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# Hornblende Megacrysts in Andesite from Hakusan Volcano

By

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## Introduction

Calc-alkaline andesites from Hakusan volcano (Lat. 36°09′ N., Long. 136°47′ E.) were briefly described by TANAKA (1924) and YAMASAKI *et al.* (1968). The volcano was formed on a crest of the basement composed of Hida metamorphic complex, the Lower Cretaceous part of Tetori Group (conglomeratic arkose sandstone and micaceous shale) and Nohi rhyolite (YAMASAKI *et al.*, 1968). Eruption of the volcano have taken place up to 1579 and built two stratified cones consisting of lava flows and pyroclastic materials of hypersthene-hornblende andesites.

Despite common occurrence of hornblende in calc-alkaline andesites and important role of hornblende in generation and fractionation of calc-alkaline andesite suite (EGGLER, 1972; EGGLER and BURNHAM, 1973; CAWTHORN and O'HARA, 1976), mineralogical data of hornblende in andesites are rather limited yet. It is so in the case of hornblende andesites from Hakusan volcano. In this report, hornblende and its host andesite are described.

## Host Rock

The rock specimen studied (NSM 5705) was taken at the Gozen peak which was constructed by the second period of the volcanic history of Hakusan volcano (Late Pleistocene; YAMASAKI *et al.*, 1968). The rock is highly porphyritic with abundant white plagioclase and sporadic dull brownish black hornblende in the ash gray groundmass. Under the microscope, plagioclase, hypersthene, hornblende and minor amount of olivine, augite and magnetite are observed as phenocrysts. Plagioclase occurs as euhedral or subhedral tabular crystals up to 5–7 mm in size. It carries inclusions of magnetite, orthopyroxene and clinopyroxene grains. Oscillatory zonings and polysynthetic twinning are common. Some crystals of plagioclase are composed of clear core, dust inclusion-rich zone and corroded rim often mantled with clinopyroxene grains. Hypersthene forms euhedral—subhedral prisms surrounded by intergrown augite or aggregates of augite grains. Hornblende phenocrysts are prismatic in form and up to 2 cm in length. They exhibit usually opacite rim and sometimes a thick reaction rim composed of clinopyroxene, orthopyroxene, plagioclase and magnetite. Similar assemblage rimming hornblendes is noted also on other calc-alkaline andesites

(NICHOLLS, 1971; JAKEŠ and WHITE, 1972; STEWART, 1975). Inclusions in the mineral are magnetite, clinopyroxene and plagioclase. Sparse olivines have irregular outlines, often rimmed by orthopyroxene. Augite crystals show subhedral—euhedral outline, carrying inclusions of magnetite and apatite. Magnetite phenocrysts ($a_0=8.413\pm 0.001$ Å) are present as irregular or slightly rounded form about 0.2 mm across. A small amount of biotite flakes found in the crushed rock sample suggests that biotite occurs as phenocrysts in this rock, though it was not confirmed in the thin sections. Glassy groundmass consists of colorless glass, plagioclase, clinopyroxene, orthopyroxene, olivine, magnetite, biotite and cristobalite.

The andesite specimen includes an andesitic block of a few centimeters in size. The andesite inclusion has sporadic white plagioclase phenocrysts (3 mm long) in light gray matrix. Microscopically, plagioclase, clinopyroxene, hornblende, orthopyroxene, olivine and magnetite and irregular pools of colorless glass are observed. Magnetite and olivine occur as crystals larger than those of clinopyroxene, hornblende and orthopyroxene. Plagioclase phenocrysts show euhedral—subhedral tabular forms. Oscillatory zonings and polysynthetic twinning are seen. Numerous dust inclusions stain the core of some crystals. Angular interstices between plagioclase laths (0.5–0.1 mm long) are filled by colorless glass. Clinopyroxene occurs as euhedral —anhedral grains (0.3 mm or less across) often with ragged outline and deformation lamella-like structure. Some crystals of clinopyroxene are accompanied by intergrown hornblende or embedded in thick hornblende mantle. Hornblende forms long thin or short prisms (up to 0.4 mm long). It displays pleochroism from pale straw yellow to light brown. Orthopyroxene makes short or thin prisms 0.3 mm long or less, with or without intergrown clinopyroxene. Olivine is rather rare. It is present as subhedral grains surrounded by small orthopyroxene grains with random orientations. Magnetite grains (usually under 0.1 mm across) are quadrilateral in form. Sometimes larger grains (0.5 mm across) with irregular rounded or ragged outline are found.

Chemical analyses of the andesite and andesite inclusion are given in Table 1 together with their CIPW norms. The host andesite is chemically very close to an essential block in the nuée ardente deposit (YAMASAKI *et al.*, 1964) erupted during the third period of the volcanic history of Hakusan. The andesite inclusion shows lower $SiO_2$ and $K_2O$ contents and higher $Fe_2O_3$, MgO and CaO contents than the host andesite. As for the CIPW norms concerned, the former is poorer in *Q*, *or* and richer in *an*, *di* and *hy* than the latter.

## Hornblende Megacrysts and Associated Phenocrysts

Table 2 consists of chemical analyses and atomic ratios of hornblende, hypersthene and plagioclase phenocrysts. The minerals were purified by hand-picking after separation by means of isodynamic magnetic separator and heavy liquids. Opacite rim sticked on hornblende grains and hypersthene grains with apatite inclusions could

Table 1. Chemical analyses of andesite and andesite inclusion

| | 1 | 2 | | CIPW norms 1 | 2 |
|---|---|---|---|---|---|
| $SiO_2$ | 61.68 | 56.96 | Q | 16.46 | 9.14 |
| $TiO_2$ | 0.75 | 1.00 | or | 13.13 | 9.74 |
| $Al_2O_3$ | 16.54 | 17.03 | ab | 29.94 | 28.15 |
| $Fe_2O_3$ | 3.08 | 3.28 | an | 22.70 | 26.67 |
| FeO | 2.71 | 3.64 | di wo | 2.15 | 4.85 |
| MnO | 0.08 | 0.10 | di en | 1.65 | 3.60 |
| MgO | 3.10 | 4.69 | di fs | 0.25 | 0.78 |
| CaO | 5.91 | 8.05 | hy en | 6.07 | 8.07 |
| $Na_2O$ | 3.54 | 3.33 | hy fs | 1.08 | 1.74 |
| $K_2O$ | 2.22 | 1.65 | mt | 4.47 | 4.75 |
| $H_2O^+$ | 0.17 | 0.40 | il | 1.43 | 1.90 |
| $H_2O^-$ | 0.08 | 0.08 | ap | 0.54 | 0.61 |
| $P_2O_5$ | 0.22 | 0.25 | | 99.87 | 100.00 |
| total | 100.08 | 100.46 | | | |

1. andesite (NSM 5705), Gozen peak*, Hakusan (collected by H. KUNO).
2. andesite inclusion in 1.

* synonymous with Misaki-miné in TANAKA (1924).

Table 2. Chemical analyses of hornblende megacrysts and associated phenocrysts

| | 1 | 2 | 3 | | atomic ratios 1 O, OH=24 | 2 O=6 | | 3 O=32 |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 45.14 | 51.59 | 56.38 | Si | 6.648 | 1.904 | Si | 10.165 |
| $TiO_2$ | 2.11 | 0.54 | — | $Al^{IV}$ | 1.352 | 0.096 | Al | 5.783 |
| $Al_2O_3$ | 8.01 | 2.86 | 27.22 | $Al^{VI}$ | 0.038 | 0.028 | $Fe^{3+}$ | 0.097 |
| $Fe_2O_3$ | 7.00 | 2.74 | 0.71 | Ti | 0.234 | 0.015 | Ca | 1.670 |
| FeO | 8.26 | 17.83 | — | $Fe^{3+}$ | 0.775 | 0.076 | Na | 2.170 |
| MnO | 0.22 | 0.66 | — | Mg | 3.053 | 1.186 | K | 0.911 |
| MgO | 13.92 | 21.57 | — | $Fe^{2+}$ | 1.017 | 0.556 | | wt% |
| CaO | 10.90 | 2.29 | 8.65 | Mn | 0.027 | 0.021 | or | 4.9 |
| $Na_2O$ | 1.23 | 0.25 | 6.21 | Ca | 1.719 | 0.090 | ab | 52.3 |
| $K_2O$ | 0.83 | 0.14 | 0.83 | Na | 0.350 | 0.018 | an | 42.8 |
| $H_2O^+$ | 1.87 | tr | 0.09 | K | 0.156 | 0.007 | | |
| $H_2O^-$ | 0.07 | tr | 0.09 | OH | 1.836 | | | |
| total | 99.56 | 100.47 | 100.18 | $\alpha$ | 1.662–1.674 | 1.699–1.686 | | 1.543–1.567 |
| | | | | $\gamma$ | 1.676–1.690 | 1.693–1.710 | | |
| | | | | $2V_\alpha$ | | 63°–65° | | |
| | | | | X | straw yellow | pale reddish brown | | |
| | | | | Z=Y | greenish brown | pale green | | |

1. hornblende megacrysts in andesite (NSM 5705).
2. hypersthene phenocrysts in andesite (NSM 5705).
3. plagioclase phenocrysts in andesite (NSM 5705).

not completely be removed.

The hornblende megacryst is mildly rich in $TiO_2$ and $Fe_2O_3$. It is less aluminous than hornblende phenocrysts in calc-alkaline andesites of Shikoku (UJIKE, 1972) and Mt. Mazama (STEWART, 1975), displaying a similarity to hornblende phenocrysts in a dacite of Santorini (NICHOLLS, 1971) and quartz latite of San Juan, Colorado (LARSEN *et al.*, 1937) or hornblendes in intermediate plutonic rocks as for $Al_2O_3$ content. According to the classification devised by LEAK (1968), the hornblende belongs to the magnesio-hornblende category. JAKEŠ and WHITE (1972) had treated the hornblende from Hakusan as a continental calc-alkaline occurrence. But the $(Na+K)-Al^{IV}$, $Al^{IV}$ (hornblende)$-SiO_2$ (rock) and $(FeO+0.9Fe_2O_3)/MgO$ (rock)$-(Fe^{2+}+Fe^{3+})/Mg$ (hornblende) relations indicate that the analyzed mineral is of the island arc type defined by JAKEŠ and WHITE (1972).

Hypersthene phenocrysts have slightly high contents of $Al_2O_3$, $Fe_2O_3$ and CaO partly due to various inclusions in the mineral.

Finely zoned plagioclase phenocrysts as a bulk have an andesine composition as had been described by TANAKA (1924).

The present hornblende shows an intermediate oxidation state between plutonic and basaltic hornblendes. Reaction rim around the hornblende megacrysts suggests that hornblende is not a stable phase in the melt with host andesite composition during nearsurface or surface crystallization, though hornblende crystallized after clinopyroxene and did not have reaction rim in the andesite inclusion. Andesine, magnesio-hornblende and biotite phenocrysts in the host andesite would have formed by crystallization at significantly low temperature and wet conditions.

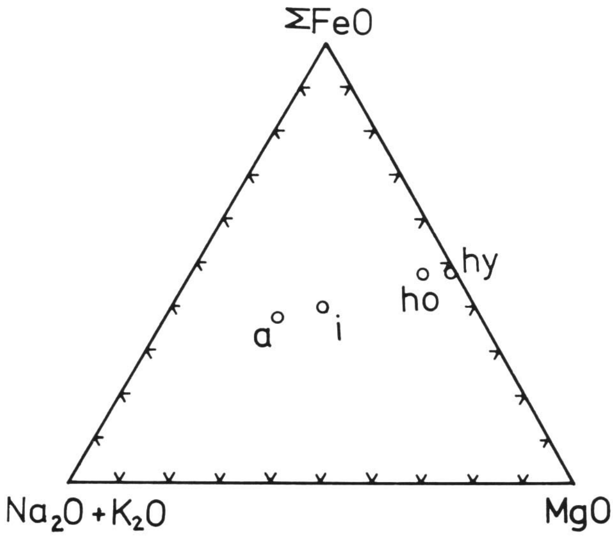


Fig. 1. $MgO-\Sigma FeO-(Na_2O+K_2O)$ diagram for the host andesite (a), andesite inclusion (i), hornblende megacrysts (ho) and hypersthene phenocrysts (hy).

Chemical analyses of the host andesite, andesite inclusion, hornblende megacrysts and hypersthene are plotted on the MgO–ΣFeO–($Na_2O+K_2O$) diagram (Fig. 1). As seen in the figure, separation of hypersthene and hornblende with $100\times MgO/(MgO+\Sigma FeO)$ ratios of about 50 from andesite melt prevents iron enrichment of the residual melt, resulting in a low ΣFeO fractionation trend.

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