Weathering at Depth - Key Process Forming REE-Rich Regolith at the Mt Weld Carbonatite (Western Australia)

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Rising demand for green technologies drives interest in rare earth elements (REE), with carbonatite-derived deposits as key exploration targets. However, the genesis of high-grade REE deposits in weathered carbonatites remains unclear due to variable bedrock composition and complex pedogenetic processes. These challenges hinder the development of predictive exploration models and limit the potential for resource extraction. A prime example is the Mt Weld deposit (WA), a world-class REE resource, which consists of a regolith profile formed by the supergene alteration of a 2.06 Ga ferroan dolomite carbonatite (FDC). This study integrates detailed mineralogical investigations and stable and radiogenic isotopic analyses to resolve how magmatic-hydrothermal and weathering processes synergize to concentrate REE.

Between the unweathered FDC and the overlying regolith lies a 60–100m thick transitional zone (TZ), exhibiting partial oxidation of sulphides into hematite/goethite, formation of porosity due to limited matrix dolomite dissolution, and precipitation of Mn-oxides and secondary REE-fluorocarbonates (e.g., bastnäsite-synchysite-parisite). Whole-rock chemistry revealed a twofold increase in REE concentrations from the FDC to the TZ, accompanied by elevated REE content in apatite (avg.=1.07%) and HREE in monazite (avg.=1136ppm). Isotopic values of $\delta^{18}O$ (<21.8‰) and $\delta^{13}C$ (<−3.5‰), higher than mantle signatures, are driven by low-temperature fluid-rock interaction involving oxidized groundwater. This meteoric water overprint can also be seen by the shift in 87Sr/86Sr from ~0.70197 in FDC to 0.70228 in weathered rocks and 208Pb/204Pb from ~34.74 to 35.99. This fluid flows through the newly formed micro-to-centimetre scale porosity, promoting the migration of the alteration front and formation of the TZ.

The transitional zone represents a critical part of the carbonatite-hosted REE ore deposits, where supergene mineral-replacement reactions upgrade the REE-carriers of magmatic-hydrothermal origin. This work highlights the importance of transitional zones during carbonatite weathering, which is an intermediate stage during the transformation of carbonatite source rock into a super resource.