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Experimental constraints on the monazite–fluorapatite–allanite and xenotime–(Y,HREE)-rich fluorapatite–(Y,HREE)-rich epidote phase relations as a function of pressure, temperature, and Ca vs. Na activity in the fluid

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Stability relations of monazite–fluorapatite–allanite and xenotime–(Y,HREE)-rich fluorapatite–(Y,HREE)-rich epidote are strongly dependent on pressure, temperature and fluid composition. The increased Ca bulk content expands stability field of allanite relative to monazite towards higher temperatures (Spear, 2010, Chem Geol 279, 55-62). It was also reported from amphibolite facies Alpine metapelites, that both temperature and bulk CaO/Na2O ratio control relative stabilities of allanite, monazite and xenotime (Janots et al., 2008, J Metam Geol 26, 5, 509-526). This study experimentally defines influence of pressure, temperature, high activity of Ca vs. Na in the fluid, and high vs. moderate bulk CaO/Na2O ratio on the relative stabilities of monazite–fluorapatite–allanite/REE-rich epidote and xenotime–(Y,HREE)-rich fluorapatite–(Y,HREE)-rich epidote.

This work expands previous experimental study on monazite (Budzyń et al., 2011, Am Min 96, 1547-1567) to wide pressure-temperature range of 2-10 kbar and 450-750°C, utilizing most reactive fluids used in previous experiments. Experiments were performed using cold-seal autoclaves on a hydrothermal line (2-4 kbar runs) and piston-cylinder apparatus (6-10 kbar runs) over 4-16 days. Four sets of experiments, two for monazite and two for xenotime, were performed with 2M Ca(OH)2 and Na2Si2O5 + H_2O fluids. The starting materials included inclusion-free crystals of monazite (pegmatite, Burnet County, TX, USA) or xenotime (pegmatite, Northwest Frontier Province, Pakistan) mixed with (1) labradorite (Ab37An60Kfs3) + K-feldspar + biotite + muscovite ± garnet + SiO_2 + CaF2 + 2M Ca(OH)2 or (2) albite (Ab100) + K-feldspar + biotite + muscovite ± garnet + SiO_2 + CaF2 + Na2Si2O5 + H_2O. 20-35 mg of solids and 5 mg of fluid were loaded into 3x15 mm Au capsules and arc welded shut.

The monazite alteration is observed in all runs. Newly formed REE-rich fluorapatite and/or britholite are stable in all experimental P-T range in the presence of both fluids. Alteration of monazite and subsequent formation of REE-rich epidote or allanite, REE-rich fluorapatite and britholite was promoted by high activity of Ca in the fluid, with high bulk CaO/Na2O ratio of ca. 11.5 in the system. In contrast, neither REE-rich epidote nor allanite does form in the presence of Na2Si2O5 + H_2O fluid, with bulk CaO/Na2O ratio of ca. 1.0. Results indicating that stability field of allanite relative to monazite expands towards higher temperatures along with increased Ca bulk content are consistent with recent thermodynamic modeling of phase equilibria (Spear, 2010). Experiments also support natural observations from the amphibolite-facies Alpine metapelites regarding the influence of CaO/Na2O ratio in bulk content on the relative stabilities of monazite and REE-rich epidote (Janots et al., 2008).

Alteration of xenotime is observed in all runs. (Y,HREE)-rich britholite or (Y,HREE)-rich fluorapatite always formed. In contrast to monazite experiments, (Y,HREE)-rich epidote formed only at 650°C and 8-10 kbar, in the presence of 2M Ca(OH)2. Results are partially consistent with natural observations showing that stability of (Y,HREE)-rich epidote is promoted by high Ca bulk content with high CaO/Na2O ratio (Janots et al., 2008). However, experimental results indicate that the relative stabilities of xenotime and (Y,HREE)-rich epidote are strongly controlled by pressure.

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