Replacement of monazite by a huttonite component: nature and experiment

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In nature, monazite contains variable amounts of $ThSiO_4$ as the huttonite component. In igneous monazite, this variability manifests itself as magmatic zoning. In metamorphic monazite it takes the form of variable curvilinear $ThSiO_4$-enriched intergrowths both in the region of the monazite grain rim as well as within the grain interior. The sharp compositional boundaries of these intergrowths strongly suggest that the original monazite grain has been partly metasomatised by a $ThSiO_4$-bearing fluid through dissolution-reprecipitation processes.

This hypothesis has been tested in the hydrothermal apparatus and the piston-cylinder apparatus (CaF_2 assemblies) at 500-1000 MPa and 300-900 °C (8-24 days duration). Here, 10 mg of inclusion-free, 100-500 µm size, euhedral monazite-(Ce) crystals ($ThSiO_4$ below EMP detection limit), 5 mg $Th(NO_3)_4$, 2.5 mg SiO_2, and 5 mg H_2O were loaded into 3 mm wide, 1.3 cm long Pt capsules that were then arc welded shut. Evaluation of each experiment via BSE imaging, EBSD analysis, and TEM indicate that a monoclinic $ThSiO_4$ phase, in the form of huttonite, partially replaced a portion of the monazite for a minority of the monazite grains. HR-TEM indicates that at the interface, the lattice fringes from the huttonite and monazite are continuous implying that the interface between the huttonite and monazite is coherent.

A similar set of experiments (900 °C; 1000 MPa) were performed using the piston-cylinder apparatus (8 days). Here, 100 µm size, inclusion-free, homogenous and unzoned natural xenotime and monazite-(Ce) (10% $ThSiO_4$ component) plus a series of fluids (2M NaOH and KOH (+ Al_2O_3 and SiO_2) and ($Na_2Si_2O_5$ + H_2O)) were loaded into the Pt capsules. In each experiment, strong evidence for high $ThSiO_4$ mobility and dissolution-reprecipitation processes was seen in the form of remobilised $ThSiO_4$ enriching the monazite and xenotime grain rims in a series of curvilinear intergrowths with sharp reaction boundaries similar to that seen in nature for metamorphic monazite.

Fluid-aided mobility of the $ThSiO_4$ component in monazite via dissolution-reprecipitation resets the affected regions to the date of the metasomatic event thus allowing for monazite to be used to date possible multiple metasomatic events for the same sample. It also allows for constraints to be put on the fluid composition such as pH.