

Sedimentary pore-fluid origin of H₂O-rich fluid in mantle wedge revealed by halogens and noble gases

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H₂O plays an important role in mantle processes in subduction zones. Yet its subducting processes to the mantle remain unknown because of scarcity of direct observations of H₂O in mantle-derived materials. Since halogen and noble gas are strongly partitioned into fluids and they show distinct elemental and/or isotopic ratios depending on their origins, their compositions in mantle rocks can provide complementary constraints on the behavior and origin of H₂O in the mantle. Although only few researches have been conducted, the subduction of halogens and noble gases derived from sedimentary pore fluids (seawater trapped in pores of deep-sea sediments) has been suggested. Pore fluid-like halogens and noble gases were found in mantle wedge peridotites which captured H₂O-rich fluids just above a subducting slab [1]. H₂O-rich fluid inclusions whose salinity is similar to that of pore fluids (salinity of pore fluids is the same level as that of seawater [2]) are found in a mantle xenolith from a subduction zone [3]. We investigated halogen and noble gas compositions of mantle wedge peridotites from subduction zones to better constrain how far the influence of subducted sedimentary pore fluids extends into the mantle.

The samples studied are harzburgitic xenoliths from the Avacha volcano in Kamchatka and the Pinatubo volcano in the Philippines, and alpine-type peridotite from the Horoman massif in Japan. H₂O-rich fluid inclusions have been found in olivine of those mantle peridotites [3,4,5].

We applied the noble gas method, in which halogens (Cl, Br, and I) are converted to corresponding isotopes of Ar, Kr, and Xe by neutron irradiation in a nuclear reactor and then the concentrations of noble gas isotopes are determined by noble gas mass spectrometry. Halogen detection limits of this method are from two to five orders of magnitude lower than conventional method, which enable to determine the low halogen abundances in mantle-derived materials. By crushing samples under ultra-high vacuum, noble gases are selectively extracted from H₂O-rich fluid inclusions. Unirradiated peridotites were also analyzed to obtain precise noble gas isotope compositions.

The halogens of all peridotites are heavily enriched in I, although the halogen ratios are distinctive in each locality. These high I/Cl ratios show a strong contribution of sedimentary pore fluids [2]. The noble gases except for He have the elemental and isotopic ratios similar to elementally fractionated atmospheric noble gases dissolved in seawater, which is probably equivalent to those dissolved in sedimentary pore fluids. The ³He/⁴He ratios are similar to that of the mantle and distinctly higher than the atmospheric ratio. This indicates that the fluids derived from subducting slabs acquired He from the ambient mantle, where He is much more enriched than in seawater.

These pore fluid-like halogen and noble gas signatures are strong evidence that the H₂O-rich fluids in the studied peridotites are derived from sedimentary pore fluids and transported to the mantle.

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