American Mineralogist, Volume 106, pages 410–429, 2021

Fluid source and metal precipitation mechanism of sediment-hosted Chang'an orogenic gold deposit, SW China: Constraints from sulfide texture, trace element, S, Pb, and He-Ar isotopes and calcite C-O isotopes

Lin Yang[1], Qingfei Wang[1,*], Ross R. Large[2], Indrani Mukherjee[2,†], Jun Deng[1], Huajian Li[1], Huazhi Yu[1], and Xuan Wang[1]

[1]State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China
[2]Centre for Ore Deposit and Earth Sciences (CODES), University of Tasmania, Private Bag 126, Hobart, Tasmania 7001, Australia

Abstract

The source of fluids and their mechanism of metal precipitation in sediment-hosted, disseminated orogenic gold deposits are ambiguous. Pyrite texture, trace element, S, Pb, and He-Ar isotope compositions of sulfides and C-O isotope data of calcite from Chang'an orogenic gold deposit in the Ailaoshan orogenic belt, southwest (SW) China, were studied to provide a new genetic model for the sediment-hosted orogenic gold deposit, furthering knowledge of the source of fluids and their mechanism of metal precipitation. Orebodies at Chang'an are mainly hosted by Ordovician turbidite with a few in Oligocene syenite. Two stages of mineralization have been identified in the deposit: stage I disseminated quartz-arsenopyrite-pyrite and stage II veined quartz-calcite-polymetallic sulfides. Five generations of pyrite have been identified in turbidite: pre-ore syn-sedimentary pyrite, py_{I-1}, and py_{I-2} in stage I, and py_{II-1} and py_{II-2} in stage II, and an unzoned pyrite population developed in syenite. Py_{I-1} commonly overgrows syn-sedimentary pyrite with irregular boundaries and contains arsenopyrite, galena, chalcopyrite, and electrum inclusions along the boundaries. Py_{I-1} is overgrown by thin and inclusion-free py_{I-2}, and crosscut by py_{II-1}, which is rimmed by py_{II-2}.

The syn-sedimentary pyrite is distributed parallel to the sedimentary bedding and contains As (620.8 ppm), Pb (61.6 ppm), Ni (59.8 ppm), Mo (54.4 ppm), Co (23.4 ppm), and Cu (13.0 ppm) with low-Au content of 0.06 ppm. This pyrite has $\delta^{34}S$ values of –18.1 to +30.4‰ and high-radiogenic Pb isotope ratios (average $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ of 19.05, 15.86, and 39.87, respectively). Py_{I-1} and coexisting arsenopyrite are enriched in invisible Au (up to 227.1 and 353.3 ppm, respectively), As, Ni, Cu, and Pb, while py_{I-2} contain much lower trace element abundances relative to py_{I-1} and arsenopyrite. Partial replacement of syn-sedimentary pyrite by py_{I-1} plus arsenopyrite, galena, chalcopyrite, and electrum, and similar Pb isotope ratios between syn-sedimentary pyrite and py_{I-1} indicate that reaction of external deep Au-rich fluids with syn-sedimentary pyrite is responsible for gold precipitation in stage I. Py_{I-1}, arsenopyrite, and py_{I-2} show a narrower $\delta^{34}S$ range of –3.2 to 7.1‰ relative to syn-sedimentary pyrite, demonstrating that the fluid-pyrite interaction has homogenized the sulfur. The unzoned pyrite in syenite has similar mineral inclusions (arsenopyrite, galena, etc.), $\delta^{34}S$ values (+0.6 to 6.3‰) and Pb isotope ratios to py_{I-1}, but much lower trace element abundances relative to py_{I-1}. It may be attributed to different reactions of similar fluids with different wall-rocks. Py_{II-1} and py_{II-2} in stage II contain elevated As, Pb, Cu, Sb, Zn, and Ag with low mean Au content (3.3 ppm) and have $\delta^{34}S$ ranges of –2.8 to +1.2‰ and –6.2 and –0.8‰, respectively. Galena in stage II has lower radiogenic Pb isotope ratios than stage I pyrites, indicative of a different Pb source or fluid evolution. The gases released from a mixture of py_{II-1}-py_{II-2} have R/Ra of 0.38 to 0.98 and $^{40}Ar^{*}/^{4}He$ of 0.50 to 1.34, falling between the fields of mantle-derived and crustal fluids. Late ore calcites have $\delta^{13}C_{PDB}$ of –8.7 to 2.7‰ and $\delta^{18}O_{SMOW}$ of 8.05 to 25.58‰, also plotting between sedimentary carbonate and mantle fields. These signatures indicate that ore fluids in stage II are base metal-rich fluids with a small amount of contribution from the mantle. Different ore assemblages, trace element composition and isotope data between stages I and II at Chang'an suggest that the deposit experienced an evolution from early Au-rich fluids to late base metal-rich ones. This study highlights that ore metals in sediment-hosted disseminated orogenic gold deposits may be sourced from both deep fluids and local wall-rock, and that fluid-rock interaction behaved as a key control on ore precipitation.

Keywords: Pyrite texture, trace element, in situ S-Pb isotopes, sediment-hosted gold deposit, Chang'an, Ailaoshan