Petrogenesis of calc-alkaline andesite from Rishiri volcano, northern Hokkaido

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1. Introduction

Volcanic rocks can provide useful information on the growth of the crust and the temporary change of the composition and thermal structure of the mantle beneath the volcano. Rishiri volcano is located in northern Hokkaido where no other active volcano is present. Therefore, it is a suitable target to elucidate the petrological evolution of a single volcano (Ishizuka and Nakagawa, 1999). Calc-alkaline andesite is a typical rock series in many island arcs and the composition is similar to the average composition of the continental crust. In Rishiri volcano, calc-alkaline andesite is a dominant rock type during a climactic volcanic stage. To understand the petrological evolution of the volcano, it is necessary to clarify the magmatic process of the calc-alkaline andesite. In this study, we have performed petrological and geochemical analysis of calc-alkaline andesite to understand the magmatic process.

2. Petrology

Whole-rock SiO_2 content of the products ranges from 58.2 wt.% to 65.3 wt.%, and they are divided into A-type (Andesite-type; SiO_2<62.5 wt.%) and D-type (Dacite-type; SiO_2>63.9 wt.%). The phenocryst assemblage of the A-type is olivine + cpx + opx + pl, and that of the D-type is cpx + opx + pl. A-type has crystal clots composed of pl ±olivine ±cpx ±opx, gabbroic xenolith and mafic inclusions. Olivine phenocrysts are anhedral and they have reaction rim of orthopyroxene. The Mg-number of the olivine core shows wide range (64-88). Clinopyroxene and orthopyroxene phenocrysts occur in all samples. 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. Plagioclase phenocryst are found in all samples. An-content of the plagioclase core in A-type (45-88) is wider than in D-type (49-59). Major and trace elements concentrations show linear trends in Harker diagrams except for Cr, Ni, Sr, Ba and Zr. Eu anomaly is found only in A-type. With increasing the SiO_2 contents, the $^{87}Sr/^{86}Sr$ and $^{206}Pb/^{204}Pb$ ratios tend to increase. The $^{143}Nd/^{144}Nd$ ratios of A-type is higher than those of D-type. There is no significant difference of the estimated P-T condition of the magma chamber between A-type(P=3.6-4.1 kbar, T=970-1000℃) and D-type(P=4.1 kbar, T=970-980℃)(two-pyroxene geo-thermometer and barometer; Putirka, 2008).

3. Discussion

The Petrological features suggest that the calc-alkaline andesite was produced by magma mixing between mafic and felsic magma. The basaltic endmember magma is suggested to have been heterogeneous on the basis of the observations that 1)the compositional trends of Ni and Cr are not linear in Harker diagram, 2)modal abundance of olivine phenocryst is the highest at around SiO_2=60 wt.%, 3)wide core composition of olivine and plagioclase. In contrast, there is no petrological evidence for magma mixing in D-type, so we interpret that D-type represents the felsic endmember magma. Therefore, A-type magma was produced by magma mixing between D-type (felsic endmember) magma and the heterogeneous basaltic endmember magma.

The chemical and isotopic composition of D-type (felsic endmember) are similar to those of high-SiO2 Adakite (Martin, 2005) and they have significantly high-MgO, Cr and Ni concentration. This adakitic composition cannot be derived from any alkaline basalts at Rishiri volcano by crystallization and differentiation process. It is also difficult to explain the adakitic signature by direct melting of the crust, because the isotopic composition of granodiorite (Kuritani et al., 2005) and gabbroic samples (included in A-type as xenolith) have significantry higher and lower $^{206}Pb/^{204}Pb$ ratios, respectively, than those of D-type samples. Therefore, the possible petrogenesis of the D-type magma is 1)the multiple processes including partial melting, differentiation and assimilation in crustal level, 2)the partial melting of middle crust and 3)the partial melting of the subducted slab.

Keywords: Calc-alkaline andesite, Magma mixing, Adakite, Rishiri Volcano