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Noble gases in olivines in Udachnaya kimberlite, Siberia

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Kimberlite is known as host rock of diamonds. Although the origin of kimberlite magma is considered to be deeper than 150 km in the mantle where diamonds formed (e.g., Dawson, 1980; Haggerty, 1994), it has not been well constrained yet (e.g., Price et al., 2000; Chalapathi Rao et al., 2004; Smith, 1983).

Isotopic ratios of noble gases in various components in the Earth are significantly different resulting from that they are sensitive to addition of radiogenic/nucleogenic isotopes to primordial ones due to their low concentrations. Because noble gases can be measured with a high sensitive mass spectrometer, they are useful tracers to constrain origins of samples derived from deep interior of the Earth. Sumino et al. (2006) analyzed olivine phenocrysts in the Udachnaya kimberlite from Siberia, and clarified that they contain plume-derived noble gases. In this work, we analyzed other new sets of samples from the same kimberlite pipe to further investigate noble gas characteristics of the Udachnaya kimberlite magma.

It is important to separate several noble gas components within a sample, because there is not only intrinsic component of magma source but also secondary components acquired from surrounding materials or accumulated radiogenic isotopes produced from the decay of radioactive elements such as U, Th, and ^{40}K. We separated olivine phenocrysts that would have been less affected from the latter two components than other minerals. Since magmatic noble gases concentrated into fluid inclusions in the phenocrysts, we employed crushing method to extract noble gases selectively from them. We also applied heating method that extracts all noble gases in the phenocrysts. In this work we developed new crushing apparatus to reduce the contaminating atmospheric noble gases, which were adsorbed on the inner surface of the apparatus.

Crushing the aliquot of olivine separates reported in Sumino et al. (2006) yielded larger contributions of radiogenic ^{4}He and nucleogenic ^{21}Ne than the previous results. Since they exist within olivine crystal lattice, the new crusher shows higher crushing efficiency than the old one, resulting in a larger contribution of the lattice-hosted components relative to the inclusion-hosted ones. However, the total abundances of radiogenic ^{4}He and nucleogenic ^{21}Ne extracted from both crushing and heating indicate that the olivines studied in this work contained more radiogenic/nucleogenic components than those in the previous ones. The results suggest different noble gas isotopic compositions among the olivine crystals from the same kimberlite.

Additionally we measured olivine samples separated from another Udachnaya kimberlite. The results showed distinct behavior during stepwise crushing. Magmatic He isotope ratio is similar to that of subcontinental lithospheric mantle, and radiogenic ^{4}He and ^{40}Ar contributions increase with the progress of crushing. The results are similar to those of the previous work. Meanwhile, Ne isotope ratios deviate from typical mantle trends toward larger contribution of nucleogenic ^{21}Ne in a Ne three-isotope plot. This is clear contrast to the previous results, in which Ne isotopic feature is explained by a two-component mixing between air and less-nucleogenic mantle component than the MORB source (Sumino et al., 2006). Since the grain sizes of the new olivine separates are relatively larger than the proper phenocrystic olivines which should be smaller than 200 microns in size (Kamenetsky et al., 2008), there might be a larger number of xenocrysts in the new separates. Inclusions in the xenocrysts may be enriched in radiogenic/nucleogenic isotopes compared with phenocrysts containing noble gases in the source magma. This work revealed that contribution of radiogenic/nucleogenic components accumulated in crystals with an old age (350 Ma of the Udachnaya kimberlite, Maas et al., 2005) becomes significant even if the crushing extraction method is applied.