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3. Sr and Nd Isotope Geochemistry of Hole 1179D Basalts[1]

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ABSTRACT

Sr and Nd isotopic compositions of 19 basalts from Hole 1179D, Leg 191 were analyzed to determine ridge and plume interaction. $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of the basalts ranged from 0.7029 to 0.7040 and from 0.5131 to 0.5132 (εNd_0 = 9.3 ~ 10.8), respectively. Calculated initial isotopic compositions at 129 Ma, the age of magnetic Anomaly M8, are $^{87}Sr/^{86}Sr_i$ = 0.7026 ~ 0.7033 and εNd_T = 9.2 ~ 10.6. The initial Sr isotope ratio is higher than that of normal mid-ocean-ridge basalts (MORBs) from the East Pacific Rise and Mesozoic MORBs. They are similar to those of the Shatsky Rise, suggesting a plume component was involved in the formation.

INTRODUCTION

Many oceanic plateaus such as Shatsky, Ontong Java, and Manihiki, which are believed to have been related to Late Jurassic to Early Cretaceous superplume activity (Larson, 1991), are distributed in the western Pacific. Recently, it has been suggested that these oceanic plateaus represent the products of several different starting-plume heads and that the Shatsky Rise was formed much earlier than the Ontong Java and Manihiki plateaus (Tejada et al., 1996, 2002). The Shatsky Rise formed at the triple junction of the Pacific, Izanagi, and Farallon plates in the latest Jurassic (Nakanishi et al., 1999; Sager et al., 1988, 1999). Based on magnetic lineations of the ocean floor, the period of volcanic activity of the Shatsky Rise has been estimated to be between 150 and 130 Ma (Nakanishi et al., 1999). The ocean floor at Site 1179 corresponds to the lithosphere of magnetic Anomaly M8 (Shipboard Scientific Party, 2001),

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which has an age of 129 Ma (Gradstein et al., 1994). At this site, oceanic crust has been produced by spreading at the Pacific–Izanagi Ridge. The timing of the formation of Site 1179 oceanic crust is just after or simultaneous with the formation of the Shatsky Rise. Because the age of the Site 1179 oceanic crust is close to the period of activity of the adjacent Shatsky Rise, we expected that the basalts from this site would preserve evidence of ridge and plume interaction. We present Sr and Nd isotope data and provide an interpretation of the geochemical features of the basalts.

SAMPLES

Twenty-eight samples were analyzed for major and trace elements (Shipboard Scientific Party, 2001; Y. Hayasaka, unpubl. data). Nineteen samples from Cores 191-1179D-11R through 22R (Table T1) were selected for Sr and Nd isotope analyses to determine the igneous evolution of and the alteration processes that occurred in the oceanic crust near the Early Cretaceous Shatsky Rise. The basalt sequence can be divided into three groups based on petrography and chemistry (Shipboard Scientific Party, 2001): basalts of the upper units (375–397 meters below seafloor [mbsf]) are mostly olivine poor and large ion lithophile element enriched (Group I); basalts of the middle units (397–439 mbsf) are mostly olivine free and Zr, Y, and V enriched (Group II); and basalts of the lower units (439–475 mbsf) are olivine rich and light rare earth element enriched (Group III).

T1. Sr and Nd isotope results for basalts, Hole 1179D, p. 11.

Calcite, celadonite, smectite/saponite, and zeolite are alteration products observed in almost all of the basalt sequence; however, alteration is minimal. This mineral paragenesis indicates low-temperature alteration due to submarine weathering.

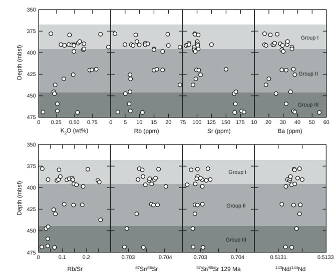
ANALYTICAL METHODS

Strontium and neodymium isotope ratios were analyzed at Hokkaido University using a Finigan MAT 262 thermal ionization mass spectrometer. Measurement procedures and analytical accuracy are described in Orihashi et al. (1997). Samples were dissolved in HF/HCl in a closed-system Teflon vessel. Sr and rare earth elements (REEs) were separated using 2.5-N HCl in an ion-exchange resin bed of AG50W-X12 200–400 mesh. Nd was separated from REEs by HIBA (α-hydroxyiso-butyric acid). The separation procedure of Sr and Nd followed Kagami et al. (1982, 1987). The published ratios of $^{87}Sr/^{86}Sr$ of Standard Reference Material (SRM) 987 and $^{143}Nd/^{144}Nd$ of La Jolla SRM at Hokkaido University were 0.710255 ± 14 (N = 63) and 0.511848 ± 8 (N = 70), respectively (Orihashi et al., 1997). In-house standard HHS-1 (Hokudai In-House Standard 1) was also measured at the same time as the La Jolla standard, and the average $^{143}Nd/^{144}Nd$ ratio of 0.511547 ± 9 (N = 30) was reported. Because the Nd standard sample La Jolla is not available over the long term, we used Geological Survey of Japan (GSJ) reference sample JB-1 and the HHS-1. The $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of GSJ reference sample JB-1 during our experiments were 0.704176 ± 12 and 0.512755 ± 11, which are consistent with those in previously published data (Orihashi et al., 1997). The results are shown in Table T1.

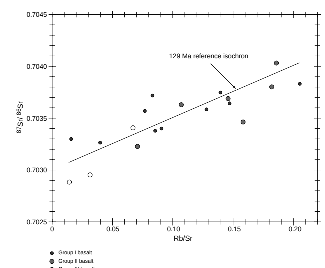
ISOTOPE DATA

The $^{87}Sr/^{86}Sr$ isotope ratios of basalts from Hole 1179D range from 0.7029 to 0.7040 (Table T1). With respect to the core depth (mbsf), the $^{87}Sr/^{86}Sr$ isotope ratios increase from bottom to top. At the depth of 375–400 mbsf, Group I basalts have $^{87}Sr/^{86}Sr$ ratios that are significantly high (Fig. F1). In the figure, variations of Rb/Sr ratios are similar to those shown by the $^{87}Sr/^{86}Sr$ ratios. Further, there is a strong correlation between these ratios (Fig. F2). Because basalts from Hole 1179D have an age of 129 Ma (Gradstein et al., 1994; Shipboard Scientific Party, 2001), correction of $^{87}Sr/^{86}Sr$ ratios results in values ranging from 0.7026 to 0.7033 (mean = 0.7030). The $^{143}Nd/^{144}Nd$ isotope ratios range from 0.51312 to 0.51320 (εNd = 9.3 ~ 10.8) (Fig. F1). Initial Sr and Nd isotopic compositions are plotted on Figure F3. The figure shows that the basalts from Hole 1179D plot on the higher $^{87}Sr/^{86}Sr$ side of the basalts from the East Pacific Rise (EPR) and have $^{143}Nd/^{144}Nd$ ratios similar to the EPR basalts. The initial Sr isotopic compositions are characterized by higher values, compared to those of recent and Mesozoic mid-ocean-ridge basalts (MORBs).

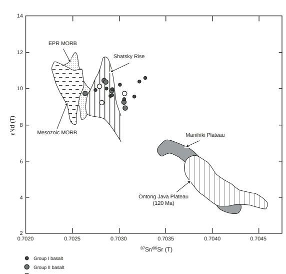
F1. Trace elements and Sr and Nd isotopes, p. 7.



F2. Rb/Sr vs. $^{87}Sr/^{86}Sr$ of basalts, p. 8.



F3. $^{87}Sr/^{86}Sr$ vs. $^{143}Nd/^{144}Nd$ of basalts, p. 9.



DISCUSSION

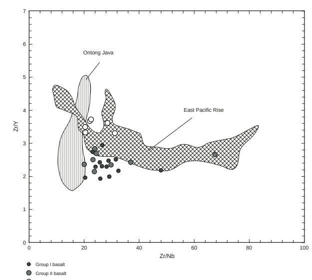
Many Mesozoic MORBs have been altered as a result of ocean floor weathering. Figure F1 shows that the K_2O and Rb contents are higher than normally found in normal mid-ocean-ridge basalts (N-MORBs), suggesting that the composition of the rocks have been changed as a result of alteration. On an $^{87}Sr/^{86}Sr$ vs. Rb/Sr diagram (Fig. F2), a good positive correlation exists between these two ratios.

Oceanic crust in Hole 1179D is dated at 129 Ma (Nakanishi et al., 1992, 1999), compared to that at Shatsky Rise, which ranges in age from 150 to 130 Ma (Nakanishi et al., 1999). The activity of the Shatsky Rise is almost the same or somewhat older than that of the adjacent oceanic crust of Hole 1179D. As mentioned by Nakanishi et al. (1999), oceanic crust in Hole 1179D was formed by the spreading of the Pacific–Izanagi Ridge, located on northwestern part of the Shatsky Rise (~500 km distance). The results of the Sr and Nd isotopic study of basalts from Site 1179 are similar to those of the Shatsky Rise (M.L. Tejada and J.J. Mahoney, unpubl. data; see also fig. 6 of Janney and Castillo, 1997) (Fig. F3). Janney and Castillo (1997) discussed the influence of plume material from the Shatsky Rise on the adjacent Mesozoic MORBs of Deep Sea Drilling Project Sites 303, 304, 307, 166, 197, and 801, based on Sr-Nd-Pb isotopes and trace element geochemistry. Sr-Nd isotope plots showed that compositions of Mesozoic MORBs and recent EPR MORBs were similar (Fig. F3), except for those at Site 304. The basalts from Site 304 show slightly higher Sr isotope ratios than those of other Mesozoic MORBs. They concluded that the relative incompatible element and ^{87}Sr enrichment was due to contamination from the Shatsky Rise. Our results of Sr and Nd isotope data support their interpretation. Location and magnetic anomaly of Site 1179 are similar to those of Site 304 in relation to Shatsky Rise. The higher $^{87}Sr/^{86}Sr$ isotope ratio of basalts from Site 1179 than Site 304 suggests that contamination at Site 1179 from the Shatsky Rise oceanic plateau was higher than that at Site 304.

Originally, based on isotopic signatures, Mahoney (1987) and Mahoney and Spencer (1991) proposed that the basalts of the Ontong Java and Manihiki plateaus were the result of mixing of MORB-type and plume-type magmas. Recently, they concluded that there is no evidence of any involvement of MORB-type mantle in the Ontong Java Plateau (Tejada et al., 2002). The formation age of the Shatsky Rise (~150–130 Ma) (Nakanishi et al., 1999) is much older than that of the Ontong Java (120 Ma) (Tejada et al., 2002) and Manihiki plateaus. Although there is a difference in ages, these oceanic plateaus are recognized as large igneous provinces in the Pacific that formed sequentially during the Late Jurassic to Cretaceous. Thus they are likely to be genetically related. The similarity in isotopic compositions of rocks in the Shatsky Rise and at Site 1179, which show higher Sr isotope ratios than those of N-MORB, provides a constraint on formation of the Shatsky Rise. If the geochemical characteristics of the Shatsky Rise plume resembled that of the Ontong Java Plateau, the Shatsky Rise must have formed by the mixing of a plume component with an N-MORB component.

Hole 1179D basalts show a wide range of Zr/Nb ratios and less variation in Zr/Y ratios (Fig. **F4**) (Neal et al., 1997), similar to basalts from the EPR (Mahoney et al., 1993a). Rocks from the Ontong Java Plateau display a greater compositional variation in Zr/Y ratios in contrast to MORBs from the EPR (Fig. **F4**). This perhaps reflects the partitioning of Y into garnet and suggests that garnet-bearing mantle is the source material for the Ontong Java magma (Neal et al., 1997). Based on composition, the basalts from Hole 1179D resemble those of the EPR. The Zr/Y ratios of Group III basalts plot higher than those of Group I and II. This may reflect a higher plume component.

F4. Zr/Y vs. Zr/Nb of basalts, p. 10.



SUMMARY

We present new Sr and Nd isotope data obtained from Early Cretaceous MORBs in Hole 1179D that were formed at the Pacific–Izanagi Ridge. Our isotope data show that a significant plume component of the Shatsky Rise was involved in their formation.

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Figure F1. Trace elements and Sr and Nd isotopes vs. drilled core level, Hole 1179D.

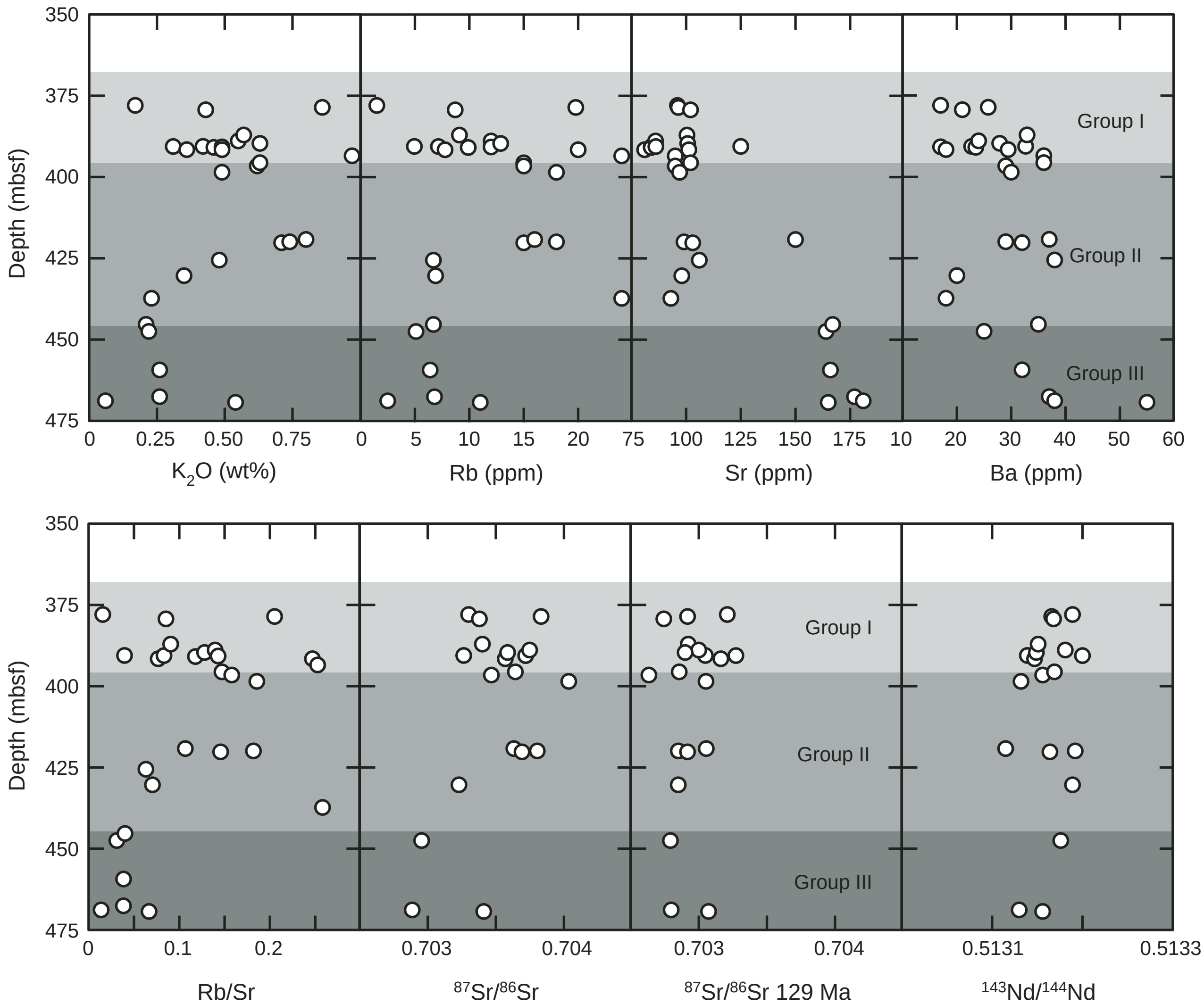

Figure F2. Rb/Sr vs. $^{87}Sr/^{86}Sr$ in Hole 1179D basalts.

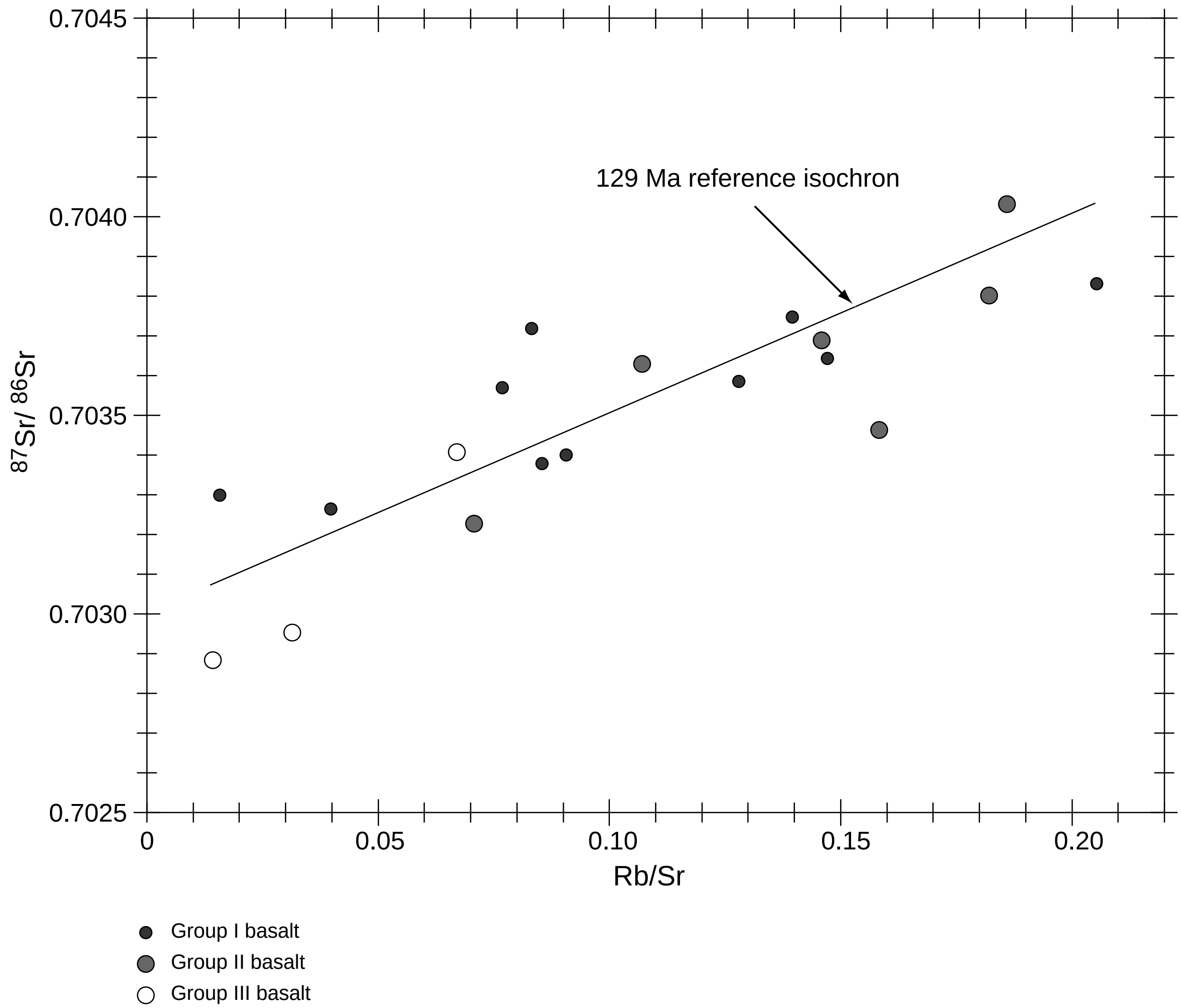

Figure F3. $^{87}Sr/^{86}Sr$ vs. $^{143}Nd/^{144}Nd$ in Hole 1179D basalts. Data sources for mid-ocean-ridge basalts (MORBs) and basalts from oceanic plateaus of Ontong Java and Manihiki are from Tejada et al. (1996); Tejada et al. (2002), and Mahoney and Spencer (1991) for Ontong Java; Mahoney and Spencer (1991) for Manihiki; Janney and Castillo (1997) for Mesozoic MORB; and Castillo et al. (2000) for East Pacific Rise (EPR) MORBs.

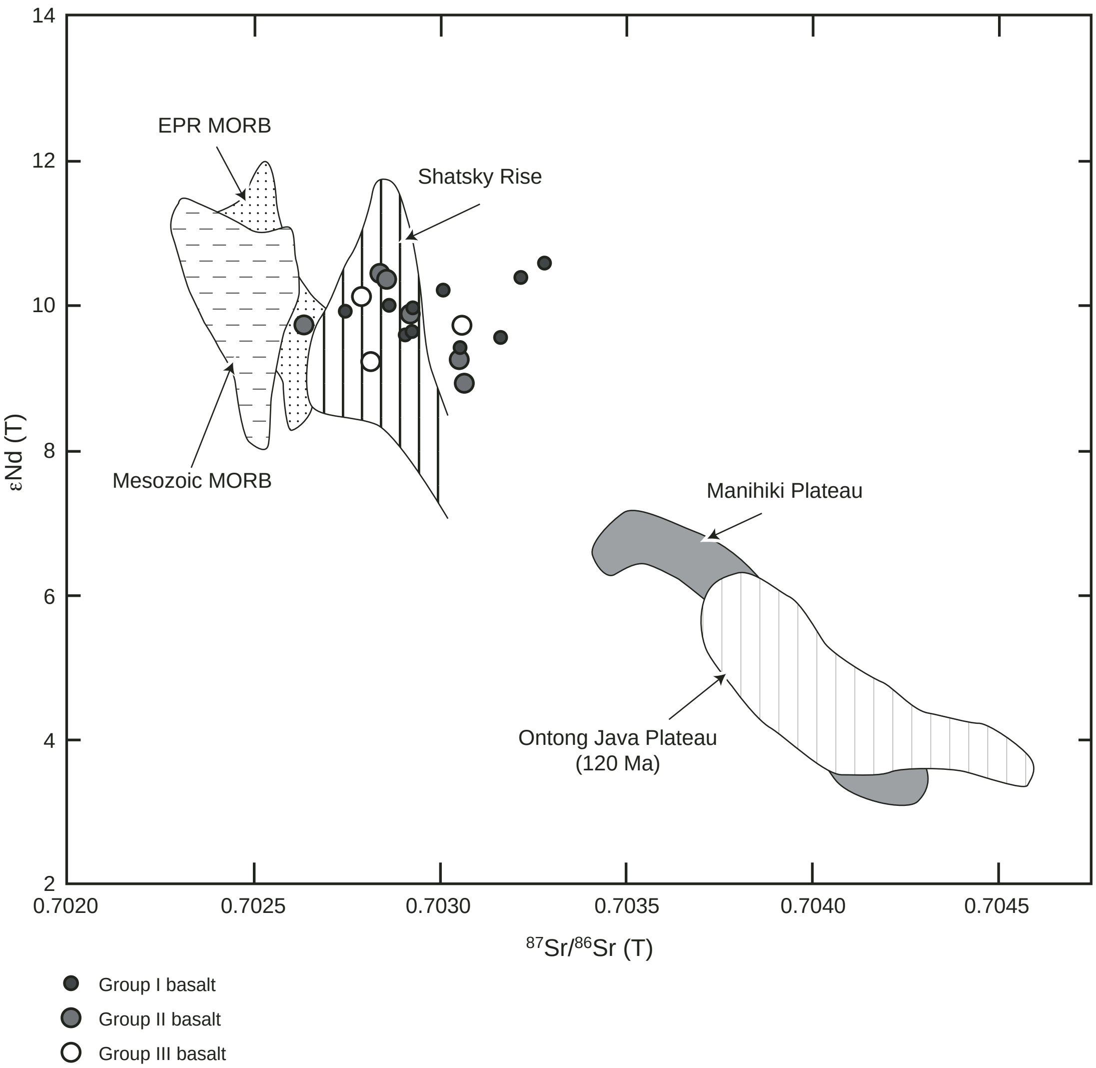

Figure F4. Zr/Y vs. Zr/Nb in Hole 1179D basalts. Data sources are based on Shipboard Scientific Party (2001) and Y. Hayasaka (unpubl. data) for Hole 1179D basalts; Thompson et al. (1989), Mahoney et al. (1993a), Hekinian et al. (1989), Ben Othman and Allegre (1990), Regelous et al. (1999), and Niu et al. (1999) for East Pacific Rise basalts; and Neal and Davidson (1989), Mahoney et al. (1993b, 1993c), Ramsey et al. (1984), and Tejada et al. (2002) for Ontong Java basalts.

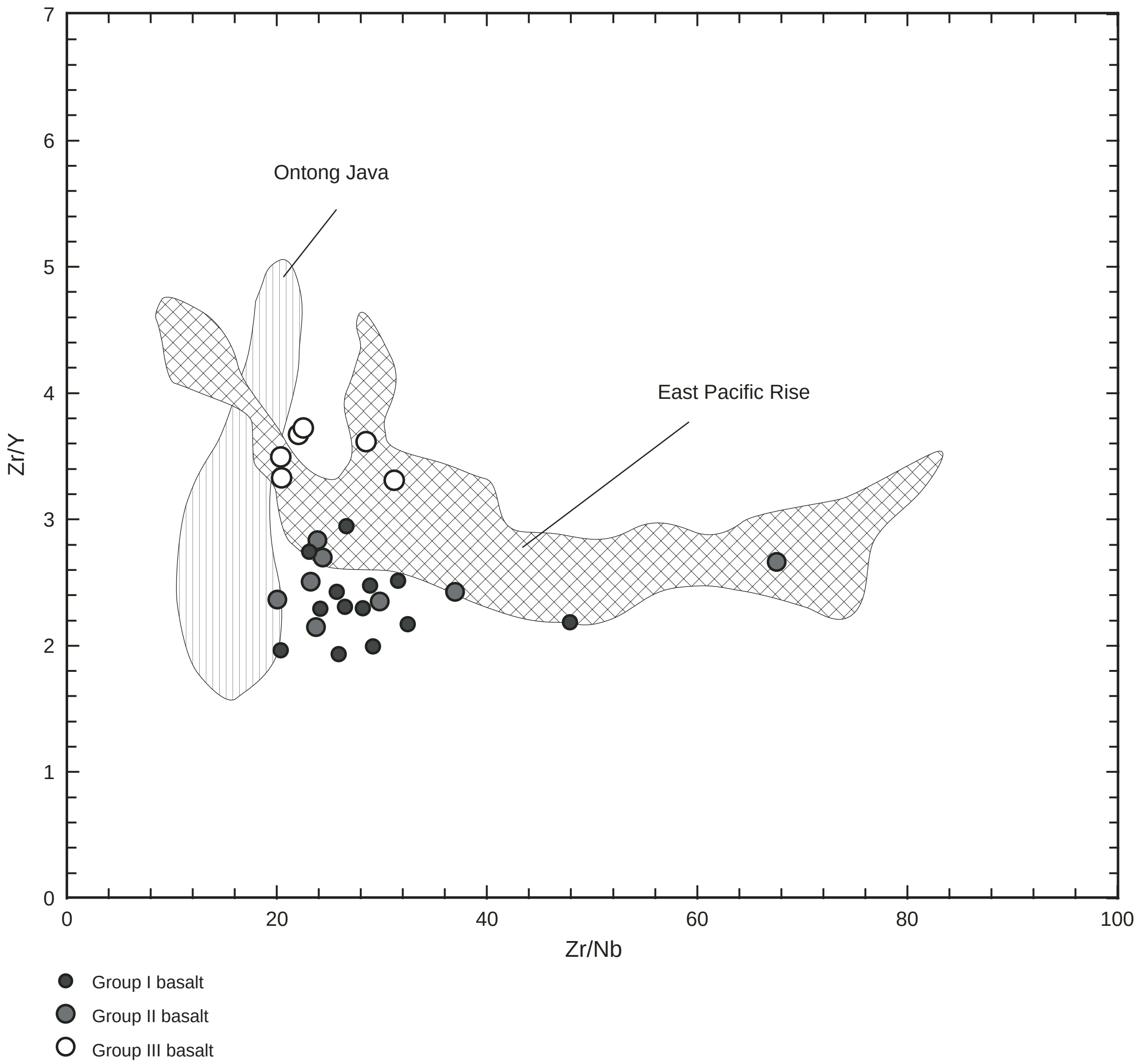

Table T1. Element concentrations and Sr and Nd isotope results for basalts, Hole 1179D.

Core, section, interval (cm)	Depth (mbsf)	K_2O (wt%)*	Ba* (ppm)	Rb* (ppm)	Sr* (ppm)	$^{87}Sr/^{86}Sr$	2σ	$^{87}Sr/^{86}Sr$ (129 Ma)	$^{143}Nd/^{144}Nd$	2σ	εNd (present)	εNd (129 Ma)†
191-1179D-												
11R-1, 86–88	377.96	0.17	17	1.5	96	0.703300	12	0.703217	0.513189	10	10.7	10.4
11R-2, 84–86	379.31	0.42	21	8.7	102	0.703379	11	0.702927	0.513168	10	10.3	10.0
11R-2, 9–135	378.57	0.84	26	20	96	0.703832	10	0.702744	0.513166	11	10.3	9.9
12R-1, 36–39	387.07	0.55	33	9.1	100	0.703401	10	0.702921	0.513151	9	10.0	9.6
12R-2, 69–71	388.89	0.54	24	12	86	0.703748	8	0.703008	0.513181	10	10.6	10.2
12R-2, 143–149	389.65	0.62	28	13	101	0.703586	11	0.702908	0.513149	10	9.9	9.6
12R-3, 89–92	390.60	0.30	23	7.2	86	0.703719	12	0.703278	0.513200	12	10.9	10.6
13R-1, 15–18	390.56	0.40	33	5.0	125	0.703264	11	0.703054	0.513139	9	9.7	9.4
13R-1, 116–120	391.58	0.48	29	7.8	101	0.703569	9	0.703162	0.513147	7	9.9	9.5
13R-4, 83–85	395.60	0.62	36	15	102	0.703643	9	0.702863	0.513169	9	10.3	10.0
14R-1, 18–20	396.58	0.61	29	15	95	0.703467	10	0.702630	0.513156	9	10.1	9.7
14R-2, 63–65	398.53	0.48	30	18	97	0.704035	8	0.703051	0.513132	14	9.6	9.3
17R-1, 40–42	419.20	0.77	37	16	150	0.703632	11	0.703066	0.513115	9	9.3	8.9
17R-1, 111–113	419.92	0.73	29	18	99	0.703804	10	0.702840	0.513192	9	10.8	10.4
17R-2, 11–13	420.21	0.70	32	15	103	0.703692	8	0.702920	0.513164	10	10.2	9.9
18R-4, 87–90	430.34	0.34	20	6.9	98	0.703229	8	0.702856	0.513189	9	10.7	10.4
20R-3, 64–67	447.49	0.22	25	5.1	164	0.702955	8	0.702790	0.513176	8	10.5	10.1
22R-4, 72–75	468.82	0.06	38	2.5	181	0.702886	11	0.702813	0.513130	9	9.6	9.2
22R-4, 120–123	469.30	0.53	55	11	165	0.703411	9	0.703058	0.513156	9	10.1	9.7
					Average:	0.703503		0.702953	0.513162		10.2	9.8
					JB-1:	0.704176	12		0.512755	11		
					SRM987:	0.710241	11					
					SRM987:	0.710249	11					
					HHS-1:				0.511552	10		
					HHS-1:				0.511548	10		
					HHS-1:				0.511539	12		

Notes: * = Data are from Shipboard Scientific Party (2001) and Y. Hayasaka (unpubl. data). † = epsilon values at 129 Ma are estimated by $^{147}Sm/^{144}Nd$ = 0.2178, based on element data of average N-MORB (Sun and McDonough, 1989).