The nature and origin of REE mineralization in the Ashram deposit, Eldor Carbonatite Complex, Québec, Canada

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A growing number of studies have suggested that hydrothermal remobilization is crucial for the formation of carbonatite-hosted rare earth element (REE) deposits [1-3]. The Ashram REE deposit, hosted by the Paleoproterozoic Eldor Carbonatite Complex [4], is an example of a REE deposit formed mainly due to hydrothermal processes in magnesio- and ferro-carbonatite. The REE minerals in the Ashram deposit, monazite-(Ce), bastnäsite-(Ce), xenotime-(Y) and minor aeschynite-(Y), are secondary, and were precipitated from hydrothermal fluids. They occur mainly as disseminations, in breccia matrices and veins, and as vug fillings. Hydrothermal apatite and fluorite are also present in appreciable quantities in REE-mineralized zones. Monazite-(Ce) was the earliest REE mineral to form, and was followed by xenotime-(Y) and bastnäsite-(Ce). The compositions of the main REE minerals vary with location in the deposit, particularly in respect to their Nd_2O_3 and ThO_2 contents. Two generations of monazite-(Ce) have been distinguished on the basis of their Nd content. Early, low-Nd monazite-(Ce) formed by replacing apatite through the substitution of $3REE^{3+}$ for $5Ca^{2+} + F^-$; low-Nd apatite is LREE-enriched compared to apatite. In contrast, the later high-Nd generation, which has a chondrite-normalized REE profile almost perfectly parallel to that of the apatite, is interpreted to have formed by dissolving the Ca^{2+} and F^- of the apatite and reconstituting the REE and phosphate as monazite-(Ce):

$Ca_{4.94}REE_{0.060}(PO_4)_3F = 0.060REEPO_4 + F^- + 4.94Ca^{2+} + 2.94PO_4^{3-}$

Bastnäsite-(Ce) developed as a replacement of monazite-(Ce) through ligand exchange (F^- and CO_3^{2-} for PO_4^{3-}), while preserving the original REE chemistry. A combination of magmatic zone-refinement and hydrothermal remobilization, involving a chloride-bearing fluid, contributed to the formation of a carbonatite-hosted REE deposit.

[1] Moore *et al.* (2015) *Ore Geol Rev* **64**, 499-521. [2] Xie *et al*. (2015) *Ore Geol Rev* **70**, 595-612. [3] Trofanenko *et al*. (2016) *Econ Geol* **111**, 199-223. [4] Machado *et al.* (1997) *Can J Earth Sci* **34**, 716-723.