

## Skarns Related to Porphyry-Style Mineralization at Caicayén Hill, Neuquén, Argentina: Composition and Evolution of Hydrothermal Fluids

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### Abstract

Located in the Main Cordillera of northwest Neuquén, Argentina, the Caicayén district shares the following features with Cu skarn-porphyry copper deposits in other parts of South, Central, and North America, as well as Asia and the South Pacific: (1) alteration and mineralization are related to I-type, magnetite series, calc-alkaline porphyritic sills of intermediate composition with stockwork veining, brittle fracturing, and brecciation; these are features indicative of a relatively shallow environment of formation (~500 bars); (2) skarns have an oxidized mineralogy dominated by garnet (Ad<sub>45-97</sub>), clinopyroxene (Hd<sub>18-60</sub>), epidote, and hematite-magnetite; (3) skarns contain up to 15 percent sulfides (pyrite >> pyrrhotite-chalcopyrite) and locally are associated with distal massive magnetite and hematite lodes; (4) massive silica-pyrite bodies replace prograde skarn and marble; (5) pyroxene-skarn and silica-pyrite alteration distal to the potassic core are Fe and Zn enriched, respectively; (6) mineralized igneous rocks exhibit characteristic early potassic-propylitic and late phyllic alteration that in the skarns can be correlated with prograde garnet-pyroxene and retrograde silica-pyrite, respectively; and (7) Cu-Au anomalies occur in exposures within the potassic and phyllic halos.

Fluid inclusions from igneous rocks record multiple fluid events: (1) a hypersaline inclusion population (up to 67 wt % NaCl equiv for halite + sylvite-bearing inclusions, 2-36 wt % KCl equiv, and 31-45 wt % NaCl equiv) that homogenized by salt dissolution between 355° and 400°C, interpreted to have been trapped at a lithostatic pressure of approximately 500 bars; (2) a second hypersaline inclusion population that homogenized by vapor bubble disappearance at 215° to 385°C and may have been trapped at similar temperatures but lower pressures relative to the first population; and (3) a population of coexisting NaCl-saturated inclusions (average salinity of 35 wt % NaCl equiv) and vapor-rich inclusions in igneous rocks close to skarn homogenized at similar temperatures (326°-360°C) that may have formed from boiling of a low-salinity fluid (up to 8 wt % NaCl) at hydrostatic pressures of 120 to 170 bars. Skarn minerals also record hypersaline fluids with similar homogenization temperatures to those measured in nearby igneous rocks but have slightly lower salinities (23.3-26 wt % NaCl equiv). Inclusions from limestone next to skarn have similar homogenization temperatures and salinities (33 wt % NaCl equiv) to skarn and igneous rock inclusions. As evidenced by boiling fluids in the phyllic zone and supercritical fluids in silicopyrite, hydrostatic regime dominated during retrograde alteration of skarn and porphyry-style alteration. The vapor phase formed by boiling fluids in igneous rocks nearby skarn produced a vapor plume that may be responsible for retrograde alteration and also of cavernous porosity in carbonate rocks at the skarn front.

Overall, Caicayén is similar to worldwide copper skarn systems emplaced at shallow levels, but it lacks multiple intrusive phases and successive fluid pulses; thus, resulting in lower copper grades than mined in other copper skarns.