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Ultrahigh-sensitive simultaneous determination of halogens and noble gases reveals the origin of water in the mantle

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Noble gas isotope ratios in various geochemical components in the Earth are significantly different, making them useful tracers to constrain origin of volatiles in the mantle. The development of noble gas mass spectrometry during the last decade has enabled us to detect less than 10000 noble gas atoms (e.g., [1]). Noble gases are generally concentrated in fluid/melt inclusions in mantle-derived minerals resulting from their high incompatibility and volatility. Noble gases in the inclusions can be extracted distinctively from mineral-hosted component by use of in vacuo crushing or laser microprobe. The great advantages of the latter are that it makes it possible to analyze an individual inclusion or small clusters of inclusions having the same origin and that it can be applied for the inclusion samples on which preceding non-destructive analyses, such as microthermometry and micro spectroscopy have been performed. Although this method remains quite challenging due to extremely low noble gas concentrations in a fluid inclusion, we have successfully applied the laser-microprobe to noble gas analysis of melt/mineral inclusions in olivine phenocrysts in kimberlites.

An extension of Ar-Ar and I-Xe dating methods enables us to simultaneously determine trace amounts of noble gases, halogens, K, Ca, Ba and U by use of ultrahigh-sensitive noble gas mass spectrometry on neutron-irradiated samples. This method has several advantages: (i) detection limits for halogens are two or three orders of magnitude lower than those of other conventional analytical methods, and (ii) several components of different origin can be distinguished based on their relationships with specific noble gas isotopes such as mantle-derived ^{3}He and by using various noble gas extraction methods.

By using this method, we analyzed halogens and noble gases in exhumed mantle wedge peridotites and eclogites from the Sanbagawa-metamorphic belt, southwest Japan in which relicts of slab-derived water are contained as hydrous mineral/fluid inclusions trapped at a depth ranging from 40 to 100 km [2, 3]. The striking similarities of the observed noble gas and halogen compositions with marine pore fluids challenge a popular concept, in which the water flux into the mantle wedge is only by hydrous minerals in altered oceanic crust and sediment (e.g., [4]). This is the first evidence of subduction of porefluid-derived water into the mantle wedge.

On the other hand, MORB-like ^{3}He/^{4} He and halogen ratios of olivines in lavas from the northern Izu-Ogasawara arc and a peridotite from the Horoman alpine-type peridotite complex in northern Japan indicate insignificant contribution to the mantle wedge of radiogenic ^{4} He and porefluid-like halogens both observed in the subduction fluids in the Sanbagawa samples. This implies a relatively small amount of the pore water subduction fluids would be released from the Izu slab at a sub-arc depth resulting in further subduction to great depths in the mantle, resulting in the seawater-like heavy noble gas composition of the convecting mantle [5].

These results demonstrate that simultaneous determination of noble gases and halogens in mantle-derived rocks yields important information about the origin of slab-derived water-rich fluids and recycling of halogens and noble gases in the mantle.

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