Origin of magma from Futamatayama volcano, Nasu volcano group, NE Japan: Evolution processes of crust–mantle interaction

*Shota Watanabe[1], Takeshi Hasegawa[1], Akiko Matsumoto[2], Festus Tongwa Aka[1], Mitsuhiro Nakagawa[2]

1. Graduate School of Science and Engineering, Ibaraki University, 2. Faculty of Science, Hokkaido University

Melting, assimilation, storage, and homogenization (MASH) processes occur at the mantle–crust transition where hot basaltic magmas ascend from the mantle wedge reach neutrally buoyant point[1]. The MASH zone segregates based on density differences with fractional crystallization and/or crustal melting creating cumulate at the lower crust and felsic melts transported to shallower crust[1]. This crust–mantle interaction contributes to crustal evolution on Earth. In this study we discuss temporal development of the crust–mantle interaction using whole-rock major/trace element and Sr-Nd-Pb isotope data of Futamatayama volcano, Nasu volcano group, NE Japan.

The basement rocks of Futamatayama volcano include 1.4–1.0 Ma Shirakawa ignimbrites. Eruptive activity of Futamatayama volcano consists of two stages: Stage 1 (ca. 160–90 ka, 3.56 km^3DRE) repeatedly ejected lava flows with a small volume pyroclastic flow; Stage 2 (between ca. 90 to 50 ka, 0.09 km^3DRE) formed lava domes accompanied with pyroclastic flow[2]. Eruption products commonly contain mafic enclaves hosted by more felsic rocks. Based on petrography and whole-rock compositions, the eruption products can be divided into four main rock types: F-1 (felsic magma in Stage 1), F-2, M-1, and M-2. Felsic types (F-1 and F-2) are andesite to dacite containing phenocrysts of plagioclase + clinopyroxene + orthopyroxene + opaque mineral ±quartz ±olivine. Mafic types (M-1 and M-2) are basalt to basaltic andesite including phenocrysts of plagioclase + clinopyroxene + orthopyroxene + opaque mineral ± olivine. Eruptive products of Stages 1 and Stage 2 form distinct linear trends indicative of magma mixing between M-1 and F-1 in Stage 1, M-2 and F-2 in Stage 2, respectively.

Mafic magmas (M-1 and M-2) show high Ba/Th, low Zr/Sm and Hf/Sm, depleted Sr-Nd isotope, that are characteristics of mantle-derived arc basalts. Identical incompatible element ratio (e.g., Ba/Nb, K_2O/Rb) of the most mafic samples from M-1 and M-2 indicate that the both mafic magmas are produced from a common mantle source. Higher Cr and Ni contents of M-1 (Cr = 200 ppm, Ni = 90 ppm at ~50 wt.% SiO_2) than those of M-2 (Cr = 30 ppm, Ni = 40 ppm at ~50 wt.% SiO_2) suggest that M-2 can be generated by olivine and pyroxene fractionation from the common primitive magma with M-1.

Felsic magmas (F-1 and F-2) show high Zr/Sm, low K_2O/Rb, Eu/Eu* features that can be explained by partial melting of lower crust with the presence of amphibole and plagioclase as melting residues. The Sr-Nd isotopic ratios of F-1 ($^{87}Sr/^{86}Sr$ = 0.7047–0.7049, $^{143}Nd/^{144}Nd$ = 0.51270–0.51274) are similar to those of Kumado ignimbrite, which is a member of Shirakawa ignimbrites. Isotope composition of F-2 ($^{87}Sr/^{86}Sr$ = 0.7045–0.7047, $^{143}Nd/^{144}Nd$ = 0.51274–0.51278) is consistent with that of M-1. These results suggest that, in Stage 1, mantle-derived M-1 magma intruded into (or underplated at) lower crust and partially melted pre-existing crustal material, which might be a common source of Kumado ignimbrite, produced F-1 magma. Also, M-1 magma formed cumulate (amphibolite or amphibole-bearing gabbro) in Stage 1. In Stage 2, F-2 magma might be produced by remelting of the cumulative lower crust by the intrusion of more differentiated mafic magma (M-2). Felsic and mafic endmember magmas mixed and erupted in each stage.

References: [1] Hildreth and Moorbath, 1988, Contrib. Mineral. Petrol. [2] Watanabe et al., in press, J. Geol. Soc. Japan. [3] Gill, 1981, Orogenic Andesites and Plate Tectonics. [4] Miyashiro, 1974, Amer. Jour. Sci. [5] Kimura and Yoshida, 2006, JPET. [6] Kimura et al., 2002, JPET. [7] Yamamoto, 2011, JVGR.

Keywords: basalt, dacite, mantle, crust, partial melting, Futamatayama volcano

