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Lamprophyres from the Harohalli dyke swarm in the Halaguru and Mysore areas, Southern India: Implications for backarc basin magmatism

Shubhangi Lanjewar, Kirtikumar Randive*

Department of Geology, RTM Nagpur University, Nagpur 440001, MH, India

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ABSTRACT

The Bangalore and Harohalli dyke swarms occur in the eastern part of the Dharwar craton. The older Bangalore dyke swarm is made up of dolerites, trending east-west, and the younger contains alkaline dykes that trend approximately north-south. The lamprophyres of the Harohalli dyke swarm occur in the Halaguru and Mysore industrial areas where they are exposed as fresh porphyritic – panidiomorphic dykes, containing crustal xenoliths, and showing chilled contacts with the country rock charnokites. They are chiefly composed of amphiboles which form well-developed phenocrysts. Clinopyroxenes are present in some of the dykes. Compositional zoning is observed in clinopyroxenes and amphiboles; their zoning patterns indicate that the magma experienced cryptic variations and that fractional crystallization was a dominant process in the evolution of the Harohalli Lamprophyres (HRL).

The HRL are calc–alkaline with shoshonitic affinity and exhibit a K_2O/Na_2O ratio of ~1. They show primitive (MORB-like) trace-element characters. LILE and LREE both show marginally enriched patterns; whereas HFSE and HREE show strongly depleted patterns. In the regional geologic sense, HRL dykes are characterised by two major influences; namely, (i) primary source region characteristics, which are geochemically more primitive, roughly falling within fields of primitive - MORB and enriched- MORB and (ii) the continental lithosphere. The data points for the HRL distinctly show their proximity to N-MORB and scatter towards the continental crust. Moreover, features like xenolith assimilation might influence the trace-element characteristics of the HRL dykes. Such magmas with mixed characters can be formed in a backarc basin environment. Geochemical proxies such as Ba/Nb vs Nb/Yb, Ba/Th vs Th/Nb, and the water content of magmas; which have been effectively used for discriminating backarc basin magmas worldwide, also indicate that the HRL magmas were generated in a backarc environment with inputs from a shallow subduction component and interaction with carbonatite melt. This paper therefore presents a new provenance for the generation of calc-alkaline lamprophyres, which were so far known to occur in orogenic belts.

1. Introduction

The calc-alkaline lamprophyres (CAL), especially spessartites and vogesites share the same (plagioclase-hornblende-feldspar ± clinopyroxene ± biotite) mineralogy as andesites, diorites, absorkites and shoshonites. However, the following criteria are commonly used to distinguish lamprophyres (Rock, 1991):

(i) castellated, globular and panidiomorphic textures;
(ii) lack of orthopyroxene but greater abundance of olivine;
(iii) amphibole, clinopyroxene and mica which are far more Mg-rich;
(iv) presence of alkali-rich pyriboles, Zn-rich spinels, primary carbonates and sulphates; and
(v) higher Mg-number, K_2O, Ba, Rb, Sr, V, Ni and LREE/HREE.

Lamprophyres occurring in the Halaguru and Mysore Industrial areas are typical CAL having the mineralogical characteristics mentioned above. They show porphyritic–panidiomorphic textures and contain ocelli. However, they contain abundant amphiboles, which are complexly zoned; occasionally resembling crystal cumulates indicating extensive fractionation of their host magma. They lack orthopyroxenes, and the absence of olivine and mica, and paucity of clinopyroxenes is significant. Nonetheless, clinopyroxenes and amphiboles are Mg-rich, but also show variation in their chemical composition. Pyriboles are not typically alkali-rich as observed in worldwide CAL (Rock, 1991). They possess higher (but variable) Mg-numbers; and higher K_2O, Ba, Rb, Sr, V, Cr, Ni and LREE/HREE. However, LREE are much depleted as compared to worldwide CAL and trace elements show MORB-like HFSE. Such features indicate that the spessartites and vogesites of HRL

* Corresponding author.
E-mail address: randivekr@nagpuruniversity.nic.in (K. Randive).

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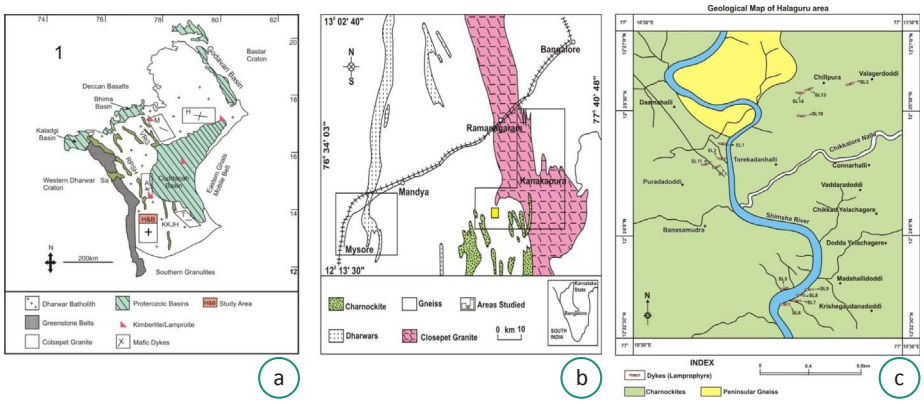

Fig. 1. (a) Sketch map of the Eastern Dharwar Craton. Archean assemblages associated with cratonization are shown here. Abbreviation for schist belts are as follows: Sa = Sandur, KKJH = Kolar-kadri = Jonnagiri-Hutti, RPSH = Ramgiri-(Penakacherla-Sirigeri) – Hungund and VPG = Veligallu-Raichur-Gadwal super belt. Dyke intrusions into the EDC are H and B = Harohalli and Bangalore swarms: M = Mahbubnagar swarm: H = Hyderabad swarms (Modified after Naqui and Rogers, 1987). (b) Geological map of Harohalli Dyke Swarm showing location of Halaguru and Mysore lamprophyre dykes. (c) Geological Map of Halaguru Area.

categorically lack calc-alkaline signatures, and therefore cannot be related to a subduction environment as has been envisaged earlier for CAL (Rock, 1991).

In this paper we discuss an alternate provenance for the lamprophyric magmas. We argue here that the backarc basin magmas, with inputs from shallow subduction components and enrichment by carbonatitic fluid, can explain the geochemical signatures observed in the Harohalli lamporphyres.

2. Regional geology

The Precambrian of Peninsular India comprises several cratonic nuclei, namely, the Aravalli–Bundelkhand, Eastern Dharwar, Western Dharwar, Bastar and Singhbhum Cratons along with the Southern Granulite Province. Each of the major cratons was intruded by granitoids of various ages, mafic dykes and ultramafic bodies throughout the Proterozoic (Meert et al., 2010). The Archaean Dharwar craton is composed of a suite of tonalite-trondhjemite-granodiorite (TTG) gneisses, called the Peninsular Gneisses, and greenstone belts. The Dharwar Craton is further divided into Western and Eastern Dharwar Cratons, which are separated by the Closepet Granites (Naqui and Rogers, 1987).

The Western Dharwar Craton (WDC) is characterized by the presence of 3000 Ma TTG (tonalite-trondhjemite-granodiorite) gneisses, comprising the Peninsular Gneissic Complex (PGC); which consists of ~3400–3580 Ma basement tonalitic gneiss enclaves, and also includes relics of older supracrustals in the form of narrow belts and enclaves, or synclinal keels that have amphibolite facies mineral assemblages. They were called ancient Supracrustals (Ramakrishnan, 1990) and later recognized as the ~3000–3200 Ma Sargur Group (Swami Nath and Ramakrishnan, 1990). The metamorphic fabric of Sargur Group rocks and the surrounding gneissic complex is truncated by the low-grade Dharwar Schists (Bababudan Group) and both the former rocks are unconformably overlain by the main schist belts of the Dharwar Supergroup (2600–2800 Ma).

The Eastern Dharwar Craton (EDC) is bounded to the north by the Deccan Traps and the Bastar Craton, to the east by the Eastern Ghats Mobile Belt, and to the south by the Southern Granulite Terrane. The craton is composed of the Dharwar Batholith (dominantly granitic), greenstone belts, intrusive as well as extrusive igneous rocks, and middle Proterozoic to more recent sedimentary basins. The ~2.5 Ga Closepet Granite is the part of a widespread Neoarchaean phase of plutonism in both the Eastern and Western Dharwar Cratons. This intrusive body is ~400 km long and approximately 20–30 km wide bounded by shear zones on both the sides. Similar convexity of adjacent schist belts and presence of granitic plutons has indicated that the Closepet Granite is a 'stitching pluton' formed during the suturing of the Eastern and Western Dharwar Cratons (Naqui and Rogers, 1987; Friend and Nutman, 1991; Balakrishnan et al., 1999; Mojzsis et al., 2003; Ramakrishnan and Vaidyanadhan, 2008).

2.1. The Harohalli dyke swarm

The Harohalli dyke swarm is located in the southern high-grade metamorphic region of Karnataka, which is a deeply eroded part of the Archaean terrain and represents a granulite–amphibolite facies transition zone. The dykes predominantly trend NNW and show easterly dip. These dykes intrude through charnockites, metasedimentary granulites, gneisses (PGC) and granite (Closepet granite). The older Bangalore dyke swarm, trending E-W, is composed of dolerites and was emplaced at ~2369–2365 Ma (U–Pb baddeleyite ages; French et al., 2004; French and Heaman, 2010). Initial Rb–Sr whole rock dating of the younger Harohalli alkaline dykes constrained ages to 850–800 Ma (Ikramuddin and Stueber, 1976; Kumar et al., 1989). However, a recent U–Pb zircon age of 1192 ± 10 Ma produced by Pradhan et al. (2008) for the alkaline dykes is interpreted as the age of emplacement.

This dyke swarm has two main eruptive centres, one near Srirangapatna and another near Kanakpura, about 56 km of Bangalore (Devaraju et al., 1995a, 1995b). They are about ~30 km apart and cover 600 km^2 and 1650 km^2 respectively.

2.2. The Halaguru dykes

All the lamprophyre dykes of Halaguru area (Fig. 1c) are located in the proximity of Shimsha River. The dykes are usually thin (width ~25 cm to length 3 m). The patchy outcrops defining the trends of dykes can be traced up to 700 m along strike. However, small clusters occur locally near Madhallidoddi, Torekadanahalli, and Valagerdoddi and Chillapura. The most prominent of the Halaguru Lamprophyre (HL) dykes is ~20 cm wide and can be traced up to 15 m along strike. The majority of the other dykes occur as elongated outcrops, which now remain only as a few boulders within the cultivated fields, the thorny shrubs in the proximity of Shimsha river and its tributaries, and within the river bed. Nevertheless, the geochemical data and trends in chemical variation diagrams indicate that the outcrops distinguished in the field are actually distinct derivatives of a fractionating magma.

The lamprophyre dykes were identified in the field on the basis of their distinct phenocryst assemblages, the presence of radiating needles of amphiboles, the presence of carbonate ocelli, occasional xenoliths of quartz and/or country rocks embedded in the groundmass which is either aphyric or a crystalline (Figs. 2–4). Sometimes minor needles of amphiboles occur in the groundmasses of dykes.

2.3. Mysore dyke

The lamprophyre dyke mentioned here occurs in the Matagalli Industrial area, close to the northeastern boundary of Mysore district and in close proximity to Srirangapatna (a historic town which was the capital of the famous warrior King, Tipu Sultan). Now this dyke is cut across for laying roads in the industrial area and the remaining part falls under the boundary of private industries. The most prominent feature