

Structural state of REE in Eudialyte-Hosted Critical Metal Deposits

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Eudialyte group minerals (EGM) are complex alkali-zirconosilicates associated with the agpaitic suite of peralkaline igneous rocks. They attract global interest as potential resources for Zr, Nb and heavy rare earth elements (HREE), i.e. elements with essential applications in modern technologies (i.e. electric vehicles, wind turbines). They contain up to 10 wt% rare earth oxides, and display favorable enrichments in Nd and heavy REE (c. 35%). Despite their economic importance and pivotal role in the geochemical evolution of the peralkaline magmas from which they crystallise, the crystal-chemical controls on preferential heavy REE enrichment in eudialyte are still poorly understood.

Here we use X-ray absorption spectroscopy (XANES and EXAFS) to determine the structural state of REE in eudialyte. We collected Y K-edge and Nd L₃-edge spectra as proxies for heavy and light REE, respectively, on compositionally variable EGM from prospective alkaline complexes (Ilímaussaq, Narsarsuk, Norra Kärr, Kipawa and Lovozero). EXAFS data yield best fits for Y in 6-fold coordination with Y-O bond distances of 2.24-2.32 Å, consistent with Y dominantly substituting for Ca on the octahedral M1 site. The second coordination sphere is successfully fitted to a structural model comprising Na, Fe, Si, Ca and O in sites surrounding M1 at c. 3.5 Å. Our results exclude preferential substitution of heavy REE on the smaller 6-fold Z site (Zr), or the larger 8-fold N4 site (Na). We explain our results using relative lattice strain partitioning models using estimated Young's Moduli for the considered sites. These predict that even the smallest REE are favoured on the M1 site, and that preferential partitioning of HREE increases with partial occupation of M1 by Mn or Fe. As such, we infer that the flat to HREE enriched profiles that make eudialyte an attractive exploration target are not the result of heavy and light REE partitioning onto different structural sites, but they may result from local ordering or coupling of HREE with Mn and Fe.

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