# 28. K, Rb, Cs, Ba, AND Sr CONTENTS AND Sr ISOTOPE RATIOS OF IGNEOUS ROCKS FROM DEEP SEA DRILLING PROJECT LEG 63<sup>1</sup>

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## INTRODUCTION

I measured alkali (K, Rb, and Cs) and alkaline-earth (Ba and Sr) element concentrations and <sup>87</sup>Sr/<sup>86</sup>Sr ratios in selected igneous rocks recovered on Leg 63 of the Deep Sea Drilling Project. My two objectives in doing so were: (1) to gather additional information on the behavior of these elements during sea-water alteration and (2) to decipher the initial chemistry of these rocks (prior to alteration).

#### **EXPERIMENTAL METHODS**

I cleaned all rock samples ultrasonically in doubly distilled  $H_2O$  before crushing them. A mixture of HF and HNO<sub>3</sub> was used for decomposing sample aliquots. Using a method similar to that of Hart and Brooks (1974), I measured K, Rb, Cs, Ba, and Sr contents by mass spectrometric isotope dilution (MSID). A V.G. Micromass 30 mass spectrometer was employed for the isotope dilution measurements as well as for the isotopic analyses of  $^{87}Sr/^{86}Sr$ . I determined  $^{87}Sr/^{86}Sr$  ratios and Sr concentrations on the same aliquot and during the same run using an enriched  $^{84}Sr$  spike, which resulted in considerably high precision for the Sr concentrations. K, Rb, Cs, and Ba were determined on a separate aliquot with the use of a combined spike consisting of enriched  $^{41}K$ ,  $^{87}Rb$ ,  $^{137}Cs$ , and  $^{136}Ba$  isotopes. An ion multiplier (Daly) was used as detector in order to keep the contamination of the machine to a minimum and the required ion currents low. Replicate measurements on International Geochemical Reference Sample BCR-1 have been satisfactory.

The method I employed in the leaching experiments is similar to the one used successfully by O'Nions and Pankhurst (1976). Accurately weighed 500 to 600 mg of samples were placed in P.T.F.E. decomposition bombs with 10 ml of quartz-distilled 6M HCl and heated at 130°C for 40 to 50 hr (instead of only overnight, as in O'Nions and Pankhurst's study [1976]). I then transferred the samples to clean centrifuge vials and removed the leachate after centrifuging. I washed the samples four times with quartz-distilled millipore-filtered water and then dried them under a continuous flow of clean air. I weighed the residue accurately in order to estimate the weight lost by the samples during the leaching experiments. I treated the leached residues (cleaned samples) in the same way as the whole rocks (uncleaned samples) for determining  $^{87}$ Sr/ $^{86}$ Sr ratios and Sr contents.

Total procedural blanks were measured several times during this work. (The average blank is as follows: 60 ng K, 0.1 ng Rb, 0.005 ng Cs, 0.7 ng Ba, and 0.2 ng Sr.)

#### SAMPLE DESCRIPTIONS

So far these samples have not been examined in detail in thin sections, nor are the  $Fe_2O_3/FeO$  ratio,  $H_2O$  content, or whole-rock chemistry available yet. Therefore only a brief synthesis of shipboard microscopic descriptions concerning alteration of rocks from different sites is presented in this section.

Significant alteration minerals in the diabases of Site 469 are: brownish green clay, calcite, and zeolite. Site 469 glasses are partly devitrified and partly altered to clay; clay also occurs along fractures.

Hole 470 basalts are classified as altered olivine-plagioclase basalts in which olivine crystals are almost completely serpentinized and vesicles are filled with calcite and brownish green clay. In Hole 470A basalts, olivine crystals are partly or completely replaced by brownish clay, and calcite and brownish clay fill cracks and some vesicles.

Site 471 diabases are intensely altered. Veins are filled with calcite; brownish green and green clays form the matrix and replace the groundmass, and zeolites(?) replace plagioclase.

Site 472 basalts are fresh to moderately altered in areas where vesicles are generally filled with calcite or clay and traces of zeolites occur in cracks. The glass in samples from this site is rimmed by yellowish brown palagonite; some glass is completely altered to palagonite.

Site 473 diabases are moderately to poorly altered. Clay, calcite, and some zeolite fill vesicles and replace mesostasis. The basalt from this site is moderately altered where clay replaces olivine and fills vesicles.

It appears, therefore, that even the freshest samples show some degree of alteration. This is not unusual for igneous rocks recovered by the Deep Sea Drilling Project. The alterations observed are consistent with other studies of oceanic basalts—(e.g., Rice et al., 1979). These authors state that olivine and chrome spinels are the first crystalline phases to break down in response to alteration. These are followed by calcic plagioclase, iron-titanium oxides, and, finally, clinopyroxene. New phases generated include serpentine (from olivine), smectite (from glassy groundmass), calcite, and K-feldspar.

Shipboard microfossil studies suggest the following basement ages for Sites 469 through 473: Site 469,  $\sim 17$  m.y.; Sites 470 and 471,  $\sim 14.5$  m.y.; Site 472,  $\sim 15$  m.y.; and Site 473,  $\sim 6.5$  m.y.

### RESULTS

Table 1 presents the effects of alteration on Sr isotopes and trace elements. Table 2 presents Sr-isotope and trace-element data on 14 igneous rocks (glasses, basalts, and diabases). Useful element ratios are also listed in these tables. Table 3 reports the results of measure-

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ments on leached samples. Finally, Table 4 compares the inferred "initial" chemistry with averages for midocean ridge basalts (MORB).

## **Alteration Effects**

I studied these effects by carefully extracting and analyzing separately two subsamples from each selected sample (Table 1).

### Oxidation

Sample 470A-8-1, 104-108 cm showed a considerable color change (brownish color) around a crack (~4 cm long) all the way from core (i.e., center) to margin. I extracted two minicores from the center of this sample: one designated "fresh" basalt (taken from the crack in the grayish area) and the other designated "oxidized" basalt (taken from very near the crack in the brownish area). Their magnetic properties were studied by Verma and Banerjee (see this volume). These subsamples show considerable chemical differences. Both K and Rb increase in "oxidized" basalt, and their enrichment is similar so that the K/Rb ratio hardly shows any change. Cs, on the other hand, shows an unexpected decrease in "oxidized" basalt. The K/Cs ratio therefore also shows an opposite effect. Thus the behavior of Cs in this sample is not consistent with what one would expect from earlier alteration studies (e.g., Hart, 1969; Hart et al., 1974). Sr content is not modified, and the 87Sr/86Sr ratio shows only a very small increase in "oxidized" basalt. A comparison of these <sup>87</sup>Sr/<sup>86</sup>Sr ratios with that obtained for a glass from this Hole (470A-13-1, 38-41 cm) shows that even the "fresh" basalt seems to have exchanged <sup>87</sup>Sr/<sup>86</sup>Sr with sea water.

In this study of oxidation effect, Ba shows by far the largest change. Ba is enriched in "oxidized" basalt by a factor of over 20. Such large changes in Ba concentrations are rather uncommon, although Rice et al. (1979) have found Ba to be enriched by a factor of 14 in altered

Table 1.	Alteration	effects	on	Sr	isotopes	and	trace	elements.	
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basalt, as compared to "fresh" samples from the same hole (417A). They interpret that this enrichment occurred by a process of adsorption-exchange with sea water, as suggested by Hart (1969) for large alkali ions. Rice et al. (1979), however, also found an over 50-fold increase in  $K_2O$  content of the altered sample. They did not measure Rb, Cs, and Sr in their samples. The changes of alkali concentrations in our sample imply that the simple model proposed by Hart (1969) is not fully satisfactory in explaining all the characteristics of chemical changes related to oxidation.

### Palagonitization

For the study of chemical effects of palagonitization, I handpicked black pieces of "fresh" glass and brownish and white pieces of highly altered "palagonitized" glass (palagonite) from Sample 472-14-1, 19-24 cm and analyzed them separately. The results show extreme variation for most elements studied. K, Rb, Cs, and Ba increase in palagonite by factors of about 21, 16, 12, and 3, respectively. On the other hand, Sr is leached from palagonitized" glass); however, the <sup>87</sup>Sr/<sup>86</sup>Sr ratio is increased from 0.7027 to 0.7057 on palagonitization. Noteworthy is the fact that whereas K and Rb show extremely large changes, the K/Rb ratios of glass and palagonite differ only by a factor of about 1.3.

Staudigel et al. (1979) have analyzed four glass-palagonite pairs. They observed that Rb, Cs, Ba, and  $^{87}$ Sr/ $^{86}$ Sr roughly increase with increasing K. Both K/Rb and K/Cs in glass form linear positive trends with increasing K. Sea water mixing produces steeper nonlinear trends. The palagonite trend, on the other hand, is of decreasing K/Rb and K/Cs with increasing K. The glass data of the present study (taken from Tables 1 and 2 and plotted in Fig. 1, A, and B) do not show such differences in glass and palagonite trends as Staudigel et al. (1979) observed.

Sample (interval in cm)	Description	Depth below Sea Floor (m)	Ka	Rb <sup>a</sup>	Csa	Ba <sup>a</sup>	Sr <sup>a</sup>	87 <sub>Sr</sub> / 86 <sub>Sr</sub> b	Rb/Sr <sup>c</sup>	K/Sr	K/Rb	K/Cs	K/Ba	Sr/Ba	Rb/Cs	Inferred Characteristics
Hole 470A																
8-1, 104-108	"Fresh" basalt	172.0	1080 + 9	1.32	0.192	7.1 ±0.01	88.9	0.70297	0.0148	12.1 + 0.1	818 + 9	5600 + 240	152	12.5	6.9	Effect of
	"Oxidized" basalt		2040 + 20	2.58 ±0.02	0.061 ±0.002	144 ±3	87.8 ±0.3	0.70312 ±7	0.094 <sup>1</sup> ±2	23.2 ±0.2	791 ±10	33400 ±1100	14.2 ±0.3	0.61 ±0.01	42 ±1	oxidation
13-1, 38-41	Glass (2 chips)	207.4	990	0.997	0.018	12.5	90.4	0.70242	0.0110	11.0	993	55000	79	7.2	55	Heterogeneity
	Glass (1 chip)		916 ±4	1.067 ±0.008	0.012 ±0.001	12.2 ±0.2	103.7 ±0.5	e	0.0103 ±1	8.8 ±0.1	858 ±7	76300 ± 6400	75.1 ±0.3	8.5 ±0.1	89 ±7	in glass
Site 472																
14-1, 19-24	"Fresh" glass	112.2	1450 ±15	2.59 ±0.02	0.036 ±0.005	34.9 ±0.2	$\begin{array}{c}118.2\\\pm 0.3\\118.2\\\pm 0.3\end{array}$	0.70269 ±7 0.70267 ±3	0.0219 ±2	12.3 ±0.1	560 ±7	40300 ± 5600	41.5 ±0.5	3.39 ±0.02	72 ±10	Effect of palagonitization
	"Palagonitized" glass		29900 + 300	40.6	0.440	95 +1	83.2 +0.2	0.70567 ±6	0.488 ±5	359 ±4	736 ±10	68000 + 2400	315	0.88 ±0.01	92 J ±3	
14-1, 145-150	Basalt "core"	113.5	1370 + 20	1.45 +0.01	0.048 ±0.005	21.2 ±0.2	153.2 ±0.4	0.70289 ±6	0.0095 ±1	8.9 ±0.1	945 ±15	28500 ± 3000	65 ±1	7.2 ±0.1	30 ±3	Effect of
	Basalt "margin"		5070 ±70	15.9 ±0.1	0.81 ±0.03	27.4 ±0.4	138.4 ±0.4	0.70302 ±8	0.1149 ±8	36.6 ±0.5	319 ±5	6260 ±250	185 ±4	5.1 ±0.1	19.6 ±0.7	alteration

<sup>a</sup> All concentrations are in µg/g (ppm).
b The 8<sup>3</sup>Sr/8<sup>6</sup>Sr ratios are normalized to 8<sup>6</sup>Sr/8<sup>8</sup>Sr = 0.11940 and adjusted to SRM 987 8<sup>7</sup>Sr/8<sup>8</sup>Sr ratio of 0.71021. The measured ratio for the SRM 987 standard is 0.71028<sub>2</sub> ± 4<sub>2</sub>(2<sub>0</sub>, n = 19) during the period of measurements of about one year. In this period, Eimer and Amend SrCO<sub>3</sub> standard gave a value of 0.70807<sub>1</sub> ± 3<sub>4</sub> (2<sub>0</sub>; n = 9). Further, the errors reported on individual 8<sup>7</sup>Sr/8<sup>6</sup>Sr ratios are two times the standard error of the mean (2 σ<sub>e</sub>) multiplied by 10<sup>5</sup>.

The quoted errors are the analytical errors on the last decimal digit reported.

d Duplicate measurements. e — = not determined.

Table 2. Sr-isotope and	trace-element	data on Le	g 63	igneous rocks
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Sample		Depth below Sea Floor						87Sr/							
(interval in cm)	Description	(m)	K	Rb	Cs	Ba	Sr	86Sr	Rb/Sr	K/Sr	K/Rb	K/Cs	K/Ba	Sr/Ba	Rb/Cs
Site 469															
48-1, 100-105	Glass	424.0	5060	10.1	0.77	27.2	83.1	0.70562	0.1220	60.9	501	6570 + 90	186	3.06	13.1 + 0.2
50-1, 120-125	Glass	442.2	1580	2.55	0.172	7.3	97.8 +0.2	0.70328	0.0261	16.2	620 + 6	9190	216	13.4	14.8
50-2, 15-17	Glass	442.7	970 ±8	1.01 ±0.01	0.059 ± 0.003	1.3 ±0.1	95.7 ±0.3	0.70271 ±7	0.0106 ±1	$10.1 \pm 0.1$	960 ±12	16440 ±850	133 ±2	13.1 ±0.2	17.1 ±0.9
Site 470															
18-3, 4-6	Basalt	164.5	2020 ±10	4.19 ±0.03	0.179 ±0.004	7.8 ±0.1	100.3 ±0.3	0.70279 ±5	0.0418 ±3	20.1 ± 0.1	482 ±4	11280 ±260	259 ±4	12.9 ±0.2	23.4 ±0.5
Hole 470A															
7-3, 76-78	Basalt	170.3	2000	3.73	0.195	24.5	172.3	0.70277	0.0216	11.6	536 +4	10260 + 320	82 + 2	7.0 +0.1	19.1 +0.6
8-1, 104-108	"Fresh" basalt	172.0	1080	1.32	0.192	7.1	88.9	0.70297	0.0148	12.1	818	5600 + 240	152 + 2	12.5 ±0.2	6.9 ±0.3
12-1, 119-123	Basalt	199.7	2460	3.75	0.194	47.9	131.2	0.70375	0.0286	18.8	656	12700	51.4	2.74	19.3
13-1, 38-41	Glass <sup>a</sup>	207.4	950 + 50	1.03	0.015	12.4	97	0.70242	0.0106	10	920 + 70	63000 + 17000	77	7.8	70 + 20
13-1, 63-67	Basalt	208.1	1640 ±12	1.31 ±0.01	0.036 ±0.003	33.6 ±0.3	131.2 ±0.4	0.70333 ±6	0.0100 ±1	12.5 ±0.1	1250 ±13	45600 ± 3800	48.8 ±0.6	3.90 ±0.04	36 ±3
Site 472															
14-1, 19-24	"Fresh" glass	112.2	1450	2.59	0.036	34.9	118.2	0.70267	0.0219	12.3	560 +7	40300	41.5	3.39	72 + 10
16-2, 62-64	Basalt	130.6	4170 ±20	7.18 ±0.06	0.400 ±0.015	76.6 ±0.7	223.4 ±0.6	0.70320 ± 3	0.0321 ±1	18.7 ±0.1	581 ±6	10400 ± 400	54.4 ±0.6	2.92 ±0.03	18.0 ±0.7
Site 473															
32-1, 77-84	Diabase	266.8	514	0.363	0.019	9.9 +0.4	122.7	0.70250	0.00296	4.19	1420 + 20	27000 + 2900	52 + 2	12.4	19 +2
34-3, 10-17	Diabase	287.1	880 +7	0.88	0.019	18.8	108.4	0.70249	0.00812	8.12 +0.07	1000 + 14	46300 + 4900	46.8 ±0.8	5.8 ±0.1	46 ± 5
34-3, 33-35	Basalt	287.3	1160 ±10	1.78 ±0.02	0.088 ± 0.003	14.3 ±0.2	114.7 ±0.3	0.70239 ±5	0.0155 ±2	10.1 ±0.1	652 ±9	13200 ±460	81 ±1	8.0 ±0.1	20.2 ±0.7

Note: See Table 1 for an explanation of footnotes a-c. <sup>a</sup> This is the mean of two independent analyses reported in Table 1. The errors are errors of the mean and not the propagated analytical errors.

## Low-Temperature Alteration

Finally, low-temperature alteration effects in a crystalline basalt are given in Table 1. Sample 472-14-1, 145-150 cm showed macroscopic zoned color differences and has been subsampled in "core" and "margin" basalts (e.g., see Hart et al., 1974; Terrell et al., 1979). The analysis of these subsamples shows that K, Rb, Cs, and Ba increase from core to margin, whereas Sr concentrations decrease and the 87Sr/86Sr ratio shows only a very slight increase in the basalt "margin." Hart (1969) has observed enrichments of K. Rb, and Cs of 2, 5, and 20 times, respectively, in outer altered margins of submarine basalt fragments. Humphris et al. (1979), however, did not observe a similar enrichment of Rb towards the margin as compared to that of K. Further, the enrichment of Sr observed by them in two basalt margins was rather small.

## **Chemistry of the Least-Altered Samples**

#### **Glass Heterogeneity**

I also investigated the heterogeneities in glass because significant heterogeneities in some glasses have recently been found-e.g., Cohen et al., 1980. These authors observed a variation by a factor of 2 in the Rb/Sr ratio of Sample A37.18N. I analyzed two separate samples (2 chips of ~75 mg and 1 chip of ~45 mg) of a fresh glass

(from Sample 470A-13-1, 38-41 cm) for this purpose and obtained the results given in Table 1. Although the differences in the two analyses are significant relative to the analytical precision of MSID (e.g., ~30% variation in Cs and  $\sim 15\%$  in Sr), the heterogeneity in this glass at ~ 50-mg scale is not as severe as that found by Cohen et al. (1980) in their glass sample.

## **Fresh Samples**

Table 2 presents the data obtained on relatively fresh samples. The results clearly show that considerable chemical and isotopic variations exist even in the freshest samples. There variations are rather large and do not seem to be primary. They seem to reflect largely the effects associated with different degrees of alteration.

The  ${}^{87}Sr/{}^{86}Sr$  ratio ranges from 0.70239  $\pm$  5 to  $0.70562 \pm 5$  (Table 2). Interactions with sea water are known to increase the 87Sr/86Sr ratio (e.g., Hart, 1971; Dasch et al., 1973). Further, such large variations in <sup>87</sup>Sr/<sup>86</sup>Sr are not uncommon for DSDP rocks. For example, for Leg 37 basalts, O'Nions and Pankhurst (1976) have observed a range of 0.70305  $\pm$  4 to 0.70451  $\pm$  4 and Gray et al. (1977) 0.70315  $\pm$  7 to 0.70450  $\pm$  7; and for Leg 38 basalts, Hamilton et al. (1976) have obtained 0.70343  $\pm$  5 to 0.70439  $\pm$  4.

Thus considerable exchange with sea water seems to have taken place in most samples from Leg 63. Further-



Figure 1. Plots of K/Rb versus K (A.) and K/Cs versus K (B.) in glasses and palagonite from Leg 63. (Glass, palagonite and seawater mixing trends of Staudigel et al. [1979] are also included for comparison.)

more, because of considerable clay mineral formation, most of the alkali data is also affected by secondary processes. The smallest variation in the whole-rock <sup>87</sup>Sr/<sup>86</sup>Sr ratio is observed for the rocks from Site 473 (0.7024-0.7025). This is also the youngest site studied. Yet it is noteworthy that there is a considerable variation in concentrations of all the elements analyzed for Site 473 rocks. Unless we can show that considerable secondary changes could result in trace-element concentrations without appreciably affecting the 87Sr/86Sr ratio, such variations have to be related to initial variations in source area and/or to later fractional crystallization processes. Considerable changes in trace-element concentrations with no appreciable difference in the 87Sr/86Sr ratio are observed in Sample 472-14-1, 145-150 cm (Table 1); however, not all the chemical variations are in the same direction as those observed for Site 473 rocks. In the core-margin pair of Sample 472-14-1, 145-150 cm, K, Rb, Cs, and Ba increase and Sr decreases on alteration. Site 473 rocks, on the other hand, do not show the highest Ba or the lowest Sr for the sample having the highest K and Rb. Similar inconsistencies can also be noticed in some trace-element ratios. Thus an alteration process responsible for the chemical differences in the core-margin of this sample (472-14-1, 145-150 cm) cannot wholly explain the differences in trace-element concentrations of Site 473.

Figure 2 shows plots of Rb versus Cs (A.) and K versus Cs (B.) in all igneous rocks studied from Leg 63. The glass and palagonite trends of Staudigel et al. (1979) are also included for comparison. The glasses of Leg 63 do not follow the glass trend of Staudigel et al. (1979) on either of these two plots. These glasses and whole rocks show considerable scatter, implying that a combination of processes is perhaps responsible for these variations.



Figure 2. Plots of Rb versus Cs (A.) and K versus Cs (B.) in glasses, palagonite, and whole rock samples from Leg 63. (Glass and palagonite trends of Staudigel et al. [1979] are also included for comparison.)

### Leaching Experiments

I conducted leaching experiments on selected samples from most sites and measured their  ${}^{87}Sr/{}^{86}Sr$  ratios and Sr contents. In all cases where these measurements for whole rocks are available, a comparison shows that both  ${}^{87}Sr/{}^{86}Sr$  and Sr are lowered by leaching (Tables 2 and 3).

The measurements on leached diabases from Site 471 show a considerable scatter in the  ${}^{87}Sr/{}^{86}Sr$  ratio (Table 3). Thus the leaching technique used in the present study does not seem to be totally satisfactory for the highly altered samples. The  ${}^{87}Sr/{}^{86}Sr$  ratio of Sample 471-86-1, 18-20 cm is the lowest (0.70333  $\pm$  5) from this site and is perhaps only slightly higher than its "pre-alteration" value. Note that this sample (of all the three studied from this site) also shows the smallest weight loss on leaching. The efforts for obtaining original  ${}^{87}Sr/{}^{86}Sr$ ratios for Site 469 diabases have also been unsuccessful, as these diabases still show considerably higher  ${}^{87}Sr/{}^{86}Sr$ than does the leached glass from the same site.

If we exclude the diabases of Sites 469 and 471, the  ${}^{87}Sr/{}^{86}Sr$  ratio of remaining leached samples shows a very narrow range (0.70232  $\pm$  6 to 0.70242  $\pm$  6). Thus the rocks from Sites 469 and 473, and from Hole 470A are all characterized by rather low values of  ${}^{87}Sr/{}^{86}Sr$ , as compared to the values for average mid-ocean ridge basalts (MORB) given by Hart (1976).

Table 4 presents chemical and isotopic compositions of the least altered rocks. Average MORB values of Hart (1976) are also included for comparison.

## SUMMARY

I have studied the chemical and isotopic effects of alteration (oxidation, palagonitization, and low-temperature alteration) and those of glass heterogeneity. Although most results are consistent with earlier studies, there are some significant differences, such as the behavior of Cs and Ba during oxidation, K/Rb and K/Cs

Table 3. Sr contents and 87Sr/86Sr ratios of leached samples.

Sample (interval in cm)	Rock Type	Depth below Sea Floor (m)	Weight Loss on Leaching (%)	Sr (ppm)	87 <sub>Sr/</sub> 86 <sub>Sr</sub>	Sr 1.s. <sup>a</sup>	
Site 469				41			
42-5, 76-78 42-6, 21-23 50-1, 120-125	Diabase Diabase Glass	386.3 386.9 442.2	35.0 39.4 40.7	$77.5 \pm 0.4$ $80.8 \pm 0.4$ $17.4 \pm 0.1$	$0.70441 \pm 9$ $0.70455 \pm 7$ $0.70235 \pm 4$	_b 	
Hole 470A							
12-1, 119-123	Basalt	199.7	32.6	$16.5 \pm 0.1$ 17.1 + 0.1	$0.70241 \pm 7$ 0.70242 + 6	0.13	
13-1, 63-67	Basalt	208.1	33.7	$32.5 \pm 0.1$	$0.70235 \pm 5$	0.25	
Site 471							
79-1, 118-120	Altered	742.2	56.1	$57.8 \pm 0.2$	$0.70566 \pm 9$	$\sim -1$	
86-1, 18-20	Altered diabase	805.2	37.2	$44.3\pm0.2$	$0.70333\pm5$	-	
88-3, 82-84	Altered diabase	817.8	46.5	$26.5\pm0.1$	$0.70400\pm8$	-	
Site 473							
32-1, 77-84 34-3, 33-35	Diabase Basalt	266.8 287.3	47.2 34.9	$\begin{array}{c} 40.8 \pm 0.2 \\ 33.0 \pm 0.1 \end{array}$	$\begin{array}{c} 0.70237 \pm 5 \\ 0.70232 \pm 6 \end{array}$	0.33 0.29	

 $a \frac{\text{Sr l.s.}}{\text{Sr l.s.}} = \frac{\text{Sr concentration in leached sample}}{\text{Sr l.s.}}$ 

Sr w.r. Sr concentration in whole rock

b — indicates ratio could not be calculated; owing to their relatively altered nature, these diabases were not analyzed as "whole rocks."

Table 4. Sr-isotope and trace-element data on the least altered rocks.

Sample (interval in cm)	к	Rb	Cs	Ba	Sr	87 <sub>Sr</sub> / 86 <sub>Sr</sub>	K/Rb	K/Cs	K/Ba
469-50-2, 15-17 (glass)	970	1.01	0.059	7.3	95.7	$0.70235\pm4^{b}$	960	16440	133
470A-13-1, 38-41 (glass)	950	1.03	0.015	12.4	97	0.70242±6	920	63300	77
473-32-1, 77-84 (diabase)	514	0.363	0.019	9.9	122.7	0.70237 ± 5 <sup>b</sup>	1420	27000	52
473-34-3, 33-35 (basalt)	1160	1.78	0.088	14.3	114.7	$0.70232 \pm 6^{b}$	652	13200	81
Average MORB <sup>a</sup>	1064	1.02	0.0131	12.2	124	0.70265	1043	81200	87

<sup>a</sup> Taken from Hart (1976) and quoted in Staudigel et al. (1979). The element ratios are calculated from the trace-element data.

<sup>b</sup> The ratios are those obtained for leached samples.

ratios in glasses and during palagonitization, and heterogeneity in glasses.

There are considerable variations even in the fresher samples. Leaching experiments, although less successful in highly altered diabases, are quite useful in deciphering "initial" isotopic characteristics of oceanic rocks. This study suggests that DSDP Leg 63 igneous rocks have a rather narrow range (0.7023–0.7024) of prealteration <sup>87</sup>Sr/<sup>86</sup>Sr ratios.

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