

The Role of Organic Matter in the Genesis of the El Soldado Volcanic-Hosted Manto-Type Cu Deposit, Chile

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Abstract

Solid bitumen (residual petroleum) occurs intimately associated with sulfides in several manto-type Cu deposits of central Chile. El Soldado (32°38' S; 71°04' W) is one of the largest manto-type deposits (>130 million metric tons @ 1.5% Cu) and is hosted by rhyolites and andesites of the Lower Cretaceous Lo Prado Formation.

As a result of basinal burial in the Early Cretaceous back-arc basin, petroleum was generated from organic-rich shales in the underlying lower Lo Prado Formation and migrated into primary and structural porosity in the upper Lo Prado Formation. Migration was controlled by extensional basinal faults. Low-temperature (<90°C) biodegradation of petroleum developed an early stage I assemblage of (mostly framboidal) pyrite (\pm sphalerite \pm chalcopyrite). Geopetal structures related to pressure degassing of semi-solid petroleum suggest that migration occurred while the strata were horizontal, at ca. 130 Ma. Continued basinal burial led to thermal degassing, increased maturation, and solidification of the petroleum.

Low-grade regional (pumpellyite-prehnite) metamorphism of the sequence was followed, at ca. 110 to 103 Ma, by the influx of high-temperature (ca. 300°C), Cu-rich fluids concurrently with emplacement of the Cretaceous batholith into the basin. Basinal fluids were focused into a now tilted sequence by a brittle shear (north-south to north-northwest) fault system. Copper sulfides (stage II assemblage) replaced preexisting pyrite and bitumen, forming zoned orebodies with a central chalcocite-hematite zone, followed outward by bornite-chalcocite, chalcopyrite-bornite, and pyrite-chalcopyrite zones. The mineralizing fluids altered the bitumen thermally and chemically as follows: (1) reflectance (R_o) increased up to ca. 5 percent in the core of the orebodies against a background of ca. 3 percent; (2) anisotropy (nongranular, microscale, and domain) developed and the bitumen was locally graphitized; (3) chlorine (\pm Cu \pm Fe) was incorporated into the bitumen affecting its reflectance. The source of Cu was most likely the overlying oxidized volcanic pile; the Cu was transported as chloride (CuCl) complexes, precipitating where the CuCl-rich solutions reacted with bitumen (adsorption/reduction) and pyrite from the stage I assemblage.

The study demonstrates that in the Lower Cretaceous basin of Chile, degraded petroleum reservoirs can be important controls for metallic mineralization derived from hydrothermal solutions of different sources, particularly if biodegradation generated pyrite.