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Efflorescent iron sulfate minerals: Paragenesis, relative stability, and environmental impact

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ABSTRACT

This study of a pyrrhotite-dominated massive sulfide deposit in the Blue Ridge province in southwestern Virginia shows that sulfate minerals formed by the oxidation of the pyrrhotite transform from one to another by a combination of oxidation, dehydration, and neutralization reactions. Significant quantities of sulfate minerals occur in the underground adits (Area I) and under overhangs along the high sidewall of the adjoining open pit (Area II). Samples from this site were analyzed to determine mineralogy, equilibrium relative humidity, chemical composition, and acid generation potential. In Area I, pyrrhotite oxidizes to marcasite + melanterite, which eventually oxidizes to melanterite + sulfuric acid. Melanterite is extruded from the rocks as a result of the volume change associated with this reaction. It accumulates in piles where halotrichite, copiapite, and fibroferrite form. In Area II, $FeSO_4$ solutions produced by pyrrhotite oxidation migrate to the exposed pit face, where they evaporate to form melanterite. The melanterite rapidly dehydrates to form rozenite, which falls into a pile at the base of the wall, where melanterite, copiapite, and halotrichite are present. The observed paragenesis can be understood using a $\log a_{O_2} - \log a_{H_2O}$ diagram that we developed from published thermodynamic data and observations of coexisting phases.

Dissolution experiments showed that fibroferrite-rich samples had the highest acid producing potential, followed by copiapite-rich samples and then halotrichite-rich samples. The most abundant metals in solutions produced by dissolving impure bulk samples of the salts were Mg, Al, Zn, Cu, Ca, and Pb. The molar concentrations of the metals varied with mineralogy. However, all of the sulfate minerals release metals and acid when they dissolve and therefore represent a potentially significant environmental risk.