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Geochemistry of potassic sills and dykes from Jharkhand: Implications for the Cretaceous lamproite magmatism of eastern India in proximity to the Kerguelen mantle plume

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Introduction

Early Cretaceous potassic magmas intruded as sills and dykes into the Gondwana sedimentary succession of the Jharia basin in Jharkhand, eastern India. These potassic minor intrusions have been classified previously as "kersantites", "mica peridotites", "minettes", "olivine lamproites" or "lamprophyres" by various workers. We analysed the bulk rock compositions of these potassic intrusives by XRF and ICP-MS techniques to study their nature and origin, using the analytical setup described in Tappe et al. (2023).

Bulk rock compositions

The Jharia sills and dykes are characterized by high MgO (10.7–19.5 wt.%), K_2O (1.1–6.7 wt.%) and TiO_2 (4.2–6.5 wt.%) concentrations but relatively low Na_2O (<0.9 wt.%) contents. They contain small amounts of Al_2O_3 (4.5–7.8 wt.%) and CaO (3.5–8.5 wt.%), which is a characteristic feature of cratonic lamproites worldwide (~5–10 wt.% Al_2O_3 and ~2–12 wt.% CaO; Mitchell 2020; Ngwenya and Tappe 2021).

Classification on the basis of geochemistry

The minor intrusions fall into the field of lamproites on a MgO–K_2O–Al_2O_3 plot, which is typically used to identify the petrogenetic affinity of primitive potassic magma suites (Fig. 1).

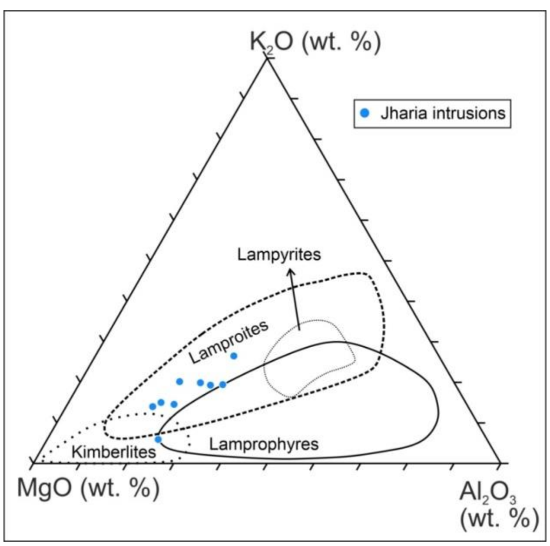

Figure 1: Classification of the Jharia potassic minor intrusions using the MgO–K_2O–Al_2O_3 diagram with fields for rock types after Krmíček and Chalapathi Rao (2022).

These intrusions have high MgO and TiO_2 contents, high K_2O/Al_2O_3 ratios, and low Al_2O_3, Na_2O and CaO contents, which is a geochemical hallmark feature of lamproites (Foley et al. 1987; Mitchell and Bergman 1991). The Jharia intrusions show compositional similarities to archetypal cratonic lamproites (e.g., West Kimberley, Wyoming, Eastern Dharwar, Bastar) and Kaapvaal orangeites. Higher TiO_2 and lower CaO distinguish the eastern India lamproites from Kaapvaal orangeites (<3 wt.% TiO_2; Ngwenya and Tappe 2021) and archetypal aillikites (>10 wt.% CaO; Tappe et al. 2006), respectively.

The anorogenic 'cratonic' character of the lamproites from Jharkhand is mirrored by low Al_2O_3/TiO_2 ratios (0.8–1.4), a negative Pb anomaly (i.e., lacking a subducted sediment signature in the mantle source), absence of a negative Nb–Ta anomaly, as well as Nb enrichment as illustrated in the Th–Hf–Nb/2 discrimination diagram (Fig. 2, 3).

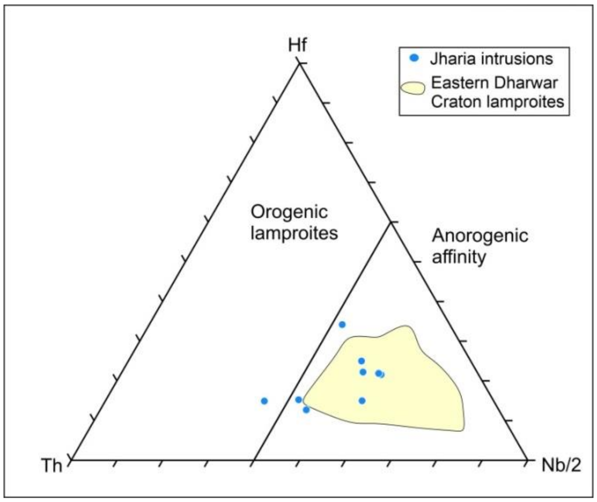

Figure 2: Classification of the Jharia minor intrusions using the Th–Hf–Nb/2 diagram to discriminate between orogenic and anorogenic lamproites (Krmíček et al. 2011). The field for the Eastern Dharwar Craton lamproites is after Talukdar et al. (2018).

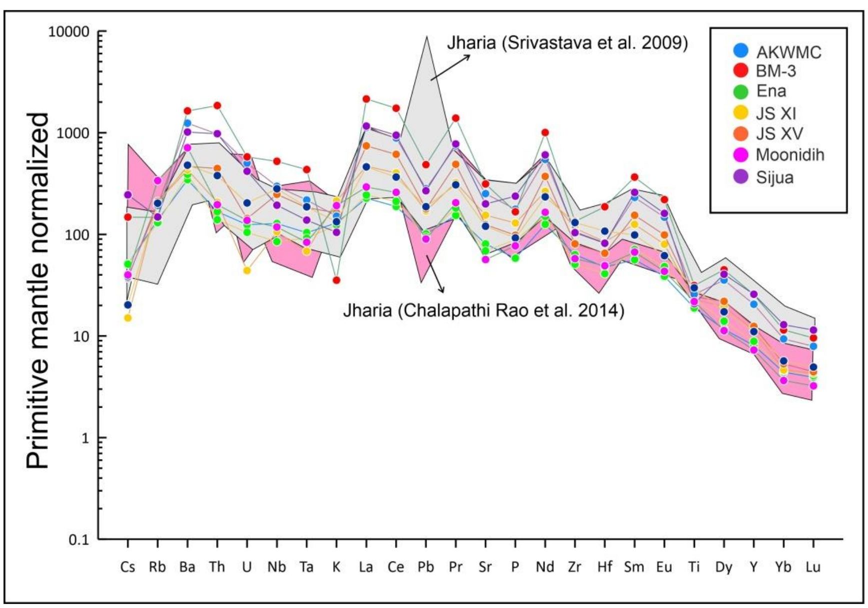

Figure 3: Primitive mantle normalized incompatible element distributions of the Jharia lamproites studied here (coloured circles), with fields for previously analyzed Jharia samples after Srivastava et al. (2009) and Chalapathi Rao et al. (2014).

Petrogenesis

Collectively, the bulk rock geochemistry of the potassic sills and dykes studied indicates lamproite magma derivation from K-metasomatized peridotitic mantle sources within the garnet stability field by low degrees of partial melting. The melting event within the cratonic mantle lithosphere of eastern India may have occurred while this region of former Gondwanaland was positioned in the periphery of the Kerguelen mantle plume, without any notable influence by subduction. A link between cratonic lamproite eruptions and plume-related flood basalt volcanism has recently been demonstrated for the Jurassic Karoo LIP in Africa (Tappe et al. 2023), and together with the evidence presented here for eastern India, plume–lithosphere interaction may be an important mechanism in the origin of anorogenic lamproites.

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