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Formation of bonanza Au-Ag-telluride ores in epithermal systems: Constraints from Cu-O isotopes and modeling

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Abstract

The formation of bonanza Au-Ag-telluride ores in adularia-sericite epithermal deposits is hypothesized to be attributed to the input of magmatic fluid into flow systems dominated by barren meteoric water. However, understanding of the role and importance of magmatic fluids in the formation of bonanza ores remains limited. To address these concerns, we conducted Cu isotope analyses of chalcopyrite, which coexists with Au-Ag-tellurides in the Te-rich Sandaowanzi deposit located in northeastern China, as well as ore-bearing quartz veins, coeval igneous rocks, and older igneous rocks that underlie the deposit. To aid interpretation, we use geochemical modeling techniques along with O isotope data from calcite and quartz, as well as thermal outputs from modern geothermal systems.

At Sandaowanzi, the δ^{65}Cu values of chalcopyrite vary widely, ranging from 0.48 to 0.86‰. These values are higher than underlying Early Jurassic monzogranite (−0.06 to 0.27‰), as well as coeval Early Cretaceous andesite and basaltic andesite (0.01 to 0.11‰) and Early Cretaceous dacite and granodiorite (0.33 to 0.52‰). The O values of calcite vary from −3.2 to 6.7‰. The present isotope data, together with previous δ^{18}O analyses of quartz, support the idea that the fluids responsible for ore formation at Sandaowanzi were derived from a magmatic source. Progressive input of magmatic fluids into convecting meteoric water explains the telluride precipitation. Subsequent boiling can explain Au, Ag, and Cu precipitation in the upwelling limb of convection cells. Injection of high-temperature magmatic fluids (~300 °C) into shallow meteoric groundwater (~250 °C) and formation of Au-Ag-telluride ores can take place over a relatively short timeframe, typically around 1000 years. In contrast, the process of electrum precipitation occurs at a later stage compared to the formation of Au-Ag-telluride ores in the boiling zones (<300 °C). These findings indicate that Au-Ag-telluride precipitation occurs at the mixing interface under high temperatures (>300 °C), suggesting that it is located at greater depths compared to typical Au-Ag mineralization in adularia-sericite epithermal systems.

Keywords: Cu-O isotopes, modeling, magmatic fluids, bonanza ores, Au-Ag-tellurides, epithermal deposit