Recent magma plumbing system at Izu-Oshima volcano

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Izu-Oshima volcano, located on the volcanic front of the Izu arc, is one of the most active volcanoes in Japan, and primarily produces mafic products. Relatively large-scale eruptions have occurred every 30–40 years in the last 200 years (1876–77, 1912–14, 1950–51, and 1986–87), and eruptions are expected to occur in the near future; therefore, many petrological and geochemical studies have been conducted to understand the current magma plumbing system beneath the volcano (e.g., Fujii et al., 1988; Kawanabe, 1991; Nakano and Yamamoto, 1991; Hamada et al., 2011, 2014; Ishizuka et al., 2015). Our knowledge of magmatic processes has greatly advanced as a result of these studies, and there is now a consensus that multiple magma chambers at different depths have been involved in the magma plumbing system (e.g., Meteorological Agency, 2008). In this study, to understand this complex magma system in more detail, we apply principal component analysis, in combination with petrological and geochemical analyses, to basaltic products (<~53 wt.%) of relatively young volcanic period (<~1.5 ka; Younger Oshima Group).

The products have variable phenocryst contents, ranging from ~0 to ~20 vol.%, and phenocryst-bearing samples commonly contain plagioclase, orthopyroxene, and clinopyroxene phenocrysts. Crystal aggregates consisting of these phenocryst phases are observed. The whole-rock Al_2O_3 contents tend to decrease with increasing SiO_2 contents, but the compositions are significantly scattered in Harker variation diagrams. This observation suggests that the compositional diversity of the products was established by at least two independent magmatic processes. To elucidate the processes responsible for this compositional diversity, principal component analysis was applied to the major element data from the basaltic samples. The results suggest that the compositional diversity of the aphyric magmas (<~3 vol.% phenocrysts) of the Younger Oshima Group was produced by fractional crystallization of plagioclase and mafic minerals, and the magmas evolved as the eruption ages progressed. The results further suggest that either crystal accumulation or magma mixing was additionally involved in forming the compositional diversity of the basaltic products of the Younger Oshima Group.

The crystallization pressures and temperatures of the pyroxene phenocrysts were estimated as ~5 kbar and ~1060ºC, respectively, by applying the two-pyroxene geothermobarometer of Putirka (2008) to clinopyroxene–orthopyroxene pairs in the products. Therefore, the compositional diversity was produced by either (1) redistribution of phenocrysts in a compositionally heterogeneous magma chamber located at ~5 kbar (~16 km depth) or (2) mixing of porphyritic magmas derived from a ~5 kbar magma chamber and heterogeneous aphyric magmas stored in another magma chamber. If scenario (1) was the correct interpretation, the plagioclase (and pyroxene) phenocrysts would have coexisted with the phenocryst-free magmas at ~5 kbar and 1060ºC before separation and accumulation. However, the plagioclase-melt hygrometer of Waters and Lange (2015) suggests that the plagioclase phenocrysts could not have been in equilibrium with the aphyric magmas. Therefore, we conclude that the compositional diversity was produced by mixing of porphyritic and aphyric magmas (i.e., scenario 2).
Based on this consideration, and combined with previous geophysical studies, we propose that aphyric magmas, stored in the 8–10 km depth magma chamber, progressively differentiated over time from the 7th to 20th centuries. Furthermore, the compositional variations in basalts resulted from mixing of the differentiating aphyric magmas with variable proportions of porphyritic magmas derived from a ~16 km

depth magma chamber. Because recent eruptions have been triggered by the ascent of porphyritic magma from the ~16 km depth magma chamber and its injection into the 8–10 km depth magma chamber, it is important to monitor the magma chamber at ~16 km depth to predict future volcanic activity.

Keywords: magma plumbing system, magma chamber process, principal component analysis

