A series of cummingtonite-bearing rhyolites in Niijima, Izu-Bonin arc, Japan: petrological and geochemical constraints

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Niijima volcano in the northern part of the Quaternary Izu–Bonin volcanic arc, Japan, consists predominantly of rhyolitic volcanic units and minor basaltic and andesitic units. Most of the rhyolites are characterized by a phenocryst assemblage of orthopyroxene (Opx), cummingtonite (Cum), biotite (Bt), and hornblende, and a lack of clinopyroxene (Cpx). These rocks can be classified into four types: Opx–Cum, Cum, Cum–Bt, and Bt according to their eruption sequence (e.g., Isshiki, 1987; Endo et al., 2010). Cummingtonite is a common phenocryst phase and is present in most of the rhyolitic units. This sequence of cummingtonite-bearing rhyolites is a unique feature amongst the silicic volcanoes of the northern Izu–Bonin volcanic arc, most of which have an Opx–Cpx phenocryst assemblage (Shukono et al., 2006; Tamura et al., 2009; Haraguchi et al., 2017).

The decreasing anorthite contents (An mol.%) of plagioclase and Mg values (Mg#) of cummingtonite and biotite with time possibly indicate a gradual decrease in the temperature (and pressure) of the magmas. The rhyolites have high whole-rock SiO_2 (73–78 wt.%) and K_2O (1.5–3.3 wt.%) contents, and their trace element contents and patterns differ slightly amongst and within the four types. Highly differentiated rare earth element (REE) patterns characterize most of the rhyolites from Niijima volcano. All rock types from Niijima volcano have limited ranges of isotope values ($^{87}Sr/^{86}Sr$ = 0.70317–0.70339; $^{143}Nd/^{144}Nd$ = 0.51303–0.51308). The phenocryst assemblages and mineral chemistries of the rhyolitic volcanic rocks suggest that these magmas were produced under low temperatures (<800°C) and low pressures (<3 kbar), and possibly water-saturated conditions, which is consistent with the experimental results for similar dacites and rhyolites from other volcanic arcs (Geschwind and Rutherford, 1992; Nicholls et al., 1992). Major and trace element variations indicate that fractionation of mostly plagioclase and amphibole was the dominant process during evolution of the rhyolitic magma, as supported by the presence of tonalite–granite xenoliths with cumulate textures and chemistries.

The coeval basaltic and andesitic volcanic units and mafic–intermediate inclusions (or enclaves) indicate that these magmas played an important role in the generation and evolution of the dominant rhyolitic magmas. The parental rhyolitic magmas are likely to have been generated by partial melting of lower to middle crust as a result of basaltic underplating, after which the magmas ascended and fractionated into more silicic magmas, producing more than 13 magma units at shallow crustal levels. At deeper crustal levels, basaltic and rhyolitic (or dacitic) parental magmas were mixed to produce andesitic to dacitic magmas, and these magmas ascended and mingled with the shallow rhyolitic magmas before eruption. The complex magmatic system beneath Niijima volcano was developed within a relatively thick crustal sequence on the rear-arc side of the Izu–Bonin volcanic arc.

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