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Coronas around monazite and xenotime recording incomplete replacement reactions and compositional gradients during greenschist facies metamorphism and deformation

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Coronas around monazite and xenotime recording incomplete replacement reactions are valuable for evaluating nucleation, transport, and growth mechanisms during metamorphism and deformation. They are investigated in Permian metapegmatites, deformed and metamorphosed under greenschist facies conditions during Alpine tectonometamorphism (Austroalpine basement, Eastern Alps). For mineralogical, microstructural and geochronological characterization we use imaging and x-ray spectroscopic techniques at the scanning electron microscope (SEM) and electron microprobe (EMP).
Coronas are found in pegmatites with similar mineral assemblage and variable strain. Variscan monazite (Mnz1) and xenotime (Xen1) partially break down into apatite – allanite/epidote coronas. In the corona core, monazite and xenotime single crystals show complex zoning: Variscan Mnz1 and Xen1 are partly replaced by secondary populations of monazite (Mnz2) and xenotime (Xen2) with different compositions and ages compared to the primary grains. EMP dating indicates for Mnz2 crystallisation around 60 $\pm$ 20 Ma. Coronas around monazite consist of an inner zone of LREE-rich apatite (LREE-Ap) surrounded by allanite (Aln), HREE-rich epidote (HREE-Ep) and epidote (Ep). Thorite and rarely thorianite/uraninite (Th/U) occur in the apatite zone. The apatite grains form a foam-structure, whereas allanite/epidote crystals are prismatic and radiate outwards resulting in an elongate shape of the corona corresponding to the stretching lineation of the sample. When enclosed as inclusion in tourmaline, monazite shows only a restricted reaction rim with apatite and allanite/epidote, in association with a fracture. In coronas around xenotime, compared to coronas around monazite, apatite has higher HREE contents (HREE-Ap) and no allanite occurs. In the matrix, few hundreds of μm away from monazite and xenotime coronas, apatite and epidote have lower REE contents than when located in the coronas.
We propose that coronas form by fluid-induced dissolution-precipitation processes generating compositional gradients, responsible for the distinct mineral growth zones. Fluid available along grain boundaries and fractures appears to control the reaction advancement, by allowing the elementary mass transfer required for the corona reaction (Ca, Al, Si, Fe). REE provided by this dissolution show restrictive mobility, as attested by the difference of apatite and epidote compositions in matrix and corona. General reactions for the monazite and xenotime breakdowns can thus be written as follows:

Mnz1 + (Si, Ca, Al, Fe)fluid → Mnz2 + LREE-Ap + Aln + HREE-Ep + Ep + Th/U

Xen1 + (Si, Ca, Al, Fe)fluid → Xen2 + HREE-Ap + HREE-Ep + Ep + Th/U

It is important to note that these are very complex reactions of a single reactant into multiple mineral products and that the final microstructures probably result from transitory stages, with progressive structural and chemical equilibration. The observations that allanite/epidote rims are elongate corresponding to the stretching lineation of the pegmatites on one hand, and that the foliation is flowing around the coronas, without the outer rim of columnar epidote showing signs of deformation on the other, indicate that the replacement took place during a late stage of deformation.