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Nature and origin of lamproite hypabyssal intrusives from the Jharia basin in eastern India

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Introduction

Occurrences of potassic minor intrusions in the Jharia basin of eastern India were first documented by Blanford in the mid-19th Century. Names such as “kersantite”, “mica peridotite”, “minette”, “olivine lamproite” and “lamprophyre” were assigned to these potassic rocks by various workers, which led to confusion regarding their nature and origin. We have undertaken a systematic mineralogical study of eleven potassic sills and dykes from the Jharia basin.

Petrography and Mineral Compositions

These potassic intrusions of early Cretaceous age (ca. 115 Ma) typically exhibit a macrocrystal texture with olivine macrocrysts and phenocryststo-microphenocrysts of olivine, phlogopite–biotite, diopside, apatite, microphenocrysts of leucite (completely pseudomorphed by K-feldspar) and ilmenite set in a groundmass of phlogopite, diopside, apatite, ilmenite, spinel, hollandite-group minerals, potassic ferroeckermannite–titanian potassic magnesioarfvedsonite, rutile and K-feldspar.

The major and minor element compositions of the minerals in Jharia intrusions were determined by a CAMECA SX-Five electron microprobe. Two populations of olivine are found in the Ena dyke (Fig. 1a). Olivine-I with high Fo (90–92) and NiO (0.38–0.4 wt. %) contents but low CaO (<0.04 wt. %) and MnO (<0.10 wt. %) is xenocrystic (mantle-related), whereas the type II olivine from the Ena and Jamadoba-XI dykes with low Fo (84–88), low-to-high NiO (0.2–0.6 wt.%) and high CaO (0.1–0.3 wt.%) and MnO (0.1–0.3 wt.%) is magmatic (melt-related; Kaur et al. 2023). Phlogopite-I is present in the Bhowra, Chasnalla, Madhuband, Akashkinari and Sijua rocks (Fig. 1b). Phlogopite-I with low Fe_2O_3 (4.7–7.3 wt. %), low-to-high Cr_2O_3 (0.6–1.9 wt. %) and high Al_2O_3 (11.2–13.5 wt. %) and TiO_2 (6.6–9.3 wt. %) is antecrystic in origin. Antecrysts are the components produced by earlier melt batches and subsequently entrained by genetically related magmas (Ubide et al. 2014; Giuliani et al. 2016). Phlogopite-II contains relatively low Al, Ti, Cr and Ni but high Fe content and is magmatic. Diopside with high TiO_2 (1.2–4.2 wt. %), low Na_2O (0.3–0.8 wt. %) and low-to-high contents of Al_2O_3 (0.3–2.8 wt. %) occurs in the Ena and Jamadoba-XI rocks and is replaced by arfvedsonite on the rims (Fig. 1c). Amphiboles from the Ena and Jamadoba-XI dykes are poor in Al_2O_3 (0.6–0.9 wt. %) and rich in TiO_2 (1.5–4.6 wt. %) and FeO_T (12.5–21.9 wt. %). Two populations of apatite are found in the Mudidih, Ena, Jamadoba-XI and Moonidih rocks. Apatite-I with high F (2.2–4.0 wt. %), low Na_2O (<0.1 wt. %), SrO (0.9–3.8 wt. %), and total LREE (<2.5 wt. %) content is magmatic. Apatite-II occurring as rims around apatite-I crystals are relatively F-depleted (<1.7 wt. %) and enriched in Na_2O (0.14–1.9 wt. %), SrO (5.4–18.5 wt. %) and total LREE (up to 4.2 wt. %; Fig. 1d). Enrichment of these elements occurred by the reaction of Na–Sr–LREE-rich late-stage hydrothermal fluids with early-formed apatite-I crystals. Hollandite group minerals occurs in the Mudidih sill and shows evolution from $K_2Fe^{2+}Ti_7O_{16}$ to $BaFe^{2+}Ti_7O_{16}$. Spinels from the Ena dyke are chromian ulvöspinel magnetites. The spinels in the Moonidih and Sijua dykes show compositional evolution from titanian magnesian chromites to chromian ulvöspinel magnetites. The Jharia ilmenites show compositional evolution from decreasing geikielite component and increasing ilmenite component towards the pure ilmenite end member in a Fe_2O_3–$FeTiO_3$–$MgTiO_3$ ternary diagram.

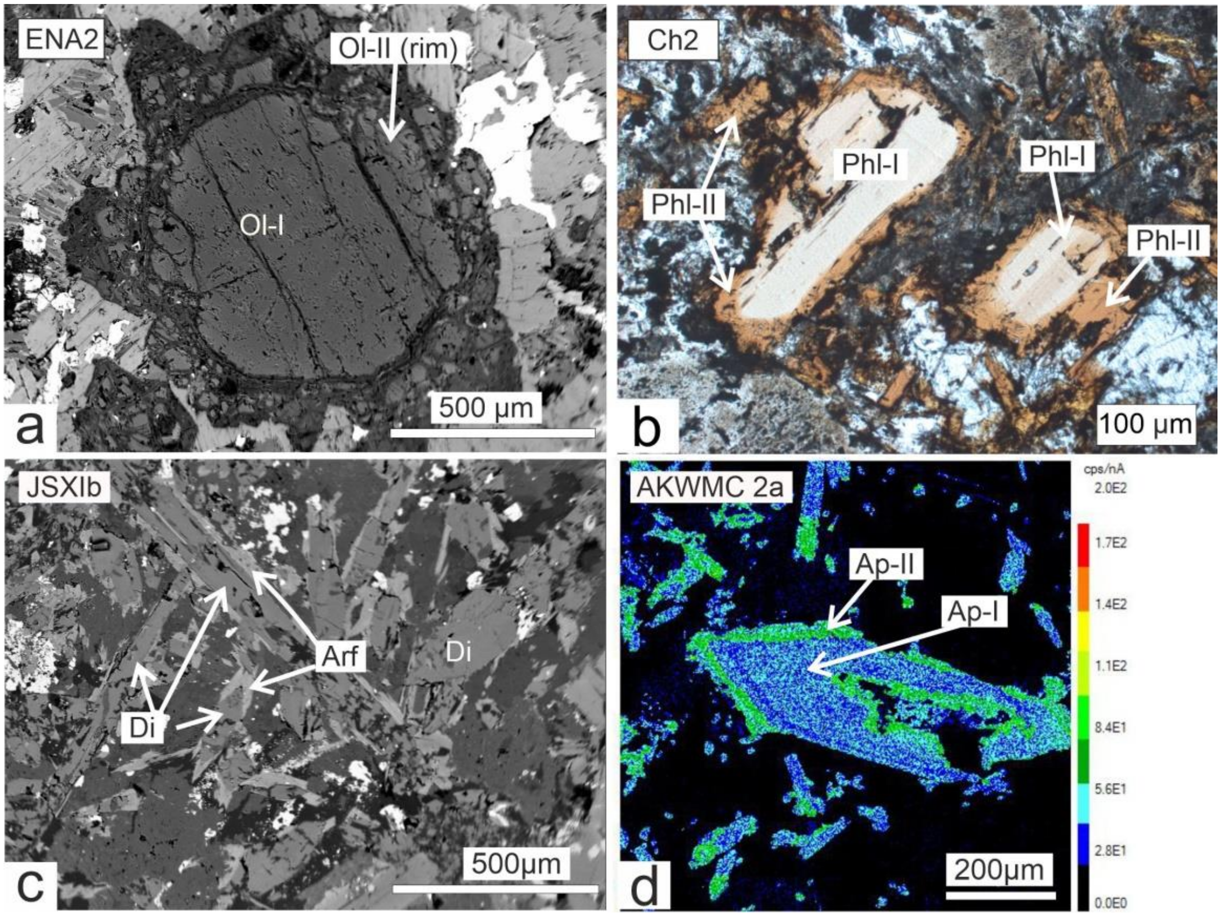

Figure 1: a. BSE image illustrating core–rim texture of Ena olivine with olivine-I core and olivine-II rim. b. Photomicrograph showing zoned phenocrystal phlogopites in groundmass of phlogopite and K-feldspar in Chasnalla (PPL). c. BSE image showing arfvedsonite replacing diopside in Jamadoba-XI. d. X-ray elemental map showing Sr variation in zoned Mudidih apatite.

Classification and Nomenclature

The lamproitic character of the Jharia intrusions is supported by the occurrence of forsteritic olivine (Fo 84–88), low-Al-Na diopside, Al-poor and Ti-rich amphiboles, hollandite group minerals, Fe-rich K-feldspar and phlogopite compositional trends of Al-decrease and Fe-increase. Groundmass spinels follow a titanomagnetite trend (T2) and apatite shows Na-Sr-LREE-enrichment from core to rim. On the basis of a mineralogical–genetic classification scheme (Mitchell and Bergman 1991; Mitchell and Tappe 2010), the Ena dyke is an olivine-phlogopite-diopside-apatite-amphibole-feldspar lamproite and the Moonidih dyke is an olivine-phlogopite-apatite-feldspar lamproite (Kaur et al. 2023). The Jamadoba-XI dyke is an olivine-phlogopite-diopside-apatite-amphibole-feldspar lamproite, the Mudidih sill is an olivine-leucite-phlogopite-apatite-feldspar lamproite and Chasnalla sill is leucite-phlogopite-apatite-feldspar lamproite. The Jamadoba-XV, Akashkinari and Sijua dykes are olivine-phlogopite-apatite lamproite, whereas, the Bhowra, Govindpur and Madhuband are olivine-phlogopite lamproite. The low Al content (< 13 wt.%) in micas, low Al_2O_3 (0.6–1.7 wt.%) and TiO_2 (1.7–3.4 wt.%) diopside and high Cr/(Cr+Al) >0.85 of spinel differentiate these rocks from aillikites (Kaur et al. 2023). The absence of monticellite, primary carbonates and melilite preclude their classification as ultramafic lamprophyres or kimberlites (Mitchell 1995, 2021; Tappe et al. 2005). The presence of secondary phases such as pyrite, dolomite, calcite, serpentine, witherite, magnesite and quartz shows that the Jharia sills and dykes have undergone varied degrees of deuteric alteration.

Petrogenesis

The occurrence of peridotite-derived olivine xenocrysts in the Ena dyke and antecrystic phlogopite in the Chasnalla sill and Bhowra, Madhuband, Akashkinari and Sijua dykes suggest that the Cretaceous lamproite magmatic event in the Jharia basin was sourced from the lithospheric mantle. The Jharia potassic intrusions show minor mineralogical variations and are considered to represent local variants that originated from the differentiation of a common parental lamproite magma. This magma formed by partial melting of K–Ti–Ba–Sr–LREE-enriched mineralogically diverse veins within ancient continental mantle lithosphere.

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