

Zircon and molybdenite geochronology and geochemistry of the Kalmakyr porphyry Cu–Au deposit, Uzbekistan: implications for mineralization processes

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Copper and gold mineralization of the giant Kalmakyr porphyry deposit (2 Gt @ 0.4% Cu, 0.6 g/t Au) in Uzbek Tien Shan occurs as stockworks, veinlets and disseminations in the phyllic and K-silicate alteration zones developed predominantly in a middle to late Carboniferous intrusive complex composed of monzonite and granodiorite porphyry. Zircon U–Pb dating yielded an age of 327.2 ± 5.6 Ma for the ore-hosting monzonite and an age of 313.6 ± 2.8 Ma for the ore-bearing granodiorite porphyry. Re–Os dating of molybdenite from stockwork ores yielded model ages from 313.2 to 306.3 Ma. These results indicate that Cu–Au mineralization post-dated the emplacement of the monzonite, started right after the emplacement of the granodiorite porphyry, and lasted for ca. 7 Ma afterward.

The high rhenium concentrations of molybdenite (98 to 899 ppm) indicate major mantle contribution of rhenium and by inference ore metals. The relatively high $\text{Eu}_N/\text{Eu}_N^*$ values (average 0.68), $\text{Ce}^{4+}/\text{Ce}^{3+}$ values (average 890) and Ce/Nd values (average 36.8) for zircon grains from the granodiorite porphyry than those from the monzonite (average $\text{Eu}_N/\text{Eu}_N^*=0.33$, average $\text{Ce}^{4+}/\text{Ce}^{3+}=624$, average Ce/Nd=3.9) suggest that the magma for the syn-mineralization granodiorite porphyry has higher oxygen fugacity than that for the pre-mineralization monzonite.

Based on these data, it is proposed that while the monzonite was emplaced, the oxygen fugacity and volatile contents in the magma were relatively low, and ore metals might disperse in the intrusive rock, whereas when the granodiorite porphyry was emplaced, the oxygen fugacity and volatile contents in the magma were increased, favoring copper and gold enrichment in the magmatic fluids. The Kalmakyr deposit formed from a long-lived magmatic-hydrothermal system connected with fertile magmatic sources in relation to the subduction of the Turkestan Ocean beneath the Middle Tien Shan.