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Amphibole Constraints on Cl Behavior Across the Magmatic Column: Implications for Porphyry Copper Deposit Formation

JACKSON S BORCHARDT[1], DOUGLAS C KREINER[1], CARL J BENO[1], SEAN P GAYNOR[1], AMY GILMER[1] AND CIN-TY LEE[2]

[1]U.S. Geological Survey
[2]Rice University

Copper porphyry deposits are important sources of Cu and other metals critical to the modern economy. These deposits form from the magmatic degassing of Cl-rich fluids, which transport and concentrate copper and other metals. While previous research has helped constrain the roles of Cl and water in ore-forming fluids, volatile behavior in the magma, prior to degassing and ore formation, is poorly constrained in intrusive rocks. In this work, we use the chemistry of magmatic amphiboles from porphyry-forming and barren magmatic intrusions, as well as improved calibrated amphibole-silicate melt Cl distribution coefficients to calculate equilibrium magmatic Cl concentrations. Combined with amphibole barometry and chemometry, the calculated equilibrium melt Cl systematics suggest that the volatile buildup and exsolution of ore forming fluids from porphyry copper magmas are unique compared to barren systems.

In mineralized systems, melt Cl concentrations initially increase with differentiation and decreasing pressures but drop at pressures less than 2 Kbar. In contrast, barren systems show decreasing Cl concentrations with differentiation and decreasing pressure, beginning from the earliest stages of amphibole crystallization. We interpret the contrasting behavior of Cl in the barren and mineralized systems to be a function of water saturation, suggesting that the distribution coefficient for Cl between a fluid and silicate melt is higher than previously reported. Barren magmatic systems saturate in water at greater depths, and thus lose Cl as they rise and differentiate, limiting ore potential. In contrast, mineralized systems only saturate at shallow depths, allowing for efficient transfer of metals into ore forming fluids. We propose that this behavior is inherited from the initial water content of the parental magmas, with porphyry-forming magmas starting with lower water concentrations than barren systems.