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Petrography, geochemistry and U-Pb dating of garnet from the Yongping skarn-type Cu-W deposit, South China: Implications for hydrothermal evolution and mineral exploration

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The association of metal minerals in skarn deposits is common (e.g., Cu-Mo, W-Sn). Among these, Cu-W systems are notable for distinct zonation patterns, typically featuring Cu in shallow zones and W in deeper regions. However, the formation of Cu-W co-mineralization remains debated, particularly regarding whether it results from a single evolving fluid event. To address this, we investigate the genesis, exploration potential, and timing of the Yongping stratabound Cu-W skarn deposit in the South China Block (SCB). Utilizing garnet mineralogy, in-situ geochemistry, and U-Pb dating, we constrain fluid evolution, metal precipitation mechanisms, and hydrothermal centers.

The linear relationship between Y and REE in garnet, alongside consistent REE patterns across different mineralization sectors, strongly indicates a closed fluid system derived from a single magmatic-hydrothermal source. Garnets exhibit distinct core-mantle-rim zoning. Al-rich cores feature high heavy rare earth elements (HREE) and high field strength elements (HFSE) with low LREE/HREE ratios, indicating a low water/rock (W/R) ratio and an acidic environment linked to early diffusion-controlled metasomatism. Conversely, Fe-enriched mantles show depleted HREE and HFSE, elevated LREE/HREE ratios, and significant Eu anomalies. This reflects intense fluid interactions at higher W/R ratios and infiltration metasomatism, enhancing permeability for subsequent Cu-W mineralization. Garnet rims retain core-like major element features but exhibit marked REE, Fe, and W depletion. This points to a return to low W/R ratios following fluid exhaustion; the resulting pH increase from carbonate neutralization facilitated early Cu and W co-precipitation.

Spatially, garnets near the hydrothermal center display higher and more uniform Fe/Al ratios, elevated LREE, lower Mn levels, and minimal oscillatory zoning. These features align perfectly with observations in the southern sector, highlighting its favorable exploration potential. Finally, in-situ garnet U-Pb dating yields 161–158 Ma, recording skarn formation and providing a maximum age constraint on mineralization. This Late Jurassic timing coincides with regional tectonic extension and the shift from Cu- to W-dominated metallogenesis in South China, suggesting Yongping formed precisely during this metallogenic transition.