32. TRACE ELEMENTS IN CRETACEOUS BASALTS AT 25°N IN THE ATLANTIC OCEAN: ALTERATION, MANTLE COMPOSITIONS, AND MAGMATIC PROCESSES

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INTRODUCTION

Previous basement drilling legs in the Atlantic Ocean (Legs 37, 45, 46, and 49) sampled relatively young crust on the flanks of the Mid-Atlantic Ridge. Drilling on Legs 51, 52, and 53 sampled much older crust, thus providing an opportunity to compare alteration processes in young and old crust and to study variations in magmatic processes and mantle compositions with time. We have investigated the compositional effects of alteration by studying K_2O, Rb, and Cs, which are particularly sensitive to low-temperature sea-floor alteration. Magmatic processes and mantle compositions have been monitored by a study of hygromagmaphile elements (low-partition coefficient elements) belonging to the second and third transition series, together with Th.

ANALYTICAL METHODS AND RESULTS

SiO_2, Al_2O_3, Fe_2O_3 (total iron), MgO, CaO, K_2O, and TiO_2 were analyzed on the *Glomar Challenger* by X-ray fluorescence (XRF) spectrometry according to the method described by Bougault (1977). MnO and P_2O_5 were analyzed on shore by XRF. In addition, Na_2O was determined by X-ray spectrometry using a T1AP diffracting crystal which permits quantitative measurements from a glass disk composed of l g of sample and 5 g of $Li_2B_4O_7$. The standardization curve used for these analyses is shown in Figure 1.

V, Co, Ni, Rb, Sr, Y, Zr, and Nb also were measured by XRF spectrometry. Matrix and instrumental effects were corrected following the procedures of Bougault and Cambon (1977). When necessary, corrections were also made for spectral interferences (TiK_β for VK_α, for example) and enhancement effects (Fe for Cr).

Sc, Co, Ni, Rb, Zr, Sb, Cs, La, Eu, Tb, Hf, Ta, and Th were measured by neutron activation analysis using epithermal neutrons (OSIRIS reactor in Saclay by Groupe Pierre Süe). The use of these particles is advantageous, for it strongly diminishes interaction of ^{46}Sc and ^{55}Fe. Irradiations were performed in Cd vials. Measurements were made with the Ge-Li detector (resolution 2 Kev at 1.33 Mev) from four days to one month after irradiation.

Because both XRF and neutron activation methods were used for measuring Co, Ni, Rb, and Zr, their results can be compared here. Neutron activation measurements of Zr are less accurate than XRF determinations; hence, the latter have been used for interpretations.

Major oxide data are listed in Table 1, trace element data in Table 2.

ALTERATION

Significant differences in the degree and type of alteration have been recognized between Hole 417A on the one hand and Holes 417D and 418A, on the other. The basalts of Hole 417A are highly altered and several alteration zones have been recognized based on the occurrence of chlorite, scolecite, and analcite. Smectite occurs throughout the hole and celadonite in limited areas. K_2O varies from about 6 per cent in very altered rocks at the top of the hole to less than 0.2 per cent in fresh tholeiites at the bottom. The variation in K_2O parallels a general decrease in alteration intensity with depth. In contrast, basalts recovered from Hole 417D, some 400 meters from Hole 417A, and Hole 418A are surprisingly fresh, often containing fresh glass. The basalts from Holes 417D and 418A are mainly plagioclase phyric but some also contain olivine and clinopyroxene phenocrysts. These rocks are similar to unaltered basalts recovered from the lower part of Hole 417A. Hence, fresh and altered basalts can be directly compared, providing a good opportunity to study the behavior of K_2O, Rb, and Cs during alteration.

Plots of Rb and Cs for Hole 417A basalts against depth (Figure 2) show a very srong similarity between these two alkali metals. K_2O, plotted as either a major oxide or a minor element, shows exactly the same trend. Basalts at the bottom of Hole 417A and in Holes 417D and 418A have Rb and Cs values very close to those of unaltered tholeiites (White and Bryan, 1977). In Hole 417A, Rb and Cs values decrease down the hole, in agreement with the general decrease in intensity of alteration with depth.

Based on absolute values and element ratios, the basement section at Hole 417A can be divided into three parts: (a) Core 23 to Core 30, (b) Core 30 to Core 40, and (c) Core 40 to Core 46. The boundary at Core 30 is based on K_2O/Rb and Cs/Rb ratios (Figures 3 and 4). Rocks above this boundary have higher K_2O/Rb and lower Cs/Rb ratios than rocks below it. The rocks in the upper zone have no counterpart in other holes, but the basalts in the interval from Core 30 to Core 40 have Cs/Rb ratios similar to those of slightly altered basalts from Hole 417D. From Core 40 to the bottom of the hole the basalts are characterized by low K_2O, Rb, and Cs values, close to those of unaltered basalt. Rocks in this interval have a composition similar to those from Hole 395A (about 7 m.y. old) at 22°N.

In addition to these general trends, variations in these elements are observed within single cores. For example, in

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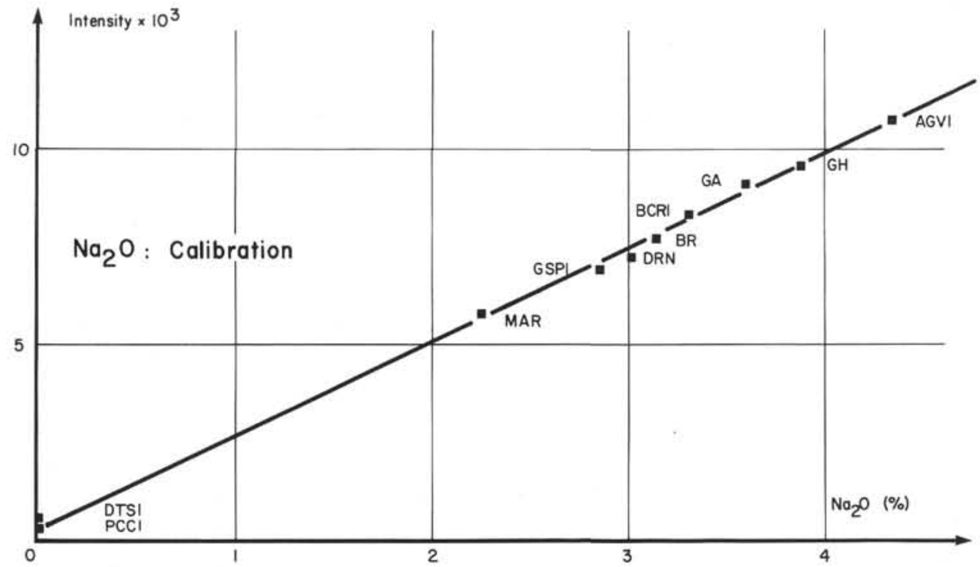

Figure 1. *Na_2O: XRF spectrometry calibration curve obtained from interlaboratory standards (squares) using a T1AP crystal (2 d = 2.590 nm). The glass disks are made of 1 gram of ignited sample and 5 grams of $Li_2B_4O_7$. The counting time is 200 s for a peak at 55.48° and that of the backgrounds are 100 s at 56.25° and 100 s at 54.00°.*

Core 35, Hole 417A, Rb varies from 12 to 29 ppm, Cs from 0.22 to 0.56 ppm, and K_2O from 0.98 to 2.04 wt. %. These differences probably reflect water circulation along local cracks and veins.

The generally high Rb, Cs, and K_2O values observed in Hole 417A are not found in Hole 417D, just 400 meters away. In the latter hole, concentrations of these elements are close to those of unaltered tholeiites, except for locally high values associated with fractures. This difference in alteration has been attributed to a difference in basement topography (Donnelly, 1978). Hole 417A is located on a topographic high that remained exposed for approximately 20 m.y. after eruption. According to Donnelly, "we might regard the 'hill' as a sort of upside down drain, which, lacking an impermeable sedimentary cap, becomes the principal conduit for convective effluent water."

None of the previously drilled basalts from the Atlantic Ocean is as altered as those from Hole 417A. For example, the maximum K_2O, Rb, and Cs values in basalts from Hole 395A (Bougault et al., in press) are an order of magnitude lower than in those from Hole 417A. If the alteration at Hole 417A occurred relatively soon after eruption, other highly altered hills should be present in young crust, up to 10 to 20 m.y. old. Such hills have not been drilled, but all sites drilled in young crust were selected in basement depressions where sediments are at least 100 meters thick.

K_2O and Cs, plotted against Rb in Figures 3 and 4, show a good correlation as expected, but the scatter of points is far higher than the analytical precision (K_2O ±0.02%, Rb ±2 ppm, and Cs ±0.02 ppm). Their concentrations correlate reasonably well with the volume of secondary minerals in the rock, but Rb and K_2O values may also reflect the proportions of different mineral species. This could account for the scatter of points in Figures 3 and 4.

Two important questions, whether these alkali metal data reflect sea water-basalt interaction and whether they are compatible with the budget of these elements in the ocean, may be approached by comparing the uptake of these elements in rocks during alteration with their residence time in the ocean. The primary reactions regulating the concentrations of alkali metals in sea water involve ion-exchange equilibria; for alteration this involves replacement of K ions by Rb and Cs in K-bearing minerals. For positively charged ions, retention increases with increasing ionic radius. This is verified in the samples studied here which have much higher Cs/Rb ratios than sea water. Hence, the residence times of alkali metals in sea water decrease with increasing ionic radius, as follows: K: 1.1×10^7 s, Rb: 2.7×10^5 s, and Cs: 4×10^4 s. If we define the uptake of an element from sea water from the ratio of the altered rock concentration to sea-water concentration, we obtain values of 44.7, 242, and 1120 for K, Rb, and Cs, respectively (Table 3). In Holes 417A and 417D the uptake of K, Rb, and Cs is inversely proportional to residence time, suggesting that most of the alkali metals in the altered rocks were derived from sea water. If this is so, alteration of the oceanic crust could play an important role in the budget of these elements in sea water.

Sr uptake during alteration probably reflects growth of secondary carbonates. In this study only samples believed to be carbonate-free were analyzed, and Sr variation is much less in the altered rocks than alkali-metal variation. Because secondary Sr is present only in the carbonates, acid-leaching of samples yields reasonable $^{87}Sr/^{86}Sr$ ratios in moderately altered samples.

MAGMATIC PROCESSES AND MANTLE COMPOSITIONS

A systematic study of the first three elements of the second and third transition series in samples obtained from the FAMOUS area and from Legs 45, 46, and 49 of the *Glomar Challenger* has led to a better understanding of the

TABLE 1
Major Oxide Data (wt. %), Holes 417A, 417D, and 418A

Sample (Interval in cm)	24-1, 99-101	24-2, 119-115	26-1, 140-143	26-2, 58-61	26-5, 28-30	27-1, 118-120	29-1, 72-74	29-3, 4-7	29-6, 30-32	30-3, 92-95	31-1, 8-10	32-3, 105-108
						Leg 51, Hole 417A						
SiO_2	54.19	51.86	48.64	47.70	49.86	50.91	49.75	49.79	48.94	48.94	48.59	52.24
Al_2O_3	20.64	19.97	15.90	16.85	19.13	19.81	17.90	17.64	17.76	16.88	17.65	19.61
FeO												
Fe_2O_3	10.19	11.92	13.35	14.71	12.06	9.95	8.93	9.48	9.90	11.24	9.69	9.74
MnO	0.12	0.16	0.20	0.22	0.14	0.14	0.16	0.17	0.16	0.17	0.12	0.13
MgO	3.06	3.33	6.58	5.41	4.79	4.10	5.49	5.32	5.44	5.63	5.11	4.21
CaO	3.66	5.52	8.08	6.68	7.68	9.91	12.53	12.39	12.77	12.15	11.48	9.74
Na_2O												
K_2O	6.38	4.26	2.89	3.19	3.03	2.89	1.16	0.70	0.80	0.72	1.64	2.14
TiO_2	1.80	1.69	1.87	1.92	1.61	1.58	1.48	1.42	1.43	1.41	1.51	1.68
P_2O_5	0.35	0.31	0.17	0.17	0.27	0.16	0.12	0.14	0.11	0.14	0.22	0.32
Total	99.39	99.01	97.68	96.85	98.57	99.45	97.52	97.05	97.31	97.28	96.01	99.81
Loss on ignition	4.75	3.75	4.35	3.20	5.45	5.75	2.75	1.85	3.50	2.60	4.90	3.25

TABLE 1 – *Continued*

Sample (Interval in cm)	40-3, 17-19	41-1, 103-105	41-4, 136-139	42-2, 20-22	43-5, 22-25	44-1, 12-15	44-3, 58-68	46-1, 56-59	21, CC	22-1, 53-67	22-4, 18-21	22-5, 57-60
									Leg 51, Hole 417D			
SiO_2	48.75	49.28	49.61	49.66	49.64	48.15	49.73	48.70	50.29	50.68	48.77	48.85
Al_2O_3	17.73	16.97	17.39	17.65	16.47	16.23	16.02	15.92	19.84	18.55	16.32	16.39
FeO												
Fe_2O_3	8.87	10.57	9.94	9.68	11.13	11.56	11.08	11.23	10.53	12.74	10.65	10.80
MnO	0.19	0.19	0.20	0.20	0.17	0.17	0.18	0.21	0.12	0.10	0.21	0.19
MgO	6.51	6.27	5.37	6.28	6.41	6.37	6.92	6.46	5.22	5.02	7.13	6.37
CaO	14.41	13.47	13.89	13.43	12.69	12.59	12.47	13.85	9.01	9.50	12.81	13.46
Na_2O												
K_2O	0.07	0.00	0.00	0.01	0.02	0.04	0.08	0.22	1.31	1.59	0.06	0.09
TiO_2	1.27	1.40	1.49	1.53	1.41	1.44	1.45	1.44	1.99	1.77	1.41	1.42
P_2O_5	0.12	0.12	0.10	0.15	0.11	0.13	0.12	0.12	0.16	0.22	0.10	0.12
Total	97.92	98.27	97.99	98.59	98.05	96.68	98.05	98.15	98.47	100.17	97.46	97.69
Loss on ignition	2.05	0.75	1.55	1.00	0.75	0.30	0.25	2.20	4.25	1.55	1.55	2.30

TABLE 1 – *Continued*

Sample (Interval in cm)	31-4, 27-29	32-1, 96-98	32-6, 60-62	33-3, 128-131	34-3, 37-40	34-5, 83-86	35-4, 36-79	36-3, 130-132	37-5, 116-119	38-5, 102-106	39-3, 39-42	40-1, 114-117
SiO_2	49.76	50.53	51.01	49.42	49.44	48.76	49.33	49.57	49.37	49.10	49.64	48.68
Al_2O_3	17.36	17.17	16.78	16.62	16.67	16.79	17.23	16.74	17.01	14.69	14.83	17.02
FeO												
Fe_2O_3	10.42	10.80	10.01	10.92	9.50	11.03	10.22	11.04	10.75	14.28	11.93	9.99
MnO	0.15	0.15	0.12	0.15	0.16	0.16	0.16	0.19	0.19	0.24	0.19	0.18
MgO	5.70	5.79	5.85	6.16	5.31	5.75	6.40	5.94	6.75	6.32	7.08	6.39
CaO	13.14	12.54	12.33	12.47	15.52	13.57	12.66	14.07	12.84	10.83	12.64	13.70
Na_2O												
K_2O	0.18	0.06	0.07	0.12	0.13	0.14	0.04	0.27	0.06	0.68	0.03	0.04
TiO_2	1.43	1.44	1.49	1.36	1.36	1.45	1.39	1.40	1.47	1.71	1.49	1.36
P_2O_5	0.11	0.12	0.10	0.12	0.12	0.15	0.11	0.13	0.13	0.16	0.19	0.18
Total	98.25	98.60	97.76	97.34	98.21	97.80	97.54	99.35	98.57	98.01	98.02	97.54
Loss on ignition	0.85	0.25	0.60	0.60	2.85	1.00	0.25	0.65	1.35	0.85	0.40	1.30

TABLE 1 – *Continued*

Sample (Interval in cm)	49-2, 20-22	49-2, 114-116	50-2, 88-90	51, CC	52-2, 41-43	52-4, 7-9	52-5, 73-75	53-1, 110	54-1, 7-9	54-5, 42-44	55-4, 96	57, 70	58-4, 139-141
SiO_2	49.70	51.60	50.90	49.40	49.70	48.20	49.30	48.60	49.40	50.80	48.20	48.6	49.70
Al_2O_3	16.50	17.70	15.70	15.50	14.70	14.80	15.80	15.50	15.70	14.70	14.90	15.3	16.30
FeO													
Fe_2O_3	10.13	9.84	10.32	12.33	11.78	12.00	11.78	11.78	12.00	11.67	12.11	12.3	10.72
MnO	0.12	0.15	0.17	0.18	0.17	0.22	0.22	0.20	0.19	0.19	0.21	0.2	0.15
MgO	7.23	6.39	6.60	6.78	7.24	6.96	6.30	6.34	6.41	6.48	6.62	7.0	6.77
CaO	11.30	10.10	13.20	12.40	12.50	13.90	12.60	13.20	12.50	12.30	13.20	13.9	12.40
Na_2O	2.44	2.54	2.17	2.08	1.95	1.93	2.08	2.28	2.40	2.54	2.43	2.19	2.52
K_2O	0.13	0.80	0.06	0.26	0.06	0.28	0.08	0.37	0.20	0.03	0.03	0.03	0.37
TiO_2	1.65	1.67	1.56	1.46	1.39	1.43	1.61	1.56	1.59	1.50	1.48	1.56	1.38
P_2O_5	0.17	0.20	0.16	0.16	0.13	0.16	0.16	0.14	0.16	0.15	0.17	0.16	0.16
Total	99.37	100.99	100.84	100.55	99.62	99.88	99.93	99.97	100.55	100.36	99.35	101.8	100.47
Loss on ignition													

TABLE 1 – *Continued*

Sample (Interval in cm)	33-5, 90-93	34-1, 28-31	34-3, 10-13	35-1, 125-128	35-4, 100-103	35-4, 111-113	36-3, 63-65	37-1, 31-34	38-3, 46-49	38-7, 35-38	39-1, 37-40	40-1, 14-17
SiO_2	50.20	49.23	49.66	47.97	49.40	49.11	48.90	48.74	48.62	49.67	49.16	48.67
Al_2O_3	18.15	16.54	17.07	19.44	17.97	17.76	17.54	16.75	18.02	17.39	17.60	18.35
FeO												
Fe_2O_3	7.78	10.89	10.19	6.38	13.18	10.39	10.63	10.81	9.52	10.69	11.54	9.54
MnO	0.15	0.15	0.23	0.13	0.11	0.15	0.15	0.16	0.19	0.15	0.13	0.13
MgO	5.45	6.09	7.05	3.57	3.57	4.21	5.53	6.80	6.17	5.38	4.59	4.40
CaO	12.92	12.45	13.41	18.53	7.67	13.32	12.57	13.16	14.12	11.60	11.55	13.30
Na_2O												
K_2O	1.43	0.59	0.76	1.20	2.04	0.98	0.78	0.03	0.00	0.83	1.15	0.99
TiO_2	1.54	1.41	1.42	1.53	1.65	1.44	1.47	1.31	1.35	1.60	1.52	1.57
P_2O_5	0.12	0.10	0.14	0.12	0.32	0.20	0.15	0.14	0.12	0.27	0.26	0.18
Total	97.74	97.45	99.93	98.87	95.91	97.56	97.72	97.90	98.11	97.48	97.50	97.13
Loss on ignition	3.35	1.15	2.30	7.45	5.10	3.60	2.20	0.30	0.70	3.35	1.70	5.25

TABLE 1 – *Continued*

Sample (Interval in cm)	26-2, 9-12	26-4, 75-77	27-3, 43-45	27-5, 25-27	28-2, 37-39	28-3, 66-68	28-4, 102-104	29-2, 83-86	29-3, 57-60	30-4, 57-60	30-8, 70-73	31-1, 29-31
SiO_2	49.03	49.16	49.79	49.34	49.37	50.95	49.34	50.85	50.0	49.14	50.42	49.01
Al_2O_3	16.45	16.64	17.17	17.27	17.36	16.31	17.15	17.54	17.25	17.09	18.16	17.04
FeO												
Fe_2O_3	10.78	11.26	10.04	9.97	10.45	11.92	10.05	9.70	10.33	10.53	9.73	11.75
MnO	0.15	0.18	0.15	0.15	0.16	0.11	0.16	0.14	0.15	0.14	0.09	0.10
MgO	6.22	6.55	5.82	6.38	6.07	6.16	6.23	5.44	5.65	5.54	5.50	5.11
CaO	13.41	12.06	13.75	13.48	14.08	9.98	14.52	13.00	13.66	13.19	11.17	11.86
Na_2O												
K_2O	0.25	0.13	0.04	0.03	0.14	1.04	0.04	0.04	0.04	0.17	0.40	0.84
TiO_2	1.49	1.53	1.44	1.36	1.42	1.39	1.27	1.39	1.39	1.41	1.54	1.39
P_2O_5	0.12	0.13	0.11	0.11	0.13	0.07	0.11	0.11	0.13	0.12	0.13	0.13
Total	97.90	97.64	98.31	98.09	99.18	97.93	98.87	98.21	98.60	97.33	97.14	97.23
Loss on ignition	2.15	0.90	1.55	1.95	1.00	3.45	1.25	0.75	1.80	1.90	1.50	2.85

TABLE 1 – *Continued*

Sample (Interval in cm)	41-3, 102-105	41-3, 43-46 and 50-52	42-3, 121-125 and 125-127	43-1, 78-81	43-2, 4-6	43-4, 130-132	43-5, 93-95	43-6, 13-15	44-1, 28-31	45-1, 35-37 and 39-41	48-5, 100-102	48-7, 84-86
SiO_2	49.90	50.07	50.81	49.38	49.80	49.57	49.65	48.83	50.27	49.16	49.60	50.30
Al_2O_3	17.61	17.13	17.12	15.75	16.24	15.79	15.55	15.75	17.44	15.89	16.20	16.50
FeO												
Fe_2O_3	10.19	9.98	10.22	11.40	11.68	12.25	10.34	11.23	10.54	11.01	9.08	10.82
MnO	0.17	0.17	0.16	0.19	0.16	0.19	0.18	0.19	0.15	0.17	0.15	0.19
MgO	6.57	6.85	6.46	6.71	6.71	6.65	6.10	6.77	6.83	6.18	6.60	7.25
CaO	10.92	13.60	13.77	12.77	12.06	13.35	15.12	12.54	12.60	12.69	13.40	12.60
Na_2O											2.31	2.25
K_2O	0.21	0.01	0.04	0.07	0.19	0.14	0.21	0.04	0.08	0.15	0.12	0.03
TiO_2	1.61	1.16	1.17	1.58	1.60	1.49	1.50	1.52	1.75	1.63	1.55	1.54
P_2O_5	0.17	0.17	0.16	0.19	0.16	0.19	0.18	0.19	0.15	0.15	0.17	0.15
Total	97.35	99.14	1.25	98.04	98.60	99.62	98.83	97.06	99.81	97.03	99.18	101.63
Loss on ignition	1.70	0.90	99.91	1.50	1.10	1.15	2.60	1.25	2.00	0.75		

TABLE 1 – *Continued*

Sample (Interval in cm)	59-5, 136	62-1, 94-96	63-2, 64-66	64-4, 87-89	64-6, 15-17	65-2, 7-9	65-4, 127-129	65-6, 37-39	66-3, 44-46	66-5, 69-73	67-2, 29-31	67-5, 33-35	67-7, 35-37
SiO_2	50.50	50.10	49.30	50.30	50.10	50.30	49.70	48.80	50.60	49.20	49.60	49.20	50.70
Al_2O_3	15.20	16.50	16.50	14.40	16.40	16.10	16.60	16.90	16.50	17.50	16.20	16.30	16.00
FeO													
Fe_2O_3	13.44	11.33	10.70	12.00	10.86	10.83	11.22	9.97	11.04	10.08	11.03	11.22	10.53
MnO	0.16	0.19	0.19	0.22	0.18	0.19	0.19	0.16	0.19	0.17	0.12	0.16	0.14
MgO	6.74	6.07	5.31	7.69	6.63	6.43	6.94	7.11	6.72	5.46	6.97	7.00	6.36
CaO	10.70	13.80	13.40	11.90	12.90	13.80	12.80	12.60	12.90	14.00	12.90	12.70	12.80
Na_2O	2.15	2.02	1.93	2.13	2.10	1.93	2.00	1.95	1.98	2.06	1.94	1.92	2.07
K_2O	1.26	0.04	0.03	0.04	0.02	0.03	0.05	0.03	0.03	0.02	0.02	0.04	0.04
TiO_2	1.36	1.47	1.43	1.66	1.39	1.37	1.36	1.12	1.36	1.37	1.33	1.34	1.42
P_2O_5	0.13	0.13	0.15	0.16	0.16	0.15	0.13	0.12	0.20	0.14	0.18	0.19	0.20
Total	101.64	101.65	98.94	100.50	100.74	101.13	100.99	98.76	101.52	100.00	100.29	100.07	100.26
Loss on ignition													

TABLE 1 – *Continued*

Sample (Interval in cm)	68-2, 48-50	68-3, 92-94	68-4, 18-20	15-1, 46-48	15-3, 36-38	16-1, 13-15	16-1, 118-120	17-2, 72-75	17-4, 139-141	18-4, 48-50	18-5, 94-96	19-4, 102-105
				Leg 52, Hole 418A								
SiO_2	48.30	51.30	50.10	49.10	49.96	50.50	50.00	50.80	50.80	49.50	50.50	50.50
Al_2O_3	22.00	15.30	15.50	16.50	16.50	17.80	18.40	18.20	16.70	15.90	15.90	15.60
FeO												
Fe_2O_3	8.02	11.67	12.00	9.92	9.44	8.26	8.21	8.73	9.36	10.30	11.44	10.22
MnO	0.11	0.15	0.15	0.15	0.16	0.16	0.13	0.13	0.14	0.16	0.18	0.16
MgO	5.20	6.88	7.04	6.88	7.44	7.28	7.67	7.19	6.91	7.11	7.81	7.44
CaO	12.60	12.10	12.60	13.20	13.10	11.80	11.00	12.00	12.90	12.80	10.30	12.80
Na_2O	1.94	2.19	8.06	2.08	2.06	2.50	2.54	2.46	2.10	1.99	2.71	2.03
K_2O	0.06	0.07	0.03	0.04	0.04	0.09	0.06	0.10	0.05	0.03	0.10	0.03
TiO_2	0.91	1.65	1.50	1.12	1.11	1.28	1.31	1.28	1.16	1.08	1.55	1.11
P_2O_5	0.09	0.22	0.19	0.11	0.11	0.13	0.10	0.12	0.10	0.12	0.13	0.11
Total	99.29	101.53	101.17	99.10	99.92	99.80	99.42	101.01	100.22	98.99	100.62	100.00
Loss on ignition												

TABLE 1 – *Continued*

Sample (Interval in cm)	20-7, 62-64	22-2, 33-35	24-1, 50-52	24-1, 76-79	25-1, 66-67	25-2, 87-89	26-2, 14-17	26-4, 111-114	28-4, 120-122	29-1, 35-37	30-1, 50-52	33-1, 18-20
SiO_2	50.60	50.90	50.30	50.40	50.80	50.00	50.90	49.70	50.50	49.80	49.70	49.50
Al_2O_3	16.00	16.20	16.00	17.00	15.30	15.70	16.00	18.30	18.30	18.20	19.50	18.90
FeO												
Fe_2O_3	10.39	10.98	10.01	9.57	10.32	11.11	10.94	9.14	8.81	8.20	7.93	8.28
MnO	0.16	0.17	0.16	0.12	0.16	0.16	0.17	0.21	0.17	0.23	0.14	0.18
MgO	7.53	6.28	7.30	6.11	7.40	7.81	6.82	7.03	6.60	6.78	6.51	6.81
CaO	12.80	13.40	13.20	12.20	12.90	12.40	13.70	12.60	12.10	13.20	13.40	12.30
Na_2O	2.10	2.09	2.02	2.34	2.30	2.23	1.96	2.25	2.60	2.56	2.36	2.59
K_2O	0.03	0.05	0.03	0.08	0.04	0.04	0.03	0.07	0.12	0.36	0.06	0.60
TiO_2	1.13	1.15	1.13	1.18	1.31	1.39	1.13	1.28	1.27	1.27	1.06	1.25
P_2O_5	0.11	0.12	0.11	0.12	0.13	0.11	0.11	0.12	0.12	0.12	0.10	0.14
Total	100.85	101.34	100.26	99.12	100.66	100.95	101.76	100.70	100.59	100.72	100.76	100.55
Loss on ignition												

TABLE 1 – *Continued*

Sample (Interval in cm)	34-1, 76-78	36-4, 18-20	38-4, 34-36	39-1, 119-121	41-1, 40-42	42-4, 89-91	44-2, 34-36	45-3, 82-84	45-4, 9-12	47-1, 27-30	48-5, 32-34
SiO_2	50.20	49.50	50.20	50.00	49.70	49.80	50.10	49.00	49.20	49.50	49.60
Al_2O_3	18.00	17.30	17.50	17.60	18.50	18.40	16.20	15.20	17.10	16.60	16.40
FeO											
Fe_2O_3	9.03	9.24	9.89	9.82	9.80	10.00	10.60	10.83	10.31	10.22	9.78
MnO	0.16	0.20	0.24	0.20	0.14	0.15	0.17	0.20	0.16	0.16	0.16
MgO	6.48	6.41	6.[illegible]8	6.99	5.50	5.40	7.87	6.94	6.65	8.17	7.45
CaO	13.30	13.60	12.70	13.70	14.50	14.30	13.20	15.50	14.20	12.90	12.70
Na_2O	2.30	2.39	2.22	2.26	2.25	2.00	1.86	1.99	1.88	1.92	1.82
K_2O	0.02	0.01	0.04	0.08	0.16	0.02	0.03	0.17	0.03	0.03	0.01
TiO_2	1.18	1.17	1.24	1.24	1.09	0.99	1.07	1.17	1.04	1.04	1.04
P_2O_5	0.11	0.11	0.13	0.11	0.11	0.09	0.11	0.10	0.11	0.10	0.10
Total	100.78	99.93	101.20	102.00	101.75	101.15	101.21	101.10	100.68	100.64	99.06
Loss on ignition											

geochemical behavior of these elements in terms of magmatic processes and mantle compositions (Bougault et al., 1979; Wood et al., 1979). The chief conclusions reached at the end of Leg 49 are:

a) **Geochemical behavior of the elements:** Y and heavy rare earths show very little fractionation, confirming a well-known characteristic of these elements. There is no fractionation of element pairs such as Zr-Hf and Nb-Ta. The elements can be classified according to their partition coefficients as follows:

Y~Tb (heavy rare earths) > Zr~Hf > Nb~Ta

These results agree with the predicted behavior of these elements based on their positions in the Periodic Table (Treuil, 1973).

b) **Mantle composition:** A primordial mantle material exists, homogeneous at the scale of the North Atlantic and characterized by Y/Tb, Zr/Hf, and Nb/Ta ratios very close to those in chondrites.

c) **Mantle differentiation:** Variable ratios of very low partition coefficient elements (insensitive to partial melting or fractional crystallization), such as Ta and Th, suggest that differentiation has occurred in the mantle. Differences in La/Ta ratios between the FAMOUS area, 45°N, and the Reykjanes Ridge on the one hand, and 22°N on the other, suggest at least two types of mantle differentiation.

d) **Alteration:** Concentrations of these elements do not reflect sea-water alteration of the basalts.

Conclusions a and b were deduced from the fact that when data from samples studied from the FAMOUS area and from Legs 45, 46, and 49 were plotted, the resulting lines passed through the origin for the ratios Zr/Hf and Nb/Ta and fell within a narrow band for Y/Tb (Figures 5, 6, and 7). If we superimpose the data from Legs 51 and 52 on these three diagrams, they appear to fall on the same lines. Thus, the geochemical behavior of these elements deduced from earlier studies is confirmed by data from Legs 51 and 52. These data also confirm the existence of a primordial mantle and show its composition to have persisted through the last 100 m.y. The essentially chondritic ratios found for Y/Tb, Zr/Hf, and Nb/Ta in basalts from Legs 51 and 52 are probably characteristic of the mantle itself.

Ta/Th ratios for North Atlantic basalts are plotted in Figure 8, and different lines in the diagram correspond to different ratios of these elements at different sites. The highest ratios correspond to the greatest degree of mantle differentiation prior to the melting event giving rise to the drilled basalts. Based on this ratio, basalts at Sites 395 and 396 (22°N) show the highest degree of differentiation from a primordial mantle. In terms of absolute concentrations of these elements, these basalts were derived from the "most depleted" mantle. Data for Legs 51 and 52 fall on the same line as young crust at 22°N, suggesting that the mantle in both locations underwent similar differentiation from the primordial mantle. Absolute concentrations in basalts from Legs 51 and 52 are lower than in those from Legs 45 and 46, suggesting different degrees of partial melting from a similar mantle material. If this interpretation is correct, different ratios should exist for two hygromagmaphile elements having partition coefficients with different orders of magnitude. Figure 9 clearly shows different ratios for two such elements (Y and La) between the two areas.

On the La/Ta diagram (Figure 10) all samples from 36°N, 45°N, and 63°N fall on the same line passing through the origin; however, samples from young crust at 22°N do not. Based on Ta/Th ratios, the basalts at 22°N correspond to the most differentiated mantle material. Such a high degree of differentiation might result in a change in the mineralogical composition of the mantle material, which in turn might modify the La and Ta partition coefficients. This could explain the two different lines obtained. La/Ta ratios for old basalts sampled on Legs 51 and 52 (25°N) fall on the same line as ratios for young basalts drilled on Legs 45 and 46 (22°N), supporting the notion of compositional homogeneity along a "flow line" at a given latitude.

SUMMARY AND CONCLUSIONS

Old basalts (108 m.y. old) recovered on Legs 51 and 52 can be compared with young basalts drilled at 22°N on Legs 45 and 46 in order to test for secular variations in alteration, magmatic processes, and mantle compositions.

Alteration: Basalts in Hole 417A have very high concentrations of K_2O, Rb, and Cs, which generally decrease with depth in the hole; bottom-hole concentrations correspond to those of unaltered tholeiites. Basalts in Hole 417D are very little altered and alkali-metal concentrations are similar to those of fresh basalts. Alkali-metal ratios in the altered basalts do not correspond to ratios in sea water; however, the uptake of alkali metals in the basalts due to alteration is in agreement with the residence times of these metals in the ocean.

Alteration of the basalts in Hole 417A probably took place within 20 m.y. after eruption, based on the length of time these rocks were exposed on the sea floor. A similar high degree of alteration has not yet been found in young crust (~ 20 m.y. old), but this may reflect the inability to drill basement sites that lack a significant sediment cover.

Magmatic Processes: Data for Legs 51 and 52 on Y, Zr, Nb, La, Tb, Hf, Ta, and Th confirm the predicted geochemical behavior of these elements. The trace element data are compatible with the existence of a primordial undifferentiated mantle, characterized by Y/Tb, Zr/Hf, and Nb/Ta ratios very close to chondritic values, underlying the North Atlantic Ocean for the last 108 m.y. This mantle material has undergone similar degrees of differentiation, evidenced by high Ta/Th ratios, in young basalts drilled at 22°N (Legs 45 and 46), and in old basalts drilled at 25°N (Legs 51 and 52).

La/Ta ratios are the same in young basalts at 22°N and old basalts at 25°N; however, this ratio varies with latitude, being lower north of 36°N. This is believed to reflect a change in mineralogical composition of the mantle as a consequence of the high degree of differentiation suggested by the Ta/Th ratios.

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TABLE 2
Trace Element Data (ppm), Holes 417A, 417D, and 418A

Sample	Sc	Ti	V	Cr	Mn	Fe	Co		Ni		Rb		Sr		Zr	Nb	Sb	Cs	La	Eu	Tb	Hf	Ta	Th	
(Interval in cm)	NA	XRF	XRF	XRF	XRF	XRF	XRF	NA	XRF	NA	XRF	NA	XRF	Y	XRF	XRF	NA	NA	NA	NA	NA	NA	NA	NA	U
Leg 51, Hole 417A																									
23-1, 99-101	46	10790	242	355	910	71270	75	72	104	94	61	59	110		97		0.14	0.86		1.44	0.96	2.54	0.13		
24-2, 113-115		10130	244	265	1130	83370	53		70		51		118		96										
26-1, 140-143		11210	453	303	1590	93370	44		72		28		144		106										
26-2, 58-61		11510	427	304	1730	102890	41		72		34		132		102										
26-5, 28-30	42	9650	292	280	1050	84350	32	29	65	58	43	38	129		81		0.24	0.73		1.59	1.11	2.42	0.13		
27-1, 118-120	42	9470	328	279	1090	69590	43	44	90	85	26	25	127		90		0.28	0.33	2.3	1.26	0.76	2.57	0.12	0.06	0.24
29-1, 72-74	41	8870	328	266	1208	62460	49	50	102	98	10	8	114		76			0.12		1.2	0.76	2.27	0.12		
29-3, 4-7	41	8515	337	259	1310	66310	53	56	119	119	6	6	106		82			0.09	2.2	1.21	0.84	2.40	0.11		
29-6, 30-32	39	8570	335	268	1250	69240	59	61	115	115	9	9	108		74				2.1	0.73	0.72	2.26	0.11	0.07	
30-3, 92-95	38	8450	360	268	1290	78620	44	42	883	77	11	10	104		85		0.02	0.20	2.1	1.09	0.72	2.13	0.11		
31-1, 8-10	42	9050	303	296	940	67770	37	36	74	69	23	20	139		93		0.16	0.44	2.7	1.21		2.33	0.13	0.05	0.47
32-3, 105-108	43	10070	293	298	990	68130	34	32	68	57	10	19	129		82		0.34	0.49	2.6	1.27		2.49	0.13	0.08	0.5
33-5, 90-93	41	9230	327	294	1140	54420		123	169	159	20	6	120		79		0.01	0.01	2.3	1.21	0.74	2.30	0.12		
34-1, 28-31	39	8450	322	262	1140	76170	39	38	82	78	11	12	103		76			0.15		1.2	0.75	2.31	0.11		
34-3, 10-13	38	8510	334	276	1770	71270	56	56	150	130	3		106		81				2.0	1.12	0.70	2.22	0.12	0.06	
35-1, 125-128	40	9170	328	305	1010	44620	48	49	126	114	7	6	146		76				2.0	1.22	0.74	2.27	0.12	0.08	0.21
35-4, 100-103	43	9890	306	334	870	92190	40	(25)	74	67	29	27	161		87		0.94	0.56	3.3	1.36	0.93	2.44	0.12		
35-4, 111-113		8630	346	317	1180	72670	28		78		12	12	113		79		0.13	0.22		1.2	0.78	2.3	0.12		
36-3, 63-65	40	8810	346	305	1140	74350	41	40	75	68	13	13	102		83		14	0.31	2.4	1.23	0.77	2.41	0.11	0.04	0.11
37-1, 31-34	39	7850	312	317	1250	75610	42	44	115	117	0		104		83				1.9	1.17	0.70	2.26	0.11		
38-3, 46-49	38	8090	328	282	1460	66590	40	42	92	95	0.3		105		85				2.1	1.15	0.66	2.22	0.10		
38-7, 35-38	42	8990	343	350	1150	74770	36	35	59	54	13	11	100		76		0.15	0.28		1.21	0.84	2.44	0.12		
39-1, 37-40	41	9110	336	318	980	80710	33	33	56	47	15	12	113		89		0.37	0.32	2.9	1.44	0.94	2.56	0.13		
40-1, 14-17		9410	303	346	1030	66730	37		64		13		280		95										
40-3, 17-19	43	7610	313	373	1470	62040	40	45	119	93	4	4	100		77		0.06	0.08	2.3	1.24	0.73	2.39	0.12	0.13	
41-1, 103-105	39	8390	336	316	1450	73930	43	43	103	102	2		111		85					1.13	0.75	2.37	0.11		
41-4, 136-139		8930	335	284	1560	69520	39		86		0		104		90										
42-2, 20-22	41	9170	363	303	1530	67700	44	43	100	95	0		104		94				2.3	1.21		2.33	0.12	0.08	
43-5, 22-25	39	8450	356	314	1300	77850	45	41	116	83	0		98		90					1.19	0.79	2.21	0.11		
44-1, 12-15	39	8630	335	287	1320	80850	41	41	87	86	1		101		91				2.2	1.24	0.73	2.41	0.10		
44-3, 58-68		8690	346	290	1390	77500	41		87		1		104		88		0.04	0.04							
46-1, 56-59	39	8630	348	282	1660	78550	64	61	129	120	3	3	104		86				2.1	1.14	0.73	2.20	0.11	0.05	0.11
Leg 51B, Hole 417D																									
21, CC	50	11900	445	281	930	73650	59	58	136	129	4.9	4.6	137.7	36	111	3	0.12		3.2	1.42	0.76	3.05	0.15	0.10	1.67
22-1, 63-67		10600	417	291	750	89108	49		124		26.1		128.8	46	99	4									
22-4, 18-21		8450	339	255	1610	74490	45		112		6.4		125		92										
22-5, 57-60	40	8510	349	245	1450	75540	48	48	112	105	1.8		110.8		77		0.06		2	1.16	0.74	2.24	0.11		0.11
26-2, 9-12	40	8930	355	239	1200	75400	61	61	164	159	2.2	3	112.1		78		0.08	0.02	2.4	1.25	0.76	2.16	0.11	0.06	0.25
26-4, 75-77	42	9170	362	244	1410	78760	48		106	104	2.1		112.7		85		0.04		2.0	1.22	0.87	2.29	0.11	0.07	0.05
27-3, 43-45	40	8630	345	256	1180	70220	43	43	104	96	0.2		114.2		84	<1			2	1.12	0.72	2.20	0.12		0.07
27-5, 25-27		8150	333	261	1200	69730	42	44.3	102	96	0.3		115.5		72										
28-2, 37-39	40	8510	351	247	1240	73090	48	53	95	134	16.2		98.4	35	99	2.6	0.01		2.1	1.20	0.73	2.29	0.11	0.05	0.28
28-3, 66-68	38	8330	291	264.5	860	83370	35		82	75	22.4	22	107.1	28	87	1.8	0.06	0.41	1.6	0.83	0.52	2.04	0.11		0.19
28-4, 102-104	38	7610	310	283	1230	70290	42	43	113	109	0.1		120.4		74	<1			1.7	1.04	0.64	1.96	0.10		0.16
29-2, 83-86		8330	343	259	1070	67840	43		102		0		113.2	37	77.5	2.3									
29-3, 57-60	41	8330	347	270	1140	72250	44	45	114	109	0.3		131.7	39	101	3	0.04		2	1.11	0.73	2.22	0.10		
30-4, 57-60	40	8390	347	263	1100	73650	49	50	120	117	0.9	7	114		81		0.06		1.9	1.15	0.71	2.29	0.11		
30-8, 70-73		9230	370.5	270	720	68060	66	68	130	126	0.5	7	100.8		75		0.17	0.05				2.44	0.12	0.07	
31-1, 29-31	40	8330	355	273	810	82180	20	20	47	42	22.3	22	113.4		85		0.15	0.46	3.2	1.25	0.78	2.07	0.11		
31-4, 27-29	40	8570	352	256	1130	72880	47	47	117	113	3.9	4.4	114.8		81		0.05	0.08	2.0	1.18	0.71	2.23	0.11		0.12
32-1, 96-98	39	8630	354	246	1200	75540	45	44	101	93	0.4		106.4		89				2.0	1.18	0.69	2.21	0.11	0.12	
32-6, 60-62	41	8930	355	263	920	70010	43	44	92	89	0.2		117.5		85		0.04		2.1	1.23	0.71	2.37	0.12	0.09	
33-3, 128-131	39.7	8150	336	230	1130	76380	43	42.8	87	86	0.6		115.6		82				1.9	1.18	0.72	2.23	0.11	0.06	
34-3, 37-40	39	8150	334	258	1220	66450	60	59	160	151	2.1		118.2	37	85	2.4	0.01		1.8	1.08	0.70	2.14	0.11		
34-5, 83-86	40	8690	339	264	1260	77150	61	47	139	106	2.6		113.6		88	1.6	0.05	0.04	2.2	1.17	0.76	2.26	0.11	0.05	
35-4, 3-6 7-9		8330	343	302	1260	71480	48	47.2	131	127	0		112.0		84										

TABLE 2 – *Continued*

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Mn XRF	Fe XRF	Co XRF	Co NA	Ni XRF	Ni NA	Rb XRF	Rb NA	Sr XRF	Y	Zr XRF	Nb XRF	Sb NA	Cs NA	La NA	Eu NA	Tb NA	Hf NA	Ta NA	Th NA	U
36-3, 130-132	40	8390	345	286	1440	77220	47	46.5	122	119	5.9	5	114.1		89	2.5	0.04		2.0	1.15	0.72	2.03	0.11		
37-5, 116-119		8810	353	300	1490	75190	48		128		0		114.3		90	1.8									
38-5, 102-106		10250	416	265	1830	99880	42		81		1.3		122.5		80.5										
39-3, 39-42	42.4	8930	361	279	1440	83440	48	47.4	115	111	0.1		106		92										
40-1, 114-117	41	8150	342	300	1430	69870	47		127	128	0.1		115.3		77				1.8	1.06	0.75	2.06	0.10	0.08	0.05
41-3, 102-105	48	9650	391	333	1285	71270	49		99	101	2.8		128.7	34	66		0.08		2.3	1.2	0.83	2.41	0.13	0.08	0.32
41-5, 43-46 and 50-52		6950	289.5	296	1290	69800	39		115		0		131.9	29	66										
42-3, 121-123 and 125-127	37	7010	294	291	1220	71480	40		106	107	0.4		113.2		67.5				1.6	0.96	0.66	1.72	0.09	0.06	
43-1, 78-81	44	9470	384	280	1500	79740	44	48	108	98	0.		113.3		98				2.3	1.25	0.78	2.45	0.11		
43-2, 4-6	45	9590	384	272	1250	81690	53		105	106	4.1	3	119.6	37	88		0.07	0.08	2.4	1.23	0.86	2.38	0.12	0.09	
43-4, 130-132	41.1	8930	352	261	1470	85680	51	49	112	100	2.8		115.7		88.5										
43-5, 93-95		8990	373	275	1420	72320	62		128		3.4		120.5		88										
43-6, 13-15	43	9110			1510	78550		48		110	0		112.3		81		0.03		2.3	1.23	0.78	2.53	0.11	0.07	
44-1, 28-31	46	10490	397	279	1180	73720	60		132	124	1.3		115.5		77		0.06		2.3	1.34	0.86	2.44	0.13	0.08	0.13
45-1, 35-37	46	9770	388	254	1360	77010	52		123	120	1.6		119.9	40	101		0.09		2.2	1.38	0.88	2.5	0.12	0.08	0.07
48-5, 100-102		9290	383	249	1160	63500	63.5		119		0		123.7	36	101	1.6									
48-7, 84-86		9230	386	251	1470	75680	62		100		0.5		120.2	35	99	<1									
49-2, 20-22		9890	434	309	930	70850	63		110.5		0.5		119.4	37	99	1									
49-2, 114-116		10010	375	279.5	1160	86820	36		57		13		129.2	37	101	<1									
50-2, 88-90		9350	371	225	1320	72180	53		106		0		128.4	40		1									
51, CC		8750	382	240	1390	86240	48.5		79		6.8		112.8	36	99	1.4									
52-2, 41-43		8330	322	253	1320	82390	48		126		1		146.8	35	84	<1									
52-4, 7-9		8570	341	246	1700	83930	44		95.5		6		115	37	91	<1									
52-5, 73-75		9651	394	269	1700	82390	51		116		0		104.2	38	105	2									
53-1, 110	43	9350	385	261	1550	82390	50	50	108.5	115	9	10	103.8	42	105	1.3	0.05	0.16	2.6	1.35	0.88	2.71	0.11		
54-1, 7-9		9530	425	294	1470	83930	56		123.5		2.5		103.4	41	103	1									
54-5, 42-44		8990	367	239	1470	81620	49		98.5		0		135.7	39.5	98	2									
55-4, 96		8870	364	237	1630	84700	46		103.5		0		147.6	37.3		1.6									
57-1, 70		9350	374	269	1630	86240	68.5		109		0		104.1	38.5	100	<1									
58-4, 139-141	45	8270	349	320	1160	74980	57.5	59	83.5	89	7	8	105.6	3.6	83	1.5	0.09	0.09		1.26	0.75	2.31	0.10	0.05	
59-5, 136		8150	333	274	1240	94000	37.5		80		27		102	25	90	0									
62-1, 94-96		8810	352	204	1470	79240	72		98		0		122.5	38	88	<1									
63-2, 64-66		8570	300	213	1470	74840	69		100		0		170.6	33	77.5	1									
64-4, 87-89		9950	404	219	1700	83930	49		83		0		103.2	45	92	2.7									
64-6, 15-17		8330	337	201	1390	75960	42		83		<1		138.3	33	76	1.4									
65-2, 7-9		8210	326	199	1470	75750	44		102		0		218.1	35.5	87.5	0									
65-4, 122-124		8150	315	236	1470	78480	43		111		0		108.7	34	98	2.2									
65-6, 37-39		6710	279	314	1240	69730	45		167		0		105	28	69	0									
66-3, 44-46		8150	333	199	1470	77220			94		<1		128.5	32	87	<1									
67-2, 29-31		7970	328	235	930	77150	43		101.5		0		107	33	87	1.5									
67-5, 33-35		8030	325	243	1240	87480	43		114.5		0		106.4	35	91	3									
67-7, 35-37	40	8510	344	203	1080	73650	42	42	73.5	77	0		120.2	36	84	0			2.1	1.22	0.78	2.33	0.12		
68-2, 46-48		5450	221	276	850	56090	37		137		<1		123.8	25	57	0									
68-3, 92-94	44	9890	384	210	1160	81620	45	46	77	76	<1		107.6	35	100	1.7			2.5	1.36	0.93	2.66	0.14		
68-4, 18-20		8990	357	268	1160	83930	49		109		0		115.4	40	97	2.2									
Leg 52, Hole 418A																									
15-1, 46-48		6710	290	219	1160	69380	42		84		<1		110.3	28	66.5	<1									
15-3, 36-38	39	6650	290	225	1240	66030	42	43	83	83	<1		112.4	29	61	<1			1.7	0.99	0.57	1.69	0.10		
16-1, 13-15	44	7670	315	270	1240	57910	44	45	88	92	<1		132	30	72	1.8			1.7	1.05	0.73	1.89	0.12		
16-1, 118-120	35	7850	327	273	1010	57420	48.5	45	90	114	2		128.7	26.5	68.5	1.2	0.4		1.4	0.84	0.49	1.5	0.07		
17-2, 72-75	43	7670	327	271	1010	61060	47	47	95	95	<1		127	27	67	1			1.7	0.97	0.62	1.78	0.11	0.08	
17-4, 139-141	40	6950	305	241	1080	65470	44	44	77	76	<1		117.2	30.5	76	1.4			1.7	1.02	0.58	1.69	0.10	0.07	
18-4, 48-50	40	6470	281	231	1240	72040	41.5	42	78	78	<1		111.7	28	67	2.3			1.8	1.01	0.61	1.8	0.11	0.08	
18-5, 94-96	(53)	9290	391	299	1390	80020	55	53	76.5	71	0		128.1	31	90	2.5			2.3	1.19	0.76	2.28	0.14	0.10	0.07
19-4, 101-105	40	6650	288	225	1240	71340	41.5	43	76	85	<1		107	27	69.5	2.5			1.7	0.96	0.65	1.72	0.10		
20-7, 62-64	40	6770	283	245	1240	72670	41.5	43	84	83	<1		109.2	27	65.5	3.7			1.9	1.05	0.60	1.7	0.11	0.07	
22-2, 33-35	40	6890	287	249	1320	76800	42		83	83	<1		118.8	28	71	0			1.8	1.04	0.47	1.82	0.11	0.07	

TABLE 2 – *Continued*

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Mn XRF	Fe XRF	Co XRF	Co NA	Ni XRF	Ni NA	Rb XRF	Rb NA	Sr XRF	Y	Zr XRF	Nb XRF	Sb NA	Cs NA	La NA	Eu NA	Tb NA	Hf NA	Ta NA	Th NA	U
24-1, 50-52		6770	282	248	1240	70010	42	48	87		0		112.6	28	72	<1									
24-1, 76-79	43	7070	316	274	930	66940	48		90	94	<1		120.6	29	81	<1				1.04	0.67	1.92	0.12	0.05	
25-1, 66-68	46	7850	334	274	1240	72180	48	49	85	87	0		116	31	76	3.3			1.9	1.12	0.68	2.03	0.13	0.09	
25-2, 87-89	46	8330	347	286	1240	77710	47	47	83.5	82	0		123.4	31	89	1.4			1.4	1.11	0.62	2.17	0.13	0.09	
26-2, 14-17	40	6770	277	245	1320	76520	44	44	95	97	0		121.8	28	65	1			1.7	1.01	0.60	1.74	0.11	0.06	
26-4, 111-113	41	7670	333	321	1630	63930	44	45	107	105	0		126.1	29	76	1			1.7	0.93	0.60	1.88	0.07		
28-4, 120-122		7610	317	307	1320	61620	45		110.5		<1		121.2	30.5	75	<1									
29-1, 35-37	(51)	7610	326	314	1780	57350	49	(58)	133	110	<1		124.8	29	74	0			1.6	1.16	0.74	2.21	0.14	0.09	0.22
30-1, 127-129	35	6350	267	251	1080	55470	36	38	98.5	93	0		121.4	23	64	2.5	0.03		1.3	0.92	0.50	1.60	0.07	0.04	0.10
33-1, 18-20		7490	321	306	1390	57910	48		116		5		128.4	30	73	0.3									
34-1, 76-78	37	7070	296	276.5	1240	63160	40	41	102	99	0		119.4	29	69	0			1.7	0.97	0.58	1.74	0.07		
36-4, 18-21		7010	289	284	1550	64630	41		96		<1		116.2	29	66	0.4									
38-4, 36-38	40	7430	275	320	1700	69170	41	46	119.5	106	0		119.2	32	85	0.8			1.5	1.0	0.58	1.87	0.09		
39-1, 119-121	41	7430	309	289	1550	68680	43	46	112	111	0		118.3	32	77	1.3	0.04		1.7	1.10	0.66	1.88	0.09		
41-1, 40-42	39	6530	339	312	1080	68540	45	44	108	121	1		126.8	30	70	0.2	0.08		1.4	0.92	0.57	1.63	0.08	0.04	
42-4, 89-91	38	5940	267	445	1160	69940	47	44	137	148	0		122.1	27	69	0.9			1.2	0.91	00.60	1.50	0.05		
44-2, 34-36		6410	274	360	1320	74140	43		129		0		98.9	30	64	0									
45-3, 82-85	42	7010	308	357	1550	75750		46	136.5	134	4	6	118.6	31	77	0	0.03	0.09	1.6	1.06	0.62	1.73	0107		0.18
45-4, 9-12	37	6230	266	343	1240	72110	43	42	143	150	<1		125.7	27	69	0	0.02		1.3	0.72	0.60	1.53	0.06		
47-1, 27-30	37	6230	278	331	1240	71480	41	43	131	131	<1		93.4	27	68	2.3			1.3	0.89	0.57	1.71	0.06	0.04	
48-5, 82-84	35	6230	264	322	1240	68400	41.5	43	129	138	0.5		93.7	26	68	0.3	0.03		1.1	0.91	0.54	1.57	0.06		

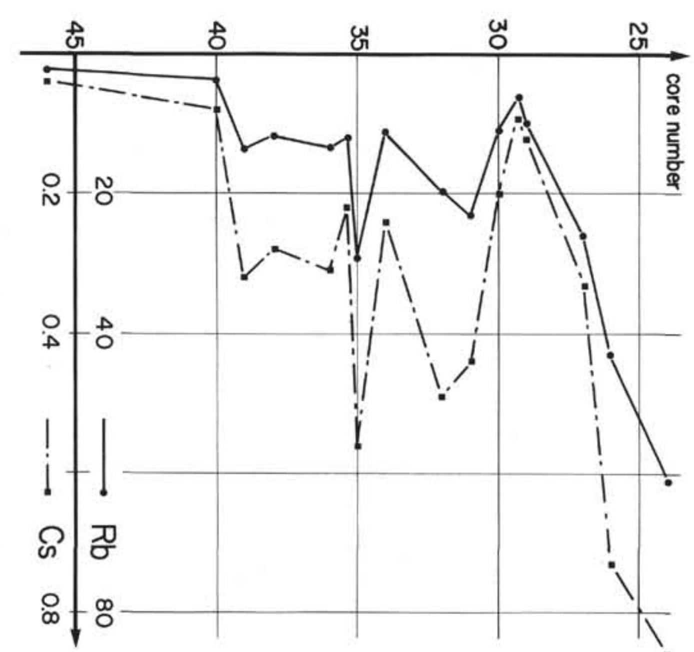

Figure 2. *Hole 417A: Rb (ppm) and Cs (ppm) variation down the hole. Core 25 is about 62 meters, Core 45 is about 197 meters into basement.*

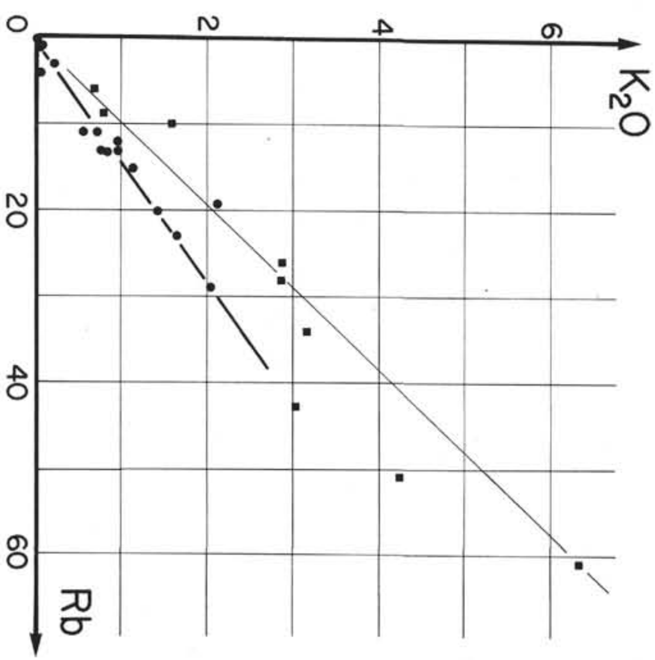

Figure 3. *K_2O (%) versus Rb (ppm) in Hole 417A. Black dots represent the data below Core 30, and the squares represent the data above Core 30.*

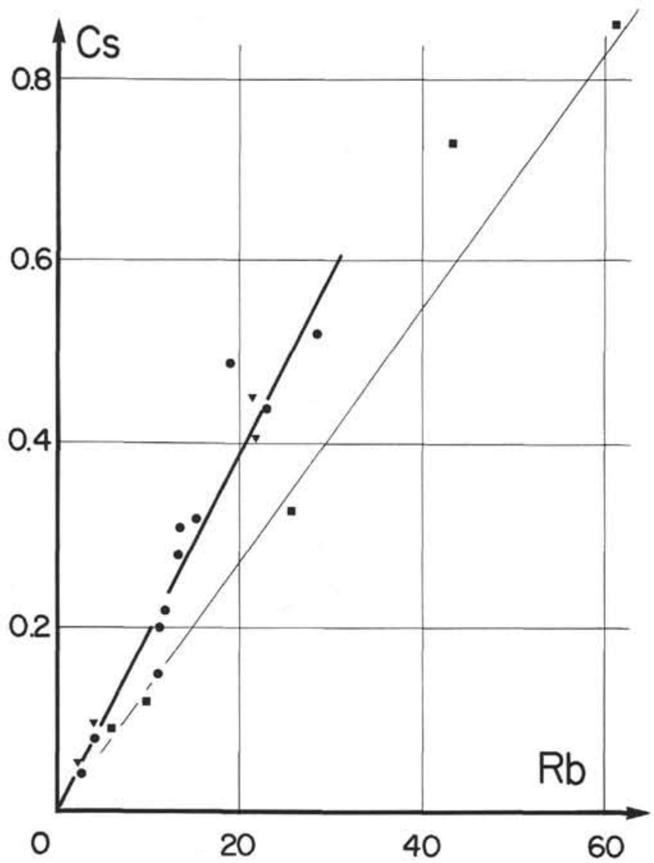

Figure 4. *Cs (ppm) versus Rb (ppm) in Hole 417A. Black dots and squares represent the same data as in Figure 3. The triangles represent altered samples from Hole 417D.*

TABLE 3
Comparison of Uptake of Alkali Metals From Sea Water and Residence Times of Alkali Metals in the Ocean

	K	Rb	Cs
Uptake:			
Altered sample/sea water			
concentration proportional to	44.7	242	1120
Residence time (s)	1.1×10^7	2.7×10^5	4×10^4

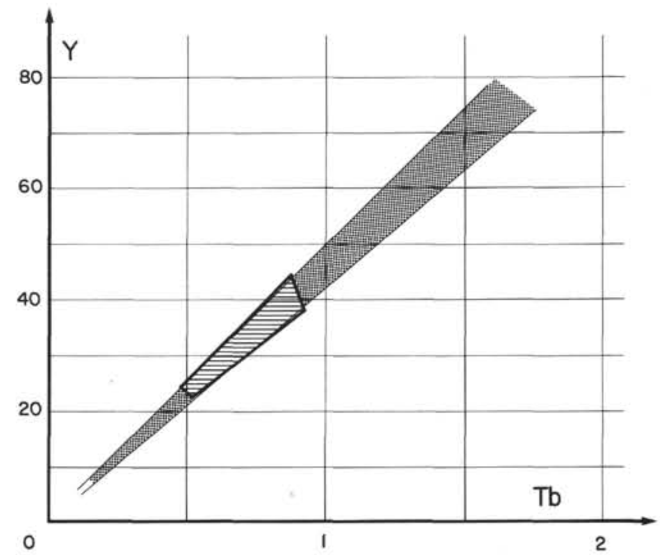

Figure 5. *Y (ppm)–Tb (ppm) compositional range of basalt samples studied from the North Atlantic Ocean at 22°N (Sites 395 and 396), 36°N (FAMOUS area, Sites 411, 412, and 413), 45°N (Site 410) and 63°N (Sites 407, 408, and 409).* ▤ *represents the compositional range of samples from Legs 51 and 52 (Sites 417 and 418).*

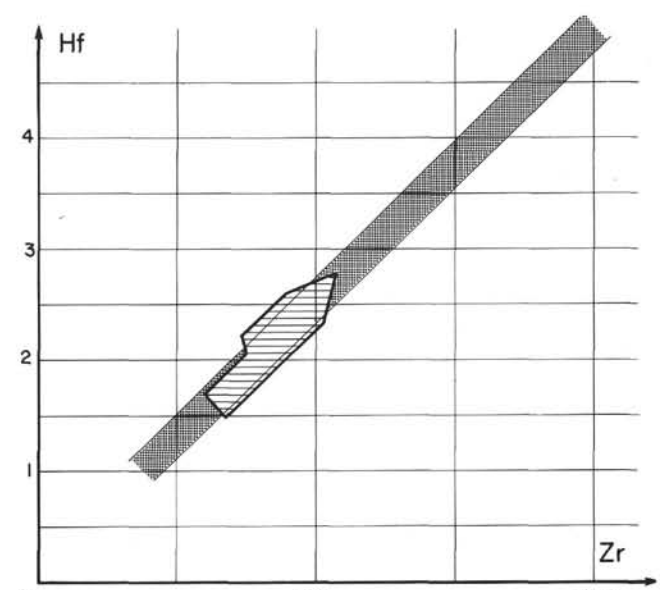

Figure 6. *Hf (ppm)–Zr (ppm) compositional range of basalt samples (see Figure 5 caption).*

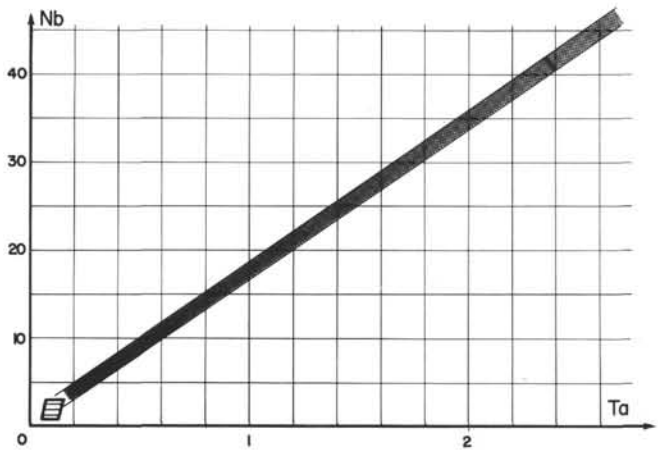

Figure 7. *Nb (ppm)–Zr (ppm) compositional range of basalt (see Figure 5 caption).*

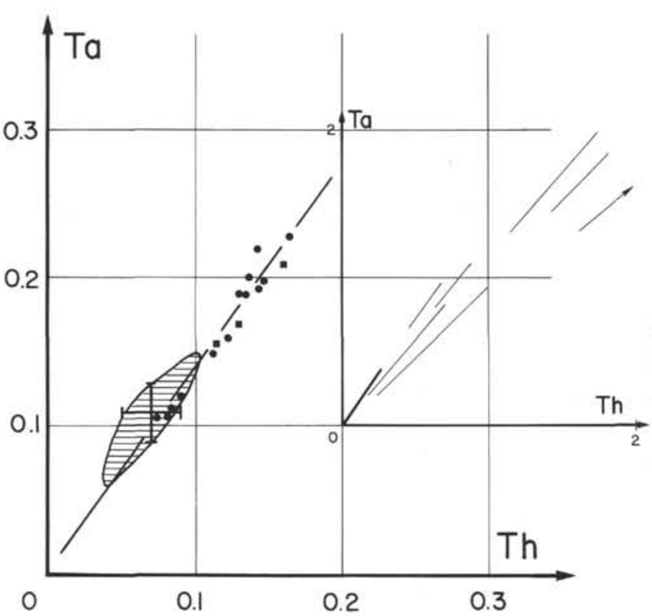

Figure 8. *Ta (ppm)–Th (ppm). The black dots represent Site 395 and the squares represent Site 396 (both sites are located at 22°N).* ▤ *represents the compositional range obtained from Legs 51 and 52 (Site 417 and 418). The cross defines range of uncertainty for a single sample and is situated at the average point obtained from Leg 51 and 52 data. On the right of the figure, the range of variation for Sites 395 and 396 (Leg 45) and Sites 417 and 418 (Legs 51 and 52) is compared with that of other DSDP and FAMOUS area sites.*

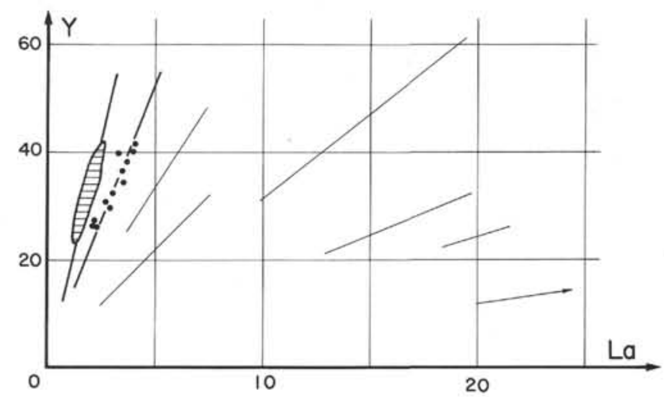

Figure 9. *Y (ppm)–La (ppm). Symbols are the same as in Figure 8. The other thin lines represent the range of variation of other DSDP sites and that from the FAMOUS area; the dispersion around these lines is higher than in the case of Ta–Th and the data from one single site can be plotted on different lines.*

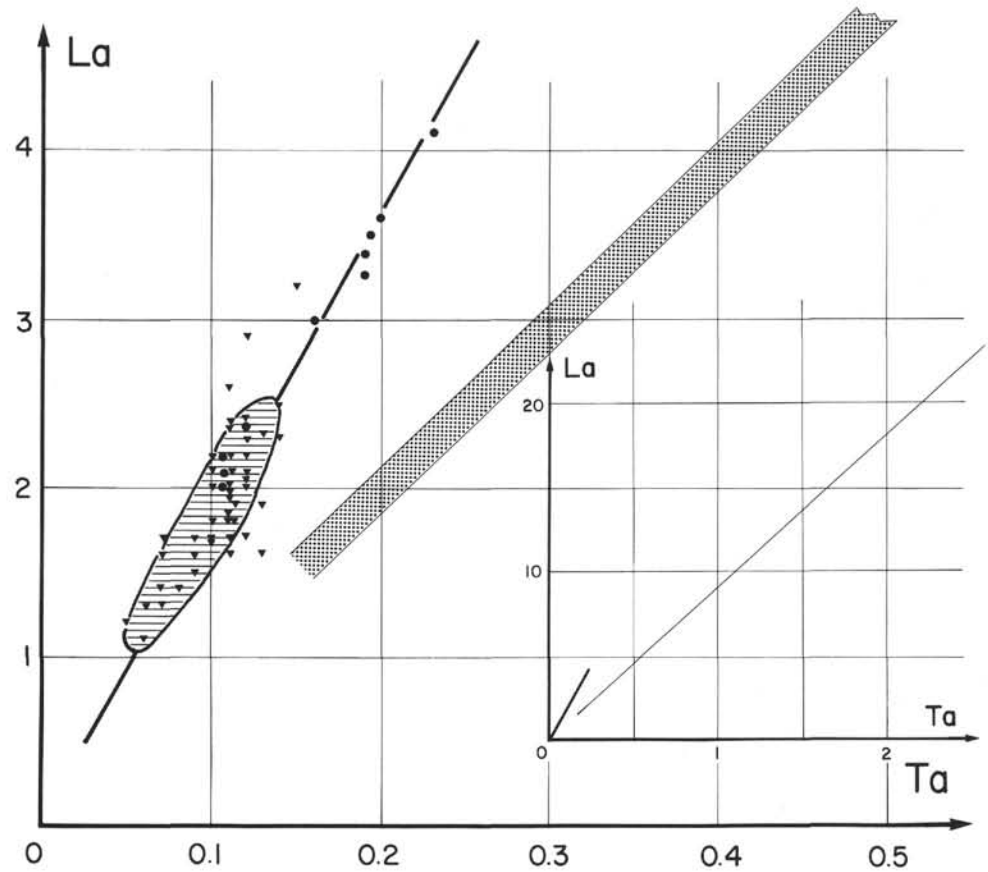

Figure 10. *La (mmp)–Ta (ppm). Black dots represent Sites 395 and 396 (Leg 45). The triangles represent Legs 51 and 52 data. Samples near 36°N, 45°N, and 63°N are plotted on a different single line. On the right of the figure is shown a comparison of the overall range variation both for Sites 417, 418, 395, and 396 on the one hand and other sites near 36°N, 45°N, and 63°N, on the other.*