Subduction of halogens and noble gases: constraints from metagabbros

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Noble gases were long considered unsubductable; however, the recognition of atmospheric Ar, Kr and Xe isotopes in the Earth's mantle [1] has meant that noble gas subduction pathways are now being re-examined [2] [3] Here we examine the systematics of noble gases (He, Ne, Ar, Kr, Xe) and halogens (Cl, Br, I) in amphibolites from the ~3.5 Myr old Mathematician Ridge of the NE Pacific Ocean.

Combined analysis of ampiboles and quartz-hosted fluid inclusions enable the relative partitioning coefficients of I, Br and Cl between calcic amphibole and brine to be estimated as $D_{Br/Cl} = 0.10 \pm 0.04$ and $D_{I/Cl} \sim 0.1$ (where $D_{X/Cl} = X/Cl_{amp}/X/Cl_{fluid}$). The preferential exclusion of Br and I from amphibole leads to Altered Ocean Crust having Br/Cl of much less than seawater. This contrasts with higher than seawater values in sedimentary pore waters and serpentinites, confirming that halogen abundance ratios can help identify different slab components in subduction-related magmas.

Amphiboles and associated quartz-epidote veins are dominated by atmospheric Ne, Ar, Kr and Xe, but preserve mantle He isotope signatures indistinguishable from MORB. These features are characteristics of seawater-derived fluids that have mobilised He (and a significant fraction of their halogens) from juvenile oceanic crust. The metamorphic amphiboles contain $2\text{-}8\times10^{-13}$ mol/g ^{36}Ar that is slightly lower than the maximum reported for seafloor serpentinites, but they are strongly enriched in He and Ne relative to Ar in both seawater and serpentinites. The high He/Ar and Ne/Ar ratios result from the presence of mantle He, phase separation which enriches vapour phases in He>Ne>Ar and possibly by the preferential incorporation of He>Ne>Ar into amphibole [3]. The strong enrichment of metamorphic amphibole in Ne/Ar underlines that it is a fallacy to assume atmospheric noble gases are subducted with seawater abundance ratios. Instead, the current data support the idea that the MORB ^{20}Ne/^{22}Ne ratio of ≤12.5 can be explained by mixing primordial solar Ne (^{20}Ne/^{22}Ne = 13.8) and atmospheric Ne (^{20}Ne/^{22}Ne = 9.8) subducted in the mantle over Earth's history.

[1] Holland and Ballentine (2006) *Nature* **441**, 186-191 [2] Kendrick et al. (2011) *Nat. Geosci.* **4**, 807-812 [3] Jackson et al. (2013) *Nat. Geosci.* **6**, 562-565.