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Multi-level magma storage and ascent in continental rifts recorded by lamprophyres

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Understanding magma plumbing systems across different tectonic environments is critical for evaluating how continental crust participates in magma generation and evolution. Lamprophyre dykes from the Elchuru Alkaline Complex (SE India) provide a unique window into the transcrustal transport and storage of mantle-derived ultrapotassic magmas emplaced during Mesoproterozoic continental rifting. Integrated petrographic, mineral chemical, and thermobarometric constraints reveal a vertically extensive, multi-level plumbing system linking the upper mantle to the shallow crust. Elchuru lamprophyres display dominant porphyritic textures, with clinopyroxene, olivine, phlogopite, and amphibole macro- to microcrysts embedded in a fine-grained groundmass comprising clinopyroxene, phlogopite, amphibole, nepheline, plagioclase, K-feldspar, and apatite (Fig. 1). Elevated MnO contents in olivine (1.17–1.72 wt%), high TiO_2 in biotite (2.06–6.77 wt%), and enriched TiO_2 (2.53–3.82 wt%) and K_2O (1.28–2.86 wt%) in amphibole attest to ultrapotassic character of the parental melts. Clinopyroxenes exhibit pronounced zoning, embayed and resorbed margins (Fig. 1), and variable Al_2O_3 (0.00–6.67 wt%) and K_2O (0.00–2.82 wt%) contents, indicating polybaric crystallization and repeated magma recharge events. Thermobarometric estimates suggest that most clinopyroxenes are antecrysts formed at pressures of ~14–21 kbar (~46–70 km) and temperatures of ~1000–1250 °C, reflecting crystallization within the mantle and lower crust. Subsequent magma evolution involved transient storage in a lower-crustal reservoir (~13–14 kbar; ~39 km) dominated by clinopyroxene crystallization, a mid-crustal reservoir (~6–7 kbar; ~18 km) characterized by biotite growth, and a shallow-crustal reservoir (~3–4 kbar; ~9 km) marked by amphibole and felsic mineral stabilization (Fig. 2). These results demonstrate that Elchuru lamprophyres record continuous magma evolution from mantle depths through vertically connected crustal reservoirs before final emplacement. The study highlights lamprophyres as robust tracers of transcrustal magmatic plumbing in continental rift environments and provides broader insights into ultrapotassic magma transport and storage beneath continental lithosphere.

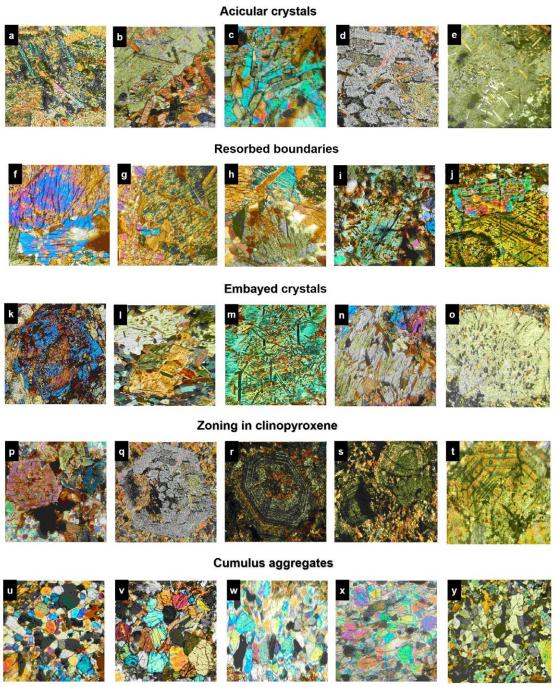

Fig. 1 Selected photomicrographs showing characteristic textural features in the Elchuru lamprophyre dykes. **(a–e)** acicular crystals; **(f–j)** resorbed boundaries; **(k–o)** embayed crystals; **(p–t)** zoning in clinopyroxene; **(u–y)** cumulate aggregates. All photomicrographs **(a–y)** are presented as zoomed views without scale, emphasizing the diagnostic textures rather than relative crystal sizes.

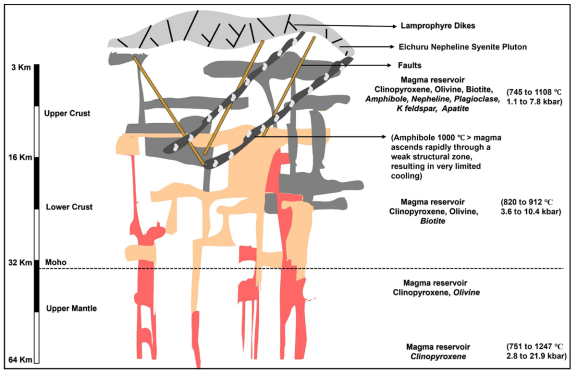

Fig. 2 Schematic model of the Elchuru lamprophyres showing a vertically integrated transcrustal magmatic system comprising three stacked magma reservoirs at ~46 km, ~24 km, and ~12 km from the upper mantle to the shallow crust possibly at density boundaries. The first level reservoir is dominated by clinopyroxene, olivine the second by biotite, and the third by amphibole. K-feldspar, plagioclase, nepheline, and apatite are abundantly crystallized in the shallow magma reservoir. The crystal-laden melts eventually intruded as dykes in the Elchuru nepheline syenite pluton.