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Experimental constraints on miscibility gap between apatite and britholite and REE partitioning in an alkaline melt

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Abstract

Apatite containing 14 wt% TREO (total rare earth oxide) and coexisting with calciobritholite with 37.2 wt% TREO has been synthesized at 800 °C and 10 kbar from a felsic melt with the addition of NaCl. The analysis of the experimental products with regression analysis of time-resolved (RATR) laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) data allowed to estimate the composition of the coexisting phases. The results suggest that equilibrium has been established during the run and both apatite and calciobritholite contained REE in [$Si^{4+}REE^{3+}$] to [$Ca^{2+}P^{5+}$] solid solution, whereas the coupled substitution [$Na^{1+}REE^{3+}$] to [$2Ca^{2+}$] was insignificant despite crystallization from an alkaline, Na-rich melt. The coexistence of the apatite and calciobritholite and available experimental data allowed the miscibility gap to be constrained between apatite and calciobritholite, and suggest complete miscibility between apatite and britholite above 950 °C. The melt that produced coexisting apatite and calciobritholite was characterized by a significant Cl content of (0.51 wt%) and elevated REE (526 ± 19 ppm Ce) and low-P content (112 ± 49 ppm). The change of the accessory mineral association from monazite to apatite and calciobritholite with the addition of NaCl illustrates the importance of halogens for mineral associations. The partition coefficients of britholite are similar to those of apatite and are distinguished mainly by a higher preference for REE and Th. Henry's law was not acting for the total REE content in the melt because of the buffered system; however the partition coefficients could still be used for the prediction of the relative REE patterns for melts that generated high-REE apatite and/or calciobritholite. These results have implications for the interpretation of the phosphate associations in alkaline volcanic and plutonic rocks.

Keywords: Apatite, britholite, calciobritholite, REE, alkaline magma, experimental petrology, LA-ICP-MS; Experimental Halogens in Honor of Jim Webster