Hydrothermal fluid signatures of the Yulong porphyry Cu-Mo deposit: Clues from the composition and U-Pb dating of W-bearing rutile

QI CHEN1, CHANGMING WANG1,*, LEON BAGAS1,2, BIN DU1,3, KANGXING SHI1, AND JIAXUAN ZHU1

1State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences (Beijing), Beijing 100083, China
2Xi’an Center of Mineral Resources Survey, China Geological Survey, Xi’an 710054, China
3China Non-ferrous Metals Resource Geological Survey, Beijing 100012, China

ABSTRACT

Hydrothermal rutile (TiO₂) is a widely distributed accessory mineral in hydrothermal veins or alteration assemblages of porphyry deposits and provides important information for further understanding hydrothermal fluid signatures. This study determines the geochemical composition and U-Pb dates of hydrothermal rutile from the Yulong porphyry Cu-Mo deposit in east Tibet, China. Three types of TiO₂ polymorphs have been identified based on their Raman spectroscopic, textural, and chemical characteristics. (1) Brookite and anatase pseudomorphs after titanite in a fine-grained matrix, indicating low-temperature hydrothermal fluids destablizing primary Ti-bearing minerals during argillic alteration (type-I). (2) Elongated and prismatic rutile present in hydrothermal veins or in clusters in accompanying alteration envelope characterized by weak zoning (type-II). And (3) rutile intergrown with sulfides in hydrothermal veins, characterized by well-developed patchy and sector zoning (type-III). In contrast to the type-I and type-II TiO₂ polymorphs, tungsten is enriched in backscattered bright patches and sector zones in type-III rutile, which is due to the substitution of W⁶⁺ in the Ti⁴⁺ octahedral site. The mechanism of the enrichment of tungsten is effectively driven by the halogen-rich (F, Cl) aqueous fluids during hydrothermal mineralization. In situ U-Pb dating of the type-III rutile yields a lower intercept age of 41.8 ± 1.2 Ma, which brackets the timing of the Cu-Mo mineralization. The relationship between rutile textures and composition indicates that W-bearing rutile can serve as a recorder of hydrothermal processes in porphyry Cu deposits.

Keywords: W-bearing rutile, hydrothermal fluid signatures, U-Pb geochronology, EMPA, mineral chemistry, porphyry Cu-Mo deposits

INTRODUCTION

Rutile is a widely distributed accessory mineral, found in metamorphic, sedimentary, and igneous rocks (Zack et al. 2004; Meinhold 2010; Zack and Kooijman 2017; Pe-Piper et al. 2019) and formed in many magmatic-hydrothermal ore deposits, such as porphyry deposits (Scott 2005; Rabbia et al. 2009; Schirra and Laurent 2021; Wang et al. 2021). Previous studies have confirmed that rutile can form as a replacement product of Ti-bearing oxides and silicates (such as ilmenite, titanite, or biotite), and contains variable concentrations of Fe, V, high field strength elements (HFSE), transition, and base metallic elements (Luvizotto and Zack 2009; Meinhold 2010; Plavsa et al. 2018; Agangi et al. 2019). The variable concentrations of trace elements are closely connected to the composition of the primary minerals, type and composition of magmatic and metamorphic fluids (Cl- or F-rich), pressure and temperature conditions, and oxygen fugacity (f°O₂) (Zack et al. 2002, 2004; Plavsa et al. 2018; Majzlan et al. 2021). Therefore, rutile enriched in V, W, Mo, Sn, and Sb can be used as a geochemical fingerprint of a hydrothermal fluid associated with mineralization (cf. Czamanske et al. 1981; Clark and Williams-Jones 2004; Scott 2005; Scott et al. 2011; Agangi et al. 2019).

Studies of rutile associated with porphyry Cu deposits have already been attempted using: (1) the trace element signature of the rutile as an indicator of mineralization (Rabbia et al. 2009; Schirra and Laurent 2021), and (2) direct U-Pb dating of rutile associated with sulfides to constrain the timing of the hydrothermal mineralization events (Schirra and Laurent 2021). Studies of variations in, and incorporation mechanism of, these pathfinder elements in rutile in porphyry deposits are still very limited. For example, individual rutile commonly contains well-developed patchy and sector zonation reflecting the distributions of various elements (e.g., W, Fe; Mercer and Reed 2013). Nonetheless, the modification of these elements driven by hydrothermal fluids is poorly understood. Published studies have reported that hydrothermal rutile containing up to 3 wt% tungsten content in porphyry deposits closely coexists with sulfides, such as the Butte deposit in the U.S.A. (Mercer and Reed 2013). However, there is still a lack of understanding of the genesis of W-bearing rutile in hydrothermal veins, including its distribution, substitution mechanism and source of W. Answers to the above-mentioned problems are potentially helpful in understanding the critical contributions of hydrothermal fluids to mineralization in porphyry deposits, and defining vectors to undiscovered systems.

The world-class Yulong Cu-Mo porphyry deposit (Fig. 1) is hosted by an extensional (post-collisional) strike-slip fault...