HYDROGEN AND STRONTIUM ISOTOPE RATIOS OF DEEP-SEA ROCKS FROM THE WESTERN PACIFIC

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Abstract Water contents, and D/H and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios were measured on the deep-sea rocks obtained from the western Pacific during the 17th cruise of R/V "Dmitry Mendeleev", the investigation by International Working Group of the IGCP "Ophiolites" in 1976. Values of D/H and water contents are fairly scattered, but $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are distributed in a narrow range. No relationship among these values has been found.

Introduction

Geochemical and Petrographical information on igneous rocks from ocean floors has been accumulated recently, but most of the information is for oceanic ridges and basins. There is little information for rocks from trenches, though their significance on various problems in earth sciences has been recognized. Fortunately many specimens of igneous rocks from trenches were obtained by dredging during the 17th cruise of R/V "Dmitry Mendeleev", the investigation by International Working Group of the IGCP "Ophiolites" in 1976. We measured water contents, and D/H and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of some of these specimens; three basalts from the Parece Vela basin, four basalts from the Mariana trench, three andesites from the Palau trench

Received March 13, 1979

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Fig. 1. Locality of sampling sites.

Nos. 1 to 9 are the same as those in Table 1.

and five basalts, two gabbros and a serpentinite from the Yap trench. The sampling sites of these specimens are shown in Fig. 1.

Table 1. D/H and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the deep-sea rocks with the pertinent chemical data.

	H ₂ O (wt%)	$\delta\text{D}(\text{‰})$	$^{87}\text{Sr}/^{86}\text{Sr}$	MgO/(FeO+Fe ₂ O ₃)*
1-1	0.80	-94.8	-	0.86
1-2	1.14	-89.6	0.7035±3	1.28
1-3	0.91	-90.3	0.7034±2	1.40
2	2.01	-90.7	0.7037±2	0.83
3-1	1.00	-55.8	0.7035±3	1.29
3-2	1.07	-80.9	0.7040±2	2.22
3-3	1.04	-78.1	0.7037±3	1.41
4-1	3.67	-39.2	0.7032±2	1.91
4-2	4.72	-40.3	0.7036±3	3.31
4-3	5.00	-43.4	0.7032±2	1.95
5-1	1.09	-44.8	0.7036±3	1.94
5-2	0.88	-45.3	0.7034±2	1.66
6	0.78	-78.7	0.7034±2	-
7-1	1.90	-44.1	0.7037±2	2.36
7-2	0.28	-74.8	-	2.32
7-3	0.54	-72.5	0.7033±2	2.23
8-1	11.98	-59.5	-	-
8-2	12.64	-56.6	-	-
9	0.83	-75.8	0.7037±2	2.25
11-1	-	-	0.7034±2	-
11-2	-	-	0.7033±1	-
12	-	-	0.7035±3	-
13	-	-	0.7036±2	-

* mole ratio (calculated from the analyses by SUGISAKI (KOMATSU, TAZAKI & SUGISAKI in preparation)).

In addition, $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of three andesites from the Isle of Sarigan and the Isle of Anatahan, and of a basalt from the Isle of Pagan were also measured.

We started this study with the expectation that there should be some relationship between $^{87}\text{Sr}/^{86}\text{Sr}$, D/H and water content of rocks. Based on the relationship, we may add certain information on the origin of trench igneous rocks. Against our expectation, the results are not so promising as seen later. However, we venture to present this paper, because we believe it supplies some parameters which may be useful to elucidate the origin of trench igneous rocks after combining with other information.

Results and discussion

The technique and accuracy of extraction of water from bulk rocks and measurement of its content and D/H ratio were already described elsewhere (KURODA *et al.*, 1974).

Note for Table 1.

Sampling sites are shown in Fig. 1 as the same numbers in this table.

1 : St. 1,398, Parece-Vela Basin, E139°10.2'–N17°08.8' to E140°11.1'–N17°07.1, 5,600–5,300 m, aphyric basalts (1-1 ; D2-11, 1-2 ; D2-14, 1-3 ; D2-17), 2 : St. 1,402–D2, Mariana trench off-shore slope, E146°56.3'–N13°36.5' to E146°59.4'–N13°33.0', 5,600–5,400 m, aphyric basalt (D2-11a), 3 : St. 1,404, Mariana trench near shore slope, E144°21.2'–N12°16.4' to E144°20.3'–N12°16.2', 5,500–5,400 m, basalts (3-1 ; D1-5-8, 3-2 ; D1-9, 3-3 ; D1-11a), 4 : St. 1,423, Palau trench near shore slope, E134°51.1'–N7°46.4' to E134°50.7'–N7°46.3', 6,700–6,250 m, andesites (4-1 ; D1-9b, 4-2 ; D1-12, 4-3 ; D1-14), 5 : St. 1,427, Yap trench near shore slope, E137°52.9'–N8°25.4' to E137°52.3'–N8°52.9', 8,200–7,650 m, gabbros (5-1 ; D1-7, 5-2 ; D1-12), 6 : St. 1,430, Yap trench near shore slope, E138°33.6'–N9°36.0' to E138°35.0'–N9°36.5', 7,600–7,250 m, basalt, 7 : St. 1,440, Yap trench off shore slope, E138°35.0'–N9°34.9' to E138°35.6'–N9°34.8', 6,100–5,800 m, basalts, (7-1 ; D1-TK01, 7-2 ; D1-TK08, 7-3 ; D1-8), 8 : St. 1,431, Yap trench near shore slope, E138°30.6'–N9°39.2' to E138°29.4'–N9°39.1', 7,500–7,100 m, serpentine (D1-2-3, 8-1 ; inner part, 8-2 ; peripheral part), 9 : St. 1,437, off shore slope of Yap–Mariana junction, E139°02.5'–N11°04.8' to E139°01.5'–N11°02.7', 7,400–7,000 m, basalt (D1-4), 11 : Sarigan Isle, andesites (11-1 ; Sg 01, 11-2 ; Sg 03), 12 : Pagan Isle, basalt (Ag 01), 13 : Anatahan Isle, andesite (An 04).

$^{87}\text{Sr}/^{86}\text{Sr}$ ratio of Aimer & Amend SrCO₃ standard reagent was 0.7031 ± 0.0002 in average, and $^{87}\text{Sr}/^{86}\text{Sr}$ values in the table were subtracted ones from values measured.

Those for $^{87}\text{Sr}/^{86}\text{Sr}$ ratio were also presented previously (SHUTO, 1974).

Results of analyses are presented in Table 1. Although the precise ages of these igneous rocks are not distinct, they would be younger than the Miocene–Eocene, judging from the ages of sediments associated with them, which contained some fossils (INTERN. WORK. GROUP. IGCP, 1977). Therefore, $^{87}\text{Sr}/^{86}\text{Sr}$ ratios measured here are probably very close to the initial ratios, though we did not measure the contents of Rb and Sr. Since the volcanic rocks from the Isles of Sarigan, Anatahan and Pagan on the Mariana ridge are of the Quaternary (ISHIKAWA & EGAWA, 1977), the

$^{87}\text{Sr}/^{86}\text{Sr}$ ratios measured are certainly the representative of the initial ratios.

The range of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of these rocks is very narrow, viz., 0.7032 to 0.7040, but that of δD values is rather wide, viz., -40 to -95‰ . Water contents of basalts are also variable from 0.28 to 5.00%. Water content of a serpentinite is reasonable. There is no regular correlation between water content and D/H ratio (Fig. 2), and also no relation between water content and $^{87}\text{Sr}/^{86}\text{Sr}$ (Fig. 3). Among the specimens even with water content less than 2%, δD values are widely scattered.

Provided that the increase in water content of the rocks is due to alteration by sea water,

it is expected that both $^{87}\text{Sr}/^{86}\text{Sr}$ and D/H ratios should become higher with the increase of water content, because $^{87}\text{Sr}/^{86}\text{Sr}$ and D/H ratios of sea water are higher than those of fresh basalts. SATAKE and MATSUDA (in preparation) found a linear relationship between water content and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for basalts from the Mid-Atlantic ridge, indicating that $^{87}\text{Sr}/^{86}\text{Sr}$ ratios were increased along with the formation of chlorite. Their conclusion was supported by the D/H measurement of the bulk water. In our case, $^{87}\text{Sr}/^{86}\text{Sr}$ ratios are distributed in a narrow range as compared with that found by SATAKE and MATSUDA, though water content and D/H ratio vary widely. It can not be considered that the rocks have been subjected to the influence of sea water. The rocks with δD higher than -60‰ can be the product after the interaction of fresh rocks with sea water, because δD of the juvenile water in the mantle would be lower than -90‰ according to KURODA *et al.* (1977). However, since the water content of original fresh basalts is not known, the amount of water picked up during rock-sea water interaction is impossible to

Fig. 2. Relationship between water content and δD value.

Numbers are the same as those in Table 1.

Fig. 3. Relationship between water content and $^{87}\text{Sr}/^{86}\text{Sr}$ of basalts and gabbros.

Fig. 4. Relationship between δD and $\text{MgO}/(\text{FeO}+\text{Fe}_2\text{O}_3)$.

Numbers are the same as those in Table 1.

be estimated.

The relationship between δD and $MgO/(FeO+Fe_2O_3)$ of these rocks is shown in Fig. 4. There is a correlation between them. It has been known that δD values of mica, amphibole, chlorite etc. depend on their

chemical composition, especially X_{Fe} (ferrous iron ratio in octahedral position), as demonstrated by SUZUOKI & EPSTEIN (1976) and KURODA *et al.* (1976).

Water content and D/H ratio of the serpentinite (No. 8 in Table 1) are reasonable values. It is also reasonable that the inner part (8–1) shows slightly lower water content and lower δD value than the peripheral part. The peripheral part may have somewhat interacted with sea water.

The $^{87}Sr/^{86}Sr$ ratios of rocks from the East Pacific rise, the western Pacific basin and the island arcs in the western Pacific are distinguishable as seen in Fig. 5. The ratios of rocks from the Mariana, Yap and Palau trenches (No. 10 in Fig. 5) are distinctly higher than those of the tholeiitic basalts from the East Pacific rise (No. 1). On the other hand, the ratios of basalts from the Palau Isles and the Mariana basin (Nos. 6, 7) are similar to those from the East Pacific rise. Many volcanic rocks of the island arcs such as the Izu–Bonin arc and the Mariana arc, except for the Palau Isles, and of the deep-sea basins in the eastern Pacific are similar to the rocks from the trenches in their $^{87}Sr/^{86}Sr$ initial ratios.

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Fig. 5. Histogram of $^{87}Sr/^{86}Sr$ initial ratios of volcanics from Pacific region.

Solid line : basalts (tholeiitic), broken line : andesites, dacites and rhyolites.

1 : East Pacific rise (after GAST, 1967 ; FERRARA *et al.*, 1969 ; HEDGE & PETERMAN, 1970 ; SUBBARAO, 1972), 2 : Izu Islands (after PUSHKAR, 1968 ; MATSUDA *et al.*, 1977), 3 : Bonin Islands (after PUSHKAR, 1968 ; MATSUDA *et al.*, 1977), 4 : North Mariana Islands (after PUSHKAR, 1968 ; MEIJER, 1976 ; MATSUDA *et al.*, 1977), 5 : South Mariana Islands (after PUSHKAR, 1968 ; MEIJER, 1976 ; MATSUDA *et al.*, 1977), 6 : Palau Islands (after MATSUDA *et al.*, 1977), 7 : Mariana basin (after HART *et al.*, 1972 ; MEIJER, 1976), 8 : Parece Vela basin (this paper), 9 : Western Pacific basin (MEIJER, 1976), 10 : Mariana, Yap and Palau trenches (this paper).

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西太平洋の海底から得られた火成岩の水素およびストロンチウムの同位体比

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(要 旨)

1976 年 IGCP オフィオライト・ワーキンググループが行なった西太平洋の海底の調査（ドミトリー・メンデレフ号による）の際得られた岩石について、D/H・含水量・ $^{87}\text{Sr}/^{86}\text{Sr}$ を測定した。試料採集地は第1図に示

すとおりであり、結果は第1表に示してある。D/H・含水量はかなりの幅で変化を示すが、 $^{87}\text{Sr}/^{86}\text{Sr}$ はほとんど変化しない。それらの間には相関関係がまったく見られない。成因論には何もふれられなかった。