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Genesis of the Heiniuao gold deposit, Baoshan block, Sanjiang Region: Constraints from fluid inclusion, stable isotope and sulfide trace element studies

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The Heiniuao gold deposit is located in the northwestern segment of the Longyang Au−Fe−Pb−Zn polymetallic ore cluster, in the northern Baoshan block, Sanjiang region, SW China. The ore cluster is characterized by Fe-Pb-Zn skarn mineralization formed at ~120 Ma in the center of the cluster and the Heiniuao Au mineralization that is more distal. The genesis of the Heiniuao deposit and its relationship to the skarn deposits is unclear. All orebodies in the Heniuao deposit are hosted in the Upper Cambrian calcareous slate and siltstone of the Hetaoping Formation, and they are controlled by NS-striking faults. Three main paragenetic stages of mineralization have been recognized based on petrographic observation: pyrite−arsenopyrite−quartz (stage I), base-metal-sulfide-pyrite-quartz-calcite (stage II), and quartz−calcite−chlorite (stage III).Three types of fluid inclusions were identified in the quartz and calcite from the stages I to III in Heiniuao, including liquid-rich (L type), vapor-rich (V type) and solid-bearing (S type) inclusions. The S type inclusions only occur in stage I quartz. The fluid inclusions from stage I homogenized at 185−326°C (mainly at 220−250°C), with eutectic temperature of -48.5°C to -36.7°C and salinities of 4.2−16.5 wt.% NaCl eqv. The fluid inclusions from stage II homogenized at 155−281°C (mainly at 190−230°C), with eutectic temperature of -51.6°C to -37.5°C and salinities of 2.5−17.6 wt.% NaCl eqv. The stage III fluid inclusions homogenized at 116−202°C (mainly at 150−170°C), with eutectic temperature of -45.5°C to -37.5°C and salinities of 3.4−15.9 wt.% NaCl eqv. The microthermometry reveals that the ore-forming fluid at the Heiniuao gold deposit is in the $H_2O-NaCl-CaCl_2$ fluid system. The carbon and oxygen isotopes of calcite show $\delta^{13}C$ and $\delta^{18}O$ values, respectively, ranging from -13.4‰ to -6.8‰ and 9.1‰ to 9.6‰ in stage II, and from -8.1‰ to -1.5‰ and 6.4‰ to 8.2‰ in stage III. The bulk marble and calcareous slate samples together have $\delta_{13}C$ and $\delta^{18}O$ values from -3.0‰ to -0.7‰ and 7.8‰ to 11.9‰, respectively. This suggests that the carbon has a mixed source of magmatic fluid and from wallrock and organic matter in the local strata. The $\delta^{18}O(H_2O)$ values of the ore-forming fluid vary from 1.6‰ to 2.5‰ in stage I, from -6.2‰ to +0.6‰ in stage II, and from -10.8‰ to -2.5‰ in stage III. This reveals that the fluid in stage I is mainly magmatic water, whereas the fluid in stage III is close to meteoric water. Combining this with the XNaCl of the ore-forming fluid that declines with the drop of fluid temperature, this evolution is considered the result of mixing with Ca-rich formation water. The sulfide $\delta^{34}S$ values range from -5.7‰ to +4.6‰ (mean=0.3‰, n=19), agreeing with the interpretation obtained from the C-O-H isotopes and fluid inclusions. LA−ICP−MS analysis of sulfides provide another line of evidence for the magmatic origin. The stage I pyrite has Cu/Ni ratios greater than 1, and a high concentration of gold; in contrast, the stage II pyrrhotite has a very low concentration of gold. This suggests that the Heiniuao deposit was probably a distal part of the Longyang skarn ore system.