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Volatile element and chalcophile metal behavior during magma differentiation in transcrustal systems: implications for magma fertility for porphyry ore genesis

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Porphyry-type Cu-Au-Mo deposits form via spatially focused precipitation of ore metal sulfides from magma-derived fluids. This requires the release of aqueous fluids simultaneously rich in ore metals and SO_2 from magma-bodies crystallizing in the upper crust. The efficiency of this process is determined by the volatile and metal budget of derivative magmas arriving in the upper crust after undergoing differentiation at deeper crustal levels, as well as the timing and efficiency of the extraction of these ore-forming constituents in the upper crust by exsolving magmatic fluids.

Comprehensive modeling of these processes requires the knowledge of an applicable liquid line of descent, models of sulfide and anhydrite solubility in silicate melts, partitioning models for ore metals between silicate melt and sulfide phases, as well as fluid/melt partitioning models for S, Cl and all ore metals considered over the relevant pressure (P) – temperature (T) and compositional (X) space. The fluid/melt partitioning models were constructed as a part of this study, in a large part based on internally consistent datasets from purpose-designed series of experiments, in particular in the case of S and Cl. They reproduce experimental data over a broad P-T-X range with median absolute percentage error lower than 30%.

The results suggest that magmatic sulfide saturation at deep crustal levels is likely to be common and can withhold a significant fraction of the original Cu budget of the magmas. If such sulfides are entrained in derivative magmas ascending to the upper crust, they would rapidly redissolve due to sulfur degassing, but their Cu budget would be transferred first back to the silicate melt rather than into the fluid phase. Therefore, sulfide transport to the upper crust is a testable hypothesis by monitoring Cu concentrations in silicate melt inclusions. Efficient Cu extraction by fluids is restricted to late stages of crystallization-driven magma degassing, whereas the efficiency of oxidized sulfur extraction is tied to the depth of magma emplacement. The generation of input fluids with stable salinity in the range of 3-10 wt% NaCl equivalent as observed in the roots of porphyry deposits requires the aggregation and periodic release of magmatic fluids.