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

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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 $^{87}Sr/^{86}Sr$ ratios of 0.7072–0.7075 and slightly negative $\varepsilon_{Nd}(t)$ values from –2.3 to –1.4, reflecting a uniform magma source. The least-altered apatites show similar (or slightly enriched) initial $^{87}Sr/^{86}Sr$ ratios (0.7080–0.7108) and $\varepsilon_{Nd}(t)$ values (–4.0 to –1.8), whereas the hydrothermally altered apatites are characterized by significantly higher initial $^{87}Sr/^{86}Sr$ ratios (0.7091–0.7119) and more negative $\varepsilon_{Nd}(t)$ values (–4.9 to –4.4), probably due to the interaction between the hydrothermal fluids and wall rocks. The zircon $\varepsilon_{Hf}(t)$ values vary from –0.9 to 1.7, corresponding to a restricted range of T_{DM2} 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. The low Ga and Ce and high Eu contents in the magmatic apatite demonstrate that the original magmas have a relatively high oxygen fugacity, which is also supported by the high zircon Ce_N/Ce_N* (22–568) and Eu_N/Eu_N* (0.38–0.71) values.

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 km^3 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 km^3) 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