Texture and geochemistry of multi-stage hydrothermal scheelite in the Tongshankou porphyry-skarn Cu-Mo(-W) deposit, eastern China: Implications for ore-forming process and fluid metasomatism

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ABSTRACT

Scheelite from the Tongshankou porphyry-skarn Cu-Mo(-W) deposit occurs mainly as disseminated grains in the altered granodiorite porphyries at depth (Sch A), in the skarn coeval with retrograde alteration (Sch B) and in distal quartz veins crosscutting marbles (Sch C). Cathodoluminescence (CL) responses within a single Sch A grain reveal two subtypes: CL-clear Sch A-I and CL-turbid, densely veined Sch A-II. The CL contrast, coupled with geochemical data, suggest Sch A-I was metasomatized to form Sch A-II. CL images reveal that Sch A-I, Sch B and Sch C are all homogenous, with blue luminescence and are depleted in heavy rare earth elements (HREE), indicating a primary origin. However, Sch A-II is characterized by higher contents of light REE and heavy REE as well as higher Sr isotopes (0.7080–0.7100) than the primary scheelite (<0.7080). These differences indicate that Sch A-II formed through dissolution-reprecipitation. The Sr isotopes of the primary scheelite (0.7073–0.7078) are generally consistent with those of the mineralized granodiorite porphyries (0.7061–0.7063) and mafic enclaves (0.7058–0.7073). The granodiorite porphyries contain low tungsten contents (3–11 ppm), whereas high tungsten contents were detected in mafic enclaves (48–75 ppm). The coexistence of mafic enclaves and tungsten mineralization at depth, and their consistent Sr isotopes, indicates that the interaction of mafic enclaves and exsolved magmatic fluids from the granodiorite porphyries may have played an important role in the extraction of tungsten from the mafic enclaves and formation of scheelite mineralization. Our work shows that scheelite geochemistry can be used to trace the mineralizing conditions but the compositions may be significantly modified during the ore-forming process. Thus, detailed textural relationships should be investigated before using scheelite geochemistry to constrain the hydrothermal fluids and ore genesis.

Keywords: Scheelite, metasomatic alteration, dissolution-reprecipitation, mineral textures, mineral geochemistry

INTRODUCTION

The elemental geochemistry of minerals has been widely used as tracers of magmatic processes (e.g., Lipin and McKay 1989; Ware et al. 2018). However, in hydrothermal systems, it is more challenging as the element distribution in hydrothermal minerals could be modified during formation, transportation, or precipitation as well as during subsequent hydrothermal events (Uspensky et al. 1998; Smith et al. 2004; Gaspar et al. 2008). During those processes, some trace elements will be remobilized and some new mineral phases could be generated (Putnis 2002, 2009; Geisler et al. 2007; Deditius et al. 2018). For example, such modification of magnetite, apatite, sulfides, and zircon in hydrothermal systems have been recently reported (Geisler et al. 2007; Hu et al. 2014; Zhao et al. 2014; Zeng et al. 2016), which caution the use of elemental geochemistry in deciphering the hydrothermal ore genesis.

Scheelite and wolframite are two main tungsten minerals (Wood and Samson 2000). Scheelite (CaWO₄) is well developed in porphyry and skarn related polymetallic deposits and is often coeval with other ore minerals such as chalcopyrite and cassiterite (Noble et al. 1984; Brugger et al. 2000; Song et al. 2014; Fu et al. 2017). Scheelite is also a common accessory hydrothermal mineral that often coexists with gold in quartz vein-hosted gold deposits (Darbyshire et al. 1996; Ghaderi et al. 1999; Brugger et al. 2002; Chugaev et al. 2010). This mineral is often coeval with other ore minerals such as chalcopyrite and cassiterite (Noble et al. 1984; Brugger et al. 2000; Song et al. 2014; Fu et al. 2017). Scheelite is also a common accessory hydrothermal mineral that often coexists with gold in quartz vein-hosted gold deposits (Darbyshire et al. 1996; Ghaderi et al. 1999; Brugger et al. 2002). Scheelite has a simple tetrahedral [WO₄]²⁻ and dodecahedral [CaO₄]³⁻ crystal structure and can host high contents of rare earth elements (REEs), Sr, and Pb through substitution of Ca²⁺ in the mineral lattice (Uspensky et al. 1998; Ghaderi et al. 1999; Dostal et al. 2009). Rubidium/Sr ratios in scheelite are typically very low (approximately zero) because of its inability to incorporate Rb into its lattice (Bell et al. 1989; Darbyshire et al. 1996; Chugaev et al. 2010). This means Sr/Sr isotopic changes little over time, so as long as the system remains closed, the measured isotope ratio can directly reflect the Sr isotopic characteristics of the fluids from which the scheelite...