

## 56. GEOCHEMICAL HISTORY OF JAPAN TRENCH SEDIMENTS SAMPLED DURING LEG 56, DEEP SEA DRILLING PROJECT

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### INTRODUCTION

A geological model of subduction postulated by Karig, Ingle, et al. (1975) and Karig and Sharman (1975) proposes that the sedimentary prism at the foot of the landward wall is being actively built as sediment is scraped off the subducting oceanic and plastered onto the base of the wedge, forming an accretionary wedge containing overthrust sedimentary layers or intense sedimentary folding. Because overlying layers must continually be uplifted and compressed to accommodate new matter at the base, the accreting wedge will provide a geochemical record of this process at or near the Japan Trench.

Several recent papers have discussed the metalliferous sediments on the active oceanic ridges. The geochemistry of such sediments is now reasonably well known: generally these deposits are considered products of volcanic processes (Boström and Peterson, 1969; Böstrom et al., 1969; Horowitz, 1970, 1974; Cronan et al., 1972; Cronan and Garrett, 1973). The geochemistry of subduction zone sediments, however, is less well known, and the need for studies of these sediments is particularly urgent if such sediments provide a record of the effects of subduction of oceanic plates under continental crust. Because the Japan Trench contains well-developed subduction zone deposits, Leg 56 sampling was of utmost importance to the discovery of how they originate.

### ANALYTICAL METHOD

The sediment samples were dried at  $< 35^{\circ}\text{C}$ . Prior to chemical analysis, samples were ground  $< 200$  mesh with a Retisch mortar grinder. Chemical analyses were carried out on a Perkin-Elmer 503 atomic absorption spectrophotometer after a combined  $\text{HF-HClO}_4\text{-HCl}$  digestion that included double fuming with  $\text{HF-HClO}_4$ . All determinations were done in duplicate and precision and accuracy checked by JG-1 and JB-1, J. G. S. standards. In most cases, accuracy of concentrations of various elements in J. G. S. standard samples was in agreement within  $\pm 15$  per cent for Al, Ti, and  $\pm 5$  per cent for other elements.

### RESULTS AND DISCUSSION

#### Vertical Variations in Metal Enrichment

The bulk chemical analyses of all the Leg 56 samples are presented on an untreated basis in Table 1 and Figure 1, because neither carbonate corrections nor normalizing to  $\text{Al} + \text{Mn} + \text{Ti}$ , or  $\text{Al}_2\text{O}_3$ , as has been suggested by various other workers (Böstrom and Peterson,

1969; Böstrom et al., 1969; Piper, 1973), markedly alters the distribution patterns.

#### Site 434 (Holes 434 and 434B) (Figure 1)

This site is located on the lower inner trench wall at 5990 meters depth. The lithology of the sediments is very uniform diatomaceous ooze, mud, and mudstone with varying amounts of vitric ash. The color, presence of pyrite, and strong  $\text{H}_2\text{S}$  odor in the upper 250 meters indicate that the sediments were deposited under reducing conditions. They are composed almost entirely of pelagic ooze and hemipelagic mud.

As Table 1 and Figure 1 indicate, there are no remarkable variations in Al and Ti content at Site 434. Al content varies from 4.8 per cent to 8.6 per cent and averages 6.2 per cent, whereas Ti content ranges from 0.3 to 0.6 per cent and averages 0.4 per cent. Although we observed no systematic variations of Al and Ti in the core column, there are relatively large amounts of these elements in the vitric diatomaceous mudstone and tuffite below 300 meters.

Fe content varies from 1.6 to 8.8 per cent and averages 2.7 per cent. However, variations are generally small except at Sections 434-5-1 and 434-17-1, in which Fe values are two to three times greater. Fe enrichments do not necessarily occur at the reducing zone in which glauconite or pyrite is predominant. Therefore it appears likely that these minerals occur in minor quantities in this zone. Mn content is significantly variable, ranging from 330 ppm to 0.48 per cent. Elevated Mn content (over 0.3%) is observed at 102 meters (0.48%), 344 meters (0.44%), 370 meters (0.33%) and 440 meters (0.34%). These values are three- to four-fold the 0.1 per cent average at this site. High Mn content generally occurs in clay-rich sediments, which suggests that a process involving scavenging of metals from sea water, adsorption onto clays, and authigenic mineral formation is in operation.

Cu content in Hole 434 sediments shows small variation (58 ppm–85 ppm with an average of 70 ppm) relative to Hole 434B, where variation is marked (23 ppm–104 ppm). The relationship between Fe and Cu content in the reducing zone is so weak that sulfide minerals of both elements are not present at the same intervals within the zone. Zn distribution is fairly constant. Its highest value (370 ppm) occurs in the section in which Fe and Mn concentrations are also high. Of other trace elements, Ni, Co, Cr, and Li have similar distribution patterns throughout the cored sections at Site 434. The few higher Sr contents are due to the sporadic presence of carbonate through Holes 434 and 434B. The differences in chemical composition between Holes 434 and

TABLE 1  
Analytical Results of Sediment Samples from Deen Sea Drilling Project Leg 56

Sample (Interval in cm)	Al (%)	Ti (%)	Fe (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Li (ppm)	Sr (ppm)
Hole 434											
4,CC-9-10	6.70	0.53	2.47	1107	71	105	59	35	31	45	25
5-1-42-43	6.65	0.487	5.92	1138	83	83	54	25	49	36	39
6,CC-28-30	5.93	0.38	2.64	485	78	88	40	10	39	34	21
7-1-16-17	5.27	0.38	2.07	432	58	102	42	23	45	33	1
9-2-25-26	6.84	0.47	2.00	393	75	75	37	28	52	43	2
12-1-79-80	5.41	0.41	2.18	4802	72	79	46	25	56	35	10
15-1-12-13	6.99	0.49	3.03	777	63	100	41	11	49	45	40
20,CC-34-35	5.77	0.44	2.52	608	61	78	48	6	41	40	18
23,CC-12-15	5.39	0.35	2.94	1133	58	196	44	9	52	37	75
24,CC-29-30	5.78	0.45	2.27	458	73	208	56	30	67	39	2
25-1-20-21	5.84	0.39	2.93	991	69	139	56	35	52	35	31
26,CC-22-24	6.61	0.41	1.97	427	64	85	52	31	34	42	2
27,CC-23-24	6.28	0.48	2.71	475	59	80	48	33	48	44	20
28,CC-17-19	7.00	0.55	2.49	999	67	100	51	34	42	51	28
29,CC-25-26	6.00	0.44	2.82	858	77	96	46	29	51	42	29
30-1-100-103	5.00	0.34	2.18	1537	85	79	41	16	42	37	13
32-1-59-60	6.72	0.40	4.76	1472	62	33	42	14	53	32	82
33,CC-12-13	6.83	0.46	2.30	403	68	141	48	40	46	40	17
33-2-100-102	6.60	0.39	2.91	979	62	169	39	21	34	36	48
Hole 434B											
3,CC-3-4	6.11	0.38	1.85	485	67	76	44	27	38	36	5
7-1-48-49	6.23	0.38	2.35	4381	80	85	46	16	51	36	21
8-2-142-148	7.06	0.45	1.93	699	80	87	42	33	15	37	35
9-3-84-85	5.02	0.38	2.04	400	45	74	45	27	42	30	13
10-6-86-87	5.18	0.44	2.48	3257	83	83	56	24	59	38	29
11-2-100-101	5.62	0.36	2.64	1095	78	75	48	26	53	34	74
15,CC-0-2	5.40	0.36	2.00	343	83	77	48	29	54	36	1
16,CC-0-2	5.62	0.39	2.21	442	76	78	22	14	48	36	18
17-1-148-150	4.78	0.30	8.77	3449	58	365	59	16	64	26	150
18-1-139-140	7.16	0.44	2.47	435	66	89	54	32	53	47	4
19-2-102-103	8.55	0.55	2.72	1157	73	89	46	47	59	47	24
20,CC-3-4	6.37	0.42	2.35	401	83	88	47	27	48	38	15
24-2-56-57	7.86	0.50	2.28	2023	104	94	55	35	51	47	1
26,CC-3-4	6.38	0.36	1.59	663	44	77	25	21	25	26	19
28,CC-3-4	5.86	0.35	1.59	738	23	61	21	16	19	19	28
33,CC-3-4	7.80	0.48	2.26	1022	95	87	54	36	46	39	8
34,CC-2-3	6.95	0.43	2.45	419	67	86	51	23	47	40	1
36-1-47-48	5.77	0.38	1.82	327	63	77	50	19	48	35	7
Hole 435											
2,CC-8-10	7.79	0.62	2.04	443	41	97	55	27	62	36	64
5,CC-14-15	7.65	0.54	2.17	465	50	104	50	28	36	36	53
6,CC-17-18	7.71	0.50	2.43	465	46	95	61	28	49	38	14
8,CC-0-2	7.02	0.50	7.16	1318	54	152	61	27	99	31	50
9,CC-11-13	2.91	0.28	1.29	344	43	79	33	13	29	21	28
10-1-61-62	8.05	0.54	1.73	402	52	91	56	23	48	47	53
10,CC-11-12	5.51	0.44	2.13	344	49	88	43	21	38	30	59
11-1-83-84	6.45	0.38	1.75	382	80	92	20	14	37	35	63
12-1-80-81	5.89	0.40	1.89	356	45	91	36	15	44	37	174
13,CC-2-3	4.96	0.29	1.61	328	34	79	38	11	33	26	183
14,CC-2-3	3.45	0.30	1.50	251	41	72	39	12	37	29	63
15,CC-12-13	3.72	0.23	1.49	222	41	82	42	15	33	31	39
16,CC-1-2	2.97	0.23	1.26	265	36	73	35	35	31	23	14
Hole 435A											
1,CC-1-2	7.24	0.56	2.16	477	32	93	51	40	56	49	44
2-1-104-106	3.16	0.30	2.12	361	35	86	34	23	41	28	46
4,CC-7-8	4.16	0.31	1.27	202	38	76	37	20	43	33	35
6,CC	3.96	0.27	1.17	192	44	81	38	19	46	28	37
7,CC-21-23	3.03	0.26	1.29	205	47	77	32	17	42	25	26
9-2-141-142	3.54	0.28	1.54	181	38	80	33	16	48	30	33
10-1-106-107	3.69	0.28	1.39	246	48	88	30	14	42	26	20
11-2-95-96	4.38	0.33	1.59	430	51	104	35	18	54	32	111
11,CC-25-26	5.37	0.38	1.75	320	60	115	43	20	61	42	20

TABLE 1 — Continued

Sample (Interval in cm)	Al (%)	Ti (%)	Fe (%)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Li (ppm)	Sr (ppm)
Hole 436											
2-3-100-101	6.79	0.45	2.04	481	72	102	46	31	38	34	29
3-5-145-146	7.32	0.53	2.29	474	82	53	76	45	50	44	29
4-5-120-121	7.97	0.57	2.59	418	80	128	73	46	56	51	33
5-4-140-141	8.15	0.54	2.33	448	91	124	63	36	36	49	24
6-5-57-58	8.07	0.43	1.87	530	46	96	51	37	28	34	31
8-5-2-3	7.75	0.49	2.38	482	80	104	62	35	35	38	23
9-5-10-11	8.82	0.49	2.11	408	95	109	56	38	29	44	17
10-2-29-30	6.76	0.42	3.02	483	101	131	87	42	28	39	11
11-7-19-20	7.47	0.51	2.65	383	131	129	62	39	36	46	26
12-6-23-24	7.05	0.50	2.47	470	95	117	49	39	37	46	32
13-5-90-91	7.59	0.52	2.06	486	83	119	52	38	46	44	30
14-4-60-61	7.02	0.35	1.82	461	60	96	43	28	27	27	47
15-7-44-45	6.21	0.39	2.50	430	90	115	52	30	38	31	44
16-7-40-41	7.15	0.48	2.10	358	105	124	47	29	46	42	38
17,CC-8-10	7.11	0.26	2.03	534	118	103	49	26	20	39	27
18-2-69-70	6.88	0.38	1.77	337	42	94	39	27	27	38	43
19-4-148-149	6.45	0.46	2.63	361	53	104	41	26	37	48	35
20-2-40-41	7.80	0.49	2.01	412	90	108	51	36	26	44	22
21-1-40-41	8.10	0.49	2.31	422	147	122	58	36	40	56	15
23-3-50-51	7.07	0.48	2.28	339	101	124	47	30	39	51	11
24-2-60-61	7.67	0.45	2.59	693	122	107	43	35	31	47	7
25-1-66-67	7.05	0.44	2.15	392	57	92	51	34	35	44	10
26,CC-15-16	6.66	0.41	2.16	324	56	99	46	30	47	41	10
28-1-119-120	7.56	0.48	2.20	339	49	101	41	36	42	46	2
29,CC-19-20	7.18	0.18	1.17	468	33	47	47	30	10	16	1
30,CC-15-16	7.40	0.40	2.55	2149	14	98	29	39	35	38	1
31-5-13-14	7.01	0.34	2.89	1395	90	96	54	38	33	42	13
32-2-137-138	8.58	0.47	3.28	5993	32	109	67	42	30	46	10
33-6-55-57	8.53	0.46	1.93	4481	55	95	69	47	22	40	6
34-4-70-71	8.08	0.45	3.06	5075	55	99	72	49	29	43	15
35-6-66-67	9.03	0.52	3.33	3345	15	103	72	46	35	47	1
36-4-73-74	8.72	0.49	2.57	1367	100	96	81	56	24	41	6
37-6-93-94	9.15	0.52	2.42	2440	171	110	102	65	35	49	1
38-7-44-45	8.41	0.62	4.28	11919	268	136	190	115	39	67	2
39-5-117-118	7.49	0.47	2.73	3415	90	98	69	53	38	46	3
40-5-80-81	1.55	0.49	4.27	16279	209	163	369	155	46	59	5

434B seem due to the discontinuity from diatomaceous ooze or diatomaceous mudstone to vitric diatomaceous mudstone or tuffite.

#### Site 435 (Holes 435 and 435A) (Figure 2)

The sediments cored at Site 435 represent hemipelagic deposits draped on the upper slope of the landward wall of the Japan Trench. The sediments are clay with a small percentage of silt and sand. Period of deposit is as follows: Pleistocene, 0 to 84 meters; upper Pliocene, 84 to 110 meters; and lower Pliocene, 110 to 245 meters.

Of the major elements, Al and Ti are plentiful in the upper sections and gradually decrease with depth to about 200 meters. Below 200 meters they tend to increase. Fe and Mn content shows similar distribution patterns. The highest values of both elements — Fe, 7.2 per cent; Mn, 0.13 per cent — occur in Sample 435-8, CC (68 m), in which Cu, Zn, and Cr are also most abundant. Ni, Co, and Li are uniformly distributed throughout the different time. On the other hand, Sr is remarkably variable, ranging from 14 ppm to 183 ppm and averaging 65 ppm. Elevated Sr content occurs in Samples 435-12-1 and 435-13, CC (100–110 m), corresponding to the late Pliocene. Generally, Al, Ti, and Fe concentrations in Site 435 samples are either somewhat less than

or similar to those in Site 434 sediment, whereas Mn and Cu are remarkably depleted at Site 435. Other trace elements in Site 435 sediments display the same magnitude of concentration as those from Site 434, except for Sr, which is twice as plentiful.

#### Site 436 (Figure 3)

Site 436 is located at the crest of the outer swell of the Japan Trench in a water depth of 5205 meters. The sediments recovered are very similar to those sampled at DSDP Sites 194 and 195, south of Site 436. Most of the sections consist of Neogene sediments that are mainly vitric diatomaceous mud and, below 250 meters, mudstone. Their ages range from Quaternary at the top to Miocene at about 360 meters. Ash layers 1 to 10 cm thick are common throughout the Quaternary and Pliocene sections and especially abundant in the Pliocene.

At this site, Al and Ti content shows irregular periodic variation irrespective of geological age. Overall, Al and Ti content is high (Al, 0.71%; Ti, 0.45%) relative to Sites 434 and 435. Although Fe and Cu are also irregularly distributed, their values tend to increase toward the bottom sections, which are pelagic clay. Mn, Ni, and Co are fairly constant down to 270 meters (Pleistocene to late Miocene). Their high values occur in yellowish-

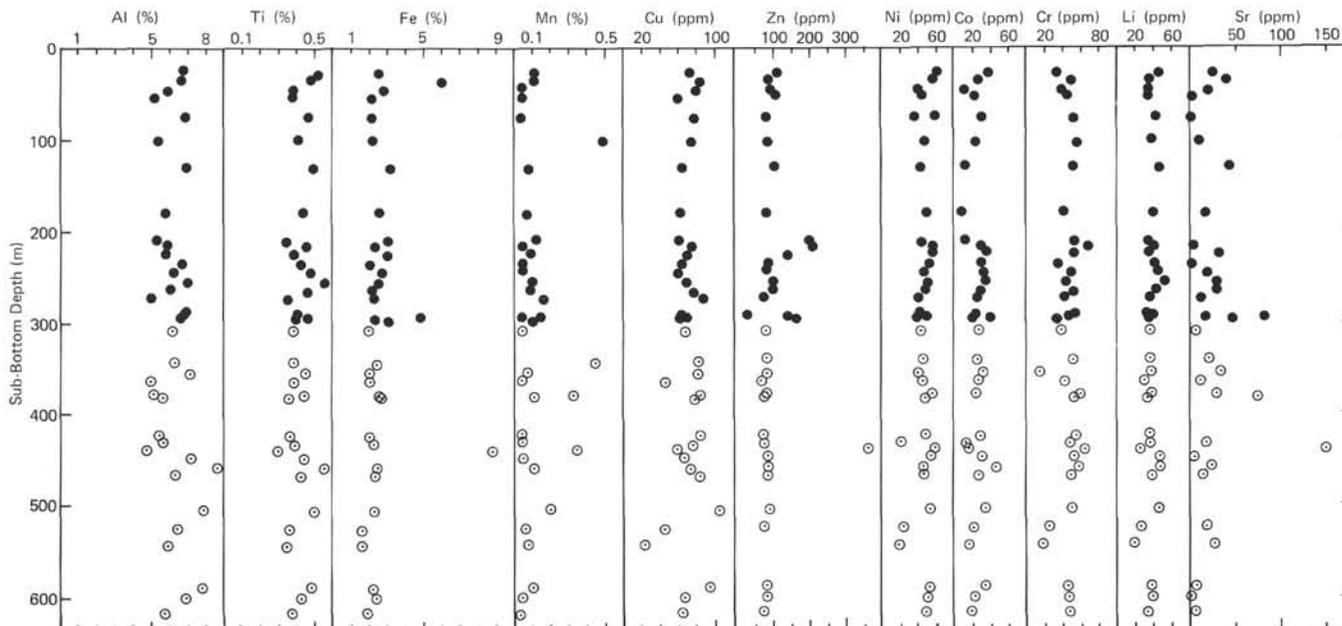


Figure 1. Sediment composition of Site 434, uncorrected for carbonate and salt, versus depth from sediment surface. (Solid circle represents Hole 434 sediments; circle with center dot represents Hole 434B sediments.)

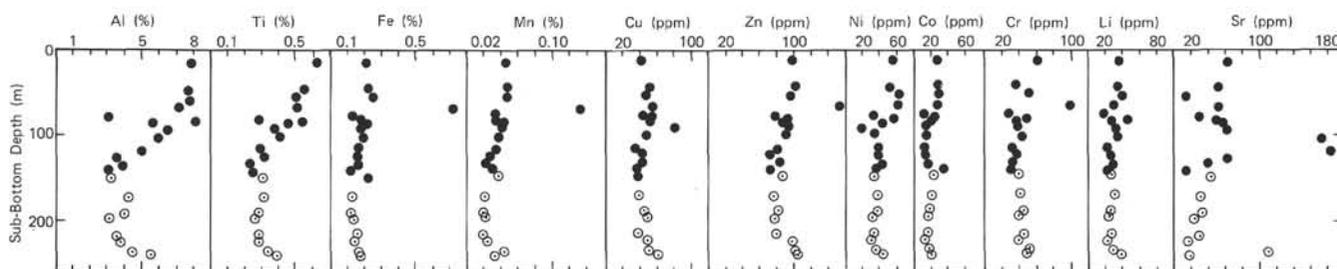


Figure 2. Sediment composition of Site 435, uncorrected for carbonate and salt, versus depth from sediment surface. (Solid circle represents Hole 435 sediments; circle with center dot represents Hole 435A sediments.)

brown Cretaceous–middle Miocene sediment, which is composed of very fine clay with abundant amorphous iron–manganese hydroxides. This sediment was apparently deposited in a pelagic environment of low biological productivity well below carbonate compensation depth. Cr and Li are generally uniform through all the sections, although small variations occur. Sr is abundant between 100 and 180 meters; below 200 meters it is very scarce.

#### Sedimentation Rates

The data in Table 2 have been calculated using the compositional data in Table 1, shipboard bulk density measurements, and paleontological age. However, there are problems with these calculated sedimentation rates. Uncertainties in dating and in physical properties may produce errors on the order of 10 to 30 per cent. More serious are the errors that may have been physiographically induced: for example, such topographical phenomena as slumping, folding, turbidity, or gentle winnowing of matter may distort sedimentation rates.

Sedimentation rates at Site 434 range from 26 mm/1000 yr to 49 mm/1000 yr through the Pleistocene–late

Pliocene. These high rates indicate a hemipelagic to shallow rather than pelagic depositional environment. Sedimentation rates at Site 435 are significantly higher in later deposits than in earlier ones and indicate that the sediments from this site originated in the continental margin area. Sedimentation rates at Site 436 show that the sedimentary environment gradually changed from pelagic to hemipelagic, implying that the ocean crust at Site 436 has been moving landward across the Pacific mid-latitudes from the Early Cretaceous to the present, as suggested by Lancelot and Larson (1975).

#### Metal Accumulation Rates

The data in Table 3 were calculated using the data in Table 1 and sedimentation rates in Table 2.

Most studies of marine sediments have concluded that Al, Ti, and nonbiogenous Si concentrations are controlled primarily by accumulation of detrital phases, whereas Fe and Mn principally reflect the abundance of authigenic constituents. This concept is undoubtedly true for many regions in the ocean.

The accumulation rates for metal constituents tend to be higher in near-surface than in near-basement sedi-

ments. Accumulation rates of Fe, Mn, Cu, and Ni, which represent authigenic fractions, are high in Pleistocene sediments, especially at Site 435. Similarly, Al and Ti accumulation rates reach a maximum in the Pleistocene. This fact may be due to breakdown of Fe–Mn oxides and upward migration of Mn and its associated metals. The description of the younger sediments from Sites 434 and 435 includes the fact that very strong H<sub>2</sub>S odor accompanied all cores down to 250 meters at Site 434 and that pyritized diatomaceous sediments extended from the Pleistocene to the early Pliocene at Site 435, indicating reducing conditions. Although under strong to mildly reducing conditions, the behavior of Fe, Mn, and Cu as well as of Zn and Ni is variable, the general trend for all these elements is toward upward mobility (Duchart et al., 1973). An alternative hypothesis is that the high accumulation rates of these elements in the younger sediments might be the result of island arc volcanic activity during the late Neogene to Recent on the nearby Japanese islands.

At Site 436, Al, Ti, Co, Cr, Li, and Sr accumulation rates are higher in the early Pliocene–Pleistocene than in the Middle–late Miocene. Much greater amounts of Cu, Zn, and Ni are accumulated in the upper sediments than in the lower. On the other hand, Mn accumulation rate is higher in the near-bottom. This finding is consistent with the fact that between the late Miocene and the early Pliocene the lithology of sediments gradually changed from pelagic clay with abundant manganese oxides to vitric diatomaceous mud. It is possible that the high Fe accumulation rate in the upper core sections is ascribable to volcanic materials which, as indicated by vitric ash layers and disseminated glass, were first deposited during the early Pliocene.

### CONCLUSIONS

Bulk chemical analyses of sediments collected from the Japan Trench show that the metal content is generally not as high as for present-day active ridge and normal pelagic sediments, with the exception of the high Fe and Mn content at Site 434. Near-basement sediments at Site 436, however, do contain the elevated amounts of Fe, Mn, Cu, Co, and Ni as same as normal Pacific pelagic sediments. Vertical abundance of elements is variable but small throughout time, indicating that the nature of detrital input and authigenic element deposition has been relatively constant since the middle–early Miocene. Chemical characteristics of the inner trench sediments (Sites 434 and 435) indicate that they are of island arc origin. It seems possible, therefore, that the materials constituting the accretionary wedge also originate in island arc rather than oceanic sediments. Bulk geochemistry of sediments from Sites 434 and 435 suggests that postdepositional migration of Mn, Ni, Cu, and Zn may have occurred.

Sedimentation rates are as follows: 2.5–5 cm/1000 yr from the early Miocene to the late Pliocene at Site 434; 0.7–26 cm/1000 yr from the early Pliocene to the late Pleistocene at Site 435; 1.2–5 cm/1000 yr at Site 436. These values are markedly greater than those of typical

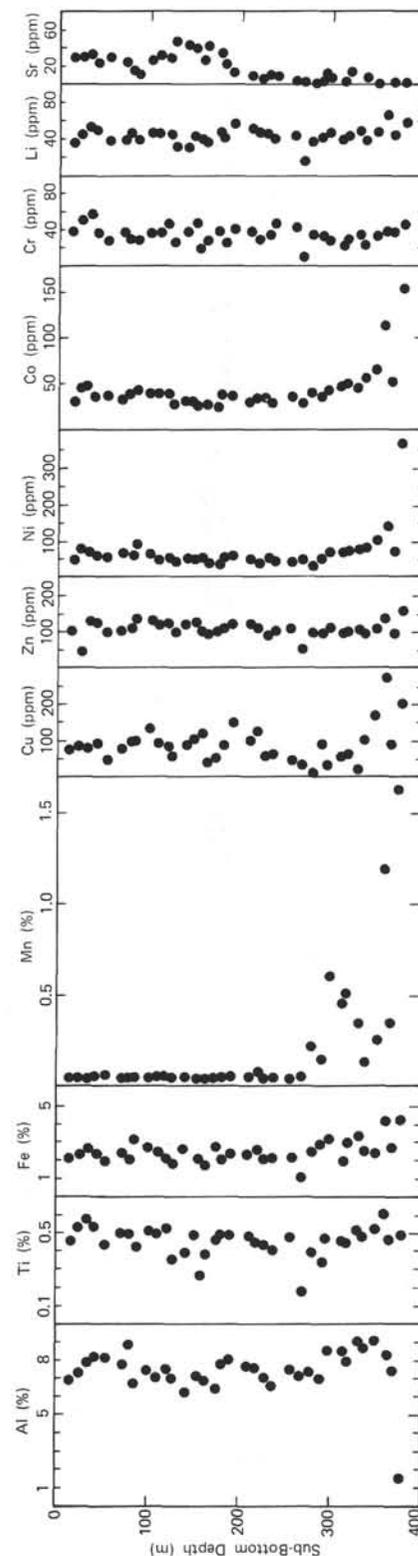


Figure 3. Sediment compositions of Site 436, uncorrected for carbonate and salt, versus depth from sediment surface.

TABLE 2  
Sample Distribution, Physical Properties, Geochronology, and Accumulation Rates  
for Sediments from Deep Sea Drilling Project Leg 56

Hole	Core/Section	Density (g/cc)	Sub-Bottom Depth (m)	Thickness (m)	Age (m.y.)	Sedimentation Rate (mm/1000 yr)	Accumulation Rate (mg/cm <sup>2</sup> /1000 yr)
434	4,CC to 5-1	1.40	6.5-45	38.5	3.3-1.8	25.7	3598
434	7-1 to 12-1	1.44	54-110	56.0	5.0-3.3	32.9	4738
434	15-1	1.59	120.5-130	9.5	5.0-3.3	5.6	894
434	20,CC to 29,CC	1.50	187-263	76.0	5.0-3.3	44.7	6700
434B	32-1 to 19-2	1.66	272.5-465	192.5	5.0-3.3	113.0	18,758
434	20,CC to 34,CC	1.82	465-609	144.0	10.6-5.0	25.7	4550
435	2,CC	1.43	0-36.5	36.5	0.15-0.01	261.0	37,323
435	5,CC to 8,CC	1.50	36.5-74.5	38.0	0.5-0.15	109.0	16,350
435	9,CC	1.45	74.5-84	9.5	1.8-0.5	7.3	1059
435	10-1 to 12,CC	1.34	84-112.5	28.5	3.3-1.8	19.0	2546
435A	14,CC to 11,CC	1.35	122-244.5	122.5	5.0-3.3	72.1	9734
436	2-3 to 9-5	1.41	0-84	84.0	1.8-0.01	46.9	6613
436	11-7 to 14-4	1.38	93-131.5	38.5	3.3-1.8	25.7	3547
436	18-2 to 26,CC	1.34	160-245	85.0	5.0-3.3	50.0	6700
436	28-1 to 33-6	1.45	245-312	67.0	10.6-5.0	12.0	1740
436	34-4 to 38-7	1.55	312-360	48.0	15.0-10.6	10.9	1690

TABLE 3  
Accumulation Rates for Constituents in Sediments from Deep Sea Drilling Project Leg 56

Age	Al (in mg/cm <sup>2</sup> /1000 yr)	Ti	Fe	Mn	Cu	Zn (in mg/cm <sup>2</sup> /1000,000 yr)	Ni	Co	Cr	Li	Sr
Site 434											
Late Pliocene	246	19	154	4127	283	345	209	110	147	151	118
Early Pliocene	217	16	88	4261	237	401	445	95	176	140	75
Late Miocene	31	19	95	372	318	379	206	122	187	187	9
Site 435											
Late Pleistocene	2556	164	761	28179	2426	3098	1680	970	1605	1306	373
Middle Pleistocene	1220	83	641	12246	818	1913	932	457	997	572	638
Early Pleistocene	31	3	137	364	46	84	35	14	31	22	30
Late Pliocene	157	10	46	922	132	224	99	43	102	89	270
Early Pliocene	370	28	145	2540	428	827	496	184	419	292	389
Site 436											
Pleistocene	518	33	147	3062	516	675	403	251	258	278	179
Late Pliocene	258	17	80	1596	326	408	184	128	131	145	121
Early Pliocene	483	30	150	2747	563	710	315	214	235	308	127
Late Miocene	134	7	41	4298	475	158	89	68	50	66	10
Middle Miocene	147	9	53	7463	206	184	174	112	54	83	8

sedimentation rates for deep sea pelagic sediments, indicating the truly hemipelagic nature of these sediments.

Metal accumulation rates from the early Pliocene to the late Pleistocene are equally high. Of authigenic fractions, Fe and Mn have considerably high accumulation rates in the near-surface sediments, where detritus constituents such as Al and Ti are also high. This finding indicates that Fe and Mn content is significantly influenced by island arc volcanic activity during the late Neogene to Recent on the nearby Japanese islands.

#### ACKNOWLEDGMENTS

I would like to thank Drs. Hakuyu Okada and Takashi Fujii for reviewing the manuscript and Miss C. Orihara for sample preparation and for typing this chapter.

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