

Mineralogic and Stable Isotope Zonation at the Surface over the El Salvador Porphyry Copper Deposit, Chile

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Abstract

We examined in detail the mineralogic and stable isotope characteristics of alteration minerals exposed at the surface of the El Salvador porphyry copper deposit. A total of 276 samples was collected from 203 localities over an area of $>5 \text{ km}^2$ at elevations between 2,900 and 3,300 m. The alteration assemblages can be separated into two groups, broadly corresponding to the stages previously identified from underground studies, although the early stage K silicate alteration identified underground is not evident at the surface. A transitional to late stage is characterized at the surface by assemblages of (1) muscovite-andalusite with trace diaspore (including some areas rich in andalusite) and (2) muscovite with trace diaspore. There is a sharp contact outward with a marginal propylitic assemblage (chlorite-calcite-epidote). Pyrophyllite occurs as a retrograde overprint of muscovite in both of the transitional to late-stage assemblages. These assemblages are concentrically zoned and centered on a core of least-altered granodiorite porphyry, a late intramineral intrusion. The muscovite-andalusite assemblage occurs up to 500 m away from the granodiorite porphyry, and andalusite-rich zones are located near the brecciated margin of the porphyry. Further outward is the muscovite zone, from 500 to 1,500 m wide. The pyrophyllite overprint overlaps the contact of the muscovite-andalusite and muscovite zones, and occurs mainly above 3,000 m elevation, such that its present distribution is controlled largely by topography. Very late alteration minerals occur in radial pebble dikes of hydrothermal breccia and their extensions, and they are dominated by an advanced argillic assemblage of alunite-(\pm aluminum phosphate-sulfate minerals)-diaspore-zunyite-pyrophyllite-dickite, with residual muscovite. In one case a breccia extends upward and appears to be the root of a 300 \times 500 m outcrop, 80 m thick, of massive quartz-alunite replacement of rhyolite.

Pure mineral separates were prepared from these samples for O, H, and S isotope analysis, including 48 samples of silicate minerals (muscovite, pyrophyllite, dickite, and supergene kaolinite), and 20 samples of alunite, some supergene in origin. Information on mineral assemblage was used to estimate temperatures of formation, which then allowed calculation of the isotopic composition of associated hydrothermal fluids. The fluid responsible for forming the muscovite had a relatively narrow range of isotopic composition, 6.5 ± 1.5 per mil $\delta^{18}\text{O}$ and -40 ± 10 per mil δD . The heaviest $\delta^{18}\text{O}$ and δD values, about 8 and -35 per mil, respectively, were obtained from the samples with andalusite-muscovite-diaspore assemblage. This composition is close to that expected for a magmatic fluid, with <10 to 20 percent meteoric-water component responsible for forming the other muscovite samples. The fluid compositions calculated for the very late stage alunite range from 5 and -30 per mil to -1 and -40 per mil $\delta^{18}\text{O}$ and δD , respectively. This range in composition agrees with the trend predicted for magmatic vapor absorbed by local groundwater, the latter similar in composition to that responsible for forming the supergene kaolinite. There is no systematic spatial zonation of the alunite samples in terms of isotopic composition or paleotemperature. The temperature estimates from S isotope geothermometry are higher than those based on mineral assemblage, possibly caused by partial supergene replacement of some hypogene alunites.

There is no strong isotopic zonation of hydrothermal minerals from surface alteration assemblages at El Salvador that can be applied to generate clear exploration guidelines. By contrast, mapping of alteration mineralogy in the field, backed up by laboratory checking of mineralogy and examination of relict minerals and replacement textures in thin section, clearly indicates the center of the late intramineral intrusion.