American Mineralogist, Volume 105, pages 307–318, 2020

The distribution and abundance of halogens in eclogites: An in situ SIMS perspective of the Raspas Complex (Ecuador)

Benjamin M. Urann[1,2,*,†], Véronique Le Roux[2], Timm John[3], Grace M. Beaudoin[4], and Jaime D. Barnes[4]

[1]MIT-WHOI Joint Program, Marine Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, U.S.A.
[2]Geology and Geophysics Department, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543, U.S.A.
[3]Institut für Geologische Wissenschaften, Freie Universität Berlin, Malteserstrasse 74-100, 12249 Berlin, Germany
[4]Department of Geological Sciences, University of Texas, Austin, Texas 78712, U.S.A.

Abstract

We present in situ secondary ion mass spectrometry (SIMS) and electron microprobe analyses of coexisting garnet, omphacite, phengite, amphibole, and apatite, combined with pyrohydrolysis bulk-rock analyses to constrain the distribution, abundance, and behavior of halogens (F and Cl) in six MORB-like eclogites from the Raspas Complex (Southern Ecuador). In all cases concerning lattice-hosted halogens, F compatibility decreases from apatite (1.47–3.25 wt%), to amphibole (563–4727 μg/g), phengite (610–1822 μg/g), omphacite (6.5–54.1 μg/g), and garnet (1.7–8.9 μg/g). The relative compatibility of Cl in the assemblage is greatest for apatite (192–515 μg/g), followed by amphibole (0.64–82.7 μg/g), phengite (1.2–2.1 μg/g), omphacite (<0.05–1.0 μg/g), and garnet (<0.05 μg/g). Congruence between SIMS-reconstructed F bulk abundances and yield-corrected bulk pyrohydrolysis analyses indicates that F is primarily hosted within the crystal lattice of eclogitic minerals. However, SIMS-reconstructed Cl abundances are a factor of five lower, on average, than pyrohydrolysis-derived bulk concentrations. This discrepancy results from the contribution of fluid inclusions, which may host at least 80% of the bulk rock Cl. The combination of SIMS and pyrohydrolysis is highly complementary. Whereas SIMS is well suited to determine bulk F abundances, pyrohydrolysis better quantifies bulk Cl concentrations, which include the contribution of fluid inclusion-hosted Cl. Raspas eclogites contain 145–258 μg/g F and at least 7–11 μg/g Cl. We estimate that ~95% of F is retained in the slab through eclogitization and returned to the upper mantle during subduction, whereas at least 95% of subducted Cl is removed from the rock by the time the slab equilibrates at eclogite facies conditions. Our calculations provide further evidence for the fractionation of F from Cl during high-pressure metamorphism in subduction zones. Although the HIMU (high U/Pb) mantle source (dehydrated oceanic crust) is often associated with enrichments in Cl/K and F/Nd, Raspas eclogites show relatively low halogen ratios identical within uncertainty to depleted MORB mantle (DMM). Thus, the observed halogen enrichments in HIMU ocean island basalts require either further fractionation during mantle processing or recycling of a halogen-enriched carrier lithology such as serpentinite into the mantle.

Keywords: Eclogite, halogens, subduction, SIMS, nominally anhydrous minerals, HIMU; Halogens in Planetary Bodies