Preservation of Na-REE Mineralisation at Kangankunde Carbonatite Complex, Malawi, with Implications for Magma Evolution

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Carbonatites account for the majority of global light rare earth element (LREE) supplies and are vital in the transition towards low-carbon technology. Current models for REE-enrichment in carbonatites are conflicting, with some invoking hydrothermal REE transport, whilst others support extreme magmatic fractionation to an alkali- and REE-rich brine, commonly referred to as 'brine-melts'.

Conceptually, brine-melts are distinct from typical hydrothermal fluids owing to a lack of observable evidence for immiscibility between a melt and hydrothermal fluid. Experimental results suggest evolved carbonatite melts should be alkali enriched, but high alkali contents are rarely preserved in natural carbonatites. Their absence may be due to the water-soluble nature of Na-carbonate phases, which are rapidly lost during weathering and consequently their role in REE-mineralisation is overlooked. Here, we use core samples from the Kangankunde Complex, Malawi, which sample below the carbonatite weathering horizon, enabling the preservation of primary Na-REE-phases. Burbankite (Na-REE-carbonate), which has previously been postulated to act as a precursor to monazite mineralisation at Kangankunde, is described here for the first time. It occurs in all samples, preserved as inclusions. Moreover, other alkali-carbonate phases, such as bradleyite (Na-carbonate-phosphate) and eitelite (Na-carbonate) are also preserved, indicating that late-stage carbonatite at Kangankunde is enriched in Na, Sr, Ba, P, and LREEs. Ephemeral alkali components are subsequently removed, and the primary mineral assemblage is replaced by more stable phases. Our results move towards reconciling the gap between experimental studies and natural examples, confirming the importance of alkalis in an evolved carbonatite magma and highlighting their influence on primary rare-earth mineralisation.