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REE-Enrichment in Alkaline Ultramafic Cumulates: new insights on The Carbonatite-Ultramafic Rock Paradox from The Riviere Noire Clinopyroxenite, Grenville Province (Québec)

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The Rivière Noire Intrusive Suite (RNIS) crops out in the Central-Western Grenville Province, North of Lac-Saint-Jean (Québec). This region hosts several REE- and Nb-rich alkaline and carbonatite intrusions, formed during and after the Grenvillian orogeny (1090–980 Ma). The RNIS is unique in the region as its emplacement time (~1130 Ma) predates the Grenvillian orogeny.

The RNIS is an alkaline complex formed by high Ba-Sr ultrapotassic rocks, consisting of titanite-apatite-allanite-bearing clinopyroxenite, with REE concentrations up to 0.3 wt.%. Locally, the presence of carbonate-amphibole-rich pockets (up to 30 cm) is interpreted as a result of the crystallisation of a late evolved carbonatitic melt. These cumulates are crosscut by mafic- to alkali-syenite dykes and pegmatitic-aplitic syenite dykes.

Diopside grains from the clinopyroxenitic cumulates are rich in primary complex inclusions formed by a fluid phase (20-80 vol.%) and solid phases. Microthermometry, Raman spectroscopy, and LA-ICP-MS were performed on these inclusions to gain insight into their composition. The fluid phase appeared to be intermediate salinity (< 18 wt.% $NaCl_{Eq}$) K-Na-Cl-H_2O-bearing fluids, while Raman spectroscopy indicates that the daughter phases are dominated by hydrated carbonates and titanites. The LA-ICP-MS analyses of those complex inclusions reveal strong enrichment in K, Ti, Ca, Sr, Ba, S, Cl, and Ti with low concentrations of Si, Mg and Fe. These results infer that the diopside grains have crystallized from a Si-poor CO_2-LILE-sulphate-rich melt. In addition, diopside, titanite, apatite, and allanite phases have an unusual sinusoidal REE pattern marked by La and Ce depletion compared to Pr and Nd, and by Yb and Lu enrichment. This feature is characteristic of the crystallisation of those minerals from a carbonatitic liquid.

Carbonatite metasomatism is a proposed process in which carbonatitic melt acts as agent of metasomatism, interacting with silicic host lithologies to form “antiskarn” rocks dominated by diopside, apatite, and titanite. This process explains the minerals sinusoidal REE pattern and the primary diopside-hosted complex inclusions. Nevertheless, the euhedral aspect of diopside grains, their Mg-Fe compositional core-rim zoning, the lack of aegirine compositions and the absence of any evidence of metasomatic reactions with the host rock during field observations challenge this hypothesis.