Experiments and numerical modeling of hydrothermal REE ore forming processes in the crust

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The rare earth element (REE) fluorocarbonate mineral, bastnäsite-(Ce), and REE phosphate mineral, xenotime-(Y), are the main light (L)REE- and heavy (H)REE-bearing minerals, respectively, in magmatic-hydrothermal REE deposits. Our understanding of how these REE deposits form, however, and the effects of hydrothermal processes on the mobilization of the REE, is very limited due mainly to the paucity of thermodynamic data for these minerals.

In this study, we report new experimentally determined thermodynamic properties for the REE fluorocarbonate minerals bastnäsite-(Ce) and parisite-(Ce) [1]. We also report measurements of the the solubility of xenotime-(Y) from 100 to 250 °C and water saturation pressure (psat). Our data differ by orders of magnitude from those that can be calculated from currently available calorimetric data [2]. The new mineral data have been incorportated in the numerical simulation code GEM-selektor (http://gems.web.psi.ch) together with available experimental data for aqueous REE species. Using the new data, we have modeled hydrothermal fluid-rock interaction processes at 450 to 150 °C and 1 kbar. These simulations of crustal REE ore forming processes were employed to explain the behavior of REE in hydrothermal fluids of peralkaline granitic and carbonatitic systems. The Strange Lake REE-Zr-Nb deposit in Canada and the HREE deposit in Lofdal, Namibia, are used as test examples. We explore a commonly occuring replacement reaction of zircon by xenotime and the effect of different ligands and acids (i.e. $HCl_{(aq)}$, $HF_{(aq)}$ and $H_3PO_{4(aq)}$) in delineating the physico-chemical conditions prevailing during the hydrothermal stages of REE ore deposition.

[1] Gysi & Williams-Jones (2015), *Chemical Geology* **392**, 87-101 [2] Gysi, Williams-Jones & Harlov (2015), *Chemical Geology* **401**, 83-95.