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Deciphering the Carbonatite-Clinopyroxenite Connection at Hogenakkal, India: Insights from Trace Elements, Sr Isotopes, and U-Pb Geochronology

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The Hogenakkal carbonatite complex comprises silicate-rich (carbonatite-I) and silicate-poor (carbonatite-II) calcite carbonatites, along with clinopyroxenite dykes in the Southern Granulite Terrane (SGT) (Bhattacharjee et al., 2024). In-situ trace element analysis identifies distinct calcite and apatite types. Magmatic Cal-1a [$(La/Yb)_{Cn}$: 18–36; Sr: 9056–11598 ppm] and Ap-1a [$(La/Yb)_{Cn}$: 45–98; Sr: 7430–8494 ppm] in carbonatite-I crystallized first, followed by LREE-depleted late-magmatic-to-carbohydrothermal Cal-1b [$(La/Yb)_{Cn}$: 0.6–5.9; Sr: 10143–11214 ppm] and Ap-1b [$(La/Yb)_{Cn}$: 11–31; Sr: 7229–8312 ppm], and similar trends in Cal-2 [$(La/Yb)_{Cn}$: 1.6–6.2; Sr: 9056–11598 ppm] and Ap-2 [$(La/Yb)_{Cn}$: 15–25; Sr: 9235–10158 ppm] of carbonatite-II due to monazite, allanite, and hydroxylbastnäsite co-crystallization. Carbohydrothermal fluids formed LREE- and Sr-depleted Cal-3 [$(La/Yb)_{Cn} < 0.5$; Sr: 3964–7637 ppm] and Ap-3 [$(La/Yb)_{Cn}$: 0.7–9.2; Sr: 3220–8349 ppm] in clinopyroxenite with Sr-rich epidote, allanite, and actinolite. Elevated Sr isotopic ratios in calcite (0.70203±0.00023) and apatite (0.70175±0.00015) compared to clinopyroxenes (0.70147±0.00021) suggest distinct magmatic origins. The elevated Sr ratios in some Cal-3 (up to 0.70313) and Ap-3 (up to 0.70260), as well as negative Ce anomalies [Ce/Ce*: 0.6–0.9; $Ce/Ce^* = Ce_{Cn}/(0.5La_{Cn} + 0.5Pr_{Cn})$] in Cal-3, suggest alteration by external hydrothermal fluids. The absence of alkaline silicate rocks, xenocrystic clinopyroxenes, and the lack of an evolutionary trend for clinopyroxene argue against liquid immiscibility and fractional crystallization. Furthermore, Sr isotopic mixing models indicate that, due to the high Sr content of the primary magma, antiskarn reactions would have yielded similar Sr isotopic ratios in carbonatite and clinopyroxenite. The carbonatites were likely formed by direct mantle melting, with high Ca/Mg ratios indicated by the absence of dolomite and primary Fe-Mg silicates. Mantle wherlitization and phlogopitization of pre-existing clinopyroxenite led to Mg loss, forming calcite carbonatites. In situ, U-Pb monazite dating (2499 ± 5 Ma) suggests carbonatite emplacement postdated the Western Dharwar Craton and Biligiri Rangan block collision in the SGT.

Reference:

Bhattacharjee, S., Chakrabarty, A., Mitchell, R.H., Patel, S.C., Kozlov, E.N., Fomina, E.N., Dey, M. & Pal, S. (2024). The role of magmatic-to-carbohydrothermal processes in rare earth mineralization in Hogenakkal carbonatites, India. Lithos **464**, 107431. https://doi.org/10.1016/j.lithos.2023.107431