Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17011

Development of new methods to track magma degassing and fluid fluxing in complex magmatic systems based on halogen ratios

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Magma degassing and fluid fluxing within trans-crustal magma reservoirs play an important role in the transport of volatile elements and ore metals. Tracking the migration of magmatic fluids within such systems is challenging, yet important for the understanding of magmatic-hydrothermal ore genesis and volcanic degassing.

We aim to develop new geochemical tools to track magma degassing and fluid fluxing over a broad melt composition range. We hypothesize that halogen ratios may be useful for this purpose because previous studies have found that the fluid/melt partition coefficients ($D^{f/m}$) of halogens significantly increase with increasing halogenide ion radius. However, the data available on Br and I partitioning is limited; therefore, we are experimentally studying the $D^{f/m}$of halogens as a function of melt composition, pressure, and fluid salinity.

The experiments were conducted at 785°C and 150 to 500 MPa in externally heated René 41, Molybdenum-Hafnium Carbide pressure vessels, and a piston cylinder apparatus. We equilibrated peralkaline, metaluminous, and peraluminous haplogranitic melts with aqueous fluids of 7 different salinities containing Br and I as minor elements in a chloride-rich fluid matrix analogous to natural systems. Halogen concentrations in the run product glasses were determined by LA-ICP-MS and LG-SIMS. The concentration of halogens in the equilibrium fluid was then derived by mass balance calculation allowing us to calculate the $D^{f/m}$ of Cl, Br, and I. In average, the $D^{f/m}$ of Br and I are 3 and 5 times higher than that of Cl, respectively. The $D^{f/m}$ of all three studied halogens increases by a factor of 3 to 8 with fluid salinity increasing from 0.5 to 32 molal. With increasing pressure, all three halogens partition stronger towards the fluid phase at low-fluid salinities, but the opposite trend was observed at high-fluid salinities. Our results indicate that the I/Cl ratio can be applied to track fluid fluxing and early degassing, whereas Br/Cl is well-suited to address more extensive crystallization-driven degassing provided by the concentrations of these halogens determined in silicate melt inclusions in phenocrysts in igneous rocks.