

Fluid-induced nucleation of (Y + REE)-phosphate minerals within apatite: Nature and experiment. Part I. Chlorapatite

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ABSTRACT

This study investigates chlorapatite [ideally $\text{Ca}_{10}(\text{PO}_4)_6\text{Cl}_2$] from two spatially separated locations in the Ødegårdens Verk apatite mine, Bamble Sector, SE Norway, which was partially metasomatized under amphibolite-facies conditions. Relative to the original chlorapatite, metasomatized areas in sample DL136 are enriched in OH and F, depleted in Na, Si, and (Y + REE) and contain numerous inclusions (1–15 μm) of monazite and xenotime. In contrast, metasomatized areas in sample TN174 are enriched in F and Si, depleted in Na, show (Y + REE) abundances similar to the original chlorapatite, and host only a few monazite and xenotime grains.

In order to define the role of fluids in the formation of (Y + REE)-phosphate minerals associated with apatite, a series of experiments covering wide ranges of temperature (900–300 °C) and pressure (1000–500 MPa) for a series of fluid compositions (pure H_2O , a 50/50 molar mix of H_2O and CaF_2 , and CO_2 with 1–2 wt% H_2O) were conducted on unaltered chlorapatite from the Ødegårdens Verk. In the H_2O experiments, features due to metasomatic alteration [depletion in Na, Si, and (Y + REE) as well as numerous monazite and xenotime inclusions], as observed in the natural sample DL136, were fully reproduced. Monazite and xenotime grains were also observed growing on the surface of the apatite in dissolution embayments in metasomatized areas. In the 50/50 CaF_2 - H_2O experiments, metasomatized regions are strongly enriched in F and Si, depleted in Na, show unchanged (Y + REE) abundances, and contain only a very few, small monazite and xenotime grains similar to what was observed in sample TN174.

Natural and experimental observation imply the presence of two coupled substitutions: $\text{Na}^+ + (\text{Y} + \text{REE})^{3+} = 2 \text{Ca}^{2+}$ and $\text{Si}^{4+} + (\text{Y} + \text{REE})^{3+} = \text{P}^{5+} + \text{Ca}^{2+}$. In the case of DL136 and H_2O -fluid experiments, Na^+ and Si^{4+} went into solution, whereas the released (Y + REE) contributed to the growth of monazite and xenotime within the metasomatized apatite structure. For sample TN174 and the 50/50 $\text{CaF}_2 + \text{H}_2\text{O}$ -fluid experiments, Na in apatite became depleted but Si was enriched thereby stabilizing the (Y + REE) in the now recrystallized fluor-hydroxylapatite structure, which retarded the growth of monazite or xenotime inclusions. The basic conclusion of this study is that nucleation of monazite and xenotime in the metasomatized chlorapatite is principally a function of the composition of the infiltrating fluid and, to a much lesser extent, temperature and pressure.