Fluid Inclusion and Carbon-Oxygen Isotopes Studies of Synmetamorphic Cu Deposits Hosted in the Paleoproterozoic Sedimentary Rock, Zhongtiao Mountains, China

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The Hujiayu Cu deposit, located in the Zhongtiao Mountains district in the southern edge of the North China Craton, is primarily hosted in graphite-bearing schists and dolomitic marbles. The ore-forming processes occurred during the regional deformation and lower amphibolite metamorphism of the host Paleoproterozoic sedimentary rock. The copper mineralization is composed of veinlets and disseminated sulfides of early stage and dolomite-quartz-sulfide veins of late stage. The early mineralization is generally conformable to the schist foliation corresponding to the peak metamorphism and the late thick veins formed during retrograde metamorphism.

This Cu deposit provides an excellent chance to test the genetic association between regional metamorphism and copper mineralization. Four fluid inclusion types were recognized in quartz from the late stage veins, including CO_2-rich inclusions (type I), low-salinity, liquid-dominated, biphase aqueous inclusions (type II), solid-bearing aqueous inclusions (type III), and solid-bearing aqueous-carbonic inclusions (type IV). Various fluid inclusion assemblages (FIAs) were identified through petrographic observation, and were classified into four groups. The group-1 FIAs, consisting of monophase CO_2 inclusions, homogenized into the liquid phase in a large range of temperatures from -1° to 28°C, suggesting postentrapment modification. The group-2 FIAs consists of type I, III, and IV inclusions, and is interpreted to reflect fluid immiscibility. The halite melting temperatures ranged from 530° to 562°C for type IIIb and type IV inclusions deprecated at 204° to 208°C. The group-3 FIA comprises type II and III inclusions, and the group-4 FIA consists of type II inclusions with consistent phase ratios. The homogenization temperatures for type II inclusions range from 132° to 170°C for group-3 FIAs and 115° to 219°C for group-4 FIAs. The group-1 and group-2 FIAs are interpreted to be entrapped during mineralization, whereas group-3 and group-4 FIAs probably represent the post-mineralization fluids. Laser Raman and SEM-EDS results show that the gas species in fluid inclusions are mainly CO_2 with minor CH_4, and the solids are dominated by calcite and halite. The calcite in the hosting marble and dolomite in the hydrothermal veins have $\delta^{13}C_{V\text{-}PDB}$ values of -0.2 to 1.2‰ and -1.2 to -6.3‰, and $\delta^{18}O_{V\text{-}SMOW}$ values of 14.0 to 20.8‰ and 13.2 to 14.3‰, respectively.

The fluid inclusion and carbon-oxygen isotope data suggest that the ore-forming fluids were probably derived from metamorphic fluids, which had reacted with organic matter in sedimentary rocks or graphite and undergone phase separation at 1.4 to 1.8 kbars and 230° to 240°C, after peak metamorphism. It is probable that fluid immiscibility caused the effective precipitation of chalcopyrite and quartz during the retrograde metamorphism. It is proposed that the Hujiayu Cu deposit consists of two mineralization stages. Early stage mineralization, characterized by disseminated and veinlet copper sulfides, probably took place in an environment similar to sediment-hosted stratiform copper mineralization. Ore minerals formed in this precursor mineralization stage were remobilized and enriched in the late metamorphic hydrothermal stage, leading to the formation of thick quartz-dolomite-sulfides veins.