Geology, mineral zoning, and lithogeochemistry of hydrothermal alteration at the El Soldado Manto Type Copper Deposit, Chile

Ricardo Boric[1] and Marcos Zentilli
Department of Earth Sciences, Dalhousie University, Halifax, NS B3H 3J5
[1]Present address: Compañía Minera Disputada Las Condes (EXXON-MOBIL), Chile

The El Soldado deposit is a giant (>130 Mt @ 1.5% Cu), representative of volcanic-hosted, stratabound, epigenetic "manto" type deposits of the southern Central Andes. At the district scale the ore is restricted to the Lower-Cretaceous, shallow-marine Lo Prado Formation, composed of bimodal felsic and mafic flow lavas, dykes, and volcaniclastic sedimentary rocks. The deposit consists of numerous irregular ore bodies with intervening barren zones, distributed in clusters. Within the clusters individual subvertical fault-controlled ore bodies occupy a generally NS to NNW regional fracture system and their shape has been influenced by primary and secondary permeability. Brittle "trachyte" in domes and flows is preferentially mineralized.

Hypogene ore minerals are chalcopyrite, bornite, and chalcocite. Many individual ore bodies within a cluster are mineralogically zoned: a core of chalcocite-hematite or chalcocite-bornite-hematite is followed outwards by approximately concentric zones of bornite-chalcopyrite, chalcopyrite, chalcopyrite-pyrite, and pyrite in the most external zone. Part of this external pyrite is diagenetic, related to degraded petroleum, and some developed by sulphurization of Fe- and Ti-bearing minerals, in a pre-ore stage alteration.

Hydrothermal minerals are calcite, chlorite, albite, microcline, epidote, opaline silica, titanite and rutile-anatase, and some sericite and clay minerals. Destruction of titano-magnetite has reduced magnetic susceptibility. Geochemically, alteration caused an increase of $CaCO_3$ and redistribution of alkalis. Na/K increases in most ore zones. Alteration depleted Fe, Mg, and Mn, whereas Ti, Al, Y, Zr, and Nb behaved as relatively immobile elements. The mine unit traditionally called "trachyte" is rhyodacite, and that called "andesite" is, in part, basaltic andesite, both of which are of calc-alkaline affinity.

The evolving genetic model envisages that Cu ores formed about 20-30 My after host rock formation, diagenetic sulphidization, low-grade metamorphism, and tilting of the sequence. Basinal fluids (ca. 350°C, chlorine-rich, oxidizing, neutral to alkaline) extracted Cu from oxidized volcanic rocks

in the column. This mineralizing event (ca. 105 Ma) roughly coincides with the emplacement of the Cretaceous batholith that outcrops about 13 km from the mine and which has minor Cu skarns. However, El Soldado ores show no clear isotopic evidence for a direct magmatic kinship with this batholith.