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# Deformation-driven trace element variability in titanite, epidote and allanite

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The tectono-magmatic and metamorphic evolution of ancient orogenic crust is complex, involving multiple overprinting events. Titanite, epidote and allanite—common accessory minerals in felsic and mafic rocks—serve as key petrochronometers for constraining timing and chemical signatures of different crustal processes. However, the mechanisms driving intra-grain trace element and isotopic variability during deformation remain poorly explored. This study integrates LA-ICP-MS trace element (TE) and U-Pb mapping with electron backscatter diffraction (EBSD) to investigate how deformation microstructures influence chemical and isotopic variability in these minerals.

We studied samples from low- and high-strain amphibolite-facies orthogneisses in a Neoproterozoic terrane in southern Brazil. In low-strain domains, titanite crystals display subtle undulose extinction. In high-strain domains, it forms aggregates of inclusion-rich titanite porphyroclasts exhibiting low-angle grain boundaries in EBSD maps, secondary titanite pressure shadows, and neoblastic growth along to the foliation—features indicative of dynamic recrystallization. While titanite in both domains displays concentric and patchy enrichments in Y, and medium- to heavy-REEs, only in high-strain domains do these enrichments correlate with lattice distortion. Epidote crystals occur surrounding allanite cores, which are significantly replaced by epidote in high-strain domains, but remain largely preserved in low-strain domains. In both strain domains epidote systematically has the same crystallographic orientation as allanite. In high-strain zones, epidote fractures at high angles to the foliation, with deformation localised at the allanite-epidote interface. Trace element distributions show high light- to medium-REEs and Y in allanite cores and epidote fractures, while Sr concentrations increase at epidote grain boundaries with the matrix.

These findings suggest that in high-strain domains, crystal-plastic deformation in titanite—including undulose extinction, subgrain boundary development, and neoblast formation—is linked to localized REE and Y enrichment. In contrast, epidote accommodates strain primarily through brittle fracturing rather than intracrystalline plasticity mechanisms, with increased REE and Sr concentrations in deformed regions. In low-strain domains, titanite and epidote-allanite assemblages remain largely undeformed, preserving their primary zoning with minimal fluid-mediated alteration. This contribution highlights the power of combining EBSD, TE, and U–Pb mapping to unravel chemical and isotopic responses to deformation in titanite, epidote, and allanite, reinforcing their robustness as key petrochronometers across different strain conditions.