

## Magnesian andesites from White Island, New Zealand: Mineralogical evidence for mixing of high-magnesian basalt and dacite magmas

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**Abstract** Andesite blocks erupted from White Island volcano in 1977 are chemically similar to the clinopyroxene-rich magnesian andesites from the Setouchi volcanic belt in southwest Japan. However, there are differences in mineralogy with Mg# decreasing from olivine to clinopyroxene and orthopyroxene with a marked compositional gap. The White Island magnesian andesite contains olivine phenocrysts normally zoned from Fo92 to Fo88, suggesting that they have crystallized from a high magnesian magma. In contrast, the clino- and orthopyroxenes are rather low in Mg#, with a highest value of 83.9, and many are reversely zoned. The clinopyroxene cores with Mg# ranging from 79 to 75 indicate their derivation from a magma significantly higher in FeO/MgO than the host rock. The White Island magnesian andesites are considered to have formed by mixing of a high-Mg basalt magma and a dacite magma with relatively high FeO/MgO.

**Key words:** magnesian andesite, magma mixing, White Island, Setouchi volcanic belt, sanukite

### INTRODUCTION

Magnesian andesites, defined here as andesites with >53 % SiO<sub>2</sub> and higher MgO than average values of basalt (6-8 %), occur mainly in two geological environments (Shiraki 1989). One is associated with subduction zone volcanism, and the other accompanies early Precambrian komatiitic volcanics; the latter has also been termed siliceous high-magnesian basalt (SHMB; Sun *et al.* 1989). The magnesian andesites in subduction zones are best interpreted as having formed by wet partial melting of peridotite (e.g., Shiraki & Kuroda 1977; Cameron *et al.* 1979; Crawford *et al.* 1989), whereas the SHMBs are considered to be products of contamination or mixing of high-temperature komatiitic magmas with siliceous crustal rocks or magmas (e.g., Arndt & Jenner 1986; Barley 1986; Sparks 1986).

Two types of magnesian andesites (MA) are associated with subduction zones: (i) those occurring in intraoceanic island arcs of the western Pacific, and some ophiolites associated with mid-

ocean ridge basalts and island-arc tholeiites. These are typically boninitic MA; (ii) calc-alkali; suites of active continental margins, of which an example is the middle Miocene Setouchi volcanic belt of southwest Japan. These range from basalt to rhyolite in composition, and include a glassy bronzite andesite which was termed 'sanukite' by Weinschenk (1891). Although this term has been abandoned by Le Maitre (1989), it is a useful term to describe the MAs associated with this environment and are referred to in this paper as sanukitic MA.

The sanukitic MAs of the Setouchi volcanic belt are characterized by high Mg (Mg# >85) and Cr (Cr<sub>2</sub>O<sub>3</sub> >0.5 %) orthopyroxenes and high concentrations of Rb, K and Ba relative to Sr and HFS elements. Rb, K and Ba were probably added by hydrous fluids from the subducted slab (Tatsumi *et al.* 1986; Shiraki *et al.* 1991). These MAs appear to be parental to the more silicic Setouchi volcanic rocks by fractional crystallization (Sato 1977; Tatsumi & Ishizaka 1982; Shiraki 1993).

The Taupo Volcanic Zone is the southward

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extension of the intraoceanic Tonga-Kermadec arc into the continental environment of New Zealand and has magnesian andesites, which chemically are very similar to the Setouchi sanukitic MAs (Clark 1960; Cole & Teoh 1975; Cole 1978). In mineral composition, however, the Taupo MAs are different from the Setouchi MAs; in most Taupo MAs clinopyroxene exceeds orthopyroxene abundances and Mg-value ( $Mg\# = 100Mg / (Mg + Fe)$ ) of the clinopyroxene is higher than that of the orthopyroxene (Froude & Cole 1985; Graham & Hackett 1987; Patterson & Graham 1988). White Island volcano, at the northeastern end of the Taupo Volcanic Zone, erupted andesite blocks during phreatomagmatic activity in March 1977 (Clark *et al.* 1979). Except for accumulative rocks, these andesites are the most magnesian so far analysed in the Taupo Volcanic Zone (Clark & Cole 1986). We carried out an electron probe study on a sample (P41600) from the andesite blocks to compare it with the Setouchi MAs (Shiraki *et al.* 1989b) and show here that mineral compositions of the White Island MA are quite different from the Setouchi MAs.

## PETROGRAPHY

Petrography of the analysed sample is given in Clark & Cole (1986), Cole & Graham (1989) and Graham & Cole (1991). Porphyritic mafic andesite (P41600) consists of phenocrysts of plagioclase (9.6 modal %), olivine (6.2%), clinopyroxene (5.8%), orthopyroxene (5.5%) and Fe oxide (0.1%) in a fresh black glass full of small microlites of feldspar and pyroxene. Plagioclase forms subhedral crystals up to 2 mm in length although some are fragmented. Olivine usually occurs as small subhedral to euhedral phenocrysts (<0.5 mm), but occasionally forms crystals of 1 mm length. The phenocrysts are unstrained, euhedral and skeletal in forms with no obvious disequilibrium textures. Clino- and orthopyroxenes reach a maximum size of 1.5 mm and are usually subhedral. Most of the opaque microphenocrysts (<0.05 mm) are magnetite but rare small octahedra of chromite up to 0.02 mm are present in the glass or enclosed in the olivines.

## MINERAL COMPOSITIONS

Mineral compositions of the White Island MA are shown in Tables 1 to 3. Olivine is highly magnesian, the maximum Fo 92.1, and is normally zoned. There is no marked difference in Fo among the euhedral, subhedral and skeletal crystals. In contrast, pyroxenes are less magnesian, the highest Mg# being 83.9 in the clinopyroxenes and 81.6 in the orthopyroxenes, and many are

reversely zoned with more magnesian rims. Clinopyroxenes range from Wo<sub>39</sub>En<sub>48</sub>Fs<sub>13</sub> to Wo<sub>38</sub>En<sub>46</sub>Fs<sub>15</sub> in the cores and from Wo<sub>39</sub>En<sub>51</sub>Fs<sub>10</sub> to Wo<sub>39</sub>En<sub>48</sub>Fs<sub>12</sub> in the rims. Orthopyroxenes range from Wo<sub>4</sub>En<sub>73</sub>Fs<sub>22</sub> to Wo<sub>4</sub>En<sub>71</sub>Fs<sub>25</sub> in the cores and from Wo<sub>4</sub>En<sub>78</sub>Fs<sub>18</sub> to Wo<sub>4</sub>En<sub>68</sub>Fs<sub>29</sub> in the rims. Plagioclases are zoned with a compositional range of An<sub>74-65</sub> and, like the pyroxenes, many show slightly reversed zonation. Chromites are Cr-rich, as are those in some basalts and magnesian andesites from island arcs and continental margins (e.g., Shiraki *et al.* 1977; Suzuki & Shiraki 1980; Dick & Bullen 1984; Arai 1992).

## DISCUSSION

Major and minor element analyses of the White Island MA, Setouchi MAs and related rocks are given in Table 4. Magnesian andesites from the Setouchi volcanic belt can be divided into two groups on the basis of their dominant phenocryst pyroxene species (Tatsumi 1982). One (cpx-MA) is characterized by clinopyroxene crystallizing prior to orthopyroxene, and the other (opx-MA) is characterized by containing bronzite with Mg# higher than that of augite. The bronzite-augite-olivine andesite from Heigun Island (No. 2 in Table 4) belongs to the cpx-MA, having augite with Mg# up to 88.0 and bronzite with Mg# up to 83.4 (Shiraki & Soejima 1989). The (augite)-olivine-bronzite andesite from Dake-san (No. 3 in Table 4) represents a typical opx-MA that crystallizes orthopyroxene following olivine, although olivine is completely altered, with enstatite reaching Mg# 91.2, similar to mantle orthopyroxene (Shiraki *et al.* 1989a). The Dake-san opx-MA has low CaO and high SiO<sub>2</sub> reflecting its high modal orthopyroxene. Both the cpx-MA and the opx-MA appear to be primary magmas that were independently generated from the peridotitic mantle (Tatsumi 1982). The White Island MA is broadly similar to the Heigun cpx-MA in chemical composition, and may be classified to the cpx-MA.

Histograms of Mg# in the mafic minerals and An in the plagioclases of the White Island MA are shown in Figs. 1 and 2, respectively, and compared with those in the Setouchi MAs. The core compositions of olivine in the White Island MA show high Mg# ranging from 92 to 88, which is unusual in andesitic lavas, while those of the pyroxenes have rather low Mg# ranging from 79 to 73. In particular, the augite cores of the White Island MA are significantly lower in Mg# than those of the Heigun cpx-MA, although the White Island MA has higher CaO than does the Heigun cpx-MA. There is a compositional gap in Mg# between the olivine and the pyroxene cores in the

Table 1 Olivine analyses.

	1-C	1-R	2-C	2-R	3	4-C	4-R	5-C	5-R	6-C	6-R	7-C	7-R
SiO <sub>2</sub>	40.56	39.47	40.67	39.69	40.65	39.96	39.65	39.89	39.87	40.02	40.15	40.05	38.84
Al <sub>2</sub> O <sub>3</sub>	0.03	0.02	0.05	0.03	0.03	0.05	0.03	0.06	0.06	0.02	0.03	0.03	0.05
FeO	7.74	9.35	7.78	10.25	8.15	8.72	10.16	9.23	9.92	10.99	11.29	11.31	15.79
MnO	0.10	0.15	0.21	0.20	0.21	0.13	0.16	0.13	0.12	0.23	0.16	0.22	0.23
MgO	50.56	49.17	50.71	48.50	49.93	49.44	48.64	48.54	48.46	47.97	48.60	47.72	42.89
CaO	0.19	0.19	0.21	0.17	0.18	0.19	0.20	0.19	0.19	0.18	0.21	0.19	0.25
Cr <sub>2</sub> O <sub>3</sub>	0.10	0.05	0.25	0.03	0.06	0.06	0.11	0.08	0.11	0.00	0.05	0.02	0.07
NiO	0.36	0.27	0.29	0.17	0.32	0.33	0.18	0.25	0.17	0.21	0.15	0.21	0.16
Total	99.64	98.67	100.17	99.04	99.53	98.88	99.13	98.37	98.90	99.62	100.64	99.75	98.28
Fo	92.10	90.34	92.08	89.41	91.61	91.02	89.52	90.37	89.71	88.61	88.47	88.24	82.86

Abbreviations C: core. R: rim.

Large euhedral phenocryst (1); 2, Subhedral microphenocryst (0.15); 3, Skeletal microphenocryst (0.07); 4, Subhedral phenocryst (0.3); 5, Euhedral phenocryst (0.3); 6, Skeletal phenocryst (0.3); 7, Skeletal microphenocryst (0.1). Figures in parentheses represent approximate size in mm.

Table 2 Pyroxene analyses

	1-C	1-R	2-C	2-R	3-C	3-R	4-C	4-R	5-C	5-R	6-C	6-R	7-C	7-R	8-C	8-R
SiO <sub>2</sub>	52.47	53.04	52.73	52.64	51.86	52.51	53.34	54.58	53.55	52.88	52.83	53.79	53.44	53.80	53.32	52.90
TiO <sub>2</sub>	0.19	0.21	0.36	0.33	0.38	0.35	0.20	0.17	0.24	0.24	0.14	0.20	0.22	0.18	0.26	0.21
Al <sub>2</sub> O <sub>3</sub>	1.90	2.14	1.88	1.64	1.89	1.95	1.21	1.29	1.17	1.16	0.93	1.02	1.13	1.12	1.17	0.88
FeO	8.14	6.16	8.69	7.77	9.53	7.71	14.24	11.36	14.61	14.37	14.88	14.64	15.76	15.13	16.20	18.48
MnO	0.28	0.18	0.27	0.23	0.30	0.25	0.33	0.21	0.38	0.33	0.35	0.39	0.34	0.41	0.39	0.42
MgO	16.87	17.96	16.74	17.10	16.19	17.02	26.10	28.31	26.49	26.26	25.97	26.74	25.15	26.05	25.65	24.52
CaO	19.14	19.24	19.10	19.28	18.63	19.18	2.11	2.09	2.07	2.20	2.10	2.09	2.07	2.09	2.03	1.88
Na <sub>2</sub> O	0.21	0.17	0.24	0.18	0.23	0.23	0.03	0.02	0.05	0.02	0.01	0.03	0.02	0.00	0.03	0.00
K <sub>2</sub> O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.02	0.01
Cr <sub>2</sub> O <sub>3</sub>	0.31	0.40	0.32	0.36	0.23	0.44	0.01	0.30	0.13	0.12	0.15	0.13	0.00	0.00	0.15	0.10
V <sub>2</sub> O <sub>3</sub>	0.01	0.00	0.04	0.03	0.06	0.04	0.01	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.03	0.06
NiO	0.05	0.10	0.07	0.04	0.02	0.05	0.06	0.12	0.06	0.10	0.05	0.01	0.12	0.09	0.02	0.01
Total	99.57	99.60	100.44	99.60	99.32	99.73	97.65	98.45	98.75	97.68	97.43	99.06	98.26	98.88	99.27	99.47
Wo	39.09	39.23	38.87	39.22	38.34	39.25	4.24	4.16	4.11	4.40	4.23	4.14	4.20	4.17	4.04	3.75
En	47.94	50.96	47.37	48.41	46.35	48.45	73.34	78.22	73.23	73.17	72.49	73.35	70.87	72.28	70.84	67.63
Fs	12.96	9.81	13.76	12.37	15.31	12.31	22.42	17.62	22.67	22.44	23.27	22.51	24.94	23.55	25.11	28.61
Mg#	78.72	83.86	77.49	79.65	75.17	79.74	76.59	81.62	76.36	76.53	75.70	76.51	73.97	75.42	73.83	70.27

1, Large euhedral clinopyroxene (cpx) phenocryst (1); 2, Subhedral cpx phenocryst (0.3); 3, Subhedral cpx phenocryst (0.3); 4, Subhedral orthopyroxene (opx) microphenocryst (0.15); 5, Opx (0.05) enclosed in plagioclase phenocryst (0.5); 6, Subhedral opx phenocryst (0.3); 7, Large subhedral opx phenocryst (1); 8, Opx (0.3) enclosed in plagioclase phenocryst (1).

White Island MA, whereas in the Heigun cpx-MA, Mg# decreases from olivine to augite and bronzite with no compositional gap, and many of these minerals are normally zoned. The pyroxene cores of the White Island MA do not appear to have crystallized from the same magma as that which crystallized the olivines.

Because Mg# of olivine in primitive MORB, that has nearly the same MgO content and FeO/MgO ratio as the White Island MA, does not exceed 91 (e.g., Frey *et al.* 1974; Donaldson & Brown 1977; Bryan 1979; Sullivan 1991; van

Heerden & le Roex 1988), the exceptionally magnesian olivine in the White Island MA may have crystallized from a magma more magnesian than the host rock. A candidate for a high-MgO magma is a basalt of similar composition to the Waimarino basalt occurring on the eastern side of Lake Taupo (No. 4 in Table 4). This can crystallize olivine with Fo92, assuming that the partitioning of Fe and Mg between olivine and liquid is 0.30 (Roeder & Emslie 1970) and the Fe<sub>2</sub>O<sub>3</sub>/FeO ratio in liquid is 0.25 (wt). The high-Cr chromite in the White Island MA also indicates its

Table 3 Chromite and plagioclase analyses

	S1	S2	1-C	1-R	2-C	2-R	3-C	3-R	4-C	4-R	5-C	5-R	6-C	6-R	
SiO <sub>2</sub>			51.41	49.89	51.07	50.50	51.99	50.43	52.60	51.53	51.82	52.18	51.02	51.97	
TiO <sub>2</sub>	0.29	0.39													
Al <sub>2</sub> O <sub>3</sub>	12.24	12.59	29.97	31.08	29.93	30.54	29.57	30.43	29.75	30.16	30.13	29.81	30.07	30.30	
Cr <sub>2</sub> O <sub>3</sub>	51.45	50.72													
V <sub>2</sub> O <sub>3</sub>	0.08	0.07													
Fe <sub>2</sub> O <sub>3</sub>	6.13	6.84													
FeO	17.76	17.01	0.63	0.59	0.60	0.64	0.65	0.72	0.68	0.79	0.68	0.64	0.62	0.70	
MnO	0.19	0.20													
MgO	10.14	10.81	0.15	0.18	0.16	0.18	0.15	0.18	0.19	0.18	0.17	0.16	0.16	0.15	
NiO	0.18	0.16													
CaO	0.05	0.02	13.46	14.63	13.52	14.39	12.98	13.65	13.28	13.71	13.52	13.08	13.41	13.35	
Na <sub>2</sub> O			3.37	2.84	3.35	2.95	3.62	3.23	3.53	3.30	3.28	3.55	3.26	3.39	
K <sub>2</sub> O			0.23	0.18	0.21	0.19	0.26	0.21	0.22	0.22	0.22	0.24	0.21	0.23	
Total	98.51	98.81	99.22	99.39	98.84	99.39	99.22	98.85	100.25	99.89	99.82	99.66	98.75	100.09	
Cr#	0.681	0.667	An	67.87	73.21	68.17	72.11	65.42	69.13	66.63	68.74	68.57	66.09	68.56	67.57
Al#	0.242	0.247	Ab	30.75	25.72	30.57	26.75	33.02	29.60	32.05	29.94	30.10	32.46	30.16	31.05
Fe#	0.077	0.086	Or	1.38	1.07	1.26	1.13	1.56	1.27	1.31	1.31	1.33	1.44	1.28	1.39

$$\text{Cr\#} = \text{Cr} / (\text{Cr} + \text{Al} + \text{Fe}^{3+}), \quad \text{Al\#} = \text{Al} / (\text{Cr} + \text{Al} + \text{Fe}^{3+}), \quad \text{Fe\#} = \text{Fe}^{3+} / (\text{Cr} + \text{Al} + \text{Fe}^{3+}).$$

S1, Euhedral spinel microphenocryst (0.01); S2, Euhedral spinel microphenocryst (0.02); 1, Large phenocryst (2); 2, Subhedral microphenocryst (0.1); 3, Subhedral phenocryst (0.5); 4, Subhedral microphenocryst (0.1); 5, Skeletal microphenocryst (0.2); 6, Subhedral microphenocryst (0.15).

derivation from a Cr-rich magma; the Waimarino basalt contains chromite with 56.44% Cr<sub>2</sub>O<sub>3</sub>.

The relatively Mg-poor pyroxene cores must have formed from liquids with lower MgO contents than the host rock. Graham & Cole (1991) suggested on the basis of the petrographical and geochemical data that the MA blocks from White Island volcano represent hybrid magmas resulting from mixing of a high-Mg basalt parent and Central Cone dacite (No. 5 in Table 4). A mixture of 2 parts of Waimarino-type basalt and 1 part of Central Cone dacite gives a fairly good approximation to the White Island MA (No. 5-A in Table 4). However, the Central Cone dacites, with relatively low FeO/MgO, crystallize pyroxene with Mg# of more than 83, provided that the partitioning of Fe and Mg between pyroxene and liquid is 0.23 (Roeder & Emslie 1970). Consequently, the acid end-member must have higher FeO/MgO than the Central Cone dacites. Dacite from Edgecumbe volcano in the Bay of Plenty area (No. 6 in Table 4) can crystallize pyroxene with Mg# 79 assuming an Fe<sub>2</sub>O<sub>3</sub>/FeO ratio of 0.2 (wt). The White Island MA composition is also approximated by mixing Waimarino-type basalt with Edgecumbe-type dacite in proportions of 3 : 1 (No. 6-A in Table 4). The more magnesian pyroxene and calcic plagioclase rims may have crystallized after the basalt and dacite magmas mixed.

In contrast to the White Island MA, most

Setouchi MAs show no compositional gap in Mg# between olivine and pyroxenes; Mg# decreases continuously from olivine to clinopyroxene and orthopyroxene in the cpx-MA and from olivine to orthopyroxene and clinopyroxene in the opx-MA, although orthopyroxene often shows reverse zoning (Tatsumi & Ishizaka 1981; Sato 1989; Shiraki & Soejima 1989; Shiraki *et al.* 1989a). Compositional variations of the Setouchi MAs are best explained by variations among primary andesite magmas and crystal fractionation from them. In the Setouchi MAs magma mixing appears to play a minor role.

#### OTHER MAGMAS FORMED BY REACTION BETWEEN HIGH-MgO AND -SiO<sub>2</sub> MATERIALS

Phanerozoic high-MgO and -SiO<sub>2</sub> lavas formed by reaction between high-MgO magmas and siliceous materials are known from several localities. In the Taupo Volcanic Zone, Graham & Hackett (1987) concluded that their type 6 lavas (No. 7 in Table 4) were generated by mixing basalt with dacite, because they show strong evidence of disequilibrium. Koyaguchi (1986) demonstrated that rocks with SiO<sub>2</sub>-enrichment trend from the Abu volcano group are products of mixing of a primitive alkali basalt magma containing olivine phenocrysts with a dacite magma containing quartz, sodic plagioclase and hornblende phenocrysts, some of which have MA compositions

Table 4 Major and minor element analyses of White Island magnesian andesite and related rocks

	1	2	3	4	5	5-A	6	6-A	7	8	9	10
SiO <sub>2</sub> %	55.94	55.50	58.40	52.87	63.51	56.42	64.77	55.85	57.35	56.63	61.10	57.56
TiO <sub>2</sub>	0.63	0.69	0.61	0.48	0.75	0.57	0.66	0.53	0.69	1.02	0.96	0.97
Al <sub>2</sub> O <sub>3</sub>	13.26	14.35	12.01	12.85	14.44	13.38	16.19	13.69	14.38	17.63	17.30	13.50
FeO	7.33	7.68	7.45	8.45	5.91	7.60	5.34	7.67	7.09	6.30	5.07	7.90
MnO	0.14	0.13	0.13	0.16	0.09	0.14	0.09	0.14	0.15	0.14	0.12	0.13
MgO	10.14	9.80	12.89	13.32	3.85	10.16	2.16	10.53	8.69	5.95	5.10	9.49
CaO	8.96	7.86	5.20	9.73	5.91	8.46	5.47	8.67	7.30	7.31	5.30	6.51
Na <sub>2</sub> O	2.39	2.32	1.63	1.66	3.25	2.19	3.23	2.05	2.77	2.80	4.28	2.01
K <sub>2</sub> O	1.15	1.54	1.56	0.44	2.17	1.02	1.99	0.83	1.46	1.94	0.77	1.73
P <sub>2</sub> O <sub>5</sub>	0.07	0.13	0.11	0.05	0.12	0.07	0.12	0.07	0.11	0.30		0.19
FeO/MgO	0.723	0.784	0.578	0.634	1.535	0.748	2.472	0.728	0.816	1.059	0.994	0.832
Rb ppm	34	55.2	69.0	15	73	34	63.2	27	49	51	51	54
Sr	169	297	208	342	182	289	246	318	277	790		189
Ba	481	317	532	122	762	335	523	222	355	650	294	383
Zr	88	87.8	109	48	155	84	106	63	115	185		129
Y	21	19.1	17.4	13	26	17			18			21
Nb	2	4.0	8.4	2					5			9
Cr	497	511	1020	1037	127	734	28.2	785	507	223	92	850
Ni	158	177	441	341	54	245	7.6	258	237	73		203
V	209	146	104	226	184	212	142	205	181	131		188

1, Andesite block (P41600), White Island, Taupo Volcanic Zone (Clark & Cole 1986; minor elements except for Rb and Sr from Graham & Cole 1991); 2, Bronzite-augite-olivine andesite, Heigun Island, Setouchi volcanic belt (Shiraki & Soejima 1989; Shiraki *et al.* 1991); 3, Augite-olivine-bronzite andesite, Dake-san, Setouchi volcanic belt (Shiraki *et al.* 1991); 4, Waimarino basalt, eastern side of Lake Taupo, Taupo Volcanic Zone (Graham & Hackett 1987); 5, Central Cone dacite (11242), White Island (Cole & Graham 1989); 5-A, 2 : 1 mixture of Waimarino basalt and Central Cone dacite; 6, Edgumbe dacite, Bay of Plenty, Taupo Volcanic Zone (Reid & Cole 1983); 6-A, 3 : 1 mixture of Waimarino basalt and Edgumbe dacite; 7, Type 6 lava (14848), Pukeonake, Taupo Volcanic Zone (Graham & Hackett 1987); 8, Olivine-augite-hornblende andesite (ABU-34), Abu volcano group, Yamaguchi-ken (Koyaguchi 1986); 9, Bronzite andesite (#39), Oshima, off Noto Peninsula (Sato *et al.* 1989; minor elements from #21); 10, Magnesian andesite (113363), Disko Island, West Greenland (Pedersen 1985).

(No. 8 in Table 4). Similar magma mixing was proposed for bronzite andesites with bronzite up to Mg# 84.7 from Hekurajima and Nanatsujima Islands in the Japan Sea (No. 9 in Table 4). The latter two are less magnesian, with MgO generally less than 6%, although relatively low in FeO/MgO. Recently, Wada & Goto (1993) reported a high-Mg andesite with 56.5% SiO<sub>2</sub> and 7.2% MgO from Mikasayama, northern Hokkaido, and concluded that it was produced by mixing of primitive basalt and dacite magmas.

Magnesian andesites derived by reaction between high-MgO magmas and siliceous materials have chemical compositions very similar to those of primary andesites formed through wet partial melting of peridotite, and hence it is generally difficult to distinguish them from primary MA on the chemical grounds alone. They can only be distinguished by having disequilibrium mineral assemblages and orthopyroxenes with relatively low Mg#, usually <85.

Magnesian andesites from Disko Island, West Greenland (No. 10 in Table 4) were considered by

Pedersen (1985) to be derived from picritic parents (MgO>18%) through reaction with siliceous crustal rocks. These rocks contain orthopyroxenes up to Mg# 86.2 and are very similar in chemical and mineral composition to the Setouchi opx-MA. If crustal rock is completely resorbed by the high-temperature picritic magma, the resultant mixed magma is very difficult to distinguish from a primary MA on the basis of petrography and mineralogy, although it would be expected to have orthopyroxene with slightly lower Mg# than that observed in the primary opx-MA. In this situation the main distinction may have to be based on detailed field studies.

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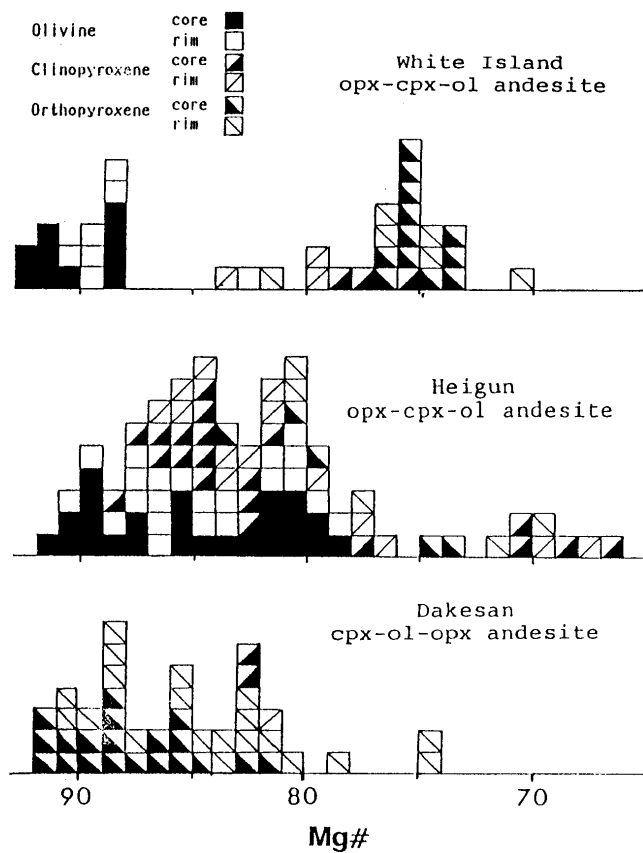


Fig. 1 Histograms of Mg# for olivine, clinopyroxene and orthopyroxene in orthopyroxene(opx)-clinopyroxene(cpx)-olivine (ol) andesite from White Island, opx-cpx-ol andesite from Heigun Island and cpx-ol-opx andesite from Dake-san. Each box represents one analysis.

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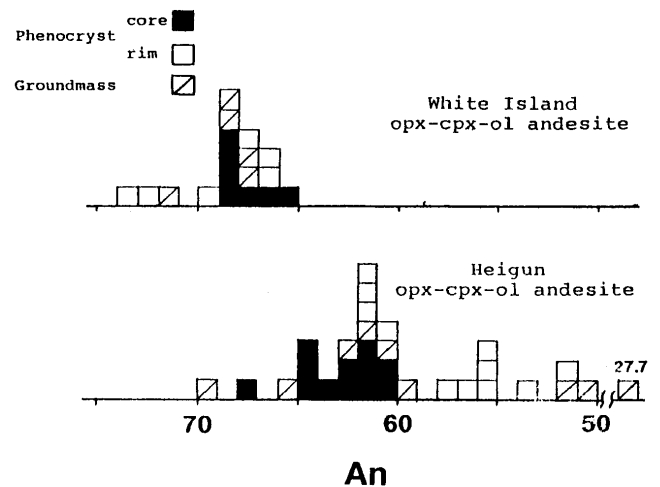


Fig. 2 Histograms of An for plagioclase in opx-cpx-ol andesite from White Island and opx-cpx-ol andesite from Heigun Island.

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## ニュージーランド、ホワイト島の高マグネシア安山岩： 高マグネシア玄武岩質とデイサイト質マグマ混合の 鉱物学的証拠

白木敬一，斎藤聡一，黒田 直，浦野隼臣，杉浦 孜，J. W. Cole

**要 旨** ホワイト島火山から1977年の噴火で放出された火山岩塊は、化学組成では、瀬戸内火山岩のカンラン石，単斜輝石，斜方輝石の順に，Mg#が連続的に減少する単斜輝石高マグネシア安山岩に似る。しかし鉱物化学組成はまったく異なり，ホワイト島高マグネシア安山岩は，著しくMgに富み ( $FO_{92.88}$ )，正規累帯をなすカンラン石と，対照的にMgに比較的乏しく (Mg# = 84-73)，逆累帯を示す単斜および斜方輝石をもつ。特に，単斜輝石の核部はMg#が79-75とカンラン石に比べ低く，カンラン石を晶出させたと同一のマグマに由来するとは考え難い。ホワイト島高マグネシア安山岩は高マグネシア玄武岩質マグマとデイサイト質マグマの混合によって生じた。

Abu 阿武  
Dake-san 嵩山  
Heigun 平郡  
Hekurajima 舳倉島  
Mikasayama 三笠山  
Nanatsujima 七ツ島  
Noto 能登  
Oshima 大島