

Hydrothermal Fluid Provenance and Evolution in the Epithermal Polymetallic Deposit of Colquijirca: Insights from In Situ Oxygen Isotope Analyses and Fluid Inclusions in Quartz

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Previous studies tackled the importance of mixing between low to moderately saline hydrothermal fluids of magmatic origin and meteoric water in ore deposition in epithermal Cordilleran deposits. Colquijirca is one of the major porphyry-related deposits belonging to the Miocene polymetallic belt in central Peru. It is an 8-km-long mineralized corridor replacing carbonates at shallow depth and exhibiting a well-defined lateral polymetallic mineralization zonation from high- to intermediate-sulfidation assemblages and, finally, carbonates outward. Previous bulk O-H isotope analyses on alunite, kaolinite, dickite, and quartz evidenced mixing between magmatic fluid and meteoric water during mineralization.

In this study, we combine fluid inclusion microthermometry and secondary ion mass spectrometry (SIMS) of in situ $\delta^{18}\text{O}$ and trace element variations in quartz to track and assess the impact of fluid mixing at different stages of mineralization. We analyzed O isotopes (^{16}O , ^{18}O) and trace elements (Li, Al, Ti, Fe) with the SwissSIMS 1280HR (University of Lausanne, Switzerland) across growth bands previously identified by scanning electron microscopy-cathodoluminescence (SEM-CL) on quartz sections prepared perpendicular to the c-axis. Spatial resolution is typically about 15 to 20 μm for O isotopes and 20 μm for trace element analyses. Fluid inclusion petrography based on SEM-CL images allowed us to perform microthermometry on primary and pseudosecondary fluid inclusion assemblages.

Microthermometry yields a narrow range of homogenization temperatures between 230° and 281°C, with a majority of temperatures clustering around 250°C. Salinities calculated on the basis of final ice melting temperatures show important variations from 0.6 to 12 wt % NaCl equiv. The obtained $\delta^{18}\text{O}$ isotopic signatures vary between 2.8‰ and 18.8‰, with up to 15.8‰ variation within a single crystal. Despite these important variations, most of the data cluster between 15.8‰ and 18.8‰. The variations between the lowermost values and the values around 15.8‰ and 18.8‰ are generally sharp on a 20- μm scale. The lowermost values are found in bands rarely exceeding 100 μm in thickness, which, in places, contain inclusions of hematite. They also are associated with the lowermost salinities (0.8–1.7 wt %) found in fluid inclusions. In contrast, the salinity of inclusions found in growth bands with $\delta^{18}\text{O}$ of about 16‰ to 18‰ ranges between 2.2 and 12 wt % NaCl equiv. The determined trace element contents show no clear correlation with the observed $\delta^{18}\text{O}$ variations or with fluid inclusion results. Finally, the zoning revealed by SEM-CL does not correlate with trace element composition. Assuming that precipitation occurred at equilibrium, and using temperatures obtained through microthermometry, we can calculate the $\delta^{18}\text{O}$ of the mineralizing fluids. This shows that the system as a whole is dominated by a fluid with magmatic signature with $\delta^{18}\text{O}$ ranging between 7‰ and 10‰. Incursions of a fluid of dominantly meteoric origin, recorded by the thin bands, with $\delta^{18}\text{O}$ as low as -7‰, are only episodic.