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Geology of the Chuquicamata Mine: A Progress Report

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Abstract

Chuquicamata, in northern Chile, is the world's greatest copper orebody. It was controlled, from the initial intrusions (probably at 36–33 Ma) through mineralization (last major hydrothermal event at 31 Ma) to postmineral brecciation and offset, by the West fault system. East porphyry, West porphyry, Banco porphyry, and Fine Texture porphyry make up the Chuqui Porphyry Complex. East porphyry, the dominant host rock, has a coarse, hypidiomorphic-granular texture. Intrusive contacts between most porphyries have not been found, but early ductile deformation, subsequent pervasive cataclastic deformation, and faulting affects all of the rocks and makes recognition of intrusive contacts very difficult.

Potassic alteration affects all porphyries, comprises partial K feldspar and albite replacement of plagioclase, and more widespread biotite replacement of hornblende, with igneous texture largely preserved. It is accompanied by granular quartz and quartz-K feldspar veinlets, which contain only trace disseminated chalcopyrite ± bornite remains from this early stage. Fine-grained quartz-K feldspar alteration, with destruction of biotite and apparently following albitization of plagioclase, accompanies strongest cataclastic deformation and destruction of igneous texture. A band of quartz-K feldspar alteration, up to 200 m wide and 1,500 m long, lies along the southward extension of Banco porphyry dikes and is the locus of the bornite-digenite center of the sulfide zoning pattern. This passes east through chalcopyrite-bornite to chalcopyrite-pyrite as sulfide abundance fades out. Sulfides in quartz-K feldspar alteration are abundant only where there is intense crackle brecciation. Propylitic alteration is superimposed on biotitic alteration at the eastern edge of the deposit, but there is no pyritic fringe. Westward, this zoning is interrupted by the superposition of pyritic main-stage veins with pervasive quartz-sericite. Veins of quartz-molybdenite, up to 5 m wide and cutting all porphyries, were emplaced between the early and the main stages. These veins and early-stage quartz veins are commonly segmented and sheared, with fine recrystallization of quartz that eliminates all original fluid inclusions. It is not clear whether quartz-K feldspar alteration was formed later or earlier than quartz-molybdenite veins.

Main-stage veins were focused along a structural zone adjacent to the West fault. This stage is distinctly younger than early-stage mineralization, although it occupies many of the same structures and may involve massive remobilization of earlier mineralization. It may represent a more brittle and much shallower environment, which followed significant erosion of the upper parts of the early mineralization system. Main-stage veins with quartz, pyrite, chalcopyrite, and bornite were formed during dextral shear of the West fault system. The last mineralization of the main stage was enargite, digenite, covellite, pyrite, and minor coarse sphalerite, along with sericite, and locally alunite but only local traces of pyrophyllite and dickite. Some northwest enargite veins were apparently opened after the sense of shear on the West fault system changed to sinistral. Vein and veinlet filling faults and fault-related shatter zones contain the overwhelming proportion of copper at Chuquicamata in all

alteration zones and assemblages, including pyrite-free early-stage assemblages. Practically all of these fractures have been opened and mineralized more than once.

A still poorly understood late stage formed digenite with relatively coarse grained covellite from deep in the sericitic zone and flaring upward and outward under what became the supergene chalcocite enrichment blanket. The presence of associated anhydrite, typical also of earlier stages but largely leached or hydrated to gypsum by later supergene action, proves this is not supergene covellite, but it is otherwise very difficult to distinguish from supergene covellite. Rims of sphalerite on primary sulfides, almost invariably with inner rims of coarse-grained covellite and/or digenite, occur below the chalcocite blanket from which Zn has been leached. The sphalerite rims are interpreted by most as supergene, but the close association with apparently late hydrothermal covellite-digenite and their absence in all other porphyry copper deposits suggests they too may be hydrothermal.

A partially preserved leached capping and oxide copper ore, replacing an upper chalcocite blanket, overlie a high-grade supergene chalcocite body that extends up to 800 m in depth in the zone of fault brecciation and pervasive main-stage sericitic alteration. Some leached copper moved laterally to form exotic copper oxides and silicate in adjacent gravels. Continued movement on the West fault produced a wide zone of brecciation and major displacements of mineralized rock. Net sinistral displacement of about 35 km is indicated by regional mapping, but the details of how much of each stage of mineralization was displaced and how far on which splits of the fault are not well understood. The uniqueness of Chuquicamata is due to its intimate and complex relationship with active regional faulting and to superposition of at least two distinct periods of mineralization.