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Mid-Cretaceous lamproite from the Kutch region, Gujarat, India: Genesis and tectonic implications

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ABSTRACT

The Phanerozoic tectonic evolution of the Kutch region (NW India) has been attributed to rifting processes. In situ U-Pb perovskite dates (all data = 124 ± 4 Ma, MSWD = 42) obtained on three samples of a newly discovered lamproite dyke emplaced in the Kutch rift setting identify a previously unknown and relatively young (Mid-Cretaceous) magmatic event in this part of India. The dyke was emplaced into the Katrol Formation of Upper Jurassic to very early Cretaceous age. The presence of xenocrystic garnet and fractionated REE distribution patterns (low HREE/LREE) in the lamproite, along with high contents of transition metals and low Al_2O_3, suggest that it was derived from the garnet stability field in the mantle. Extreme impoverishment in HREE and HFSE suggest a mantle source region that has experienced both depletion and later enrichment. In situ analysis of Nd isotopes in perovskite of three samples gives a mean $\varepsilon Nd = 0.4 \pm 1$ and a T_{DM} model age of 598 ± 64 Ma, while in situ Sr-isotope analysis gives a mean $^{87}Sr/^{86}Sr = 0.70388 \pm 2$ (2SE), corresponding to $\varepsilon Sr = 8.6 \pm 0.3$; both datasets suggest mixing between lithospheric-mantle and depleted-mantle components. The fault-controlled emplacement of this body highlights the role of deep-penetrating fault systems in providing a pathway and initiating decompressional melting of the mantle source rocks. The lamproite represents an earlier phase of rift related magmatism, different from the emplacement of the melanephelinite–basanites and basalts that dominate the igneous activity related to the Deccan volcanism in the Kutch mainland.

1. Introduction

The Deccan Trap flood basalts of south-central India are often cited as the world's best example of the initial plume-head stage of hot-spot development and are regarded as the manifestation of the Reunion hot spot (Duncan and Richards, 1991; Campbell, 1998). The occurrence of 72–73 Ma Reunion Island-like alkalic lavas (Mahoney et al., 2002) as well as 69 Ma alkali dolerites and ultramafic lamprophyre sills (Kerr et al., 2010) in Pakistan, and 68.5 Ma alkalic intrusions in northern India (Basu et al., 1993) suggest a southward progression of the igneous activity before it culminated in the major outburst at 65 (+1) Ma in western and central India.

However, in some plume-related basaltic provinces the peak flood–basalt eruption was preceded (by a few million or even tens of millions of years) by the emplacement and intrusion of small-volume alkalic magmas, which may be considered to represent the initial melts of the mantle plume, and/or the lithospheric mantle above it, before large-scale melting commenced (e.g. Kent et al., 1992; Basu et al., 1993; Mahoney et al., 2002; Zhu et al., 2008; Kerr et al., 2010). The Kutch region in the northwestern state of Gujarat exposes some of the earliest magmatic rocks of the Deccan Volcanic Province. Most of these occur in the northern Island Belt Uplift, where the intrusive rocks occur as dykes, sills and plutons, particularly in the Pachham area. Among these, metagabbroic rocks occur around Kuran, mafic dykes at the core of the Kaladongar anticline, mafic sills around Sadara (Ray et al., 2006) and a differentiated plutonic igneous complex near Nir Wandh. The main rock types in the Nir Wandh complex include pyroxenite, alkali gabbro, alkali diorite, nepheline syenite and lamprophyre. Both alkalic and tholeiitic intrusions and lavas occur in the Kutch mainland, and many of the alkalic intrusions carry mantle-derived xenoliths (De, 1964; Mukherjee and Biswas, 1988; Krishnamurthy et al., 1989; Karmalkar et al., 2000; Karmalkar and Rege, 2002; Guha et al., 2005; Karmalkar et al., 2005; Sen et al., 2009).

Here we present new data constraining the age and origins of a Cretaceous lamproite dyke from the Kutch region, and discuss its implications for the tectonic evolution of this part of India. As far as

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we know, there has not been any previous report of lamproite or kimberlite intrusions from Kutch.

1.1. Background: the timing of the Deccan Traps

Nearly 100 identified kimberlitic/lamproitic pipes and dikes occur within the Dharwar craton, southern India and the Bundelkhand craton, central India (Fig. 1). These all have yielded Mesoproterozoic ages with a peak at 1100 Ma (Anil Kumar et al., 1993; Chalapathi Rao et al., 1999; Gregory et al., 2006). The lamproite occurrences at Majhgawan, Bhander in the Bundelkhand Craton and Zangamrajupalle in the Dharwar Craton also are dated at 1.1 Ga (Anil Kumar et al., 2001; Gregory et al., 2006; Masun et al., 2009), while those from Chelima in the Dharwar craton are dated at 1.38 Ga (e.g. Murthy et al., 1987; Chalapathi Rao et al., 1996, 1999; Anil Kumar et al., 2001, etc.).

A cluster of several kimberlitic pipes containing both micro- and macro-diamonds have recently been discovered near Mainpur in the Bastar craton of central India (Newlay and Pashine, 1993; Chatterjee et al., 1995; Mainkar and Lehman, 2007). According to Lehman et al. (2010), previous attempts to date the Kodomali pipe (Chalapathi Rao et al., 2007) was hampered by the fact that a chloritized phlogopite megacryst was sampled. The resulting $^{40}Ar/^{39}Ar$ age spectrum therefore, had a large scatter, and the integrated age of 491 ± 11 Ma for 35% Ar release from 1000 to 1500 °C was erroneously interpreted as the kimberlite emplacement age. Lehman et al. (2010) have obtained new $^{40}Ar/^{39}Ar$ whole-rock and U–Pb perovskite ages around 65 Ma for these kimberlites, which overlap with the main phase of the Deccan flood basalt magmatism.

Available $^{40}Ar/^{39}Ar$ dates place the age of the Deccan volcanism between 69 and 64 Ma (Venkatesan et al., 1986; Shukla et al., 2001). However, Duncan and Pyle (1989) and Courtillot et al. (1986) have bracketed the entire eruption within a time span of just 1 Ma, with a mean age of 65 Ma. Pande et al. (1989) obtained $^{40}Ar/^{39}Ar$ plateau ages of 67 ± 0.6 to 65 ± 1 Ma on plagioclase separates from the xenolith-bearing alkali-basalt lavas, suggesting a span of about 2 Ma for the alkaline magmatism in Kutch. One of the alkali basalts from Dharam hill gives an age of 68 ± 2 Ma and thus places their eruption close to the period of Deccan volcanism (Venkatesan et al., 1986).

1.2. Perovskite — a useful mineral

Perovskite ($CaTiO_3$) is a common accessory mineral in the matrix of kimberlites and lamproites and usually occurs as discrete crystals or as reaction rims around magnesian ilmenite. It also occurs as a magmatic component in the matrix of many mantle-derived mafic and ultramafic diatremes, dykes and small intrusions, and in alkaline igneous rocks. In recent times, this mineral has gained significance in the determination of age and initial isotopic compositions because of some of its peculiar chemical characteristics. Perovskite is a major carrier of Sr, U, Th, Zr, Hf and LREE (Jones and Wyllie, 1984; Mitchell, 1986; Mitchell and

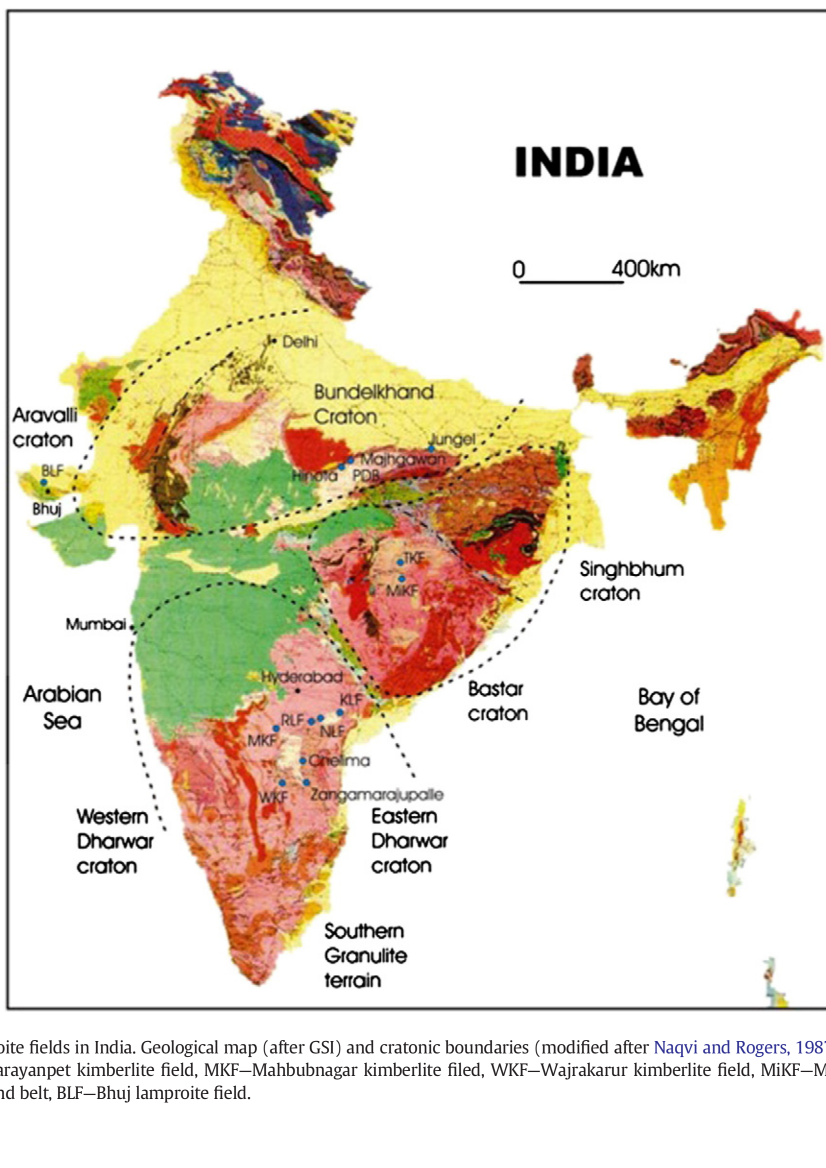

Fig. 1. Location of kimberlite/lamproite fields in India. Geological map (after GSI) and cratonic boundaries (modified after Naqvi and Rogers, 1987). KLF—Krishna lamproite field, RLF—Ramadugu lamproite field, NKF—Narayanpet kimberlite field, MKF—Mahbubnagar kimberlite filed, WKF—Wajrakarur kimberlite field, MiKF—Mainpur kimberlite field, TKF—Tokapal kimberlite field, PDB—Panna diamond belt, BLF—Bhuj lamproite field.