Magma generation processes beneath Rishiri Volcano-2: Generation of rear-arc magmas induced by influx of supercritical liquids

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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 (e.g. Gill, 1981). 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 (e.g. Elliot et al., 1997; Sisson & Bronto, 1998; Turner et al., 2000; Grove et al., 2002; Manning, 2004; Portnyagin et al., 2007). 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 (Numaura lava and Araragiyama lava) from Rishiri Volcano, using precise major and trace elements and Sr, Nd, Pb and Th isotopic data. In part 1, we showed that the two lavas represent magmas produced by a series of progressive fluid-fluxed melting, and the Numaura magmas were produced by lower degree of melting than those of the Araragiyama lavas. In part 2, mechanism of magma generation and a nature of slab-derived materials are discussed.

It is widely accepted that primary arc magmas normally consist of three geochemical components; depleted MORB source mantle (DMM), altered oceanic crust (AOC) and the overlying sediment layer (SED) in a subducting slab (e.g. Elliot, 2003 and references therein). The lead isotopic compositions of the two lavas actually fall within the compositional range formed by the possible compositions of the three end components in a Pb isotopic compositional space. The lava trends extend away from the DMM component to the composition between the AOC and the SED components. This observation suggests that the geochemical variations of the lavas were produced by mixing of depleted MORB source mantle with slab derived materials consisting of an altered oceanic crust component and a sediment component.

In the two lavas, Sr, Nd, Pb and Th isotopic compositions change systematically with the major element compositions, suggesting that the slab-derived materials contained significant amounts of these elements. It is well known that Sr and Pb are mainly transported by aqueous fluids in subduction zones (e.g. Brenan et al., 1995), on the other hand, Nd and Th are not highly soluble in aqueous fluids (e.g. Ayers et al., 1997). These observations suggest that the slab-derived materials beneath Rishiri Volcano could have had aqueous fluid-like natures, but they also had significant silicate melt components. It is, therefore, plausible to consider that they were supercritical liquids. In fact, it has been shown that such supercritical liquids can contain significant amounts of Nd and Th, as well as Sr and Pb (Kessel et al., 2005). The depth to the Wadati-Benioff zone is 300 km at Rishiri Volcano, and the slab-derived materials could have been supercritlcal during the transport from the slab to the melting regions (e.g. Bureau & Keppler, 1999; Kawamoto 2006).

Arc lavas commonly have ^{238}U-^{230}Th disequilibrium with U-excess signatures, because U is preferentially partitioned relative to Th in aqueous fluids released from the subducting slabs. On the other hand, the Numaura and Araragiyama lavas possess ^{238}U-^{230}Th disequilibrium with 10˜20 % of ^{230}Th excess. We demonstrate that this ^{230}Th excess signature resulted primarily from the high Th nature of the slab derived materials ((^{238}U/^{232}Th) = ˜0.7), and the effect of Th enrichment due to melting in the presence of garnet and aluminous clinopyroxene was not essential.