

Comparative zoning studies in titanite

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Chemical and isotopic zoning in titanite contains a wealth of information about the timing, duration, and conditions of metamorphism and deformation. The challenge is to uniquely determine the processes reflected in the zoning. A rigorous approach is to compare zoning of several elements and/or isotope systems to more tightly constrain the zoning processes. This work details how the comparison of oxygen isotope zoning with zoning in minor elements, trace elements, and U-Pb dates can inform interpretations.

Many Grenville-aged titanite grains from the NW Adirondack Mtns (New York) show gradational, core-to-rim, diffusive oxygen isotope zoning that is uncorrelated with major or minor element zoning. Inverse modelling of diffusive oxygen isotope zoning indicates these Adirondack rocks experienced a brief metamorphic peak of 750-800 °C lasting ≤ 1 m.y., followed by rapid cooling to ca. 500 °C 2-4 m.y. later. This thermal history provides a context to evaluate more the ambiguous trace-element and U-Pb isotope records. In most titanite, minor elements (Al, Fe, F) and trace elements (Zr, Ce, Nd, Y) show step-like variations and/or patchy, irregular zoning, both near grain rims and within grain interiors. Conservatively calculated Zr-in-titanite temperatures range from 800° to 960°C and vary by 50-150 °C within a given grain. These high Zr temperatures and significant intragrain oscillations suggest kinetic controls on mobility or attachment of minor and trace elements during titanite crystallization rather than strictly equilibrium partitioning. Th/U zoning closely tracks major and minor element zoning in titanite, but U-Pb trends sometimes correlate with oxygen diffusion zoning and sometimes correlate with minor element zoning. With a detailed knowledge of zoning patterns, it is possible to recognize both Pb diffusion and variations in initial Pb composition within the Adirondack titanite suite. Overall, the Adirondack example suggests that minor and trace element zoning in titanite, even in high-temperature rocks, can be dominated by local kinetic processes.