

Geology, isotope geochemistry, Ar-Ar and U-Pb geochronology constraints on the genesis of the Liyuan lode gold deposit, northern Shanxi Province, central North China Craton

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The Liyuan lode gold deposit is located in the northern Shanxi Province, central part of the North China Craton. The gold orebodies are mainly hosted in the Neoproterozoic Fuping Group metamorphic rocks and structurally controlled by the NNE-trending faults (and their subsidiary faults). Gold mineralization occurs as disseminated, stockworks, and auriferous quartz-sulfides veins/veinlets within the hydrothermally altered rocks. Ore-related hydrothermal alterations include potassic, silicic, sericite, chlorite, pyrite, and carbonate alterations. The mineralization can be divided into three stages based on mineral assemblages and crosscutting relationships: (1) quartz-pyrite stage, (2) quartz-polymetallic sulfides stage, and (3) quartz-carbonate stage. Gold mainly introduced in the second stage, and occurring as electrum and kuesterite enclosed in pyrite or along the microfractures of sulfides and quartz. Previous studies suggest that the ore-forming fluids of Liyuan gold deposit belong to the $\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}\pm\text{CH}_4$ system with the characteristics of medium temperature, enrichment of CO_2 , and medium-low salinity, which are very similar to orogenic-type gold deposits worldwide.

Isotope systems (Ar-Ar, U-Pb, C, O, S and Pb) were investigated from the Liyuan deposit as clues to determine the age and genesis of this deposit. One hydrothermal sericite sample associated with gold mineralization were collected from the pyritic phyllic alteration zone and yielded an $^{40}\text{Ar}/^{39}\text{Ar}$ isotopic plateau age of 133.3 ± 1.2 Ma, which is consistent with zircon U-Pb age (134.1 ± 1.1 Ma) of the quartz porphyry dikes in the Liyuan gold mine, indicating a close temporal and possibly genetic relationship between gold mineralization and granitic magmatism in the region during early Cretaceous.

The sulfur isotope compositions of pyrite from stage I have a narrow range from -0.3 to 4.1 ‰, indicating a deep-seated magmatic source. However the sulfides from the second stage have lower $\delta^{34}\text{S}$ values of -7.2 to 3.0 ‰, illustrating that the ore-forming fluids gradually became SO_4^{2-} -enriched and relatively oxidized during Au mineralization. The Pb isotopic composition of the sulfides from the orebodies and K-feldspars of quartz porphyry dikes from Liyuan gold deposit are very similar, which demonstrates that the Pb of gold ores and quartz porphyry was both originated from the lower crust. The $\delta^{13}\text{C}_{\text{V-PDB}}$ values of calcite from the late quartz-carbonate stage vary from -9.6 to -3.6 ‰, which correspond to the range of magmatic carbon (-9 to -3 ‰) and that of mantle carbon (-5 to -2 ‰), suggesting the ore-forming fluids originated from the deep magmatic sources, and the $\delta^{18}\text{O}_{\text{V-SMOW}}$ ranging from 12.1 to 16.1 ‰, reflecting a low temperature alteration process. Due to the lack of granite plutons at the present mining levels, we speculate that the ore-forming fluids may have been exsolved from a concealed granite body at greater depth or directly transported from depth via deep faults.

Based on the regional geology, ore geology, C-O-S-Pb isotope geochemistry, age of mineralization, and tectonic setting, we suggest that the Liyuan deposit belongs to orogenic gold deposit that located in the interior North China Craton, and probably related to thecoevalgranitic magmatism during early Cretaceous.