29. GEOCHEMISTRY OF NAURU BASIN BASALTS FROM THE LOWER PORTION OF HOLE 462A, DEEP SEA DRILLING PROJECT LEG 61[1]

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ABSTRACT

Atomic-absorption spectrophotometry and instrumental neutron activation analysis were used to determine concentrations of SiO_2, Al_2O_3, FeO_t, MgO, CaO, Na_2O, K_2O, MnO, La, Ce, Sm, Eu, Tb, Yb, Lu, Sc, Co, Cr, Th, Hf, and Ta for 14 basalt samples from the lower portion of Hole 462A in the Nauru Basin. The basalts are similar to normal mid-ocean ridge basalt (MORB) for the elements analyzed, and light rare-earth elements (LREE) are depleted relative to heavy rare-earth elements (HREE). Two samples are extensively altered to smectites and show significant reductions in Al_2O_3, CaO, MnO, Na_2O, REE, Sc, Co, and Hf and gains in MgO and FeO_t relative to unaltered samples. The increase in MgO and decrease in CaO indicate that alteration was caused by hydrothermal solutions.

INTRODUCTION

Drilling at Site 462, Hole 462A (07°15′N, 165°02′E), penetrated over 500 meters of basaltic flows and sills and sediments in the Nauru Basin, west central Pacific Ocean. The thick volcanic sequence appears to represent a mid-Cretaceous intraplate plateau sequence of tholeiitic basalts structurally similar to the Caribbean Sea floor. The lower portion of Hole 462A, Cores 75 through 90, were drilled on the extension of Leg 61. These lower basalts have been analyzed in this study.

The Nauru Basin is bounded to the east by the Marshall Island atolls and to the west by the Caroline Islands. The basin is regarded as having formed at a fast-spreading Pacific plate boundary about 145–155 m.y. ago (Late Jurassic), and Site 462 was drilled in the Jurassic magnetically quiet zone (Larson, 1976) on magnetic Anomaly *M*-26. The magmas giving rise to the volcanic complex apparently penetrated Jurassic basement without significantly disturbing the well-defined lineation pattern observed in the Nauru Basin. The drill holes closest to Site 462 are in the Marshall Islands, the Bikini hole (Emery et al., 1954) and the Eniwetok hole (Ladd et al., 1953).

The Nauru Basin represents a region of buoyant ocean floor that does not fit the normal age-versus-depth curve (Sclater et al., 1971). The Pacific Ocean contains many exceptions to the curve (Winterer, 1976), although most have a volcanic topography. The region that appears most similar to the Nauru Basin is the Caribbean Basin. The Caribbean crust is abnormally thick (Officer et al., 1959; Edgar et al., 1971), largely because of the intrusion of a great thickness of sills in the Late Cretaceous (Burke et al., 1978). However, intrusion of sills in the Caribbean is regarded as responsible for the lack of magnetic anomalies in that region (Fox and Heezen, 1975), and in this respect the Caribbean Basin stands in contrast to the Nauru Basin with its well-defined magnetic anomalies. The extent to which heating of oceanic lithosphere might contribute to the buoyancy of these regions, in the manner suggested by Crough (1978) for hot-spot swells, is discussed by Schlanger and Premoli Silva (this volume).

STUDY TECHNIQUES

Basalts from the lower part of Hole 462A basalts have been analyzed for Na_2O, FeO_t, for trace elements by an instrumental neutron-activation analysis (INAA) technique described by Jacobs et al. (1977), and for major elements by atomic absorption spectrophotometry (AA). Major element oxides FeO_t and Na_2O and trace elements La, Ce, Sm, Eu, Tb, Yb, Lu, Sc, Co, Cr, Th, Hf, and Ta were determined by INAA. SiO_2, Al_2O_3, FeO_t, MgO, CaO, Na_2O, K_2O, and MnO were determined by AA. Reference standards, run simultaneously with Nauru Basin basalts, include USGA standards BCR-1, BHVO-1, AGV-1, and GSP-1 and NASA standard Knippa. Rare earth elements (REE) are plotted relative to chondrites using chondrite values of Haskin et al. (1968).

DATA

Geochemical data given in Table 1 represent a downhole continuation of data given by Batiza (this volume). Batiza presents data for Hole 462 and the upper portion of Hole 462A (down through Core 74). These data continue from Core 74 to the bottom of Hole 462A, and include Cores 75 through 90, the portion of Hole 462A drilled on the extension of Leg 61 by the Leg 62 crew.

The geochemistry of basalt Cores 75 through 79 is very similar to that of basalts from Cores 74 upward, and appears to represent a continuation of those basalts. From Core 80 down, however, the geochemistry is somewhat different, marked most noticeably by higher concentrations of REE, FeO_t, and Hf, and less abundant MgO and Cr. Two samples (462A-88-2, 100–102 cm and 462A-88-3, 9–11 cm) are badly altered to smectites, and their geochemistry is distinct from that of either the upper basalts (Cores 75–79) or the lower basalts (Cores 80–90).

All basalts studied are LREE-depleted relative to HREE (Fig. 1), although the two altered samples show

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Table 1. Geochemistry of Nauru Basin basalts from the lower portion of DSDP Hole 462A. (Oxides are in wt. % and elements in ppm.)

	Upper Basalts			Lower Basalts									Altered Basalts	
Core-Sec., Interval (cm)	76-1, 41–43	79-3, 79–81	79-5, 127–130	80-3, 58–61	80-3, 145–148	80-4 36–39	81-3, 63–65	84-4, 56–58	87-1, 105–107	88-2, 95–97	89-3, 125–127	90-4, 63–65	88-2, 100–102	88-3, 9–11
SiO_2	49.78	49.22	49.35	49.19	48.70	48.57	50.26	49.95	50.25	48.95	49.23	50.32	49.32	49.35
Al_2O_3	13.74	13.86	13.81	13.63	13.80	13.89	14.34	13.68	13.69	13.77	14.71	14.05	12.13	12.27
FeO_t	11.67	11.67	11.57	13.13	12.34	12.33	12.45	12.65	12.73	12.72	13.39	11.71	13.41	13.45
MgO	7.76	7.71	7.81	6.79	6.44	6.71	7.03	6.86	7.26	6.95	7.03	6.98	9.68	8.78
CaO	11.83	12.31	12.20	11.48	11.27	11.09	11.32	11.18	11.13	11.18	11.71	11.36	10.09	10.37
Na_2O	2.11	2.08	2.15	2.30	2.26	2.29	2.18	2.30	2.16	2.25	2.23	2.45	1.78	1.81
K_2O	0.06	0.01	0.02	0.03	0.06	0.04	0.01	0.06	0.05	0.07	0.03	0.08	0.03	0.03
MnO	0.19	0.20	0.21	0.22	0.20	0.21	0.21	0.21	0.21	0.21	0.25	0.19	0.14	0.15
La	2.83	2.66	2.73	3.40	3.41	3.38	3.41	3.45	3.12	3.29	3.24	3.47	2.70	2.10
Ce	8.12	8.31	8.49	10.2	9.70	9.38	9.45	10.2	9.19	10.5	9.94	10.7	6.84	5.61
Sm	2.25	2.26	2.25	2.67	2.81	2.74	2.84	2.94	2.44	2.75	2.82	2.89	1.50	1.56
Eu	0.86	0.92	0.88	1.06	1.02	0.99	1.01	1.06	0.95	1.03	0.99	1.09	0.63	0.59
Tb	0.59	0.56	0.62	0.73	0.67	0.68	0.71	0.71	0.79	0.66	0.76	0.72	0.41	0.43
Yb	2.24	2.19	2.43	2.99	2.95	2.90	2.99	3.07	2.66	2.86	3.00	2.80	1.65	1.76
Lu	0.34	0.37	0.36	0.47	0.43	0.42	0.44	0.46	0.42	0.42	0.47	0.45	0.26	0.26
Sc	47.3	48.7	48.3	50.0	47.3	48.1	47.9	49.1	49.8	49.1	50.7	51.6	42.6	42.7
Co	49.4	50.4	50.2	51.1	48.4	48.6	48.7	50.4	50.4	49.9	51.3	52.1	39.0	39.6
Cr	313	325	325	194	181	187	180	180	207	186	200	197	212	205
Th	0.12	—	0.25	0.27	0.22	0.21	0.14	0.23	0.18	0.21	0.16	—	—	0.09
Hf	1.70	1.71	1.77	1.02	2.01	2.05	2.10	2.23	2.04	2.04	2.09	2.21	1.02	1.14
Ta	0.17	0.21	0.16	0.26	0.19	0.21	0.18	0.27	0.27	0.20	0.20	0.24	—	—

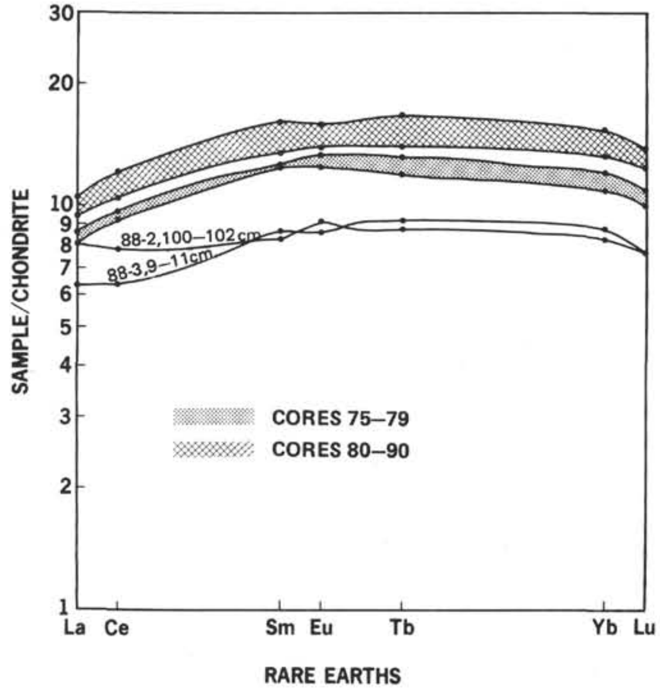

Figure 1. Normalized rare-earth element abundances of basalts from the lower portion of Hole 462A. These basalts are divided into three groups: the lower basalts (Cores 80-90), the upper basalts (Cores 75-79), and two altered basalts with lower total REE but higher LREE/HREE ratios.

less LREE depletion. Plots of selected elements show three distinct groups: (a) the upper basalts, (b) the lower basalts, and (c) the two altered basalts (Figs. 2–4). Separation of upper and lower basalts is best observed in the plot of Cr versus Hf (Fig. 2). The upper basalts are much richer in Cr than lower basalts, and have relatively lower Hf values. Both badly altered samples have very low Hf values, as does one sample of lower basalt (462A-80-3, 58-61 cm) in which alteration is not obvious. Figure 3 shows that upper basalts have a higher MgO/(MgO + FeO_t) ratio than lower basalts, and that alteration has noticeably increased the MgO/(MgO + FeO_t) ratio in the two altered lower basalts. On the Yb-versus-Sm plot, the sample from Core 87 is intermediate between upper and lower basalts, although all samples still form a linear plot (Fig. 4).

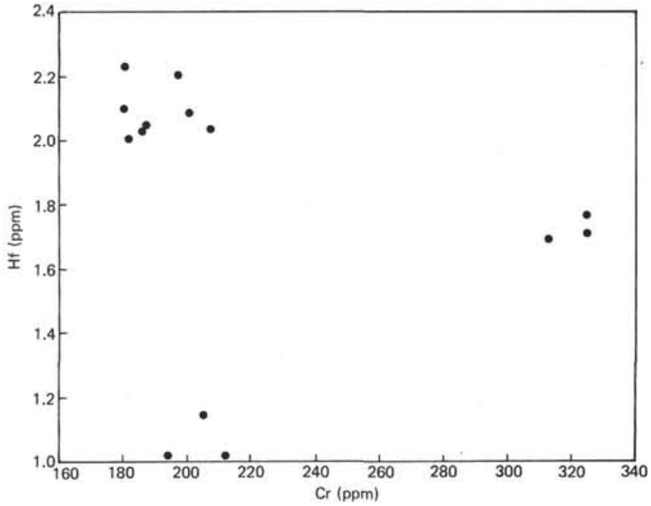

Figure 2. Plot of Hf versus Cr, showing the much greater abundance of Cr in the upper basalts (>300 ppm) compared with the lower basalts (<220 ppm). The altered basalts have both very low Cr and Hf contents.

DISCUSSION

Basalts from the lower portion of Hole 462A have the geochemical characteristics of normal (N-type) MORB (Sun et al., 1979). Chondrite-normalized REE plots

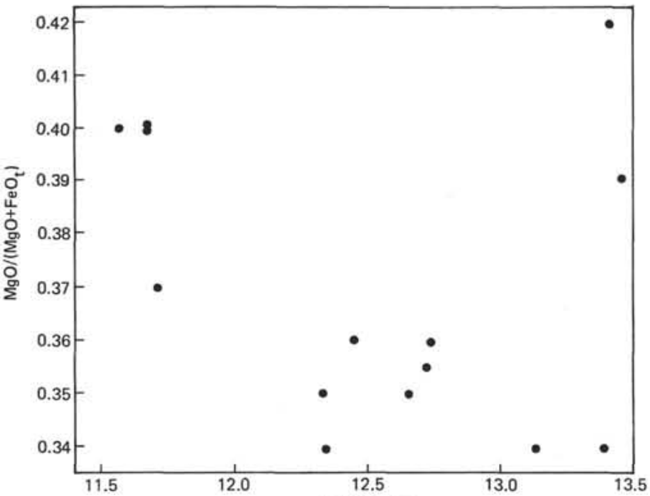

Figure 3. Plot of MgO/(MgO + FeO$_t$) versus FeO$_t$, showing the higher MgO/(MgO + FeO$_t$) ratio in upper and altered basalts relative to lower basalts.

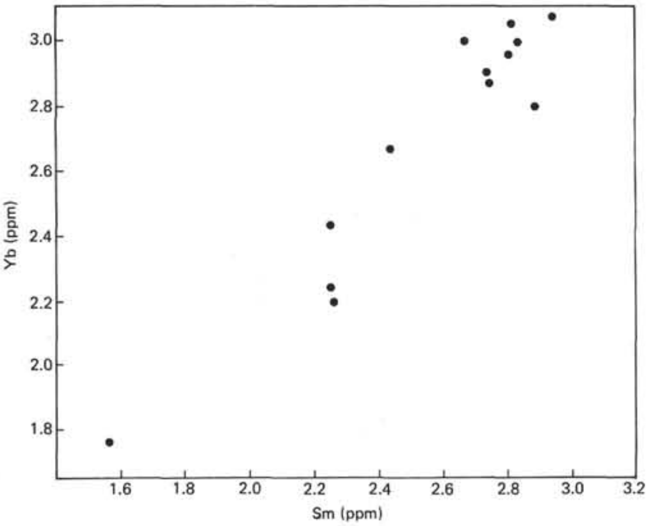

Figure 4. Plot of Yb versus Sm, exhibiting the greater abundance of Yb (>2.6 ppm) and Sm (>2.4 ppm) in the lower basalts compared with the upper basalts. The altered basalts have very low concentrations of Yb (<1.8 ppm) and Sm (<1.6 ppm), and yet lie on a straight line through the lower and upper basalt values.

(Fig. 1) all show the LREE to HREE depletion typical of normal MORB. These basalts are interpreted as being derived from a previously depleted mantle source, and are found in all oceans. Both the transitional (T-type) and plume (P-type) MORB are more enriched in LREE relative to HREE (Frey et al., 1974; Schilling and Noe-Nygaard, 1974).

The geochemical differences in oceanic basalts have been variously explained as resulting from: different degrees of partial melting; a heterogeneous mantle; magmatic differentiation; or secondary alteration. In basalts from the lower portion of Hole 462A, the two groups of basalts can be distinguished by their contents of MgO, Cr, Hf, and total REE. The higher MgO/(MgO + FeO$_t$) and Cr contents of upper basalts relative to higher Hf and total REE contents in lower basalts is perhaps best explained by differences in degree of magmatic differentiation, since the basalts have similar contents of Co and Sc and similar Hf/Ta ratios. If the difference between the upper basalts (Cores 75–79) and lower limits (Cores 80–90) in this study is explained as part of a series undergoing magmatic differentiation, the lower basalts must be regarded as more differentiated, and thus more recent, than the upper basalts. However, all basalts from the lower portion of Hole 462A are interpreted to be flows (Batiza et al., "Summary of Petrological and Geochemical studies of Leg 61 Basalts," this volume).

Samples 462A-88-2, 100–102 cm and 462A-88-3, 9–11 cm both exhibit considerable alteration, and X-ray diffraction analysis indicates broad smectite peaks. The two altered samples have significantly reduced CaO, Al_2O_3, Na_2O, MnO, REE, Sc, Co, and Hf contents relative to unaltered samples. MgO and FeO$_t$ contents appear to have increased. The increase in MgO concentration and decrease in CaO concentration indicates high-temperature hydrothermal alteration, as defined by several experimental studies, such as that by Seyfried and Bischoff (1979). The LREE/HREE ratio has also increased in the two altered basalts, and may indicate enrichment in LREE, as observed by Ludden and Thompson (1979) and several others. The low value of Hf for Sample 462A-80-3, 58–61 cm places that sample with the two altered samples on the Cr-versus-Hf plot, and may also be due to alteration. Sample 462-A-87-1, 105–107 cm occupies an intermediate position on the Yb-versus-Sm plot; this may also be an alteration effect.

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