Metal source and hydrothermal evolution of the Jiaoxi quartz vein-type tungsten deposit (Tibet): Insights from textural and compositional variations of wolframite and scheelite

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Abstract

We evaluate the controlling factors of hydrothermal wolframite and scheelite precipitation in the quartz vein-type Jiaoxi tungsten deposit situated in the western part of the Lhasa terrane (Tibet, China) using texture, major and trace element mineral geochemistry, and sulfur stable isotope geochemistry. Pyrite and chalcopyrite that are intergrown with Fe-enriched wolframite and siderite, have distinct in situ S isotope compositions (δV-CDT) of −31.38 to +1.77‰, and +2.07 to +2.30‰, respectively. Major and trace element contents and in situ S isotope compositions of pyrite and chalcopyrite indicate that the hydrothermal evolution involved fluid-fluid mixing and greisenization. We report evidence for an early magmatic fluid, which is characterized by the enrichment of W, Mn, Zr, Ti, Sc, and Sn and depletion of Fe. This magmatic fluid was diluted by meteoric water and interacted with biotite monzogranite porphyry to leach Fe, Mg, and Zn into the system to form wolframites with variable Fe/(Fe+Mn) ratios ranging between 0.06–0.84. The late Fe-enriched magmatic fluid released from the muscovite granite mixed with meteoric water that leached minor Fe and S from shale to form late shale-hosted wolframite with a Fe/(Fe+Mn) mass ratio of >0.75 and coeval siderite and sulfides. This study highlights that multiple Fe sources were present in the system, including muscovite granite-released Fe through fluid exsolution, biotite monzogranite porphyry-released Fe during greisenization, and minor Fe released from the shale as a result of meteoric water leaching.

Keywords: Wolframite, scheelite, trace element geochemistry, in situ S isotope, multiple Fe sources, Jiaoxi quartz vein-type W deposit

Introduction

Quartz vein-type tungsten (W) deposits represent a major class of hydrothermal deposits and typically occur as wolframite-bearing quartz veins hosted either in pelitic rocks or in granites (Wang et al. 2010; Jingwen et al. 2013). Generally, tungsten is considered to be sourced from Fe-depleted highly evolved felsic magmatic rocks that are spatially associated with the deposit (Romer and Kroner 2016; Hulsbosch et al. 2016). However, formation of wolframite [(Fe, Mn)WO4] does not only require W but also significant Fe and Mn in the ore-forming fluid. Therefore, tracing the source of Fe and Mn in quartz vein-type wolframite deposits has long been a subject of interest (Audétat et al. 2000; Lecumberri-Sanchez et al. 2017; Legros et al. 2019; Pan et al. 2019). However, there is no consensus on the origin of the metals because the pristine signature of the primary fluid is overprinted by multiple post-mineralization fluid events in numerous deposits (Polya et al. 2000; Harlaux et al. 2018). Recently, in situ high spatial microanalysis of W-bearing mineral phases, using multi-collector laser-ablation inductively coupled-plasma mass spectrometry (MC-LA-ICP-MS), has been used to identify multiple fluid infiltration events and the metal source (Wang et al. 2017; Hong et al. 2017; Jiang et al. 2021; Carocci et al. 2021).

Wolframite and scheelite, which can accommodate a wide range of trace elements including Ti, Sc, Zr, Hf, Nb, Ta, and REE, have been studied to constrain the hydrothermal evolution and metal sources (e.g., Kempe and Wolf 2006; Song et al. 2014; Zhu et al. 2014; Xiong et al. 2017; Sun and Chen 2017; Han et al. 2020). For example, the negative Eu anomaly of wolframite has been interpreted to be inherited from a highly evolved granite, thus indicating a magmatic source (Harlaux et al. 2018). Scheelite that precipitated from a highly evolved granite-exsolved fluid is generally Sr-depleted such that the variability of the Sr content in scheelite indicates formation in a metamorphic environment, in which the metasedimentary or volcanic source rocks can release Sr into the hydrothermal system (Poulin et al. 2018). Although trace element contents in wolframite and scheelite have widely been reported, comprehensive studies of both minerals to constrain the hydrothermal evolution and the metal sources are rare (e.g., Zhang et al. 2018).