

Atacamite Inclusions in Rock-Forming Feldspars and Copper-Bearing Smectites from the Radomiro Tomic Mine, Chile: Copper-Insoluble Mineral Occurrences

GEORGE H BRIMHALL,[†]

Department of Earth and Planetary Science and the Earth Resource Center, University of California at Berkeley, Berkeley, California
94720-4767

BEATRIZ LEVI,

Kallforsvägen 8, SE-12432 Bandhagen, Sweden

JAN OLOV NYSTRÖM,

Swedish Museum of Natural History, Box 50007, SE-10405 Stockholm, Sweden

AND ENRIQUE TIDY F.

Exploration Division, CODELCO, Santiago, Chile

Abstract

Recovery of copper from the Radomiro Tomic deposit in Chile employs innovative large-scale hydrometallurgical extraction methods, with sulfuric acid used for heap leaching. Here, we report on improvements in understanding mineral components of copper oxide ores, which are insoluble in acid leach solutions, in order to advance leaching technology. Using optical, electron microprobe, X-ray diffraction, energy dispersive spectroscopy, and least squares inversion methods, two different occluded mineral occurrences were discovered in oxide ores, which present two distinct metallurgical challenges for heap leaching but offer important new opportunities in process mineralogy. First, in a high chloride to sulfate ratio, feldspar-stable portion of the orebody at Radomiro Tomic, disseminated atacamite ($\text{Cu}_4\text{Cl}_2(\text{OH})_6$) inclusions, 1 to 8 μm in diameter, occur in microfractured feldspars and biotites. These account for the acid-insoluble fraction, often as high as 30 percent of the total contained copper. About 70 percent of the total copper occurs generally as atacamite in cracks, which upon crushing is exposed along surfaces of the rock fragments and is hence soluble. In contrast, in more intensely hydrothermally altered, feldspar destructive, weak argillic alteration zones, insoluble copper exists more probably within the crystal structure of well-crystallized saponitic smectite clays in nonexchangeable, octahedral crystallographic sites. The two different forms of applied acid-insoluble components are products of contrasting microchemical environments, one in a reactive potassic alteration gangue and the second in a nonreactive gangue. In both cases, however, the nature of hydrothermal alteration, though pervasive, was relatively weak and left intact rock mineral buffers capable of neutralizing acidic and reducing fluids. Hence, the insoluble components with respect to the applied sulfuric acid reflect strong wall-rock mineral assemblage control on the behavior of copper on all scales: the macrofield zonal scale, the microscale of individual crystals in cracks, and the atomic scale of octahedral sites in the clay structure.

The metallurgical implications of these atacamite microinclusions in rock-forming minerals and structurally bound copper in smectites are different. In the former case, exposing ore inclusions on fragment surfaces would require extremely costly grinding to a grain size well below 400 mesh. Secondly, chemical extraction of microinclusion copper from feldspar host phases would entail high acid consumption, as hydrolysis of feldspars by chemical reaction with applied acid would occur causing neutralization. In the case of Cu smectites, since the copper occurs in structurally bound, nonexchangeable sites, processes to remove the copper via ion exchange or acidic leach cannot work. Alternatives to ion exchange could involve destroying the smectite host mineral, perhaps by its conversion to kaolinite that may only incorporate copper or other divalent cations in negligible amounts. □