

## Hydrothermal Alteration of the Nechalacho Rare Metal Deposit, Canada

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The Nechalacho deposit, Northwest Territories, constitutes an important resource of rare earth elements (REE), zirconium and niobium. Its Basal Zone contains a measured resource of 12.56 Mt grading 1.71 wt. % REE-oxide with a heavy REE proportion of 22.5% and additional indicated and inferred resources of 107.5 Mt. The deposit formed by magmatic accumulation and interstitial crystallization of eudialyte (kentbrooksit, a REE-Nb-zirconosilicate) near the top of a 2176 Ma old layered nepheline syenite intrusion. Radiogenic and stable isotope, whole rock and mineral chemical data indicate that the rocks crystallized from a mantle-derived magma that underwent multiple stages of fractional crystallization in the source and at the emplacement level to acquire high REE-Zr-Nb concentrations. Despite the enrichment of REE, Nb and Zr by igneous processes and a lack of evidence for hydrothermal remobilization of these elements in the Basal Zone, hydrothermal alteration had drastic implications for the mineralogy of the deposit: eudialyte was completely replaced by REE-Nb-enriched zircon and secondary REE-Nb-minerals, mainly fergusonite-(Y) and bastnäsite-(Ce). The host rock aegirine-nepheline syenite was metasomatized into a biotite-quartz-magnetite-ankerite-fluorite assemblage. Previous monazite dating indicated alteration ages from 1835 to 1871 Ma. Fluid inclusion data and mass-balance considerations indicate that the alteration fluids were aqueous-carbonic and contained MgCl<sub>2</sub>. Mineral equilibria calculated for 300 °C and 4 kbar show that the fluid was reducing ( $f_{O_2}$  was 1.3 to 2.0 log units above the quartz-fayalite-magnetite buffer) and that pH was mildly acidic to neutral (between 3.2 and 4.7). With Ca and CO<sub>2</sub> in the modeled fluid, ankerite becomes stable and the reaction biotite-ankerite buffers pH at 3.7. Likely, the alteration fluid was initially acidic and neutralized upon reaction with the nepheline syenites. Sodium was lost in large proportions during the alteration (reaction of aegirine, a Na-Fe-clinopyroxene, to magnetite). To evaluate the origin of this fluid, we calculated the pH of a magmatic fluid in equilibrium with fresh nepheline syenite using the HCh software. The magmatic fluid would have alkaline pH, produced by the reaction of nepheline to analcime. Hence, we conclude that the acidic, MgCl<sub>2</sub>-bearing hydrothermal fluid responsible for the *in situ* replacement of eudialyte and alteration of the host syenites was an externally derived crustal fluid and was likely related to the 1835-1871 Ma regionally pervasive hydrothermal event. The identity and composition of the secondary REE-Nb-minerals was controlled by the original chemistry of eudialyte and by the composition of the fluid (e.g., high CO<sub>2</sub> content stabilized REE-fluorocarbonates).