

7. DATA REPORT: EXCHANGEABLE CATION COMPOSITION OF TERRIGENOUS HEMIPELAGIC SEDIMENTS IN THE EASTERN FLANK OF THE JUAN DE FUCA RIDGE¹

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INTRODUCTION

Fluid circulation at midocean ridge flank areas where the igneous crust is young and still hot and sediment cover is usually thin actually produces a major chemical exchange between the ocean and the crust, although temperatures and rates of fluid flow are low (Mottl and Wheat, 1994). The primary objectives of Ocean Drilling Program Leg 168 were to elucidate the mechanism driving flow through the crust and seafloor, the magnitude of elemental chemical exchange between the crust and ocean, and the factors controlling the chemistry of fluids circulating in ridge flanks covered by sediments (Shipboard Scientific Party, 1997). To this purpose, Leg 168 drilled a series of holes in the eastern flank of the Juan de Fuca Ridge along a transect from Site 1023, a transition site from crust without sediment cover, to Site 1027, a site with sediment cover that is about 100 km east of the ridge axis (Fig. 1). My research objective on the cruise was to understand the role of sediments in controlling the chemistry of circulating fluid.

It is generally known that the composition of fluids circulating through the sediment column is influenced by many processes, such as diagenetic and/or hydrothermal reactions involving solids and solution, as well as advective and diffusive transport of dissolved constituents (e.g., Berner, 1971, 1980). Ion exchange reactions of dissolved constituents occur ubiquitously between pore waters and sediments, even where significant mineralogical changes in solid phases have been petrographically undetected in sediments from near the seafloor through hundreds of meters of burial. If an ion exchange reaction is so rapid that chemical equilibrium is essentially maintained in the front of advection and diffusion, then it has little kinetic impediment to the material transport processes through the sediment column. Nevertheless, if the equilibrium constant of an ion exchange reaction is significantly large, the ion exchange reactions between solid and solution might appreciably influence the solute transport associated with fluid flow as well as the gross pore-water composition (Berner, 1976, 1980).

In this report, all of the data obtained in a shorebased laboratory study involving the total cation exchange capacity (CEC) and equivalent fractions of adsorbed cations on Leg 168 sediments is compiled. Some data on the exchangeable cation composition of clay-rich marine sediments have been reported (Russell, 1970; Manheim and Sayles, 1974; Bischoff et al., 1975; Sayles and Mangelsdorf, 1977), but variation of the composition is poorly understood as functions of temperature with burial depth and of distance from ridge axis because hydrological and geological situations of ridge-flank areas are generally complex and their sediment covers are highly variable in composition and geological history. The present study characterizes the two-dimensional distribution of exchangeable cation compositions in

organic-poor terrigenous sediments on the ridge flank as functions of distance from the ridge axis and burial depth.

STUDY SAMPLES AND METHODS

Samples

Recovered sediments from ten sites (Sites 1023–1032) consist of turbidites (silt to sand), hemipelagic mud (clayey silt to silty clay), and nannofossil-rich mud to mudstone of variable thicknesses (Shipboard Scientific Party, 1997). In total, 562 samples were taken aboard ship with particular emphasis on obtaining clayey sediments in close proximity to the pore-water sampling points and to provide an even distribution of sampling points through the sediment column. The mineral composition of the clayey sediments is relatively homogeneous, involving plagioclase, K-feldspar, quartz, amphibole, biotite, illite, chlorite, smectite, calcite, and pyrite, based on XRD and smear-slide examinations in the shipboard lab. Smectite weight percentage of the sediments quantified by XRD ranged from 0 to 48 wt%, and it was relatively lower in sandy sediments and higher in clayey sediments. Total organic carbon (TOC) content of the sediments is usually less than 1 wt%, but locally exceeds more than 1 wt%. Details of the lithological and sedimentological characteristics, in addition to geophysical and geochemical details, are contained in the companion Leg 168 *Initial Reports* volume (Shipboard Scientific Party, 1997).

Experiments

The samples collected were first freeze dried, dispersed, and, to avoid a mixed signal reflecting pore waters and cations exchanged onto minerals in the bulk sediment, dialyzed with distilled water until chloride could not be detected in supernatant solution. Chloride-free samples were then cation exchanged. About 3 g of the samples were put in a polyethylene bottle with 50 mL of 0.1-N strontium chloride solution to extract exchangeable cations from the sediments. After keeping the bottles for 4–6 days at room temperature, the suspension was separated into solid and solution phases by centrifugation. Then Na, K, Mg, and Ca in the supernatant solutions were analyzed as exchangeable cations of the bulk sediment by atomic absorption spectroscopy. The accuracy of exchangeable cation determination in the present study was about 0.05 meq/100 g sample. Other exchangeable cations were not analyzed, but it was estimated that the contributions to the total CEC are generally negligible in the sediments studied. Equivalent fractions (X_i) of exchangeable sediment cations were calculated from: $X_{Na} + X_K + X_{Mg} + X_{Ca} = 1$ using values of Na, K, Mg, and Ca derived from the exchange experiments.

EXPERIMENTAL DATA

Total CEC and equivalent fractions of Na, K, Mg, and Ca in the bulk sediment are listed in Table 1. Total CEC values of studied samples ranged from 2 to 59 meq/100 g. Preliminary plots of the CEC and smectite percentage showed a parallel variation through the sediment

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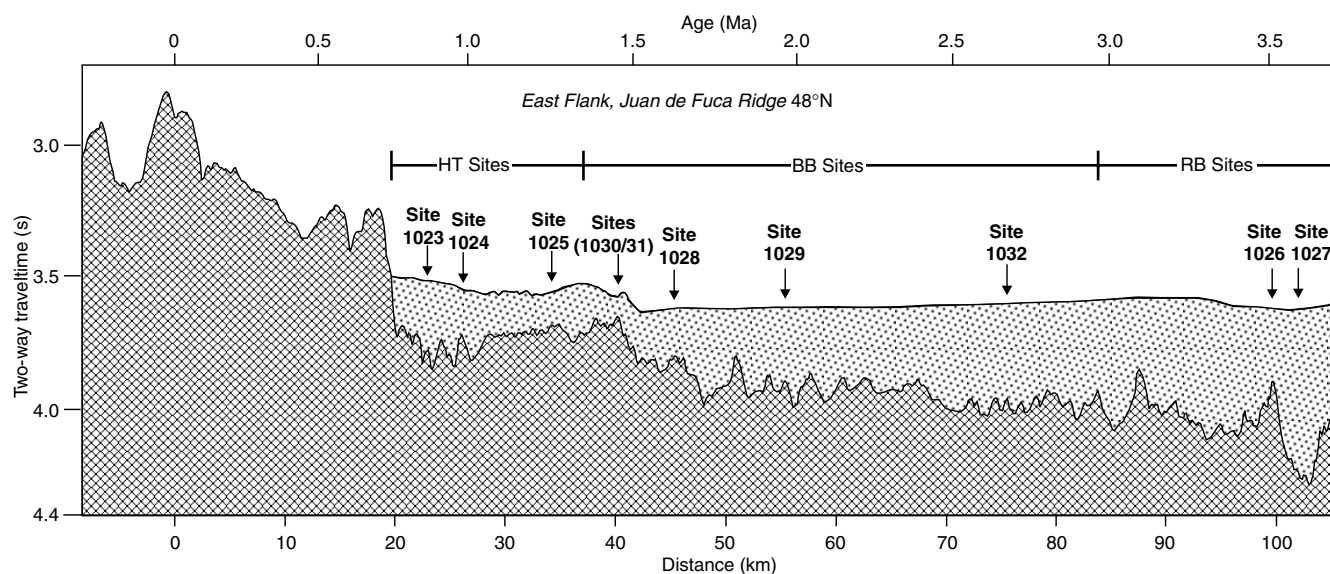


Figure 1. Basement topography (hatched area) and sediment cover (stippled area) along the ODP Leg 168 transect (Shipboard Scientific Party, 1997). HT = Hydrothermal Transition; BB = Buried Basement; RB = Rough Basement, which are subdivisions of the transect.

column, although the CEC-measured samples in the present study are not the same as those used for mineral quantification by XRD.

For illustrative purpose, relations of equivalent fractions vs. depth at each site are plotted in Figure 2. The equivalent fractions of Na, K, Mg, and Ca are roughly constant at the seafloor, and the average values calculated from data from 0 to 4 m below seafloor (mbsf) at nine sites, excluding Site 1032, are $X_{Na} = 0.21 \pm 0.04$, $X_K = 0.08 \pm 0.01$, $X_{Mg} = 0.33 \pm 0.09$, and $X_{Ca} = 0.38 \pm 0.09$. The values change systematically with depth at each drilling site and distance from the ridge axis, mirroring variations in pore-water composition. In general, the equivalent fractions of K and Mg decrease monotonously with increasing depth, and the degree of decrease is much more remarked with increasing distance from the ridge axis. There seems to be a mirror image between variations of Na and Ca. Distinct variations observed at Sites 1030 and 1031 are related to upwelling hydrothermal fluids from the basement.

In summary, analysis of exchangeable cation composition in bulk sediments where smectite is assumed to be the primary ion exchanger, together with analysis of pore-water composition data, may provide insight into understanding of the factors controlling the composition of circulating fluids in ridge flanks. Further discussion of this topic and the theoretical model for calculating ion selectivity coefficients from the data in Table 1 will be presented elsewhere.

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Table 1. Composition of exchangeable cations in sediments.

Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)	Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)				
		Na	K	Mg	Ca				Na	K	Mg	Ca					
168-1023A-						4H-4, 107-112						32.17	0.23	0.10	0.37	0.30	16.94
1H-1, 99-105	0.99	0.15	0.06	0.40	0.38	11.36	4H-6, 97-102	35.07	0.19	0.08	0.40	0.34	0.34	14.00			
1H-2, 98-104	2.48	0.18	0.07	0.39	0.36	19.26	5H-1, 127-133	37.37	0.30	0.11	0.33	0.26	19.00				
1H-3, 97-103	3.97	0.24	0.08	0.38	0.30	19.42	5H-3, 129-134	40.39	0.25	0.10	0.35	0.30	19.01				
1H-4, 97-103	5.47	0.21	0.08	0.38	0.33	19.62	5H-5, 127-132	43.37	0.29	0.10	0.34	0.27	18.37				
1H-5, 97-103	6.97	0.17	0.07	0.36	0.41	16.97	6H-1, 127-133	46.87	0.21	0.07	0.38	0.34	14.90				
1H-6, 98-104	8.48	0.20	0.07	0.36	0.37	17.80	6H-3, 136-142	49.96	0.25	0.10	0.34	0.31	17.75				
2H-1, 107-113	10.37	0.19	0.06	0.39	0.36	16.98	6H-5, 120-127	52.80	0.14	0.06	0.39	0.41	8.25				
2H-2, 113-118	11.93	0.13	0.07	0.38	0.42	16.71	7H-2, 137-142	57.97	0.25	0.09	0.33	0.33	18.53				
2H-3, 107-113	13.37	0.15	0.07	0.40	0.37	18.59	7H-4, 138-143	60.98	0.30	0.10	0.35	0.25	18.41				
2H-4, 104-109	14.84	0.19	0.07	0.39	0.35	14.88	7H-6, 88-95	63.48	0.32	0.10	0.37	0.20	18.98				
2H-5, 101-111	16.36	0.18	0.06	0.38	0.39	14.40	8H-2, 58-63	66.68	0.30	0.09	0.33	0.28	22.09				
2H-6, 106-111	17.86	0.22	0.07	0.38	0.34	22.19	8H-4, 78-83	69.88	0.21	0.08	0.35	0.36	15.17				
2H-7, 27-32	18.37	0.25	0.06	0.37	0.32	17.63	8H-6, 97-103	73.07	0.32	0.09	0.31	0.28	18.15				
3H-1, 88-93	19.68	0.30	0.09	0.35	0.26	19.94	9H-1, 89-95	74.99	0.12	0.04	0.25	0.59	30.34				
3H-2, 87-93	21.19	0.22	0.07	0.39	0.32	16.89	9H-3, 89-94	77.99	0.33	0.10	0.29	0.28	21.99				
3H-3, 67-73	22.49	0.34	0.09	0.34	0.23	17.77	9H-5, 88-93	80.98	0.34	0.10	0.32	0.23	18.98				
3H-4, 83-89	24.15	0.15	0.08	0.41	0.36	8.83	9H-7, 42-47	83.52	0.23	0.08	0.34	0.35	16.61				
3H-5, 52-58	25.34	0.24	0.08	0.39	0.30	18.17	10H-1, 52-57	84.12	0.37	0.10	0.36	0.17	17.03				
3H-6, 100-106	27.32	0.31	0.07	0.34	0.28	17.55	10H-3, 33-38	86.93	0.35	0.10	0.28	0.26	26.56				
3H-7, 20-25	28.02	0.18	0.08	0.39	0.34	29.08	10H-5, 90-95	90.50	0.25	0.09	0.30	0.35	19.72				
4H-2, 103-107	30.83	0.17	0.07	0.40	0.36	13.16	11H-1, 68-73	93.78	0.35	0.10	0.26	0.29	22.21				
4H-4, 56-60	33.36	0.22	0.05	0.39	0.33	14.49	11H-3, 104-110	97.14	0.40	0.10	0.25	0.25	23.41				
4H-7, 45-49	37.75	0.22	0.07	0.38	0.33	14.26	11H-5, 48-53	99.58	0.19	0.07	0.31	0.43	15.94				
5H-1, 90-95	38.70	0.20	0.08	0.37	0.35	15.13	11H-7, 41-47	102.51	0.20	0.07	0.36	0.37	13.01				
5H-7, 35018	46.91	0.21	0.07	0.36	0.36	16.47	12H-1, 76-81	103.36	0.22	0.06	0.36	0.36	13.65				
6H-2, 106-112	49.86	0.25	0.08	0.33	0.34	18.61	12H-3, 81-86	106.41	0.21	0.06	0.35	0.38	13.89				
6H-4, 26-31	52.06	0.27	0.07	0.34	0.31	17.09	12H-5, 39-44	108.99	0.18	0.06	0.34	0.43	13.78				
6H-6, 38-44	55.18	0.33	0.07	0.33	0.27	18.27	12H-7, 5-9	110.85	0.24	0.07	0.38	0.31	13.46				
7H-2, 121-126	59.51	0.31	0.08	0.33	0.28	20.57	13H-2, 57-62	114.17	0.31	0.09	0.29	0.30	20.08				
7H-4, 50-55	61.80	0.30	0.08	0.33	0.29	15.91	13H-4, 58-63	117.18	0.18	0.06	0.32	0.44	15.25				
7H-6, 56-61	64.86	0.28	0.08	0.34	0.30	16.35	13H-6, 58-64	120.18	0.10	0.04	0.22	0.64	10.20				
8H-1, 124-129	67.54	0.27	0.07	0.34	0.32	19.33	14X-1, 58-64	122.18	0.24	0.08	0.32	0.36	17.03				
8H-3, 117-122	70.47	0.22	0.06	0.38	0.34	14.72	14X-3, 104-109	125.64	0.26	0.08	0.31	0.35	15.09				
8H-5, 72-77	73.02	0.26	0.06	0.35	0.33	14.08	14X-5, 78-84	128.38	0.21	0.07	0.34	0.37	14.67				
8H-7, 53-57	75.83	0.31	0.08	0.33	0.28	20.37	14X-7, 5-10	130.65	0.18	0.06	0.35	0.42	16.04				
9H-2, 129-133	78.19	0.33	0.08	0.31	0.28	17.24	15X-1, 34-36	131.54	0.18	0.06	0.34	0.42	14.33				
9H-4, 95-100	80.85	0.24	0.07	0.34	0.35	17.16	15X-3, 59*61	134.79	0.18	0.07	0.36	0.38	19.90				
9H-6, 41-46	83.31	0.30	0.08	0.33	0.29	19.03	15X-5, 53-55	137.73	0.19	0.06	0.34	0.41	14.86				
10H-2, 88-93	87.68	0.30	0.08	0.33	0.29	17.09	15X-7, 30-32	140.50	0.26	0.10	0.37	0.27	17.57				
10H-4, 45-49	90.25	0.26	0.07	0.32	0.34	18.13	16X-1, 106-111	141.86	0.20	0.07	0.32	0.41	16.46				
10H-6, 27-32	93.07	0.26	0.08	0.36	0.31	15.20	16X-3, 106-112	144.86	0.21	0.07	0.33	0.39	15.03				
11H-1, 108-112	95.88	0.32	0.08	0.33	0.27	20.13	16X-5, 108-114	147.88	0.17	0.07	0.33	0.43	15.81				
11H-3, 115-120	98.95	0.29	0.08	0.35	0.29	17.76	16X-7, 22-27	150.02	0.19	0.07	0.32	0.42	15.67				
11H-5, 45-50	101.25	0.34	0.08	0.33	0.25	18.96	17X-1, 64-70	151.04	0.11	0.06	0.27	0.56	17.95				
11H-7, 42-46	104.22	0.32	0.08	0.31	0.29	20.04	17X-3, 69-74	154.09	0.20	0.09	0.31	0.41	17.31				
12H-2, 118-123	106.98	0.29	0.08	0.32	0.32	18.63	17X-5, 114-120	157.54	0.07	0.03	0.16	0.74	34.50				
12H-4, 127-133	110.07	0.22	0.07	0.35	0.36	16.84	17X-7, 18-23	159.58	0.18	0.06	0.32	0.44	18.44				
12H-6, 76-82	112.56	0.29	0.07	0.33	0.31	16.94	18X-2, 127-132	162.77	0.17	0.07	0.33	0.43	12.93				
13H-1, 115-121	114.95	0.24	0.07	0.35	0.34	16.16	18X-4, 126-131	165.76	0.25	0.10	0.25	0.40	33.90				
13H-3, 81-87	117.61	0.34	0.08	0.29	0.30	24.14	18X-6, 5-11	167.55	0.11	0.05	0.17	0.67	36.66				
13H-5, 86-92	120.66	0.28	0.08	0.32	0.32	18.11	168-1025B-										
14H-2, 87-94	125.67	0.27	0.07	0.30	0.35	21.70	1H-1, 127-133	1.27	0.19	0.08	0.39	0.35	21.46				
14H-4, 87-93	128.67	0.36	0.08	0.29	0.27	22.75	1H-3, 130-135	4.30	0.25	0.10	0.33	0.32	19.87				
15H-2, 97-103	132.47	0.29	0.08	0.32	0.32	19.69	1H-4, 73-79	5.23	0.31	0.10	0.32	0.27	20.29				
16X-2, 103-107	135.23	0.20	0.07	0.35	0.37	16.03	2H-2, 125-130	7.75	0.15	0.07	0.36	0.42	16.35				
16X-4, 103-108	138.23	0.20	0.06	0.35	0.38	14.66	2H-4, 121-128	10.71	0.17	0.07	0.35	0.41	10.52				
16X-6, 131-136	141.51	0.17	0.05	0.35	0.43	15.16	2H-6, 133-138	13.83	0.23	0.08	0.36	0.33	15.45				
17X-1, 89-94	143.19	0.19	0.06	0.33	0.42	16.13	3H-2, 118-124	17.18	0.28	0.08	0.33	0.31	20.34				
17X-3, 92-97	146.22	0.22	0.06	0.31	0.41	24.48	3H-4, 34-38	19.34	0.22	0.09	0.35	0.34	20.39				
17X-5, 89-95	149.19	0.18	0.06	0.37	0.40	13.97	3H-6, 86-90	22.86	0.29	0.10	0.31	0.31	17.70				
18X-3, 77-82	155.67	0.23	0.07	0.34	0.35	14.73	4H-2, 100-105	26.50	0.18	0.06	0.35	0.40	13.46				
18X-6, 16-20	159.56	0.27	0.07	0.32	0.34	18.61	4H-3, 56-61	27.56	0.20	0.06	0.31	0.42	18.02				
19X-2, 50-54	163.60	0.19	0.06	0.32	0.43	17.28	4H-5, 123-128	31.23	0.25	0.07	0.33	0.34	11.85				
19X-4, 89-93	166.99	0.31	0.08	0.31	0.30	19.09	4H-6, 28-33	31.78	0.30	0.10	0.31	0.28	18.44				
20X-2, 58-63	173.28	0.26	0.07	0.33	0.34	16.06	4H-7, 26-32	33.26	0.17	0.07	0.36	0.39	17.41				
20X-4, 49-54	176.19	0.23	0.08	0.33	0.36	13.68	5H-1, 66-71	34.16	0.24	0.10	0.30	0.36	18.78				
20X-6, 66-72	179.36	0.13	0.05	0.37	0.45	6.93	5H-3, 92-97	37.42	0.27	0.08	0.31	0.34	16.90				
21X-1, 74-79	181.54	0.15	0.06	0.34	0.45	13.52	5H-5, 121-126	40.71	0.21	0.07	0.32	0.40	11.95				
21X-3, 76-81	184.56	0.09	0.05	0.23	0.63	31.85	5H-7, 52-57	43.02	0.27	0.09	0.29	0.34	17.99				
21X-5, 67-72	187.47	0.21	0.08	0.30	0.41	26.19	6H-4, 137-143	49.03	0.27	0.07	0.27	0.39	18.77				
21X-7, 7-12	189.87	0.18	0.07	0.34	0.42	14.42	6H-5, 132-137	50.15	0.18	0.06	0.28	0.47	11.05				
22X-2, 26-31	191.69	0.17	0.07	0.31	0.45	22.13											

Table 1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)	Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)
		Na	K	Mg	Ca				Na	K	Mg	Ca	
11X-1, 116-123	91.86	0.06	0.02	0.10	0.81	49.52	22X-3, 122-126	197.72	0.33	0.10	0.25	0.33	28.73
11X-3, 116-124	94.86	0.18	0.07	0.21	0.54	31.56	22X-5, 18-23	199.68	0.31	0.07	0.30	0.32	17.88
11X-CC, 6-12	97.25	0.14	0.03	0.13	0.70	40.17	23X-1, 64-69	203.84	0.34	0.04	0.29	0.33	16.52
168-1026A-							23X-CC, 0-5	204.52	0.33	0.04	0.29	0.34	18.06
1H-1, 125-130	1.25	0.30	0.09	0.32	0.29	30.00	24X-CC, 0-5	212.80	0.22	0.06	0.32	0.40	15.23
1H-3, 104-109	4.04	0.22	0.07	0.31	0.41	25.00	25X-1, 47-52	222.87	0.36	0.09	0.24	0.31	18.03
2H-2, 112-117	8.02	0.29	0.08	0.31	0.31	22.84	25X-CC, 1-6	224.94	0.18	0.06	0.32	0.44	17.28
2H-4, 61-66	10.51	0.27	0.09	0.32	0.32	20.14	26X-2, 110-117	234.60	0.30	0.06	0.28	0.36	16.96
2H-5, 120-124	12.60	0.16	0.06	0.37	0.41	16.02	26X-4, 19-25	236.69	0.24	0.05	0.26	0.46	16.29
2H-6, 138-144	14.28	0.19	0.06	0.34	0.41	20.55	27X-2, 54-59	243.64	0.28	0.03	0.29	0.40	16.27
3H-1, 45-50	15.35	0.22	0.06	0.35	0.37	19.51	28X-1, 122-127	252.52	0.18	0.06	0.31	0.45	18.86
3H-3, 112-117	19.02	0.18	0.06	0.36	0.40	12.88	28X-3, 114-119	255.44	0.29	0.09	0.26	0.36	22.91
3H-5, 122-127	22.12	0.15	0.04	0.36	0.44	5.56	28X-5, 118-123	258.48	0.25	0.08	0.26	0.41	22.57
3H-6, 65-70	23.05	0.16	0.05	0.36	0.42	7.79	29X-1, 127-134	262.17	0.41	0.09	0.23	0.27	20.44
4H-1, 64-70	25.04	0.05	0.02	0.17	0.75	31.51	29X-3, 132-138	265.22	0.39	0.09	0.22	0.30	25.39
4H-3, 127-134	28.67	0.25	0.06	0.35	0.33	16.71	29X-6, 111-118	269.51	0.32	0.06	0.25	0.36	16.26
4H-5, 59-66	30.99	0.22	0.05	0.34	0.38	14.36	30X-2, 129-134	273.29	0.35	0.04	0.27	0.35	16.32
5H-2, 84-89	36.24	0.19	0.06	0.33	0.42	18.71	30X-4, 128-133	276.28	0.40	0.07	0.29	0.24	18.54
5H-4, 142-147	39.82	0.20	0.06	0.33	0.41	19.15	30X-6, 14-19	278.14	0.33	0.08	0.21	0.38	31.97
5H-6, 25-30	41.65	0.32	0.07	0.32	0.30	19.33	31X-1, 131-134	281.41	0.12	0.04	0.28	0.56	15.30
6H-1, 69-74	44.09	0.29	0.06	0.31	0.35	19.23	31X-3, 92-96	284.02	0.15	0.03	0.19	0.63	37.16
6H-3, 79-84	47.19	0.33	0.07	0.35	0.26	10.34	31X-5, 115-118	287.25	0.27	0.05	0.24	0.43	17.49
6H-6, 64-69	51.54	0.23	0.06	0.34	0.37	15.29	32X-1, 18-21	289.98	0.25	0.05	0.25	0.44	18.19
7H-2, 122-127	55.62	0.25	0.05	0.32	0.38	13.53	32X-3, 74-77	298.54	0.30	0.05	0.24	0.41	21.31
7H-4, 139-145	58.79	0.30	0.07	0.33	0.31	15.09	32X-5, 132-136	297.12	0.19	0.05	0.28	0.49	19.51
7H-6, 96-101	61.36	0.26	0.06	0.32	0.36	13.17	32X-7, 34-36	299.14	0.29	0.06	0.22	0.43	20.76
8H-3, 48-53	65.88	0.31	0.06	0.30	0.33	16.19	33X-2, 123-127	302.13	0.22	0.05	0.26	0.47	25.32
8H-5, 129-134	69.69	0.29	0.07	0.33	0.31	15.16	33X-4, 76-79	304.66	0.12	0.03	0.20	0.65	32.72
8H-7, 53-59	71.93	0.28	0.06	0.31	0.36	16.43	33X-6, 128-131	308.18	0.26	0.05	0.23	0.46	19.61
9H-2, 30-35	73.70	0.27	0.06	0.30	0.37	16.36	34X-2, 97-99	311.57	0.23	0.04	0.23	0.50	21.62
9H-4, 112-116	77.52	0.27	0.07	0.33	0.33	11.92	34X-5, 126-128	316.36	0.20	0.03	0.24	0.53	19.83
10H-4, 18-23	86.08	0.21	0.05	0.30	0.45	12.22	34X-6, 13-16	316.73	0.20	0.03	0.24	0.53	20.93
10H-6, 99-104	89.89	0.26	0.05	0.30	0.38	12.10	35X-2, 128-130	321.48	0.26	0.04	0.23	0.47	23.21
11H-3, 76-81	94.66	0.16	0.05	0.30	0.49	13.34	36X-2, 118-120	331.08	0.32	0.02	0.22	0.43	20.40
11H-3, 145-150	95.35	0.23	0.06	0.30	0.41	15.24	36X-4, 120-122	334.10	0.25	0.03	0.22	0.49	20.68
11H-5, 135-140	98.25	0.26	0.07	0.29	0.38	13.55	36X-6, 118-121	337.08	0.43	0.03	0.18	0.35	22.39
11H-6, 49-54	98.89	0.25	0.06	0.30	0.39	12.86	37X-2, 49-52	339.99	0.25	0.03	0.23	0.49	22.49
11H-7, 15-20	100.05	0.23	0.05	0.29	0.43	11.75	37X-4, 52-55	343.02	0.38	0.03	0.19	0.40	25.70
12H-CC, 14-19	101.32	0.24	0.06	0.29	0.41	14.70	37X-6, 52-55	346.02	0.34	0.03	0.20	0.43	23.39
168-1026C-							38X-1, 110-112	348.80	0.26	0.03	0.24	0.47	14.76
1R-1, 12-16	84.72	0.17	0.05	0.31	0.47	18.16	38X-3, 103-105	351.73	0.29	0.03	0.22	0.46	19.33
3R-CC, 15-17	104.23	0.20	0.05	0.29	0.45	12.74	38X-5, 41-43	354.11	0.31	0.03	0.21	0.45	31.49
4R-1, 17-23	113.67	0.29	0.04	0.17	0.50	42.43	38X-7, 26-28	356.96	0.47	0.02	0.18	0.33	21.98
5R-1, 83-88	123.93	0.27	0.05	0.17	0.51	31.83	39X-2, 133-134	360.13	0.44	0.03	0.21	0.32	19.41
6R-1, 1-7	132.71	0.30	0.06	0.19	0.45	30.32	39X-4, 129-131	363.09	0.24	0.03	0.22	0.51	17.06
7R-CC, 8-14	143.86	0.31	0.04	0.15	0.50	20.65	39X-6, 126-128	366.06	0.34	0.03	0.19	0.44	21.15
9R-1, 11-16	161.71	0.30	0.04	0.11	0.55	24.51	40X-2, 141-144	369.91	0.28	0.01	0.21	0.49	17.46
9R-CC, 17-22	164.13	0.17	0.02	0.08	0.72	26.22	40X-4, 137-140	372.87	0.34	0.03	0.19	0.44	20.39
10R-1, 25-28	171.45	0.18	0.03	0.12	0.67	18.42	40X-6, 127-131	375.77	0.35	0.03	0.23	0.39	15.56
10R-3, 67-70	174.87	0.25	0.04	0.09	0.62	20.46	41X-1, 134-136	377.94	0.21	0.03	0.23	0.54	14.35
10R-5, 43-45	177.63	0.15	0.03	0.12	0.70	19.14	41X-3, 140-142	381.00	0.35	0.03	0.23	0.39	24.38
12R-1, 41-44	190.91	0.18	0.04	0.12	0.66	18.38	41X-CC, 34-37	381.37	0.47	0.03	0.15	0.35	21.24
13R-2, 34-38	201.94	0.19	0.04	0.10	0.67	19.88	42X-1, 105-110	387.25	0.41	0.02	0.20	0.38	21.11
13R-4, 12-16	204.72	0.05	0.01	0.04	0.89	53.64	42X-3, 107-112	390.27	0.32	0.03	0.22	0.44	17.48
13R-6, 22-26	207.82	0.25	0.04	0.09	0.62	26.41	42X-4, 66-70	391.36	0.33	0.03	0.20	0.43	17.56
14R-1, 114-118	210.84	0.07	0.02	0.06	0.85	40.87	42X-6, 44-49	394.14	0.30	0.03	0.19	0.49	22.28
14R-3, 98-102	213.68	0.21	0.04	0.10	0.65	24.94	43X-2, 76-80	398.06	0.30	0.03	0.20	0.46	21.11
14R-5, 3-7	215.73	0.20	0.04	0.09	0.67	31.54	43X-3, 48-53	399.28	0.29	0.03	0.21	0.46	18.70
14R-6, 25-29	217.45	0.11	0.03	0.06	0.80	36.88	43X-4, 60-63	400.90	0.39	0.03	0.19	0.40	22.34
15R-2, 23-26	221.03	0.15	0.05	0.16	0.64	25.10	43X-6, 57-61	403.87	0.36	0.01	0.18	0.44	23.03
15R-4, 78-81	224.58	0.11	0.03	0.07	0.79	35.05	44X-2, 133-134	408.23	0.40	0.03	0.20	0.37	21.26
15R-6, 100-103	227.80	0.15	0.03	0.05	0.77	43.33	44X-5, 121-123	412.61	0.31	0.03	0.23	0.44	16.31
168-1027B-							44X-6, 77-79	413.67	0.21	0.01	0.20	0.58	16.82
1H-2, 117-123	2.67	0.21	0.06	0.32	0.41	22.43	44X-7, 41-44	414.81	0.25	0.02	0.21	0.52	20.48
3H-1, 129-134	14.99	0.16	0.05	0.36	0.42	6.35	45X-2, 79-80	417.29	0.34	0.03	0.19	0.43	19.04
3H-2, 130-135	16.50	0.20	0.05	0.40	0.34	10.12	45X-4, 76-78	420.26	0.44	0.03	0.15	0.38	23.76
3H-4, 131-136	19.51	0.21	0.07	0.38	0.33	15.47	45X-5, 111-114	422.11	0.37	0.03	0.21	0.40	23.56
3H-5, 132-137	21.02	0.27	0.06	0.33	0.34	11.82	46X-1, 111-115	425.71	0.45	0.03	0.19	0.33	24.01
3H-6, 109-114	22.29	0.18	0.06	0.39	0.37	8.61	46X-3, 115-118	428.75	0.37	0.03	0.18	0.42	21.88
4H-1, 114-119	24.34	0.26	0.06	0.35	0.33	17.17	46X-5, 88-91	431.48	0.26	0.03	0.25	0.47	21.96
4H-3, 128-133	27.48	0.18	0.03	0.37	0.43	6.66	47X-1, 52-57	434.72	0.47	0.03	0.16	0.35	37.41
4H-5, 28-33	29.48	0.28	0.06	0.31	0.34	18.61	47X-5, 110-115	441.30	0.29	0.03	0.19	0.50	19.6

Table 1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)	Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)
		Na	K	Mg	Ca				Na	K	Mg	Ca	
52X-3, 29-32	485.49	0.23	0.02	0.19	0.55	16.31	15X-2, 72-77	126.05	0.17	0.05	0.19	0.59	16.51
52X-5, 31-35	488.49	0.36	0.03	0.14	0.48	21.52	15X-4, 41-46	129.02	0.22	0.04	0.18	0.56	18.48
52X-7, 31-35	491.51	0.37	0.02	0.16	0.44	19.12	15X-6, 41-46	131.71	0.16	0.03	0.08	0.73	54.18
53X-2, 117-119	494.37	0.59	0.03	0.29	0.09	9.02							
53X-4, 123-124	497.43	0.39	0.02	0.14	0.45	37.56	168-1029A-						
53X-5, 97-101	498.67	0.35	0.01	0.14	0.49	21.75	1H-1, 49-53	0.49	0.20	0.10	0.38	0.32	16.42
53X-7, 18-22	500.88	0.37	0.03	0.14	0.47	22.35	1H-3, 90-94	3.90	0.27	0.09	0.34	0.29	20.20
54X-1, 114-116	502.44	0.24	0.02	0.16	0.57	23.64	2H-1, 132-137	5.82	0.24	0.09	0.33	0.34	18.40
54X-3, 141-143	505.71	0.34	0.02	0.14	0.49	20.56	2H-3, 138-142	8.88	0.31	0.09	0.31	0.28	18.43
54X-4, 143-145	507.23	0.34	0.02	0.13	0.50	19.59	2H-5, 33-37	10.83	0.34	0.10	0.30	0.25	20.21
54X-6, 139-142	510.19	0.32	0.01	0.13	0.54	24.15	3H-2, 60-65	16.10	0.27	0.08	0.34	0.31	16.55
55X-2, 40-44	512.90	0.39	0.03	0.10	0.47	31.30	3H-4, 78-83	19.28	0.30	0.10	0.32	0.28	19.40
55X-4, 85-89	516.35	0.36	0.03	0.12	0.49	25.99	3H-5, 98-103	20.98	0.35	0.11	0.30	0.24	18.28
55X-5, 116-119	518.16	0.31	0.03	0.12	0.54	26.81	3H-6, 108-113	22.58	0.23	0.10	0.36	0.30	15.94
55X-6, 22-27	518.72	0.37	0.03	0.12	0.49	23.69	4H-2, 74-79	25.74	0.27	0.08	0.35	0.30	16.35
55X-7, 14-18	520.14	0.27	0.03	0.13	0.57	23.49	4H-4, 116-121	29.16	0.31	0.06	0.33	0.30	17.36
56X-1, 117-121	521.77	0.32	0.03	0.14	0.50	20.38	4H-5, 5-10	29.55	0.31	0.06	0.32	0.30	19.36
56X-3, 113-117	524.73	0.40	0.03	0.12	0.45	23.70	4H-6, 5-10	31.05	0.36	0.09	0.29	0.26	23.16
56X-5, 101-106	527.61	0.35	0.03	0.12	0.50	24.24	5H-2, 62-67	35.12	0.31	0.10	0.30	0.28	16.76
56X-7, 49-52	530.09	0.32	0.03	0.11	0.54	22.33	5H-4, 28-32	37.78	0.25	0.08	0.36	0.32	16.76
57X-1, 126-130	531.56	0.30	0.03	0.12	0.55	23.94	6H-1, 32-37	42.82	0.31	0.10	0.31	0.28	16.91
57X-2, 114-118	532.94	0.28	0.03	0.11	0.58	22.66	6H-2, 25-30	44.25	0.38	0.09	0.29	0.23	20.53
57X-3, 80-85	534.10	0.25	0.03	0.12	0.59	19.06	6H-4, 110-115	48.10	0.31	0.11	0.30	0.28	16.71
57X-5, 118-122	537.48	0.42	0.03	0.10	0.45	25.26	6H-5, 115-120	49.65	0.32	0.10	0.31	0.27	17.47
58X-2, 141-144	542.81	0.22	0.03	0.20	0.55	18.13	7H-1, 92-97	52.92	0.34	0.10	0.29	0.27	17.70
58X-4, 141-144	545.81	0.43	0.04	0.10	0.44	31.68	7H-3, 117-120	56.17	0.37	0.10	0.30	0.23	17.16
58X-6, 128-133	548.68	0.30	0.03	0.09	0.58	27.60	8H-1, 74-79	62.24	0.41	0.11	0.26	0.23	28.54
59X-1, 97-99	550.47	0.25	0.03	0.11	0.62	24.55	8H-3, 78-83	65.28	0.37	0.10	0.28	0.25	20.09
59X-3, 99-101	553.49	0.25	0.03	0.11	0.61	28.52	8H-5, 5-10	67.55	0.39	0.11	0.27	0.23	17.25
59X-5, 95-97	556.45	0.25	0.02	0.11	0.63	22.25	9H-2, 8-13	72.58	0.36	0.09	0.26	0.29	17.34
59X-7, 55-57	558.85	0.23	0.03	0.09	0.66	27.00	9H-4, 59-64	76.09	0.35	0.09	0.27	0.29	18.98
60X-1, 117-122	560.27	0.15	0.03	0.10	0.72	23.03	9H-5, 83-88	77.83	0.31	0.07	0.27	0.35	17.40
60X-3, 83-85	562.93	0.25	0.03	0.11	0.61	21.99	9H-6, 56-61	79.06	0.36	0.09	0.28	0.28	18.47
60X-5, 68-72	565.78	0.27	0.04	0.10	0.59	22.68	9H-7, 12-17	80.12	0.31	0.07	0.28	0.35	17.66
60X-7, 30-34	568.40	0.24	0.03	0.10	0.63	27.45	10H-1, 72-77	81.22	0.31	0.07	0.28	0.34	10.68
60X-CC, 20-24	568.76	0.20	0.03	0.09	0.68	28.03	11H-3, 130-135	94.30	0.38	0.07	0.24	0.31	18.27
62X-CC, 28-31	573.08	0.08	0.03	0.08	0.81	23.45	11H-4, 21-27	94.71	0.28	0.06	0.27	0.39	14.21
							12H-2, 138-143	102.38	0.26	0.06	0.25	0.43	19.73
168-1027C-							12H-4, 45-50	104.45	0.39	0.06	0.20	0.35	20.95
1R-6, 78-80	591.68	0.13	0.04	0.09	0.75	21.79	12H-6, 130-135	108.30	0.33	0.05	0.23	0.39	18.52
2R-1, 50-54	594.90	0.10	0.03	0.10	0.77	22.81	12H-7, 30-36	108.80	0.31	0.05	0.24	0.40	16.04
2R-3, 62-65	597.08	0.05	0.03	0.10	0.82	22.46	13X-2, 75-81	111.25	0.35	0.06	0.23	0.36	17.47
2R-5, 78-82	600.24	0.07	0.03	0.10	0.80	20.09	13X-4, 2-7	113.52	0.37	0.05	0.21	0.37	19.54
2R-7, 21-25	602.67	0.12	0.03	0.06	0.79	39.68	14X-1, 88-94	115.78	0.36	0.05	0.21	0.39	18.03
3R-1, 45-48	604.55	0.02	0.01	0.02	0.95	56.56	14X-3, 106-112	118.96	0.34	0.05	0.22	0.39	29.05
3R-2, 50-54	605.60	0.15	0.02	0.03	0.80	43.22	14X-5, 41-46	121.31	0.35	0.05	0.21	0.40	19.54
3R-2, 84-86	605.94	0.17	0.02	0.05	0.77	57.22	16X-2, 87-93	132.77	0.33	0.04	0.18	0.45	17.53
							16X-4, 133-138	136.23	0.41	0.04	0.17	0.39	22.15
168-1028A-							16X-CC, 20-25	137.06	0.37	0.04	0.17	0.42	18.91
1H-2, 56-61	2.06	0.18	0.06	0.34	0.41	20.70	17X-2, 48-53	141.98	0.28	0.04	0.17	0.51	15.67
2H-1, 129-135	4.99	0.24	0.07	0.34	0.35	16.24	17X-4, 35-40	144.85	0.23	0.03	0.18	0.56	17.89
2H-3, 73-78	7.43	0.18	0.07	0.35	0.39	15.78	17X-6, 126-130	148.76	0.32	0.04	0.16	0.48	20.24
3H-2, 81-87	15.51	0.28	0.10	0.31	0.30	18.12	17X-CC, 28-33	149.77	0.17	0.02	0.12	0.69	27.94
3H-4, 108-113	18.78	0.24	0.08	0.35	0.33	14.64	18X-1, 21-25	149.81	0.27	0.04	0.20	0.49	16.67
3H-6, 119-125	21.89	0.20	0.06	0.35	0.39	17.15	18X-3, 77-80	153.37	0.28	0.04	0.18	0.50	18.31
4H-1, 62-66	23.32	0.30	0.10	0.30	0.31	21.32	18X-5, 54-57	156.14	0.28	0.04	0.17	0.52	19.25
4H-3, 57-62	26.27	0.28	0.08	0.32	0.32	17.91	18X-7, 30-33	158.90	0.28	0.03	0.15	0.54	17.18
4H-5, 88-93	29.58	0.19	0.07	0.34	0.40	17.41	19X-2, 38-41	161.08	0.19	0.03	0.16	0.61	17.96
4H-7, 41-46	32.11	0.22	0.07	0.35	0.36	15.99	19X-3, 62-65	162.82	0.27	0.04	0.14	0.55	18.30
5H-2, 44-49	34.14	0.23	0.08	0.33	0.36	14.91	19X-5, 134-136	166.54	0.22	0.04	0.16	0.58	22.96
5H-4, 118-123	37.88	0.24	0.09	0.31	0.36	17.97	20X-1, 134-136	170.14	0.25	0.04	0.15	0.56	19.96
5H-6, 109-115	40.79	0.20	0.07	0.35	0.39	15.77	20X-3, 133-135	173.13	0.28	0.04	0.15	0.54	20.96
6H-1, 137-142	43.07	0.28	0.09	0.28	0.35	22.99	20X-5, 57-60	175.37	0.28	0.04	0.14	0.54	20.45
6H-3, 140-144	46.10	0.30	0.09	0.28	0.32	19.35	20X-CC, 22-25	177.96	0.32	0.04	0.14	0.51	19.79
6H-5, 95-99	48.65	0.29	0.09	0.29	0.33	19.85	21X-1, 136-141	179.76	0.19	0.03	0.09	0.69	33.04
6H-7, 38-43	51.08	0.24	0.09	0.32	0.35	22.57	21X-3, 90-95	182.30	0.25	0.04	0.13	0.58	20.72
7H-1, 53-58	51.73	0.30	0.09	0.28	0.34	21.49	22X-2, 63-68	190.13	0.28	0.04	0.12	0.56	24.12
7H-3, 90-95	55.10	0.29	0.09	0.28	0.34	19.92	22X-4, 104-109	193.54	0.24	0.04	0.14	0.58	29.68
7H-5, 75-81	57.95	0.30	0.09	0.27	0.34	20.03	22X-6, 92-97	196.42	0.22	0.04	0.15	0.59	20.17
7H-7, 9-14	60.29	0.29	0.08	0.34	0.29	17.39	23X-1, 103-107	198.63	0.27	0.04	0.14	0.54	22.53
8H-2, 29-34	62.49	0.36	0.08	0.25	0.32	27.23	23X-3, 89-94	201.49	0.24	0.05	0.12	0.60	15.20
8H-4, 32-37	65.52	0.30	0.08	0.27	0.35	21.57	24X-2, 66-68	209.36	0.27	0.05	0.11	0.57	23.32
8H-6, 29-34	68.49	0.28	0.06	0.28	0.39	18.81	24X-4, 71-74	212.41	0.22	0.05	0.13	0.60	23.86
8H-7, 45-49	70.15	0.33	0.07	0.25	0.34	24.23	24X-6, 46-48	215.16	0.21	0.05	0.13	0.60	23.29
9H-1, 120-125	71.40	0.45	0.07	0.23	0.24	26.13	25X-1, 12-16	216.92	0.11	0.05	0.12	0.72	30.17
9H-3, 44-50	73.64	0.32	0.06	0.26	0.37	20.53	25X-3, 3-4	219.83	0.33	0.05	0.11	0.51	55.81
9H-5, 119-124	77.39	0.19	0.05	0.29	0.47	16.47							
9H-7, 35-40	79.55	0.32	0.05	0.32	0.31	12.28	168-1030B-						
10H-1, 100-104	80.70	0.18	0.05	0.28	0.50	19.25	1H-1, 43-48	0.43	0.19	0.08	0.34	0.39	15.82
10H-3, 118-122	83.88	0.25	0.05	0.26	0.44	17.08	1H-3, 17-22	3.17	0.19	0.08	0.17	0.56	19.28
10H-5, 122-126	86.92	0.27	0.05	0.25	0.43	19.20	2H-1, 110-114	5.10	0.20	0.06	0.10	0.65	20.97
10H-7, 22-27	88.92	0.25	0.05	0.25	0.45								

Table 1 (continued).

Core, section, interval (cm)	Depth (mbsf)	Equivalent fraction				Total CEC (meq/100 g)
		Na	K	Mg	Ca	
4H-7, 29-34	32.29	0.16	0.05	0.08	0.72	21.65
5H-1, 137-142	33.87	0.16	0.06	0.08	0.70	20.22
5H-3, 143-148	36.93	0.08	0.03	0.05	0.84	42.74
5H-5, 25-30	38.75	0.18	0.05	0.07	0.70	22.96
5H-7, 7-12	41.57	0.13	0.04	0.07	0.76	28.76
6X-CC, 9-15	41.09	0.15	0.05	0.09	0.71	21.45
168-1031A-						
1H-2, 124-129	2.74	0.24	0.08	0.12	0.56	19.83
1H-4, 95-100	5.45	0.21	0.06	0.09	0.64	19.05
1H-6, 99-104	8.49	0.16	0.06	0.10	0.69	24.40
2H-1, 103-108	9.83	0.22	0.06	0.08	0.64	20.68
2H-3, 104-109	12.84	0.25	0.08	0.06	0.61	25.15
2H-5, 92-97	15.72	0.18	0.06	0.08	0.68	18.11
3H-2, 98-103	20.78	0.14	0.05	0.14	0.68	21.63
3H-4, 95-100	23.75	0.05	0.01	0.03	0.91	56.71
3H-6, 096-101	26.76	0.09	0.03	0.04	0.84	42.63
4H-1, 39-44	28.19	0.22	0.07	0.08	0.63	30.54
4H-3, 27-32	31.07	0.06	0.02	0.04	0.89	45.84
4H-5, 73-78	34.53	0.09	0.03	0.05	0.82	34.11
4H-7, 14-18	36.94	0.19	0.06	0.08	0.67	32.32
5H-1, 87-92	38.17	0.13	0.05	0.09	0.73	23.71
5H-3, 37-38	40.67	0.33	0.05	0.04	0.58	39.06
5H-3, 82-87	41.12	0.30	0.06	0.06	0.59	42.97
168-1032A-						
1R-1, 15-17	184.65	0.22	0.04	0.25	0.49	13.57
1R-CC, 5-7	185.78	0.20	0.04	0.21	0.55	14.28
2R-1, 11-13	194.21	0.21	0.03	0.22	0.54	17.15
2R-CC, 11-13	196.50	0.28	0.04	0.20	0.48	25.46
3R-1, 44-46	204.14	0.23	0.04	0.21	0.53	20.52
4R-CC, 1-3	213.31	0.29	0.04	0.17	0.51	24.71
5R-1, 33-36	223.23	0.18	0.03	0.14	0.65	17.82
5R-3, 92-96	226.82	0.13	0.02	0.08	0.76	38.27
6R-1, 119-124	233.69	0.26	0.03	0.13	0.58	20.26
6R-3, 77-79	236.27	0.25	0.04	0.14	0.57	21.92
7R-1, 86-88	242.96	0.23	0.03	0.12	0.61	18.72
7R-2, 41-43	244.01	0.18	0.03	0.14	0.65	16.63
8R-2, 93-96	254.13	0.23	0.04	0.11	0.61	20.54
8R-CC, 17-20	256.25	0.21	0.04	0.13	0.62	16.56
10R-3, 29-34	274.29	0.24	0.03	0.08	0.65	25.88
10R-CC, 8-13	276.81	0.17	0.04	0.16	0.63	21.26
11R-2, 106-109	283.16	0.09	0.03	0.08	0.81	31.56
11R-4, 15-18	285.25	0.05	0.01	0.04	0.90	58.59
11R-CC, 12-14	285.79	0.27	0.06	0.06	0.61	39.11
12R-1, 0-9	290.20	0.08	0.02	0.06	0.84	54.13

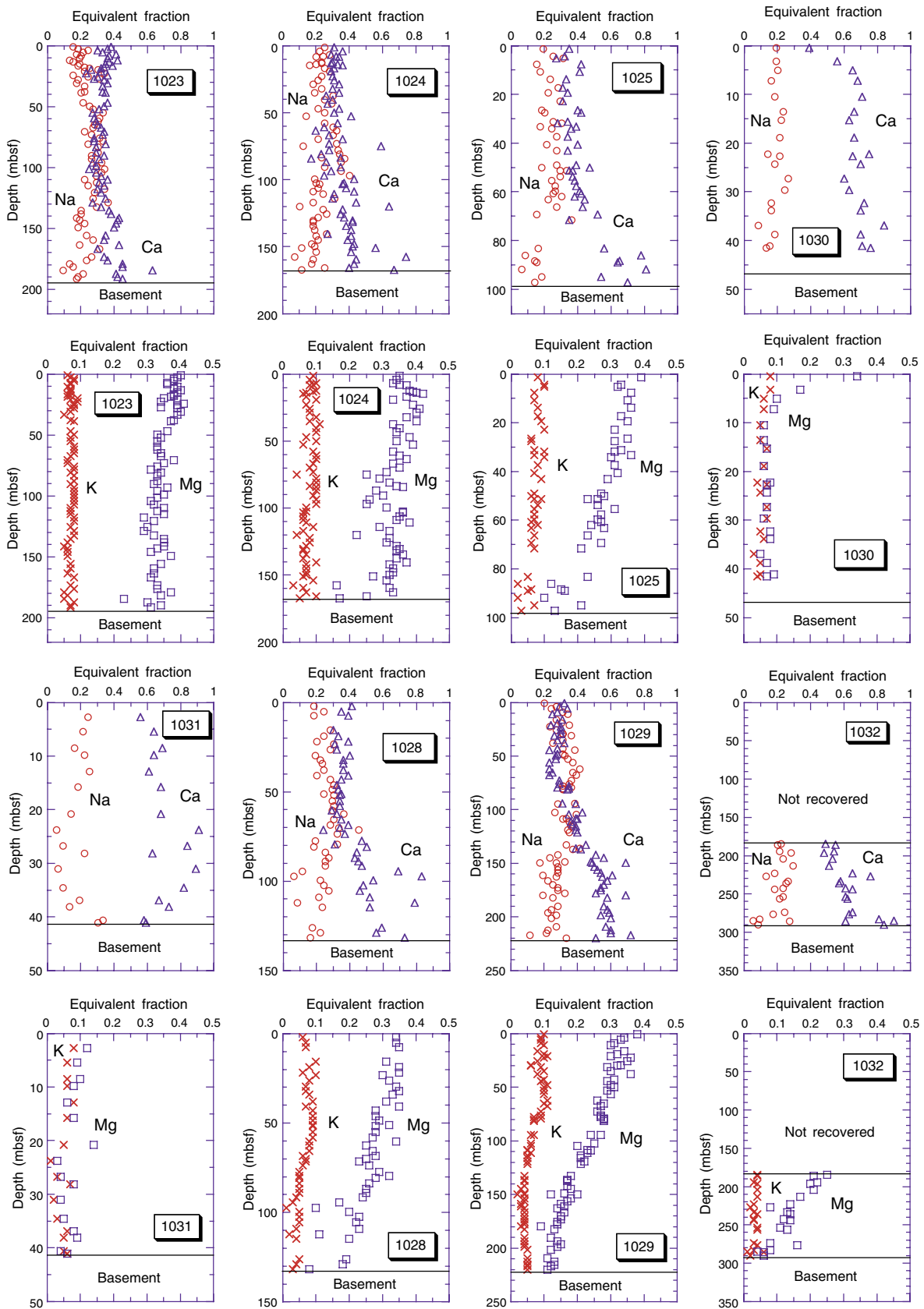


Figure 2. Plots of equivalent fractions of exchangeable cations vs. depth in Sites 1023–1032.

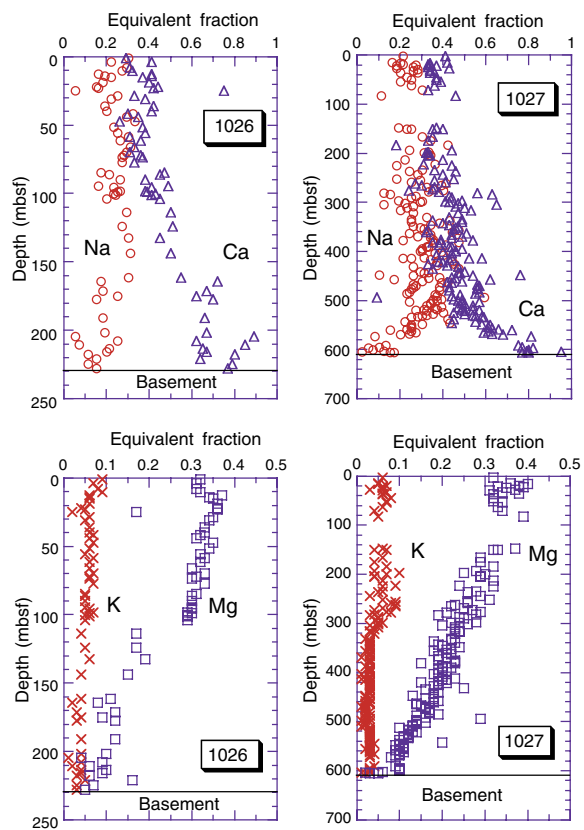


Figure 2 (continued).