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Diagenetic and Metallogenic Geochronology Study and the Geological Features of Jiangligou W-Cu-Mo Polymetallic Deposit, West Qinling

LU Dongyu¹, YE Huishou², YU Miao^{2,3}, CHAO Weiwei¹, WANG Peng¹ and ZHANG Jiexian¹

1 Faculty of Earth Science and Mineral Resources, China university of Geosciences, Beijing 100083, China

2 MLR Key Laboratory of Metallogeny and Mineral Assessment, Institute of mineral Resources, Academy of Geological Sciences, Beijing 100037, China

3 School of Earth and Space Sciences, Peking University, Beijing 100871, China

1 Geological Features of the Deposit

Jiangligou tungsten-copper-molybdenum polymetallic deposit is located in the Gangcha overturned anticline, Qinghai Nanshan fold belt, western part of West Qinling orogenic belt. The strata cropped out in the mining area are mainly the Lower Permian Daguanshan group, consisting of sandstone, conglomerate, siltstone, fine sandstone, slate and marble; The Lower Triassic Longwuhe group, which composed of tuffaceous sandstone, calcareous siltstone and slate. Intrusive rocks, named Jiangligou complex, are complex granites combined by three intrusions, including porphyritic granite, granite porphyry and fine-grained granite in order of intrusive timing. Skarn type tungsten (Cu, Mo) ores mainly occur as bedded, lenticular and pod forms between porphyritic granite and marble of Lower Permian strata or tuffaceous sandstone of the Lower Triassic Longwuhe group. While the greisens-type tungsten ore bodies and porphyry-type molybdenum ore bodies are host in the Jiangligou complex pluton. The metal reserve of tungsten has been estimated around 50,000 tons with average grade of 0.82% and highest grade of 11.36%, and the Cu and Mo ore bodies also can be recoverd as byproducts. This deposit can be characterized by four mineralization stages: skarn stage, retrograde alteration stage, early-quartz-sulfide stage, late-quartz-sulfide stage and quartz-carbonate vein stage. Skarn stage: scheelite distributed in the skarn zone, formed by contact metasomatism during the intrusion of granitoids, between garnets and diopside. The retrograde aleration stage: the garnet and diopside were alerated into tremolite, epidote, chrysotilum. Early-quartz-sulfide stage: the cholpyrite and the pyrrhotite mainly formed in the skarn zone. Late-quartz -sulfide stage: lead-zinc quartz vein occured along the fault in marble; Quartz-carbonate vein stage: formed quartzcarbonate veins intersecting early mineralized quartz veins. Meanwhile the granite developed a wide range hydrothermal alteration, the alteration mineral mainly contains K-feldspar, quartz, sericite, greisen, chlorite, epidote displaying the typical characteristics of porphyry skarn deposits.

2 The Diagenetic and Metallogenic Age

The precise LA-MC-ICPMS zircon U-Pb dating results showed intrusive timing of porphyritic granite is 228.3 ± 2.2 Ma (MSWD = 1.4), granitic porphyry is 219.6 ± 1.9 Ma (MSWD = 1.8) and fine-grained granite is 217 ± 2.5 Ma (MSWD = 1.4), respectively, indicating that the Jiangligou granite complex diagenesis occured in the Late Triassic.

Molybdenite Re-Os isotope dating of 16 samples from Jiangligou W-Cu-Mo Polymetallic deposit yields model age ranging from 213.2 ± 3.4 Ma to 219.6 ± 3.5 Ma, with weighted age of (216.85 ± 0.77 Ma) (MSWD = 1.01), while isochron age of (217 ± 1 Ma) (MSWD = 1.4). The above results suggest the Jiangligou W-Cu-Mo Polymetallic deposit mineralization formed in late Triassic.

These results also suggest that the intrusive age of the earliest pluton of the Jiangligou W-Cu-Mo Polymetallic deposit does not match the mineralization age with a gap of 11Ma. But, the age of middle and the late intrusive ages and mineralization ages are consistent within the error range. Mineralization of tungsten and molybdenum in the Jiangligou W-Cu-Mo Polymetallic deposit is mainly developed within granitic porphyry, porphyritic granite as well as the associated outer contact zone. But not all of the contact zone display skarn and mineralization between porphyritic granite and marble. Skarns and mineralization

^{*} Corresponding author. E-mail: ludongyu1989@163.com

only occur in the contact within a certain range near the middle and late intrusions. To sum up, the porphyritic granite caused heat contact metamorphism. Then, the granite porphyry and fine-grained granite intrusived and caused contact metamorphism and mineralization. Combined with regional metallogenic regularity that the Jiangligou W-Cu-Mo Polymetallic deposit formed in magmatic hydrothermal metallogenic system related to the emplacement in late Triassic.

3 The Features of Fliuid Inclusion and S/H/O Isotopes

Based on petrography study of garnet and quartz veins, fluid inclusions are mainly divided into four types as follows: two-phase type (gas and liquid), single-phase type (gas, liquid), sub-crystal type(brine or sylvite) and threephase type inclusions containing liquid CO₂, bubble CO₂ and aqueous. Liquid immiscibility has been observed in the quartz vein as the fluid inclusions in different types, vaporrich, acqueous-rich with brine, fluid inclusions, same homogenized in the temperature. The homogenization temperatures of two phases type fluid inclusions in the garnets and quartz of orebody range from 450° to 550°; The homogenization temperatures of two phases and single phase type inclusions in the quartz of copper-rich quartz vein range from 280° to 340°; The homogenization temperatures of two phases type fluid inclusions in the quartz-carbonate veins mainly concentrated around 180°; The temperature evolution displays wide variation of the ore-forming fluid from high temperature to low temperature; coincident with salinity from high salinity (30% to 60%) to the low salinity (3.94% to 12.47%). Fluid inclusions raman spectroscopy gas composition analysis showed that the gas composition is rich in CH₄, CO₂ and H₂S. Group inclusions composition analysis showed: fluid rich in Na⁺, Mg²⁺, Ca²⁺, SO₄²⁻, F⁻, Cl⁻, and small amount of NO₃⁻, HCO₃⁻. H-O isotopic analysis showed δD data under the original magmatic water indicated magma degassing occurred. The early sulfide stage H-O isotopes show a magmatic fluid character. But the quartz-carbonate H-O isotopes data falls near the meteoric water line, showing the meteoric mixing feature. (Zhang Hui, 2013, He Mouchun, 2010, unpublished data)

4 Metallogenic Model

The fine-grained granite and granite porphyry, products of magmatic evolution of the Jiangligou W-Cu-Mo polymetallic deposit intruded in late Triassic, in contact with the porphyritic granite, Lower Permian and Lower Triassic strata. Simultaneously large amounts of fluids cause extensive metasomatism and forming porphyryskarn type alteration and mineralization. Diagenesis and metallogenesis belong to the same magmatic-fluid activity occured in the Late Triassic Age. Skarn stages: the fluid characted by high temperature, high oxygen fugacity, rich in volatiles, meanwhile S²⁻ activity is low, no sulfide precipitation occurred in this stage. However, the scheelite precipitated, [WO₄]²⁻ complex anion migrated and combined with the Ca2+ came from the host rock or retrograde alteration. Quartz sulfide stage:fluid pressure and temperature decreased after mixed with meteoric water in contact zone and tectonic fractures, causing the escape of CO₂, F, CL and H₂0, increasing of pH, reducing of xidation. Then, complex decomposition, Cu2+,Fe2+ and Mo^{2+} combined with S^{2-} due to the changing of conditions, forming the orebodies. Quartz-carbonate stage: oreforming fluid containing CO₂ and CH₄, mixed with meteoric water leading to temperature and salinity decrease and formation of veins along the fracture or cross the early formation.

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