Geology and petrology of Futamata volcano, Nasu volcano group, NE Japan

*Shota Watanabe[1], Takeshi Hasegawa[1]

1. Ibaraki Univ.

Futamata volcano (FV) composes Nasu stratovolcano group (NSG), NE Japan. The activities of NSG started from Kasshiasahi-dake (540-420ka), and the locus of eruptions shifted to south forming Sanbon-yari-dake (360-270ka), Asahi-dake (170-70ka), Minamigassan (210-80ka) and Chausu-dake (16ka-present). However, FV (140-90ka) was the only unique volcano formed in the northern part of NSG (Ban & Takaoka, 1995; Fujita, 1988; Yamamoto, 1999). In order to reveal the eruption history and magmatic processes, we performed geological and petrological study for Futamata volcano.
Yamamoto (1999) defined an outline of stratigraphy of FV as consisting of Iwayama lava flow, Futamata pyroclastic flow deposit and Futamatayama lava dome in ascending order. In this study, we revised the Iwayama lava flow into 12 units by geomorphology, distribution and mineral assemblages: FLN (north: 3 units), FLW (west: 3 units) and FLS (south: 6 units); Futamata pyroclastic flow deposit can be divided into 2 units: FBW (west) and FBE (east), and Futamatayama lava dome into 2 units: FOD and FMD. We summarized these units into two stages by combining geological and petrological data, such as first lava flow stage (S1) and second lava dome stage (S2). The S1 is composed of FLN, FLW, FLS and FBW. S2 consists of FOD, FMD and FBE.
Mafic inclusions are common in all ejecta of FV, and they often show quenched margins at the boundary with host rocks. The host rocks of S1 are mainly quartz-bearing olivine clinopyroxene orthopyroxene andesite to dacite. On the other hand, host rocks in S2 are clinopyroxene orthopyroxene andesite to dacite, and they sometimes contain hornblende. SiO_2contents of host rocks of S1 and S2 are in the range of 53.5 to 68.4 wt.%. Mafic inclusions of both stages are predominantly olivine clinopyroxene orthopyroxene basalt to basaltic andesite. Their SiO_2contents range from 50.6 to 59.3 wt.%.
Chemical difference between two stages is clearer at mafic inclusions on Miyashiro (FeO*/MgO vs. SiO_2) diagram. Each stage forms a distinctive linear trend subparallel to one another (S1: FeO*/MgO = 1.9; S2: FeO*/MgO = 2.2, at SiO_2= 64.1 wt.%), and mafic samples of S1 and S2 can be categorized as calc-alkaline and tholeiitic series in the diagram respectively. On a plot of K_2O vs. SiO_2, chemical trends between two stages diverge on felsic compositions. K_2O composition of S1 is larger than that of S2 at a given SiO_2 content (S1: K_2O = 1.6 wt.%; S2: K_2O = 1.3 wt.%, at SiO_2= 63.8 wt.%). Cr contents of S1 mafic samples are remarkably higher (Cr = 120 - 180 ppm) than those of S2, characterized by depleted Cr concentration (Cr = 32 - 66 ppm) below 55 wt.% SiO_2contents.
Different trends between the two stages in the FeO*/MgO vs. SiO_2diagram suggests that each eruptive stage was derived from a distinct magma system rather than a single long-lived magma system. Heterogeneous features of host rocks with mafic inclusions in all units indicate that felsic and mafic magmas coexisted and mingled. Mixing processes of different magmas are also supported by disequilibrium phenocryst assemblage, such as olivine and quartz at the same unit. At least four end members can be assumed at FV: S1 mafic/felsic, and S2 mafic/felsic. S1 and S2 felsic end members can be characterized as bearing quartz and hornblende, respectively, on the basis of phenocryst assemblages of host rocks. No changes in the ratios of incompatible elements between S1 and S2 mafic samples, and depletion of Cr contents of S2 mafic samples suggest that more evolved, that is fractionated, mafic magma could be injected and mixed with felsic magma at the later stage (S2).

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