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Chlorine isotope geochemistry of hydrothermally altered oceanic crust: Mineralogical controls and experimental constraints

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Chlorine stable isotopes (^{37}Cl and ^{35}Cl) can provide an important fingerprint for geochemical recycling of subducted oceanic lithosphere and fluid-rock interaction due to chlorine's high solubility in aqueous phases. To implement Cl isotopes as a tracer of volatile element recycling, we must constrain the δ^{37}Cl value of potential Cl reservoirs and determine fractionation factors between Cl-bearing phases.

δ^{37}Cl and Cl concentrations of hydrothermally altered oceanic crust (AOC) samples from seven IODP/ODP/DSDP drill sites have been measured on bulk rock samples (n = 50). For ease of comparing results, samples are categorized into three lithologies: 1) extrusive lavas, 2) sheeted dikes, and 3) gabbros. Extrusive lava Cl concentrations vary from <0.01 wt% to 0.03 wt% (avg = 95 ppm Cl; n= 20) and δ^{37}Cl values range from -1.4 to +1.0‰ (avg = 0.0 ± 0.6‰). Chlorine concentrations of the sheeted dikes range from < 0.01 wt% to 0.05 wt% (avg = 163 ppm Cl; n = 11) and δ^{37}Cl values of dikes range from − 0.4 to + 1.4‰ (avg = 0.1 ± 0.3‰). Bulk chlorine concentrations of the gabbros range from < 0.01 wt% to 0.09 wt% (avg = 244 ppm Cl; n = 19). δ^{37}Cl values of gabbros range from − 0.6 to + 1.8‰ (avg = 0.6 ± 0.6‰). Three general conclusions can be derived from these AOC bulk rock results:

1) δ^{37}Cl values and Cl concentrations increase with increasing total amphibole content.

2) Based on re-calculations of mass balance equations using updated AOC Cl concentrations (~3 times higher than previous estimates, this study), the total amount of Cl hosted in AOC is higher than previously estimated.

3) [Cl] and δ^{37}Cl values can provide a crude estimate of metamorphic grade in AOC samples.

Amphibole-water Cl isotope fractionation experiments are necessary for quantifying the magnitude of Cl fractionation and to aid in interpreting the range of natural Cl isotope variation. Determination of equilibrium fractionation factors between hydrous minerals and co-existing fluid often also provides the ability of determining the isotopic composition of the water removed from the original mineral-water pair. 'Pseudo' isotope exchange experiments (O'Neil, 1986) are currently being carried out in cold-seal pressure vessels by synthesizing hastingsite in the presence of a Cl bearing solution of known isotopic composition. Several variable hornblende compositions (near ferro-pargasite or hastingsite) have successfully been synthesized at 700°C and 0.2 GPa, carrying out experiments for 2-4 days, approximately at the wuestite-magnetite buffer. Fractionation experiments are being run at a constant pressure and varying temperatures that will successfully synthesize amphibole and approach reasonable kinetic rates in order to achieve equilibrium. It will also be important to note the variation in equilibrium fractionation factors based on amphibole composition and fluid/rock ratio (Graham et al., 1984).

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