50. COSTA RICA RIFT: VARIABLY DEPLETED BASALTS IN THE SAME HOLE[1]

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ABSTRACT

The basalts recovered from the Costa Rica Rift by drilling at Deep Sea Drilling Project Sites 501, 504, and 505 during Legs 68, 69 and 70 of the *Glomar Challenger* are the most depleted in the most-hygromagmaphile elements (Th, Ta, Nb, and La) of all MORB recovered to date by the *Glomar Challenger*. The invariant ratios Nb/Ta, Zr/Hf, and Y/Tb show "chondritic values" (expected for Nb/Ta because of the very low concentrations in these elements). Four samples from a single unit are exceptions: they present a flat to slightly enriched, extended Coryell-Masuda plot, and at the same time their La/Ta ratio is 9 (normalized ratio = 1) instead of 19 (normalized ratio = 2), the value for all other samples. Only one of these two values of the La/Ta ratio had been found so far within a single hole, and moreover within large areas of the oceanic crust (several holes or dredges). The present result shows that local heterogeneity of the upper mantle with respect to the La/Ta ratio may exist.[5]

INTRODUCTION

Six holes (501, 504A, 504B, 505, 505A, 505B) were drilled during Legs 68, 69, and 70 of the *Glomar Challenger*, in a limited area of the Costa Rica Rift: Site 501 (1°13.63'N, 83°44.06'W); Site 504 (1°13.6'N, 83°44'W); Site 505 (1°54.8'N, 83°47.4'W). Trace-element data obtained by neutron activation analysis (NAA) and by X-ray fluorescence spectrometry (XRF) are presented in this paper. These data are compared to major-element analyses and sample descriptions obtained on board, and allow us to refine the characterization and classification of the different basaltic units. We, then, interpret them in terms of high- and low-partition-coefficient elements. The behavior of low-partition-coefficient elements (hygromagmaphile elements) is discussed on the basis of comparative geochemistry by using an extended Coryell-Masuda plot, including both rare-earth and other trace elements.

ANALYTICAL CHEMISTRY, RESULTS, AND INVARIANT RATIOS

The XRF analytical procedure used on board for the measurements of concentrations of major elements is the classical heavy-absorber method. The specific arrangement for shipboard determinations was described by Bougault (1977a), and some modifications were made during leg 45 (Melson et al., 1978). The major-element data are given in Table 1.

The trace-element data (Table 2) are arranged in the order of increasing atomic number. Blank lines separate the homogeneous sets of data versus depth corresponding to the different basalt lithologic units. A brief look at these data shows that four hygromagmatophile elements (Th, Nb, Ta, La, which behave with low solid/liquid bulk partition coefficients) have very low concentrations. For these four elements, the concentrations are close to the limits of detection. It is therefore necessary to discuss accuracy of the appropriate analytical method before interpreting these data with confidence.

In order of increasing atomic number, all the element concentrations up to Nb have been determined by XRF, except Sc, which was analyzed by NAA, and Co and Ni, for which both XRF and NAA data are available. From Sb to Th, all concentrations have been measured by NAA. XRF interferences are corrected, where necessary, according the procedure described by Bougault et al. (1977b). In the case of Nb, there is no instrumental interference; the accuracy of Nb determination is then limited by the method of calculation of the matrix effects and the measurements of both peak and background intensity. For low Nb concentrations, close to the 1-ppm detection limit, the accuracy is limited mainly by the counting statistics of both peak and background intensities, and by the method of measuring and substracting the background. NAA measurements are made with a Ge-Li detector from 4 days to 1 month after irradiation (Jaffrezic et al., 1977). For low concentration levels, the accuracy also is limited by the counting statistics of intensities and the method of measuring and substracting the background. Thus, for both methods, the accuracy can be considered to be the sum of two terms. The first one, the precision, dx, presents a random character reflecting the counting statistics, and can be written $\pm dx$. The second term, ΔX, is constant and can be positive or negative; it corresponds, for instance, to the method of substracting the background. ΔX corresponds to a systematic error which cannot be identified, despite the care taken in the calibration (blanks, standards, etc.). Any measurement has to be written $X + \Delta X \pm dx$. The value dx can be improved by repeating the measurements. As an example, the points in Figure 1 represent

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[1] Cann, J. R,. Langseth, M. G., Honnorez, J., Von Herzen, R. P., White, S. M., et al., *Init. Repts. DSDP*, 69: Washington (U.S. Govt. Printing Office).

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[5] Measurements on samples of Hole 504B category 3 (Samples 504B-18-1, 84-88 cm; 504B-18-2, 98-102 cm; 504B-19-1, 73-77 cm; 504B-19-2, 46-49 cm) and category 2 (Samples 504B-54-1, 16-18 cm; 504B-56-1, 139-142 cm; 504B-57-1, 51-55 cm) have been completed since the text was written. The value 16 ± 1 of the Nb/Ta ratio is confirmed for all of these samples. The normalized La/Ta (La/Nb) ratio of category 2 is about 2, and this normalized ratio is confirmed for category 3. (See text.)

Table 1. Major-element analyses.

Sample (interval in cm)	Component SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	LOI
501-10-1, 12-16	49.64	1.03	14.95	11.26	0.19	7.88	12.31	2.18	0.10	0.09	99.63	0.97
10-1, 120-124	49.45	1.07	15.23	10.60	0.18	7.76	12.29	2.15	0.15	0.09	98.97	2.34
11-1, 85-88	49.88	1.04	14.73	11.91	0.19	7.69	12.24	2.36	0.35	0.10	100.49	1.57
11-2, 87-89	49.65	1.07	14.61	11.89	0.18	7.69	12.10	1.95	0.42	0.13	99.69	2.25
12-1, 12-9	49.23	1.11	15.40	11.42	0.18	7.47	11.90	2.27	0.35	0.12	99.45	2.54
12-1, 59-62	50.27	1.14	15.85	10.44	0.15	7.83	11.69	2.49	0.23	0.09	100.18	3.15
13-1, 47-49	49.72	1.05	15.01	10.51	0.15	8.23	12.10	2.13	0.02	0.07	98.99	1:61
13-2, 112-114	49.81	1.06	14.84	10.74	0.16	8.55	12.19	1.88	0.03	0.07	99.33	1.96
14-1, 10-25	50.05	1.04	14.62	11.28	0.17	8.49	12.27	2.09	0.03	0.07	100.11	1.13
14-1, 59-62	50.62	1.03	14.72	11.28	0.17	8.57	12.27	2.03	0.02	0.08	100.79	1.47
14-2, 121-126	50.47	1.06	14.77	11.06	0.17	7.76	12.08	2.30	0.02	0.09	99.78	1.27
14-3, 135-138	50.00	0.87	16.07	9.67	0.19	8.34	12.78	1.96	0.05	0.06	99.99	0.81
15-1, 135-138	49.68	0.87	16.08	10.10	0.18	7.59	12.97	1.86	0.15	0.07	99.55	2.39
15-4, 18-19	49.58	0.87	15.92	9.63	0.17	7.93	13.01	2.16	0.06	0.08	99.41	1.80
16-1, 118-120	49.05	0.85	16.30	9.80	0.17	8.75	12.66	2.04	0.08	0.08	99.78	2.40
16-1, 118-120	49.37	0.86	16.29	9.64	0.16	8.62	12.69	1.82	0.04	0.06	99.55	2.13
17-1, 86-89	50.01	0.89	15.83	9.92	0.16	8.05	12.83	2.03	0.03	0.07	99.82	2.50
18-1, 119-124	49.15	0.89	15.81	10.27	0.18	7.90	12.73	2.06	0.12	0.07	99.18	1.78
18-2, 34-37	49.47	0.93	15.23	10.81	0.18	7.63	12.54	1.99	0.25	0.08	99.11	n.d.
18-2, 89-93	50.63	1.02	14.80	11.02	0.19	7.75	12.22	2.05	0.35	0.08	100.11	1.20
18-3, 100-103	49.97	0.91	16.04	10.11	0.18	8.15	12.78	2.01	0.11	0.07	100.33	2.11
19-1, 68-71	49.83	1.04	17.39	9.24	0.13	8.66	10.60	2.22	0.31	0.09	99.51	5.57
19-2, 124-127	49.41	0.96	15.47	10.54	0.17	8.20	12.51	2.05	0.18	0.07	99.56	1.94
20-2, 137-141	49.89	0.90	14.93	10.88	0.20	8.15	12.61	1.94	0.12	0.08	99.70	1.00
20-3, 81-84	49.75	0.90	15.06	10.96	0.19	7.94	12.65	1.96	0.24	0.07	99.74	1.35
504A-6-1, 64-67	50.29	1.05	14.60	11.28	0.18	7.89	12.30	2.12	0.04	0.10	99.85	0.68
6-2, 96-98	49.87	1.06	15.18	11.01	0.18	7.96	12.49	2.33	0.21	0.09	100.38	0.99
6-3, 63-65	50.45	1.11	15.18	10.21	0.19	8.39	12.51	2.16	0.07	0.10	100.37	0.95
7-1, 75-77	49.56	1.09	14.98	11.20	0.18	8.29	12.18	2.16	0.16	0.13	99.93	1.05
7-2, 51-53	50.70	1.12	15.45	9.22	0.18	8.56	12.30	2.32	0.04	0.10	99.99	1.22
504B-2-1, 107-110	50.63	1.11	15.59	9.46	0.17	8.07	12.57	2.17	0.06	0.09	99.92	0.96
3-1, 102-105	49.63	1.07	14.98	11.70	0.17	7.89	12.21	1.93	0.31	0.10	99.99	1.01
4-1, 32-38	49.76	0.88	16.04	9.66	0.17	8.20	13.09	1.70	0.12	0.08	99.71	0.57
4-2, 52-58	49.61	0.90	16.22	9.86	0.18	7.61	13.35	1.89	0.07	0.08	99.77	1.23
4-3, 27-30	50.13	0.88	15.84	9.77	0.17	8.28	13.07	1.87	0.03	0.07	100.11	0.94
4-4, 83-87	49.83	0.88	16.18	9.76	0.17	8.19	12.92	2.02	0.15	0.06	100.16	1.55
4-5, 36-41	49.47	0.91	16.09	9.91	0.18	7.98	13.30	2.09	0.08	0.06	100.07	1.06
5-1, 86-92	49.15	0.89	15.88	10.07	0.18	8.51	13.07	1.88	0.12	0.07	99.82	0.96
5-2, 110-115	49.52	0.90	16.55	9.22	0.18	8.08	13.36	2.08	0.03	0.08	100.00	1.24
6-1, 79-80	49.73	0.92	16.46	9.86	0.16	8.56	11.99	1.84	0.12	0.07	99.71	1.17
6-1, 88-90	53.28	0.11	6.38	10.83	0.08	25.14	1.28	1.88	0.15	0.01	99.14	6.66
6-2, 98-105	49.48	0.93	15.41	10.49	0.16	8.20	12.83	1.90	0.19	0.06	99.65	0.83
7-1, 91-93	50.02	0.93	16.69	9.23	0.17	7.59	13.23	1.97	0.07	0.08	99.98	1.03
7-2, 91-96	49.25	0.88	15.86	9.89	0.18	8.65	13.04	1.79	0.09	0.07	99.70	0.77
7-3, 116-120	50.38	0.91	15.93	9.90	0.16	7.65	13.13	1.88	0.02	0.06	100.02	1.04
7-4, 64-69	49.51	0.89	16.16	10.03	0.18	8.06	13.13	1.83	0.13	0.08	100.00	1.15
7-5, 71-74	50.47	0.91	16.22	9.40	0.16	8.24	13.03	2.11	0.03	0.08	100.65	1.21
8-1, 109-115	49.59	0.90	16.29	9.84	0.15	8.08	13.02	1.97	0.13	0.07	100.04	1.15
8-2, 125-131	50.08	0.88	16.25	9.37	0.15	8.14	13.08	1.76	0.02	0.06	99.89	1.15
8-3, 113-116	49.43	0.88	16.54	9.99	0.16	7.49	13.20	2.05	0.10	0.06	99.90	1.13
8-4, 120-124	50.53	0.89	16.27	8.79	0.18	8.22	13.29	2.14	0.03	0.07	100.41	1.18
9-1, 54-59	49.76	0.88	15.96	9.84	0.16	8.01	13.07	1.78	0.03	0.08	99.57	1.28
9-2, 63-68	49.25	0.98	16.29	10.12	0.16	7.94	12.35	2.07	0.16	0.08	99.40	1.13
10-1, 53-58	49.99	1.03	16.31	9.44	0.16	7.74	12.21	2.34	0.17	0.09	99.48	1.01
10-2, 113-118	50.32	0.98	15.46	9.77	0.17	8.32	12.63	2.44	0.18	0.08	100.35	0.78
11-1, 16-21	50.59	0.98	15.51	9.50	0.17	8.16	12.62	2.18	0.18	0.08	99.97	0.63
11-2, 86-95	50.56	0.99	15.40	9.63	0.16	8.32	12.78	2.22	0.13	0.09	100.28	1.04
11-3, 74-83	50.33	0.98	15.32	9.18	0.17	8.51	12.72	2.45	0.11	0.07	99.84	0.66
12-2, 123-127	50.25	0.96	15.07	9.79	0.17	8.26	12.70	2.13	0.16	0.07	99.56	0.56
13-1, 135-140	50.38	0.95	15.21	9.81	0.17	8.35	12.55	2.12	0.31	0.07	99.92	1.04
13-2, 113-119	50.44	0.99	15.34	9.39	0.14	8.18	12.70	2.23	0.14	0.07	99.62	1.11
13-3, 87-94	50.07	0.96	15.09	10.15	0.19	8.17	13.03	1.91	0.19	0.08	99.84	0.87
13-4, 44-49	50.95	0.97	15.73	8.51	0.16	8.45	12.81	2.07	0.02	0.08	99.75	1.17
14-2, 34-40	50.38	0.92	15.43	9.98	0.16	8.44	12.71	1.88	0.13	0.07	100.10	1.01
15-1, 125-129	50.00	0.91	14.64	10.71	0.19	8.49	13.00	1.67	0.07	0.07	99.75	0.31
15-2, 38-44	50.04	0.95	15.21	10.31	0.18	8.19	12.82	2.01	0.10	0.07	99.88	0.70
15-3, 133-137	50.06	0.92	15.35	9.34	0.16	8.64	12.89	2.03	0.11	0.07	99.57	0.98
15-4, 58-62	50.10	0.92	14.49	10.80	0.18	8.69	12.74	1.89	0.11	0.06	99.98	0.26
15-5, 17-22	50.16	0.93	15.26	10.26	0.18	8.34	12.84	1.92	0.15	0.07	100.11	0.64
16-1, 141-143	49.21	0.98	14.63	11.36	0.19	8.04	12.53	2.02	0.29	0.09	99.34	0.97
16-2, 89-92	49.32	0.82	15.48	10.93	0.17	8.09	12.97	1.73	0.10	0.07	99.68	0.93
16-3, 129-139	49.21	0.90	15.59	9.76	0.18	8.85	12.92	1.92	0.11	0.09	99.53	1.38
16-5, 21-26	49.41	0.94	15.96	9.42	0.21	8.56	12.86	1.78	0.14	0.09	99.39	1.05
17-1, 3-6	53.52	0.03	6.48	10.63	0.06	25.70	1.32	1.79	0.08	0.01	99.62	6.16
17-1, 110-114	49.27	0.91	15.69	9.89	0.18	9.06	12.51	1.95	0.11	0.09	99.66	1.22
17-2, 94-97	49.65	0.92	15.94	9.90	0.19	8.46	12.88	2.08	0.14	0.09	100.25	1.03
17-3, 22-24	49.93	0.95	15.70	9.86	0.19	8.39	12.77	1.88	0.21	0.09	99.97	0.84
18-1, 84-98	49.13	1.24	16.85	10.19	0.18	6.92	12.81	2.38	0.39	0.16	100.25	1.72
18-2, 98-102	49.95	1.33	16.72	8.44	0.22	7.03	13.05	2.41	0.12	0.18	99.45	1.58
19-1, 73-77	49.26	1.37	17.22	9.43	0.20	6.49	13.28	2.33	0.15	0.19	99.92	1.56
19-2, 46-49	49.69	1.23	17.41	9.04	0.18	6.71	13.08	2.17	0.15	0.17	99.83	1.61
19-2, 88-92	49.71	0.86	16.16	9.88	0.18	7.87	13.21	2.07	0.15	0.06	100.15	0.99
20-1, 142-145	49.63	1.01	16.21	10.07	0.18	7.64	12.97	2.17	0.14	0.11	100.13	1.55
21-1, 70-75	49.66	1.00	16.59	9.79	0.16	7.57	12.96	2.16	0.12	0.09	100.10	1.68
21-2, 101-105	49.60	0.76	16.76	9.45	0.17	7.76	13.49	1.82	0.09	0.07	99.97	1.07
21-3, 110-115	50.05	0.99	15.85	9.66	0.20	7.75	13.13	2.14	0.04	0.08	99.89	1.32
21-5, 43-46	49.81	0.74	16.09	9.72	0.18	8.51	13.20	1.81	0.12	0.06	100.24	0.96
22-1, 25-28	49.29	0.70	16.23	9.24	0.19	9.68	12.88	1.67	0.09	0.06	100.03	1.90
22-2, 56-62	49.62	0.74	16.60	9.26	0.17	8.37	13.42	1.77	0.07	0.06	100.08	1.14
23-1, 112-117	49.79	0.88	16.42	9.77	0.17	7.71	13.15	1.95	0.14	0.07	100.05	0.61
24-1, 62-66	49.48	0.85	15.96	9.69	0.18	8.60	12.99	1.95	0.08	0.09	99.87	0.93
24-2, 85-88	49.62	0.88	15.82	9.77	0.18	8.49	13.08	1.93	0.09	0.08	99.94	0.77

Table 1. (Continued).

Sample (interval in cm)	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	LOI
						Component						
504B-24-3, 104–106	49.57	1.00	16.19	9.52	0.18	8.54	12.89	1.99	0.15	0.08	100.11	0.83
25-1, 94–98	50.20	0.99	14.71	10.56	0.19	8.37	12.84	2.01	0.09	0.08	100.04	0.18
25-2, 96–99	50.89	1.01	15.13	9.24	0.16	8.64	12.92	2.38	0.11	0.07	100.55	0.63
26-1, 52–54	50.36	1.00	15.06	9.98	0.18	8.43	12.71	2.25	0.17	0.07	100.21	0.54
27-1, 130–134	49.60	1.12	17.68	9.07	0.16	6.39	13.34	2.95	0.09	0.10	100.50	1.41
28-1, 110–116	50.22	0.94	15.27	10.38	0.16	8.05	12.94	1.90	0.18	0.08	100.12	0.94
28-2, 39–43	49.51	1.09	16.92	10.06	0.17	6.75	12.93	2.29	0.10	0.11	99.93	1.65
28-3, 33–37	49.91	0.93	16.10	9.82	0.18	7.94	13.12	1.92	0.04	0.08	100.04	0.43
28-3, 35–40[c]	53.76	0.03	6.07	11.35	0.06	25.19	1.31	2.09	0.15	0.03	100.04	6.53
28-4, 23–27	49.26	0.93	15.96	10.11	0.19	7.85	13.19	1.86	0.09	0.09	99.53	0.40
28-5, 6–9	50.08	0.91	15.99	9.49	0.17	8.07	13.21	1.94	0.02	0.08	99.96	0.97
29-2, 11–16	50.49	0.99	14.90	9.78	0.17	8.49	12.83	2.36	0.15	0.08	100.24	0.96
32-1, 142–145	49.85	0.93	15.16	10.20	0.16	8.71	13.04	1.89	0.04	0.09	100.07	0.19
35-1, 99–105	48.26	0.80	17.12	9.35	0.14	8.92	13.37	1.76	0.08	0.09	99.89	0.86
36-1, 11–16	49.88	0.89	15.93	9.42	0.15	8.81	13.07	1.87	0.08	0.11	100.21	0.73
36-2, 59–64	49.71	0.93	14.95	10.44	0.16	8.77	12.82	1.84	0.06	0.11	99.79	n.d.
36-3, 8–12	49.69	0.79	16.11	9.19	0.14	9.46	13.02	1.75	0.08	0.12	100.35	0.44
36-3, 123–127	50.04	0.94	15.05	10.33	0.16	8.45	12.80	1.86	0.06	0.11	99.80	0.52
36-4, 109–114	50.05	0.91	14.87	10.38	0.16	8.27	12.83	1.91	0.08	0.10	99.56	1.10
39-1, 77–80	49.86	0.96	15.95	9.66	0.16	8.45	12.50	2.12	0.11	0.10	99.87	0.71
39-2, 24–28	50.10	0.92	15.24	10.31	0.16	8.31	13.10	1.89	0.05	0.11	100.19	0.08
39-3, 53–55	50.00	0.81	16.29	9.60	0.14	8.57	12.90	1.60	0.08	0.09	100.08	0.35
40-1, 14–17	50.02	0.80	16.27	9.30	0.14	8.40	12.96	1.76	0.07	0.11	99.83	1.25
40-1, 138–141	49.71	0.80	16.25	9.25	0.14	8.76	12.99	1.96	0.07	0.10	100.03	0.51
40-3, 80–83	49.97	0.80	16.16	9.25	0.15	8.93	13.14	1.62	0.04	0.11	100.17	1.06
40-3, 139–141	50.67	0.74	16.66	8.95	0.14	7.86	13.62	1.80	0.07	0.10	100.61	0.50
40-4, 67–72	50.25	0.79	16.66	9.17	0.14	8.68	13.17	1.91	0.06	0.12	100.95	0.21
40-5, 31–34	50.47	0.80	15.98	9.37	0.15	8.48	12.94	1.72	0.08	0.10	100.09	0.83
41-1, 128–130	49.64	0.81	16.30	9.34	0.15	8.67	13.03	1.76	0.07	0.10	99.87	1.04
41-2, 25–30	49.71	0.80	16.26	9.32	0.14	8.94	12.90	1.68	0.05	0.10	99.90	1.27
41-2, 136–138	50.08	0.83	15.91	9.60	0.15	9.02	12.95	1.77	0.12	0.10	100.53	0.74
42-2, 40–44	50.13	0.86	15.86	9.43	0.15	8.71	13.02	1.99	0.11	0.10	100.36	1.43
44-1, 25–28	49.63	1.38	14.96	10.34	0.16	8.24	12.80	2.23	0.12	0.18	100.04	1.20
44-2, 93–96	50.04	0.91	15.70	10.37	0.16	7.98	13.30	1.68	0.07	0.10	100.31	1.10
45-1, 85–88	50.18	0.90	16.01	9.82	0.16	8.02	13.29	2.10	0.10	0.10	100.68	1.04
45-2, 91–96	50.24	0.96	15.81	10.33	0.16	8.41	12.61	1.90	0.07	0.11	100.60	0.60
47-1, 43–45	50.44	0.99	14.30	11.04	0.17	8.57	12.29	1.92	0.13	0.11	99.96	0.08
47-2, 20–23	50.63	1.00	14.09	11.52	0.18	8.40	12.20	1.87	0.12	0.13	100.14	1.12
47-2, 103–108	50.16	0.96	14.93	10.74	0.15	8.40	12.65	1.73	0.14	0.11	99.97	1.12
47-3, 24–27	50.18	0.99	14.90	10.80	0.16	8.59	12.68	2.04	0.10	0.10	100.54	0.90
48-2, 80–84	50.68	0.99	14.54	10.94	0.17	8.44	12.47	1.95	0.12	0.11	100.41	0.81
48-3, 97–100	49.64	0.87	16.14	9.64	0.15	8.55	13.24	1.71	0.04	0.10	100.08	0.64
50-1, 68–72	49.80	0.84	16.08	9.50	0.15	8.60	13.20	2.20	0.09	0.10	100.56	1.70
51-1, 132–135	50.35	0.85	15.07	9.37	0.15	8.72	13.20	1.86	0.07	0.12	99.76	1.80
52-1, 62–65	50.13	0.85	15.59	9.41	0.15	8.47	13.55	1.88	0.08	0.11	100.22	1.12
52-2, 55–60	50.22	0.85	15.99	9.48	0.15	8.49	13.14	1.69	0.12	0.10	100.23	0.20
52-3, 100–103	50.17	0.85	15.90	9.38	0.15	8.77	13.12	1.82	0.08	0.09	100.33	1.35
52-4, 63–66	50.03	0.87	15.68	9.63	0.15	8.84	13.03	1.67	0.10	0.10	100.10	1.50
54-1, 16–18	49.94	0.93	15.58	9.90	0.16	8.35	13.22	1.98	0.07	0.10	100.23	0.96
56-1, 139–142	49.65	1.37	14.65	10.59	0.17	8.59	12.41	2.13	0.05	0.18	99.79	0.57
57-1, 51–55	50.06	1.36	14.90	10.12	0.16	8.54	12.37	2.25	0.11	0.18	100.05	1.25
57-2, 26–30	49.90	0.98	15.31	9.90	0.16	8.86	12.70	2.10	0.04	0.14	100.09	0.36
58-1, 141–146	50.15	0.91	15.92	9.85	0.16	8.18	13.04	1.86	0.09	0.12	100.28	1.22
58-3, 14–17	50.04	0.92	15.61	10.02	0.16	8.31	13.08	1.88	0.08	0.11	100.21	0.95
59-1, 46–48	49.87	1.02	15.58	9.98	0.16	8.49	12.78	1.90	0.14	0.12	100.04	1.17
60-1, 50–54	50.28	1.06	14.86	10.80	0.17	8.73	12.70	1.85	0.06	0.12	100.63	1.22
61-1, 112–115	49.39	1.05	15.20	11.20	0.18	8.28	13.17	1.72	0.07	0.14	100.40	1.37
63-2, 103–105	50.23	1.03	14.65	10.80	0.17	8.73	12.71	1.70	0.07	0.10	100.19	1.03
64-2, 107–109	50.35	1.18	13.83	11.82	0.18	8.44	11.75	2.03	0.04	0.11	99.73	1.28
64-4, 78–82	50.07	1.00	15.27	11.02	0.17	8.49	12.60	1.80	0.08	0.12	100.62	1.21
70-1, 56–60	50.31	1.10	14.25	11.53	0.19	8.79	11.96	1.79	0.05	0.11	100.08	1.06
505-25-1, 26–28	48.45	0.71	17.44	8.15	0.13	9.67	13.22	1.64	0.08	0.08	99.57	0.78
26-1, 33–36	48.03	0.76	17.46	8.25	0.14	9.07	13.43	1.88	0.09	0.10	99.21	0.94
505A-1-1, 28-30	49.13	0.95	16.16	9.74	0.16	8.53	12.79	2.00	0.07	0.09	99.62	0.23
2-1, 51–55	48.93	0.95	15.94	9.69	0.15	8.82	12.60	2.32	0.04	0.08	99.52	0.95
505B-2-1, 19–23	49.58	0.98	15.94	9.59	0.15	8.92	12.69	2.08	0.06	0.08	100.07	1.04
2-2, 87–90	49.63	0.96	16.23	9.34	0.14	8.40	12.89	1.98	0.08	0.08	99.73	1.20
2-3, 51–52	49.70	0.96	16.24	9.64	0.18	7.72	12.89	2.46	0.17	0.09	100.05	1.71
2-3, 78–83	49.62	0.96	16.05	9.36	0.14	8.89	12.63	2.17	0.05	0.08	99.95	1.17
3-1, 76–79	49.52	0.95	16.21	9.54	0.15	8.71	12.56	2.19	0.13	0.08	100.04	0.33
3-2, 102–103	49.67	0.95	15.94	9.51	0.14	8.70	12.57	2.11	0.06	0.08	99.73	0.96
5-1, 40–43	49.63	0.97	16.60	9.37	0.14	8.53	12.64	2.12	0.07	0.08	100.15	0.96
6-1, 114–116	50.04	0.97	15.90	9.44	0.15	8.34	12.85	2.17	0.05	0.09	100.00	1.01
6-2, 20–23	49.64	0.97	15.79	9.72	0.15	9.15	12.61	2.11	0.06	0.08	100.28	0.57

[a] Oxidized.
[b] Nonoxidized.
[c] Smectite.

the average values (Nb, Ta) for the various basaltic units encountered in the Gulf of California at 22°N, Sites 482, 483, and 485, drilled during Leg 65; the indicated error bars correspond to dx. The dx value of a single determination is about 1.5 ppm for Nb. The dx values indicated in Figure 1 are lower, and account for several determinations of different samples of the same basaltic unit. By definition, there is no way to improve the ΔX value. When X is low, and of the order of magnitude of the estimated value of ΔX, it is not possible to compute a ratio of concentrations (Nb/Ta, for instance) from a single pair of values. Nevertheless, it is still possible to estimate such a ratio from a least-squares calculation, provided that the number of points is sufficient, and that they lie in a range of values larger, at least by a factor two, than the dx precision values which account for the reproducibility of measurements. The Nb and Ta data for Leg 65 (Fig. 1) fulfill these requirements. The

Table 2. Trace-element analyses.

Sample (interval in cm)	Element																							
	Sc	Ti	V	Cr	Mn	Fe	Co_x	Co_n	Ni_x	Ni_n	Zn	Rb	Sr	Y	Zr	Nb	Sr	Cs	La	Eu	Tb	Hf	Ta	Th
501-10-1, 12–16	n.d.	6180	357	234	1471	78820	44	n.d.	78	n.d.	76	1.4	65	32	55	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
10-1, 120–124	45.8	6420	365	215	1394	74200	47	47.3	n.d.	80	82	0.6	67	31	57	0.2	0.05	0.04	1.22	0.93	0.64	1.58	0.04	0.04
11-1, 85–88	43.6	6240	357	220	1471	83370	46	45.6	n.d.	71	77	7.7	64	34	53	1.8	0.04	0.20	1.07	0.86	0.64	1.31	0.03	0.04
11-2, 87–89	n.d.	6420	362	207	1394	83230	43	n.d.	79	n.d.	n.d.	8.6	66	32	49	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
12-1, 129	n.d.	6660	370	222	1394	79940	40	n.d.	60	n.d.	74	7.8	70	34	56	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
12-1, 59–62	n.d.	6840	384	230	1162	73080	42	n.d.	77	n.d.	82	4.2	76	32	58	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-1, 47–49	n.d.	6300	357	202	1162	73570	45	n.d.	120	n.d.	72	0.5	65	31	56	0.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-2, 112–114	n.d.	6360	364	214	1239	75180	46	n.d.	113	n.d.	70	0.0	65	32	52	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14-1, 10–25	n.d.	6240	335	191	1316	78960	43	n.d.	110	n.d.	67	0.0	64	32	54	1.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14-1, 59–62	n.d.	6180	341	187	1316	78960	44	n.d.	106	n.d.	71	1.4	65	32	54	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14-2, 121–126	44.3	6360	360	203	1316	77420	47	47.3	107	87	73	1.5	65	30	50	0.6	n.d.	n.d.	1.12	0.87	0.59	1.58	0.03	0.03
14-3, 135–138	38.1	5220	291	446	1471	67690	43	43.4	n.d.	137	65	1.5	66	29	48	2.4	n.d.	0.01	1.45	0.82	0.48	1.39	0.02	0.02
15-1, 135–138	38.0	5220	280	455	1394	70700	42	42.1	143	129	60	2.8	66	28	50	1.2	0.02	0.06	0.87	0.72	0.48	1.22	0.02	n.d.
15-4, 18–19	38.8	5220	281	457	1316	67410	43	43.0	131	143	64	0.9	62	27	48	1.6	n.d.	0.03	1.04	0.71	0.47	1.73	0.03	0.09
16-1, 118–120[a]	n.d.	5100	277	523	1316	68600	42	n.d.	145	n.d.	67	1.8	61	26	48	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
16-1, 118–120[b]	n.d.	5160	272	479	1239	67480	41	n.d.	171	n.d.	63	0.7	59	25	51	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
17-1, 86–89	39.1	5340	287	421	1239	69440	39	41.3	140	135	58	0.9	61	28	66	0.3	n.d.	0.02	1.03	0.75	0.58	1.65	0.03	0.01
18-1, 119–124	40.7	5340	324	283	1394	71890	46	48.3	175	138	77	1.1	53	29	73	1.3	0.01	0.04	0.83	0.81	0.55	1.34	0.03	0.02
18-2, 34–37	40.5	5580	341	286	1394	75670	45	44.3	107	86	76	3.9	51	29	56	1.3	n.d.	0.09	0.97	0.74	0.52	1.37	0.02	0.00
18-2, 89–93	44.9	6120	361	221	1471	77140	45	45.9	104	107	85	7.1	53	32	49	0.0	0.01	0.10	0.76	0.82	0.70	n.d.	0.03	0.01
18-3, 100–103	36.5	5460	337	300	1394	70770	45	42.6	182	121	74	2.4	54	29	41	0.0	n.d.	0.03	1.17	0.75	0.45	1.16	0.02	0.01
19-1, 68–71	n.d.	6240	353	301	1007	64680	45	n.d.	89	n.d.	73	2.6	70	31	48	1.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
19-2, 124–127	42.8	5760	353	273	1316	73780	46	47.7	100	105	79	3.5	45	34	45	0.2	0.02	0.01	0.95	0.85	0.52	1.22	0.01	0.01
20-2, 137–141	42.5	5400	333	286	1549	76160	46	47.9	111	106	72	2.0	39	29	39	2.0	0.02	0.05	0.88	0.82	0.52	1.22	0.03	n.d.
20-3, 81–84	n.d.	5400	326	287	1471	76720	51	n.d.	150	n.d.	71	6.2	39	28	39	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
504A-6-1, 64–67	43.3	6300	361	221	1394	78960	46	46.2	146	82	77	1.5	69	32	63	0.1	0.03	0.03	1.28	0.80	0.59	1.42	0.03	0.03
6-2, 96–98	44.9	6360	382	246	1394	77070	49	49.2	112	106	81	4.6	73	33	56	0.1	0.04	0.06	1.39	0.87	0.58	1.40	0.03	0.02
6-3, 63–65	45.9	6660	392	233	1416	71470	47	46.5	72	73	86	0.1	75	35	59	0.1	0.02	n.d.	1.14	0.86	0.58	1.93	0.04	0.04
7-1, 75–77	45.1	6540	389	223	1394	78400	49	45.2	93	91	82	1.1	76	35	59	1.7	0.04	0.04	1.21	0.88	0.64	1.61	0.04	n.d.
7-2, 51–53	47.3	6720	405	241	1394	64540	52	55.2	122	129	84	0.7	78	35	64	1.7	0.01	n.d.	1.42	0.89	0.60	1.60	0.03	n.d.
504B-2-1, 107–110	n.d.	6660	393	225	1316	66220	49	n.d.	129	n.d.	86	1.3	77	36	60	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
3-1, 102–105	n.d.	6420	383	215	1316	81900	45	n.d.	76	n.d.	79	6.2	73	32	58	0.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4-1, 32–38	n.d.	5280	290	460	1316	67620	41	n.d.	134	n.d.	62	3.3	69	27	50	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4-2, 52–58	44.2	5400	291	496	1394	69020	42	n.d.	139	n.d.	65	0.3	70	28	50	0.0	0.06	0.04	0.98	0.87	0.54	1.44	0.02	0.01
4-3, 27–30	36.5	5280	286	452	1316	68390	41	42.0	140	139	62	0.5	66	27	49	0.8	n.d.	0.03	0.95	0.70	0.48	1.30	0.03	n.d.
4-4, 83–87	n.d.	5280	290	459	1316	68320	43	n.d.	153	n.d.	68	3.0	74	26	45	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
4-5, 36–41	n.d.	5460	284	462	1394	69370	42	n.d.	136	n.d.	66	1.0	71	25	50	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
5-1, 86–92	n.d.	5340	279	445	1394	70490	40	n.d.	140	n.d.	63	1.9	70	23	53	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
5-2, 110–115	n.d.	5400	301	454	1394	64540	42	n.d.	141	n.d.	63	1.6	72	22	49	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6-1, 79–80	38.9	5520	311	513	1239	69020	45	45.6	145	146	62	1.5	79	19	58	0.0	0.03	0.03	0.88	0.86	0.49	1.30	0.02	
6-1, 88–90	5.7	660	57	31	619	75810	15	10.7	72	85	71	1.9	74	2	11	0.0	0.03	0.03	1.48	0.29	0.17	0.12	0.00	0.00
6-2, 98–105	n.d.	5580	306	444	1239	73430	39	n.d.	115	n.d.	59	4.2	69	25	53	0.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7-1, 91–93	n.d.	5580	302	491	1316	64610	43	n.d.	140	n.d.	68	1.0	74	27	53	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7-2, 91–96	n.d.	5280	273	445	1394	69230	43	n.d.	155	n.d.	67	1.6	66	27	50	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7-3, 116–120	37.6	5460	283	441	1239	69300	42	41.7	129	128	65	0.1	67	27	57	0.1	n.d.	n.d.	1.15	0.70	0.49	1.31	0.02	n.d.
7-4, 64–69	n.d.	5340	285	438	1394	70210	41	n.d.	131	n.d.	65	1.7	69	28	49	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7-5, 71–74	n.d.	5460	290	417	1239	65800	42	n.d.	140	n.d.	58	0.4	71	28	50	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
8-1, 109–115	n.d.	5400	289	395	1162	68880	37	n.d.	103	n.d.	53	3.5	72	26	51	0.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
8-2, 125–131	n.d.	5280	284	381	1162	65590	39	n.d.	126	n.d.	59	0.0	71	29	47	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
8-3, 113–116	n.d.	5280	281	421	1239	69930	37	n.d.	99	n.d.	61	2.5	71	28	49	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
8-4, 120–124	n.d.	5340	287	429	1394	61530	41	n.d.	156	n.d.	60	0.5	71	27	55	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d
9-1, 54–58	38.2	5280	279	459	1239	68880	41	44.8	143	159	67	0.3	68	27	52	0.3	0.02	0.08	1.58	0.91	0.55	1.33	0.07	0.07
9-2, 63–68	43.5	5880	345	309	1239	70840	49	49.8	105	109	79	4.1	63	31	51	0.4	0.07	0.04	0.97	0.76	0.55	1.73	0.02	n.d.
10-1, 53–58	n.d.	6180	323	415	1239	66080	44	n.d.	108	n.d.	74	3.3	86	30	58	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
10-2, 113–118	n.d.	5880	308	392	1316	68390	43	n.d.	108	n.d.	65	4.2	80	29	56	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
11-1, 16–21	n.d.	5880	304	405	1316	66500	46	n.d.	111	n.d.	67	3.9	80	27	51	2.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
11-2, 86–95	n.d.	5940	315	361	1239	67410	42	n.d.	119	n.d.	68	3.6	81	28	52	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
11-3, 74–83	42.3	5880	314	397	1316	64260	47	50.1	108	111	67	1.3	80	28	52	0.0	0.01	0.06	1.19	0.92	0.55	1.40	0.02	0.04
12-2, 122–127	41.7	5760	302	388	1316	68530	44	45.1	96	101	67	2.6	75	29	51	0.0	0.02	0.12	1.00	0.87	0.52	1.94	0.03	0.00
13-1, 135–140	n.d.	5700	294	370	1316	68670	42	n.d.	104	n.d.	68	7.3	77	28	52	0.8	n.d.	n.d.	0.00	n.d.	n.d.	n.d.	n.d.	n.d.
13-2, 113–119	n.d.	5940	305	384	1084	65730	47	n.d.	119	n.d.	69	2.7	82	30	58	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-3, 87–89	n.d.	5760	295	387	1471	71050	41	n.d.	101	n.d.	63	4.4	75	27	58	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
13-4, 44–49	n.d.	5820	313	391	1239	59570	43	n.d.	108	n.d.	61	1.1	81	28	51	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
14-2, 34–40	n.d.	5520	328	342	1239	69860	45	n.d.	118	n.d.	70	3.3	67	26	48	1.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
15-1, 125–129	39.8	5460	328	357	1471	74970	45	43.9	103	98	69	2.1	61	27	54	0.5	0.03	0.03	0.92	0.71	0.51	1.23	0.02	0.04
15-2, 38–44	n.d.	5700	334	363	1394	72170	47	n.d.	110	n.d.	74	1.4	65	31	49	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
15-3, 133–137	38.7	5520	335	331	1239	65380	46	45.3	126	118	71	2.3	65	28	51	0.0	0.01	0.04	0.83	0.77	0.47	1.23	0.02	0.02
15-4, 58–62	44.3	5520	330	350	1394	75600	45	47.2	103	106	78	2.1	60	28	53	0.8	0.03	0.04	1.11	0.78	0.65	1.29	0.02	0.01
15-5, 17–22	n.d.	5580	327	341	1394	71820	44	n.d.	103	n.d.	74	1.7	61	30	48	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
16-1, 141–143	n.d.	5880	331	322	1471	79520	41	n.d.	78	n.d.	68	7.1	61	31	52	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
16-2, 89–92[a]	40.3	4920	288	326	1316	76510	40	37.5	87	94	54	0.7	63	26	47	1.0	0.02	0.04	0.94	0.69	0.58	1.63	0.02	0.01
16-3, 129–139	36.5	5400	255	468	1394	68320	42	44.6	174	185	59	2.0	90	25	52	1.3	0.04	0.09	1.37	0.82	0.47	1.38	0.05	0.04
16-5, 21–26	n.d.	5640	275	504	1626	65940	44	n.d.	175	n.d.	60	3.6	90	26	57	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
17-1, 110–114	n.d.	5460	265	486	1394	69230	45	n.d.	174	n.d.	59	1.6	82	26	57	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
17-2, 94–97	37.0	5520	261	480	1471	69300	42	44.7	159	176	61	1.3	84	27	57	0.5	0.03	0.07	1.29	0.80	0.47	1.84	0.04	0.04
17-3, 22–24	38.2	5700	287	501	1471	69020	48	49.9	138	148	69	4.1	83	26	58	1.1	0.03	0.12	1.44	0.79	0.48	1.36	0.04	n.d.
18-1, 84–88	36.5	7440	254	390	1394	71330	34	34.8	110	105	58	10.1	153	28	87	9.9	n.d.	n.d.	6.10	1.01	0.57	2.20	0.70	0.80
18-2, 98–102	37.5	7980	271	367	1704	59080	41	44.8	160	138	63	1.2	182	31	95	13.1	n.d.	n.d.	7.60	1.16	0.61	2.37	0.81	0.84
19-1, 73–77	37.2	8220	279	400	1549	66010	39	40.1	117	110	63	1.8	178	30	96	13.2	n.d.	n.d.	7.90	1.12	0.62	2.47	0.85	0.84
19-2, 46–49	36.9	7380	283	408	1394	63280	42	43.9	123	127	68	1.6	159	30	85	9.8	n.d.	n.d.	5.90	1.00	0.59	2.12	0.62	0.62
19-2, 88–92	37.8	5160	287	443	1394	69160	41	40.1	121	126	64	4.6	68	26	51	0.5	0.00	0.10	0.86	0.71	0.47	1.24	0.03	n.d.
20-1, 142–145	n.d.	6060	278	415	1394	70490	41	n.d.	114	n.d.	62	2.5	96	28	54	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
21-1, 70–75	n.d.	6000	286	415	1239	68530	43	n.d.	133	n.d.	66	3.7	97	26	59	0.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
21-2, 101–105	n.d.	4560	289	423	1316	66150	41	n.d.	121	n.d.	70	1.7	58	25	41	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
21-3, 110–115	n.d.	5940	270	419	1549	67620	43	n.d.	121	n.d.	62	0.6	95	29	60	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
21-5, 43–46	37.4	4440	284	407	1394	68040	45	45.9	139	142	61	2.6	55	22	36	0.4	n.d.	n.d.	0.67	0.57	0.44	1.05	0.02	n.d.

Table 2. (Continued).

Sample (interval in cm)	Sc	Ti	V	Cr	Mn	Fe	Co_x	Co_n	Ni_x	Ni_n	Zn	Rb	Sr	Y	Zr	Nb	Sr	Cs	La	Eu	Tb	Hf	Ta	Th
504B-22-1, 25–28	34.5	4200	253	408	1471	64680	40	44.0	139	146	52	2.6	50	22	33	0.0	0.04	0.03	0.64	0.63	0.39	0.96	0.01	0.02
22-2, 56–62	n.d.	4440	273	432	1316	64820	40	n.d.	131	n.d.	55	1.6	53	23	36	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
23-1, 112–117	39.1	5280	310	321	1316	68390	40	42.9	117	118	67	2.2	67	26	49	0.8	0.05	0.06	0.87	0.70	0.46	1.25	0.02	n.d.
24-1, 62–66	n.d.	5100	274	433	1394	67830	42	n.d.	132	n.d.	56	2.2	63	25	46	0.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
24-2, 85–88	n.d.	5280	283	430	1394	68390	41	n.d.	115	n.d.	60	2.7	61	25	48	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
24-3, 104–106	n.d.	6000	291	448	1396	66640	42	n.d.	118	n.d.	71	2.9	90	27	60	2.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
25-1, 94–98	n.d.	5940	323	344	1471	73920	44	n.d.	93	n.d.	72	1.9	69	30	54	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
25-2, 96–99	43.6	6060	329	330	1239	64680	45	46.0	115	115	73	1.7	70	31	53	0.9	0.01	0.03	0.89	0.83	0.55	1.44	0.01	n.d.
26-1, 52–54	n.d.	6000	325	328	1394	69860	45	n.d.	103	n.d.	69	4.4	69	32	55	0.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
27-1, 130–134	n.d.	6720	275	459	1239	63490	46	n.d.	168	n.d.	68	0.4	114	30	69	0.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
28-1, 110–116	42.8	5640	337	275	1239	72660	46	47.9	114	118	71	3.6	52	31	44	0.7	0.02	0.05	0.98	0.80	0.52	1.25	0.029	0.27
28-2, 39–43	n.d.	6540	257	443	1316	70210	45	n.d.	160	n.d.	68	2.4	108	29	71	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
28-3, 33–37	n.d.	5580	295	330	1394	68740	41	n.d.	100	n.d.	n.d.	1.9	60	27	45	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
28-4, 23–27	n.d.	5580	302	302	1471	70710	40	n.d.	93	n.d.	65	2.4	60	29	52	0.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
28-5, 6–9	38.7	5460	301	334	1316	66430	40	42.0	107	113	69	0.0	59	28	49	1.2	n.d.	n.d.	0.91	0.73	0.48	1.40	0.028	n.d.
29-2, 11–16	n.d.	5940	301	303	1316	68460	43	n.d.	103	n.d.	67	1.9	70	31	52	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
32-1, 141–145	n.d.	5560	313	328	1012	71260	42	n.d.	95	n.d.	52	1.0	60	28	53	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
35-1, 99–105	n.d.	4600	234	413	885	64890	44	n.d.	185	n.d.	48	1.7	79	24	53	2.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
36-1, 11–16	n.d.	5280	293	385	948	65450	37	n.d.	102	n.d.	47	0.7	54	28	45	0.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
36-2, 59–66	n.d.	5580	301	301	1012	73080	41	n.d.	94	n.d.	51	0.7	60	27	53	1.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
36-3, 8–12	43.3	4740	330	257	885	64050	39	n.d.	89	n.d.	53	0.2	61	27	53	1.5	n.d.	n.d.	1.00	0.80	0.54	1.35	0.02	0.02
36-3, 123–127	43.2	5640	280	292	1012	71960	37	n.d.	95	n.d.	52	1.6	63	29	50	1.6	n.d.	n.d.	0.96	0.81	0.55	1.40	0.02	n.d.
36-4, 109–112	n.d.	5400	310	369	1012	71890	40	n.d.	85	n.d.	57	0.5	52	28	53	1.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
39-1, 77–80	n.d.	5700	345	466	1012	67130	44	n.d.	98	n.d.	65	0.7	64	30	48	1.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
39-2, 24–28	n.d.	5520	318	375	1012	72100	44	n.d.	95	n.d.	55	1.5	63	29	55	2.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
39-3, 53–55	n.d.	4860	240	363	885	66990	36	n.d.	132	n.d.	42	0.5	59	25	51	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
40-1, 14–17	n.d.	4740	252	419	885	64260	36	n.d.	130	n.d.	42	0.5	65	25	51	0.8	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
40-1, 138–147	n.d.	480	248	373	885	64400	37	n.d.	126	n.d.	45	0.0	65	24	46	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
40-3, 80–83	n.d.	4740	232	345	948	64050	36	n.d.	120	n.d.	45	1.4	66	24	49	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
40-4, 67–72	37.1	4740	244	359	885	64050	37	n.d.	117	n.d.	53	0.9	63	24	44	0.4	n.d.	0.04	0.97	0.71	0.47	1.24	0.02	0.02
40-5, 31–34	n.d.	4740	245	187	948	65030	37	n.d.	n.d.	n.d.	n.d.	1.4	65	24	42	1.7	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
41-1, 128–130	n.d.	4800	223	348	948	64680	37	n.d.	125	n.d.	42	2.1	57	24	48	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
41-2, 25–30	n.d.	4740	229	376	885	64400	36	n.d.	130	n.d.	43	0.7	65	21	50	1.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
41-2, 136–138	n.d.	4920	263	418	948	66710	40	n.d.	146	n.d.	44	1.1	66	25	55	0.6	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
42-2, 40–44	n.d.	5100	326	283	948	65100	50	n.d.	133	n.d.	52	0.0	61	27	50	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
44-1, 25–28	43.3	5520	314	414	1012	68600	43	46.3	103	102	61	0.8	62	29	49	0.2	n.d.	n.d.	0.78	0.85	0.54	1.41	0.01	n.d.
44-2, 93–96	n.d.	5400	301	452	1012	71820	45	n.d.	114	n.d.	60	0.0	59	29	47	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
45-1, 85–88	n.d.	5340	316	449	1012	68040	44	n.d.	112	n.d.	56	0.1	60	28	53	0.0	n.d.	n.d.	0.76	n.d.	n.d.	n.d.	n.d.	n.d.
45-2, 91–96	n.d.	5700	307	376	1012	71890	43	n.d.	97	n.d.	62	1.5	67	28	55	0.1	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
47-1, 43–45	42.1	5940	340	154	1075	77210	44	45.9	73	84	66	0.4	55	30	58	0.0	n.d.	n.d.	1.0	0.83	0.57	1.42	0.02	0.01
47- , 20–23	n.d.	5940	341	135	1138	79730	43	n.d.	74	n.d.	65	0.9	55	30	51	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
47-2, 103–108	n.d.	5700	357	176	948	74430	46	n.d.	79	n.d.	67	1.3	54	28	48	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
47-3, 24–27	n.d.	5880	360	167	1012	71900	44	n.d.	79	n.d.	66	0.3	54	29	46	0.3	n.d.	n.d.	1.05	n.d.	n.d.	n.d.	n.d.	n.d.
48-2, 80–84	n.d.	5880	371	303	1075	75950	46	n.d.	93	n.d.	70	1.5	54	30	56	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
48-3, 97–100	n.d.	5160	331	313	948	67040	43	n.d.	96	n.d.	61	0.2	53	27	50	0.0	n.d.	n.d.	0.70	n.d.	n.d.	n.d.	n.d.	n.d.
50-1, 68–72	n.d.	4980	262	382	948	65380	40	n.d.	109	n.d.	52	1.4	64	24	53	0.2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
51-1, 132–138	n.d.	5040	270	387	948	64400	38	n.d.	114	n.d.	50	0.2	63	25	51	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
52-1, 62–65	37.0	5040	286	368	948	65100	37	40.6	108	123	50	0.3	66	26	46	0.2	n.d.	0.02	0.91	0.74	0.46	1.18	0.02	0.00
52-2, 55–60	n.d.	5100	281	370	948	66220	36	n.d.	105	n.d.	46	1.1	65	25	51	1.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
52-3, 100–103	n.d.	5040	288	368	948	64750	38	n.d.	111	n.d.	45	0.6	64	25	49	1.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
52-4, 63–66	n.d.	5160	287	356	948	66430	39	n.d.	106	n.d.	53	1.2	64	26	49	0.4	n.d.	n.d.	0.75	n.d.	n.d.	n.d.	n.d.	n.d.
54-1, 16–18	46.5	8160	353	271	1012	71540	43	n.d.	88	n.d.	60	0.0	106	35	97	3.1	n.d.	n.d.	3.60	1.25	0.73	2.55	0.16	0.18
56-1, 139–142	46.5	8160	356	285	1075	73710	43	n.d.	86	n.d.	63	0.4	107	37	106	3.0	n.d.	n.d.	3.20	1.24	0.72	2.54	0.16	0.18
57-1, 51–55	45.8	8040	366	357	1012	69930	44	n.d.	n.d.	n.d.	62	0.3	107	37	105	4.0	n.d.	n.d.	2.90	1.22	0.72	n.d.	0.16	0.17
57-2, 26–30	n.d.	5880	282	367	1012	69020	41	n.d.	117	n.d.	60	1.1	78	28	64	2.3	n.d.	n.d.	1.20	n.d.	n.d.	n.d.	n.d.	n.d.
58-1, 143–146	n.d.	5400	322	265	1012	68110	38	n.d.	82	n.d.	57	1.6	53	27	58	0.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
58-2, 14–17	n.d.	5460	319	289	1012	69440	38	n.d.	88	n.d.	56	1.5	64	28	56	1.3	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
59-1, 46–48	n.d.	6060	312	379	1012	69020	44	n.d.	119	n.d.	58	0.0	80	29	66	0.5	n.d.	n.d.	1.37	n.d.	n.d.	n.d.	n.d.	n.d.
60-1, 50–54	n.d.	6300	337	323	1075	74630	42	n.d.	92	n.d.	56	0.2	75	31	62	0.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
61-1, 112–115	n.d.	6240	348	351	1138	77350	47	n.d.	122	n.d.	70	1.3	53	32	58	0.4	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
63-2, 103–105	n.d.	6120	349	335	1075	74830	42	n.d.	118	n.d.	64	1.5	52	31	61	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
64-2, 107–109	42.0	6960	363	150	1138	81690	43	44.8	59	73	71	0.4	57	35	72	0.8	n.d.	n.d.	1.20	0.92	0.64	1.83	0.03	n.d.
64-1, 78–82	41.8	5940	361	237	1075	76230	44	44.6	87	100	71	0.6	57	30	54	1.9	n.d.	n.d.	0.95	0.75	0.55	1.37	0.02	n.d.
70-1, 56–60	43.7	6540	364	172	1201	79870	45	46.4	71	81	64	1.5	59	33	65	1.5	n.d.	n.d.	n.d.	0.87	0.60	1.63	0.02	0.01
505-25-1, 26–28	30.9	4260	224	605	1007	57050	39	40.8	202	222	52	0.6	81	19	42	1.1	n.d.	0.07	1.26	0.68	0.38	0.99	0.06	0.04
26-1, 33–36	n.d.	4560	237	608	1084	57550	38	n.d.	173	n.d.	56	1.8	89	22	47	1.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
505A-1-1, 28–30	38.1	5700	272	449	1239	68180	42	44.8	154	153	61	0.4	80	26	51	1.0	0.04	n.d.	1.19	0.92	0.55	1.38	0.07	0.04
2-1, 51–55	38.9	5700	266	436	1162	67830	41	44.1	148	166	67	1.1	74	28	57	0.9	n.d.	n.d.	1.49	0.83	0.74	1.43	0.05	n.d.
505B-2-1, 19–23	n.d.	5880	271	430	1162	67130	44	n.d.	153	n.d.	61	0.4	75	29	56	1.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
2-2, 87–89	40.3	5760	266	457	1084	65380	42	46.0	167	178	60	0.6	81	28	56	0.8	0.01	0.04	1.61	0.88	0.64	1.43	0.06	0.06
2-3, 51–52	38.1	5760	262	431	1394	67480	43	43.0	154	167	57	3.0	109	28	56	0.4	0.04	0.14	1.22	0.89	0.49	n.d.	0.06	0.05
2-3, 78–83	38.8	5760	272	447	1084	65520	42	44.4	160	172	58	0.0	74	28	53	0.4	0.25	0.04	0.04	0.82	0.53	1.38	0.07	0.08
3-1, 76–79	38.0	5700	270	455	1162	66780	41	44.5	157	149	60	3.0	78	29	57	0.3	0.01	0.02	0.96	0.79	0.48	1.16	0.02	0.02
3-2, 102–105	37.9	5700	267	437	1084	66570	44	44.5	168	174	59	0.6	77	27	56	1.2	n.d.	n.d.	1.51	0.84	0.54	1.50	0.06	0.07
5-1, 40–43	n.d.	5820	261	437	1084	65590	43	n.d.	167	n.d.	57	0.1	76	27	59	1.5	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
6-1, 114–116	39.8	5820	270	437	1162	66080	42	44.1	152	171	62	1.6	79	27	52	1.0	n.d.	n.d.	1.38	0.91	0.72	n.d.	0.06	n.d.
6-2, 20–23	39.6	5820	263	441	1162	68040	43	44.4	165	161	62	0.5	75	27	58	1.3	0.01	0.02	1.37	0.92	0.65	1.49	0.07	0.04

[a] Oxidized.
[b] Nonoxidized.

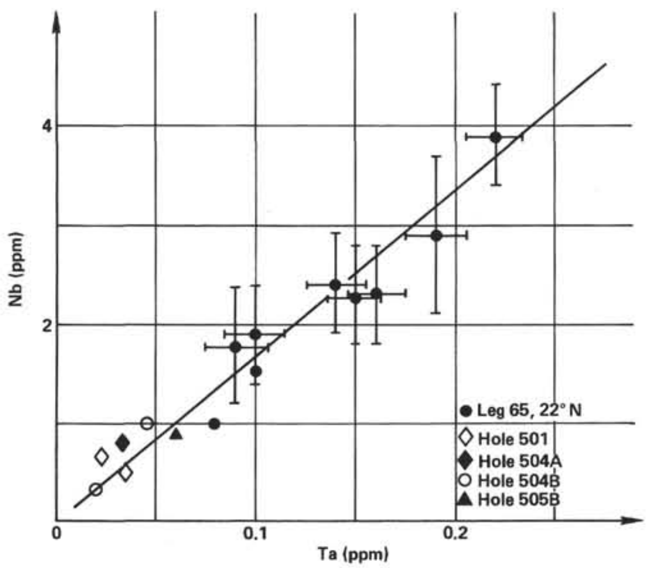

Figure 1. Nb versus Ta. Dots correspond to the different basaltic units encountered at 22°N on the East Pacific Rise during Leg 65. The two open circles are related to Hole 504B; the lower one corresponds to the averages Ta 0.02 ppm and Nb 0.3 ppm; the upper one corresponds to the averages Ta 0.045 ppm and Nb 1 ppm (representing Samples 504B-16-3, 129-139 cm, 504B-17-2, 94-97 cm, and 504B-17-3, 22-24 cm.

value of the slope Nb = f(Ta) derived from the least-squares calculation is 16.4. It corresponds to the value found so far for oceanic basalts and is independent of the notion of enrichment or depletion of hygromagmatophile elements. On the other hand, all Nb, Ta, La, and Th values, except four samples reported in Table 2 (Hole 504B) for Cores 18 and 19, probably lie within the ΔX values of these elements, and within twice their dx values. In such cases, it is impossible to infer from Figure 1 a Nb/Ta ratio for the low values encountered at Sites 501, 504, and 505. It is possible to say only that the values found are compatible with a Nb/Ta ratio of 16. There is no ambiguity for the larger concentrations encountered in Samples 504B-18-1, 84-88 cm, 504B-18-2, 98-102 cm, 504B-19-1, 73-77 cm, and 504B-19-2, 46-49 cm, whose average Nb/Ta ratio of 15.4 fits with the value 16 ± 1 of oceanic basalts.

La is plotted versus Ta in Figure 2, for 22°N samples of the East Pacific Rise (Leg 65), and for Sites 501, 504, and 505. Two values of the La/Ta ratio have been found so far in the Atlantic: 9 and 19 (Bougault, Treuil, and Joron, 1979); only the value 19 has been found so far on the East Pacific Rise (Joron et al., 1980; Cambon et al., 1980). The same comments as for Nb and Ta can be made about the low La and Ta values at Sites 501, 504, and 505. It is difficult to give a La/Ta ratio for these low concentrations, but it can be stated that these concentrations are compatible with the value 19 of the La/Ta ratio. On the contrary, the four samples from Hole 504B (Table 2) represent the other value, 9, of the La/Ta ratio. This result is very important, because it is the first time that it is clearly established that basalts with low La/Ta values of about 9 are found in the same hole as

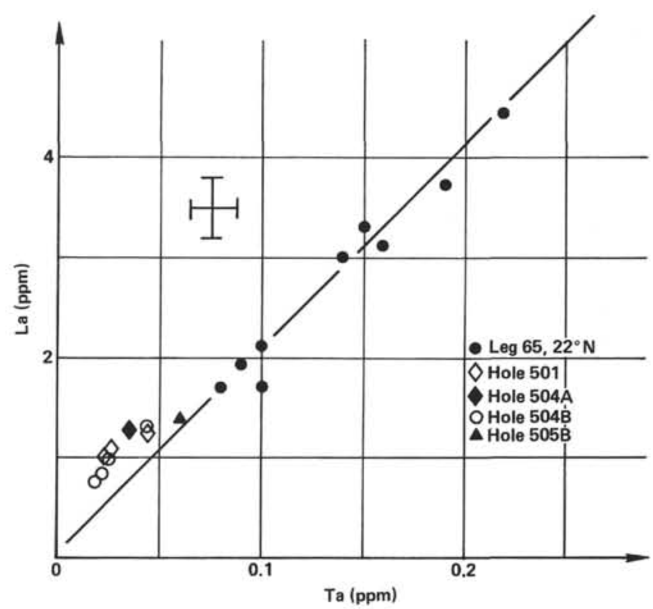

Figure 2. La versus Ta. (Compare Fig. 1.)

depleted basalts which probably have La/Ta of approximately 18.

It has recently been confirmed further that Zr and Hf, as well as Y and Tb, fractionate very little during magma genesis (Bougault, Treuil, and Joron, 1978). The values of Zr/Hf and Y/Tb ratios, 40 and 50, respectively, are very close to the values already found for oceanic basalts.

There is a clear correlation between the concentrations of the various alkali metals. The observed variations are of the same order of magnitude as those observed at Hole 395A, at 22°N on the Mid-Atlantic Ridge (Bougault, Treuil, and Joron, 1979). These variations do not reflect primary variations, but appear to be the result of low-temperature alteration.

The high-partition-coefficient elements Cr and Ni show typical concentrations for tholeiites. The least-fractionated samples are two from Hole 505 (Table 2) which almost fulfill the theoretical requirements of being primary melts (Cr, 600 ppm; Ni, 250 ppm; Bougault, 1977b). The observed variations (Cr, 200-600 ppm; Ni, 80-200 ppm) are probably due both to fractional crystallization and to the occurrence of some phenocrysts in some units.

HYGROMAGMAPHILE ELEMENTS

Several authors have long proposed different ways of presenting geochemical data, either on the basis of chemical properties of some elements, or as discriminants among different rock suites. Because of the available methods and equipment, authors use different elements to try to solve the same problems. For example, the normalized rare-earth-element diagram proposed by Coryell et al. (1963) and Masuda (1962) is one of the most popular. The triangular diagram for Y, Zr, and Ti of Pearce and Cann (1971) also is well known. Do Y, Zr, and Ti on the one hand, and rare-earth elements on the other, indicate different processes? If they are sensitive to the same processes, is it possible to find a unique way of presenting the data? Such attempts are common and lately have been based on the combination of rare earths and non-rare earths in an extended Coryell–Masuda plot. This plot uses concentrations normalized to chondrite abundances, and has the elements arranged according to their bulk behavior to the behavior of rare earths. The data presented in such a way have not always removed ambiguities, for several reasons: (1) some elements, such as alkali metals, are too sensitive to low-temperature alteration or sea-water contamination, which act to obscure initial abundances; (2) for other elements, such as Zr, the normalizing concentrations (average chondrite concentrations) are not known with suitable precision (Schmitt et al., 1964; Ganapathy et al., 1976; Ehmann and Rebagay, 1970; Shima, 1979); (3) in such extended rare-earth-element diagrams, the dispersion of points along the "continuous" curve often is very large compared to the dispersion of the rare-earth elements themselves; this makes interpretation difficult, especially with respect to the evidence of possible anomalies, such as the Eu anomaly (Tarney, Wood, Varet, et al., 1979; Sun et al., 1979; Tarney, Wood, Saunders, et al., 1980; Morrison et al., 1980; Sun, 1980); (4) very few homogeneous data (rare-earth and non-rare-earth concentrations measured from the same samples) are available in the literature for samples which present different characteristics.

One of us (Bougault, 1980), has proposed a method for presentation of the data which is based on an extended Coryell–Masuda plot, for the purpose of comparative geochemistry. This is not in opposition to approaches such as that proposed by Gast (1968), Shaw (1970), Langmuir et al. (1977), or by ourselves (Bougault, Joron, and Treuil, 1979). First of all, alkali elements, Sr, and Ba are not included in such a representation, because of alteration and contamination problems. Only the elements of "hygromagmaphile" character (such as rare earths) are considered; these elements have low "bulk" solid/liquid partition coefficients, and show an affinity for the liquid phase of the magma. It is meaningless to plot high-partition-coefficient elements such as Ni or Cr in such a diagram, because such elements behave during magmatic processes in different ways than hygromagmaphile elements. Such hygromagmaphile elements correspond to transition elements whose ions show a rare-gas electronic structure (except Group V). Instead of choosing single or average values as normalizing concentrations for non-rare earth elements from the chondritic concentrations proposed in the literature, the normalizing concentrations have been calculated by using an "inverse method," accounting for all of the homogeneous (analytical, obtained from the same samples) data of oceanic basalts obtained since Leg 37. Similarly, the position of non-rare-earth elements among rare earths has been determined using an inversion method. This classification of the elements on the basis of their hygromagmaphile character relies upon the continuous variation of the hygromagmaphile character of the rare earths.

The classification has been confirmed by a more theoretical approach, involving the incompatibility of these elements in a crystal structure, and their availability to form complexes in the liquid. The parameter ϕ, which accounts for these two factors, involving ionic radius, R, and the ionic charge, n, is reported in Table 3, together with the normalizing concentrations. These results have three implications: (1) the expression large ion lithophile element (LILE) has to be abandoned: Ta and Nb ($R = 0.68$ Å) behave like La ($R = 1.06$ Å). We propose replacement of this expression by "hygromagmaphile," to account for the affinity of the element for the liquid phase of the magma; (2) rare-earth and non-rare-earth elements plot in an extended Coryell–Masuda diagram with the same precision; (3) anomalies, in addition to the widely known Eu anomaly, have been observed: there are possible Ti negative anomalies, possibly caused by opaque-mineral crystallization (El Azzouzi, 1981), and there are anomalies in the abundance of La compared with Nb and Ta, which have been interpreted so far in terms of mantle heterogeneity.

On the basis of the extended Coryell–Masuda plots, the data available for Sites 501, 504, and 505 can be divided into three categories. First, the category which corresponds to the majority of samples would plot in Figure 3 between the filled circles and filled diamonds. These basaltic units are more depleted in Th, Ta, Nb, and La than any other rocks drilled during the DSDP project. The second category is represented by only three samples (Table 2; Hole 504B, 54-1 to 57-1), which are less depleted in La and Nb than those of category 1. The third category is represented by four samples of Unit 5 of Hole 504B (Samples 504B-18-1, 84–85 cm to 504B-19-2, 46–49 cm). The normalized concentrations of hygromagmaphile elements present a flat distribution, even somewhat enriched in Th, La, Nb. The major difference between these and samples of the two other categories lies in the fact that the La, Ta, and Nb normalized concentrations have the same value: this feature corresponds to the La/Ta ratio equal to 9, mentioned earlier. For category 2, even if the Ta concentration is not available at the moment, from the Nb position, and using a Nb/Ta ratio equal to 16, the La/Ta ratio of category 2 can be estimated to be close to 19, based on Figure 3. For the first category, as already discussed in the preceding paragraph, because of the very low values, it is not possible to propose a value for the La/Ta ratio, but the data and the position of the related points in Figure 3 are compatible with the value 19.

One important result of drilling the Costa Rica Rift lies in the La/Ta anomaly. Either the value 9 (normalized ratio: 1) or the value 19 (normalized ratio: 2) has been found so far at one site and for large areas of the sea floor. This bimodal distribution has heretofore been interpreted in terms of mantle domains, and it is very difficult to propose another interpretation at the moment. If the values of La/Ta do reflect mantle heterogeneity, then the two values found in Hole 504B imply that the mantle can be locally heterogeneous. This result is clearly shown in Figure 3 by the relative position of Nb and Ta points compared to La; either the open diamonds

Table 3. Classification and normalized concentrations of hygromagmaphile transition elements.

Parameter	Th	La	Ta	Nb	Ce	Pr	Nd	Zr	Hf	Sm	Ti	Eu	Gd	Tb	Y	Dy	Ho	Er	Tm	Yb	Lu	V	Sc
Ch	0.028	0.32	0.031	0.53	0.85	0.112	0.60	5.13	0.128	0.19	460	0.07	0.25	0.047	2.16	0.32	0.07	0.21	0.03	0.20	0.033	22	
R	0.99	1.06	0.68	0.69	1.03		0.99	0.79	0.79	0.96	0.68	0.95	0.94	0.92	0.92	0.90		0.88		0.86	0.85	0.59	0.73
n	4	3	5	5	3	3	3	4	4	3	4	3	3	3	3	3	3	3	3	3	3	(5)	3
ϕ	8.34	7.35	7.25	7.35	6.90		6.33	5.74	5.74	5.89	5.88	5.71	5.66	5.37	5.34	5.16		4.93		4.72	4.64	(9.23)	4.22

Note: Ch = chondrite-normalized concentrations; *R* = ionic radius; *n* = ionic charge or oxidation state; ϕ = computed hygromagmaphile character.

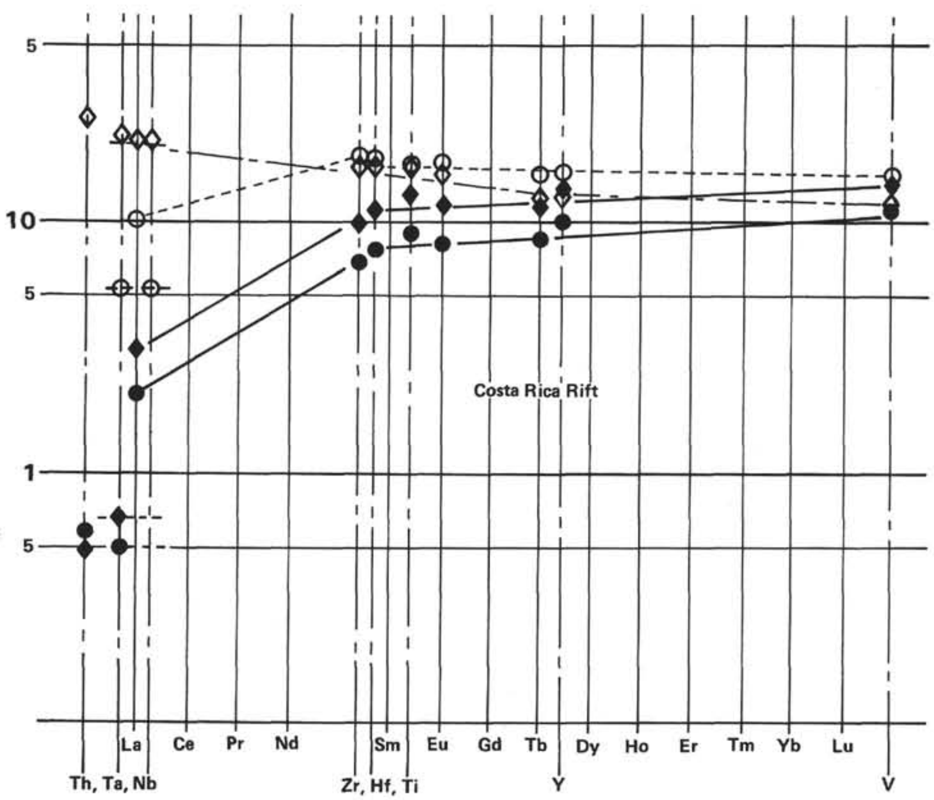

Figure 3. Costa Rica Rift, extended Coryell-Masuda plot. The examples chosen on this figure are from Hole 504B (Table 2). Filled circles: 504B-21-5 to 504B-22-2; filled diamonds, 504B-25-2, 96–99 cm; open circles: 504B-54-1 to 504B-57-1, 51–55 cm; open diamonds: 504B-54-1 to 504B-57-1, 51–55 cm. Because of low Ta and Nb values and related accuracies (see Fig. 1), the positions of filled diamonds and circles have to be associated with a large error for those two elements.

(with normalized La/Ta or Nb/La of 1) or Nb and/or Ta plot at a lower position than La (with normalized La/Ta or Nb/La of 2).

CONCLUSIONS

The basalts drilled from the Costa Rica Rift are more depleted in the most-hygromagmaphile elements (Th, Ta, Nb, and La) than any other basalts drilled under the aegis of DSDP. Most of the concentrations of these elements are close to the precision limits of neutron-activation analysis and X-ray fluorescence. Despite the very low concentrations of Ta, Nb, and La, it can be stated that these data are compatible with the value 16 ± 1 of the invariant ratio Nb/Ta, and the value 19 of the La/Ta. The two other invariant ratios, Zr/Hf and Y/Tb, show the typical values 40 and 50 respectively.

Among more than 160 analyzed samples, only four samples present a flat or slightly enriched extended rare-earth pattern and a La/Ta ratio equal to 9 (1 for the normalized ratio). Previously, we believed that these ratios characterized large mantle domains, based on the observation that large areas are characterized by one of the two La/Ta (or La/Nb) ratios, but this finding (both ratios in the same hole) suggests that local mantle heterogeneity is likely.

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