26. CHEMICAL AND MINERALOGICAL STUDIES, SITE 323

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INTRODUCTION

The purpose of this study was to provide data on the mineralogy and chemistry of the solid phases from Site 323 and to provide a basis for interpretation of the interstitial water chemistry and isotopic data reported elsewhere in this volume.

EXPERIMENTAL METHODS

The samples were dispersed in distilled water, washed to remove excess salts, and the clay fraction was separated by centrifugation. Initially the separation was made at 2 μ m esd (equivalent spherical diameter); however, at a meeting of geochemists working on Leg 35 materal, it was agreed that the separation should be made at 1 μ m. Comparison of the <2 μ m with the <1 μ m fraction of the same sample (Table 1) suggests that the two are very similar in chemistry and mineralogy.

The clay fraction of each sample was examined by Xray diffraction using the sample preparation technique of Drever (1973), and analyzed chemically by atomic absorption spectrophotometry after dissolution in HF using the technique of Buckley and Cranston (1971). The >2 (or 1) μ m fraction was examined by X-ray diffraction and scanning electron microscopy, and, for certain samples the zeolites were separated from other minerals by heavy liquid separation using dibromomethane.

RESULTS AND DISCUSSION

The chemical analyses are presented in Tables 1-5, and Figures 1 and 2. The routine X-ray diffraction results are not presented here, as they essentially duplicate the data presented in Zemmels and Cook (this volume).

Above 639 meters most components of the sediment are typical of land-derived material. The clays are a mixture of illite, smectite, chlorite, and kaolinite in varying proportions, and the dominant minerals in the silt fraction are quartz, feldspars (both K-feldspar and plagioclase), mica (at least some of which is biotite), chlorite, and biogenic silica. The silts above 639 meters also contain small amounts of clinoptilolite, which is presumably authigenic, and laumontite, whose origin is discussed below. The major and minor element chemistry of the clay fraction above 639 meters is quite uniform (Figures 1 and 2), which is consistent with the idea that the material is relatively unmodified terrigenous debris. The CaO content of the coarse fraction above 639 meters does decrease with depth (Table 3), which would be consistent with progressive alteration of plagioclase (see Kastner, this volume).

At approximately 639 meters (in Core 14, Section 2) there is an abrupt change in mineralogy and chemistry. The dominant mineral in the clay fraction below this

depth is a smectite showing no evidence of mixed layering, with minor illite, clinoptilolite, and quartz. The major element chemistry of the clay fraction shows large variations which do not appear to correlate with variations in mineralogy observed by X-ray diffraction. The transition metals and strontium are highly enriched between 639 and 670 meters (Table 2 and Figure 2). Presumably this represents the ferromanganese material described originally by Boström and Peterson (1966) from the East Pacific Rise, and subsequently encountered immediately above basement in many DSDP cores. There are two notable aspects of the transition metal distribution at Site 323. First, the enriched zone is 30-74 meters above the basement, and the basal 30 meters of sediment is generally not enriched in transition metals. If the ferromanganese-rich sediments are much younger than the lowermost basal sediments, as suggested by the shipboard paleontologic studies, it may be difficult to relate the source of the metals directly to spreading-center activity. Second, although all the transition metals analyzed are enriched in the same 31meters interval, the correlations between individual pairs of elements within this interval are not at all close. This suggests either that the source of the metals was variable, or that some postdepositional migration has taken place.

Barium in the clay fraction shows a distribution unlike that of any other element analyzed. It is relatively uniform throughout the core with the exception of a sharp maximum immediately above the basement.

From 639 to 669 meters the principal minerals of the silt fraction are quartz, feldspar (both K-feldspar and plagioclase), mica, and smectite, with calcite occurring between 663 and 669 meters. Below 669 meters the assemblage is quartz, K-feldspar, smectite, clinop-tilolite, and plagioclase. Laumontite was found in one sample only, 18-4, 10-11 cm. Under the scanning electron microscope the K-feldspar appears as large (10-30 μ m) angular grains whose morphology suggests that they are authigenic. The clinoptilolite appears as irregularly shaped laths which are typically 5 μ m or less in length. The chemical analysis of an essentially pure clinoptilolite fraction from heavy liquid separations is given in Table 5.

The change in mineralogy and chemistry at 639 meters suggests a change from a dominantly volcanic source for the basal sediments to a dominantly terrigenous source for the sediments in the upper part of the core.

The $<0.2 \ \mu m$ fraction was separated from selected samples by centrifugation and analyzed chemically (Table 4) and mineralogically. It is in this fraction that mixed-layer illite-smectites are most easily studied, and diagenetic changes in illite-smectites are most apparent.

Samplea Depth SiO₂ Fe2O3b MnO^c (Interval in cm) CaO MgO Na₂O K20 (m) Al203 1-5, 0-15 (2) 57.3 13.7 9.3 0.77 3.34 1.21 3.00 0.10 81.5 1-5, 0-15 (1) 81.5 9.5 0.77 3.46 1.20 3.13 0.10 55.5 13.7 2-2, 0-15 (1) 162.5 55.2 15.8 8.9 3.56 1.44 3.17 0.07 1.13 0.95 3, CC (1) 265.5 59.0 15.0 10.8 1.26 4.08 2.030.13 4, CC (1) 3.19 322.5 54.6 15.7 7.6 1.07 3.38 1.12 0.08 7-3, 31-46 (1) 9.7 367.5 59.0 14.6 3.59 1.67 3.28 0.10 1.10 8, CC (1) 417.5 54.6 14.9 9.6 0.97 3.73 1.40 3.16 0.08 9-2, 0-10 (1) 457 9.4 3.04 55.2 15.3 1.06 3.86 1.29 0.119, CC (1) 465 59.3 14.9 7.0 0.91 2.94 1.03 3.35 0.19 10-3, 0-12 (1) 3.29 506 57.2 14.4 9.1 0.99 1.34 3.30 0.14 11-1, 0-10 (1) 550.5 60.5 17.4 7.3 0.93 3.06 1.02 3.64 0.13 11-1, 86-87 (2) 7.1 0.95 2.93 551.5 17.0 55.8 1.23 3.60 0.14 11-2, 75-76 (2) 553 56.1 15.9 7.4 0.94 3.02 1.07 3.40 0.15 12-1, 135-150 (1) 599.5 54.8 18.4 7.3 0.75 3.25 1.07 4.66 0.08 13-5, 125-126 (2) 3.25 3.70 0.26 624 49.5 18.2 10.1 0.92 1.42 13-5, 135-150 (1) 624.5 56.9 20.0 8.6 0.94 3.80 0.92 4.00 0.15 13, CC (2) 626.5 52.4 18.7 8.6 0.99 3.15 1.40 4.30 0.26 14-1, 140-150 (1) 1.00 1.00 3.75 0.26 637.5 56.2 18.4 12.0 3.47 14-2, 10-11 (2) 637.5 50.0 17.7 10.1 0.88 2.94 1.62 3.40 0.22 n.d.d 14-2, 10-11 (1) 637.5 0.83 3.03 3.31 0.22 50.0 18.0 10.0 14-2, 61-62 (2) 638 52.7 18.4 8.4 0.82 3.11 1.40 3.80 0.11 14-2, 99-100 (2) 638.5 43.3 15.6 13.6 1.46 2.69 1.62 1.35 3.25 14, CC (2) 1.33 645.5 43.1 15.5 1.39 2.71 3.28 14.4 1.71 14, CC (1) 645.5 43.5 15.9 14.9 1.45 2.84 1.83 1.50 2.75 15-1, 39-40 (2) 655.5 38.0 13.9 19.1 1.27 2.67 1.49 1.25 4.61 15-3, 76-77 (2) 659 46.8 17.0 13.5 1.20 2.85 1.52 1.60 2.38 15-5, 140-150 (1) 662.5 2.00 2.93 0.41 2.71 50.0 19.0 15.1 2.46 15-6, 47-48 (2) 663 1.23 29.2 12.2 9.4 16.8 1.81 1.82 2.75 16-1, 52-53 (2) 665 34.4 8.3 13.0 2.47 1.94 1.11 4.13 11.1 16-2, 19-21 (2) 16-2, 56-58 (2) 18.7 30.7 7.5 2.42 2.37 0.89 666 9.9 1.06 666.5 42.1 11.8 8.0 10.2 3.41 2.57 0.80 0.44 667.5 16-2, 142-143 (2) 54.5 9.9 1.43 3.89 2.00 0.84 14.3 1.12 16-3, 27-29 (2) 2.00 0.79 0.97 668 54.6 14.0 10.2 1.32 3.76 16-3, 27-29 (1) 668 53.3 14.8 10.1 1.34 n.d. 2.20 0.74 1.05 16-3, 130-132 (2) 52.9 1.28 1.89 0.70 669 13.0 12.5 3.08 2.06 16-4, 72-73 (2) 670 53.5 12.9 14.5 1.45 3.09 2.23 0.93 0.70 17-6, 133-135 (2) 683.5 52.4 13.7 11.3 1.57 3.00 2.00 1.10 0.60 18-2, 132-133 (2) 696 52.0 15.0 11.3 1.07 2.80 2.00 1.48 0.11 18-4, 10-11 (2) 697.5 1.08 2.84 1.79 1.46 55.5 14.0 12.0 0.13 18-5, 147-150 (2) 700.5 48.2 10.8 15.2 1.17 3.04 3.11 1.35 0.31 18-6, 4-6 (2) 701 53.6 11.0 15.2 1.20 3.54 1.86 1.28 0.20 18-6, 4-6 (1) 2.05 701 53.5 15.2 1.23 3.69 1.34 0.20 11.6

 TABLE 1

 Major Element Composition of Clay Fraction, Site 323

^aNumber in parentheses is size fraction; (2) is less than 2 μ m esd; (1) is less than 1 μ m esd.

^bTotal iron reported as Fe₂O₃.

^cTotal manganese reported as MnO.

 $d_{n.d.}$ = Not determined.

In Cores 15 and 16 the only mineral identifiable by Xray diffraction is a smectite which is essentially 100% expandable (by the criteria of Reynolds and Hower, 1970). The low K₂O contents are consistent with the mineralogic interpretation. Samples 13-5, 125-126 cm and 14-2, 10-11 cm contain a mixed-layer illite-smectite with approximately 60%-70% expandable layers, and traces of discrete illite. These samples have much higher K2O contents, which is again consistent with the mineralogy. Sample 14-2, 99-100 cm contains a more expanded illite-smectite (approximately 80%) plus traces of discrete illite. The mixed-layer clays in the upper two samples are typical of terrigenous weathering products, while the clays in the lower samples are typical of altered ash. The clays in the lower samples show no evidence of the type of diagenesis described by Perry and Hower (1970) for sediments from the Gulf Coast, suggesting that these clays had not been subjected to temperatures greater than 90° C.

Laumontite

Laumontite, a calcic zeolite with the approximate formula CaAl₂Si₄O₁₂ \cdot 4H₂O, was positively identified in Samples 2-2, 0-15 cm; 4, CC; 7-3, 31-46 cm; and in one subsample from 18-4, 10-11 cm. Laumontite was tentatively identified in some other samples from the core above 640 meters, and we believe that the material referred to as U-1 in the X-ray diffraction data (Zemmels and Cook, this volume) is probably laumontite.

The X-ray identification is based on the presence of peaks at 9.6Å and 6.86Å in the untreated heavy liquid

 TABLE 2

 Minor Element Concentrations in Clay Fraction, Site 323

Sample ^a (Interval in cm)	Depth (m)	Mn (wt%)	Cu (ppm)	Zn (ppm)	Co (ppm)	Ni (ppm)	Pb (ppm)	Mo (ppm)	Sr (ppm)	Ba (ppm)
1-5, 0-15 (1)	81.5	0.08	115	200	60	90	85	<4	140	1200
1-5, 0-15 (2)	81.5	0.08	145	180	60	90	n.d.b	n.d.	120	1000
2-2, 0-15 (1)	162.5	0.05	225	165	25	35	n.d.	n.d.	160	640
3, CC (1)	265.5	0.10	140	180	28	50	n.d.	n.d.	200	240
4, CC (1)	322.5	0.06	55	165	22	30	n.d.	n.d.	160	400
7-3, 31-46 (1)	367.5	0.08	130	180	40	60	n.d.	n.d.	160	800
8, CC (1)	417.5	0.06	145	140	27	55	n.d.	n.d.	200	640
9-2, 0-10 (1)	457	0.09	230	210	32	50	n.d.	n.d.	120	680
9, CC (1)	465	0.15	40	110	17	20	n.d.	n.d.	160	440
10-3, 0-12 (1)	506	0.11	135	185	37	50	n.d.	n.d.	200	600
11-1, 0-10 (1)	550.5	0.10	43	120	22	30	n.d.	n.d.	160	440
11-1, 86-87 (2)	551.5	0.11	50	200	30	55	60	<4	160	500
11-2, 75-76 (2)	553	0.12	60	425	40	55	80	<4	140	300
12-1, 135-150 (1)	599.5	0.06	35	90	20	30	n.d.	n.d.	160	560
13-5, 125-126 (2)	624	0.20	120	210	50	100	85	<4	160	400
13-5, 135-150 (1)	624.5	0.12	150	180	50	75	n.d.	n.d.	160	640
13, CC (2)	626.5	0.20	120	208	60	100	60	9	170	800
14-1, 140-150 (1)	637.5	0.20	165	210	47	115	n.d.	n.d.	80	400
14-2, 10-11 (2)	637.5	0.17	148	180	50	110	75	5	140	600
14-2, 61-62	638	0.09	106	160	115	130	60	5	190	500
14-2, 99-100 (2)	638.5	2.52	500	220	145	370	110	47	330	1200
14, CC (2)	645.5	2.54	600	270	170	440	150	50	380	900
15-1, 39-40 (2)	655.5	3.57	500	500	110	670	100	180	760	1000
15-3, 76-77 (2)	659	1.84	310	300	100	240	110	95	490	300
15-5, 140-150 (1)	662.5	2.10	225	195	65	150	n.d.	n.d.	320	600
15-6, 47-48 (2)	663	2.13	210	270	70	150	110	70	560	500
16-1, 52-53 (2)	665	3.20	170	220	90	100	90	30	540	800
16-2, 19-21 (2)	666	0.82	170	235	35	80	100	<4	630	100
16-2, 56-58 (2)	666.5	0.34	175	230	30	100	50	<4	430	100
16-2, 142-143 (2)	667.5	0.65	170	250	40	85	45	<4	130	100
16-3, 27-29 (2)	668	0.75	175	235	75	100	40	<4	130	100
16-3, 130-132 (2)	669	1.60	210	265	50	100	50	10	170	900
16-4, 72-73 (2)	670	0.54	200	310	50	135	55	<4	130	100
17-6, 133-135 (2)	683.5	0.46	310	280	60	120	95	<4	150	100
18-2, 132-133 (2)	696	0.09	200	250	40	100	65	4	170	800
18-4, 10-11 (2)	697.5	0.10	370	280	40	105	80	<4	250	2500
18-5, 147-150 (2)	700.5	0.24	380	265	40	220	90	<4	170	3500
18-6, 4-6 (2)	701	0.15	250	260	35	200	60	<4	230	4000

^aNumber in parentheses is size fraction; (2) is less than 2 μ m esd; (1) is less than 1 μ m esd.

^bn.d. = Not determined.

separate. On heating to 350°C for 4 hr these peaks disappear and are replaced by peaks at 10.8Å, 8.6-8.8Å, and 6.3Å (Furbish, 1965). In the subsample of 18-4, 10-11 cm which contained laumontite (a later subsample contained no detectable laumontite), the laumontite occurs as euhedral laths approximately 100 μ m in length. Energy-dispersive X-ray analysis of the grains of the scanning electron microscope shows no detectable Na or K and a Si/Al ratio (atomic) of approximately 2.5:1. Clinoptilolite from the same sample has easily detectable Na, K, and Ca, and an Si/Al ratio of approximately 4.5:1. The laumontite in Cores 2, 4, and 7, by contrast, appears to have a grain size of 5 μ m or less.

The origin and significance of the laumontite is still under investigation. The common occurrences of laumontite are in zeolite facies metamorphic rocks. Laumontite-rich rocks of Lower Cretaceous age are exposed on adjacent areas of Antarctica (Horn, 1968), so that it is conceivable that the laumontite is detrital. If this is the case the sediments should contain abundant epidote which occurs with the laumontite in Antarctica (J.R. Boles, personal communication). If the laumontite is found to be authigenic, related perhaps to the high calcium concentrations in the interstitial water, this will have great significance in zeolite facies metamorphism. At present there is debate as to the relative importance of pressure and temperature compared to chemical factors in determining zeolite mineralogy (Boles and Coombs, 1975). The formation of laumontite at low temperatures and pressures would be a critical datum for this problem.

Clay Vein in Basalt

We analyzed one small fragment of a clay vein (18-6, 73-83 cm). Mineralogically it consists of a smectite plus calcite plus quartz. Chemically (Table 5) it has an Mg/Al ratio (atomic) of 1.9:1 and an Mg/Fe ratio of 1.8:1, indicating that the smectite should be classified as a saponite.

Altered Basalt

We received one small chip of basalt (18-6, 14-15 cm, part of which was reddish-brown in color, and part gray. Chemical analyses (Table 5) suggest that the color

TABLE 3 Major Element Composition of Coarse Fraction, Site 323

Sample ^a (Interval in cm)	Depth (m)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ ^b	CaO	MgO	Na ₂ O	K20	MnO ^c
1-5 0-15 (1)	81.5	67.0	11.3	3 74	1.42	1.69	2 36	2 75	0.06
3 CC (1)	265 5	63.3	12.4	3.14	3.18	1.48	2.94	2.42	0.70
8 CC (1)	417.5	65.1	12.4	3.02	2 47	1.32	3.06	2.45	0.21
9-2 0-10 (1)	457	63.3	13.4	4 38	3.76	1.57	3.26	2.45	0.50
9 CC (1)	465	69.7	11.9	3.72	1.49	1.30	2.61	3.00	0.06
11-1 $0-10$ (1)	550 5	67.7	12.1	3.69	1.75	1 34	2.64	3 31	0.00
12-1, 135-150(1)	599.5	69.9	12.1	3.47	1.20	1.54	2.04	3 33	0.05
13-5 125-126 (2)	624	66.6	12.7	4 89	1.30	1.82	212	3.28	0.19
13 CC (2)	626 5	71.3	10.2	2.89	1.11	1 14	2.07	3.00	0.36
14-2 10-11 (2)	637.5	74 5	10.1	2.05	0.84	1.15	2.07	3.06	0.09
14-2, 61-62 (2)	638	70.2	11.7	3 50	0.67	1 54	1 72	3.84	0.06
14-2, 99-100 (2)	638 5	574	13.8	7 30	2 35	213	2 23	3 33	1.18
14. CC (2)	645.5	58.5	14.2	7.60	2.04	2 20	2 35	3.42	1.10
15-3, 76-77 (2)	659	58.5	15.5	7.80	1 49	2.10	2.03	4 35	0.83
15-6, 47-48 (2)	663	22.0	6.80	4 4 8	32.0	0.90	0.36	1.65	1.07
16-1, 52-53 (2)	665	29.7	7.50	4 00	29.0	1.24	0.52	2.07	1.09
16-2, 19-21 (2)	666	36.4	9.00	5 23	20.0	1.75	0.67	2.35	0.58
16-2, 56-58 (2)	666.5	40.3	9.90	4.71	18.2	1.93	0.80	2.55	0.36
16-2, 142-143 (2)	667.5	59.3	14.1	5.12	1.42	2.02	1.62	5.28	0.27
16-3, 27-29 (2)	668	59.8	13.7	6.90	2.14	2.39	1.83	4.09	0.34
16-3, 130-132 (2)	669	55.2	12.8	8.60	1.42	2.43	2.05	2.96	1.00
16-4, 72-73 (2)	670	58.3	12.9	7.80	1.60	1.95	2.42	3.32	0.34
18-2, 132-133 (2)	696	60.9	13.8	4.89	1.14	1.52	2.49	4.30	0.00
18-6, 4-6 (2)	701	57.4	10.5	8.80	1.52	2.14	1.39	3.86	0.16

^aNumber in parentheses is size fraction; (2) is greater than 2 μ m esd; (1) is greater than 1 μ m esd. ^bTotal iron reported as Fe₂O₃.

^cTotal manganese reported as MnO.

TABLE 4 Major Element Composition of the <0.2 µm Fraction, Site 323

Sample (Interval in cm)	Depth (m)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ ^a	CaO	MgO	Na ₂ O	к20	MnO ^b
13-5, 125-126	624	48.6	15.4	11.2	1.00	3.42	1.88	2.60	0.31
14-2, 10-11	637.5	48.8	15.3	11.1	1.09	3.11	1.79	2.40	0.25
14-2, 99-100	638.5	43.1	13.6	14.0	1.57	2.76	2.22	1.00	3.66
15-1, 39-40	655.5	40.3	12.0	18.0	1.31	2.74	2.03	0.80	4.91
15-5, 140-150	662.5	41.5	15.1	13.3	1.90	2.59	1.78	1.23	3.55
16-2, 19-21	666	48.2	11.6	10.4	2.84	3.57	2.77	0.71	1.62
16-2, 56-58	666.5	46.0	10.8	8.20	4.00	3.87	4.40	0.61	0.51
16-2, 142-143	667.5	49.5	12.2	9.40	1.44	3.89	2.94	0.80	0.98
16-4, 72-73	670	49.6	10.4	14.3	1.36	3.05	3.02	0.56	0.78

^aTotal iron reported as Fe₂O₃.

^bTotal manganese reported as MnO.

TABLE 5 Chemical Analyses of Basalt and Clinoptilolite Separate, Site 323

					-	1011 19		
sio ₂	Al ₂ O ₃	Fe ₂ O ₃ ^a	CaO	MgO	Na ₂ O	к20	MnO ^b	TiO ₂
Reddi	sh-stained	portion of t	asalt chi	p, 18-6, 1	4-15 cm			
50.5	18.7	6.0	7.5	1.09	3.27	2.72	0.34	2.25
Gray c	olored po	rtion of sam	e chip					
52.5	19.2	6.3	7.1	1.23	3.20	3.04	0.13	2.31
Smecti	ite plus cal	lcite vein in	basalt, 18	8-6, 72-7	3 cm			
40.4	5.2	7.2	10.7	10.7	0.3	1.17	2.63	0.2
Clinop	tilolite sep	parated from	18-4, 10)-11 cm				
67.0	12.8	1.5	1.16	0.67	3.67	1.88	0.02	< 0.1

^aTotal iron reported as Fe₂O₃. ^bTotal manganese reported as MnO.



Figure 1. Ratios of K, Na, and Mg to Al in clay fraction, Site 323.



Figure 2. Minor element content of clay fraction, Site 323.

difference does not reflect any major difference in degree of alteration. Compared to typical unaltered basalt, the altered chip is depleted in CaO and MgO, and greatly enriched in K_2O . This is the normal pattern for submarine alteration of basalt. Under the scanning electron microscope, secondary K-feldspar can be seen in defects in the plagioclase crystals, presumably accounting for the increased K_2O . The relationships between basalt alteration and interstitial water chemistry will be discussed in the next section.

SOLID PHASES AND INTERSTITIAL WATER CHEMISTRY

The interstitial water data (Gieskes, this volume) suggest that reactions which release calcium and take up magnesium occur in the upper 170 meters, at approximately 450 meters, and in the basal sediments or underlying basalt. Since we have only one sample from above 170 meters, no statements can be made regarding reactions occurring in that interval. At 450 meters there are no obvious changes in the mineralogy of chemistry of the clay fraction. It appears (Kastner, this volume) that the controlling reactions are closely associated with localized porcelanite formation. Uptake and release reactions in the basal 60 meters are difficult to evaluate, as the chemistry and mineralogy of these sediments at the time of burial are not known. The Mg/Al ratio in the clays of the basal 60 meters is higher than in the overlying sediments, but difference cannot be related to diagenetic changes unless the initial composition is known. The principal Mg-bearing phase in the basal 60 meters is smectite, which could have formed in situ after burial, or could have formed on the sea floor prior to burial. Isotopic studies are now in progress to answer this question.

The gradients in interstitial calcium and magnesium appear to continue to the base of the sediments, and it is probable that magnesium uptake and calcium release are occurring within the basalt. Isotopic studies (Anderson and Lawrence, this volume; Lawrence et al., this volume) indicate extensive interaction between the pore water and the underlying basalt. For calcium the process appears to be simple release of calcium from alteration of pyroxenes or plagioclase and diffusion of Ca⁺⁺ through the overlying sediments. The process controlling Mg⁺⁺ cannot be as simple. The basalt appears to be acting as a sink for Mg⁺⁺ in the interstitial water, and yet the altered basalt contains less MgO than fresh basalt. This discrepancy can be explained by either of two hypotheses:

1) When the basalt is first extruded and altered there is relatively free circulation of seawater, and the water at the sites of alteration has essentially the same CO₂ content and pH as seawater. Under these conditions Mg is leached from the basalt. When the basalt is buried and continues to alter, water circulation is restricted, CO₂ is depleted by the alteration process, and the pH rises. At slightly elevated pH values Mg becomes fixed in smectites (Deffeyes, 1965, discussed in Drever, 1974), causing a depletion of Mg⁺⁺ in the interstitial water and the establishment of the observed diffusion gradient.

2) When the basalt is first altered it loses Mg and forms a metastable secondary phase. Over a long period

of time the metastable phase recrystallizes to stable phases, and during this recrystallization Mg is taken up from solution.

Experiments are now underway to test these hypotheses.

The interstitial K⁺ concentration drops to essentially zero some distance above the basalt-sediment contact. This suggests that K uptake is occurring within the basal sediments. Authigenic K-feldspar in the basal sediments and within the basalt is an obvious sink for K, but, unless anomalously high pH values or dissolved aluminum values are postulated, K-feldspar should be undergoing alteration rather than growth in the present-day interstitial water. It is possible that the K-feldspar is relict from a time when the interstitial water chemistry was different, and the present-day control of K⁺ is uptake by clinoptilolite or by the smectite. The X-ray diffraction patterns of the basal 60 meters of sediment show no evidence for the development of illitic interlayers, but the K/Al ratios of the clays (which are dominated by smectite) are quite variable; and the variation may reflect formation of a few illitic layers which are not yet sufficiently numerous to be detected by X-ray diffraction.

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