

The Lightning Creek Sill Complex, Cloncurry District, Northwest Queensland: A Source of Fluids for Fe Oxide Cu-Au Mineralization and Sodic-Calcic Alteration

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Abstract

The Lightning Creek Cu-Au prospect is hosted by a cogenetic suite of plutonic, I-type granitoids. The dominant rock type is a porphyritic quartz monzodiorite that is intruded by more fractionated rocks, including monzogranite and alkali feldspar granite. A series of flat-lying sills are interpreted to be late-stage differentiates, based on their timing, mineralogy, and chemistry.

In parts of the prospect there is pervasive sodic-calcic alteration (pyroxene after amphibole, albite after K feldspar and oligoclase) of the plutonic rocks. This alteration predates sill emplacement and is unrelated to veining or fracturing of any kind. The presence of small amounts of carbonate in the altered rocks suggests that the fluids were CO₂ bearing. Quartz and feldspar separates from these altered rocks have oxygen isotope compositions similar to those from fresh quartz-monzodiorite, suggesting that the fluids were hot and of magmatic composition. Sodium and Ca were added and K, Fe, Cl, and Cu were stripped during what is interpreted as an autometasomatic event.

The sills display considerable textural and mineralogical complexity and evolved from equigranular, quartzofeldspathic rocks (aplites), with magmatic chemistry, to unusual Fe-rich rocks (albite-magnetite-quartz) that exhibit a range of bizarre spherulitic textures. Some of the albite and magnetite in the sills is secondary. Albite forms pseudomorphs after K feldspar (Na-Fe ± Ca alteration) along sill margins and within sills, at the contacts between different textural zones. Halos of disseminated magnetite + clinopyroxene (Fe-Ca ± Na alteration) are developed adjacent to early magnetite veins.

Fluid inclusion studies indicate that these rocks crystallized at temperatures in excess of 500°C and at pressures in excess of 1.5 kbar. The range of spherulitic textures is taken to indicate crystallization under hydrous conditions with the episodic release of a fluid phase. This magmatic fluid phase was dominated by H₂O, CO₂, and chlorine and underwent phase separation into a CO₂-rich vapor and a hypersaline brine (33–55 wt % NaCl equiv). The hypersaline fluid was enriched in Fe (~10 wt %) and Cu (~1 wt %, PIXE analysis), in addition to Na, K, and Ca. Where this fluid was retained within Fe-rich portions of the sills, it caused Ca-Fe ± Na alteration (pyroxene-albite ± magnetite growth at the expense of quartz). Where the fluid was expelled from the sills, it produced quartz-magnetite ± clinopyroxene ± albite veins (broadly coeval with the early magnetite veins). Although rich in Cu, these granitoid-derived magmatic fluids did not generate significant Cu(-Au) mineralization, perhaps because of the high temperatures involved and/or a lack of reduced sulfur in the fluids or host rock. However, the amount of iron present is estimated (from the aeromagnetic anomaly) to be in excess of 2,000 million tonnes (Mt).

A later generation of calcite ± chlorite ± pyrite ± chalcopyrite veins contain traces of Cu-Au mineralization. Fluid inclusion and stable isotope work indicate that these veins probably crystallized from cooler (<200°C), more dilute (15–28 wt % NaCl equiv) fluids, perhaps generated by the admixture of a meteoric component.

The conclusions reached in this study have implications for understanding the genesis of Fe oxide Cu-Au deposits and related sodic-calcic alteration. The study indicates the potential for CO₂-rich granitoid magmas to evolve hypersaline, Fe- and Cu-rich fluids capable of causing intense magnetite veining and Cu(-Au?) mineralization. Autometasomatic sodic-calcic alteration of the granitoids may be an important precursor to mineralization, contributing Fe, K, Cu, and Cl to the magmatic fluids.