Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34442

Damodar Valley lamproite Sr-Nd-Hf-Pb-C-O isotopes indicate melt hybridization of asthenospheric melts with SCLM metasomes

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Genetic lamproite petrological models [1,2] indicate common site melting of veined mantle metasomes, comprising carbonate-bearing or enriched K-silicate hydrate, within cold (and pressures between 3-4 GPa) subcontinental lithospheric mantle (SCLM). Here we attempt to constrain SCLM metasome compositions from lamproite dykes, intruded into the Damodar Valley Raniganj Permian coaliferous basin, that were emplaced near-coeval with Rajmahal flood basalt whose eruption is directly linked to the Kerguelen mantle plume. These lamproite compositions add to the dataset left out by [3]. The lamproite [4] yielded a precise whole-rock, phlogopite (Phl), olivine (Ol) Rb-Sr isochron age of 122 ± 1.2 Ma (2σ, MSWD=0.94, n=8) with Sr_i=0.7056 ± 0.0001 (2σ, Fig.1). Measured ranges in isotopic ratios of whole-rock fractions, Phl and Ol were: $^{87}Sr/^{86}Sr$ = 0.705488 – 0.705776, $^{143}Nd/^{144}Nd$ = 0.512298 – 0.512399, $^{176}Hf/^{177}Hf$ = 0.282520 – 0.282785, $^{206}Pb/^{204}Pb$ = 17.91 –18.27, $^{207}Pb/^{204}Pb$ = 15.51 – 15.56 and $^{208}Pb/^{204}Pb$ = 37.95 – 38.25. These are similar to Endmember 1 lamproites of [3], and in Sr-Nd-Hf-Pb isotopic space, plot in the enriched mantle EM1 field. Their elemental $\delta^{13}C_{V\text{-}PDB}$ are lighter at ~ −27 ‰, indicate mantle asthenosphere derivation. We propose lamproite magma formation by melt hybridization between Kerguelen plume asthenospheric melt endmember component (~70%) with ~30% SCLM metasome (modelled synthetic mica-peridotite-MARID mixture, Fig.2). Phlogopite melting in metasomes (either K-rich silicate hydrate or carbonate-bearing peridotite) by interaction with plume asthenospheric melts and would have hybridized to form lamproite magma. Melt hybridization was likely very efficient with low temperature separation of carbonatitic melts, as supported by Ol and Phl carbonate $\delta^{13}C_{V\text{-}PDB}$ of ~ −11 ‰ ($\delta^{18}O_{V\text{-}SMOW}$ of ~ +12 ‰), similar to natrocarbonatite [6]. This supports the formation mechanism proposed by [5] for lamproites.

[1] Foley, S., 1992, *Lithos* 28, 435-453. [2] Ulmer and Sweeny, 2002 *GCA* 66(12), 2139-2153; [3] Sarkar et al., 2025 *GCA* 394, 220-243. [4] Saini et al., 2022, *Lithos* 434, 106916; [5] Sarkar et al., 2022, *Geology* 50(11), 1296–1300; [6] Suwa et al., 1975. *Phy. Chem. Earth.* 9, 735-745.

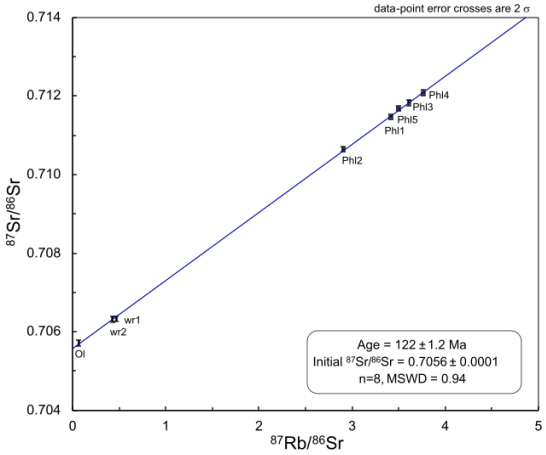


Fig. 1. Rb-Sr isochron of phenocryst and megacryst separates (phlogopite [Phl] and olivine [Ol]) and whole rock [wr] fractions of the Raniganj lamproite

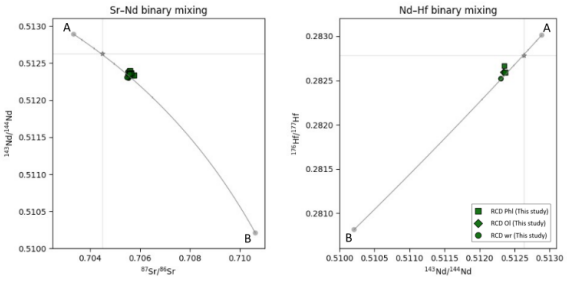


Fig. 2. Hyperbolic mixing curves between endmembers Kerguelen plume (A) and synthetic mica peridotite + MARID metasome (B) in Sr-Nd and Nd-Hf isotopic spaces.