Enrichment of the rare-earth elements in mafic alkaline rocks: Insights from monazite saturation in carbonatitic and carbonated nephelinitic melts

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Abstract

The rare-earth elements (REE; the lanthanides as well as Y and Sc) have a number of applications particularly in high-tech products, for example permanent magnets and rechargeable batteries. Mafic alkaline rocks, including carbonatite–alkaline complexes, are important reservoirs of the REE in which monazite, a phosphate mineral containing variable amounts of Ce, La, Nd, Pr and Th, is a common REE ore. However, the conditions under which REE enrichment and monazite formation took place are not fully understood. In this study, experiments were conducted to investigate the solubility of synthetic Nd-monazite (to avoid complications due to the redox variability of Ce) in nephelinitic compositions with varying carbonate contents (~6–37 wt. %) and containing a large number of trace elements at 1 GPa and 1100 °C to 1500 °C. Monazite crystals ranging in size from several microns at 1100 °C to 50 µm at 1500 °C, as well as glass occasionally showing spinifex silicate crystals were identified as the experimental products. The Nd concentration of the glass revealed by energy-dispersive X-ray analysis varied from ~3.5 wt. % at 1100 °C to ~21.5 wt. % at 1500 °C for a nephelinite containing ~6 wt. % carbonate. The effect of carbonate concentration on the solubility of monazite is being investigated and monazite-melt partition coefficients for trace elements will be determined. Our findings could provide insights into monazite formation and REE enrichment in economically significant REE deposits that are often associated with carbonatite–alkaline complexes and possess unusually high REE contents (up to wt. % levels), for example Mountain Pass in California, USA.