

Halogen heterogeneity in the subcontinental lithospheric mantle

*Hirochika Sumino¹, Masahiro Kobayashi², Ray Burgess³, Chris J Ballentine⁴

1. Department of Basic Science, Graduate School of Arts and Sciences, University of Tokyo, 2. Tokyo Metropolitan Industrial Technology Research Institute, 3. School of Earth and Environmental Sciences, University of Manchester, 4. Department of Earth Sciences, University of Oxford

Volatile recycling back to the Earth's mantle at subduction zones has a significant, yet poorly constrained impact to the volatile budget in the mantle. Halogen and noble gas systematics are powerful tracers of volatile recycling. The presence of noble gases and halogens with seawater and sedimentary pore-fluid signatures in exhumed mantle wedge peridotites from the Sanbagawa-metamorphic belt, southwest Japan [1], and in forearc serpentinites [2] along with seawater-like heavy noble gases (Ar, Kr, and Xe) in the convecting mantle [3] strongly suggest the subduction of sedimentary-pore-fluid-like noble gases and halogens. In order to better constrain how such subduction fluids may modify the halogen composition of subcontinental lithospheric mantle, we have analyzed halogens in mantle-derived xenoliths from volcanic front and back-arc regions of subduction zones, and intraplate continental settings.

In addition to a MORB-like halogen component observed in most of the samples, three other distinct components were identified: (A) a marine-pore-fluid-like component with high Br/Cl and I/Cl ratios similar to mantle wedge peridotites [1], (B) a Cl-enriched component relative to MORB, similar to bulk altered oceanic crust [4]; and (C) a component enriched in Br and moderately in I compared to MORB, which resembles to fluid components in altered oceanic crust and diamonds [4,5].

The component (A) is typically observed in the volcanic front samples containing abundant H₂O-rich fluid inclusions. This suggests that marine pore fluids in deep-sea sediments are carried by serpentine and supplied to the mantle wedge, preserving their original halogen and noble gas compositions. However, the measured Cl/H₂O and ³⁶Ar/H₂O in the peridotites are higher than those in sedimentary pore fluids and serpentine in oceanic plates [2]. The halogen/noble gas/H₂O systematics are interpreted within a model where water is incorporated into serpentine in a closed system formed along fracture zones developed at the outer rise, where oceanic plates bend prior to entering subduction zones, preserving Cl/H₂O and ³⁶Ar/H₂O values of sedimentary pore fluids. Dehydration-hydration process within the oceanic lithospheric mantle maintains the closed system until the final stage of serpentine dehydration. The sedimentary pore fluid-like halogen and noble gas signatures in fluids released at the final stage of serpentine dehydration are preserved due to highly channelized flow [6].

The samples involving the component (B) have higher Cl concentration and trace elements ratios, whereas the samples involving the component (C) have relatively low Cl concentration and low ratios of highly incompatible elements relative to heavy rare earth elements. Considering that these two components are observed in some back-arc samples having radiogenic/nucleogenic noble gases [7], they could be remnants of metasomatic agents derived from subducted altered oceanic crust, or could result from secondary processes of volatile loss during partial melting and secondary phase formation during interaction with melts [8].

The common primary MORB-like halogen ratios in mantle xenoliths from different parts of the globe indicate that the mantle itself must have a relatively uniform composition over a wide scale. The mantle has maintained its halogen composition over billion year timescales without being affected by I-rich

halogens being transported into the mantle. Mass balance calculations suggest that, in order to maintain the I/Cl ratio of the convecting mantle over 2 Gyr, the I/Cl ratio of the subducted halogens must be no more than several times higher than the present-day mantle value [8].

[1] Sumino *et al.* *EPSL* 2010. [2] Kendrick *et al.* *EPSL* 2013. [3] Holland & Ballentine *Nature* 2006. [4] Chavrit *et al.*, *GCA* 2016. [5] Burgess *et al.*, *GCA* 2009. [6] Kobayashi *et al.* *EPSL* 2017. [7] Jalowizki *et al.*, *EPSL* 2016. [8] Kobayashi *et al.*, *G-cubed* 2019.

Keywords: halogen , subcontinental mantle, noble gas, subduction, volatile recycling