JOURNAL OF THE GEOLOGICAL SOCIETY OF JAPAN, Vol. 85, No. 6, p. 355—359, June 1979

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

Yoshimasu KURODA[1], Kenji SHUTO[2], Koichi TAZAKI[3], Masayuki KOMATSU[4], Masanori ISHIKAWA[5], Tetsuro SUZUOKI[6] and Sadao MATSUO[7]

Abstract Water contents, and D/H and $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ 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 and five basalts, two gabbros and a serpentinite from the Yap trench. The sampling sites of these specimens are shown in Fig. 1.

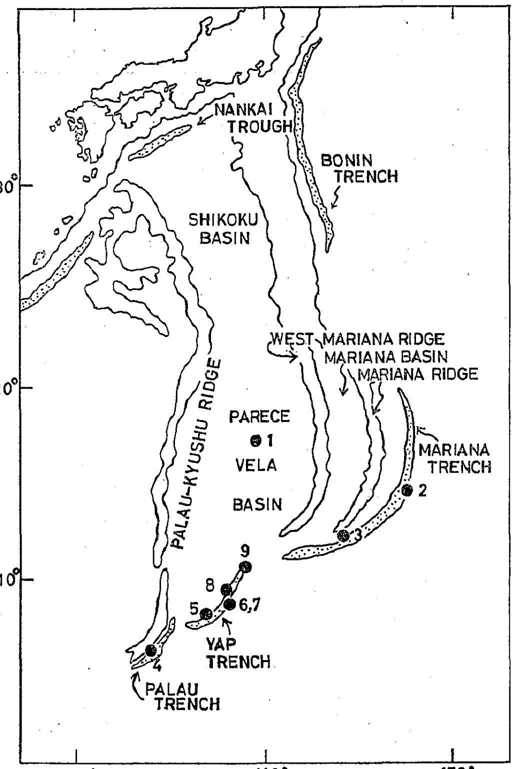

Fig. 1. Locality of sampling sites.
Nos. 1 to 9 are the same as those in Table 1.

Received March 13, 1979

1 Department of Geology, Shinshu University, Matsumoto, 390 Japan.
2 Johoku High School, Tokyo, 115 Japan.
3 Institute for Thermal Spring Research, Okayama University, Misasa, Tottori, 682-02 Japan.
4 Department of Geology and Mineralogy, Niigata University, Niigata, 950-21 Japan.
5 Department of Marine Resources, Tokai University, Shimizu, 424 Japan.
6 Marine Department, Japan Meteorological Agency, Tokyo, 100 Japan.
7 Department of Chemistry, Tokyo Institute of Technology, Tokyo, 152 Japan.

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

	H_2O(wt%)	δD(‰)	$^{87}Sr/^{86}Sr$	$MgO/(FeO+Fe_2O_3)$*
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)).

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).

$^{87}Sr/^{86}Sr$ ratio of Aimer & Amend $SrCO_3$ standard reagent was 0.7081±0.0002 in average, and $^{87}Sr/^{86}Sr$ values in the table were subtracted ones from values measured.

In addition, $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$, 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 promissing 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). Those for $^{87}Sr/^{86}Sr$ 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, juding from the ages of sediments associated with them, which contained some fossils (INTERN. WORK. GROUP. IGCP, 1977). Therefore, $^{87}Sr/^{86}Sr$ 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

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

The range of $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ (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 $^{87}Sr/^{86}Sr$ and D/H ratios should become higher with the increase of water content, because $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ ratios for basalts from the Mid–Atlantic ridge, indicating that $^{87}Sr/^{86}Sr$ 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, $^{87}Sr/^{86}Sr$ 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

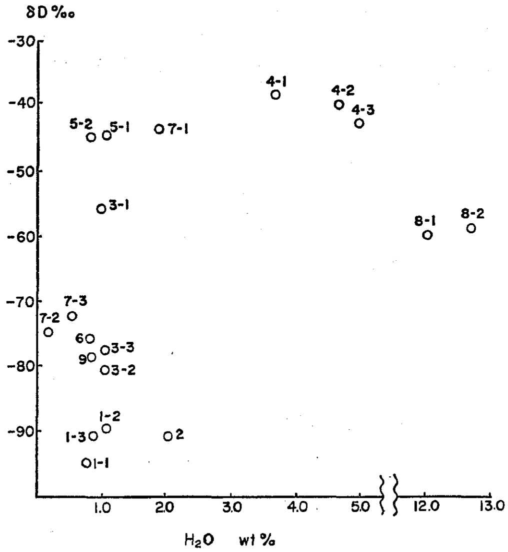

Fig. 2. Relationship between water content and δD value.

Numbers are the same as those in Table 1.

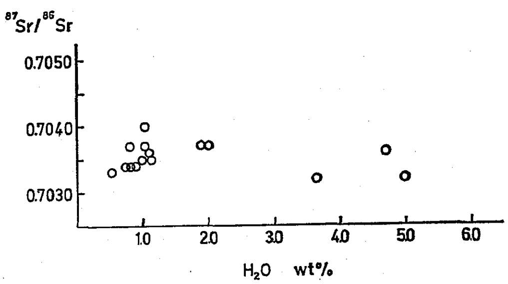

Fig. 3. Relationship between water content and $^{87}Sr/^{86}Sr$ of basalts and gabbros.

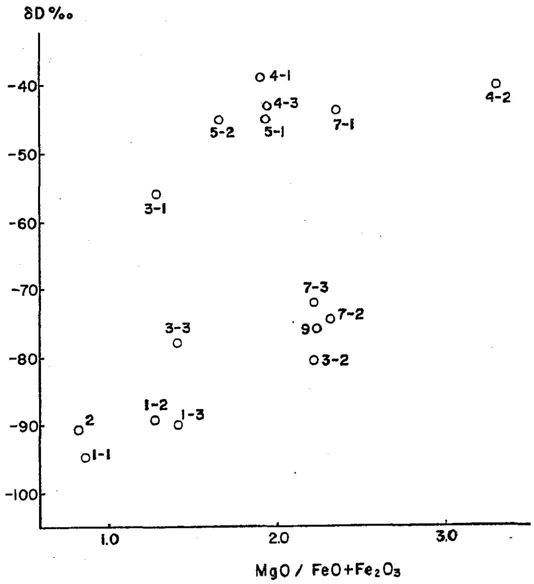

Fig. 4. Relationship between δD and $MgO/(FeO+Fe_2O_3)$.

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).

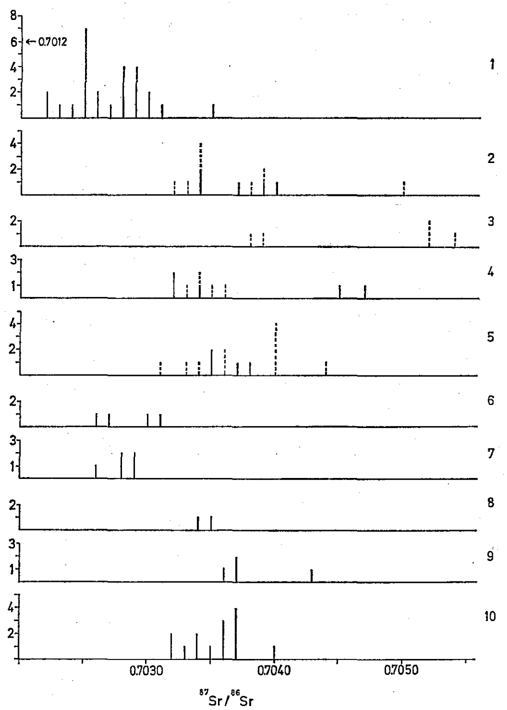

Fig. 5. Histogram of $^{87}Sr/^{86}Sr$ initial ratios of volcanics from Pacific region.
Solid line : basalts (tholeiitic), broken line : andesites, dacites and rhyolites.
1 : East Pacific rise (after GAST, 1967 ; FERRARA *et al.*, 1969 ; HEDGE & PETERMAN, 1970 ; SUBBARAO, 1972), 2 : Izu Islands (after PUSHKAR, 1968 ; MATSUDA *et al.*, 1977), 3 : Bonin Islands (after PUSHKER, 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).

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.

References

FERRARA, G., CLARKE, W. B., MURTHY, V. R. and BASS, M. N., 1969 : K–Ar ages of Juan Fernandez Islands and southeast pacific dredge faults (Abstract). *Amer. Geophys. Union Trans.*, **50**, 329.

GAST, P. W., 1967 : Isotope geochemistry of the volcanic rocks : in Basalt. *In* H. H. HESS, ed. : *The Poldervaart treatise on rocks of the basaltic composition*, **1**, 525—558. Interscience, New York.

HART, S. R., GLASSLEY, W. E. and KARIG, D. E., 1972 : Basalts and sea floor spreading behind the Mariana Island arc. *Earth Planet. Sci. Lett.*, **15**, 12—18.

HEDGE, C. E. and PETERMAN, Z. E., 1970 : The strontium isotopic composition of basalts from the Gordo and Juan de Fuca rises, northeastern Pacific ocean. *Contr. Mineral. Petrol.*, **27**, 114—120.

INTERNATIONAL WORKING GROUP ON THE IGCP

OPHIOLITES, 1977 : Initial report of the geological study of oceanic crust of the Phillipine sea floor. *Opioliti*, **2**, 137—168.

ISHIKAWA, M. and EGAWA, R., 1977 : Volcanic rocks from northern Mariana islands. *Earth Sci.*, **31**, 55—69.

KURODA, Y., SUZUOKI, T., MATSUO, S. and KANISAWA, S., 1974 : D/H fractionation of coexisting biotite and hornblende in some granitic rock masses. *Jour. Japan. Assoc. Min. Pet. Econ. Geol.*, **69**, 95—102.

———, ——— and ———, 1977: Hydrogen isotope composition of deep-seated water., *Contr. Mineral. Petrol.*, **60**, 311—315.

———, ———, ——— and SHIROZU, H., 1976 : A preliminary study of D/H ratios of chlorites. *Ibid.*, **57**, 223—225.

MATSUDA, J., ZASHU, S. and OZIMA, M., 1977 : Sr isotopic studies of volcanic rocks from island arcs in the western Pacific. *Tectonophysics*, **37**, 141—151.

MEIJER, W. J., 1976 : Pb and Sr isotopic data bearing on the origin of volcanic rocks from the Mariana island-arc system. *Geol. Soc. Amer., Bull.*, **87**, 1358—1369.

PUSHKAR, P., 1968 : Strontium isotope ratios in volcanic rocks of three island arc area. *Jour. Geophys. Res.*, **73**, 2701—2714.

SHUTO, K., 1974 : The strontium isotopic study of the Tertiary acid volcanic rocks from the southern part of Northeast Japan. *Sci. Rep. Tokyo Kyoiku Daigaku*, Sec. C, **12**, 75—140.

SUBBARAO, K. V., 1972 : The strontium isotopic composition of basalts from the East Pacific and Chile rises and abyssal hills in the eastern Pacific ocean. *Contr. Mineral. Petrol.*, **37**, 111—120.

SUZUOKI, E. and EPSTEIN, S., 1976 : Hydrogen fractionation between OH-bearing silicate minerals and water. *Geochim. Cosmochim. Acta*, **40**, 1229—1240.

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

黒田 吉益・周藤 賢治・田崎 耕市・小松 正幸・
石川 政憲・鈴置 哲朗・松尾 禎士

(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・$^{87}Sr/^{86}Sr$ 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，$^{87}Sr/^{86}Sr$ 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．