57.86'N 173°53.91'W	5915	pilot 5-20 5- 20 cm	10.38	.66	4.47	104
				II 60-70 127-137 cm	11.36	.97	4.52	134
				III 60-70 227-237 cm	11.61	.92	4.38	124
				IV 20-30 287-297 cm	11.55	.39	4.43	117

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
					H <sub>2</sub> O(±) (%)	Mn (%)	Fe (%)	Co (%)				
193	304	130	36	*	*	*	*	*	*	*	*	*
146	360	110	41	*	*	*	*	*	*	*	*	*
145	400	118	39	*	*	*	*	*	*	*	*	*
204	356	112	36	*	*	*	*	*	*	*	*	*
133	343	102	33	*	*	*	*	*	*	*	*	*
102	313	134	26	*	*	*	*	*	*	*	*	*
221	456	152	49	*	*	*	*	*	*	*	*	*
244	491	162	34	*	*	*	*	*	*	*	*	*
242	433	144	28	*	*	*	*	*	*	*	*	*
176	411	140	26	*	*	*	*	*	*	*	*	*
178	211	97	4	*	*	*	*	*	*	*	*	*
102	149	63	12	*	*	*	*	*	*	*	*	*
158	265	83	8	*	*	*	*	*	*	*	*	*
134	255	112	18	*	*	*	*	*	*	*	*	*
*	*	*	*	Sr/Dr	13.07	26.90	4.96	.16	.99	1.09	1657	325
*	*	*	*	Ir/Vr/SPr	?	28.36	5.78	.20	.83	1.10	1833	177
147	386	106	21	*	*	*	*	*	*	*	*	*
*	*	*	*	Dr/Sr	11.69	31.06	3.30	.17	1.15	1.19	2141	240
*	*	*	*	Sr/Vr	10.77	28.17	4.84	.19	.97	1.09	1761	248
160	385	127	31	*	*	*	*	*	*	*	*	*
307	516	141	36	*	*	*	*	*	*	*	*	*
240	521	138	37	*	*	*	*	*	*	*	*	*
105	478	139	31	*	*	*	*	*	*	*	*	*

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(—) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
				IV 80-90 347-357 cm	12.24	1.20	4.38	147
				V 60-70 427-437 cm	12.50	1.19	4.60	152
				VI 60-70 525-535 cm	13.10	.80	4.05	121
				VII 60-70 625-635 cm	13.46	.87	3.72	125
				VIII 60-70 725-735 cm	13.11	.91	3.64	140
	FG244-1 (Sr)	8°58.05'N 173°53.34'W	5901	*	*	*	*	*
	FG244-1 (S/ab)			*	*	*	*	*
	FG244-2	8°57.96'N 173°53.24'W	5902	*	*	*	*	*
1641	B29	9°46.81'N 174°31.04'W	5829	0 cm	11.60	.52	4.05	83
	FG245-1	9°46.78'N 174°31.04'W	5829	*	*	*	*	*
	FG245-2	9°46.92'N 174°30.77'W	5839	*	*	*	*	*
1642	P178	11°06.38'N 175°30.07'W	5441	I 20-30 20-30 cm	9.28	.53	4.53	86
				II 30-40 90-100 cm	9.66	.59	4.56	100
				III 60-70 220-230 cm	10.45	.68	4.65	117
				IV 60-70 320-330 cm	11.37	.62	4.40	107
				V 60-70 420-430 cm	12.15	.67	4.29	107
				VI 60-70 520-530 cm	12.52	.79	4.42	137
				VII 60-70 620-630 cm	13.23	.70	3.96	118
				VIII 20-30 680-690 cm	12.59	.77	3.87	129
				VIII 70-80 730-740 cm	11.36	1.10	4.20	151
	FG246-1	11°06.26'N 175°29.50'W	5430	*	*	*	*	*
	FG246-2	11°06.19'N 175°29.45'W	5429	*	*	*	*	*
1643	FG247-1	11°49.40'N 176°04.87'W	5253	*	*	*	*	*

(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	H <sub>2</sub> O(±) (%)	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
						Mn (%)	Fe (%)	Co (%)					
348	637	151	38	*	*	*	*	*	*	*	*	*	
305	507	153	40	*	*	*	*	*	*	*	*	*	
218	481	161	31	*	*	*	*	*	*	*	*	*	
306	512	182	32	*	*	*	*	*	*	*	*	*	
294	387	179	32	*	*	*	*	*	*	*	*	*	
*	*	*	*	Sr/SEr	12.22	23.95	6.08	.20	1.07	1.02	1081	318	
*	*	*	*	Sr	15.49	21.61	10.75	.27	.71	.53	756	591	
*	*	*	*	Sr/SEr	10.58	24.68	6.31	.20	1.23	1.20	1033	447	
147	443	128	26	Sr/SPr/Dr/Db	9.71	30.48	4.79	.09	1.72	1.80	1465	403	
*	*	*	*	Sr/SEr	12.04	24.00	5.98	.20	1.29	1.20	1068	471	
*	*	*	*	Sr/SEr	13.27	24.43	5.86	.20	1.19	1.19	1088	439	
138	384	140	35	*	*	*	*	*	*	*	*	*	
157	443	140	30	*	*	*	*	*	*	*	*	*	
203	505	153	33	*	*	*	*	*	*	*	*	*	
199	544	149	27	*	*	*	*	*	*	*	*	*	
178	591	124	29	*	*	*	*	*	*	*	*	*	
240	583	159	33	*	*	*	*	*	*	*	*	*	
217	611	159	30	*	*	*	*	*	*	*	*	*	
263	626	154	33	*	*	*	*	*	*	*	*	*	
291	396	143	35	*	*	*	*	*	*	*	*	*	
*	*	*	*	DPs/IDPs	12.11	19.15	13.40	.32	.45	.33	572	1000	
*	*	*	*	DPs/IDPs	13.58	19.13	12.77	.32	.49	.38	572	828	
*	*	*	*	DPs/IDPs	14.00	18.10	12.34	.33	.46	.31	558	979	

## Appendix XV-1

Station No.	Observation No.	Latitude Longitude	Collected depth (m)	Depth below the bottom	H <sub>2</sub> O(—) (%)	Bottom sediment		
						Mn (%)	Fe (%)	Co (ppm)
	FG247-2	11°49.36'N 176°04.84'W	5256	*	*	*	*	*
1644	P179	13°16.99'N 177°08.35'W	5027	pilot 5-17	9.60	.50	3.85	122
				5- 17 cm				
				VI 50-60 148-158 cm	11.28	1.40	3.59	201
				VII 60-70 192-202 cm	11.08	1.07	2.99	125
				VIII 70-80 302-312 cm	12.46	1.06	2.74	97
1645	B30	14°06.61'N 177°47.28'W	5068	0 cm	8.31	.50	4.48	94
	FG249-1	14°06.20'N 177°46.83'W	5123	*	*	*	*	*
	FG249-2	14°06.30'N 177°46.88'W	5117	*	*	*	*	*
1646	B31	15°22.48'N 178°45.46'W	5537	0 cm	8.82	.55	4.21	96
	FG250-1	15°22.79'N 178°45.21'W	5512	*	*	*	*	*
	FG250-2	15°22.74'N 178°45.17'W	5526	*	*	*	*	*
1647	B32	16°10.14'N 179°19.82'W	5292	0 cm	7.95	.50	4.76	99
	FG251-1	16°10.17'N 179°19.87'W	5292	*	*	*	*	*
	FG251-2	16°10.10'N 179°19.81'W	5291	*	*	*	*	*



(Continued)

Ni (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)	Nodule type	Manganese nodule				Ni (%)	Cu (%)	Zn (ppm)	Pb (ppm)
					H <sub>2</sub> O(±) (%)	Mn (%)	Fe (%)	Co (%)				
*	*	*	*	DPS/IDPs	13.88	20.61	13.27	.38	.56	.38	605	939
295	255	128	29	*	*	*	*	*	*	*	*	*
384	349	145	40	*	*	*	*	*	*	*	*	*
415	357	170	32	*	*	*	*	*	*	*	*	*
259	518	286	34	*	*	*	*	*	*	*	*	*
138	274	126	31	Ds/DPS	9.53	17.58	14.80	.29	.49	.39	578	1507
*	*	*	*	DPS/IDPs	12.35	20.47	15.58	.49	.46	.27	581	1269
*	*	*	*	DPS/IDPs	12.78	18.98	14.81	.45	.43	.25	556	1216
194	292	104	28	Ds/DPS/Ls	11.38	20.42	11.57	.41	.94	.60	852	890
*	*	*	*	Ls/Ds	11.05	15.81	9.30	.24	.68	.37	575	617
*	*	*	*	DPS/Ls	12.88	20.77	12.21	.37	.61	.44	647	1049
148	268	132	32	Ds	11.01	21.07	10.13	.37	.95	.63	807	852
*	*	*	*	Fs	14.00	20.93	14.02	.48	.52	.33	641	1216
*	*	*	*	Ds/Ss	11.98	19.98	16.17	.51	.44	.25	569	1350