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Research paper

Petrogenesis of the crater-facies Tokapal kimberlite pipe, Indrāvati Basin, Central India

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ABSTRACT

New geochemical data of the crater-facies Tokapal kimberlite system sandwiched between the lower and upper stratigraphic horizons of the Mesoproterozoic Indrāvati Basin are presented. The kimberlite has been subjected to extensive and pervasive low-temperature alteration. Spinel is the only primary phase identifiable, while olivine macrocrysts and juvenile lapilli are largely pseudomorphed (talc-serpentine-carbonate alteration). However, with the exception of the alkalies, major element oxides display systematic fractionation trends; likewise, HFSE patterns are well correlated and allow petrogenetic interpretation. Various crustal contamination indices such as $(SiO_2 + Al_2O_3 + Na_2O)/(MgO + K_2O)$ and Si/Mg are close to those of uncontaminated kimberlites. Similar La/Yb (79–109) of the Tokapal samples with those from the kimberlites of Wajrakarur (73–145) and Narayanpet (72–156), Eastern Dharwar craton, southern India implies a similarity in their genesis. In the discriminant plots involving HFSE the Tokapal samples display strong affinities to Group II kimberlites from southern Africa and central India as well as to 'transitional kimberlites' from the Eastern Dharwar craton, southern India, and those from the Prieska and Kuruman provinces of southern Africa. There is a striking similarity in the depleted-mantle (T_{DM}) Nd model ages of the Tokapal kimberlite system, Bastar craton, the kimberlites from NKF and WKF, Eastern Dharwar craton, and the Majhgawan diatreme, Bundelkhand craton, with the emplacement age of some of the lamproites from within and around the Palaeo-Mesoproterozoic Cuddapah basin, southern India. These similar ages imply a major tectonomagmatic event, possibly related to the break-up of the supercontinent of Columbia, at 1.3–1.5 Ga across the three cratons. The 'transitional' geochemical features displayed by many of the Mesoproterozoic potassic-ultrapotassic rocks, across these Indian cratons are inferred to be memories of the metasomatising fluids/melts imprinted on their source regions during this widespread event.

1. Introduction

Despite their volumetric insignificance kimberlites continue to attract wide global attention primarily due to their (i) derivation from greater depths than any other known rock type, (ii) entrained mantle- as well as crustal-xenoliths, and (iii) association with diamond (see Pearson et al., 2003; Pilbeam et al., 2013; Sparks, 2013; Tappe et al., 2013). Much of the kimberlite terminology and genetic models in vogue are influenced to a great extent by the southern African occurrences and three variants of kimberlites, viz., Group I (kimberlite *sensu stricto*), Group II (or orangeite) and 'transitional' type are known from the Kaapvaal craton of southern Africa. These are distinguished based on their differing mineralogy, geochemistry and radiogenic (Sr, Nd and Pb) isotopes (e.g., Smith, 1983; Mitchell, 1995; Le Roex et al., 2003; Becker and Le Roex, 2006; Becker et al., 2007). Whereas Group I type (or archetypal) kimberlites are known from Archaean cratons world-wide, the Group II kimberlites were, for long, considered to be restricted only to the Kaapvaal craton of southern Africa (Skinner, 1989; Mitchell, 1995) but such rocks have also been reported from (i) the Siberian

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Province, Russia (Bobrievich et al., 1959) and (ii) the Mainpur field of Bastar craton, central India (Lehmann et al., 2010; Chalapathi Rao et al., 2011; Fig. 1A). Likewise, the 'transitional' kimberlites have also been reported from the Koidu Province, West Africa (Taylor et al., 1994), the Kola–Kuloi craton (Beard et al., 2000) and Nukyan Province, Russia (Agashev et al., 2008), the São Francisco craton, Brazil (Bizzi et al., 1994), the Kimberley craton in north-western Australia (Edwards et al., 1992), the Guyana craton in Venezuela (Kaminsky et al., 2004), the Bundelkhand craton in north central India (Chalapathi Rao, 2005), and the Eastern Dharwar craton of southern India (Haggerty and Birkett, 2004; Chalapathi Rao and Dongre, 2009; Chalapathi Rao et al., 2012b).

The recent discovery of end-Cretaceous diamondiferous Group II kimberlites synchronous with the eruption of the Deccan flood basalts, in the Mainpur field of the Bastar craton of central India (Lehmann et al., 2010) has given a new impetus to the genesis of the Group II kimberlites as well as diamond exploration activities in India. This has also necessitated a re-look at the kimberlites reported from various Indian cratons to ascertain their Group II kimberlitic affinities, if any, since the generation of the latter implies specific geodynamic settings, viz., mantle-plume lithosphere interactions (Le Roex, 1986; Chalapathi Rao et al., 2011) or extensional events related to supercontinent breakup (Phillips et al., 1998). Even though the crater-facies Tokapal pipe has been well-studied over the years in terms of its geology, petrology, geochemistry and diamond potential (Ramakrishnan, 1987; Mainkar et al., 2004; Lehmann et al., 2006; Chalapathi Rao et al., 2012a), little attempt was made to understand its petrogenetic aspects especially in comparison with the well-characterised kimberlites from the Wajrakarur, Narayanpet and Raichur fields of the Eastern Dharwar craton and the Group II kimberlites from the Mainpur field, Bastar craton, (see Fig. 1A for locations) which is the main purpose of this paper.

2. Geological set-up

The Tokapal kimberlite is a saucer-shaped volcanic sheet, with a diameter of ~2.5 km, occurring in the western part of the Mesoproterozoic platformal sequence of the Indrāvati Basin on the Bastar craton of central India (Fig. 1B). Together with its NE exposure at Bejripadar, which constitutes its satellite body, it is one of the world's largest (>550 ha) crater-facies kimberlites (Mainkar et al., 2004; Lehmann et al., 2006). The kimberlite system is exposed at the peneplained surface (Fig. 2A), in dug-wells as well as in stream cuttings and excavations (Fig. 2B). The SE part of the kimberlite is capped by a thick laterite cover and the circular course of the Bahar Nala (stream) marks its margin (Fig. 1B). The Tokapal kimberlite system is located stratigraphically between the lower Indravati Group of sedimentary rocks of the Cherakur (comprising micaceous purple shale) and Kanger formations (white and grey limestone) and the upper Jagdalpur Formation (limestone, calcareous shale and sandstone intercalations) and represents volcanic activity during intracratonic sedimentation denoting an event break (Ramakrishnan, 1987; Mishra et al., 1988). Gravity, magnetic and resistivity surveys over the kimberlite system revealed its thickness to be >50 m at many places and well over 90 m at a few sites (Das et al., 2005). *In situ* U-Pb dating on titanite from Bejripadar tuff-facies kimberlite gave a minimum Neoproterozoic age of 620 ± 30 Ma (Lehmann et al., 2007). However, U-Pb ages of magmatic zircons from the rhyolitic tuff from the uppermost Jagdalpur Formation of the Indrāvati Basin gave an age of 1000 Ma (Mukherjee et al., 2012) suggesting that the titanite age possibly represents an overprinted age (Pan-African event?). Thus, the emplacement age of the Tokapal system needs to be in excess of 1000 Ma and very likely coincides with the 1100 Ma widespread kimberlite event recorded from the Eastern Dharwar craton (Anil Kumar et al., 2007; Chalapathi Rao et al., 2013a) thereby constituting the world's known oldest crater-facies kimberlite system.

3. Analytical techniques

Nine kimberlite samples, free from visible crustal contamination, have been collected from various exposed domains of the

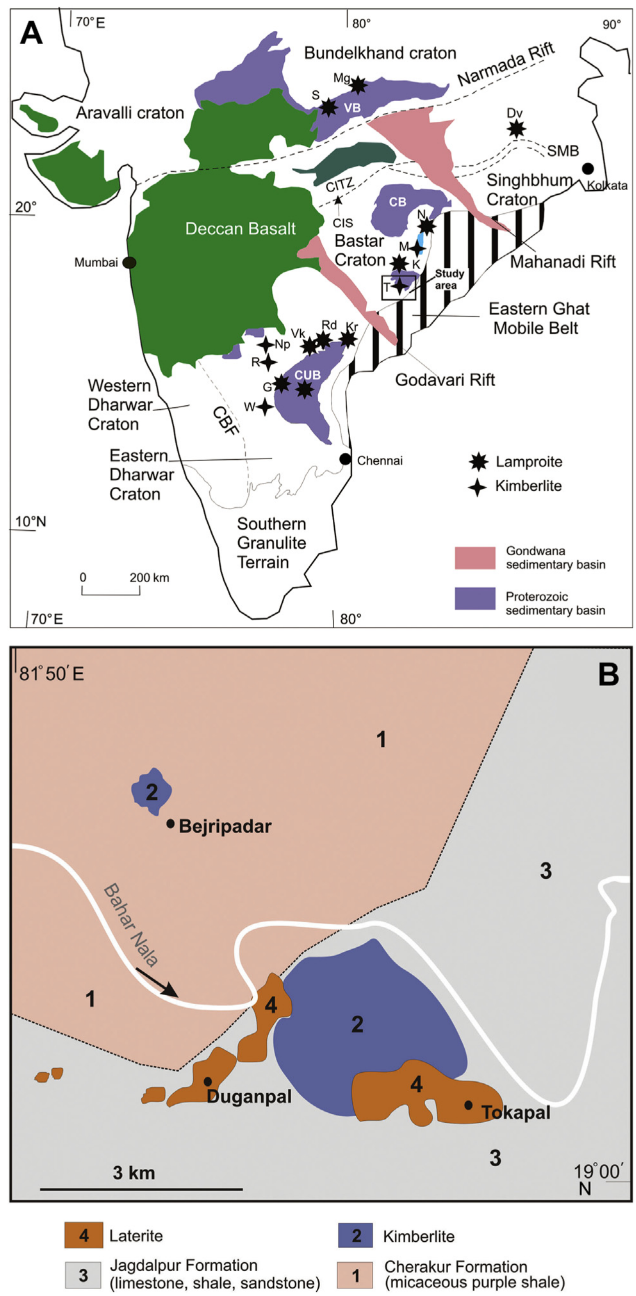

Figure 1. (A) Generalised geological map of India showing the location of the Tokapal kimberlite in the Bastar craton, central India. The occurrence of other lamproites and kimberlites in various cratons (modified after Sahu et al., 2013) is also shown. CBF = Chitradurga fault; CITZ = Central Indian tectonic zone; CUB = Cuddapah basin; CB = Chhattisgarh basin; VB = Vindhyan basin; SMB = Singhbhum mobile belt; CIS = Central Indian shear zone; W = Wajrakarur kimberlite field; R = Raichur kimberlite field; Np = Narayanpet kimberlite field; T = Tokapal kimberlite; M = Mainpur kimberlite field; Dv = Damodar valley; Mg = Majhgawan; S = Saptarshi; K = Khadka; N = Nuapada; G = Garledinne; Vk = Vattikod; Kr = Krishna; Rd = Ramadugu. (B) Geological setting of the Tokapal kimberlite system (adapted from Mainkar et al., 2004).