

A magmatic flotation model for iron oxide copper-gold and iron oxide-apatite deposits

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Iron oxide copper-gold deposits (IOCG) and iron oxide-apatite (IOA) deposits are commonly spatially and temporally associated with one another and with coeval magmatism. However, a genetic model that accounts for observations of natural systems remains elusive, with few observational data able to distinguish among working hypotheses that invoke meteoric fluid, magmatic-hydrothermal fluid, and immiscible iron-rich melt. Here, we use high-resolution trace element concentrations of magnetite, hematite, apatite and pyrite, high-precision Fe and O stable isotope data of magnetite and hematite, H isotopes of magnetite and actinolite, and Re and Os concentrations of magnetite and pyrite, from samples collected from the Mantoverde IOCG and Los Colorados IOA deposits in the Chilean Iron Belt to develop a new genetic model that explains IOCG and IOA deposits as a continuum produced by a combination of magmatic and magmatic-hydrothermal processes. Magnetite grains from Los Colorados are zoned. Cores of magnetite have Ti, V, Al, and Mn concentrations that overlap igneous magnetite. The concentrations of Ti, V, Al, and Mn decrease systematically from core to rim, a trend consistent with magnetite that grows from a cooling magmatic-hydrothermal fluid. Pyrite grains from Los Colorados and Mantoverde have high Co/Ni ratios, consistent with a magmatic-hydrothermal origin. The δD values for magnetite and actinolite from Los Colorados indicate a mantle source for H. The values of $\delta^{56}Fe$ and $\delta^{18}O$ for magnetite and hematite from both deposits indicate a magmatic source for Fe and O. The Re-Os systematics overlap data from Andean porphyry Cu-Mo deposits and are consistent with a magmatic-hydrothermal origin. Together, the data are consistent with the following genetic model. 1) Magnetite cores record crystallization of magnetite microlites from silicate melt, which results in concentrations of Ti, V, Al, and Mn that overlap igneous magnetite. 2) Magnetite crystallization promotes volatile saturation of the melt and magnetite crystal surfaces serve as nucleation sites for gas bubbles. The exsolved volatile phase efficiently scavenges Fe, P, S, Cu, Au from the silicate melt. 3) With progressive degassing of the melt during decompression, the volatile phase coalesces and encapsulates magnetite to form a magnetite-fluid suspension that is less dense than the surrounding magma as long as the suspension contains ≤ 37 vol% magnetite. 4) Regional extension creates permeable pathways that allow the buoyant magnetite-fluid suspension to ascend. Magnetite grows in equilibrium with the fluid and takes on a magmatic-hydrothermal character (i.e., lower Ti, V, Al, Mn). Halite-saturated fluid inclusions in the rims of magnetite are consistent with growth of magnetite in equilibrium with a fluid. 5) During ascent along pre-existing faults, magnetite reaches neutral buoyancy and drops out of the fluid suspension forming an ore body that is concordant with the fault. The fluid suspension may percolate laterally into the host rock forming disseminated mineralization. 6) The further ascending fluid transports Fe, Cu, Au and S toward the surface where magnetite, hematite and sulfides precipitate to form IOCG deposits. This model is globally applicable and explains the observed temporal and spatial relationship between magmatism and formation of IOA and IOCG deposits.