Geology, geochemistry, and duration of the magmatic–hydrothermal event at the Wenquan porphyry molybdenum-copper deposit, West Qinling orogen, China*

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Studies on porphyry deposits of the Qinling orogen have important implications for the genesis of such deposits during crustal evolution, and also provide insight into how porphyry deposits evolve, both geochemically and dynamically. However, compared to Jurassic-Cretaceous East Qinling orogen, the largest Mo province worldwide, the porphyry Mo systematics in the Triassic West Qinling Orogen remain poorly understood.

The Wenquan Mo-Cu deposit is closely associated with the concentrically zoned multiphase Wenquan batholith in the West Qinling orogen. Characteristics of the exposed part of the oval-shaped batholith, including abundant mafic micro-granular enclaves, lack of oriented structures, high SiO₂, Al₂O₃, and alkali concentrations, enrichment in LILE and LREE, and depletion in HFSE, indicate that it is the product of passive emplacement in an extensional environment.

The composite intrusion ranges in composition from granodiorite to porphyritic monzogranite, and has zircon U-Pb ages ranging from 224.6±2.5 to 216.2±1.7 Ma, the youngest phase being porphyritic and spatially associated with Mo mineralization. Zircon ε⁵⁷⁹⁰(t) data indicate that mixing between a mafic magma derived from Neoproterozoic sub-continental lithosphere mantle and felsic melts formed in the lower continental crust resulted in a hybrid magma. Re-Os dates on molybdenite are between 212.7±2.6 and 215.1±2.6 Ma, consistent with the age of the ore-bearing phase of the batholith, indicating a close temporal and thus possible genetic relationship between molybdenite mineralization and granitic magmatism, which took place during initial tectonic relaxation following collision of the North and South China Blocks. This period also corresponds to metamorphism and deformation in the South Qinling terrane along the suture and the exhumation of the Dabie-Sulu ultrahigh pressure metamorphic rocks to the east.

Three distinct types of hypogene alteration are developed at the Wenquan deposit, including an early potassic assemblage that occurs in the mineralized rock. A propylitic assemblage concentrically surrounds the potassic zone. Both of these assemblages have been overprinted locally by phyllic alteration, which is associated with the highest Mo-Cu grades. The high content of SiO₂ (~71.21%), and alkali elements (Na₂O+K₂O=8.22%, K₂O > Na₂O) of the unaltered porphyries are similar to typical Mo-bearing granitoids worldwide. Fluid inclusion waters extracted from Mo-bearing quartz have δD values of -96 to -68‰, whereas the calculated δ¹⁸O_H₂O values range from 8.0 to 9.5‰. These stable isotopes indicate that ore fluid was likely magmatic in origin, with the addition of minor amounts of meteoric water. The δ³⁴S values of pyrite and molybdenite vary between 5.02 to 5.66 ‰. These values are typical of many porphyry Mo deposits, and strongly suggest a magmatic source for the sulfur at Wenquan.
Zircon ages of multiple intrusive phases indicate the episodic growth of the Wenquan batholith lasted nearly 10 myr. Overlapping mineralization ages correlate with the youngest intrusive phase and do not necessarily indicate a prolonged hydrothermal episode responsible for Mo mineralization due to multiple intrusive episodes. Potassium-argon cooling ages of biotite (ca. 209 Ma) suggest relatively rapid cooling rates after cessation of igneous activity.