LETTER

$^{143}\text{Nd}/^{144}\text{Nd}$ ratios of twelve GSJ rock reference samples and reproducibility of the data

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The $^{143}\text{Nd}/^{144}\text{Nd}$ ratios were determined for twelve GSJ (Geological Survey of Japan) rock reference samples. The results are summarized in Table 1.

Analytical uncertainties in $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of several separate measurements are slightly larger for granite standard samples (JG-1, JG-1a) than for basalt (JB-1) and andesite (JA-1) samples. This is possibly due to incomplete sample decomposition and Nd separation, or to inhomogeneity in modal composition, hence chemical composition of the powdered samples.

INTRODUCTION

The measurement of Sr and Nd isotope ratios of rocks and minerals has become a standard technique for discussing geologic ages and petrogenesis. The determination of isotope compositions of standard rock samples is particularly important for checking the precision of data and for interlaboratory comparison of the data. For $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the GSJ (Geological Survey of Japan) rock reference samples, many data have been accumulated and their evaluation has been made (Ando *et al.*, 1987; Ando and Shibata, 1988; Kagami *et al.*, 1989). However there is not enough data for $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of the GSJ rock reference samples. Furthermore, a heterogeneity in REE concentrations was recently pointed out for some of the GSJ rock reference samples, particularly when the samples with the size of 100 mg were handled (Kamioka and Tanaka, 1989). If this is true and the heterogeneous sample has relatively older crystallization age, the larger uncertainty would also appear in the $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of the sample. In this report, $^{143}\text{Nd}/^{144}\text{Nd}$ ratios were deter-

mined for twelve GSJ rock reference samples (igneous rock series) and the reproducibility of the data was discussed.

ANALYTICAL PROCEDURES

Approximately 100 to 150 mg of powdered samples were decomposed with a HF and HClO_4 (or HNO_3) mixture in a teflon beaker or a sealed teflon vessel with stainless steel jacket. Especially for the granite (granodiorite) standards, the sealed teflon vessel was used for complete decomposition. Strontium separation was made by following the method of Arakawa (1985). Rare-earth elements (REE) remaining in the cation-exchange resin after Sr separation were extracted with 6N HCl solution. Neodymium was further separated from other REE using another small column ($2.5\phi \times 10\text{ cmH}$) filled with cation-exchange resin (Dowex AG 50W-X8, 200–400 mesh) with 0.2 M hydroxy-isobutyric acid adjusted to pH of 4.6.

The extracted Nd samples were loaded on Re filament using 10% HNO_3 . The measurements were done with a double Re filament assembly,

Table 1. Analytical results of $^{143}\text{Nd}/^{144}\text{Nd}$ ratios for 12 GSJ rock reference samples and comparison with previously reported data

	(A) $^{143}\text{Nd}/^{144}\text{Nd} \pm 2\sigma_m$	(B) $^{143}\text{Nd}/^{144}\text{Nd} \pm 2\sigma_m$	Ref.
JB-1	0.512758 ± 0.000008	0.512786 ± 0.000015	c
	0.512784 ± 0.000008	0.512763 ± 0.000009	e
	0.512785 ± 0.000007		
	0.512781 ± 0.000012		
	0.512791 ± 0.000011		
	0.512780 ± 0.000007		
	0.512780 ± 0.000009 ($n=6$)*		
JB-1	0.512777 ± 0.000006	0.512784 ± 0.000011	d
	0.512765 ± 0.000009	0.512780 ± 0.000006	e
	0.512771 ± 0.000012 ($n=2$)*	0.512773 ± 0.000005	f
JB-2	0.513055 ± 0.000008	0.51311 ± 0.00002	a
		0.51309 ± 0.00003	b
		0.513078 ± 0.000008	e
		0.513085 ± 0.000006	f
JB-3	0.513046 ± 0.000009	0.51299 ± 0.00002	b
		0.513054 ± 0.000008	e
JA-1	0.513085 ± 0.000007	0.51310 ± 0.00002	a
	0.513088 ± 0.000008	0.513065 ± 0.000010	d
	0.513085 ± 0.000006	0.513088 ± 0.000008	e
	0.513096 ± 0.000011		
	0.513087 ± 0.000010		
	0.513075 ± 0.000011		
	0.513086 ± 0.000009		
	0.513086 ± 0.000005 ($n=7$)*		
JA-2	0.512550 ± 0.000012		
JG-1	0.512372 ± 0.000010	0.51242 ± 0.00002	a
	0.512356 ± 0.000008	0.51234 ± 0.00003	b
	0.512396 ± 0.000007	0.512370 ± 0.000020	c
	0.512334 ± 0.000008		
	0.512379 ± 0.000011		
	0.512367 ± 0.000021 ($n=5$)*		
JG-1a	0.512368 ± 0.000006	0.512377 ± 0.000019	d
	0.512387 ± 0.000009		
	0.512378 ± 0.000018 ($n=2$)*		
JG-2	0.512232 ± 0.000007	0.512220 ± 0.000010	e
JG-3	0.512619 ± 0.000007		
JR-1	0.512906 ± 0.000006	0.51285 ± 0.00002	b
JGb-1	0.512624 ± 0.000008		

(A), This study. (B), Previously reported data. Errors listed are within run precision ($2\sigma_m$). * Uncertainty ($2\sigma_m$) of separate measurements (n =number of measurements).

References are as follows: a, Nohda and Wasserburg (1981). b, Tanaka et al. (1987). c, Kagami et al. (1987). d, Kagami et al. (1989). e, Okano et al. (1989). f, Takahashi and Masuda (1990). Data of Nohda and Wasserburg (1981) were renormalized with $^{146}\text{Nd}/^{144}\text{Nd}=0.7219$. Others are reported data.

using a Finnigan MAT 262Q mass spectrometer equipped with seven Faraday collectors. The data were acquired in the static mode with pre-measurement gain calibration of each Faraday collector. The measured $^{143}\text{Nd}/^{144}\text{Nd}$ ratios were normalized to the $^{146}\text{Nd}/^{144}\text{Nd}$ ratio of 0.7219 and a trace contribution from ^{144}Sm was corrected by monitoring ^{147}Sm . Usually, ^{144}Sm contribution was negligible. The data were computed from repeated 100 measurements (ten scans in each of ten blocks). The total time for measuring one sample is about one hour including filament heat-up process. The total blank of Nd in the whole procedure is less than 0.3 ng. The La Jolla Nd standard measured during this study gave an average $^{143}\text{Nd}/^{144}\text{Nd}$ ratio of 0.511864 ± 0.000006 ($n=18$). Also determined are the average values (5 runs) of other isotope ratios for the La Jolla Nd standard; they are 1.141851 ± 0.000026 for $^{142}\text{Nd}/^{144}\text{Nd}$, 0.348414 ± 0.000011 for $^{145}\text{Nd}/^{144}\text{Nd}$, 0.241564 ± 0.000008 for $^{148}\text{Nd}/^{144}\text{Nd}$ and 0.236394 ± 0.000033 for $^{150}\text{Nd}/^{144}\text{Nd}$. These values agree well with those reported by Wasserburg *et al.* (1981). The standard errors ($2\sigma_m$) of $^{143}\text{Nd}/^{144}\text{Nd}$ ratios for each run of the standard rock samples range from 0.000006 to 0.000012 which correspond to 0.0012% to 0.0023% of the data. Kagami *et al.* (1989) used two step normalization to reduce the dispersion of $^{143}\text{Nd}/^{144}\text{Nd}$ data, with $^{142}\text{Nd}/^{144}\text{Nd}=1.141827$ after $^{146}\text{Nd}/^{144}\text{Nd}=0.7219$. In our measurement system, however, no large variation in Nd isotope ratios was found after the normalization with $^{146}\text{Nd}/^{144}\text{Nd}=0.7219$. Therefore any additional normalization other than that with $^{146}\text{Nd}/^{144}\text{Nd}$ was not made in this study.

RESULTS AND DISCUSSION

The analytical data of the twelve GSJ rock reference samples are summarized in Table 1. Six separate analyses of JB-1 sample give an average $^{143}\text{Nd}/^{144}\text{Nd}$ ratio of 0.512780 with standard error of 0.000009 ($2\sigma_m$). This value agrees with the value, 0.512786 ± 0.000015 of Kagami *et al.* (1987), and is close to 0.512763 ± 0.000009 of

Okano *et al.* (1989). Similarly the mean $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of separate analyses for JA-1, JB-1a and JG-1a are identical or close to the previously reported values (Table 1). For JB-2, JB-3, JG-1 and JR-1, however, the measured data do not always coincide with the reported values. Since the difference in $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of those samples between laboratories is not systematic, the difference may not be attributed to inter-laboratory difference of mass spectrometry. For JA-2 (andesite), JG-3 (granodiorite) and JGb-1 (gabbro), the $^{143}\text{Nd}/^{144}\text{Nd}$ ratios were newly determined.

Uncertainties of $^{143}\text{Nd}/^{144}\text{Nd}$ ratios ($2\sigma_m$) by separate analyses of JB-1 and JA-1 are relatively small (0.000009 and 0.000005), being identical to that of the La Jolla Nd standard (0.000006). On the other hand, five measurements of JG-1 and two measurements of JG-1a gave larger uncertainties of 0.000021 and 0.000018, respectively. Since the total blank of Nd is low as compared with the concentrations of Nd in JG-1 and JG-1a (about 20 ppm: 2–3 μg Nd in 100–150 mg powdered samples) (Ando *et al.*, 1987), it is difficult to assume that the relatively larger uncertainties for the granite samples were brought in by the blank Nd. It is generally recognized that granitic and granodioritic rocks are not easily decomposed completely by acids compared with mafic rocks (Tanaka, 1985 and others). This is due to the relatively strong resistance of accessory minerals to acids. Incomplete decomposition of samples in the chemical procedures could cause the larger uncertainties of $^{143}\text{Nd}/^{144}\text{Nd}$ ratios.

Another possible cause of the larger uncertainty is chemical inhomogeneity of powdered samples, especially for the samples with the size of 100–150 mg. Kamioka and Tanaka (1989) ascertained that the powdered samples of JG-1 and JG-1a with about 100 mg weight are relatively heterogeneous in concentrations of some elements including REE as compared with that of JB-1. The chemical heterogeneity correlates with the heterogeneity in modal composition (relative abundances of minerals) of the powdered samples. In granitic rocks, rare earth elements

Table 2. Calculation for the change in $^{143}\text{Nd}/^{144}\text{Nd}$ ratio in response to the deviation from the mean Sm/Nd ratio of JG-1

Sm/Nd (★)	$^{147}\text{Sm}/^{144}\text{Nd}$	$^{143}\text{Nd}/^{144}\text{Nd}$
0.1523 (−30%)	0.0921	0.512348
0.1740 (−20%)	0.1052	0.512356
0.1958 (−10%)	0.1184	0.512363
0.2175 (0%)	0.1315	0.512370
0.2393 (+10%)	0.1447	0.512377
0.2610 (+20%)	0.1578	0.512385
0.2828 (+30%)	0.1710	0.512392

Following values were assumed as the mean values and age for JG-1: Sm=3.61 ppm, Nd=16.6 ppm, Sm/Nd=0.2175 (Tanaka et al., 1987), $^{143}\text{Nd}/^{144}\text{Nd}$ =0.512370, Crystallization age=85 Ma (Ando et al., 1987).

* The percentage of deviation of Sm/Nd ratio from the mean value.

generally concentrate in biotite and accessory minerals, such as apatite, zircon, monazite, allanite etc. (e.g., Faure, 1986; Gromet and Silver, 1983; Henderson, 1984). As the JG-1 and JG-1a standard rocks are Cretaceous in age (85 Ma) (Ando et al., 1987), the present values of $^{143}\text{Nd}/^{144}\text{Nd}$ are expected to be different between mineral phases. If there exists difference in relative abundances of those minerals between aliquots of the powdered samples, a discordance would appear in Sm/Nd ratio, hence in the $^{143}\text{Nd}/^{144}\text{Nd}$ ratio. Kamioka and Tanaka (1989) reported that the variations in Nd and Sm concentrations of JG-1 and JG-1a reach 10–20% (1 σ). Table 2 shows possible variation in the $^{143}\text{Nd}/^{144}\text{Nd}$ ratios of JG-1 due to the heterogeneity in Sm/Nd ratio of the powdered samples. The difference of $\pm 20\%$ in Sm/Nd ratio corresponds to variation of ± 0.000015 in $^{143}\text{Nd}/^{144}\text{Nd}$ ratio. The magnitude of the variation in $^{143}\text{Nd}/^{144}\text{Nd}$ ratio is identical to that associated with the analytical results of JG-1 (Table 1). These results suggest that the comparatively large uncertainty in $^{143}\text{Nd}/^{144}\text{Nd}$ ratio for the granite standards is possibly due to the inhomogeneity in Nd and Sm contents of the powdered samples of 100 mg size. To estimate a reliable whole-rock value and the extent of homogeneity in the samples, analyses with different sample size (more than 100 mg) or with

smaller grain size are required.

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