12th International Kimberlite Conference Extended Abstract No. 12IKC-122, 2024

# Revisiting Sr-Nd-Hf isotope variations in global cratonic lamproites

**Soumendu Sarkar[1,2], Hayden Dalton[1], Andrea Giuliani[3], David Phillips[1], D. Graham Pearson[4], Geoff M. Nowell[5], Jon D. Woodhead[1], Janet Hergt[1], Roland Maas[1], A. Lynton Jaques[6], N.V. Chalapathi Rao[7,8], Sujoy Ghosh[2], Yaakov Weiss[9]**

[1]*The University of Melbourne, Melbourne, Australia,* soumendus@student.unimelb.edu.au, hayden.dalton@unimelb.edu.au, dphillip@unimelb.edu.au, jdwood@unimelb.edu.au, jhergt@unimelb.edu.au, maasr@unimelb.edu.au

[2]*Indian Institute of Technology Kharagpur, Kharagpur, India,* sujoy.ghosh@gg.iitkgp.ac.in

[3]*ETH Zurich, Zurich, Switzerland,* andrea.giuliani@erdw.ethz.ch

[4]*University of Alberta, Edmonton, Canada,* gdpearso@ualberta.ca

[5]*University of Durham, Durham, UK,* g.m.nowell@durham.ac.uk

[6]*Australian National University, Canberra, Australia,* lynton.jaques@anu.edu.au

[7]*Banaras Hindu University, Varanasi, India,* nvcrao@bhu.ac.in

[8]*National Centre for Earth Science Studies, Thiruvanathapuram, India*

[9]*The Hebrew University of Jerusalem, Jerusalem, Israel,* yakov.weiss@mail.huji.ac.il

## Introduction

Cratonic lamproites are rare ultrapotassic rocks that are dispersed across several continents and diverse time periods (0-2000 Ma) and show some of the most geochemically enriched Sr-Nd-Hf isotope compositions on Earth. Previous research has led to suggestions that cratonic lamproites may arise from the melting of hydrous veins, such as MARIDs (mica-amphibole-rutile-ilmenite-diopside), in peridotites or phlogopite-rich peridotites (e.g. Fraser et al. 1985; Foley 1992; Giuliani et al. 2015). In contrast, olivine compositions indistinguishable from those of kimberlites (Sarkar et al. 2022) and the occurrence of diamonds containing inclusions of majorite-bearing garnet in some cratonic lamproites (Stachel et al. 2018), suggest that primary lamproitic (or proto-lamproitic) melts originate in the convecting mantle. This prompts questions about whether the genesis of cratonic lamproites requires contributions from the sub-lithospheric (convective) mantle, as previously proposed for some K-rich ultramafic lamprophyres (e.g., Tappe et al., 2008; Dalton et al. 2019). Here, we present new major, trace element and Sr-Nd-Hf isotopic compositions for 61 fresh lamproite samples, to complement existing published data for global cratonic lamproites. Sample selection criteria were based on addressing the paucity of Hf isotope data in literature, while including as many lamproite provinces as possible. We then re-evaluate the origin of cratonic lamproites on a global scale. Specifically, we seek to identify specific source components included in lamproite melts as well as the mantle processes that might have contributed to the observed isotopic variations in these rocks.

## Results and discussion

Initial $^{87}Sr/^{86}Sr$ values for the current samples vary significantly across different lamproite provinces (0.7037 to 0.7092), although $^{87}Sr/^{86}Sr_{(i)}$ values show a more restricted range within individual clusters. Furthermore, the $\varepsilon Nd_{(i)}$ and $\varepsilon Hf_{(i)}$ values of the studied samples range from 1.1 to -23.7 and 2.4 to -34, respectively. The Nd-Hf isotopic compositions of all the examined samples are similar to other cratonic lamproites worldwide, but are less radiogenic compared to archetypal kimberlites worldwide (e.g. Woodhead et al. 2019, Giuliani et al. 2021).

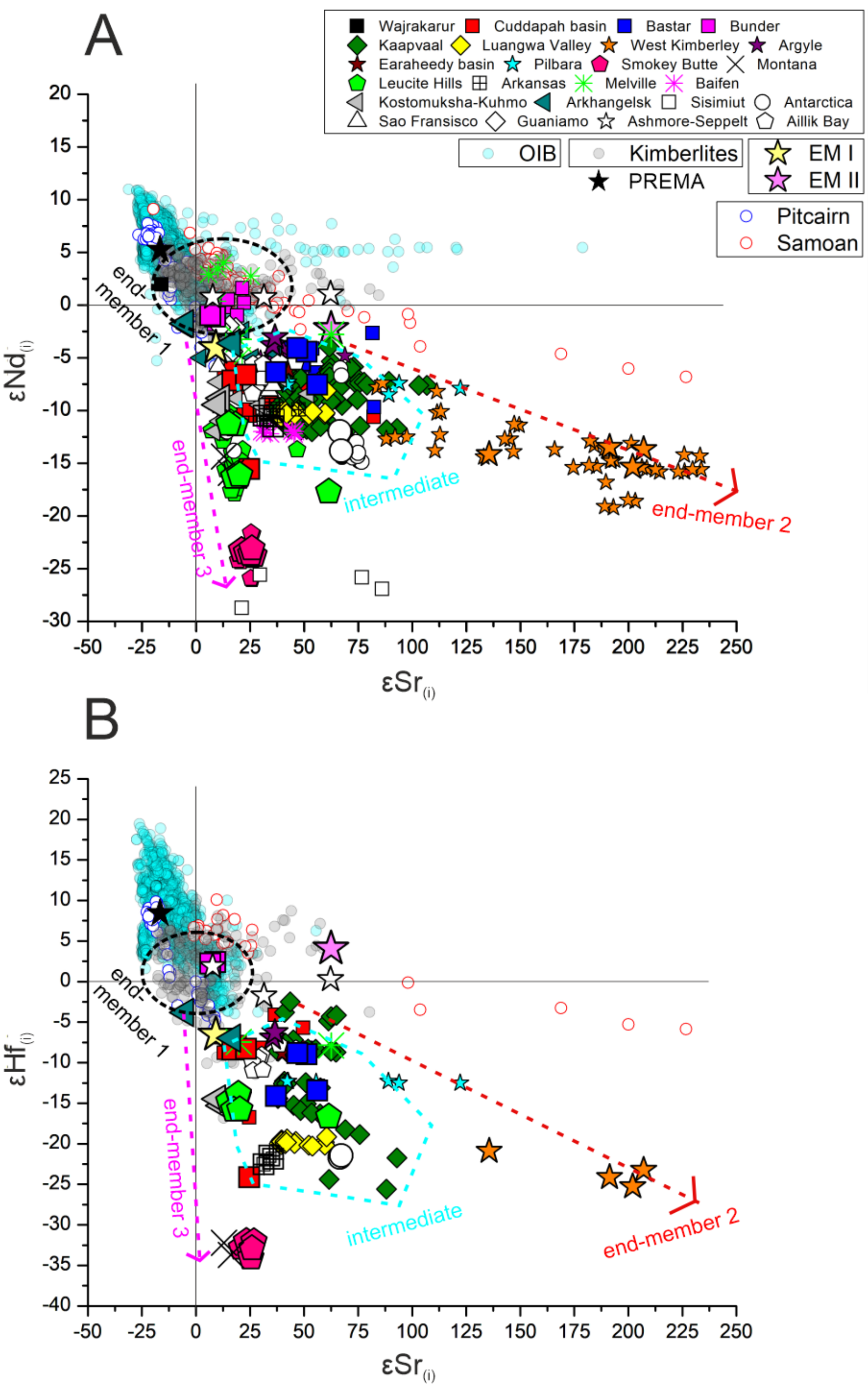


Figure 1: Bulk Sr-Nd-Hf isotope covariation plots for global cratonic lamproites. Larger data points are from this study. Kimberlites and PREMA – PREvalent Mantle are from Giuliani et al. (2021). OIBs are from Stracke et al. (2022). Mantle end-member compositions are from Konter et al. (2008) and Stracke et al. (2022): EM I – Enriched Mantle I, EM II – Enriched Mantle II.

Within the global Sr-Nd-Hf data (Fig. 1), three distinct isotopic end-members are identified. The first end-member (referred as "end-member 1"; Fig. 1) consists of lamproites from Wajrakarur, Bunder, Melville, Arkhangelsk, Ashmore-Seppelt, which have depleted $\varepsilon Sr_{(i)}$-$\varepsilon Nd_{(i)}$-$\varepsilon Hf_{(i)}$ compositions, overlapping with OIB and kimberlite compositions and plot at similar to marginally more geochemically-depleted compositions than the bulk silicate earth (BSE). The second end-member corresponds to the array defined by the West Kimberley lamproites, which exhibit elevated $\varepsilon Sr_{(i)}$ values, but a limited range in $\varepsilon Nd_{(i)}$ and $\varepsilon Hf_{(i)}$ values, referred to as "end-member 2" (Fig. 1). The third isotopic end-member (referred as "end-member 3") is represented by lamproites from Leucite Hills, Smokey Butte and Sisimiut, with values that extend from BSE to more negative $\varepsilon Nd_{(i)}$-$\varepsilon Hf_{(i)}$ values at mildly radiogenic Sr. The remaining lamproites have 'intermediate' isotopic composition between these endmembers.

Major and trace element compositions, along with the results from isotope mixing models, indicate that global cratonic lamproites require contributions from both lithospheric and asthenospheric components. It is apparent that the heterogeneity in mixing proportions of each component in various regions plays a crucial role in generating distinct isotopic compositions. Regardless of the local 'flavour' imparted due to regional heterogeneities, a prevailing asthenospheric contribution, akin to typical kimberlites, coupled with an enriched phlogopite-bearing lithospheric component and/or input from subduction, appears to be important in the genesis of cratonic lamproites. This reinforces the idea that primary lamproitic (or proto-lamproitic) melts might originate in the convective mantle rather than being exclusively generated in the lithospheric mantle (e.g. Sarkar et al. 2022).

**References**


Foley S. (1992) Vein-plus-wall-rock melting mechanisms in the lithosphere and the origin of potassic alkaline magmas. Lithos 28:435–453.

Fraser KJ, Hawkesworth CJ, Erlank AJ, Mitchell RH, Scott-Smith BH (1985) Sr, Nd and Pb isotope and minor element geochemistry of lamproites and kimberlites. Earth Planet Sci Lett 76:57–70.

Giuliani A, Jackson MG, Fitzpayne A, Dalton H (2021) Remnants of early Earth differentiation in the deepest mantle-derived lavas. Proc Natl Acad Sci 118(1): e2015211118.

Giuliani A, Phillips D, Woodhead JD, Kamenetsky VS, Fiorentini ML, Maas R, Soltys A, Armstrong RA (2015) Did diamond-bearing orangeites originate from MARID-veined peridotites in the lithospheric mantle?. Nat Commun 6:6837.

Dalton H, Giuliani A, O'Brien H, Phillips D, Hergt J, Maas R (2019) Petrogenesis of a hybrid cluster of evolved kimberlites and ultramafic lamprophyres in the Kuusamo area, Finland. J Petrol 60(10):2025–2050.

Konter JG, Hanan BB, Blichert-Toft J, Koppers AAP, Plank T, Staudigel H (2008) One hundred million years of mantle geochemical history suggest the retiring of mantle plumes is premature. Earth Planet Sci Lett 275: 285–295.

Sarkar S, Giuliani A, Phillips D, Howarth GH, Ghosh S, Dalton H (2022) Sublithospheric melt input in cratonic lamproites. Geology 50(11):1296–1300.

Stachel T, Harris JW, Hunt L, Muehlenbachs K, Kobussen AF (2018) Argyle diamonds: How subduction along the Kimberley Craton edge generated the world's biggest diamond deposit. In: Davy T, et al. (eds) Geoscience and Exploration of the Argyle, Bunder, Diavik, and Murowa Diamond Deposits. Soc Econ Geol Sp Public 20:145–167.

Stracke A, Willig M, Genske F, Béguelin P, Todd E (2022) Chemical geodynamics insights from a machine learning approach. Geochem, Geophys, Geosys 23(10): e2022GC010606.

Tappe S, Foley SF, Kjarsgaard BA, Romer RL, Heaman LM, Stracke A, Jenner GA (2008) Between carbonatite and lamproite—Diamondiferous Torngat ultramafic lamprophyres formed by carbonate-fluxed melting of cratonic MARID-type metasomes. Geochim Cosmochim Acta 72:3258–3286.

Woodhead J, Hergt J, Giuliani A, Maas R, Phillips D, Pearson DG, Nowell G (2019) Kimberlites reveal 2.5-billion-year evolution of a deep, isolated mantle reservoir. Nature 573:578–581.