30. GEOCHEMISTRY OF COCOS PLATE PELAGIC–HEMIPELAGIC SEDIMENTS IN HOLE 487, DEEP SEA DRILLING PROJECT LEG 66[1]

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INTRODUCTION

The sedimentary sequence recovered from Hole 487 documents northeast seafloor spreading on the Cocos Plate. A basal 65-meter unit of upper Miocene–Pliocene brown clay was deposited on the subsiding east flank of the East Pacific Rise. The overlying 105-meter unit of gray hemipelagic silt and mud was deposited when Site 487 drifted within reach of terrigenous sediment derived from the Mexican continental margin.

Analyses of 21 elements in 45 samples, taken at regular intervals up Hole 487, give a geochemical profile which shows metal enrichment in basal sediment similar to that observed in previously recovered basal sediment sections in the Eastern Pacific (e.g., von der Borch & Rex, 1970; von der Borch et al., 1971). This verifies that the basalt cored at the base the hole is oceanic basement, since the first sediment to be deposited on newly formed ocean crust is characteristically enriched in metals, particularly Fe and Mn. The metals precipitate from circulating hydrothermal-exhalative solutions which are an integral part of active ridge volcanism (summary in Jenkyns, 1978). In this chapter I discuss the geochemistry of the basal metalliferous sediment from Hole 487.

The geochemical data may also prove useful in studies of onshore volcanism: mass-balance calculations show that much (possibly all) of the incoming Cocos Plate sediment has been subducted since the Miocene (Watkins et al., this volume). It may have contributed to the genesis of magmas erupted in the Mexican volcanic arc.

ANALYTICAL PROCEDURES

Dried sediment samples were digested in hydrofluoric–perchloric acid and analyzed on an inductively coupled plasma spectrometer (A.R.L. 34000) capable of simultaneous interelement interference corrections.

LITHOLOGY

The Quaternary mud is a homogeneous grayish olive deposit with local indistinct millimeter-scale, darker parallel laminations and common ash beds. The mud itself is vitric in the 96 to 97.5 meter interval. Local mottling suggests bioturbation. The presence of reworked calcareous microfossils from 0 to 77 meters, a small shell fragment at 58 meters, and a wood fragment at 86.5 meters, together with the local lamination, suggest that much of the mud may be redeposited, probably as suspension load from large trench-overtopping turbidity flows.

The underlying brown clay is predominantly moderate to dusky yellowish brown, in places dusky red to dark reddish brown, and commonly variegated with orange areas. Zeolite micronodules and millimeter-scale better-lithified nodular developments are common. At 134 meters a 70-cm pale olive clay interbed has a sharp contact with underlying brown clay. At 160 meters color change from grayish brown above to dusky brown below is caused by a concentration in the latter of amorphous grains of isotropic material, probably Fe oxide, up to several tens of microns in diameter.

Rare reworked calcareous microfossils occur at the very base of the brown clay, but carbonate determinations were below the detection limit throughout the hole (i.e., $<0.05\%$ $CaCO_3$) and all the sediment must have accumulated below the calcite compensation depth. Hence it is not necessary to correct analyses for carbonate content.

In the basal 3 meters small angular fragments of basalt are mixed in the brown clay.

RESULTS

Fe and Mn are both significantly enriched in the basal 15 meters or so, reaching maxima of 20.4% and 9.8%, respectively (Table 1). An anomalously high concentration (19%) of Mn occurs at 144 meters and may reflect incorporation of a manganese micronodule in the sample. A similarly anomalous high Fe total (27%) occurs in the top meter of gray clay; together with a very high Mo analysis (1006 ppm), this probably reflects a 1% component of heavy minerals observed in smear slides taken at this level.

The high Fe and Mn values in basal sediment are complemented by Al and Ti values which are lower than those in the younger brown clay (Fig. 1). Relative impoverishment of Al and Ti is a widely recorded characteristic of metalliferous sediments (e.g., references in Table 2).

The high Fe and Mn content of metalliferous sediments also characteristically follows with high concentrations of certain trace elements, principally metals (summary in Boström, 1973). At Site 487 brown clay, Cu, P, and Sr show relative enrichment in the basal 15

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Table 1. Geochemistry of Cocos Plate hemipelagic–pelagic sediments in Hole 487, DSDP Leg 66. (Analyses of Al to P in %, Ba to V in ppm.)

Sample No.	Sample (interval in cm)	Al	Ca	Fe	Mn	Mg	Na	K	Ti	P	Ba	Co	Cr	Cu	La	Li	Ni	Mo	Pb	Sr	Zn	V	Depth Sub-bottom (m)
1	1-1, 139-143	6.32	0.72	27.32	0.41	0.99	1.08	1.34	0.26	0.06	536	26	216	83	14	52	69	1006	191	165	306	171	1.4
2	2-2, 32-36	8.20	1.22	4.96	0.16	1.68	1.96	1.17	0.47	0.08	1757	22		86	23	69	67	27	126	198	157	204	2.8
3	2-5, 100-104	10.29	1.10	5.17	0.13	1.38	1.92	1.58	0.46	0.08	665	21	117	71	28	87	52	15	97	155	157	181	6.0
4	3-3, 52-56	5.40	0.54	5.66	0.19	1.14	1.35	0.68	0.25	0.07	2163	19	105	81	28	47	62	21	128	146	155	125	14.0
5	5-2, 94-98	8.89	1.32	5.12	1.39	1.66	1.88	1.18	0.46	0.10	831	23	89	114	22	74	84	31	101	186	188	229	31.9
6	6-3, 60-65	8.36	0.89	5.08	0.29	1.57	1.63	1.15	0.43	0.08	962	23	68	106	24	74	83	23	94	164	238	212	42.6
7	7-2, 66-71	8.83	0.94	5.25	0.50	1.58	1.65	1.32	0.43	0.07	994	23	74	119	24	75	92	25	88	167	199	211	50.7
8	8-1, 69-73	8.40	1.07	5.46	0.66	1.73	2.22	1.26	0.43	0.09	1983	24		166	22	74	124	24	102	184	251	208	58.7
9	9-2, 100-105	9.00	1.01	5.96	0.47	1.73	1.50	1.33	0.47	0.09	1382	26	87	175	26	77	146	28	112	192	314	236	70.0
10	9-5, 38-43	8.93	1.44	5.64	0.22	1.71	2.30	1.34	0.30	0.11	1379	23	123	151	23	82	125	27	92	195	207	218	73.8
11	10-4, 64-68	9.12	0.91	6.03	0.16	1.73	1.57	1.30	0.47	0.08	1292	27	78	172	26	80	133	28	101	198	217	246	81.6
12	11-1, 98-102	8.49	0.84	5.66	0.08	1.61	2.00	1.32	0.40	0.06	1321	27	76	190	27	78	169	21	101	174	274	228	87.5
13	11-4, 72-75	8.38	0.89	6.13	0.06	1.62	1.70	1.31	0.38	0.08	926	23	100	205	36	83	204	13	62	209	230	254	91.7
14	12-1, 22-25	8.22	1.01	6.95	0.10	1.67	2.11	1.37	0.39	0.09	2569	25	83	255	40	74	168	38	166	221	246	209	96.2
15	12-1, 99-104	8.22	0.94	5.95	0.11	1.53	2.17	1.46	0.38	0.08	1757	34	77	518	39	72	266	19	85	196	276	258	97.0
16	12-3, 59-63	6.67	1.23	7.94	0.86	1.98	2.53	1.08	0.32	0.08	2184	58	57	645	34	62	397	27	100	204	364	308	99.6
17	13-1, 7-12	8.56	0.87	6.85	0.15	1.80	2.09	1.20	0.39	0.13	3399	39	132	185	50	70	122	15	74	229	188	198	105.6
18	13-3, 6-9	8.07	1.31	7.11	0.10	1.84	2.39	1.18	0.39	0.18	4706	40	132	251	56	57	128	16	97	281	203	199	108.6
19	14-2, 20-25	5.61	1.27	13.23	3.66	1.60	1.86	0.94	0.30	0.37	5604	92	94	585	107	35	371	25	129	289	262	501	116.7
20	14-3, 24-28	4.99	1.14	12.04	7.40	1.57	1.65	0.72	0.27	0.34	4955	50		509	82	32	259	21	138	267	241	467	118.2
21	15-1, 79-83	4.88	0.72	11.45	2.28	1.71	2.69	0.78	0.23	0.18	2662	51	109	453	57	29	244	26	90	311	217	259	125.3
22	15-2, 26-30	5.03	0.68	11.18	1.70	1.59	1.67	0.97	0.21	0.17	2357	42	75	407	60	29	201	16	76	285	226	226	126.6
23	15-6, 99-103	4.89	1.03	12.92	2.53	2.00	2.23	0.73	0.26	0.24	3945	55	96	561	61	29	270	32	110	307	309	252	133.0
24	16-1, 35-39	4.04	0.68	13.74	0.42	2.20	1.75	0.77	0.22	0.14	2837	34	58	333	70	31	266	24	76	255	325	406	134.3
25	16-1, 98-102	4.47	1.21	12.92	1.90	1.88	1.98	0.78	0.22	0.36	2528	49	98	492	91	26	242	23	101	335	238	208	135
26	16-4, 117-122	4.46	0.76	10.91	2.07	1.58	3.25	0.86	0.20	0.18	2496	49	92	398	58	24	228	22	86	306	213	243	139.7
27	17-1, 84-89	3.25	1.45	8.26	18.99	1.64	1.05	0.48	0.15	0.26	1640	38	106	598	45	21	188	31	135	210	299	199	144.3
28	17-1, 98-102	4.77	0.82	13.22	2.82	1.72	1.84	0.74	0.24	0.23	1732	73	83	547	106	28	235	21	142	358	224	303	144.5
29	17-2, 69-79	4.74	0.86	13.59	3.01	1.55	2.02	0.70	0.24	0.31	4324	57	70	478	75	24	209	25	82	384	218	374	145.7
30	18-1, 99-103	4.94	0.83	10.96	3.26	1.93	2.50	0.62	0.25	0.18	3357	52		324	65	33	127	48	83	333	238	217	154.0
31	18-1, 146-150	7.06	1.03	5.41	1.23	2.38	1.84	0.50	0.26	0.09	1876	18		388	25	66	93	21	50	197	258	95	154.5
32	18-3, 99-103	4.77	0.70	11.32	3.94	2.10	2.25	0.60	0.20	0.19	3030	28		594	50	51	153	50	84	279	302	304	157.0
33	18-4, 99-103	2.88	0.90	20.36	8.33	1.72	1.29	0.65	0.16	0.48	3579	64		733	106	17	371	77	142	461	394	525	158.0
34	18-5, 89-93	2.16	1.08	17.81	9.81	2.19	1.32	0.77	0.12	0.45	3391	55		698	83	18	449	75	131	437	392	350	158.9
35	18-6, 98-102	2.14	1.06	16.81	8.42	2.07	1.92	0.76	0.12	0.47	4027	47	57	625	81	17	348	65	88	418	356	347	160.0
36	19-1, 61-66	2.28	1.55	18.44	7.34	1.79	1.82	0.66	0.13	0.57	3213	55	77	752	88	16	325	38	115	623	362	516	163.1
37	19-2, 29-31	2.71	1.92	17.01	5.10	1.94	2.20	0.96	0.13	0.77	1815	50		620	94	20	339	36	103	579	329	379	164.3
38	19-3, 3-5	2.09	1.42	18.73	6.33	1.88	1.46	0.70	0.12	0.46	5215	56		654	84	17	302	53	127	656	373	479	165.5
39	19-4, 93-95	2.89	1.27	15.68	6.26	2.37	1.59	1.02	0.15	0.37	2147	53	59	499	73	24	304	66	115	399	370	221	167.9
40	19-5, 49-53	3.03	2.35	14.51	5.52	2.13	2.64	0.79	0.16	0.37	2776	45		528	70	20	271	73	100	415	307	295	169.0
41	19-5, 78-80	4.90	5.20	14.64	4.49	2.80	1.33	0.44	0.29	0.30	732	55	173	439	55	15	241	83	95	337	246	382	169.2
42	19-5, 149-150	5.82	6.07	11.24	3.13	3.17	1.72	0.32	0.34	0.21	1709	53	151	328	39	14	214	57	103	256	188	335	170.0
43	20-1, 103-105	4.87	3.58	14.04	4.07	2.45	1.64	0.66	0.27	0.32	3513	58	76	465	68	19	259	60	159	355	261	365	173.0
44	20-2, 4-6	5.46	4.18	12.90	3.52	2.66	1.73	0.51	0.31	0.27	2811	60	159	423	57	17	231	55	84	292	227	348	173.5
45	20-2, 16-18	6.89	6.81	11.04	2.33	3.25	1.80	0.35	0.40	0.18	3687	55	166	277	35	13	189	70	115	218	178	355	173.7

meters (Table 1, Fig. 1). Ba, Co, Cr, Ni, Pb, Zu, and V show no significant variation down the brown clay sequence.

In the basal 5 meters the metalliferous brown clay has lower Fe and Mn than the 10 meters or so of metalliferous sediment above it; Al and Ti values are concomitantly higher (Fig. 1). This probably reflects contamination of the samples by fragments of basalt previously mentioned.

The geochemical differences between the brown clay and overlying greenish gray hemipelagic mud are reflected principally by uniformly higher values for Fe, Mn, P, Cu, Sr, Co, and La in the former and for Al, Ti, and Li in the latter. The yellowish gray clay interval at about 110 meters does not have a significantly different geochemistry from the hemipelagic mud.

Within the brown clay sequence high metal concentrations are probably located in the amorphous isotropic oxide grains seen under the microscope. A high concentration of these gives rise to the dusky brown color noted in the basal 12 meters. Other color change features of interest in the brown clay sequence are the 70-cm interbedded olive clay at about 134 meters and a decimeter-scale interbed of orange-pink clay with millimeter-scale indurated areas at 154.5 meters. The former shows a markedly lower Mn content than is normal in the brown clay, though without change in the Fe level (Sample 24, Table 1). The latter shows lower Fe and Mn and higher Al than normal brown clay (Sample 31, Table 1).

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REFERENCES

Boström, K., 1973. The origin of ferromanganoan active ridge sediments. *Stockholm Contrib. Geol.*, 26:149–243.

Boström, K., and Peterson, M. N. A., 1969. The origin of aluminium-poor ferromanganoan sediments in areas of high heat flow on the East Pacific Rise. *Econ Geol.*, 61:1258–1265.

Dymond, J., Corliss, J. B., Heath, C. W., et al., 1973. Origin of metalliferous sediments from the Pacific Ocean. *Geol. Soc. Am. Bull.*, 84:3355–3372.

Jenkyns, H. C., 1978. Pelagic environments. *In* Reading, H. G. (Ed.), *Sedimentary Environments and Facies:* Oxford (Blackwell Scientific Publications), pp. 314–371.

Turekian, K. K., and Wedepohl, K. H., 1961. Distribution of the elements in some major units of the Earth's crust. *Geol. Soc. Am. Bull.*, 72:175–192.

von der Borch, C. C., Nesteroff, W. D., and Galehouse, J., 1971. Iron-rich sediments cored during Leg VIII of the Deep Sea Drilling Project. *In* Tracey, J. I., Jr., Sutton, G. H., et al., *Init. Repts. DSDP*, 8: Washington (U.S. Govt. Printing Office), 829–836.

von der Borch, C., and Rex, R., 1970. Amorphous iron oxide precipitates in sediments cored during Leg V, DSDP. *In* McManus, D. A., Burns, R. E., et al., *Init. Repts. DSDP*, 5: Washington (U.S. Govt. Printing Office), 541–544.

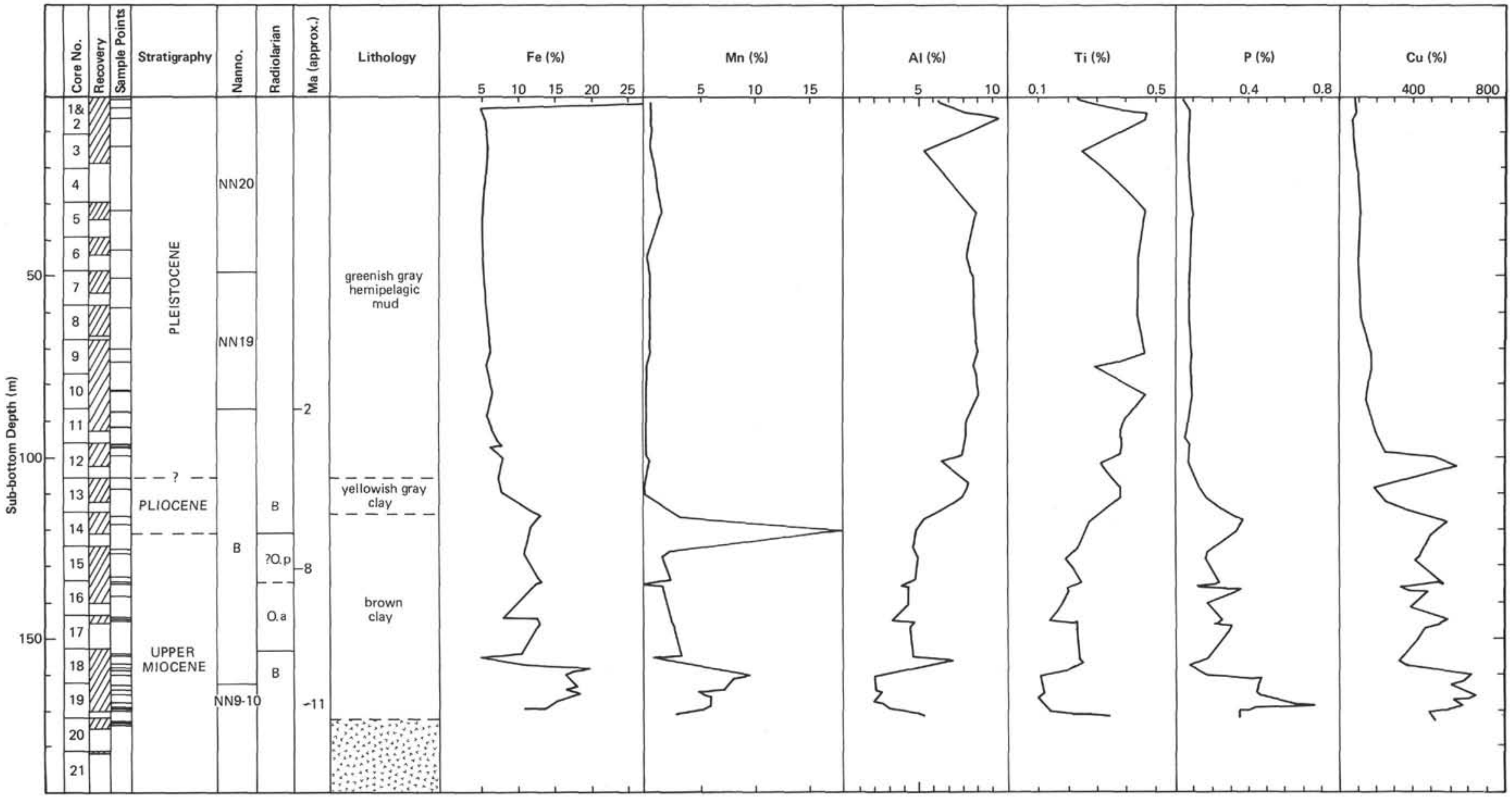

Figure 1. Geochemical profiles for Fe, Mn, Al, Ti, Cu, and P in Hole 487, DSDP Leg 66, Cocos Plate.

Table 2. Geochemistry of basal Cocos Plate sediments, Hole 487: Comparison with other basal Pacific sediments and normal deep sea clay.

	Fe	Mn	Al	Ti	Cu	Zn	Ba	Pb	Sr
Cores 18, 19 (13 samples)	14.8 (5.4–20.4)	5.6 (1.2–9.8)	3.7 (2.1–7.0)	0.19 (0.09–0.77)	552 (324–752)	317 (188–394)	2836 (732–4027)	103 (50–142)	415 (197–656)
Metalliferous sediments from the East Pacific Rise[a]	18.0 (5.7–22.6)	3.9 (0.6–8.8)	3.5 (0.6–8.5)	0.2 (0.01–0.4)	870 (400–1800)	315 (190–530)	n.a.	n.a.	n.a.
East Pacific Rise and basal Pacific metalliferous sediments[b]	21.2 (12.7–28.5)	5.9 (4.53–7.66)	1.9 (0.58–3.41)	n.a.	958 (600–1490)	n.a.	5128 (1500–15000)	n.a.	n.a.
Average deep sea clay[c]	6.5	0.7	8.4	0.46	250	160	100	68	180

Note: Range of averaged values in parentheses. Fe to Ti as %, Cu to Sr as ppm. n.a. = not analyzed.
[a] From Boström & Peterson, 1969 (21 samples, recalculated on a carbonate-free basis).
[b] From Dymond et al., 1973 (11 samples).
[c] From Turekian & Wedepohl, 1961.