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Petrogenesis of the Mesoproterozoic Lamproites from the Krishna Valley, Eastern Dharwar Craton, Southern India

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ABSTRACT

Petrology and geochemistry of eleven Mesoproterozoic lamproites from the Krishna valley, Eastern Dharwar craton, are presented. The Krishna lamproites show wide variation in their petrography and modal mineralogy and constitute excellent examples of rare phenomenon of heteromorphism. Ti-phlogopite, clinopyroxene, richterite, Fe-rich sanidine, sphene, F-rich apatite, ilmenite, and rutile are the major minerals present in varying proportions. Their mineral compositions overlap with those present in world-wide Phanerozoic lamproites and casts doubt on recent suggestions regarding the absence of archetypal lamproites and kimberlites from the Indian cratons. Incompatible trace element ratios (i) rule out the Krishna lamproites to be products of direct plume- (asthenospheric) derived mantle as well as subduction-related components and (ii) demonstrate their derivation from sources similar to those of the co-spatial Cuddapah basin lamproites and Wajrakarur- and Narayanpet-kimberlites from the Eastern Dharwar craton. The source enrichment of the Krishna lamproites is related to the period of global-scale mantle upwelling at ~1.9 Ga that included the emplacement of Large igneous provinces of similar age and magmatism in the Dharwar and Bastar cratons (India), the Superior Craton (Canada) and the Kaapvaal craton (southern Africa). We find that the observed petrological and geochemical characteristics of the Krishna lamproites can be best explained by the vein-plus-wall-rock model involving phlogopite + amphibole + rutile + clinopyroxene + apatite + titanite occuring as metasomatic veins in a depleted lithospheric mantle, within the garnet stability field. Our study illustrates the significant role of the lithospheric thickness and its attendant metasomatism in influencing petrogenesis of the co-spatial Mesoproterozoic lamproites and kimberlites from the Eastern Dharwar craton.

1. Introduction

Lamproites are very rare Mg-rich ($MgO > 5$ wt%), peralkaline [$(K_2O + Na_2O)/Al_2O_3 > 1$ (molar)], perpotassic [$(K_2O/Al_2O_3) > 1$ (molar)] and ultrapotassic [$(K_2O/Na_2O > 3$ (molar)] igneous rocks that yield significant information on the nature of the Earth's upper mantle (e.g., Bergman, 1987). Lamproites are thought to represent the most extreme incompatible element enriched products of ancient and anomalously metasomatised (enriched) mantle and the crustal contamination is considered to have little effect on their trace element composition (e.g., Nelson et al., 1986; Mitchell and Bergman, 1991; Foley, 1992a; Mitchell, 2006). The presence of diamond in them imply a great depth (>150 km) of derivation and therefore lamproite studies provide direct information about the composition and processes taking place in the lower part of the continental plates.

In comparison to the Phanerozoic lamproites, e.g., Leucite Hills lamproites, U.S.A., Mediterranean lamproites (Spain, Italy, Balkans and Turkey) and Fitzroy Trough lamproites of Western Australia, the Precambrian lamproites are rare (Table 1) and a significant number of them were erupted during the Proterozoic in the Indian shield, in general, and the Dharwar craton in particular. Seismic receiver function studies reveal that the present-day lithosphere of the Indian shield is abnormally thin (80–100 km) compared to its other Gondwana counterparts (Australia, Antarctica and Africa), whose present day lithosphere varies from 250 to 300 km thickness (Kumar et al., 2007). A study of Proterozoic lamproites of the Dharwar craton, therefore, provides a unique opportunity to investigate Proterozoic tectono-magmatic processes operating at a time when southern India formed a part of the Gondwana supercontinent.

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Table 1
A summary of the distribution and emplacement age of global Precambrian lamproites. In case of the Indian lamproites the respective cratons are also provded.

Location	Age (Ga)	Reference
Majhgawan, India (Bundelkhand craton)	1.1	Gregory et al. (2006)
Bhander, India (Bundelkhand craton)	1.1	Masun et al. (2009)
Zangamarajupalle, India (Dharwar craton)	1.1	Anil Kumar et al. (2001)
Finland	1.1	O'Brien et al. (2003)
Argyle, Australia	1.18	Skinner et al. (1985)
Greenland	1.2	Jensen et al. (2002)
Krishna lamproites, India (Dharwar craton)	1.38–1.22	Chalapathi Rao et al. (1996); Anil Kumar et al. (2001)
Chelima, India (Dharwar craton)	1.38	Murthy et al. (1987); Chalapathi Rao et al. (1996, 1999); Anil Kumar et al. (2001)
Bobi, Ivory Coast	1.43	cf. Mitchell and Bergman (1991)
East European Platform, Ukranian and Baltic shields, Russia	1.72–1.23	Nikitina et al. (1999); Bogatikov et al. (2007)
Karelia, Russia	2.74	Sergreev et al. (2007)

Historically world-famous diamonds such as the Koh-I-Noor, Hope, Orloff, Darya-I-Noor, Great Mogul, and Pitt were all recovered from the diamondiferous gravels in the lower reaches of Krishna River in close proximity to the lamproites of the Krishna valley, Eastern Dharwar craton, southern India. However, their primary source remains elusive despite centuries of extensive search. In this context, a detailed petrological and geochemical investigation of the Krishna lamproites assumes considerable significance. Furthermore, the Krishna lamproites are also co-spatial with the Mesoproterozoic kimberlites of the Eastern Dharwar craton and their study therefore provide an opportunity to assess the petrogenetic relationship, if any, between them.

The objectives of this study are to (i) document the petrological and geochemical characteristics of the Krishna lamproites from an enlarged data base, (ii) evaluate their relationship to the nearby lamproites from the Cuddapah basin and the Mesoproterozoic kimberlites from the Eastern Dharwar craton, (iii) compare the new data from this study with world-wide lamproite occurrences in order to decipher their similarities and differences, (iv) infer the nature and composition of the mantle source regions of the Krishna lamproites in light of the recent petrogenetic models

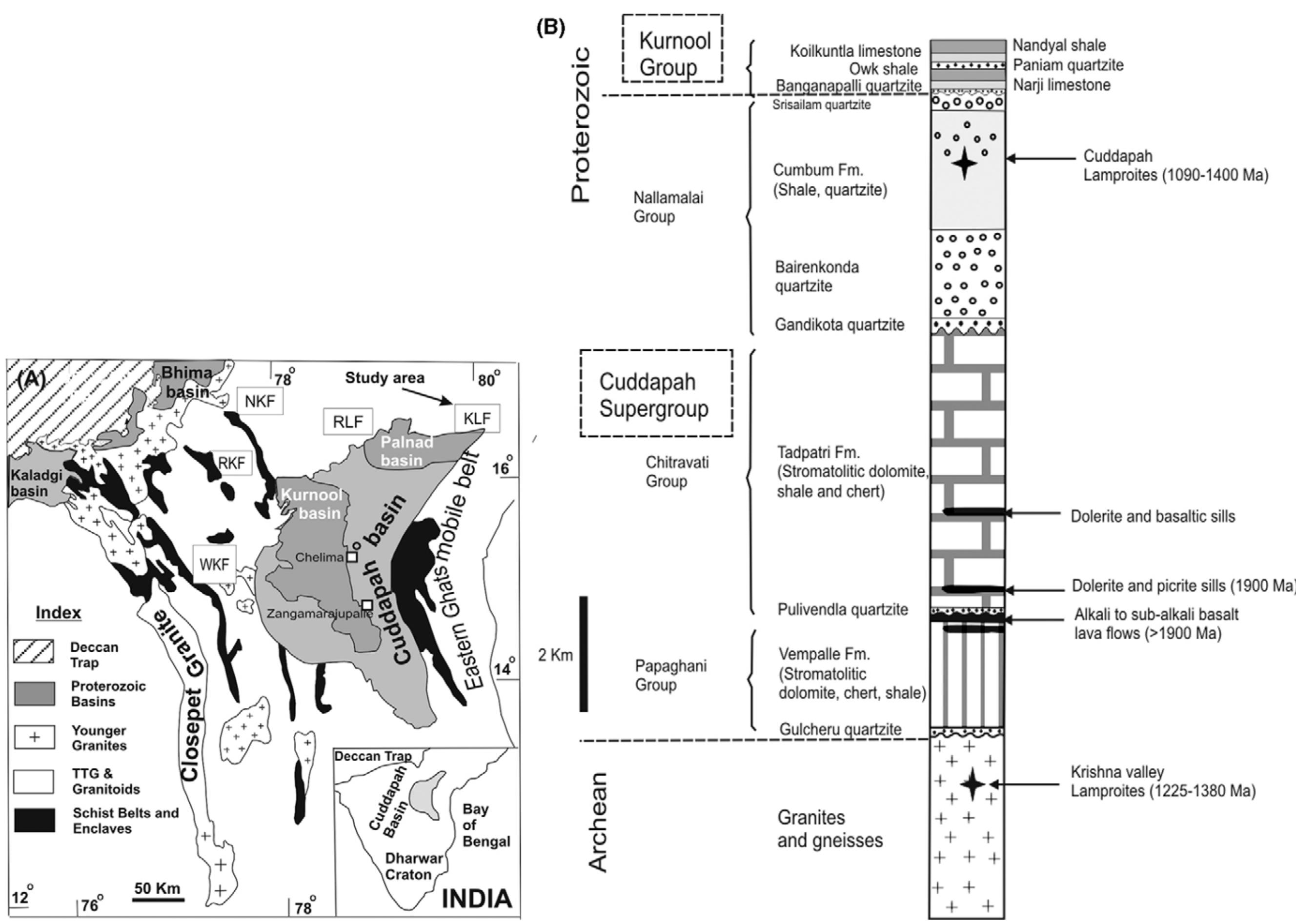

Fig. 1. (A) A generalised geological map of the Dharwar craton, southern India, showing the Proterozoic Cuddapah Basin and the disposition of various kimberlite and lamproite fields (adapted from Naqvi, 2005). WKF = Wajrakarur kimberlite field; RKF = Raichur kimberlite field; NKF = Narayanpet kimberlite field; RLF = Ramadugu lamproite field; KLF = Krishna lamproite field; Cuddapah lamproites are located at the Chelima and Zangamarajupalle. (B) Stratigraphic column of the Cuddapah Basin (after Nagaraja Rao et al., 1987; Anand et al., 2003).