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Native gold enrichment process during growth of chalcopyrite-lined conduits within a modern hydrothermal chimney (Manus Basin, PNG)

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Abstract

Seafloor hydrothermal chimneys from back-arc basins are important hosts for metals such as Cu, Zn, Pb, Ag, and Au. Although the general growth history of chimneys has been well documented, recent studies have revealed that the fine-scale mineralogy can be highly complex and reflects variable physicochemical conditions of formation. This study utilized a novel combination of scanning electron microscopy (SEM)-based electron backscattered diffraction (EBSD) and synchrotron X-ray fluorescence microscopy (SXFM) to uncover the detailed growth processes of multiple chalcopyrite-lined conduits within a modern chalcopyrite-sphalerite chimney from Manus Basin and to assess the controls on native gold precipitation. On the basis of previous studies, the chimney conduit was thought to develop from an initial sulfate-dominated wall, which was subsequently dissolved and replaced by sphalerite and chalcopyrite during gradual mixing of hydrothermal fluids and seawater. During this process, sphalerite was epitaxially overgrown by chalcopyrite. Accretionary growth of chalcopyrite onto this early formed substrate thickened the chimney walls by bi-directional growth inward and outward from the original tube wall, also enclosing the outgrown pyrite cluster. A group of similar conduits with slightly different mineral assemblages continued to form in the vicinity of the main conduit during the further fluid mixing process. Four types of distinct native gold-sulfide/sulfosalt associations were developed during the varying mixing of hydrothermal fluids and seawater. Previously unobserved chains of gold nanoparticles occur at the boundary of early sphalerite and chalcopyrite, distinct from gold observed in massive sphalerite as identified in other studies. These observations provide baseline data in a well-preserved modern system for studies of enrichment mechanisms of native gold in hydrothermal chimneys. Furthermore, native gold is relatively rarely observed in chalcopyrite-lined conduit walls. Our observations imply that: (1) native gold is closely associated with various sulfides/sulfosalts in chalcopyrite-lined conduit walls rather than limited to the association with tennantite, Bi-rich minerals, and bornite as reported previously; and (2) the broad spectrum of gold occurrence in chalcopyrite-line conduits is likely to be determined by the various mixing process between hot hydrothermal fluids with surrounding fluids or seawater. Quantitative modeling of fluid mixing processes is recommended in the future to probe the precise gold deposition stages to efficiently locate gold in modern hydrothermal chimneys.

Keywords: Seafloor hydrothermal chimneys, gold, sulfides, fluid mixing, EBSD, synchrotron XFM