Magma generation processes beneath Rishiri Volcano-1: Compositional variation of lavas controlled by progressive mantle melting

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Materials and energy have been continuously transported from the Earth's interior by magmatism throughout Earth's evolution, and convergent margins have been one of the most important tectonic settings for such transports. There is now a consensus that water-rich materials released from the subducting slab play a fundamental role in the generation of arc magmas. However, debates have continued as to detailed subduction-zone processes, such as a nature and chemical compositions of slab derived materials, processes and timescales of material transport from the slab to the source mantle, and a relative importance of decompression melting to fluid-fluxed melting. In order to understand subduction-zone processes generally, it is necessary to accumulate more field-based constraints to be supported by accurate and precise geochemical data.

In this study, magma generation processes are investigated for alkali basalt lavas from Rishiri Volcano, using precise major and trace elements and Sr, Nd, Pb and Th isotopic data. In part 1, formation processes of compositional variations of the lavas are considered, and it is shown that they were produced essentially by a series of progressive mantle melting induced by slab-derived fluids.

Numaura lava and Araragiyama lava, investigated in this study, belong to the final stage of the volcanic activity of Rishiri (Kobayashi, 1987; Ishizuka, 1999). Olivine is essentially the sole phenocryst phase. The eruption ages of the two lavas have not been determined. However, these lavas are younger than ~20 ka (Kuritani et al., 2007), and are older than ~8 ka (Miura, 1995).

The two lavas show tight whole-rock compositional trends. MgO contents of both lavas are higher than 7.5 wt.%, suggesting that magmas of these lavas were near primary. Samples of the two lavas can be discriminated clearly by their TiO_2 contents, and the Numaura and the Araragiyama lavas are characterized by high and low TiO_2 contents, respectively. With increasing SiO_2 content, Na_2O and P_2O_5 contents increase abruptly in the Numaura lava, whereas they are mostly constant in the Araragiyama lava. Isotopic compositions of the two lavas are also clearly distinctive, and the Numaura lava is low in $^{87}Sr/^{86}Sr$ and $^{206}Pb/^{204}Pb$ and high in $^{143}Nd/^{144}Nd$ compared with the Araragiyama lava.

The isotopic compositions of the two lavas change systematically with the major element compositions. One possible process is that they were formed by assimilation and fractional crystallization in a crustal magma chamber. However, in the Numaura lava, Ba concentrations tend to decrease with increasing SiO_2 contents, which cannot be explained by processes involving fractional crystallization. It is also difficult to explain the formation of the Araragiyama trend by AFC, because the P_2O_5 content of the lava is mostly constant while the TiO_2 content varies greatly. Thus it is plausible to consider that the compositional variations of the two lavas were produced primarily during magma generation.

The source mantle for the Rishiri magmas might have been garnet peridotite, considering that the depth to the Wadati-Benioff zone is ~300 km. Previous melting experiments of garnet peridotite have shown that the partial melt tends to increase systematically in MgO and CaO contents and decrease in TiO_2 and Na_2O contents with increasing degrees of melting (e.g. Kushiro, 1996). These observations coincide with the features of the compositional variations of the two lavas. Therefore, it is suggested that these lavas represent magmas produced by a series of progressive mantle melting, and the Numaura magmas were produced by lower degree of melting than those of the Araragiyama magmas. The correlation between the major element variations and the isotopic variations can also be explained by influx of slab-derived materials during magma generation.