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Monazite Eu Anomalies: Beyond Feldspar

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Trace-element concentrations and ratios in accessory minerals can be used to qualitatively link accessory-mineral growth to the growth/breakdown of major minerals during metamorphism and anatexis. This approach—along with experimentally calibrated trace-element thermobarometers (so-called "4+" and Y+REE thermometers) and modeling accessory-mineral stability—is widely combined with in-situ U–Pb geochronology to infer P–T–t paths of metamorphic rocks that underpin interpretations of their geodynamic significance. This multilayered perspective on the petrological and geological significance of ages retrieved from accessory minerals forms the foundation of petrochronology.

In this submission, we address one of the trace-element ratios most commonly used to link U–Pb dates to a P–T path—the Eu anomaly[1], usually used as a proxy for feldspar stability—with a focus on the petrochronometer monazite. We present case studies and models (pseudosections coupled with trace-element partitioning budgets) that suggest monazite Eu anomalies are strongly influenced by changes in Eu valence (proportion of bulk-rock Eu2+ and Eu3+) resulting from changes in fO_2, which can be internally or externally buffered. Consequently, Eu anomalies in monazite may not always be exclusively linked to the behavior of feldspar, which is commonly used as a proxy for depth in high-pressure metamorphic rocks or partial melting in high-temperature metamorphic rocks.

Determining the relative importance of feldspar stability and bulk-rock Eu valence on the measured monazite Eu anomalies in a sample can be achieved by assessing the correlation between Eu anomalies and Sr concentrations. If Eu valence remained constant during growth/recrystallization, monazite Eu anomalies should be positively correlated with Sr due to the near-identical ionic radii of Eu2+ and Sr2+ (Sr has only one common valence state at rock forming fO_2) and changes in Eu anomaly might reliably record feldspar growth/breakdown. If Eu anomalies are not correlated with Sr, then they likely record changes in fO_2, through closed-system changes in mineral assemblage or open-system fluid–rock or melt–rock interaction. Therefore, an assessment of the covariance of Sr and Eu in monazite is required to determine if feldspar was present or absent during monazite growth, which has implications for inferring the timing of high-pressure metamorphism in subduction zones and in deep crustal granulites.

([1]Eu anomaly is defined here as Eu/Eu*, where Eu* is the geometric mean of Sm and Gd concentrations; all concentrations normalized to a whole-rock or chondrite composition)