

Insights into volatile recycling at subduction zones from noble gases and halogens in wedge mantle peridotite

Hirochika Sumino[1]; Tomoyuki Mizukami[2]; Simon Wallis[3]

[1] Lab. Earthquake Chem., Univ. Tokyo; [2] Earth Sci., Sci&Eng., Kanazawa Univ.; [3] Earth and Planetary Sci., Nagoya Univ.

Water-rich fluids released from subducting slabs play an important role in arc volcanism. Trace volatiles, such as noble gases and halogens are strongly partitioned into the slab released fluids. This process is thought to act as a 'subduction barrier' [1,2] preventing their transport deeper into the mantle. Recently, however, Holland and Ballentine [3] have challenged the subduction barrier model by identifying heavy non-radiogenic noble gases that are indistinguishable from those found in seawater but nevertheless, are intimately associated with the primordial noble gases used to characterize mantle fluids. Understanding the relationship between the noble gases in the mantle and atmosphere remains a key challenge in understanding whole Earth volatile origin and cycling. However, no study has revealed the 'missing link' between subducting materials and the convecting mantle to verify whether and how subduction fluids preserve a seawater signature. In particular, the volatile composition of the slab-derived fluid, which is expected to provide the most important clue to the volatile circulation, is not well characterized.

Atmospheric noble gases associated with mantle-derived He have been identified in mantle peridotites from subduction zones [4,5]. These observations suggest that subducted atmospheric noble gases may be present in the uppermost mantle in subduction zones, though when and how these components became incorporated in the mantle are not well constrained.

Shimizu et al. [6] report the presence of atmospheric noble gases in arc magmas from the northern Izu-Ogasawara arc that decrease as the distances of volcanic centers from the Izu-Ogasawara trench increase. By comparing noble gas isotope ratios of possible subducting materials, such as altered oceanic crust, and sediments on the northwestern Pacific plate, they conclude that the origin of the atmospheric noble gases is likely to be seawater, probably preserved as pore-fluids in rocks, rather than hydrous minerals in subducting materials.

Recently, we have shown that the Higashi-akaishi peridotite body in the Sanbagawa metamorphic belt-a sliver of the former mantle wedge of the eastern Eurasian plate margin-exhumed subduction fluid noble gas and halogen signatures from a depth of ~100 km [7]. 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. Taking into account that the P-T path of the Higashi-akaishi peridotite body implies a hotter mantle wedge than those of mature subduction zones [8], pore-fluid contributions to the water budget in the mantle wedge may well be larger in cooler more common arc settings. This suggests that pore-fluid subduction is an important recycling process in contradiction to some studies that essentially dismiss its importance (e.g., [9]).

Pore fluid subduction can account not only for the contributions of atmospheric and/or seawater-like noble gases in volcanic rocks and gases from subduction zones [2] but also the heavy noble gases observed in the convecting mantle [3]. However, how pore fluids could subduct deep into the mantle without being released remains unsolved. Further investigation is required to quantify contributions of pore fluids and hydrous minerals in subducting materials to the water budget in subduction zones.

[1] Staudacher and Allegre (1988) EPSL, 89, 173-183. [2] Hilton et al. (2002) Rev. Mineral. Geochem., 47, 319-370. [3] Holland and Ballentine (2006) Nature, 441, 186-191. [4] Matsumoto et al. (2001) EPSL, 185, 35-47. [5] Matsumoto et al. (2005) EPSL, 238, 130-145. [6] Shimizu et al. (2006) AGU Fall Meeting, V41B-1719. [7] Sumino et al. (2008) AGU Fall Meeting, U52A-08. [8] Mizukami and Wallis (2005) Tectonics, 24, TC6012. [9] Jarrard (2003) G-cubed, 4, 8905.