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Monazite and xenotime solubility in hydrous, boron-bearing rhyolitic melt

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Abstract

We conducted a series of monazite and xenotime dissolution experiments in a boron-bearing silicic melt at 1000–1400 °C and 800 MPa in a piston-cylinder apparatus. We present new measurements of monazite and xenotime solubility in hydrous (~3 wt% water), boron-bearing rhyolitic melts, as well as the diffusivities of the essential structural constituents of those minerals (LREE, P, and Y). We compare our results to the previous studies and discuss the implications of this study on the understanding of natural, silicic (granitic/rhyolitic) systems.

We propose one equation describing the relationship between the solubility of xenotime and temperature in hydrous rhyolitic melts:

$$\ln Y = 18.3 \pm 0.3 - \frac{125499 \pm 3356}{\mathrm{R}T}$$

and another for monazite:

$$\ln\Sigma\mathrm{LREE} = 18.6 \pm 1.5 - \frac{129307 \pm 18163}{\mathrm{R}T}.$$

In the presence of sufficient phosphorous, the concentration of LREE needed for monazite saturation is within the uncertainty of the Y concentration needed from xenotime saturation and indicates that in the case of equilibrium crystallization the mineral that forms will only depend on the availability of LREE and Y and HREE. Given the similarity of the solubility of xenotime to that of monazite, we propose that previously published models of monazite solubility in silicic melts can potentially be applied to xenotime, and could, like monazite, serve as a geothermometer.

In the case of disequilibrium crystallization in front of rapidly growing crystals, Y will diffuse faster than LREE and xenotime will only crystallize when LREE are depleted. We also found that the diffusion of Y is greater than the diffusion of P from dissolving xenotime, unlike the similar diffusivities of LREE and P during monazite dissolution. The significant difference between Y and P diffusivities suggests that the components forming xenotime diffuse as separate entities rather than molecular complexes.

The dissolution of phosphates (monazite, xenotime, apatite) in hydrous, silicic melts with the addition of boron leads to liquid-liquid immiscibility at high temperatures where the saturation values of P and either light rare earth elements or Y are in the weight percent range. Immiscibility is not observable at low, magmatic temperatures, most probably due to the lower concentrations of P_2O_5 necessary for phosphate saturation at these conditions; however addition of other components, notably F, may result in liquid-liquid immiscibility at magmatic temperatures.

Keywords: Monazite solubility, xenotime solubility, silicate melts, LREE diffusion, Y diffusion, liquid-liquid immiscibility