Magnesian andesites in the Oono volcanic rocks, central Kyushu : westward continuation of the Setouchi volcanic belt

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Abstract

Magnesian andesite (HMA), which characterizes the Setouchi volcanic belt, was found as a dike intruding the Oono volcanic rocks that have previously been correlated to the middle Miocene Setouchi volcanic rocks from petrography and dating.

A similar HMA dike is also emplaced at Takenaka along the Sashu Fault, part of the Median Tectonic Line. These HMAs have high Rb, K and Ba contents and Rb/Sr ratio, a feature characteristic of HMA in the Setouchi volcanic rocks. In north and central Kyushu there are many HMA occurrences, but high-Rb HMAs are relatively rare. Some HMAs with high Rb/Sr in northern Kyushu are different in age from the Oono and the Setouchi volcanic rocks; the Setouchi volcanic belt does not appear to continue into northern Kyushu. The only Setouchi correlative in Kyushu other than the Oono and Takenaka HMAs occurs further southwestward at Kameura of Amakusa-Shimoshima.

Key words : magnesian andesite, Oono volcanic rocks, Oita Prefecture, Setouchi volcanic belt, sanukite, trace element

Introduction

Primitive rocks from the middle Miocene Setouchi volcanic belt in southwest Japan are characterized by the predominance of (high)-magnesian andesite (HMA) (Ujike, 1972; Sato, 1977; Tatsumi and Ishizaka, 1982; Shiraki, 1993) which is defined as andesite with >53% SiO₂ and higher MgO than average values of basalt (6–8%) (Shiraki et al., 1994 b). The common occurrence of HMA is rare, except for the boninite series in intraoceanic island arcs, and distinguishes the Setouchi volcanic rocks from other calc-alkali series in active continental margins. The Oono (Ono) volcanic rocks, erupted in a westward extension of the Setouchi volcanic belt into central Kyushu, have been correlated to the Setouchi volcanic rocks from petrography and dating (Matsumoto, 1933; Horikoshi, 1972; Miyahisa, 1972; Shibata and Ono, 1974; Tatsumi et al., 1980; Matsumoto, 1987), but no HMA has yet been found. Here we describe an HMA intruded as a dike into the Oono volcanic rocks, show that this HMA may represent a primary magma parental to the Oono volcanic rocks on the basis of major and trace element analyses, and discuss its relations to other HMAs in Kyushu and Setouchi.

Oono volcanic rocks

The Oono volcanic rocks are distributed in the mid-stream area of the Oonogawa river lying 30 to 40 km southwest of Oita city (Fig. 1). They have been divided into the Mure Conglomerate, the Shiraiwasan Pyroclastic Flow Deposit, the Koguraki Tuff, the Daisangoyama Andesite and the Miyakeyama Pyroclastic Flow Deposit in ascending order (Teraoka et al., 1992). In addition a mafic dike cuts the Miyakeyama Pyroclastic Flow Deposit east of Miyakeyama (Ono, 1963).

The Shiraiwasan and Miyakeyama Pyroclastic Flow Deposits consist mainly of dense-welded, gray to white rhyolite with minor dacite and pitchstone. The rhyolites comprise biotite rhyolite and orthopyroxene rhyolite, containing phenocrysts of quartz and plagioclase with or without sanidine and clinopyroxene (Ono, 1963); in addition, the Miyakeyama rhyolites have phenocrysts of iron-rich olivine (Matsumoto, 1959). The dacites, ranging in SiO₂ content from 65 to 70%, are high in phenocrysts of ortho- and clinopyroxenes compared to the rhyolites with > 70% SiO₂.

The principal rock type of the Daisangoyama Andesite is represented by a compact, glassy

Fig. 1. Distribution of Oono volcanic rocks (shown in black), HMAs and bronzite andesites in north and central Kyushu. Open circles indicate high-Rb HMA. Partial list of references: Usui (Mikami et al., 1972; Nagao et al., 1992a); Yoake (Kakubuchi, 1994); Imabuku (Sato, 1989); Arita (Seno, 1980; Sato, 1989); Taradake (Ikawa, 1994); Ikeshima (Matsui, 1987); Iwayasan (Shiraki et al., 1992); Gesujima (Nagao et al., 1992b); Hisatsu (Nagao and Sakaguchi, 1989).

clinopyroxene-orthopyroxene andesite. It is similar in appearance to sanukite, a glassy variety of bronzite andesite (Weinschenk, 1890). The Daisangoyama Andesite, however, is different from sanukite in the common presence of plagioclase and clinopyroxene phenocrysts.

The dike intruding the Miyakeyama rhyolites has a strike of $N60^{\circ}W$ and a dip of $70^{\circ}NE$ with about 10 m wide (Ono, 1963), and is called Oono dike hereafter. It is an orthopyroxene-clinopyroxene-olivine andesite containing phenocrysts of olivine (17.0 modal %) and microphenocrysts of clinopyroxene (9.4%), plagioclase (2.6%) and orthopyroxene (0.7%) in a groundmass with intergranular texture composed of plagioclase, pyroxenes, opaque minerals, and mesostasis or alkali feldspar and silica minerals. Olivine is partially altered, but pyroxenes are fresh.

Another dike is emplaced along the Sashu Fault at Takenaka, Oita city, 30 km northeast of the Oono dike (Fig. 1); the Sashu Fault bounds the Sanbagawa Metamorphic Rocks on the Upper Cretaceous Onogawa (Onogawa) Group, and is considered to form part of the Median Tectonic Line (MTL) (Teraoka et al., 1992). The Takenaka dike trends north with 10 to 20 m wide. It is a gray andesite having altered olivine (9.0%) phenocrysts up to 2 mm across and orthopyroxene (2.5%) and clinopyroxene (0.8%) microphenocrysts up to 0.5 mm set in a groundmass of plagioclase, pyroxenes, opaques, and mesostasis or silica minerals and alkali feldspar; quartz veins and patches are com-

monly present.

Radiometric dating brackets ages of the Oono volcanic rocks at 15 to 13 Ma (Shibata and Ono, 1974; Tamanyu, 1978; Tatsumi et al., 1980); the Oono dike is younger than these ages. The age of the Takenaka dike is unknown, but Tazaki et al. (1990) have reported K-Ar ages of 15.5 to 15.1 Ma from andesites including HMA emplaced along the MTL in northwestern Shikoku.

Chemical compositions

Major and trace elements in the Oono volcanic rocks and associated dikes were determined by XRF (JEOL JSX-60S7) at Yamaguchi University using methods of Kakubuchi et al. (1989). Representative analyses are listed in Table 1 with those of related rocks. Variations of some elements in the Oono volcanic rocks are shown in Fig. 2. MORB-normalized incompatible element patterns are given in Fig. 3.

The Daisangoyama Andesite (No. 1 in Table 1) has chemical compositions very similar to those of andesite (No. 7) with comparable SiO_2 from the Setouchi volcanic belt, although the former is slightly higher in high-field strength elements (HFSE) such as TiO_2 , P_2O_5 , Zr, Y and Nb than the latter. The dacites and rhyolites in the Oono volcanic rocks are more fractionated and higher in incompatible elements except for TiO_2 , P_2O_5 and Sr than the Daisangoyama Andesite (Fig. 3a). The Miyakeyama rhyolites contain zircons similar in morphology to those from the Daisangoyama Andesite (Hayashi, 1993).

The Oono dike (Nos. 4, 5) is unusually high in MgO despite relatively high SiO_2 . This may reflect high modal phenocrystic olivine and presence of orthopyroxene as a microphenocryst. This rock can be classified as HMA. The Takenaka dike (No. 6) also has an HMA composition with 61% SiO_2 at 7.2% MgO, although its unusually high SiO_2 may be partly due to secondary alteration. The Takenaka HMA is lower in MgO and higher in large-ion lithophile elements (LILE) except for Sr than the HMA in the Oono volcanic rocks. Both HMAs, however, are similar in Sr and HFSE concentrations (Fig. 3a). Rb, K and Ba show a progressive increase from the Oono HMA through the Takenaka HMA to the andesite, dacite and rhyolite in the Oono volcanic rocks (Figs. 2 and 3a).

Discussion

The Oono and Takenaka HMAs have high Rb, K and Ba contents and Rb/Sr ratio. The high concentrations of LILE except for Sr characterize the Setouchi HMA (Sato, 1981; Ishizaka and Carlson, 1983). The order of LILE enrichment in the Setouchi HMA compared to the associated basalts is $Rb > K > Ba$ (Tatsumi et al., 1986; Shiraki et al., 1991; Shiraki and Yamatsu, 1993); the Setouchi HMA shows no en-

Table 1. Major and trace element analyses of Oono volcanic rocks and related rocks.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO ₂ (%)	61.17	68.69	74.34	54.08	54.29	60.80	61.23	56.95	52.17	54.20	59.38	55.83	55.15	57.13
TiO ₂	1.25	0.90	0.18	0.92	0.90	0.90	0.85	0.72	0.80	0.75	0.73	0.60	1.06	0.76
Al ₂ O ₃	16.70	15.79	13.93	13.85	14.13	14.96	17.97	14.01	16.01	15.54	13.87	12.81	15.74	15.50
Fe ₂ O ₃	6.08	4.66	1.80	8.66	8.38	6.62	5.74	7.66	8.24	7.19	7.68	8.21	8.47	7.40
MnO	0.10	0.06	0.04	0.14	0.13	0.10	0.07	0.13	0.14	0.12	0.12	0.09	0.14	0.13
MgO	2.91	1.48	0.29	10.98	10.55	7.21	2.55	8.96	10.07	10.10	8.47	10.85	6.87	7.43
CaO	5.78	2.71	1.15	7.36	7.52	4.90	5.45	7.01	9.39	7.93	5.84	8.16	8.35	7.42
Na ₂ O	2.99	2.62	3.16	2.45	2.52	2.55	3.34	2.73	2.50	3.30	2.04	1.58	3.15	2.97
K ₂ O	2.80	2.96	5.09	1.41	1.41	1.78	2.58	1.68	0.52	0.73	1.71	1.71	0.84	1.12
P ₂ O ₅	0.23	0.12	0.04	0.16	0.16	0.17	0.20	0.15	0.17	0.14	0.16	0.17	0.21	0.15
Rb (ppm)	98.6	130	187	49.0		67.8	104	67.2	10	16.3	56.6	41	21	34
Sr	318	187	87.6	302		297	283	269	355	425	208	315	423	364
Ba	401	483	747	289		331	443	328	198	239	402	438	250	228
Zr	214	286	204	116		125	169	114	75	80.0	124	96	152	115
Y	28.6	35.1	40.1	18.3		19.2	26.5	19.2	18	21.4	20.3	12	48	30
Nb	13.0	13.4	14.0	6.3		9.1	9.7	5.9	9	4.7	8.7	3	10	8
Cr	28.7	50.2	6.8	665		830	43.0	560	675	477	681	941	314	510
Ni	12.8	4.8	1	255		191	12.5	203	182	221	137	339	125	152
V	111	17.5	1	151		143	138	156	171	121		167	190	139
Zn	74.4	67.6	64.9	77.8		68.7	77.2	78.6	70	62.6		72	113	67
Rb/Sr	0.310	0.695	2.135	0.162		0.228	0.367	0.250	0.028	0.038	0.272	0.130	0.050	0.093

1-3, Oono volcanic rocks (1, andesite, average of 4 samples ; 2, hypersthene dacite ; 3, rhyolite, average of 2 samples) ; 4 and 5, Oono dike (4, average of 2 analyses ; 5, collected by Y. Matsumoto) ; 6, Takenaka dike ; 7, Nishi-Setouchi andesite (3-1% MgO, Shiraki et al., 1991) ; 8, Nishi-Setouchi HMA (>6% MgO, Shiraki et al., 1991) ; 9, Yabakei tholeiite (Kakubuchi and Matsumoto, 1990) ; 10, Aso HMA ; 11, Kameura HMA (Nagao et al., 1992 b) ; 12, Hikosan HMA (Kakubuchi, 1994) ; 13, Ikeshima HMA ; 14, Iwayasan HMA.

Fig. 2. MgO, Al₂O₃, K₂O, Cr, Sr and Rb vs. SiO₂ in Oono (dike, solid circles ; andesite, squares ; dacite, open triangles ; rhyolite, solid triangles) and Nishi-Setouchi (crosses) volcanic rocks, and Takenaka dike (open circle). Major element data include those of Matsumoto (1959) and Ono (1963). Nishi-Setouchi data from Shiraki et al. (1991).

Fig. 3. MORB-normalized incompatible element patterns for Oono volcanic rocks, Takenaka HMA and Nishi-Setouchi andesite (a) and Oono HMA and primitive rocks from SW Japan (b). Data from Table 1. MORB-normalized values from Pearce (1983).

richment in Sr as well as HFSE (Fig. 3b). Here we define HMA with $Rb/Sr > 0.1$ as high-Rb HMA.

The high-Rb HMAs with a marked enrichment in Rb, K and Ba relative to Sr and HFSE are rarely found in Kyushu other than the Oono and Takenaka HMAs. Rocks similar in composition to the Oono HMA have been reported from Kameura in Amakusa-Shimoshima 150 km to the southwest (Nagao et al., 1992b) and from west of Hikosan 70 km to the northwest (Kakubuchi, 1994) (Fig. 3b). The Kameura HMA has been dated at 14.2 ± 0.3 Ma, which is contemporaneous with the Oono volcanic rocks and the early stage of the Setouchi volcanic activity (Yoshida et al., 1993). The age of the Hikosan HMA is unknown, but K-Ar age determinations for tholeiitic basalts, HMAs and andesites from the Yabakei and Chikuho districts have resulted in 8 to 3 Ma (Nakada and Kamata, 1991; Matsumoto et al., 1992). The middle Miocene Setouchi volcanic belt does not appear to continue into northern Kyushu, although Ueji (1932) has reported a bronzite andesite with HMA compositions intruded as a dike into a coal-seam from the Chikuho coalfield.

Magnesian andesites from the western slope of Aso

somma, located some 50 km southwest of the Oono HMA, are different from the Oono and Setouchi HMAs in low contents of Rb, K and Ba, but not very different in Sr and HFSE. The Aso HMA has slightly higher Rb, K and Ba than and almost the same Sr and HFSE as the Yabakei tholeiitic basalts (Fig. 3b). Moreover, the age, ca. 4 Ma, of the Aso HMA is younger than the Setouchi HMA (Shiraki et al., 1994a).

Koto (1916) has suggested that the Setouchi volcanic belt may extend to Northwest Kyushu, where bronzite-bearing volcanic rocks (sanukitoids) are widespread. In NW Kyushu sanukite quite identical with that of the type locality has been found at Hario-jima (Yamaguchi, 1964), and HMAs including some high-Rb HMAs (Sato, 1989) have been reported from several localities (Fig. 1). However, these bronzite andesites and HMAs are different from the Oono and Setouchi volcanic rocks in age ranging from 9 to 4 Ma (Tatsumi et al., 1980; Matsui, 1987; Tajima et al., 1992). Moreover, Rb, K and Ba in the HMAs from NW Kyushu are not as high as those in the Oono and Setouchi HMAs. Most HMAs in Kyushu have Rb, K and Ba concentrations intermediate between the Setouchi HMA and the Yabakei tholeiitic basalts, whereas Sr and HFSE concentrations are highly variable (Fig. 3b).

Both the Oono and the Takenaka HMAs bear a strong resemblance to the Setouchi HMA in marked enrichment in Rb, K and Ba relative to Sr and HFSE. They seem to represent a westward continuation of the middle Miocene Setouchi volcanic belt into east-central Kyushu. Further southwestward, the Setouchi volcanic belt may extend to the Kameura HMA of Amakusa-Shimoshima, which is very similar in age and composition to the Oono and Setouchi volcanic rocks.

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*: in Japanese with English abstract. **: in Japanese.

〈地 名〉

Amakusa	天草	Arita	有田	Aso	阿蘇
Chikuho	筑豊	Daisangoyama	代三五山	Gesujima	下須島
Hariojima	針尾島	Hikosan	英彦山	Hisatsu	肥薩
Ikeshima	池島	Imabuku	今福	Iwayasan	岩屋山
Kameura	亀浦	Koguraki	小倉木	Miyakeyama	三宅山
Mure	牟礼	Oono (Ono)	大野	Sashu	佐志生
Shiraiwasan	白岩山	Takenaka	竹中	Taradake	多良岳
Usui	碓井	Yabakei	耶馬溪	Yoake	夜明

(要 旨)

Shiraki, K., Yoshioka, K. and Matsumoto, Y., 1995, Magnesian andesites in the Oono volcanic rocks, central Kyushu : westward continuation of the Setouchi volcanic belt. *Jour. Geol. Soc. Japan*, **101**, 387-392. (白木敬一・吉岡賢二・松本雅夫, 1995, 中部九州, 大野火山岩類の高マグネシア安山岩: 瀬戸内火山帯の西方延長. *地質雑*, **101**, 387-392.)

瀬戸内火山岩類に対比されてきた, 大分県中部の中期中新統大野火山岩類を貫く岩脈として, 瀬戸内火山帯を特徴づける高マグネシア安山岩を発見した. 高マグネシア安山岩組成の岩脈はまた, 大分市竹中において, 中央構造線の一部とされる佐志生断層に沿っても貫入している. これら2つの高マグネシア安山岩は, Rb・K・Baに富みSrに比較的乏しく, 瀬戸内高マグネシア安山岩の特徴と一致する. 北・中部九州には多くの高マグネシア安山岩が知られているが, Rb/Srの高いものは少ない. 九州北部の高Rb/Srをもつ高マグネシア安山岩は, 10 Ma以下の年代を示し, 瀬戸内火山帯は九州北部に延長するようにはみえない. 大野および竹中の高マグネシア安山岩に, 組成および年代において類似する高マグネシア安山岩は, 天草下島亀浦に現れ, 中期中新世の瀬戸内火山帯はさらに南西に延びるかもしれない.