

Porphyry Gold Deposits of the Refugio District, Maricunga Belt, Northern Chile

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Abstract

The porphyry gold deposits of the Refugio district and similar deposits in the Maricunga belt contain the lowest known copper to gold ratios (% Cu/ppm Au = ~0.03) of any porphyry-type deposit. The gold deposits are associated with subvolcanic andesitic to dacitic intrusions emplaced into coeval volcanic rocks. Both the Verde and Pancho deposits are zoned in space from a deeper zone of banded quartz veinlets associated with chlorite-magnetite-albite and/or pyrite-albite-clay alteration to a shallow zone of pyrite-albite-clay and local quartz-alunite ledges. Pancho contains an additional, deepest, porphyry copperlike zone, with quartz veinlets (A-veinlets) and potassic alteration. Relative to Verde, Pancho is telescoped, with all three zones present within a 400-m-vertical interval.

The porphyry copperlike zone at Pancho is characterized by A-veinlets and pervasive potassic alteration, both restricted to intrusive rocks. A-veinlets range from hairline streaks of magnetite ± biotite with minor quartz and chalcopyrite, and K feldspar alteration envelopes to sugary quartz veinlets <1 cm in width with magnetite and chalcopyrite and no alteration envelopes. Hypersaline liquid inclusions coexisting with vapor-rich inclusions indicate temperatures above 600°C and salinities as high as 84 wt percent NaCl equiv. A pressure estimate of 250 bars indicates a depth of 1,000 m, assuming lithostatic pressure. Potassic alteration consists of a central zone of magnetite-K feldspar-oligoclase that changes outward to a biotite-rich zone. Total sulfide content, predominately as chalcopyrite, is generally <1 vol percent, whereas magnetite content is 2 to 5 percent. Where A-veinlets and potassic alteration predominate, grades are typically 0.1 wt percent hypogene copper and 0.5 to 1 ppm gold.

Banded quartz veinlets are present at both Verde and Pancho, where they occur mostly above A-veinlets and cut A-veinlets where they overlap. They are less than 2 cm in thickness and lack alteration envelopes. Dark gray bands, whose color is due to abundant vapor-rich fluid inclusions and micrometer-sized grains of magnetite, commonly occur as symmetric pairs near the vein walls. The bands are commonly botryoidal and are continuous through quartz grains, suggesting that the quartz recrystallized from a silica gel. Rare liquid-rich fluid inclusions in quartz indicate temperatures =350°C and salinities <35 wt percent NaCl equiv. Estimated pressures are <200 bars, suggesting depths of 190 to 1,500 m under hydrostatic pressure. Gold occurs both in the dark bands with magnetite and outside the dark bands with pyrite, chlorite, illite, and K feldspar. Banded veinlets occupy steeply dipping radial and shallowly dipping concentric fractures. Zones of abundant banded veinlets without early A-veinlets generally contain 0.5 to 2 ppm gold and <0.05 wt percent hypogene copper.

Most of the differences between porphyry gold deposits at Refugio and porphyry copper deposits can be attributed to shallower depths of formation—less than 1 km compared to 1.5 to 4 km that is typical for porphyry copper deposits. Shallower depths resulted in lower sulfide concentrations, local garnet veinlets, widespread albite-bearing alteration, and most importantly banded quartz veinlets, which are unique to porphyry gold deposits. Banded quartz veinlets are a direct result of episodic intrusion of magma to within 1 km of the surface and exposure of high-temperature magmatic fluids to hydrostatic pressures. Episodic rupturing of a brittle-ductile boundary surrounding the intrusive centers at Verde and Pancho led to flashing of magmatic fluids, loss of sulfur to vapor, and low sulfide/gold ratios in ore.