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Decoding the origin of the newly discovered Ag-Cu-(Ni-Co-As-Bi-Hg-U) ore shoots in Aouli Pb-Zn fault-fill veins (Morocco): insights from fluid inclusion microthermometry and copper and iron isotopes

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This contribution provides the first microthermometric measurements along with Cu and Fe isotope data for the newly discovered Ag-Cu-(Ni-Co-As-Bi-Hg-U) ore shoots in the Aouli Pb-Zn fault-fill veins to further constrain metal sources, flow paths and redox processes that governed the formation of these ore shoots. The Aouli deposit is amongst the top three largest argentiferous Pb-Zn vein-type producers of Morocco, with significant Ag output averaging 350 g/t. The orefield consists of subparallel, open-space fillings of mostly ENE-WSW, WNW-ESE, and E-W trans-tensional steeply dipping veins, veinlets, and en echelon tension gashes and breccia veins. Besides the early Pb-Zn stage I, an unusual "five elements" hydrothermal stage II is recognized. In this latter stage, polymetallic mineralization occurs as patchy and discontinuous ore shoots with the ore mineralogy comprising a complex sequence of native metals (i.e., Ag and Bi), Ni-Co-Fe arsenides, Ag-As-Sb sulfides, and sulfosalts, set in a matrix of quartz, fluorite, and barite. Fluid inclusion microthermometry shows that the ore-forming fluids correspond to evolved $NaCl-CaCl_2$ basin-derived hot (50-180°C), saline fluids with total salinities varying in a wide range from 4.2 to 23.7 wt.% equiv. ($CaCl_2$ + NaCl). The homogenization temperatures are consistent with the formation temperature estimated from the GGIMFis sphalerite geothermometer. Moreover, copper and iron isotope compositions of chalcopyrite separate show large variations in $\delta^{65}Cu$ and $\delta^{56}Fe$ ranging from -2.32 to 1.51‰ $\delta^{65}Cu$ with a mean value of 0.02‰ (± 1.00‰ 2σ, n = 14) and from -0.24 to 2.03‰ $\delta^{56}Fe$ averaging 0.64‰ (± 0.68‰ 2σ, n = 9). Remarkably, the distribution of the $\delta^{65}Cu$ vs. $\delta^{56}Fe$ values shows a distinct positive correlation which is interpreted as a mixing trend. Collectively, the combination of fluid inclusions microthermometry and copper and iron isotope data suggests that the Aouli Ag-Cu-(Ni-Co-As-Bi-Hg-U) ore precipitated from mixing and subsequent redox processes between two Ca-Na-rich and Na-only rich saline fluids of ca. 19 wt.% equiv. NaCl and low-salinity meteoric fluid.