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Apatite as an Indicator in Tungsten-Mineralized Magmatic–Hydrothermal System

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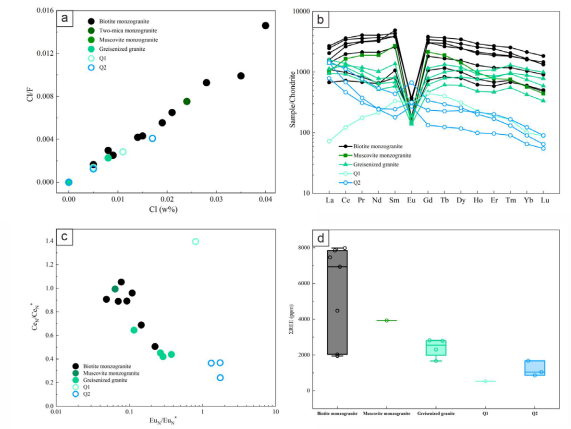


Figure 1. Compositions of magmatic apatite in biotite monzogranite, two-mica monzogranite, muscovite granite, and greisenized granite as well as hydrothermal apatite in wolframite-mineralized quartz veins (Q1 and Q2): a) Cl/F ratios versus Cl (wt%), b) chondrite-normalized REE patterns, c) Ce_N/Ce_N^* versus Eu_N/Eu_N^* (where $Ce_N^* = Sqrt(La_N \times Pr_N)$ and $Eu_N^* = Sqrt(Sm_N \times Gd_N)$), and d) box plot of ∑REE contents.

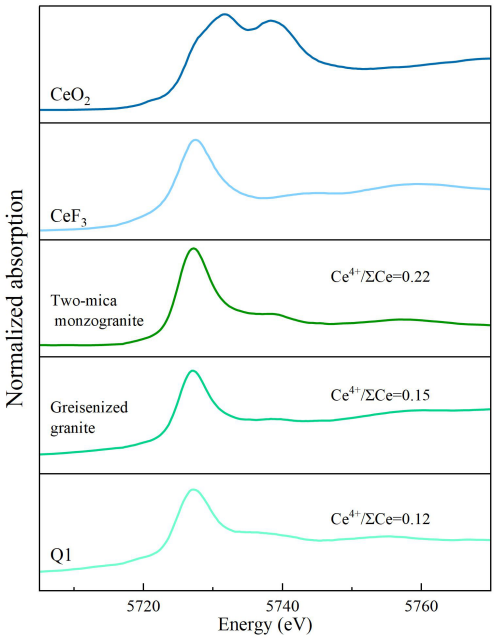


Figure 2. Cerium L_3-edge μXANES spectra of apatite in comparison with two model compounds CeF_3 and CeO_2. The $Ce^{4+}/\sum Ce$ (where $\sum Ce = Ce^{3+} + Ce^{4+}$) values are calculated using the deconvolution method of Deevsalar et al. [1].

Apatite, as a ubiquitous accessory mineral in granites, crystallizes from both early magmatic stages and late-stage hydrothermal alteration, providing an excellent record of the magmatic-hydrothermal evolution and related mineralization processes. In this study, we present an integrated investigation of apatite from the Late Triassic Chuankou granite-hosted tungsten deposit in South China. Magmatic apatite from biotite, two-mica, and muscovite granites defines a fractionation trend, characterized by systematic changes in F and Cl contents (Fig. 1a), chondrite-normalized rare-earth element (REE) patterns (Fig. 1b), a negative correlation between Ce_N/Ce_N^* versus Eu_N/Eu_N^* (where $Ce_N^* = Sqrt(La_N \times Pr_N)$ and $Eu_N^* = Sqrt(Sm_N \times Gd_N)$; Fig. 1c), and total REE contents (Fig. 1d). Hydrothermal apatite associated with wolframite-mineralized veins exhibits a compositional continuum with its magmatic counterparts (Fig. 1a,b). This continuity provides a strong line of evidence that the ore-forming fluids were most likely derived from the highly fractionated magmatic system. Microbeam synchrotron X-ray absorption near-edge structure (μXANES) analyses of apatite at cerium (Ce) L_3-edge (Fig. 2) also reveal a systematic decrease in the $Ce^{4+}/\sum Ce$ value (where $\sum Ce = Ce^{3+} + Ce^{4+}$) from early magmatic to late hydrothermal stages. Moreover, the spectroscopically determined $Ce^{4+}/\sum Ce$ ratios of apatite correlate with its Eu anomalies in chondrite-normalized REE patterns, further demonstrating a systematic change in the redox state with the exsolution of reduced hydrothermal fluids responsible for wolframite mineralization. These results demonstrate that apatite not only archives the fingerprints of magmatic differentiation, volatile saturation, and redox transitions but also provides useful information about the dominant controls on tungsten transport and deposition, establishing apatite as a robust, mineral-scale tracer for deciphering complex ore-forming processes in magmatic-hydrothermal systems.

Reference:

[1] Deevsalar, R., Pan, Y., Cao, K., Zhu, Y., Tunc, A., Chen, N., Shakouri, M. & Xiao, Q. (2025) Cerium speciation in Durango fluorapatite from X-ray photoelectron and synchrotron X-ray absorption spectroscopy: Implications for the Ce-in-apatite oxybarometer. The Canadian Journal of Mineralogy and Petrology, Vol. 63: 371-383.