

Generation of calc-alkaline magma controlled by water content of primary magma at Rishiri Volcano, southern Kuril arc

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<Introduction>

Calc-alkaline andesite is a typical rock series in many island-arcs (eg. Miyashiro, 1974) and the composition is similar to the average composition of the continental crust (e.g. Rudnick and Gao, 2003). The petrographical features and the isotope ratios suggest that calc-alkaline andesite magmas are produced by external magma mixing between mantle-derived mafic magma and crust-derived felsic magma (Tatsumi, 2003). However, calc-alkaline andesite commonly coexists with basalt and/or tholeiitic-series andesite in individual volcanoes. In general, basalt and tholeiitic andesite do not show evidence of magma mixing and they evolved by crystal differentiation or AFC process. Why do calc-alkaline andesite magmas coexist with non-mixed basalt and tholeiitic-series andesite magmas in island-arcs? What is the dominant factor to produce calc-alkaline magmas? In order to clarify this problem, we studied calc-alkaline andesite from Rishiri volcano, southern Kuril arc. First, we clarified magma process of calc-alkaline andesite. Second, we estimated the features (chemical composition, H₂O concentration, temperature, etc...) of mafic end-member magma for the calc-alkaline andesite, and compared them with those of basalt and tholeiitic andesite magmas from the volcano.

<Results>

Rishiri volcano has produced alkali basalts and tholeiitic-series andesites, as well as calc-alkaline andesite (Ishizuka and Nakagawa, 1999). The calc-alkaline andesite can be divided into A-type (olivine-bearing two pyroxene andesite) and D-type (two pyroxene dacite) from petrography. Whole-rock SiO₂ content of the A-type and D-type ranges from 58.2 wt.% to 62.5 wt.% and 63.9 wt.% to 65.3 wt.%, respectively. Olivine phenocrysts are anhedral and they have reaction rim of orthopyroxene. The Mg-number of the olivine cores show wide range (71-89). Pyroxenes phenocrysts in A-type are reversely or normally zoned with wide core compositions. In contrast, pyroxenes phenocrysts in D-type only show normal zonation with narrow core composition. An-content of the plagioclase cores in A-type (45-87) is wider than in D-type (49-59). With increasing the SiO₂ contents, the ⁸⁷Sr/⁸⁶Sr and ²⁰⁶Pb/²⁰⁴Pb ratios tend to increase. The ¹⁴³Nd/¹⁴⁴Nd ratios of A-type is higher than those of D-type.

<Discussion>

The petrological and geochemical features suggest that the A-type magma was produced by magma mixing between mantle-derived mafic magma and crust-derived felsic magma. The basaltic end-member for the A-type magma was estimated to be primitive alkali basalt with H₂O=~5.4 wt.%. The chemical composition is not so different from those for Kutsugata-Tanetomi lava (Kuritani, 1999a; 2001; Kuritani et al., 2005) and Nozuka lava (Kuritani and Nakagawa, 2016). On the other hand, H₂O concentration is significantly higher than those of Kutsugata lava (~4 wt.%) and Nozuka lava (2.1-2.2 wt.%).

The model calculation suggests that water saturation of the high-H₂O (5.4 wt.%) primitive melt would have been attained when it crystallized ~10-20 wt.%, whereas water saturation of the low-H₂O (2.1 wt.%) primitive melt was attained when it crystallized up to ~60-70 wt.%. This observation indicates that the hydrous primitive end-member magma for the calc-alkaline andesite released much more vapors compared with the low-H₂O alkali basalt and tholeiitic andesite magmas when they crystallized due to cooling. The vapor phases would have been transported to the surrounding crust, and caused its partial melting because of the depression of the solidus temperatures. Then, the calc-alkaline andesite magmas were produced by mixing of the primitive basalt magmas with the crustal melt. For these considerations, we suggest that H₂O concentration of primary magma can control if calc-alkaline andesite magma is produced or not.

<References>

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