Geology of the Los Sulfatos Porphyry Copper-Molybdenum Deposit, Los Bronces-Río Blanco District, Central Chile

Juan Carlos Toro,[†] Jorge Zamorano, Marcial Pablo, and Esme Tristram

Anglo American Exploration Chile Limitada, Pedro de Valdivia 291, Providencia, Santiago, Chile

[†]Corresponding author: e-mail, jctoro@anglochile.cl

Los Sulfatos (7.5–6.3 Ma) is a recently discovered world-class porphyry system situated at the southern extremity of the Río Blanco-Los Bronces copper-molybdenum district (global resource exceeding 220 Mt of copper), within the late Miocene to early Pliocene magmatic arc of central Chile. Despite a history of exploration and mining in the district since the late 19th century, it was not until the past decade that Los Sulfatos became recognized as a very large, high-grade porphyry deposit. Currently still an exploration project, the inferred mineral resource at Los Sulfatos is 1,200 million tonnes (Mt) averaging 1.46% Cu and 0.02% Mo, and the potential mineral inventory is considered to be on the order of 4,000 to 5,000 Mt grading 0.8 to 1.0% Cu.

Copper and molybdenum introduction at Los Sulfatos occurred in spatial association with a multiphase porphyry and igneous/hydrothermal-cemented breccia complex emplaced into folded andesitic volcanic and volcaniclastic rocks of the Abanico and Farellones formations. At least two separate mineralized centers are recognized, one at La Paloma, and the other at Los Sulfatos (sensu stricto) 1 km southeast of La Paloma.

High-grade hydrothermally cemented breccias host much of the copper in both centers at Los Sulfatos. The breccia cement displays vertical zonation, with a shallow assemblage of tourmaline, pyrite, chalcopyrite, anhydrite, and specularite, and clasts altered to sericite with or without chlorite. At depth (400–700 m below surface), breccia textures become vaguer, hydrothermal biotite (locally chloritized) becomes more widespread, and chalcopyrite-bornite dominates the sulfide mineralogy to the exclusion of pyrite.

Los Sulfatos Stock

At least four discrete intrusive phases formed a composite granodiorite porphyry stock at Los Sulfatos. Earliest recognized are two porphyry phases with crowded textures, abundant plagioclase, and minor phenocrysts of quartz and mafic phases. A K-silicate assemblage (K-feldspar-biotite) containing chalcopyrite-bornite in sinuous ("A-type") quartz veinlets has affected these intrusions. Third in the intrusive sequence is a gray, intermineralization porphyry displaying fine-grained (chilled) margins against the crowded early porphyry intrusions. This intermineralization phase contains abundant A-type quartz veinlets with chalcopyrite. A late intermineralization granodiorite porphyry with a weak K-silicate assemblage and minor chalcopyrite, and lacking A-type veinlets, is the final intrusive phase recognized at Los Sulfatos. An assemblage of chlorite-sericite and later sericite-tourmaline overprints the original high-grade center of the porphyry deposits, where the A-type veinlet intensity is greatest. In this zone, chalcopyrite-pyrite has replaced the original chalcopyrite-bornite assemblage and locally reduced grades to <0.4% copper.

La Paloma Stock

Abundant quartz phenocrysts and a less crowded texture distinguish the La Paloma granodioritic-quartz dioritic porphyry center from the Los Sulfatos stock. The early porphyry phase contains abundant A-type and chalcopyrite-bornite veinlets, whereas two intermineralization facies are cut by only a few quartz veinlets and contain predominantly disseminated chalcopyrite ± bornite.

Remnants of advanced argillic alteration assemblages occur as veins and ledges of chalcedony, dumortierite, alunite, pyrophyllite, native sulfur, and pyrite; outcrops are present at the highest elevations (>4,600 m).

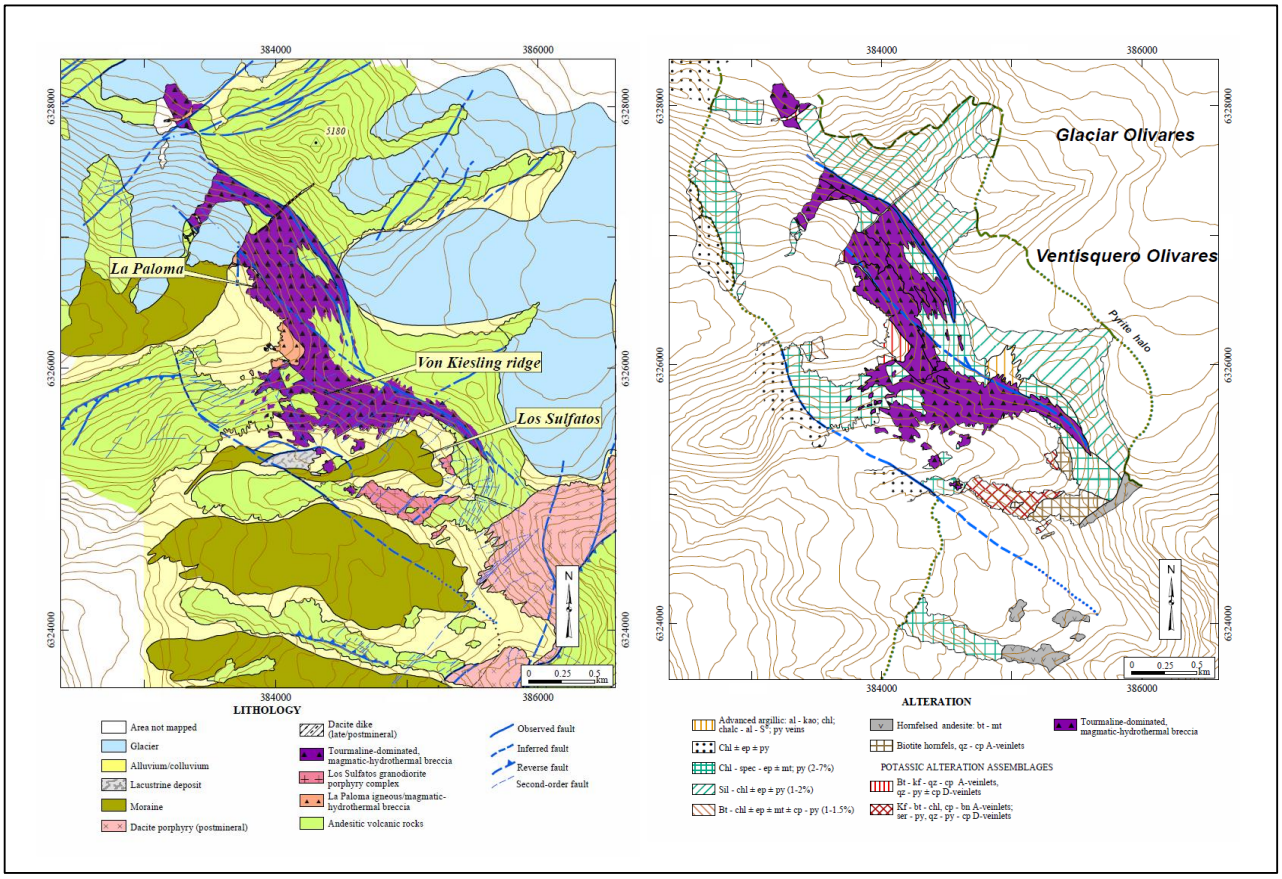

Fig. 1. Geology (lithology and alteration) of Los Sulfatos project.