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Initial Sr Isotope Ratio of the Hobutsu-san Granite, San'in Belt, SW Japan: Implications for Sr Isotope Variation of Cretaceous-Paleogene Igneous Rocks in the Inner Zone of SW Japan

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The Hobutsu-san granite stock, the southwestern part of Tottori prefecture, SW Honshu, has a Rb-Sr whole rock isochron age of 72.3±2.8 Ma with an initial ratio of 0.70681. The initial ratio is remarkably high for granitoids of the San'in Belt. High Sr isotope ratios of some lower crustal granulite xenoliths included in an alkali basalt of the Oki islands, suggest that the lower crust could have been a magma source for the Hobutsu-san granite. Initial Sr isotopic ratios of Cretaceous-Paleogene igneous rocks in the Inner Zone of Southwest Japan decrease from south to north through a transitional zone. This supports a previous suggestion by KAGAMI *et al.* (1987) that the magmas for the granites of SW Honshu and North Shikoku have been derived from three source regions with different geochemistry.

Introduction

Cretaceous-Paleogene plutonic rocks associated with contemporaneous volcanic rocks are extensively distributed in the Inner Zone of Southwest Japan. On the basis of Sr isotope composition, SHIBATA and ISHIHARA (1979) demonstrated regional variation of initial Sr isotope ratios and pointed out that such variation is generally correlated with thickness of the continental crust. TERAKADO and NAKAMURA (1984) found that ε Nd values for silica-rich plutonic and volcanic rocks decrease from west to east, and suggested that such variation may be due to the heterogeneous composition of the lower crust, and ultimately to that of the upper mantle beneath Southwest Japan.

On the basis of recent Nd and Sr isotope data, KAGAMI *et al.* (1987) suggested that the Cretaceous-Paleogene igneous rocks in the Inner Zone of Southwest Japan may have been derived from three source regions with different geochemistry. In the course of our geochemical study, we analysed rocks from the Hobutsu-san pluton and found them to have a high initial Sr isotope ratio when compared with the Sr ratios of granitoids elsewhere in the San'in Belt.

In this report we present a Rb-Sr whole rock isochron age and an initial Sr isotope ratio for Hobutsu-san granite pluton in the southwestern part of Tottori prefecture (Fig. 1), and comment on its implication for regional variation of Sr isotope ratios in the

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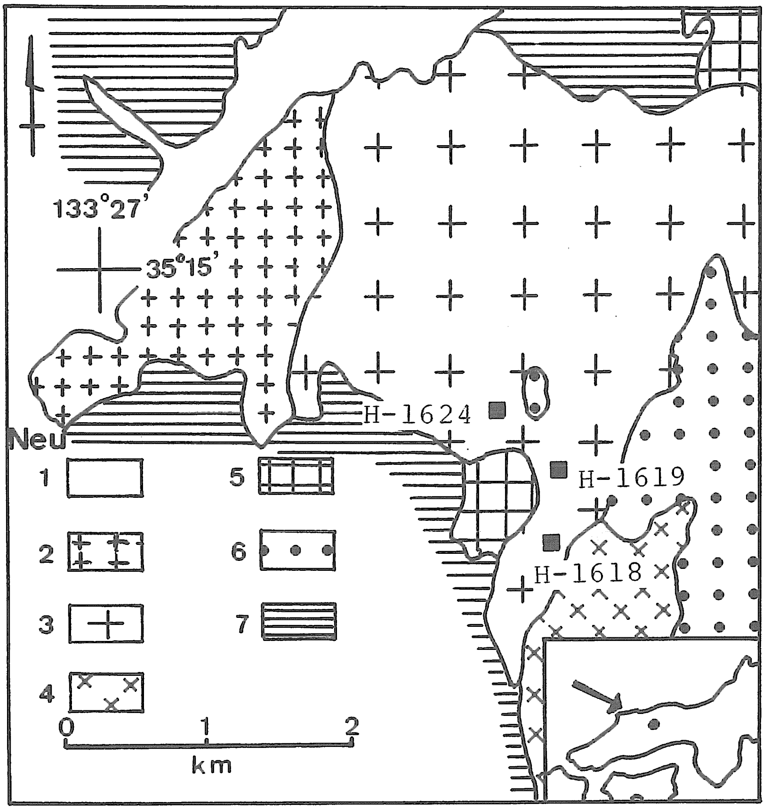


Fig. 1. Geological map around the Hobutsu-san granite (HATTORI and KATADA, 1964) and sample localities.

1: Alluvial deposits; 2: Neu granite; 3: Hobutsu-san granite; 4: Asagari-dani granodiorite; 5: quartz diorite∼quartz gabbro; 6: acid∼intermediate volcanic rocks; 7: Sangun metamorphic rocks.

Cretaceous-Paleogene igneous rocks in the Inner Zone of Southwest Japan.

The Hobutsu-san granite is a stock with a diameter of about 3 km. It is mainly composed of fine- to medium-grained leucocratic biotite adamellite and granophyre∼granite porphyry. It is classified within the magnetite-series granitoids by ISHIHARA (1977). The pluton intrudes the Sangun metamorphic rocks and Cretaceous volcanic and plutonic rocks which include the Asagaridani granodiorite (Fig. 1). The Asagaridani granodiorite has a Rb-Sr whole rock isochron age of 74.5 ± 5.2 Ma (IIZUMI *et al.*, in preparation). The Hobutsu-san granite is intruded by the Neu pluton, one of a series of plutons that intrude large areas of the San'in Belt (HATTORI and KATADA, 1964)

Initial Sr Isotope Ratio of the Hobutsu-san Granite

Isotope measurements were made using a Varian MAT261 mass spectrometer at the Institute for Study of the Earth's Interior, Okayama University. Rb and Sr were extracted from the samples following by the methods described by KAGAMI *et al.* (1982), and their concentrations were determined by the isotope dilution method. Measured $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr=0.1194$. The age and the initial ratio were calculated by the least squares regression method of YORK (1966), using $\lambda =$

Table 1. Rb and Sr concentrations and Sr isotope compositions of the Hobutsu-san granite.

Samples	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	± 2σ
H-1618	161.8	83.6	5.60	0.71253	0.00003
	161.0	84.1	5.54		
H-1619	180.5	81.0	6.45	0.71311	0.00004
H-1624	139.8	94.2	4.29	0.71121	0.00004
	140.2				

H-1618: biotite granite porphyry.
H-1619: porphyritic biotite granophyre.
H-1624: medium-grained biotite adamellite.

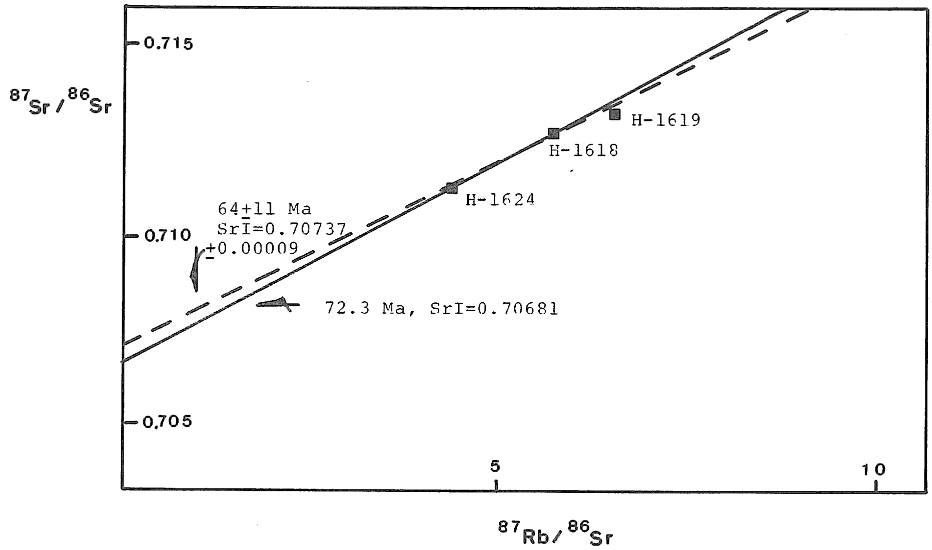


Fig. 2. Rb-Sr whole rock isochron for the Hobutsu-san granite.

$1.42 \times 10^{-11} y^{-1}$ for the decay constant of ^{87}Rb.

The results are listed in Table 1 and the isochron is plotted in Fig. 2. The isochron given by the three samples gives an age of 64 ± 11 Ma with an initial ratio of 0.70737 ± 0.00009. This isochron is not considered to represent the true age of the Hobutsu-san granite, in view of the field evidence that the pluton intrudes the Asagari-dani granodiorite with an age of 74.5 Ma, and is in turn intruded by the Neu pluton with a Rb-Sr whole rock isochron age of 64.8 ± 0.5 Ma (IIZUMI *et al.*, 1984). This age discrepancy may be ascribed to alteration of the sample, H–1619, in which plagioclase and K-feldspar are altered in some extent to chlorite, sericite, calcite, epidote and albite. The isochron defined by the two samples, H–1618 and H–1624, therefore, may give the correct age and the initial ratio for the Hobutsu-san granite. The isochron gives an age of 72.3 ± 2.8 Ma and an initial ratio of 0.70681 (Fig. 2). Nevertheless the Hobutsu-san granite has a remarkably high initial ratio with regard to other granitoids in the San'in Belt.

Discussion

It is well known that most of the granitoids in the San'in Belt have lower initial Sr isotopic ratios than those of the Ryoke and Sanyo Belts. Some granitoids in the eastern part of the San'in Belt, however, have higher initial ratios than 0.7060 (SHIBATA and ISHIHARA, 1979; SUDO *et al.*, 1982; HONMA, 1986). The Okinosen granite, which is a typical zoned pluton in the San'in Belt (TAINOSHO, 1985), has an age of 81.5 Ma with an initial ratio of 0.7062 (SHIBATA and ISHIHARA, 1979). The Chizu-Koshihata and Mochigase granites have radiometric ages of about 80 Ma, and have the initial ratios of 0.7086 and 0.7065, respectively (HONMA, 1986). The age of these granitoids is comparable to granitoids in the Ryoke and Sanyo Belts, but a high initial ratio has been reported from the Tottori granite, located to the south of Kurayoshi. This granite has a well defined isochron of 60.4 Ma. The Hobutsu-san granite with a high initial ratio of 0.70681 has an intermediate age of 72.3 Ma.

Among the granitoids with higher initial ratios in the San'in Belt, the Kurami-Nagisen and Mochigase granites are identified as ilmenite-series granitoids and the others are magnetite-series granitoids (TAINOSHO, 1982) with the exception of the Chizu granite which is a combination of both of the magnetite- and ilmenite-series granitoids (KAWAZU, 1985). These facts indicate that there is no correlation of Sr isotope ratios, ages and the granite series of the granitoids in the San'in Belt.

SHIBATA and ISHIHARA (1979) suggested that the rocks with relatively low initial Sr isotope ratios were formed from magmas contaminated by various amounts of crustal material, and those with high ratios were derived from deep-seated magmas contaminated with crustal material or from magmas generated within the continental crust. A mixing model of mantle- or lower crust-derived magmas contaminated with upper crustal material suggests a possible explanation for the high initial ratio of the Hobutsu-san granite. There is, however, no evidence suggesting contamination or assimilation by the magma of upper crustal rocks, since the rock type is fairly constant within the pluton.

Recently KAGAMI *et al.* (1987) have determined Nd and Sr isotope ratios of mafic to ultramafic xenoliths included in Cenozoic alkali basalts from the Oki islands. Among them spinel lherzolite and mafic granulite xenoliths are considered to represent samples from the upper mantle and lower crust respectively (TAKAHASHI, 1978). They have a wide range of Sr isotope ratios, and it is worth noting that some of the granulite xenoliths have very high ratios of up to 0.7070, which is similar to the initial ratio of the Hobutsu-san granite. If such granulites constitute a part of the lower crust beneath the San'in region, then we suggest that granitic magmas with initial Sr isotopic ratios of up to 0.7070 may have ben derived from partial melting of such granulite.

Initial Sr isotopic ratios of Cretaceous-Paleogene acidic, intermediate and basic rocks from the Chugoku and Shikoku areas together with that of the Hobutsu-san granite are plotted in Fig. 3. Those rocks located south of the solid line in Fig. 3 have higher Sr ratios (>0.706) than those to the north of the broken line. In the area

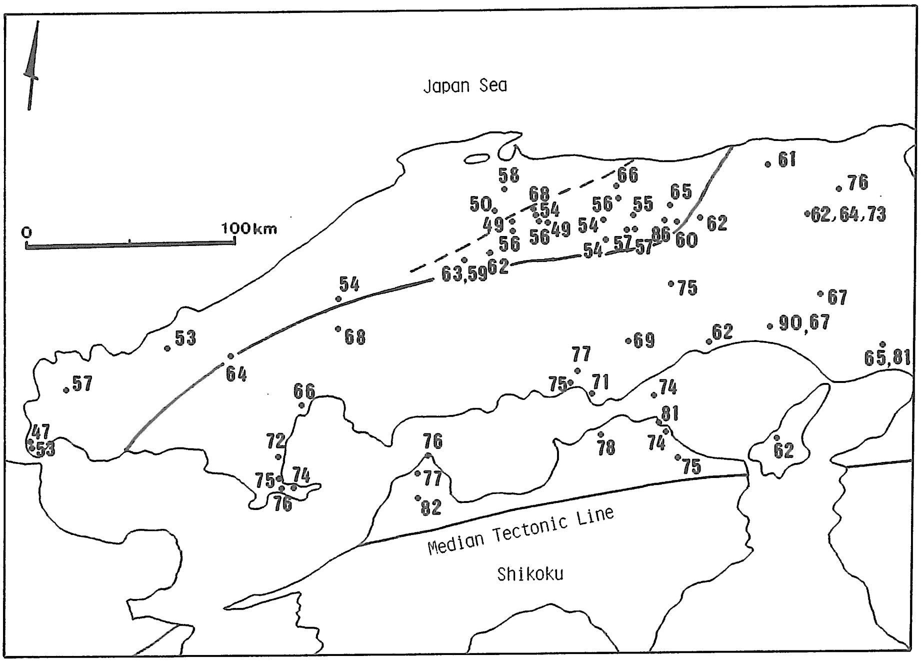
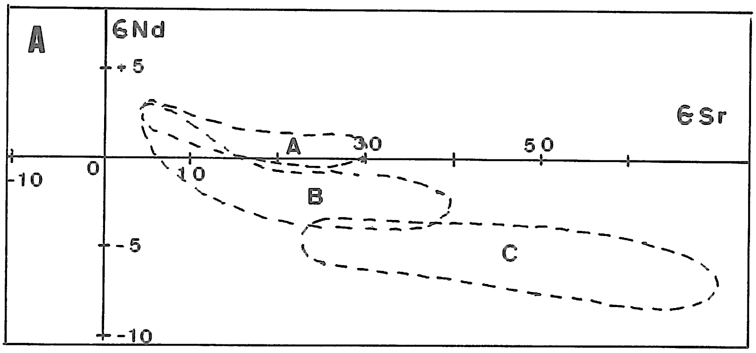


Fig. 3. Distribution of initial Sr isotope ratios for the Cretaceous-Paleogene igneous rocks in the Chugoku and Shikoku areas. Figures represent the last two digits of the initial Sr isotope ratios. Data sources: HATTORI and SHIBATA (1974), HONMA (1986), HONMA et al. (1983), IIZUMI et al. (1982), IIZUMI et al. (1984), IIZUMI and KAGAMI (this work), OKANO and HONMA (1983), SEKI (1981), SHIBATA and ISHIHARA (1979), SHIGENO and YAMAGUCHI (1976), SHIRAHASE (1981), SUDO et al. (1983), TERAKADO and NAKAMURA (1984).

between the two lines, both types of igneous rocks occur. Although this area is rather ill defined in some places, it appears to extend in an ENE–WSW direction, following the boundary between the San'in and Sanyo Belts.

Based mainly on Nd isotope data, KAGAMI *et al.* (1987) pointed out that the Cretaceous-Paleogene igneous rocks in the Inner Zone of Southwest Japan can be divided into three groups, which plot in fields A, B and C on the ε Nd– ε Sr correlation diagram (Fig. 4A). Samples plotting within these fields were collected from the areas A, B and C shown in Fig. 4B, respectively. The solid line 2 shown in Fig. 4B represents the approximate boundary between areas B and C, and virtually coincides with the solid line in Fig. 3. KAGAMI *et al.* (1987) considered that the observed variation of the isotope ratios reflects a fundamental difference in geochemistry of their source regions. Taking Mesozoic tectonic development of Southwest Japan into account, KAGAMI *et al.* (1987) suggested that the Cretaceous igneous rocks in area C in



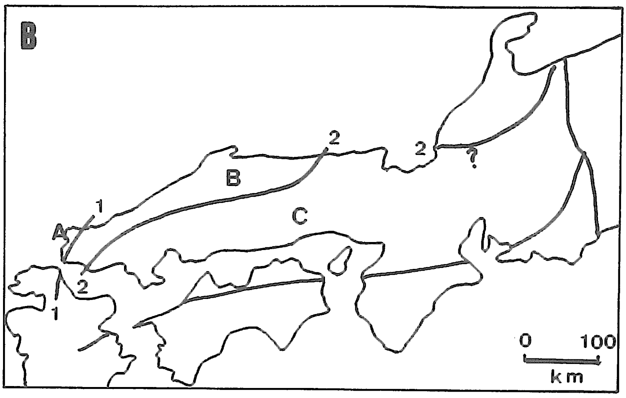


Fig. 4. A: εSr– εNd correlation diagram for Cretaceous-Paleogene igneous rocks from the Inner Zone of Southwest Japan (KAGAMI et al., 1987).
B: Regional variation of εNd. The samples collected from areas A, B and C plot in fields, A, B and C in Fig. 4A.

Fig. 4B may have been derived from magmas generated at the lower crust or upper mantle of a micro-continent which had collided with the eastern margin of the Asian continent before the Cretaceous, and that the solid line 2 in Fig. 4B may roughly represent the northwestern margin of the collided micro-continent.

As already mentioned above, the lower crustal material beneath area B is considered to have been capable of yielding magmas with Sr isotope ratios of up to 0.7070. Many igneous rocks including mafic rocks in area C, however, have higher initial Sr ratios than 0.7070. The regional variation shown by Sr isotopes, therefore, may support the idea presented by KAGAMI *et al.* (1987).

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