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流体包有物の希ガス・ハロゲン分析によるマントルウエッジ流体の起源に対する制約

Noble gas and halogen in fluid inclusions in mantle-derived rocks: insights into the origin of mantle wedge fluids

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Water-rich fluids released from subducting slabs play an important role in arc volcanism. Fluid inclusions in mantle-derived rocks from subduction zones have a potential for preserving geochemical characteristics of the slab-derived fluids. Noble gases are key tracers not only of mantle volatile origin and evolution but also of the origin of the subduction fluids. This relates to their relatively high concentration and distinct elemental/isotope compositions in seawater/pore fluid compared to those in minerals in sediment and oceanic crust. The heavy halogens (Cl, Br, and I) have high aqueous fluid-silicate melt partition coefficients and distinct elemental ratios in seawater, pore-fluid, sediment, oceanic crust, and in the mantle, thus may be one of the most reliable tracers for water cycling in subduction systems.

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 in fluid 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 select for analysis individual fluid inclusion or from small clusters of fluid inclusions having the same origin and that it can be applied to the fluid inclusion samples on which non-destructive analyses, such as microthermometry and micro spectroscopy have been performed. If the method is combined with geobarometer by use of micro-Raman spectroscopy [2] for example, depth origin and noble gas characteristics of a fluid inclusion in mantle-derived rock can be constrained simultaneously. Although this method remains quite challenging due to extremely low noble gases concentration in fluid inclusion, we have successfully applied the laser-microprobe to noble gas analysis of melt/mineral inclusions in olivine and plagioclase phenocrysts in volcanic rocks [3].

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 high-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.

Recently, we have shown that serpentine inclusions, a relic of former water-rich fluid inclusions, in the Higashi-akaishi peridotite from the Sanbagawa metamorphic belt preserve noble gas and halogen signatures of water-rich fluid released from subducting slab at a depth of ca. 100 km [4]. The striking similarities of the observed noble gas and halogen compositions with marine pore fluids requires subduction and closed system retention of marine pore fluid to at least 100 km. This is the first evidence that pore fluid has a significant contribution in a recycling process beneath arc. This study demonstrates that simultaneous determination of noble gases and halogens in (former) fluid inclusions yields important information about the origin of slab-derived water-rich fluids. However, how pore fluids could subduct into the mantle beyond the depth of 20 km previously considered possible unless the expelled water formed hydrous minerals remains unsolved. Further investigations on noble gases and halogens in fluid inclusions in mantle-derived rocks from arc settings will provide new insights into the water budget in subduction zones.

[1] Sumino et al. (2001) J. Mass Spectrom. Soc. Jpn. 49, 61-68. [2] Yamamoto et al. (2002) Earth Planet. Sci. Lett. 198, 511-519. [3] Sumino et al. (2008) J. Volcanol. Geotherm. Res. 175, 189-207. [4] Sumino et al. (2008) AGU Fall Meeting, U52A-08.

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