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Quartz textures, trace elements, fluid inclusions, and in situ oxygen isotopes from Aktogai porphyry Cu deposit, Kazakhstan

Changhao Li[1,2], Ping Shen[1,2,3,*], Reimar Seltmann[4], Di Zhang[3,5], Hongdi Pan[6], and Eleonora Seitmuratova[7]

[1]Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[2]Institutions of Earth Science, Chinese Academy of Sciences, Beijing 100029, China
[3]University of Chinese Academy of Sciences, Beijing 100049, China
[4]Center for Russian and Central EurAsian Mineral Studies, Natural History Museum, London SW7 5BD, U.K.
[5]State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[6]College of Earth Sciences, Chang'an University, Xi'an 710054, China
[7]Laboratory of Geological Formations, K. Satpaev Institute of Geological Sciences, Almaty 050010, Kazakhstan

Abstract

The Paleozoic Aktogai Group in Kazakhstan ranks among the 30 largest porphyry Cu deposits globally. The Aktogai deposit is the largest one in the Aktogai Group and is characterized by intensive potassic alteration where the dominant orebody occurred. However, its mineralization processes still need to be clarified. Our investigation focused on the texture, trace elements, fluid inclusions, and in situ oxygen isotopes of the quartz from the ore-related tonalite porphyry and associated potassic alteration at Aktogai to trace the deposit's mineralization processes. Ti-in-quartz thermobarometry, fluid inclusion microthermometry, and geological characteristics indicate that the ore-related magma at Aktogai originated from a shallow magma chamber at ~1.9 ± 0.5 kbar (~7.2 ± 1.9 km) and intruded as the tonalite porphyry stock at ~1.7–2.4 km. The potassic alteration and associated Cu mineralization comprise five types of veins (A1, A2, B1, B2, and C) and two types of altered rocks (biotite and K-feldspar). Among them, nine types of hydrothermal quartz were identified from early to late: (1) VQ_{A1} in A1 veins and RQ_{bt} in biotite-altered rocks; (2) VQ_{A2} in A2 veins and RQ_{kfs} in K-feldspar altered rocks; (3) VQ_{B1} in B1 veins and VQ_{B2E} in B2 veins; and (4) quartz associated with Cu-Fe sulfides (VQ_{B2L}, VQ_{BC}, and VQ_C) in B and C veins. Titanium contents of the quartz decreased, while Al/Ti ratios increased from early to late. Fluid inclusion microthermometry and mineral thermometers reveal that VQ_{A1}, RQ_{bt}, and hydrothermal biotite formed under high-temperature (~470–560 °C) and ductile conditions. VQ_{A2}, RQ_{kfs}, VQ_{B1}, and hydrothermal K-feldspar formed during the transition stage from ductile to brittle, with temperatures of ~350–540 °C. The rapid decrease in pressure from lithostatic to hydrostatic pressure led to fluid boiling and minor involvement of meteoric water (~11–14%) in the mineralizing fluid. Extensive recrystallization in VQ_{A1} to VQ_{B1} was associated with repeated cleavage and healing of the intrusion. With cooling, K-feldspar decomposition and hydrolysis increased. Fluid cooling and water-rock reactions resulted in the co-precipitation of Cu-Fe sulfides, white mica, chlorite, VQ_{BC}, and VQ_C at temperatures of ~275–370 °C and brittle conditions. The Paleozoic Aktogai deposit exhibits formation depths and fluid evolution processes similar to Mesozoic and Cenozoic porphyry Cu deposits worldwide. The close association between Cu-Fe sulfides and later quartz formed under intermediate-temperature conditions at Aktogai implies that Cu-Fe sulfides are not precipitated under early high-temperature conditions in porphyry Cu deposits.

Keywords: Fluid evolution, emplacement depth, fluid source, Ti-in-quartz thermobarometry, Central Asian Orogenic Belt