Noble gas and halogen subduction processes constrained by the analysis of olivines from Izu-Mariana arc lavas

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The presence of noble gases and halogens with seawater and sedimentary pore-fluid signatures in exhumed mantle wedge peridotites and eclogites from the Sanbagawa-metamorphic belt, southwest Japan [1,2], mantle-derived xenoliths from Kamchatka and Luzon arcs [3], and in seafloor and forearc serpentinites [4] along with seawater-like heavy noble gases (Ar, Kr, and Xe) in the convecting mantle [5] strongly suggest the subduction of sedimentary-pore-fluid-like noble gases and halogens. The noble gas and halogen compositions of olivines in arc lavas of the Izu-Mariana subduction zone were determined to develop a better understanding of the processes that control the return of these volatile and highly incompatible elements into the mantle. Trace amounts of halogens (Cl, Br, and I) in the olivine samples were measured using a combination of neutron irradiation and noble gas mass spectrometry [6].
The $^{3}He/^{4}He$ ratios of samples are in the range of the mid-ocean ridge basalt (MORB) value. This is consistent with helium isotope ratios of the subduction zone mantle xenolith [3], which indicates a considerably low contribution to the mantle wedge beneath the arc of radiogenic ^{4}He in the subduction fluids observed in the Sanbagawa samples exhumed from depths in the range from 30 to 100 km [1,2]. In contrast, the $^{40}Ar/^{36}Ar$ ratios for each volcano (299–620) are significantly lower than the MORB source (up to 32,000 [5]), which indicates significant involvement of atmospheric Ar ($^{40}Ar/^{36}Ar$ = 296) in the arc magmas. Systematically higher $^{40}Ar/^{36}Ar$ ratios in the rear arc than in the volcanic front suggest that subduction of seawater-derived Ar has a significant effect on the noble gas composition of the magma-generation region. Although the halogen compositions of most of the olivines are close to that of MORB-source mantle, some samples from the rear-arc regions show a significant contribution from pore-fluid-derived halogens. Combined with the noble gas results, halogen-poor fluid associated with atmospheric noble gases may be dominantly released from the subducting slab beneath the arc, while halogen supply from the subducted slab is limited to the magma generation region beneath some volcanoes in the rear arc. This implies the relative persistence of halogens in the subducting slab compared with noble gases.
A simple mass balance calculation of subducted and mantle-derived Ar isotopes reveals that higher subduction flux than that of seawater-derived Ar in the pore fluids of the subducting sediment/crust is required. Although the serpentinized lithosphere in the subducting slab has been regarded as the best candidate for the carrier of seawater-derived Ar with high subduction flux [4], the ratios of halogens and noble gases to water of slab-derived fluids preserved in the fluid inclusions of subduction zone mantle peridotites are inconsistent with the ratios in serpentinites collected from the Earth’s surface. This requires strong coupling behavior of halogens and noble gases with their host water during hydration of the subducting materials, release of aqueous fluids from subducted slab, and upward migration of the fluids in the mantle wedge. It remains unclear whether noble gases and halogens in the subducting materials are completely released beneath the Izu-Mariana rear arc. However, the presence of seawater-like noble gases in the convecting mantle [3] implies that a small portion of seawater-dissolved atmospheric noble gases may be transported to greater depths in the deeper mantle, and then incorporated into the mantle convection.

[1] Sumino *et al. EPSL* 2010. [2] Sumino *et al. Mineral. Mag.* 2011. [3] Kobayashi *et al. Mineral. Mag.* 2013. [4] Kendrick *et al. Nature Geosci.* 2011. [5] Holland & Ballentine *Nature* 2006. [6] Turner *JGR* 1965.

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