

Modeling the Role of Sodic Alteration in the Genesis of Iron Oxide-Copper-Gold Deposits, Eastern Mount Isa Block, Australia

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Abstract

Liberation of iron and potassium by widespread postmetamorphic albitization of country rocks was one of the likely contributing processes in the formation of both barren and mineralized magnetite ± chalcopyrite + biotite + gold + hematite + clinopyroxene + actinolite + apatite ironstones in the Cloncurry district of the Proterozoic Mount Isa block. Whole-rock geochemical data indicate nearly immobile Al, Ga, ±Ti, Zr during transformation of a variety of least altered rocks toward albitite. The data indicate that the addition of Na from a brine to the rock accompanied the loss of Fe, K, Ba, Rb ± Ca, Sr, Co, V, Mn, Pb, and Zn from those altered rocks and enrichment in the brine, but that Cu was not systematically stripped from a variety of wall rocks during albitization. Conversely, the formation of metasomatic ironstones, the immediate hosts to some Cu-Au ores, involves addition of most of the same elements that were lost during albitization. The correlation between intensity of alteration, its distribution and timing (e.g., in breccias cored by ca. 1530–1500 Ma granitoids), and convergence of all rock types toward magmatic stable isotope values provides strong evidence for a substantial component of igneous-derived fluid. Simulations of the albitization process were carried out isothermally at 550°C and 350 MPa and polythermally from these conditions down to 400°C and 200 MPa, using the Gibbs minimization method with HCh software and the UNITHERM database. Both simple fluid-rock mixing models and more complicated reactor-style algorithms used a range of input fluids (from fluids equilibrated fluid with two-feldspar granite through to Na/K ratios consistent with fluid inclusion results) and geochemical data for initially unaltered wall rocks. The apparent paradox of widespread albitization resulting from fluid released by two-feldspar granites can be explained by relatively small shifts away from the K-feldspar-albite equilibrium curve, and even isothermal model fluids derived from two-feldspar granites produce albitites in calc-silicate rocks outboard of granite-proximal K-feldspar-clinopyroxene skarns, matching field patterns. Those models with fluid Na/K ratios similar to those of fluid inclusions produced the most realistic alteration assemblages, dominated by albite, for both isothermal conditions and decreasing temperature, which approximate those observed in the field. PIXE and microthermometric data on fluid inclusions from quartz in two-feldspar quartz monzonite and pegmatite at the top of the Mount Angelay pluton indicate bulk Na/K molar ratios in the fluid of between 10 and 20, considerably higher than our thermodynamically calculated values for fluid in equilibrium with two-feldspar granite of around 3 (at 550°C, 350 MPa). Such shifts may have been attained by admixture of magmatic-hydrothermal fluid with small amounts of NaCl brines trapped along grain boundaries in scapolite-bearing calc-silicate wall rocks, by fluid immiscibility due to high initial CO₂ contents in the felsic intrusions, by contributions from mafic magmas, or from dissolution of salt-rich layers into the intrusions prior to crystallization and fluid release. With increasing amounts of fluid-rock interaction in the models, the fluids were enriched in K, Fe, and Ca, approaching compositions observed in fluid inclusions in the ore deposits. These fluids, reacted with pelitic rocks (which are common ore hosts), would produce magnetite-clinopyroxene ± biotite-actinolite alteration at high temperature, similar to the proximal alteration around ore deposits. We infer that precipitation of sulfides in the Cu-Au deposits was the result of mixing of Cu-bearing brine, of ultimately magmatic origin, but modified extensively via albitization, with sulfur-bearing fluids or reaction of the brine with sulfur-bearing rocks. When Cu was absent from the initial magmatic fluid, barren ironstones may have been the result.

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