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Geochemistry and petrogenesis of Paleo–Mesoproterozoic mafic dyke swarms from northern Bastar craton, central India: Geodynamic implications in reference to Columbia supercontinent

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ABSTRACT

Field setting, petrography, geochemistry and available radiometric ages of Proterozoic mafic dykes from the northern Bastar craton have helped to identify four sets of mafic dykes; two Paleoproterozoic [viz. NW–SE North Bastar dykes (NBD) and ENE–WSW Dongargarh-Chhura dykes (DCD)] and two Mesoproterozoic [viz. 1.42 Ga ENE–WSW Bandalimal dykes (BDD) and 1.44 Ga N–S Lakhna dykes (LKD)]. Their petrographic and geochemical characteristics are very distinct and suggest their derivation from different mantle melts. Chemistry of all the four sets suggests different petrogenetic histories and samples of each distinct set are co-genetic nature. The NBD, the DCD and the BDD samples are sub-alkaline tholeiitic in nature, whereas the LKD samples show alkaline nature. Very distinct REE patterns are observed for all the four sets again suggesting their different petrogenetic histories. Geochemical comparison between the studied samples and mafic dyke samples of southern and central parts of the Bastar craton suggests very different picture for the northern Bastar craton. Only one set of northern Bastar dykes, i.e. the NBD, matches with BD1 dykes; no other dyke sets match with any of the dyke swarms identified in southern and central Bastar craton. Geochemically it is not straightforward to confirm crustal contamination, however, on the other hand, possibility of crustal contamination cannot be ruled out completely. A petrogenetic model based on trace element data suggests that all the four sets are derived from different mantle melts. The NBD and the DCD are probably generated within spinel stability field, whereas the BDD and the LKD may be derived from melts generated within garnet stability field. Available geological and geochemical data support the emplacement of studied dykes in a stable continental rift tectonic setting, however earlier intrusions have chemistry similar to N-MORB. The available geological, geochemical and geochronological data on the four indentified sets of mafic dykes from the northern Bastar craton indicate their relation to the assembly and break-up of Columbia supercontinent.

1. Introduction

Dykes signify crustal extension and are important indicators of crustal stabilization events, supercontinental assembly and dispersal; crust–mantle interaction plays a significant role in the delineation of crustal provinces as well as in deciphering crustal evolution events (Halls, 1982; Bleeker and Ernst, 2006; Ernst et al., 2010; Srivastava, 2011 and references therein). The geological record of every continent was periodically punctuated by phases of mafic magmatism, that eventually represent major thermal events due to extensive mantle melting (Ernst et al., 2005; Ernst, 2007). These records may also be linked to important tectonic events that affect the continent. Mafic dyke swarms are prominent landmarks in Archean granite-greenstone and gneiss–granulite terrains, Proterozoic sedimentary basins, Phanerozoic rift valleys and Large Igneous Provinces (LIPs) (Halls and Fahrig, 1987; Parker et al., 1990; Baer and Heimann, 1995; Hanski et al., 2006; Srivastava et al., 2010; Srivastava, 2011). Dykes are also an integral part of continental rifting and supposed to be a valuable time markers and may be used as global correlation tools (Bleeker and Ernst, 2006; Halls, 2008; Ernst et al., 2010; Srivastava, 2011). Petrogenetic modeling is being increasingly applied to find a suitable mantle connection for the giant dyke swarms. On the whole, mafic dyke swarms record the rhythm of intraplate mantle melting events through time (e.g., Ernst and Buchan, 1997; Bleeker, 2004; Ernst et al., 2010).

The Indian shield is broadly an assembly of dominantly Archean–Paleoproterozoic cratonic blocks and predominantly Meso–Neoproterozoic mobile belts with Archean protoliths (Naqvi, et al., 1974; Naqvi and Rogers, 1987; Ramakrishnan and Vaidyanadhan, 2010; Meert et al., 2010), that contain a number of distinct Proterozoic dyke swarms of different compositions and orientations (Murthy, 1987;

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Devaraju, 1995; Srivastava et al., 2008a,b; French et al., 2008; Srivastava and Ahmad, 2008, 2009; Srivastava, 2011). One of these Indian shield Archean cratons is the Bastar craton, which evidenced a number of mafic magmatic events during Precambrian, mostly in a form of dykes (Srivastava and Gautam, 2009). Although, early Precambrian mafic dykes are also well exposed in the northern parts of the Bastar craton (Subba Rao et al., 2003, 2004; Hussain et al., 2008; Srivastava and Gautam, 2009), geochemical data are lacking with the exception of dykes in the Lakhna area (Ratre et al., 2010; Pisarevsky et al., 2013).

Subba Rao et al. (2003, 2004, 2008) reported dyke composed of boninite, high Mg-norite and metapyroxenitic dykes along with dolerites. A boninite dyke from the Bijli rhyolite, that is the lower volcanic horizon in the Nandgaon Group of the Dongargarh Supergroup, has also been reported (Chalapathi Rao and Srivastava, 2009). Few dolerite dykes related to Cretaceous Deccan magmatic event are also reported to cut Raipur Group of Proterozoic Chhattisgarh basin (Subba Rao et al., 2007; Chalapathi Rao et al., 2011). In the present study only dolerite dykes are considered. The prime aim of this contribution is to provide petrologic and whole rock geochemical data for the distinct Paleoproterozoic mafic dykes exposed in northern parts of the Bastar craton (see Fig. 1) to understand their petrogenetic and geodynamic aspects. This would help to understand (i) whether all of these mafic dykes are co-genetic in nature and belong to the same magmatic event or fed from different magma batches? and (ii) whether these are similar or different in geochemical nature and genesis to other occurrences of mafic dykes exposed in other parts of the Bastar craton?

2. Geological setting

Geology of the Archean Bastar craton is presented elsewhere by a number of workers (Crookshank, 1963; Ramakrishnan, 1990; Naqvi and Rogers, 1987; French et al., 2008; Srivastava and Gautam, 2009; Meert et al., 2010; Ramakrishnan and Vaidyanadhan, 2010 and references therein). In general, the Bastar craton is bounded by NW–SE trending Godavari and Mahanadi rifts, ENE–WSW trending Narmada-Son rift and NE–SW trending Eastern Ghats Mobile Belt (see Fig. 1b). It is important to note that ENE–WSW trending Narmada-Son rift (lineament), thought to be existed since the Archean and extends into the mantle (Naqvi et al., 1974; Naqvi and Rogers, 1987), and is an integral part of the Central Indian Tectonic Zone (CITZ). The CITZ has experienced polyphase tectonothermal events involving several cycles of volcanosedimentary deposition, deformation, metamorphism and magmatism (Acharyya and Roy, 2000; Acharyya, 2001; Roy and Hanuma Prasad, 2003; Meert et al., 2010). The Bastar craton is mainly covered by a vast tract of granitoids with inliers of supracrustal rocks of the Dongargarh, Sakoli, Sausar, Sukma, Bengpal, and Bailadila Series and these are overlain by many unmetamorphosed Proterozoic sedimentary basins (Crookshank, 1963; Ramakrishnan, 1990; Chaudhuri et al., 2002; Ramakrishnan and Vaidyanadhan, 2010). Granitoids vary from 3.5 to 3.6 Ga TTG basement gneisses and granites to relatively un-deformed and un-metamorphosed ~2.5 Ga granites (Sarkar et al., 1993; Rajesh et al., 2009).

Mafic dykes of different ages and compositions are conspicuous in the Bastar craton and mainly intrude Archean granitoids and metamorphites (Srivastava and Gautam, 2009 and references therein). Most of these dykes trend in NW–SE to WNW–ESE. On the basis of field setting, geochemistry, available ages of granitoids and U–Pb geochronology of a set of mafic dykes, three sets of mafic dyke swarms are identified in the southern parts of the Bastar craton (Bandyopadhyay et al., 1990; Ramakrishnan, 1990; Sarkar et al., 1990, 1993, 1994; Srivastava et al., 1996; Srivastava and Singh, 2004; Srivastava, 2006a, b; Mondal et al., 2007; French et al., 2008; Srivastava and Gautam, 2008, 2009; Srivastava et al., 2011); these include ~2.7 Ga sub-alkaline mafic dykes (BD1) (Srivastava et al., 2009), ~2.4–2.5 Ga boninite-norite dykes (BN) (Srivastava, 2008), and 1.88–1.89 Ga sub-alkaline mafic dykes (BD2) (French et al., 2008). A dense concentration of mafic dyke swarm is also well exposed in central part of the Bastar craton, particularly around Bhanupratappur-Keshkal region (Ramachandra et al., 1995; Gautam and Srivastava, 2011), however these are thought to be equivalent to BD1 and BN swarms (Srivastava and Gautam, 2012).

Mafic dykes of present study exposed in northern parts of the Bastar craton (NBC), particularly south of the Proterozoic Chhattisgarh sedimentary basin (see Fig. 1c). Most of these mafic dykes emplaced within Archean gneisses, 2.55–2.48 Ga granitoids and Paleoproterozoic supracrustal rocks (Subba Rao et al., 2003, 2004, 2008; Hussain et al., 2008; Srivastava and Gautam, 2009), however a couple of mafic dykes are also reported to cut Proterozoic Chhattisgarh sedimentary basins (Tripathi and Murti, 1981; Das et al., 2011; Sinha et al., 2011). Predominantly they trend in NW–SE (to NNW–SSE), however a number of dykes also trend in N–S and ENE–WSW to nearly E–W (see Fig. 1c). NW–SE trending mafic dykes are mainly distributed around southern periphery of the Chhattisgarh basin; around Kusumkasa, north of Keshkal, Gariaband, Chhura, and Patewa. A mafic dyke trends NW–SE, not reported earlier, intrude sandstone of the Chandrapur Group of the Chhattisgarh basin near Dongargaon. N–S trending mafic dykes are concentrated around Lakhna and one of such dyke is encountered between Sohela-Padmapur road. ENE–WSW trending mafic dykes mainly exposed around Dongargarh, Chhura, Lakhna and Bandalimal. At Chhura, an ENE–WSW mafic dyke is encountered to cut a NW–SE mafic dyke suggesting younger age for the former. A couple of ENE–WSW mafic dykes is encountered from Bandalimal area, which is emplaced within the Chhattisgarh sedimentary basin; mainly Singhora Group of rocks (Das et al., 2011; Sinha et al., 2011). A couple of nearly E–W trending mafic dykes are also reported from Lakhna area, which are supposed to be younger to the N–S dolerite, rhyolite and trachyte dykes (Ratre et al., 2010; Pisarevsky et al., 2013).

It is important to point out that there are a number of geological and geochemical evidences, that have been reported in the literature (Naqvi et al., 1974; Naqvi and Rogers, 1987; Rajurkar et al., 1990; Ramakrishnan, 1990; Kale, 1991; Neogi et al., 1996; Srivastava et al., 1996; Chaudhuri et al., 2002; Srivastava, 2008; Srivastava and Gautam, 2009), evidently support the emplacement of early Precambrian mafic dykes of the Bastar craton in an intracratonic rift setting. Limited geochronological data are available on mafic dykes of the Bastar craton. Few mafic dykes emplaced in southern parts of the Bastar craton have been dated. These includes (i) a couple of samples from the BD2 dykes placed at 1883 ± 1.4 Ma and 1891.1 ± 0.9 Ma using the U–Pb isotope system in zircon and baddeleyite (French et al., 2008) and (ii) one sample from the metamorphosed the BN dyke placed at 2118 ± 2 Ma using U–Pb isotope system in metamorphic rutile (Srivastava et al., 2011). The later age is interpreted to indicate the time of exsolution of retrograde rutile from Ti-rich actinolite. This represents a robust minimum age constraint for the timing of emplacement of the BN, and by inference the BD1 dyke swarm (Srivastava et al., 2011). Srivastava et al. (2009) indicated that the BD1 dykes were emplaced ~2.7 Ga. Few mafic samples from northern parts of the Bastar craton are also radiometrically dated. Das et al. (2011) have presented Sm–Nd mineral and whole rock age for a sample from ENE–WSW trending mafic intrusive body from Bandalimal area, which yield an isochron age of 1421 ± 23 Ma; they considered it as the emplacement age of the intrusive. Rhyolite, trachyte and alkali gabbro samples from N–S trending Lakhna dykes are dated by U–Pb zircon method; zircons from rhyolite dyke gave age of 1450 ± 22 Ma, whereas trachyte dykes placed at 1453 ± 19 Ma. A sample from alkali gabbro of same area corresponds to age of 1442 ± 30 Ma, which represents the best age estimate for the emplacement of the dyke (Ratre et al., 2010). Pisarevsky et al. (2013) also obtained a similar U–Pb zircon age (1466.4 ± 2.6 Ma) for one of the N–S trending rhyolitic dykes of N–S Lakhna area. No other radiometric ages are available for mafic dykes of this region.