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Quartz texture and the chemical composition fingerprint of ore-forming fluid evolution at the Bilihe porphyry Au deposit, NE China

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Abstract

Quartz is widely distributed in various magmatic-hydrothermal systems and shows variable textures and trace element contents in multiple generations, enabling quartz to serve as a robust tracer for monitoring hydrothermal fluid evolution. This study demonstrates that integrated high-resolution SEM-CL textures and trace element data of quartz can be used to constrain physicochemical fluid conditions and trace the genesis of quartz in porphyry ore-forming systems. The Bilihe deposit is a gold-only porphyry deposit located in the Central Asian orogenic belt, NE China. Four quartz generations were distinguished following a temporal sequence from early-stage dendritic quartz, unidirectional solidification textured quartz (UST quartz), gray banded vein quartz (BQ), to late-stage white calcite vein quartz (CQ), with the Au precipitation being mostly related to dendritic quartz, UST quartz, and BQ. The well-preserved dendritic quartz with sector-zoned CL intensities and euhedral oscillatory growth zones crystallized rapidly during the late magmatic stage. The relatively low Al contents of dendritic quartz were interpreted to be related to contemporaneous feldspar or mica crystallization, while the high-Ti contents indicate high-crystallization temperatures (~750 °C). The comb-layered UST quartz displays heterogeneous, patchy luminescence with weak zoning, hosts coeval melt and fluid inclusions, and retains the chemical characteristics of magmatic dendritic quartz. High-Ti and low-Al contents of UST quartz suggest a formation at relatively high temperatures (~700 °C) and high-pH conditions. Three sub-types can be defined for hydrothermal BQ (BQ1, BQ2, and BQ3) based on contrasting CL features and trace element contents. The Al contents increase from BQ1 to BQ2 followed by a drop in BQ3, corresponding to an initial decrease and subsequent increase in fluid acidity. Temperature estimates of BQ decrease from BQ1 (635 °C) to BQ3 (575 °C), which may, however, be disturbed by high growth rates and/or high-TiO_2 activities. The CQ typically displays a CL-bright core and CL-dark rim with oscillating CL intensities and is characterized by the lowest Ti and highest Al, Li, and Sb contents compared to the other quartz types, which suggests a deposition from more acidic and lower temperature fluids (~250 °C). Trace element patterns indicate that a coupled $Si^{4+} \leftrightarrow (Al^{3+}) + (K^{+})$ element exchange vector is applicable to dendritic quartz, UST quartz, and BQ. By contrast, charge-compensated cation substitution of $Si^{4+} \leftrightarrow (Al^{3+}, Sb^{3+}) + (Li^{+}, Rb^{+})$ is favored for CQ. The comparison with compiled trace element data of quartz from other porphyry Au, Cu, and Mo deposits worldwide suggests that Ti, Al, Li, K, and Ge concentrations, as well as Al/Ti and Ge/Ti ratios, have the potential to discriminate the metal fertility of porphyry mineralization.

Keywords: Bilihe, porphyry Au deposit, quartz, SEM-CL texture, trace elements, fluid evolution