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Osmium transportation by slab-derived supercritical liquid: constraints from alkali basalt lavas from Rishiri Volcano

Takeshi Kuritani[1*], Ryoko Senda[2], Katsuhiko Suzuki[2], Takeyoshi Yoshida[1], Yoshitaka Nagahashi[3]

[1]Tohoku University, [2]JAMSTEC, [3]Fukushima University

The Re-Os system has been used as a unique and powerful tool to constrain processes and timescales of long-term chemical evolution of the Earth. For elucidating the material circulation in the Earth's interior using the Re-Os system, understanding of behaviors of Re and Os in subduction zones is especially important, because subducting slabs undergoing dehydration and/or melting in sub-arc upper mantle will be transported to the deep interior of the Earth. To extract direct information on the Re-Os elemental fractionation in subduction zones, Re-Os systematics have been investigated extensively for arc lavas (e.g., Alves et al., 1999), as well as for sub-arc mantle xenoliths (e.g., Brandon et al., 1996). Arc lavas have a potential to provide direct information on geochemical features of slab-derived fluids involved in the magma generation (e.g., Stolper and Newman, 1994). However, quantitative estimation of subduction flux of Re and Os is still challenging, because information of the Re-Os system of primary magmas is highly susceptible to modification by interaction with the crust en route to the surface (e.g., Borg et al., 2 000; Lassiter and Luhr, 2000).

In this study, we examined the Re-Os systematics of primitive alkali basalt lavas from Rishiri Volcano, located at the rear of the Kurile arc. Using comprehensive geochemical data (major and trace element compositions and Sr, Nd, Pb, and Th isotopic compositions), previous study has suggested that the Rishiri lavas primarily represent magmas generated by a series of progressive fluid-fluxed melting of the source mantle, without evidence of crustal assimilation (Kuritani et al., 2008). In addition, the depth to the Wadati-Benioff zone is 300 km and the slab-derived fluid is suggested to have been supercritical liquid. Therefore, the lavas are expected to provide useful information on the behavior of Re and Os during melting of the sub-arc mantle fluxed with slab-derived supercritical liquid.

Rhenium-osmium isotopic analysis for representative samples shows that, with decreasing whole-rock TiO_2content of the lavas from 1.4 wt.% to 1.1 wt.%, $^{187}Os/^{188}Os$ ratios change systematically from 0.26 to 0.20, and the Os and Re concentrations tend to increase from 20 ppt to 40 ppt and decrease from 100 ppt to 50 ppt, respectively. The systematic covariance among the TiO_2 contents, $^{206}Pb/^{204}Pb$ ratios, and $^{187}Os/^{188}Os$ ratios of the lavas negates the possibility that the $^{187}Os/^{188}Os$ ratios were affected greatly by crustal assimilation, and therefore, the $^{187}Os/^{188}Os$ ratios of the primary magmas are suggested to have decreased systematically with increasing the degree of melting of the source mantle (note that TiO_2content in melt has been used as a good index of the degree of melting of the source mantle, and partial melts commonly tend to decrease in $TiO_2$with increasing the melting degree). One possibility for the origin of the compositional variation of the lavas is melting of the source mantle in which the depleted MORB mantle (DMM) and the slab-derived fluid were perfectly mixed (i.e., in equilibrium in terms of Os partitioning). However, this mechanism would produce a positive correlation between $^{187}Os/^{188}Os$ ratios and the degree of melting, contrary to the observation. It is thus inferred that the DMM and the influxing slab-derived fluid did not attain equilibrium in terms of Os partitioning (i.e., disequilibrium partial melting; Allegre and Minster, 1978), probably because of incomplete diffusive equilibration in the residual sulfides and/or dissolution of sulfide phases by influx of slab-derived fluid. The Os concentration in the slab-derived supercritical liquid for the Rishiri magma generation was estimated as about 100 ppt, assuming that the $^{187}Os/^{188}Os$ ratio of the slab-derived material was 0.8 9 (Brandon et al., 1996) and that the melting was perfectly disequilibrium in terms of Os partitioning.

Keywords: Osmium, Island arc, Slab-derived fluid, Wedge Mantle, Alkali basalt