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

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ABSTRACT

To elucidate at what pressure and temperature and for what fluid compositions monazite may be induced to form from fluorapatite, the LREE-enriched Durango fluorapatite has been metasomatized experimentally at temperatures of 300, 600, 700, 800, 850, and 900 °C and pressures of 500 and 1000 MPa. Fluids used included pure H_2O, various NaCl, KCl, and $CaCl_2$ brines (salt/H_2O = 50/50, 30/70, or 10/90), and either 90/10 CO_2/H_2O or 40/60 CO_2/H_2O mix. Monazite formed in the fluorapatite + H_2O, fluorapatite + 40/60 CO_2/H_2O, and the fluorapatite + KCl brine experiments. At 900 °C and 1000 MPa, monazite formed both as inclusions within the fluorapatite and externally on its surface. Below 900 °C, monazite grew only externally on the fluorapatite, either as euhedral to semi-euhedral crystals or as partial mantles over smaller fluorapatite grains. Monazite, especially at 900 °C and 1000 MPa, is compositionally heterogeneous, specifically with respect to the Th content (ThO_2 = 4–38 wt%). Whereas the reactant fluorapatite in the pure H_2O experiments remained unzoned at lower temperatures, three coupled zones with different (LREE+Si+Na) abundances developed at 900 °C. These zones roughly follow the rim of the fluorapatite enclosing a fourth zone or the core, resembling the original composition. Monazite inclusions formed only in the one zone where the LREE are depleted. In the NaCl brine experiments, the Na replaced Si lost to the solution, which stabilized the LREE, and precluded formation of monazite. Similarly, the high activity of Ca in the $CaCl_2$ brine caused Ca to replace (LREE+Na) on the Ca site and discouraged the growth of monazite. The fluorapatite recrystallized to a fluor-chlorapatite, which displays oscillatory zoning, specifically with respect to the LREE. The results from this study imply that the presence of monazite inclusions and rim grains associated with fluorapatite (1) can be metasomatically induced; (2) can give insights into the chemistry of the metasomatizing fluids; (3) can provide some information on the grade of the metasomatic overprint; and (4) could indicate the occurrence of one or more metasomatic events.