Zircon and apatite geochemical constraints on the formation of the Huojihe porphyry Mo deposit in the Lesser Xing’an Range, NE China

KAI XING¹,², QIHAI SHU¹,*, DAVID R. LENTZ², and FANGYUE WANG³

¹State Key Laboratory of Geological Processes and Mineral Resources, and School of Earth Sciences and Resources, China University of Geosciences, Beijing 100083, China
²Department of Earth Sciences, University of New Brunswick, Fredericton, New Brunswick E3B 5A3, Canada
³Ore Deposit and Exploration Center (ODEC), Hefei University of Technology, Hefei 230009, Anhui, China

ABSTRACT

Northeastern China is an important Mo resource region in China, with more than 80 Mo deposits and occurrences. The Huojihe deposit located in the Lesser Xing’an Range represents one of the many Mesozoic porphyry Mo deposits in NE China and has been selected for investigation attempting to clarify the possible mechanisms controlling Mo mineralization. In this study, accessory minerals, including zircon and apatite from the causative intrusions (biotite monzogranite and granodiorite), have been analyzed to reveal their chemical and isotopic compositions, which provide insights into the nature of the source magmas and a better understanding of the factors affecting their mineralization potential.

Zircon U-Pb dating shows that the biotite monzogranite from the Huojihe deposit formed at 181.6 ± 0.6 Ma, which is identical to the previously reported molybdenite Re-Os age (~181 Ma), indicating that the Mo mineralization is probably genetically related to the intrusion. The intrusion samples share homogeneous geochemical and Sr-Nd isotopic compositions, with initial ⁸⁷Sr/⁸⁶Sr ratios of 0.7072–0.7075 and slightly negative εNd(t) values from –2.3 to –1.4, reflecting a uniform magma source. The least-altered apatites show similar (or slightly enriched) initial ⁸⁷Sr/⁸⁶Sr ratios (0.7080–0.7108) and εNd(t) values (~4.0 to ~1.8), whereas the hydrothermally altered apatites are characterized by significantly higher initial ⁸⁷Sr/⁸⁶Sr ratios (0.7091–0.7119) and more negative εNd(t) values (~4.9 to ~4.4), probably due to the interaction between the hydrothermal fluids and wall rocks. The zircon εNd(t) values vary from ~0.9 to ~1.7, corresponding to a restricted range of TDM2 ages from 1279 to 1120 Ma. The Sr-Nd-Hf isotope results suggest that the primary magmas associated with the Mo mineralization could be generated from a dominantly Mesoproterozoic lower crust source, with rare contributions from the depleted mantle.

Estimates of absolute sulfur concentrations in the mineralization-related melt using available partitioning models for apatite return relatively low magmatic sulfur concentrations in Huojihe (20–100 ppm), indistinguishable from those of larger or smaller deposits or even barren magmatic bodies. Using the sulfur concentration data, a minimum volume of 10–50 km³ magma has been suggested to be necessary to produce the Huojihe Mo deposit based on mass balance modeling. Besides, the Mo concentration in the original magma has also been roughly estimated based on the magma size (10–50 km³) and the contained Mo in Huojihe (0.275 Mt). The magmatic Mo concentrations (2–10 ppm) are similar to many other porphyry Mo systems (e.g., the Climax-type porphyry Mo deposits), and are also comparable to subeconomic to barren magma systems. This study suggests that pre-degassing enrichments of Mo and S in the original magma is not necessarily important in the formation of the Huojihe Mo deposit; rather, factors other than melt composition may be more critical in forming a porphyry Mo deposit. This understanding might also apply to other porphyry Mo mineralized systems worldwide.

Keywords: Apatite and zircon geochemistry, magmatic S and Mo contents, mineralization mechanism, Huojihe porphyry Mo deposit, NE China

INTRODUCTION

In the past decade, more than 80 porphyry Mo deposits have been discovered in northeast (NE) China, resulting in a total Mo metal resource of >11.4 Mt (Shu et al. 2016; Chen et al. 2017). These deposits are generally characterized by high abundances of Mo with little or no Cu. Many of them have Jurassic to Early Cretaceous ages and have been suggested to be related to magmatic events during the subduction or subsequent slab rollback of the Paleo-Pacific oceanic plate (Wu et al. 2011; Ouyang et al. 2013; Shu et al. 2016; Zhai et al. 2018). However, to date it is still unclear what factors have controlled the large-scale Mesozoic porphyry Mo mineralization in this region. Whether there is any inherent Mo