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The effect of crystal-melt partitioning on the budgets of Cu, Au, and Ag

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Abstract

We have performed five separate sets of experiments to elucidate the effects of magnetite, ulvöspinel-magnetite solid solution, and pyrrhotite crystallization on the budgets of Au, Cu, and Ag at magmatic conditions. The experiments were done in both hydrous and anhydrous assemblages at temperatures between 800 and 1050 °C, pressures from ambient to 140 MPa, $\log f_{O_2}$ from NNO-0.25 to NNO, and $\log f_{S_2}$ from –1.5 to –3.0. Nernst-type partition coefficients (±1σ) at 800 °C in a water-saturated assemblage are $D_{Ag}^{Mt/melt} = 2 \times 10^{-4} \pm 2 \times 10^{-9}$, $D_{Cu}^{Mt/melt} = 0.82 \pm 0.69$, $D_{Cu}^{Usp/melt} = 26 \pm 17$, $D_{Au}^{Usp/melt} = 50 \pm 31$, $D_{Cu}^{Po/melt} = 174 \pm 25$. Nernst-type partition coefficients (±1σ) at 1050 °C in an anhydrous assemblage are $D_{Cu}^{Po/melt} \geq 200$, $D_{Ag}^{Po/melt} = 58 \pm 8$, $D_{Au}^{Po/melt} = 120 \pm 50$. The calculated values for $D_{Au}^{Usp/melt}$ and $D_{Cu}^{Usp/melt}$ indicate that the addition of Ti to magnetite increases significantly the Au- and Cu-scavenging potential of ulvöspinel relative to end-member magnetite. Partition coefficients for Cu and Au between pyrrhotite and melt indicate that a temperature change from 1050 to 800 °C in an anhydrous and hydrous assemblage, respectively, results in no observable change in Cu partitioning. The calculated partition coefficients are used to model the effect of crystal fractionation on the concentrations of Ag, Cu, and Au. Model results suggest that the co-crystallization of magnetite and pyrrhotite sequester no more than 2% Ag, 7% Cu, and 37% Au from the melt over the first 25% solidification. If the melt reaches volatile saturation after 25% crystallization, the presence of end-member magnetite and pyrrhotite do not appear to inhibit the Cu-, Au-, and Ag-ore potential of the magma. Ulvöspinel-magnetite, however, may reduce the Au concentration in the melt by approximately one-third relative to its initial value that decreases the overall Au available to partition into the volatile phase.

Keywords: Metal budgets, magma evolution, element partitioning, differentiation, crystal fractionation