

# Extreme Post-Magmatic REE Enrichment Process in Kamthai Carbonatite Complex, India constrained by Combined Petrologic and Geochemical Studies

AYUSH GUPTA<sup>1</sup>, ANUPAM BANERJEE<sup>1</sup>, DEBAJYOTI PAUL<sup>1</sup>, GELU COSTIN<sup>2</sup>, TAO SUN<sup>2</sup> AND RAJDEEP DASGUPTA<sup>2</sup>

<sup>1</sup>Indian Institute of Technology Kanpur

<sup>2</sup>Rice University

Presenting Author: bobbygupta134@gmail.com

Carbonatites are rare igneous rocks, often enriched in rare earth elements (REEs) mined to meet the global demand for energy transition toward zero-carbon sources. Therefore, understanding the REE enrichment process in carbonatites is critical. The Kamthai carbonatite complex in Rajasthan comprises intrusive veins, sills/dykes, and plugs of carbonatite within the associated alkaline silica-undersaturated host rocks (e.g., nephelinite, phonolite, etc.) and are highly REE-enriched. Earlier studies have linked the origin of this complex to the Deccan-Reunion plume activity. To understand the REE enrichment mechanism in these carbonatites, we performed petrography, whole rock and mineral chemistry, and carbon and oxygen stable isotope systematics of carbonatites and associated alkaline rocks.

WD-XRF results indicate Kamthai carbonatites are mainly calciocarbonatites (CaO: 40.7-52.4 wt%; MgO: 0.28-2.42 wt%, Fe<sub>2</sub>O<sub>3</sub>: 0.39-6.62 to wt%), with two of our samples being silico-carbonatites (SiO<sub>2</sub> ~20-24 wt%). ICP-MS analyses show high BaO (0.3-1.5 wt%) and Sr (1.1-5.7 wt%). The associated rocks are dominantly phonolite with minor basalt and trachyte, with some having BaO up to 0.6 wt% and ΣREE of 0.012-0.2 wt%. ΣREE in carbonatites typically vary from 0.4 to 1.5 wt% but reach up to ~7.3 wt% in samples showing hydrothermal alteration signature. Chondrite-normalized REE patterns reveal high LREE enrichment and LREE/HREE fractionation (La/Lu<sub>N</sub>: 40-3400) in carbonatites compared to the alkaline rocks, a process compatible with hydrothermal fractionation of REE [1]. EPMA analyses reveal the dominant occurrence of fluoroapatite and REE-minerals such as carbocearnite, bastnaesite, hydroxylbastnaesite, ancylite, parisite and synchysite in REE-rich carbonatites. BSE images show thick exsolved lamellae and symplectic intergrowth of REE minerals (e.g., hydroxylbastnaesite) along grain boundaries of (REE-poor) primary magmatic calcite/carbocearnite. Minor cerianite, aegirine, augite, feldspar, amphibole, phlogopite, barite, witherite, thorite and xenotime are present in carbonatites. Occurrences of Mn(OH)<sub>2</sub> and FeO(OH) pseudomorphs replacing primary phases indicate hydrothermal alteration. Less hydrothermally altered carbonatites show a mantle source origin (delta<sup>13</sup>C<sub>V-PDB</sub> ~-5.5‰ and delta<sup>18</sup>O<sub>V-SMOW</sub> ~-7.9‰). Highly altered and REE-enriched samples have delta<sup>18</sup>O<sub>V-SMOW</sub> »25‰ indicating

a meteoric/hydrothermal origin. Our results indicate that post-magmatic (hydrothermal) leaching from magmatic phases and precipitating as REE-rich minerals led to REE enrichments in Kamthai carbonatites.

[1] Patel, A. K. et al. (2023), *Lithos*, 444–445.