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Porphyry-Epithermal Transition: Maricunga Belt, Northern Chile

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Abstract

The Refugio, Aldebarán, and La Pepa districts in the Maricunga belt of northern Chile contain advanced argillic alteration zones that locally host high-sulfidation epithermal gold deposits in proximity to porphyry gold (± copper) deposits. The spatial association suggests a genetic link. Mineralized zones are characterized by four main vein types that formed at different times and have specific zonal relationships.

A-veinlets are the earliest and deepest vein type. They are restricted to potassic alteration zones in intrusive rocks. A-veinlets contain variable amounts of quartz, magnetite, biotite, and chalcopyrite and locally have K feldspar halos. They have nonmatching, irregular vein walls and lack internal symmetry. Hypersaline liquid-rich inclusions coexisting with vapor-rich inclusions in A-veinlets indicate temperatures as high as nearly 700°C and pressures between 200 and 400 bars. Assuming a lithostatic load, depths of 0.8 to 1.6 km are inferred. Zones of abundant A-veinlets contain mostly <1 ppm gold and 0.1 to 0.4 percent hypogene copper.

Banded quartz veinlets occur mostly above A-veinlets and cut A-veinlets where they overlap. Dark gray bands, the color resulting from a high density of vapor-rich fluid inclusions and micron-sized grains of magnetite, commonly occur as symmetric pairs near the vein walls. Vein walls are parallel and slightly wavy, vuggy vein centers are common, and alteration envelopes are absent. Data from rare liquid-rich inclusions in banded quartz veinlets indicate temperatures =350°C at pressures between 20 and 150 bars. Assuming a hydrostatic load, depths of 0.2 to 1.5 km are inferred. Zones of abundant banded quartz veinlets generally contain 0.5 to 2 ppm gold and <0.1 percent hypogene copper.

D-veins are pyrite veins with quartz-sericite-pyrite halos. They are widespread and crosscut A-veinlets and banded quartz veinlets. The brittle nature of D-veins and limited fluid inclusion data suggest temperatures <400°C. D-veins serve as important time lines. They are nowhere truncated or crosscut by intrusions, A-veinlets, or banded quartz veinlets.

Quartz-alunite replacement veins, referred to as ledges in this paper, are typical of the high-sulfidation epithermal environment. They are mostly limited to overlying volcanic rocks. They contain local core zones of vuggy residual quartz that can contain enargite or, at higher elevations, barite. Of the three districts studied only La Pepa has mineable quartz-alunite ledges, which contain an average gold grade of about 20 ppm.

A spectrum of porphyry-style deposits exists. Cerro Casale at Aldebarán shares many characteristics of porphyry copper deposits worldwide, whereas Verde at Refugio is a true porphyry gold deposit. Potassic alteration zones and A-veinlets are strongly developed at Cerro Casale, whereas they are absent at Verde. Banded quartz veinlets predominate at Verde, whereas they occur only at the upper levels of Cerro Casale. The Pancho deposit at Refugio and the Cavancha deposit at La Pepa are telescoped systems in which banded quartz veinlets overprint potassic alteration zones and A-veinlets.

A-veinlets and banded quartz veinlets cut and are cut by intrusions, indicating multiple cycles of intrusionÆpotassic alterationÆA-veinletsÆbanded quartz veinlets during formation of porphyry-style mineralization. Banded quartz veinlets are thought to have formed by flashing of magmatic fluids during episodic transitions from lithostatic to hydrostatic pressure. Loss of sulfur to the vapor phase during flashing inhibited formation of copper-sulfides in banded quartz veinlets and, therefore, resulted in high gold/copper ratios. Where rising magmatic vapors condensed into overlying meteoric water along faults, barren quartz-alunite ledges formed. This conclusion is supported by equivalent $^{40}Ar/^{39}Ar$ dates on hydrothermal biotite associated with porphyry-style ore and alunite from barren ledges at Aldebarán.

$^{40}Ar/^{39}Ar$ dates at La Pepa indicate alunite formed at least 140,000 years to as long as 900,000 years after hydrothermal biotite. Within the high-sulfidation epithermal environment, the development of ore depends on the ability of late, moderate-salinity magmatic fluids to reach the surface without condensing a brine upon ascent. Cooling and boiling of the moderate-salinity fluid below its critical temperature results in the formation of sericite at depth and alunite near the surface that is essentially synchronous with high-sulfidation ore formation. The timing of the switch from lithostatic pressures to brittle hydrostatic

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conditions, relative to the life of the hydrothermal system, might determine how much porphyry-style ore forms relative to high-sulfidation epithermal ore.