Genisis of silicic magma in Torishima volcano, Izu-Bonin arc

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Torishima, located 600km south of Tokyo, is an active Quaternary volcano of the Izu-Bonin arc. In recent years, the volcano has erupted in 1902, 1939 and 2002. The total volume of this volcano is 466 cubic km, making it the second largest volcano within the arc. Due to the inaccessibility of this isolated island, the geology and petrography of Torishima has not been well studied yet. We have performed precise geological survey and sampling of the island in September 2003. The results revealed that this volcano had bimodal eruptions in its volcanic history. The silicic volcanism of Torishima has strong and direct evidences of basaltic magma incorporation.

Volcanic history of this island can be mainly separated into two stages; stratovolcano stage and post-caldera stage. The stratovolcano stage basaltic lava and dike constructed main body of the island. Then prior or simultaneous to the caldera formation, voluminous andesite to dacite pyroclastic eruptions occurred. From stratigraphic evidence, this silicic magmatism started from an andesitic eruption and then shifted to dacitic eruptions. The post-caldera eruptions are characterized by the large effusive lava flows of basalt to basaltic andesite magmas.

The stratovolcano stage basalts have phenocryst assemblage of plagioclase, olivine and clinopyroxene. Plagioclase is the most dominant phase, and the modal proportion of the plagioclase phenocrysts sometimes exceeds 40 vol.%. From the least square mass balance calculation, the compositional variation in major elements and some trace element can be explained by the crystal fractionation of clinopyroxene, olivine and small amount of plagioclase.

The olivine phenocrysts in stratovolcano stage basalts have foresterite content ranges from Fo68 to Fo87. The stratovolcano stage andesite and dacite also contain olivine phenocrysts that have higher range of Fo content variation (Fo78 to Fo89) compared to those of the basalts.

Stratovolcano stage andesite and dacite occur as pumice and volcanic glass. The phenocryst assemblage is plagioclase, olivine, clinopyroxene, orthopyroxene and titanomagnetite. The plagioclase and clinopyroxene phenocrysts have bimodal compositions. The orthopyroxene and low-Mg clinopyroxene are reverse zoned in Mg content. The orthopyroxene, low-An plagioclase and titanomagnetite phenocrysts contain rhyolitic glass inclusions.

From petrological evidences, these andesite and dacite contain phenocrysts that had derived from two different endmember magmas; type 1) unevolved basaltic magma of high-Fo olivine + high-Mg clinopyroxene + high-An plagioclase phenocrysts, type 2) rhyolitic magma of low-Mg clinopyroxene + low-An plagioclase + orthopyroxene + titanomagnetite phenocrysts. Tamura and Tatsumi [2002] proposed that a solidified hydrous andesitic middle crust is heated by the hot basaltic magma to produce a partial melt of silicic magma. If so, the rhyolitic end-member magma of Torishima andesite and dacite may have derived from the partial melts of an andesitic middle crust. To test this hypothesis, dehydration melting experiment of Tanzawa tonalite was done at 3kbar, 900-1000C. The melt produced in these experiments have equivalent compositions as the rhyolitic glass inclusions in the Torishima andesite and dacite. Moreover, residual phase assemblage obtained from the experiment are low-An plagioclase, low-Mg clinopyroxene, orthopyroxene and Fe-Ti oxide, which are same as those of silicic endmember magma of the andesite and dacite.

Therefore, the silicic magmatism of the staratovolcano stage is most likely to have generated from the partial melting of an andesitic middle crust, accompanied by a magma mixing process. The basaltic magma played an important role not only as a heat source but also to produce various silicic magmas by mixing with the silicic end-member magma.