30. EAST PACIFIC RISE, GALAPAGOS SPREADING CENTER AND SIQUEIROS FRACTURE ZONE, DEEP SEA DRILLING PROJECT LEG 54: HYGROMAGMAPHILE ELEMENTS—A COMPARISON WITH THE NORTH ATLANTIC

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ABSTRACT

Basalt samples collected on DSDP Leg 54 are fresh, with some showing extensive Fe- and Ti-enrichment. Samples from many sites were contaminated with Co, Ta, and, to a lesser extent, Nb, because they were powdered using a tungsten carbide shatter box onboard ship. Y/Tb, Zr/Hf, and (for uncontaminated samples) Nb/Ta ratios are similar to those of North Atlantic basalts and chondritic meteorites; these ratios are probably characteristic of the primordial mantle. The La/Ta and Y/La ratios indicate that the Leg 54 eastern Pacific basalts were derived from "depleted" mantle similar to the source of North Atlantic basalts drilled on DSDP Leg 45 (22°N; Miocene crust) and Legs 51 through 53 (25°N; Cretaceous crust).

INTRODUCTION

DSDP Leg 54 was the first IPOD leg in the North Pacific dealing with the oceanic crust. Several sites were drilled: the western flank of the East Pacific Rise (EPR) at 9°N (Figure 1), Sites 420, 421 (~3.5 m.y. old), 423 (~1.2 m.y. old), 422, 428 (~2 m.y. old), and 429 (~4.5 m.y. old); the Galapagos spreading center at 0°N, 86°W, four holes at Site 424, and Site 425 (62 km north of the Galapagos spreading center axis); and the Siqueiros fracture zone, Site 427 (8°N, ~5 m.y. old).

Samples from this drilling program should give us a picture of the variability of basalts produced in this area and a basis of comparison with results obtained in the North Atlantic. Our investigations focused on Y/Tb, Zr/Hf, and Nb/Ta ratios, shown to be constant for DSDP and dredged samples in the North Atlantic, and on the La/Ta ratio.

In the North Atlantic, on the basis of La/Ta ratios, we can identify two main mantle sources for the basalts of the oceanic crust. The first source is characterized by a La/Ta ratio equal to 18, which represents the so-called "typical MORB tholeiites." Basalts drilled at Sites 395 and 396 on either side of the Mid-Atlantic Ridge during Legs 45 and 46 have this ratio. The second source is characterized by a La/Ta ratio equal to 9 and represents the basalts of the oceanic islands and seamounts and also of parts of the ridges near these islands. Basalts drilled and dredged in the FAMOUS area at 36°N, at 45°N, and near Iceland, during Leg 49, have this ratio (see Figure 2).

We also deal with a contamination problem caused by powdering the samples in a tungsten carbide shatter box onboard the *Glomar Challenger.*

ANALYTICAL CHEMISTRY: THE CONTAMINATION PROBLEM

Analytical procedures (X-ray fluorescence [XRF] both onboard ship and on shore and neutron activation analysis) have been described previously (Bougault, 1977; and Bougault et al., 1978). As on several previous legs, we have systematically analyzed trace elements in samples selected onboard ship for shipboard analysis. Unfortunately, on Leg 54 the oil tank of the generator of the XRF unit burned out. This represented the first major breakdown of our shipboard equipment since we started analysis onboard the *Glomar Challenger* (Leg 37) and, consequently, most of our major-oxide results were obtained on shore. In addition, the agate mortar was cracked, pitted, and was therefore unusable. Consequently, we prepared the powders onboard ship using the shipboard tungsten carbide shatter box. We knew in advance that this procedure would lead to cobalt contamination but did not know the extent of the problem. Although some results may not be suitable for geochemical interpretation, we measured the same elements as on previous cruises, to determine what other elements (if any) were involved in the contamination.

Hole 427 samples (Table 13b) provided a good opportunity to ascertain which elements were contaminated by use of the tungsten carbide shatter box, as some specimens were ground in this manner, others by means of the agate mortar. The former evinced a high tungsten concentration. We confirmed the anticipated contamination of cobalt: values as high as 80 ppm in contaminated samples occur, whereas the average in uncontaminated samples is about 46 ppm, a typical value in oceanic

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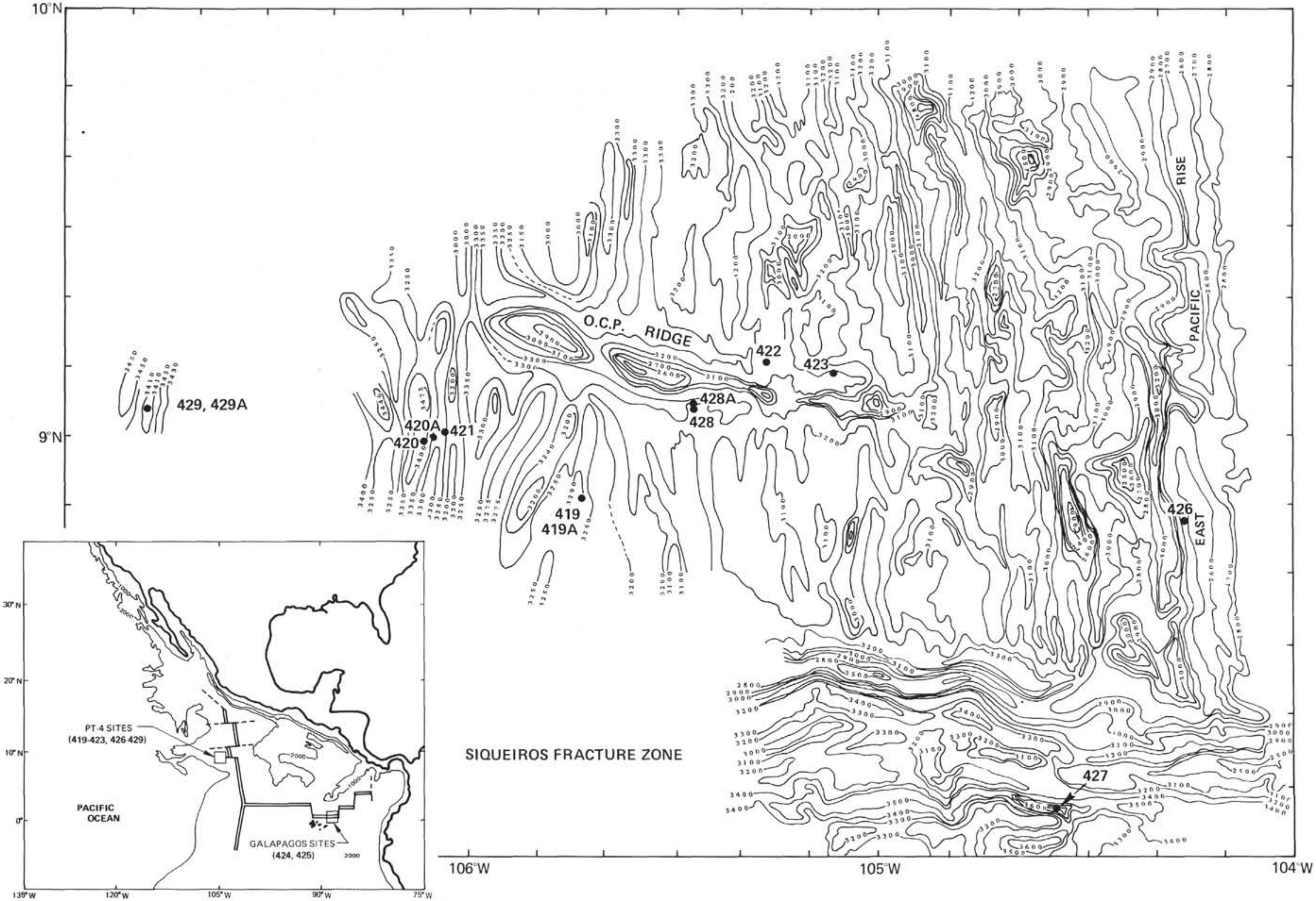

Figure 1. *Sites drilled on Deep Sea Drilling Project Leg 54. Contours in meters.*

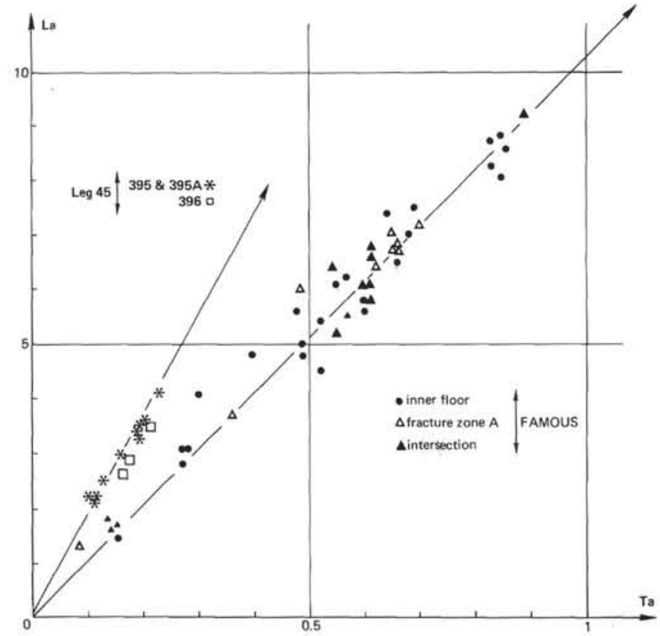

Figure 2. *La (ppm) versus Ta (ppm) for basalts drilled and dredged on Leg 49. Symbols for this and Figures 3 through 8 are as follows: ● : Hole 420 ; + : Hole 421 ; × : Hole 422 ; △ : Hole 423 ; □ : Hole 424 and 424 A ; ■ : Holes 424 B and 424C ; ★ : Hole 425 ; ☆ : Hole 427 ; ▲ : Holes 428 and 428 A ; and ○ : Hole 429 A.*

tholeiites. Correspondingly, very high tantalum concentrations (3 to 5 ppm) occur in contaminated samples, whereas the average contents in uncontaminated samples is 0.37 ppm. Niobium is also subject to contamination but to a lesser extent. Values of about 9.3 ppm occur in contaminated samples, whereas the average value in uncontaminated samples is 7.2 ppm. The other elements investigated — Hf, Th, Sc, V, Cr, Ni, Rb, Sr, Y, and Zr — showed no evidence of contamination.

These observations are confirmed on the one hand by samples of Holes 420 through 425 (Tables 1b, 2b, 3b, 4b, and 12b), all of them ground with the tungsten carbide shatter box, and on the other hand by the samples of Holes 428 and 429 (Tables 5a, 6b, and 7b) which were ground with the agate mortar. Thus, it appears that the tungsten carbide shatter box used on Leg 54 causes considerable contamination of cobalt and tantalum, and, to a lesser extent, niobium. This evaluation is, of course, made by comparison with the concentrations of uncontaminated samples presently studied, which are Co ~ 45 ppm, Ta ~ 0.3 ppm, and Nb ~ 7 ppm. Contamination of Ta and Nb results from impurities in the tungsten, that of cobalt because this metal is used as a binder for the tungsten carbide.

RESULTS

The tables are arranged not by hole or site numbers but according to drilling area. Tables 1 through 7 are concerned with the western flank of the EPR, Holes 420, 421, 423, 422, 428, 428A, and 429, respectively. Table 8 through 12 relate to the Galapagos spreading center — Holes 424, 424A, 424B, 424C, and 425, respectively. Table 13 relates to the Siqueiros transform fault (Hole 427).

In the first place, all of the samples have low loss on ignition, and are considered reasonably fresh. Only one significant instance was found, in Hole 428 (Tables 6a and 6b), of alkali metals being sensitive to alteration effects (Bougault et al., 1978; Joron et al., in press). From the oxide analyses in 17 samples it appears that the basalts of this hole are homogeneous. Alkali-metal concentrations are low ($K_2O < 0.2\%$, $Rb < 3$ ppm, and $Cs < 0.05$ ppm), except for Sections 428A-1-4, No. 9 and 428A-2-1, No. 4 (K_2O: 0.44 and 0.29%, Rb: 6.7 and 3.9 ppm, and Cs: 0.28 and 0.17 ppm, respectively). This enrichment results from a moderate alteration effect, comparable to alteration observed in Hole 395 of Leg 45 (Bougault et al., 1978). This variation is by no means to be interpreted as the result of magmatic processes.

With respect to both major oxide and trace elements, despite the number of holes drilled on the western flank of the EPR, the range of basaltic types is rather limited. Choosing TiO_2 as an indicator, three types of hygromagmaphile element increases can be distinguished: Type 1 (Holes 428, 428A, and 422) with TiO_2 about 1.45 per cent; Type 2 (Section 10-2, No. 3 of Hole 422, Holes 420, 423, and 421) with TiO_2 about 2 per cent and Type 3 (first two samples of Hole 421) with TiO_2 about 2.5 per cent.

Within Type 1, four samples (Sections 9-1, 9-3, 9-4, and 9-5 in Hole 422; Table 2a) have higher Al_2O_3 (15.8% instead of 14.2%) and Sr (174 ppm instead of 137 ppm) than other samples within this group. Enrichment in plagioclase and clinopyroxene phenocrysts could account for the variations observed, but Y, Zr, Tb, and Hf are the same as in other samples of the group. Sr and Th are enriched, and Sc is depleted (and remains somewhat problematic).

Within Type 2, some significant differences can be observed; that is, Section 10-2, No. 3 of Hole 422 and Hole 420 have TiO_2 contents of about 1.92 per cent, Hole 423 TiO_2 contents of about 2.05 per cent, and Hole 421 TiO_2 contents of about 2.13 per cent. These differences are confirmed by other elements (Figures 3, 4, and 5).

Basalts having at least two different compositions were obtained in Hole 429 (4.5 m.y. old); they appear to be similar to Type 1 basalts.

From the Galapagos rift, samples recovered in Holes 424, 424A, 424B, and 424C appear to be identical. They are characterized by low Al_2O_3 values (12.6%), high Fe_2O_3 values (15.1%), and very low strontium concentrations (66 ppm) as compared with typical values of oceanic tholeiites. TiO_2 is about 1.87 per cent. Two main groups are present in Hole 425 drilled at 62 km north of the spreading center: they have TiO_2 values of 0.98 per cent and 1.19 per cent (one other sample has $TiO_2 = 1.42\%$). A feature in common with the Site 424 samples is the low value of strontium (50 ppm). From the data available, this low strontium concentration seems to be a characteristic feature of the Galapagos rift.

TABLE 1a
Hole 420 (EPR, 9° N, ~ 3.5 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
14-1, 0-8	50.43	13.77	12.40	0.20	7.18	11.21	2.55	0.16	1.94	0.19	0.14	100.17
15-1 (No. 4)	50.38	13.99	11.63	0.19	6.69	11.31	2.75	0.16	1.92	0.16	1.01	100.19
16-1, 2-10	50.65	13.87	12.47	0.20	7.02	11.14	2.62	0.30	1.92	0.17	0.38	100.74
17-1, 27-30	50.67	14.28	11.00	0.19	6.30	11.20	2.80	0.43	1.99	0.16	1.10	100.09

TABLE 1b
Hole 420 (EPR, 9° N, ~ 3.5 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
14-1, 0-8	43	11640	363	160	92	93	64	0.8	111	50	134	8.1	0.13	–	–	4.4	1.66	1.66	3.6	5.6	0.26	–	857
Section 15-1, (No. 4)	43	11520	364	166	174	177	91	4	126	51	133	7.3	–	0.12	9	4.1	1.67	1.67	3.5	6.9	0.26	–	1040
16-1, 2-10	43	11520	364	162	107	104	61	4	118	50	122	8.4	0.06	0.11	5	3.8	1.59	1.59	3.4	6.12	0.20	–	933
17-1, 27-30	45	11940	391	176	115	117	102	7	131	51	130	6.3	–	–	–	4.1	1.73	1.73	3.6	6.58	0.22	–	864

TABLE 2a
Hole 421 (EPR, 9° N, ~ 3.5 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
2-1, 5-7	50.32	13.11	13.90	0.22	6.42	9.86	2.69	0.44	2.54	0.23	0.83	100.55
3-1, 30-33 (No. 5)	50.91	13.74	11.68	0.22	6.39	10.54	3.52	0.40	2.47	0.23	1.43	101.53
3-1, 72-75 (No. 11)	50.66	13.97	11.14	0.21	7.22	11.26	2.83	0.27	2.14	0.22	0.67	100.63
3-1, 117-120	51.54	14.14	10.82	0.20	6.44	11.04	2.78	0.37	2.15	0.19	0.86	100.53
3-1, 145-148	51.05	13.98	10.85	0.20	6.78	11.26	2.81	0.35	2.11	0.22	0.95	100.54
4-1, 4-7 (No. 1)	51.49	14.04	10.33	0.23	6.74	11.14	2.89	0.37	2.22	0.22	0.67	100.35
4-1, 32-36	49.68	13.27	13.45	0.21	6.74	10.61	2.87	0.23	2.11	0.21	1.10	100.48
BIT 10-13 (No. 2)	50.24	18.85	12.42	0.20	7.11	10.76	2.59	0.45	2.12	0.19	0.76	100.68

TABLE 2b
Hole 421 (EPR, 9° N, ~ 3.5 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
2-1, 5-7	44	15240	453	78	100	96	48	5	118	68	177	8.9	0.08	0.10	–	–	2.09	1.18	4.8	5.12	0.28	0.28	–
3-1, 30-33 (No. 5)	45	14820	447	90	102	103	55	3	146	67	167	8.3	–	0.04	27	–	2.07	1.31	4.65	2.89	0.29	0.29	–
3-1, 72-75 (No. 11)	44	12840	375	165	202	207	61	3	135	57	147	6.5	0.04	0.10	32	–	1.89	1.09	3.85	4.4	0.35	0.35	–
3-1, 117-120 (No. 17)	45	12900	415	164	102	106	93	2	133	58	151	7.1	0.03	0.07	27	–	1.99	1.14	4.03	4.34	0.22	0.22	–
3-1, 145-148	45	12660	380	135	125	130	45	3	135	56	157	6.9	0.04	0.15	25	–	1.91	1.07	3.86	3.72	0.21	0.21	–
4-1, 4-7 (No. 1)	45	13320	420	147	126	133	82	1	138	62	159	8.8	–	–	44	–	2.06	1.21	4.1	6.03	0.29	0.29	–
4-1, 32-36	42	12660	391	131	167	165	56	3	110	59	149	11.6	0.05	0.03	–	–	1.97	.099	3.70	11.61	0.22	0.22	–
BIT 10-13 (No. 2)	43	12720	388	130	92	90	53	–	127	56	156	7.8	0.05	0.20	13	–	1.62	1.01	3.95	3.46	0.24	0.24	

Hole 427 which was drilled in the Siqueiros fracture zone consists of one single homogeneous unit. Although the Al_2O_3 content is rather low (13.3%), Sr concentrations (~125 ppm) correspond to a typical Sr value in oceanic tholeiites. These samples are similar to Type 3 basalts, as defined by the two uppermost samples of Hole 421 on the western flank of the EPR.

HYGROMAGMAPHILE ELEMENTS

In all samples recovered by drilling in the Atlantic Ocean (as well as those recovered during the FAMOUS operation), for each pair Y-Tb, Zr-Hf, and Nb-Ta, one element has been shown not to fractionate with respect to the other (Bougault et al., in press; Joron et al., in press). Thus, the ratios of these elements are constant or nearly constant for each pair, and close to chondritic ratios.

Because of the contamination problem, Nb and Ta data are available only for two EPR sites (Holes 428, 428A, and 429A) and for the Siqueiros fracture zone (Hole 427). The parallel lines on Figure 6 show a major portion of the range of North Atlantic data (absolute values go up to 7.8 ppm for Ta and 93 ppm for Nb at 45°N); data of Leg 54 plot on the same line.

All Zr-Hf and Y-Tb data can be used since no contamination has been observed for these elements. As with Nb-Ta, all the Zr-Hf data of Leg 54 plot in the range defined by the samples of the Atlantic Ocean (Figure 3). On the Y-Tb diagram (Figure 4) the data plot on a line the slope of which is a little higher than the average slope of the Atlantic. Since this difference can result from a small systematic difference of 2 to 3 ppm in Y or 0.1 to 0.2 ppm in Tb, we do not state that the Leg 54 line is distinct from the North Atlantic line.

TABLE 3a
Hole 422 (EPR, 9° N, ~ 2 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
5-1, 23-26 (No. 5)	50.26	14.03	10.59	0.18	7.66	12.04	–	0.11	1.44	0.16	0.33	96.81
7-1, 6-10	50.44	14.26	10.46	0.17	7.80	11.95	2.61	0.17	1.46	0.15	0.76	100.23
7-1, 20-25	50.49	14.17	10.61	0.17	7.83	11.98	2.39	0.13	1.44	0.17	0.76	100.14
7-1, 89-92 (No. 7)	50.55	14.30	10.70	0.18	7.82	12.02	2.75	0.11	1.44	0.16	0.19	100.21
7-1, 122-131	50.56	14.30	10.56	0.17	7.78	12.09	2.59	0.18	1.43	0.14	0.48	100.28
Section 7-2, (No. 3)	50.74	14.28	10.58	0.18	8.04	12.00	2.70	0.13	1.45	0.15	0.21	100.46
8-5, 23-26 (No. 5)	–	–	–	–	–	–	2.77	–	–	–	–	–
8-5, 132-135 (No. 14)	50.73	14.32	10.46	0.17	8.21	11.99	2.74	0.10	1.45	0.17	0.14	100.46
9-1, 70-73 (No. 4c)	50.28	13.99	10.65	0.17	7.87	11.92	2.71	0.09	1.43	0.15	1.04	100.30
9-2, 135-138 (No. 6)	49.76	15.96	9.80	0.19	8.54	11.72	2.83	0.22	1.40	0.20	0.67	101.30
9-3, 91-94 (No. 6c)	48.59	15.50	9.38	0.19	8.45	11.59	2.85	0.23	1.38	0.18	1.33	99.66
9-4, 41-45 (No. 3b)	49.64	15.96	7.67	0.15	8.73	11.67	2.80	0.25	1.40	0.20	0.67	101.14
9-5, 72-75 (No. 6)	49.77	15.83	9.79	0.15	8.63	11.68	2.83	0.21	1.43	0.18	0.33	100.82
10-2, 19-25 (No. 3)	50.39	13.92	11.84	0.20	7.09	11.72	2.94	0.31	1.88	0.21	0	100.50
10-1, 12 ?	–	–	–	–	–	–	2.41	–	–	–	–	–

TABLE 3b
Hole 422 (EPR, 9° N, ~ 2 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
7-1, 6-10	–	8760	278	231	–	–	–	0.5	137	42	97	8.3	–	–	–	–	1.31	0.69	–	–	–	–	–
7-1, 20-25	40	8640	286	236	130	129	69	1	138	40	108	5.4	0.01	.04	–	3.2	–	–	2.34	4.73	0.10	–	757
Section 89-92, (No. 7c)	–	8640	296	237	299	–	–	1	138	37	156	5.5	–	–	–	–	1.36	0.71	–	–	–	–	–
7-1, 122-131	41	8580	295	281	–	90	81	0.2	146	36	–	5.7	0.06	–	–	2.9	1.41	0.62	2.41	4.37	0.09	0.34	664
Section 7-2, (No. 3)	41	8700	276	237	–	98	75	0.1	140	37	97	5.5	0.02	–	–	3.2	1.3	0.72	2.63	5.98	0.09	0.21	836
8-5, 23-26 (No. 5)	41	–	–	–	–	108	78	–	–	–	–	–	–	–	–	3.0	–	–	2.40	7.72	0.11	–	1111
8-5, 132-135 (No. 14)	–	8700	–	–	–	–	–	0.2	137	39	107	5.7	–	–	–	–	–	–	–	–	–	–	–
9-1, 70-73 (No. 4c)	–	8580	284	265	105	–	–	0.2	137	40	105	6.7	–	–	–	–	–	–	–	–	–	–	–
9-2, 135-138 (No. 6)	34	8400	236	300	126	132	138	0.3	179	37	108	8.2	0.04	0.08	31	4.6	1.23	0.66	2.41	4.51	0.43	–	608
9-3, 91-94 (No. 6c)	34	8280	–	–	–	94	143	2.5	173	36	105	8.9	0.02	0.03	31	4.3	1.31	0.64	2.43	6.74	0.39	–	926
9-4, 41-45 (No. 3b)	33	8400	241	314	88	96	127	2.5	166	34	108	8.2	0.02	–	19	5.0	1.28	0.64	2.35	5.53	0.44	–	803
9-5, 72-75 (No. 6)	34	8580	241	301	92	102	140	0.7	179	32	119	8.3	0.04	0.03	37	5.7	1.30	0.65	2.40	5.09	0.46	–	682
10-2, 19-25 (No. 3)	41.6	11280	389	249	116	120	73	2.4	114	47	132	5.5	0.03	0.13	–	4.4	1.71	0.96	3.42	3.67	0.21	–	590

TABLE 4a
Hole 423 (EPR, 9° N, ~ 1.2 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
5 CC, 40-42 (No. 4)	50.43	13.59	11.36	0.21	6.79	11.02	2.92	0.32	2.09	0.24	1.14	100.11
6-1, 28-34 (No. 5)	50.14	13.40	13.02	0.20	6.92	10.97	1.94	0.23	2.06	0.23	0.83	99.94
Section 7-1, (No. 11)	49.75	13.28	13.53	0.18	6.60	10.68	2.43	0.35	2.04	0.20	1.00	100.01
7-1, 46-47 (No. 7)	50.37	13.55	12.70	0.18	6.88	10.75	–	0.36	2.05	0.22	0.76	97.82
8-1, 40-42 (No. 6)	50.90	13.55	12.31	0.18	6.82	10.87	2.57	0.35	2.10	0.22	0.81	100.67

TABLE 4b
Hole 423 (EPR, 9° N, ~ 1.2 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
5 CC, 40-42 (No. 4)	40.2	12540	377	–	170	173	100	–	–	–	–	–	–	0.10	–	4.0	2.10	1.05	3.54	8.9	0.23	–	1308
6-1, 28-34 (No. 5)	42	12360	–	–	104	101	67	1	119	–	149	–	–	0.07	–	4.2	1.91	10.2	3.61	5.94	0.25	–	–
Section 7-1, (No. 1b)	41.6	12240	230	160	97	91	56	4.1	131	51	144	10.3	–	0.17	–	4.0	1.58	0.96	3.49	6.27	0.19	–	–
7-1, 46-47 (No. 7)	–	12300	–	–	–	–	–	2.2	118	65	138.6	10.1	–	–	–	–	–	–	–	–	–	–	–
8-1, 40-42 (No. 6)	–	12600	376	196	146	–	–	4.3	128	61	141	10	–	–	–	–	–	–	–	–	–	–	–

Figure 5 is a plot of Zr versus Ti; only slight fractionation is observed between these elements, confirming the hygromagmaphile behavior of Ti (Bougault, 1977b). The slope found is 1.1×10^{-2}, very close to the value obtained at 22°N and 36°N in the Atlantic: 1.15×10^{-2} (Bougault et al., 1978).

These results confirm that there is little or no fractionation between such pairs of elements as Y-Tb, Zr-Hf, and Nb-Ta. Thus, we conclude that the ratios are distinctive of the mantle prior to differentiation. Since these ratios are the same, or nearly the same, in the Atlantic and Pacific oceans, and in addition are similar to chondritic ratios, it is very probable that they are characteristic of the earth itself.

With respect to two hygromagmaphile elements whose partition coefficients are different by an order of magnitude, for instance Y and La, it has been shown (Bougault et al., in press 1,2) that the Y/La ratio may vary widely. Being very similar to the Sm/La ratio used by Shilling (1973), it is a function of mantle differentia-

TABLE 5a
Hole 428 (EPR, 9° N, ~ 2 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
5-4, 38-40 (No. 4)	50.62	14.40	10.62	0.18	7.25	11.97	2.30	0.14	1.45	0.14	0.45	99.52
5-4, 78-80 (No. 9)	49.85	14.22	10.27	0.22	7.11	12.07	2.54	0.09	1.43	0.12	0.45	98.37
6-2, 1-3 (No. 1)	50.01	14.17	10.46	0.20	7.52	11.84	2.44	0.08	1.45	0.14	0.36	98.67

TABLE 5b
Hole 428 (EPR, 9° N, ~ 2 m.y. old): Trace Elements

Sample (Interval in cm)	Sc	Ti	V	Cr	Co		Ni	Rb	Sr	Y	Zr	Nb	Sb	Cs	Ba	La	Eu	Tb	Hf	Ta	Th	U	W
	NA	XRF	XRF	XRF	XRF	NAA	NAA	XRF	XRF	XRF	XRF	XRF	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA
5-4, 38-40 (No. 4)	42.2	8700	281	313	41	43	81	1.2	139	42	107	5.3	–	–	–	3.1	1.29	0.73	2.5	0.25	0.24	–	–
5-4, 78-80 (No. 9)	42.4	8580	286	324	41	42	82	0.8	128	40	107	5.2	–	–	17	3.0	1.21	0.72	2.44	0.24	0.21	–	–
6-2, 1-3 (No. 1)	41.9	8700	298	309	45	42	77	0.6	129	40	105	4.9	–	–	–	3.4	1.29	0.72	2.57	0.25	0.21	–	–

TABLE 6a
Hole 428A (EPR, 9° N, ~ 2 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
1-1, 21-23 (No. 3)	50.87	14.61	10.46	0.31	7.31	11.87	2.36	0.23	1.48	0.16	0	99.66
1-1, 27-29 (No. 4)	50.48	14.53	10.13	0.32	7.05	12.26	2.60	0.10	1.48	0.14	0.5	99.59
1-1, 92-94 (No. 10)	50.19	14.23	10.86	0.21	7.35	12.01	–	0.21	1.48	0.14	0.71	–
1-1, 120-122 (No. 13)	50.32	14.23	10.55	0.21	7.16	12.01	2.22	0.22	1.46	0.13	0.62	99.13
1-2, 49-51 (No. 6)	50.45	14.28	10.79	0.19	7.40	12.03	2.35	0.17	1.50	0.16	0.33	99.58
1-3, 72-74 (No. 3b)	50.08	14.35	10.87	0.18	8.05	11.70	2.43	0.07	1.47	0.15	0.52	99.86
1-4, 67-70 (No. 9)	50.59	14.36	11.19	0.17	7.27	11.77	2.30	0.44	1.46	0.19	0.76	100.49
2-1, 33-37 (No. 4)	50.92	14.60	10.93	0.17	7.72	11.92	2.50	0.29	1.47	0.17	0.09	100.77
3-1, 131-133 (No. 12a)	50.31	14.57	10.73	0.16	8.28	11.67	2.36	0.01	1.45	0.19	0.83	100.56
4-1, 123-126 (No. 14a)	49.39	14.22	10.45	0.17	7.95	12.21	2.52	0.04	1.43	0.18	1.72	100.29
4-2, 107-109 (No. 8)	50.35	13.80	11.75	0.19	7.52	11.34	2.54	0.16	1.73	0.20	1.13	100.71
5-1, 113-115 (No. 9)	50.32	14.58	11.15	0.16	7.45	11.78	2.50	0.10	1.49	0.19	0.79	100.51
5-2, 88-91 (No. 5e)	50.71	14.70	10.67	0.16	8.01	11.96	2.56	0.09	1.49	0.17	0.37	100.89
5-3, 38-40 (No. 3)	51.17	14.75	10.46	0.16	7.70	12.01	2.56	0.07	1.50	0.20	-0.05	100.58
5-4, 84-86 (No. 6)	50.78	14.77	10.19	0.16	7.90	12.03	2.41	0.10	1.45	0.17	0.65	100.61
6-1, 52-53 (No. 8)	50.54	14.85	10.23	0.16	7.91	12.44	2.62	0.09	1.41	0.18	0.52	100.93
7-1, 94-96 (No. 6e)	50.30	14.45	10.81	0.16	8.31	11.85	2.63	0.06	1.47	0.17	0.40	100.60

TABLE 6b
Hole 428A (EPR, 9° N, ~ 2 m.y. old): Trace Elements

Sample (Interval in cm)	Sc	Ti	V	Cr	Co		Ni	Rb	Sr	Y	Zr	Nb	Sb	Cs	Ba	La	Eu	Tb	Hf	Ta	Th	U	W
	NA	XRF	XRF	XRF	XRF	NAA	NAA	XRF	XRF	XRF	XRF	XRF	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA
1-1, 21-23 (No. 3)	41.4	8880	292	320	41	42	83	–	–	–	–	–	–	0.05	21	3.3	1.36	0.74	2.44	0.25	0.24	0.07	–
1-1, 27-29 (No. 4)	42	8880	299	336	43	43	87	–	134	42	110	5.0	–	–	8.3	4.1	1.20	0.71	2.51	0.25	0.22	–	–
1-1, 92-94 (No. 10)	41.4	8880	–	–	–	42	84	3.0	131	–	101	4.5	–	0.03	13.8	3.8	1.24	0.73	2.46	0.24	0.23	–	–
1-1, 120-122 (No. 13)	42.2	8760	287	310	40	43	88	2.0	135	42	109	5.9	–	0.06	–	4.0	1.25	0.72	2.45	0.26	0.23	0.12	–
1-2, 49-51 (No. 6)	42.3	9000	293	321	42	42	80	2.1	128	40	109	5.7	0.02	0.06	20.9	3.7	1.30	0.72	2.52	0.26	0.24	–	–
1-3, 72-74 (No. 3b)	42.6	8820	300	311	46	42	79	0.2	131	38	95	–	0.03	0.01	9	3.9	1.34	0.76	2.67	0.26	0.25	0.07	–
1-4, 67-70 (No. 9)	41.3	8760	295	313	48	40	75	6.7	129	39	104	5.3	0.05	0.28	15.5	3.7	1.30	0.71	2.43	0.25	0.22	0.13	–
2-1, 33-35 (No. 4)	42.4	8820	300	309	46	42	82	3.9	128	38	101	4.9	0.05	0.17	–	3.9	1.24	0.75	2.42	0.25	0.26	–	–
3-1, 131-133 (No. 12a)	41.9	8700	295	316	44	42	84	0.6	131	37	92	4.6	0.03	0.03	–	3.6	1.26	0.73	2.48	0.24	0.22	–	–
4-1, 123-126 (No. 14a)	41.8	8580	291	305	45	42	84	0.2	–	36	97	4.2	0.04	–	8.8	3.8	1.31	0.77	2.54	0.24	0.22	–	–
4-2, 107-109 (No. 8)	42.4	10380	290	314	48	42	85	0.5	136	39	111	4.7	0.01	–	8.7	3.5	1.36	0.73	2.67	0.24	0.26	0.13	–
5-1, 113-115 (No. 9)	41.6	8940	304	296	45	42	81	1.1	–	38	–	4.4	0.03	0.05	–	3.8	1.25	0.72	2.78	0.26	0.22	–	–
5-2, 88-91 (No. 5e)	42.1	8940	302	315	45	42	77	0.1	135	38	–	4.3	0.03	–	9	3.7	1.30	0.80	2.81	0.25	0.24	–	–
5-3, 38-40 (No. 3)	43.9	9000	302	319	46	43	54	0.1	131	40	109	5.8	0.03	0.02	22	4.4	1.41	0.87	2.51	0.28	0.23	0.09	–
5-4, 84-86 (No. 6)	42.3	8700	289	375	44	42	87	0.1	131	37	–	4.5	0.03	–	18	3.3	1.27	0.77	2.30	0.24	0.20	0.11	–
6-1, 52-53 (No. 8)	41.6	8460	288	385	45	43	90	0.1	134	36	98	4.2	0.03	0.01	11.4	3.5	1.28	0.69	2.69	0.24	0.22	0.34	–
7-1, 84-96 (No. 6e)	42.0	8820	293	315	45	42	83	0.8	134	37	97	3.3	–	–	6	4.0	1.35	0.71	–	0.25	0.19	–	–

tion and partial melting and can vary within a single hole (Wood et al., in press). For this reason, we believe that this ratio by itself is not sufficient indication of the heterogeneity of different sources in the mantle. Figure 7 shows where the samples of Leg 54 plot in comparison with the data obtained in the North Atlantic. All the Leg 54 samples fall in what has so far been considered to be a "depleted" field. But again, this is not sufficient reason to deduce that these basalts were produced from a "depleted" mantle. A good example is given by some samples of Hole 409 (North Atlantic) which show a "depleted" character (high Y/La and Sm/La); but

TABLE 7a
Hole 429A (EPR, 9° N, ~ 4.5 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
1-1, 43-45 (No. 1)	49.72	15.87	8.79	0.15	7.12	12.99	2.33	0.08	1.15	0.11	0.98	99.29
2-1, 87-89 (No. 12)	50.05	13.84	12.05	0.18	6.73	11.51	–	0.5	1.60	0.14	0.71	97.36
Section 3-1, (No. 7b)	50.57	13.89	11.91	0.16	7.07	11.44	2.42	0.08	1.61	1.15	0.43	99.73
2-1, 16-18 (No. 3)	49.71	15.51	9.07	0.14	7.69	12.26	2.38	0.18	1.26	–	0.99	99.19
2-2, 14-16 (No. 2)	50.23	14.14	10.58	0.18	6.73	11.69	2.57	0.31	1.47	–	0.53	98.43
Section 3-1, (No. 1)	49.23	15.75	8.65	0.15	7.05	13.18	2.41	0.06	1.20	–	1.29	98.97

TABLE 7b
Hole 429A (EPR, 9° N, ~ 4.5 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
1-1, 43-45 (No. 1)	38.9	6900	352	372	52	51	126	0.5	140	29	80	3.6	0.05	0.03	–	2.2	1.03	0.57	1.86	0.09	0.05	0.17	–
2-1, 16-18 (No. 3)	–	7560	239	403	46	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2-1, 87-89 (No. 12)	43.6	9960	–	157	50	37	47	3.7	113	43	107	4.0	0.02	0.49	12	3.6	1.31	0.87	2.92	0.20	–	0.15	–
2-2, 14-16 (No. 2)	43.2	8820	–	144	40	40	49	–	350	–	–	–	0.01	0.29	26	3.8	1.46	0.86	3.0	0.21	0.14	0.09	–
3-1, 66-69 (No. 1)	39	7200	–	398	65	69	203	3	235	–	–	–	0.07	0.04	–	2.3	1.04	0.59	2.06	0.09	0.07	0.15	–
Section 3-1, (No. 7b)	42.6	9660	219	151	49	44	61	–	–	–	–	–	–	–	10	3.4	1.40	0.78	2.94	0.20	0.15	–	–

TABLE 8a
Hole 424 (Galapagos Spreading Center, 0°N 86° W): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
5-1, 9-14 (No. 2)	50.33	12.70	14.99	0.21	6.51	10.56	1.99	0.15	1.89	0.19	0.62	100.13
5-1, 35-40 (No. 5)	50.15	12.70	15.06	0.21	6.23	10.56	1.97	0.14	1.87	0.18	1.14	100.19
5-1, 131-136 (No. 13)	49.90	12.53	14.69	0.21	6.67	10.39	1.00	0.08	1.86	0.19	1.10	99.62
5-2, 56-61 (No. 2b)	50.31	12.84	15.27	0.20	6.71	10.43	2.78	0.05	1.89	0.16	0.18	100.81
5-3, 20-23 (No. 2)	50.37	12.75	15.06	0.20	6.90	10.47	2.07	0.06	1.87	0.17	0.10	100.01
5-4, 2-5 (No. 1)	50.28	12.66	15.21	0.20	6.66	10.49	2.12	0.04	1.92	0.19	0.29	100.07
6-1, 32-36 (No. 5)	50.30	12.64	15.20	0.20	6.71	10.39	1.94	0.01	1.89	0.18	0.29	99.76
6-1, 102-107 (No. 10c)	50.24	12.66	15.16	0.20	6.83	10.49	2.32	0.03	1.89	0.21	0.19	100.21
7-1, 0-10	50.59	12.85	14.63	0.21	6.77	10.79	1.86	0.16	1.86	0.19	0.43	100.35

TABLE 8b
Hole 424 (Galapagos Spreading Center, 0°N 86°W): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
5-1, 9-14 (No. 2)	41.5	11340	439	161	217	199	85	0.5	66	53	119	7.3	0.02	–	–	2.9	1.55	0.91	2.80	5.50	0.30	–	902
5-1, 35-40 (No. 5)	43.5	11220	440	76	83	75	58	0.5	65	54	119	6.6	–	–	–	2.6	1.59	0.99	3.05	2.31	0.19	0.32	382
5-1, 131-136 (No. 13)	–	11160	433	82.7	99	–	–	–	61	53	125	6.9	–	–	–	–	–	–	–	–	–	–	–
5-2, 56-61 (No. 2b)	45.5	11340	456	104	52	84	62	0.5	65	55	117	7.0	–	–	17	3.1	1.63	1.00	2.86	2.90	0.19	–	410
5-3, 20-23 (No. 2)	45.8	11220	440	83	94	87	61	0.5	73	54	120	7.0	–	–	–	3.3	1.55	1.07	3.07	2.80	0.18	–	396
5-4, 2-5 (No. 1)	45.6	11520	442	76	92	83	54	0.5	64	55	116	7.5	–	–	–	3.2	1.62	1.09	2.77	3.70	0.15	–	548
6-1, 32-36 (No. 5)	–	11340	440	77	84	–	–	0.5	65	55	118	6.6	–	–	–	–	–	–	–	–	–	–	–
6-1, 102-107 (No. 10c)	46.4	11340	–	–	–	92	59	2.4	59	–	123	6.9	–	–	–	3.1	1.70	1.09	3.27	4.60	0.2	–	681
7-1, 0-10	46.	11160	444	112	122	120	69	1.8	–	57	109	5.9	0.03	0.09	–	2.61	1.63	1.03	3.03	4.32	0.17	–	733

when we consider La/Ta (discussed below), these basalts are clearly derived from the same "undepleted" source as the other portion of Hole 409.

Samples from the North Atlantic at 36°N, 45°N, and 63°N all lie on a single line on a La-Ta diagram, the range of variation being 0.2 to 7.8 ppm for Ta, and 1.5 to 50 ppm for La. Seeing that this wide range of concentrations produces no change in the ratio between the two elements signifies that La does not fractionate with respect to Ta. But for samples from 22°N (young crust) and 25°N (old crust), a different line is found; Ta ranges from 0.05 to 0.25 ppm, and La from 1.0 to 4.3 ppm (Figure 8). This difference in slope and ratio of La-Ta is attributed to a different property of the mantle between 22°N and 25°N on the one hand and 36°N, 45°N, and 63°N on the other. It reflects either different values for La/Ta in the mantle sources or different partition coefficient ratios for these elements in the two areas. Leg 54 data plot very nearly on the trend defined at 22°N to 25°N in the Atlantic. They would thus correspond to a mantle "depleted" in lanthanum.

Since the Y/Tb, Zr/Hf, and Nb/Ta ratios are constant in both the Atlantic and Pacific oceans, we deduce that these ratios are characteristic of the primordial mantle. If the two fundamental La/Ta values which have been found are confirmed by further studies, it may be possible to conclude that sources in the mantle are not completely uniform in composition and that

TABLE 9a
Hole 424A (Galapagos Spreading Center, 0°N 86° W): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
4-1, 3-5 (No. 1)	50.47	12.66	14.91	0.22	5.72	10.61	2.37	0.13	1.88	0.17	0.48	99.61
4-1, 45-47 (No. 6)	50.12	12.85	14.82	0.21	5.57	10.69	2.31	0.18	1.90	0.15	0.76	99.50
1-1, 90-95[a]	49.35	0.52	30.38	0.14	2.37	0.05	–	2.27	0.03	0.04	13.9	99.05

[a]Sediment: hydrothermal deposit.

TABLE 9b
Hole 424A (Galapagos Spreading Center, 0°N 86°W): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
4-1, 3-5 (No. 1)	44.3	–	439	129	170	167	83	1	63	57	117	7.9	0.03	0.05	17	2.9	1.84	1.03	3.04	5.85	0.18	–	1010
4-1, 45-47 (No. 6)	–	–	447	91	114	–	–	3	62	58	118	7.6	–	–	–	–	–	–	–	–	–	–	–

TABLE 10a
Hole 425B (Galapagos Spreading Center, 0°N 86° W): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
5-1, 10-14 (No. 2)	50.58	12.61	15.02	0.21	6.17	10.59	2.04	0.07	1.87	2.04	0.12	99.43
5-1, 44-48 (No. 6)	50.65	12.80	14.94	0.21	5.70	10.68	2.37	0.14	1.90	2.37	0.48	100.01
5-1, 51-54 (No. 7)	49.98	12.45	15.06	0.21	5.99	10.50	2.03	0.01	1.88	2.03	0.71	98.95
5-1, 67-70 (No. 9)	50.45	12.64	15.11	0.21	5.87	10.60	2.32	0.02	1.87	2.32	0.29	99.55
5-1, 159 (No. 15)	–	–	–	–	–	–	–	–	–	–	–	–
5-2, 1-6 (No. 1)	51.29	12.74	14.88	0.20	5.58	10.61	2.46	0.12	1.91	2.46	0.38	100.34
5-2, 52-56 (No. 6)	49.84	12.54	15.01	0.22	6.14	10.47	1.88	0.04	1.85	1.88	0.36	98.43
6-1, 30-35 (No. 5)	50.03	12.64	14.91	0.21	5.95	10.53	1.91	0.14	1.87	1.91	0.31	98.68
6-1, 75-80 (No. 11)	49.92	12.76	15.26	0.22	6.02	10.58	1.95	0.15	1.87	1.95	0.33	93.16
6-1, 110-120 (No. 16)	50.67	12.60	15.00	0.21	5.73	10.59	2.02	0.10	1.88	2.02	0.19	99.44
6-1, 138-144 (No. 19)	49.96	12.79	14.94	0.22	–	10.69	–	0.10	1.89	–	0.29	96.76

TABLE 10b
Hole 425B (Galapagos Spreading Center, 0°N 86°W): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
5-1, 10-14 (No. 2)	44.4	11220	418	88	–	115	60	0.1	62	55	112	9.5	–	–	–	3.1	1.73	0.99	3.17	9.02	0.24	–	1336
5-1, 44-48 (No. 6)	–	11400	443	111	–	–	–	1.9	62	55	114	8.2	–	–	–	–	–	–	–	–	–	–	–
5-1, 51-54 (No. 7)	45.4	11280	444	83	197	92	63	0.1	63	50	108	9.1	0.02	0.03	–	3.1	1.57	1.02	3.16	3.9	0.23	–	567
5-1, 67-70 (No. 9)	44.7	11220	438	103	81	196	63	0.1	63	55	116	10.3	–	–	–	3.1	1.54	0.95	3.02	9.8	0.24	–	1552
5-2, 1-6 (No. 1)	45.4	11460	445	84	89	75	57	1.5	65	57	115	7.3	0.04	0.04	–	3.1	1.63	1.02	3.19	2.54	0.22	0.26	350
5-2, 52-56 (No. 6)	–	11100	424	80	111	–	–	0.1	63	52	117	8.2	–	–	–	–	–	–	–	–	–	–	–
6-1, 30-35 (No. 5)	46.3	11220	442	78	–	107	58	0.4	63	54	113	9.3	0.02	–	–	2.9	1.63	1.01	2.99	7.52	0.22	–	1157
6-1, 75-80 (No. 11)	45.5	11220	–	94	106	56	66	1.7	62	54	114	7.9	0.02	0.07	–	3.1	1.66	1.03	3.12	7.9	0.14	–	1197
6-1, 110-120 (No. 16)	–	11280	428	–	–	101	62	0.1	61	–	92	–	–	0.02	–	–	1.68	1.09	3.25	6.5	0.20	–	1005

they are not differentiated from the primordial mantle in the same way. The different values found for such ratios as Y/La and Sm/La are a consequence of both heterogeneous mantle sources and variable partial melting processes.

CONCLUSION

Grinding samples in a tungsten carbide mortar introduces considerable contamination of Co and Ta, and, to a lesser extent, Nb.

Y/Tb, Zr/Hf, and Nb/Ta ratios have the same single values close to chondrites as in the North Atlantic and are probably characteristic of a primordial mantle. The La/Ta ratio, in agreement with the Y/La ratio, shows that Leg 54 basalts derive from a so-called depleted mantle. The La/Ta ratio is close to the value obtained at 22°N and 25°N in the Atlantic but different from that at 36°N, 45°N, and 63°N in the North Atlantic ("undepleted" mantle).

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TABLE 11a
Hole 424C (Galapagos Spreading Center, 0°N 86° W): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
2-1, 8-15 (No. 2)	50.69	12.74	15.17	0.22	6.09	10.52	2.26	0.06	1.86	0.17	0.33	100.11
Section 2-1, (No. 7)	50.45	12.64	14.49	0.23	6.07	10.69	2.37	0.10	1.87	0.14	0.43	99.48
3-1, 16-31 (No. 2)	50.72	12.70	15.27	0.21	6.23	10.61	2.28	0.03	1.88	0.15	0	100.08
3-1, 44-57 (No. 4)	50.92	12.76	15.05	0.22	5.89	10.65	2.37	0.14	1.88	0.15	0.19	100.21

TABLE 11b
Hole 424C (Galapagos Spreading Center, 0°N 86°W): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
2-1, 8-15 (No. 2)	44.2	11160	421	86	136	132	56	0.5	64	53	123	8.5	–	–	–	2.7	1.41	0.96	3.20	11.92	0.17	–	1773
Section 2-1, (No. 7)	45.9	11220	442	98	206	211	64	0.7	66	–	113	9.4	–	–	–	3.2	1.67	1.20	3.26	8.45	0.20	2.1	1207
3-1, 16-31 (No. 2)	45.8	11280	438	69	89	85	49	0.5	66	52	122	7.8	0.01	–	–	3.0	1.42	1.15	3.2	5.20	0.17	–	755
3-1, 44-57 (No. 4)	45.1	11280	427	102	91	86	51	0.5	66	54	126	6.1	–	0.03	–	3.1	1.40	1.06	3.3	4.68	0.20	–	713

TABLE 12a
Hole 425 (Galapagos Spreading Center, 60 km from the axis): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
7-1, 44-47 (No. 7)	50.44	13.55	12.92	0.18	7.03	11.28	2.18	0.02	1.42	0.09	0.10	99.20
7-1, 81-85 (No. 11)	–	–	–	–	–	–	2.20	–	–	–	–	–
7-2, 4-6 (No. 1)	–	–	–	–	–	–	2.05	–	–	–	–	–
7-2, 52-54 (No. 7a)	50.58	14.06	11.63	0.17	7.58	11.94	2.08	0.01	1.19	0.07	0.01	99.32
7-2, 55-59 (No. 7a)	50.89	13.55	12.75	0.14	6.90	11.64	2.10	0.14	1.36	0.11	0.29	99.86
7-2, 90-95 (No. 8b)	50.56	13.71	11.95	0.18	7.48	11.88	2.07	0.015	1.17	0.10	0.33	99.43
8-1, 30-35 (No. 5)	–	–	–	–	–	–	2.01	–	–	–	–	–
8-1, 105-110 (No. 12)	50.17	15.13	10.65	0.16	7.20	12.77	1.88	0.01	0.98	0.06	0	99.01
9-1, 20-28 (No. 5)	50.61	13.77	11.99	0.17	7.51	11.69	2.05	0.03	1.18	0.08	0.24	99.31
9-1, 59-66 (No. 9)	50.32	13.95	11.57	0.19	7.59	12.30	2.08	0.08	0.99	0.08	0.43	99.57
9-1, 106-110 (No. 15)	50.14	13.99	11.53	0.18	7.33	12.32	1.96	0.08	0.98	0.06	0.76	99.32
9-2, 68-73 (No. 7)	50.44	13.72	11.58	0.17	7.65	12.05	1.98	0.03	0.97	0.09	0.62	99.30
9-3, 3-5 (No. 1)	50.49	13.88	11.53	0.17	7.71	11.94	1.83	0.05	0.99	0.06	0.33	98.98
9-3, 62-65 (No. 9)	51.48	14.33	10.78	0.17	7.28	12.47	2.04	0.01	0.99	0.08	-0.33	99.58

TABLE 12b
Hole 425 (Galapagos Spreading Center, 60 km from the axis): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
7-1, 44-47 (No. 7)	–	8520	375	141	107	–	–	0.1	56	46	68	6.3	–	–	–	–	–	–	–	–	–	–	–
7-1, 81-85 (No. 11)	42.5	–	–	–	–	389	75	–	–	–	–	–	–	–	–	1.25	0.87	0.74	2.2	7.5	–	–	1240
7-1, 4-6 (No. 1)	41.7	–	–	–	–	84	83	–	–	–	–	–	–	0.02	–	1.12	0.91	0.61	1.71	4.25	0.01	–	640
7-2, 52-54 (No. 7a)	41.8	7140	323	215	141	91	80	0.1	57	36	67	5.6	–	–	–	1.30	1.11	0.63	1.84	4.39	–	–	709
7-2, 90-95 (No. 8b)	–	7020	331	227	133	–	–	0.1	56	34	65	4.0	–	–	–	–	–	–	–	–	–	–	–
8-1, 105-110 (No. 12)	39.3	5880	286	311	90	94	85	0.1	54	–	–	1.5	–	–	–	1.04	0.84	0.53	1.47	4.67	–	–	653
9-1, 20-28 (No. 5)	–	7080	327	241	101	–	–	0.1	53	35	62	4.0	–	–	–	–	–	–	–	–	–	–	–
9-1, 59-66 (No. 9)	–	5940	319	263	115	–	–	0.1	49	34	50	4.1	–	–	–	–	–	–	–	–	–	–	–
9-1, 106-110 (No. 15)	41.5	5880	317	300	90	91	104	0.1	47	35	51	4.2	0.05	0.06	–	0.92	0.90	0.53	1.28	3.69	0.04	–	615
9-2, 68-73 (No. 7)	41.8	5820	475	264	120	123	91	0.5	48	30	55	3.7	–	–	–	0.81	0.64	0.55	1.5	4.21	0.01	–	734
9-3, 3-5 (No. 1)	–	5940	309	244	135	–	–	0.1	–	33	53	7.4	–	–	–	–	–	–	–	–	–	–	–
9-3, 68-65 (No. 9)	42.6	5940	318	294	99	101	106	–	50	31	47	4.4	0.02	–	–	0.77	0.89	0.57	1.49	5.45	–	–	790

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TABLE 13 a
Hole 427 (Siqueiros fracture zone, 8°N ∿ 5 m.y. old): Major Oxides

Sample (Interval in cm)	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
9-1, 38-40 (No. 4b)	50.16	13.33	14.00	0.20	6.19	10.09	2.80	0.09	2.47	0.26	0.30	99.89
9-2, 3-5 (No. 1)	50.23	13.41	13.37	0.18	6.69	10.41	2.76	0.05	2.45	0.27	0.48	100.28
9-3, 16-19 (No. 2)	49.78	13.05	14.22	0.20	6.59	10.15	2.83	0.07	2.48	0.25	0.29	99.91
9-4, 56-59 (No. 8a)	50.35	13.29	14.35	0.20	6.35	10.09	2.71	0.14	2.45	0.24	0.33	100.46
9-5, 86-89 (No. 7)	49.79	13.28	14.03	0.20	6.81	10.32	2.58	0.12	2.40	0.27	0.24	100.04
10-1, 64-67 (No. 4a)	49.41	13.25	13.95	0.22	6.78	10.21	2.11	0.08	2.46	0.26	0.67	99.39
10-2, 9-12 (No. 1a)	49.40	13.25	13.77	0.18	6.70	10.35	2.63	0.12	2.38	0.27	0.43	99.47
10-2, 134-137 (No. 4)	49.78	13.27	13.85	0.26	6.65	10.53	2.77	0.13	2.39	0.26	0.48	100.36
10-3, 100-103 (No. 8)	49.37	13.34	13.66	0.17	6.24	10.08	2.74	0.13	2.39	0.25	0.48	98.84
10-3, 145-148 (No. 9c)	50.34	13.11	14.09	0.18	6.38	10.31	–	0.19	2.40	0.23	0.52	97.74
10-4, 136-138 (No. 1k)	49.63	13.38	13.73	0.18	6.89	10.34	2.82	0.06	2.40	0.27	0.38	100.08
10-4, 41-44 (No. 10e)	49.64	13.34	13.91	0.19	6.84	10.14	2.71	0.15	2.35	0.25	0.24	99.75
10-5, 82-84 (No. 4b)	49.88	13.26	13.74	0.19	6.80	10.31	3.02	0.06	2.41	0.27	0.10	100.03

TABLE 13 b
Hole 427 (Siqueiros fracture zone, 8°N ∿ 5 m.y. old): Trace Elements

Sample (Interval in cm)	Sc NA	Ti XRF	V XRF	Cr XRF	Co XRF	Co NAA	Ni NAA	Rb XRF	Sr XRF	Y XRF	Zr XRF	Nb XRF	Sb NAA	Cs NAA	Ba NAA	La NAA	Eu NAA	Tb NAA	Hf NAA	Ta NAA	Th NAA	U NAA	W NAA
9-1, 38-40 (No. 4b)	–	14820	415	111	46	–	–	0.9	127	70	187	8.4	–	–	–	–	–	–	–	–	–	–	–
9-2, 3-5 (No. 1)	44.6	14700	423	112	49	43	61	–	–	–	–	–	0.03	–	–	6.0	1.94	1.24	4.48	0.38	0.28	–	–
9-3, 16-19 (No. 2)	44.3	14880	426	156	–	44	55	–	–	64	173	7.1	–	–	–	6.3	1.86	1.14	4.56	0.37	0.33	–	–
9-4, 56-59 (No. 8a)	43.7	14700	431	114	51	44	57	0.6	124	70	178	7.2	–	–	–	6.0	1.84	1.20	4.52	0.36	0.31	–	–
9-5, 86-89 (No. 7)	45	14400	419	111	49	44	61	0.7	125	67	175	7.1	–	0.01	24	6.2	1.88	1.20	4.46	0.37	0.31	0.17	–
10-1, 64-67 (No. 4a)	43.5	14760	418	97	87	–	77	0.1	121	67	177	9.8	0.03	–	–	5.6	1.98	1.21	4.21	4.21	0.31	0.35	717
10-2, 9-12 (No. 1a)	–	14280	394	146	79	–	–	0.5	–	62	175	7.1	–	–	–	–	–	–	–	–	–	–	–
10-2, 134-137 (No. 4)	44	14340	416	123	49	44	61	–	126	68	178	7.6	0.03	–	–	5.5	1.86	1.19	4.22	0.36	0.30	–	–
10-3, 100-103 (No. 8)	43	14340	415	132	80	74	66	0.8	121	65	178	9.2	0.01	–	28	5.7	1.96	1.18	4.25	3.39	0.33	–	522
10-3, 145-148 (No. 9c)	–	14400	418	114	50	–	–	0.4	–	69	187	7.5	–	–	–	–	–	–	–	–	–	–	–
10-4, 136-138 (No. 1k)	–	14400	421	116	49	–	–	0.4	122	69	176	7.2	–	–	–	–	–	–	–	–	–	–	–
10-4, 41-44 (No. 10e)	43	14100	413	120	81	78	64	0.8	118	66	168	8.9	0.02	0.03	–	5.9	1.79	1.09	4.08	3.62	0.30	–	498
10-5, 88-84 (No. 4b)	43	14460	415	104	102	97	82	–	117	66	173	9.7	0.02	–	–	5.7	1.96	1.16	4.26	5.51	0.33	–	779

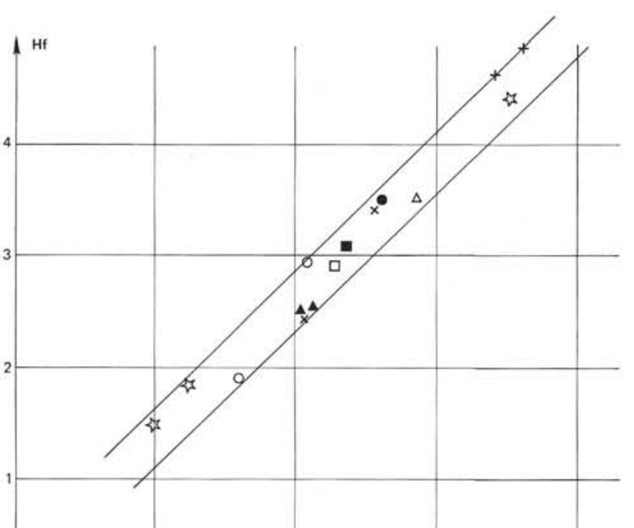

Figure 3. *Hf (ppm) versus Zr (ppm) : the two parallel lines define the range where the North Atlantic data plot. Symbols as for Figure 2.*

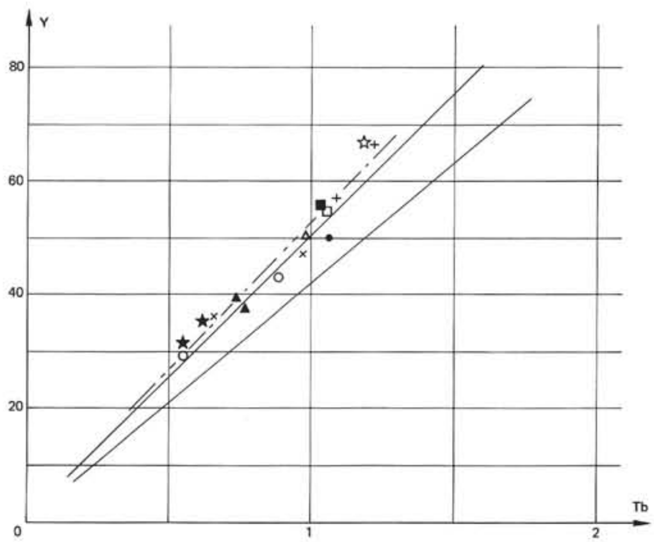

Figure 4. *Y (ppm) versus Tb (ppm) : the two lines define the range where the North Atlantic data plot. Symbols as for Figure 2.*

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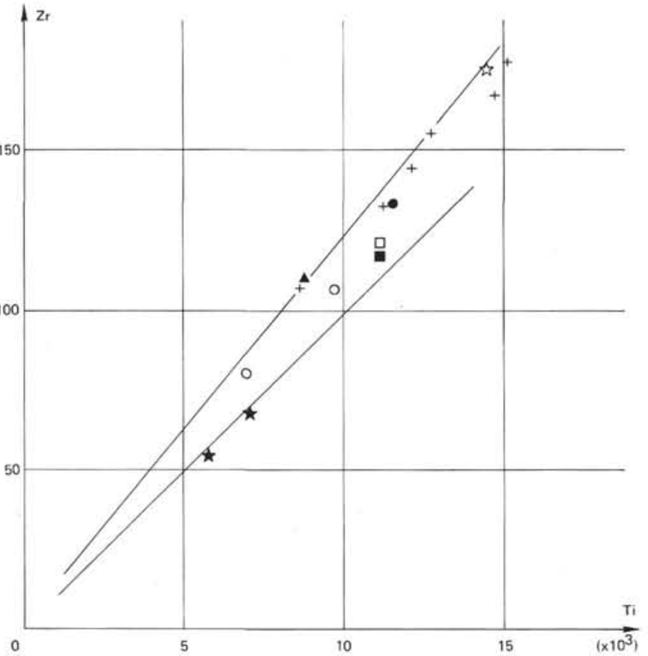

Figure 5. *Zr (ppm) versus Ti (ppm) : symbols as for Figure 2. The two lines are a tentative envelope.*

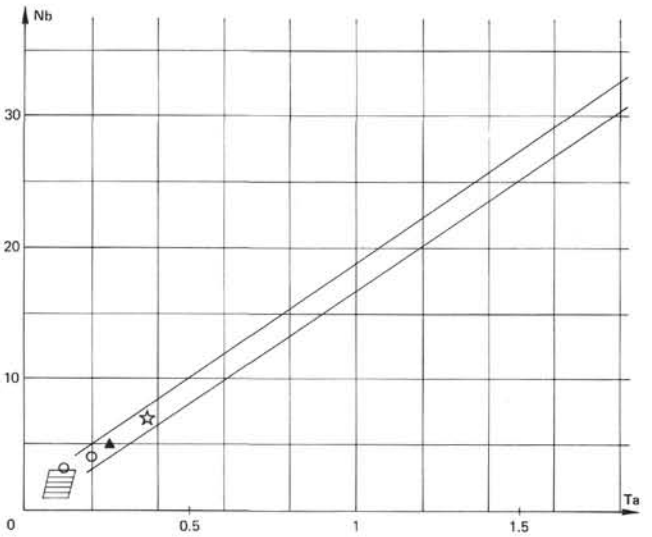

Figure 6. *Nb (ppm) versus Ta (ppm) : the two parallel lines define the range where the North Atlantic data plot. ▤ is specifically related to 25° N old crust in the Atlantic (Legs 51 and 52).*

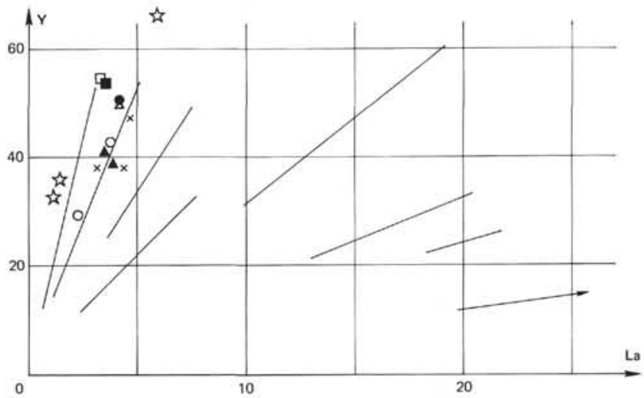

Figure 7. *Y (ppm) versus La (ppm) : the different segments are related to the North Atlantic data ; one single hole can plot on two of these lines (see text). Symbols as for Figure 2.*

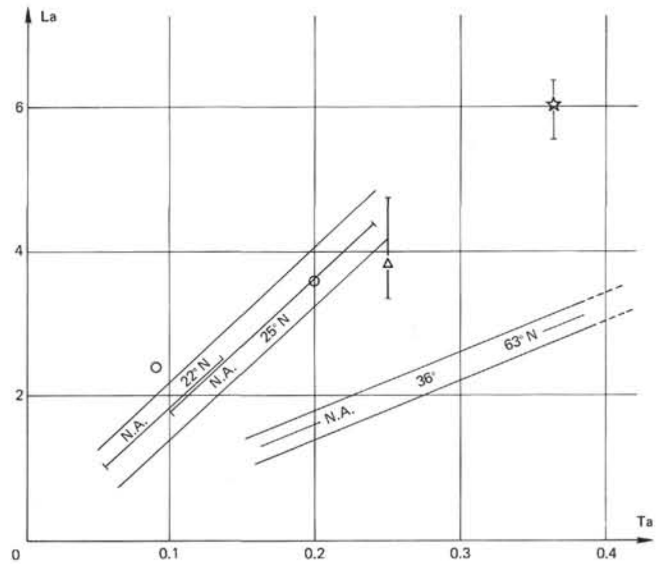

Figure 8. *La (ppm) versus Ta (ppm) : ranges where the North Atlantic (N.A.) data plot. Symbols as for Figure 2.*