

## **Evidence for syngenetic micro-inclusions of As<sup>3+</sup>- and As<sup>5+</sup>-containing Cu sulfides in hydrothermal pyrite**

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### **ABSTRACT**

Most frequently arsenic is nominally monovalent (As<sup>1-</sup>) in pyrite (FeS<sub>2</sub>) and substituted for S. Nominally trivalent arsenic (As<sup>3+</sup>) has been reported previously in hydrothermal Peruvian pyrite and was considered to be substituted for Fe based on the negative correlation between the concentrations of the two elements. Here, we provide the first observation of the incorporation of As<sup>3+</sup> in goldfieldite [Cu<sub>12</sub>(As,Sb,Bi)<sub>2</sub>Te<sub>2</sub>S<sub>13</sub>] and As<sup>5+</sup> in colusite [Cu<sub>26</sub>V<sub>2</sub>(As,Sb)<sub>4</sub>Sn<sub>2</sub>S<sub>32</sub>] inclusions in As<sup>1-</sup>-pyrite from high-sulfidation deposits in Peru. This information was obtained by combining spatially resolved electron probe (EPMA), synchrotron-based X-ray fluorescence (SXRF), and absorption spectroscopy (micro-XANES and micro-EXAFS) with new high energy-resolution XANES spectroscopy (HR-XANES). The two Cu sulfide inclusions range from several to one hundred micrometers in size, and the As<sup>3+</sup>/As<sup>5+</sup> concentration varies from a few parts per million (ppm) to a maximum of 17.33 wt% compared to a maximum of 50 ppm As<sup>1-</sup> in pyrite. They also contain variable amounts of Sn (18.47 wt% max), Te (15.91 wt% max), Sb (8.54 wt% max), Bi (5.53 wt% max), and V (3.25 wt% max). The occurrence of As<sup>3+</sup>/As<sup>5+</sup>-containing sulfosalts in As<sup>1-</sup>-containing pyrite grains indicates that oxidizing hydrothermal conditions prevailed during the late stage of the mineralization process in the ore deposits from Peru. From an environmental perspective, high concentrations of potentially toxic As, contained in what appear to be non-As-bearing pyrite, may pose a heretofore unrecognized threat to ecosystems in acid mine drainage settings. More generally, the combination of techniques used in this study offers a new perspective on the mineralogy and crystal chemistry of hazardous elements in pyrite, such as highly toxic and little studied thallium.

**Keywords:** Pyrite, goldfieldite, colusite, arsenic, high-sulfidation deposits