

Experimental study of apatite-fluid interaction and partitioning of rare earth elements at 150 and 250 °C

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ABSTRACT

Apatite is a common accessory phase in igneous and metamorphic rocks. Its stability in magmatic-hydrothermal and hydrothermal systems is known to be a key control on the mobility of rare earth elements (REE). To better constrain how apatite is altered during fluid-rock interaction at comparably low temperatures, batch-type apatite dissolution experiments were conducted at 150 and 250 °C at saturated water vapor pressure in acidic to mildly acidic (pH of 2–4) aqueous fluids having variable salinities (0, 0.5, and 5 wt% NaCl). The study reveals the dominance of apatite dissolution textures with the formation of micrometer-scale etch pits and dissolution channels developing prominently along the c-axis of the apatite crystals. Backscattered electron imaging shows an increase in apatite dissolution with increasing temperature and upon reacting the crystals with more acidic and higher salinity starting fluids. This study also demonstrates an increase in dissolved REE in the experimental fluids corroborating with the observed apatite dissolution behavior. Backscattered electron imaging of secondary minerals formed during apatite dissolution and scanning electron microscopy-based energy dispersive spectrometry peaks for Ca, P, and REE support the formation of monazite-(Ce) and minor secondary apatite as deduced from fluid chemistry (i.e., dissolved P and REE concentrations). The studied apatite reaction textures and chemistry of the reacted fluids both indicate that the mobility of REE is controlled by the dissolution of apatite coupled with precipitation of monazite-(Ce), which are enhanced by the addition of NaCl in the starting fluids. This coupled process can be traced by comparing the REE to P ratios in the reacted fluids with the stoichiometry of the unreacted apatite crystals. Apatite metasomatized at temperatures <300 °C is therefore controlled by dissolution rather than dissolution-reprecipitation reactions commonly observed in previous experiments conducted above 300 °C. Furthermore, this study demonstrates that the presence of NaCl plays a crucial role in increasing the solubility of apatite, which controls the availability of REE to form secondary phosphates even in mildly acidic aqueous fluids. This implies that both the effects of acidity/alkalinity of the fluids and the role of dissolved alkalis (NaCl and KCl), need to be considered for understanding the controls on REE in magmatic-hydrothermal systems. Lastly, the experiments of this study expand the known conditions at which apatite is susceptible to be overprinted by hydrothermal alteration from 900 °C down to 150 °C and highlights the necessity of appropriately screening apatite grains using backscattered electron and cathodoluminescence imaging for signs of hydrothermal alteration textures in igneous apatite.

Keywords: Apatite, monazite, REE mobility, dissolution-precipitation, metasomatism, hydrothermal fluids, experiments; Experimental Halogens in Honor of Jim Webster