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Tracking dynamic hydrothermal processes: Textures, in-situ Sr-Nd isotopes, and trace-element analysis of scheelite from the Yangjiashan vein-type W deposit, South China

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ABSTRACT

Texturally complex minerals can provide critical information on dynamic hydrothermal processes. This study combines cathodoluminescence (CL), laser ablation-inductively coupled plasma-mass spectrometry (LA–ICP–MS), and high-resolution femtosecond laser ablation multi-collector inductively coupled plasma mass spectrometry (fs–LA–MC–ICP–MS) analyses to document textures, in situ Sr-Nd isotope systematics, and trace element compositions of texturally complex scheelite from the Yangjiashan W deposit, South China. The major motivation for this contribution was to reveal the correlation between CL response, textures, and trace element concentrations; document the origin of various REE fractionation patterns; and characterize grain-scale in situ variability of Sr-Nd isotopes of scheelite.

Five sub-types of scheelite from both stages, including Sch1 and Sch2 from Stage 1, and Sch3 to Sch5 from Stage 2, are identified. CL images feature complex oscillatory, patchy, and evidence for coupled dissolution-reprecipitation reaction. These scheelites precipitated from reduced fluids and are close to end-member in composition, with Mo concentrations below 46 ppm. Concentrations of other elements vary, e.g., Sr (36–1025 ppm), Nd (8–351 ppm), and Na (7–300 ppm). LA–ICP–MS element maps reveal a large variability in REE concentrations among oscillatory zones and no consistent behavior between REE, Sr and Mo concentration, and CL intensity. Four distinct chondrite-normalized REE fractionation patterns are recognized: LREE-enriched, MREE-enriched, HREE-enriched, and flat patterns. Complex Eu anomalies (δEu = 0.2 to 20.7) are recognized among the five sub-types and are commonly observed within individual grains. Fluid compositions, different substitution mechanisms (i.e., $Ca^{2+} + W^{6+} = REE^{3+} + Nb^{5+}$, and $2Ca^{2+} = REE^{3+} + Na^{+}$, $3Ca^{2+} = 2REE^{3+} + \square Ca$, where $\square Ca$ is a Ca-site vacancy), primary-secondary processes (i.e., oscillatory and dissolution-reprecipitation, respectively), all contribute to the variation in REE fractionation patterns. Local fluctuation in fluid pH is responsible for the complex Eu anomalies. In situ Sr and Nd isotope signatures for the five sub-types of scheelite show relatively large ranges, i.e., the initial $^{87}Sr/^{86}Sr$ ratios range from 0.71336 to 0.72617, and the initial εNd values ranging from –24.9 to –7.7, suggesting a source derived from a mixture of magmatic-hydrothermal fluids and the Neoproterozoic slate. Decreasing $^{87}Sr/^{86}Sr$ ratios from Sch2 to Sch5 record decreasing fluid-rock interaction intensity. Large variation of εNd(t) values (–24.9 to –7.7) of scheelite with oscillatory zoning textures may relate to changes of Sm/Nd ratio of scheelite and contamination from wall rock with inhomogeneous Nd isotope composition. This study highlights the importance of performing coupled LA–ICP–MS mapping and in situ Sr-Nd isotope analyses on sample material that has been characterized in detail at the micrometer scale.

Keywords: Scheelite, REE fractionation patterns, in situ Sr-Nd isotope analysis, tungsten deposits, Yangjiashan