Geophysical Research Abstracts
Vol. 20, EGU2018-18565, 2018
EGU General Assembly 2018

Compositions of magmatic fluids exsolved from mafic and felsic melts: Implications for volatile fluxes and ore formation

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Magmatic fluids, generated by degassing of subvolcanic melts, are commonly complex mixtures of H_2O, CO_2 and other volatiles, ligands, plus non-volatile solutes including economically important metals. Compositions of fluids exsolved from silicate melts are strongly dependent on the melt chemistry, and consequently the compositions of magmatic fluids evolve as igneous fractionation proceeds. Fluid and melt inclusions hosted in igneous phenocrysts and magmatic-hydrothermal veins provide a particularly rich source of information on the compositions and evolution of magmatic fluids. In mafic settings, much of the recent literature has focused on degassing of CO_2, particularly in light of the discovery of CO_2 vapor within bubbles in melt inclusions. However, solubility modeling indicates that CO_2 degassing ought to occur in tandem with degassing of sub-equal quantities of H_2O. In this context, melt inclusion bubbles present unique opportunities to characterize exsolved fluids in situ. Specifically, the incipient (“fresh”) bubbles in equilibrium with basaltic melt contain CO_2 plus H_2O in proportions consistent with solubility modeling. These bubbles also contain S and non-volatile solutes including metals, indicating complex fluid compositions exsolved from mafic melts. In felsic settings, exsolved fluids are generally significantly more H_2O-rich and saline, and aqueous fluid inclusions coeval with silicate melt inclusions are extremely common. Intermediate-felsic melts associated with porphyry-style mineralization commonly exhibit magmatic-hydrothermal features such as veins and unidirectional solidification textures, which record repeated pulses of degassing. The stage of pressure buildup by confined degassing is recorded by assemblages of silicate melt inclusions coeval with a “supercritical” aqueous fluid – low density, moderate salinity, and containing appreciable dissolved metals. Pressure drop by fluid release is represented by assemblages of coeval vapor and hypersaline brine, which form via brine condensation, prior to resealing and repeating the process. Carbon dioxide is essentially absent from this process, undetected in any primary fluid inclusions. In contrast, in more felsic settings, such as in late-stage magmatic degassing in porphyry roots, CO_2 is a common (albeit dilute) constituent of relatively low-salinity, high-density exsolved aqueous fluids, which may be variably enriched in lithophile elements. This very late-stage degassing of small quantities of CO_2 in highly evolved settings likely reflects a different solution mechanism, compared to the CO_2-rich fluids exsolved from mafic melts. Together, these observations reveal a nuanced and complex picture of magmatic fluid compositions across a spectrum of mafic to felsic melts.