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Isotopic and trace element geochemistry of alkalic–mafic–ultramafic–carbonatitic complexes and flood basalts in NE India: Origin in a heterogeneous Kerguelen plume

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Abstract

The Archean East Indian cratonic margin was affected by the Kerguelen plume (KP) ~117 Ma, causing flood-basalt eruptions of the Rajmahal–Bengal–Sylhet Traps (RBST). The RBST cover ~one million km^2 in and around the Bengal Basin as alkalic–ultrabasic intrusives in the west and Sikkim in the north, and Sylhet basalts and alkalic–carbonatitic–ultramafic complexes in the Shillong plateau – Mikir hills farther east of the Rajmahal–Bengal Traps. We provide new Nd–Sr–Pb-isotopic and trace element data on 21 unreported discrete lava flows of the Rajmahal Traps, 56 alkalic–carbonatitic–mafic–ultramafic rocks from four alkalic complexes, and three dikes from the Gondwana Bokaro coalfields, all belonging to the RBST. The data allow geochemical correlation of the RBST with some contemporaneous Kerguelen Plateau basalts and KP-related volcanics in the southern Indian Ocean. Specifically, the new data show similarity with previous data of Rajmahal group I–II basalts, Sylhet Traps, Bunbury basalts, and lavas from the southern Kerguelen Plateau, indicating a relatively primitive KP source, estimated as: $\varepsilon_{Nd(I)} = +2$, $^{87}Sr/^{86}Sr_{(I)} = 0.7046$, with a nearly flat time-integrated rare earth element (REE) pattern. We model the origin of the uncontaminated RBST basalts by ~18% batch melting with a 2× chondritic KP source in the spinel-peridotite stability depths of 60–70 km in the mantle. The new geochemical data similar to the Rajmahal group II basalts indicate a light REE enriched average source at $\varepsilon_{Nd(I)} = -5$, $^{87}Sr/^{86}Sr_{(I)} = 0.7069$. Our geochemical modeling indicates these lavas assimilated granulites of the Eastern Ghats, reducing the thickness of the continental Indian lithosphere. Lack of an asthenospheric MORB component in the RBST province is indicated by various trace element ratios as well as the Nd-Sr isotopic ratios.

Three alkalic complexes, Sung, Samchampi, and Barpung in NE India, and one in Sikkim to the north are of two groups: carbonatites, pyroxenites, lamproites, nephelinites, sovites, melteigite in the first group and syenites and ijolites in the second. The Nd–Sr–Pb-isotopic and trace element geochemistry of the first group of carbonatitic–ultrabasic rocks are consistent with similar data of the RBST lavas of the present and previous studies, and are modeled as derived from a relatively primitive carbonated garnet peridotite source in the KP. In contrast, the syenites and ijolites of the second group show a wide range of Nd–Sr–Pb isotopic compositions, modeled by low-degree melts of an ancient recycled carbonated eclogite also in the KP. The KP thus reflects heterogeneities in the lower mantle-derived plume with carbonated components yielding ultrabasic melts at greater depths with low-degree melting, followed by rise of the plume at shallower depths causing tholeiitic flood basalt volcanism. Collectively, these data imply a zone of influence of the plate-motion-reconstructed KP head for ~1000 km around the Bengal Basin, as represented by the widely scattered and diverse rock types of the RBST.

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1. INTRODUCTION

Large volume basaltic volcanism that erupted in the Early Cretaceous on the eastern Indian continental margin, southwestern Australia (Bunbury-Naturaliste Plateau), and Antarctica (Fig. 1) are considered to have caused the opening of the Indian Ocean (e.g. Mahoney et al., 1983; Frey et al., 2000). This widespread volcanism is attributed to a large plume, the remnant of which is a hot spot beneath the Kerguelen Plateau (e.g. Storey et al., 1989; Weis et al., 1989; Kent et al., 1997). The Kerguelen plume is believed to have created the Ninetyeast Ridge (NER), Broken Ridge, Bunbury basalts, Naturaliste and Kerguelen Plateaus in the southern Indian Ocean, and the Comei igneous Province in southern Tibet (Fig. 1) (e.g. Weis and Frey, 1991; Frey et al., 2000; Zhu et al., 2009; Ghatak and Basu, 2011). The Kerguelen hotspot with high $^{3}He/^{4}He$ ratios (18 R/R_A) belongs to the same group of hotspots as Hawaii and Iceland (Ingle et al., 2004). Based on geochronological, geochemical data and plate reconstructions, the largest episode of Kerguelen volcanism seem related to the eastern Indian volcanic province of the RBST (Fig. 2a) of 116 ± 3.5 Ma age (Pantulu et al., 1992; Baksi, 1995; Kent et al., 2002; Ray et al., 2005; Ghatak and Basu, 2011).

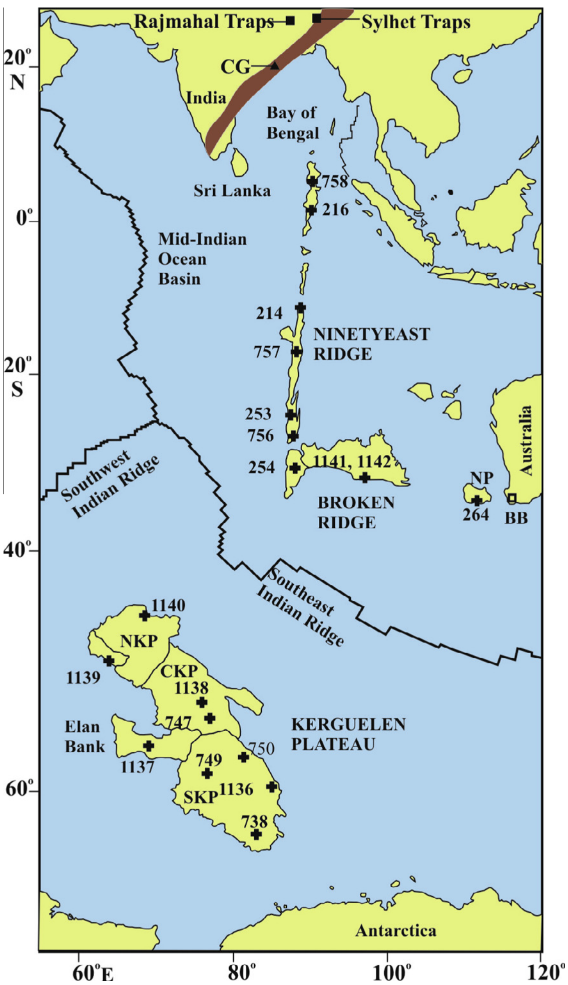

Fig. 1. Map of part of the Indian Ocean and surrounding continents with physiographic features, after Ingle et al. (2002) and Frey et al. (2000), showing locations of the Sylhet and Rajmahal Traps in northeastern India. Also shown in gray is the extended Eastern Ghats – Shillong orogenic belt (Yin et al., 2010) along the east coast of India. Basalt provinces attributed to the Kerguelen plume (Frey et al., 2002) include Kerguelen Plateau, Broken Ridge, Ninetyeast Ridge, Bunbury basalts and Rajmahal Traps. Abbreviations used for relevant fields of comparison are: BB – Bunbury basalt drill core sites; NP – Naturaliste Plateau (Site 264); NKP – North Kerguelen Plateau; CKP – Central Kerguelen Plateau; SKP – South Kerguelen Plateau; CG – Chilka Granulites (Chakrabarti et al., 2011). Black crosses are ODP sites. Sites 253, 254, 756, 757, 214, 216, and 758 are from the Ninetyeast Ridge and are grouped as NER in subsequent Nd–Sr–Pb isotopic plots.

The RBST (Fig. 2) occupy 2×10^{5} km^{2} (Baksi, 1995; Kent et al., 2002). The early geochemical studies of the Rajmahal Traps did not consider a connection between the Kerguelen basalts and the volcanism in eastern India although the Kerguelen plume was implicated as the heat source for the basaltic traps from a compositionally 'normal' asthenosphere (Mahoney et al., 1983; Baksi et al., 1987; Storey et al., 1992).

It is being recognized now that Rajmahal-age volcanic rocks are wide-spread in and around the Bengal Basin as diverse groups of alkalic, ultrabasic, carbonatitic rocks and basalts over an area of ~1 million km^{2} (Fig. 2a); from the Rajmahal hills in the west, these volcanic suites are believed to extend beneath the Tertiary sediments of the Bengal Basin in West Bengal (e.g. Ghatak and Basu, 2011). These alkalic rocks include lamproite dikes in the Gondwana sediments to the west, carbonatite–alkalic complexes in the Shillong plateau and Mikir hills to the northeast, and lamproite dikes of the Sikkim Himalayas to the north (Fig. 2a). The alkalic intrusives are similar to those found in the Deccan and Siberian and other flood basalt provinces in an association commonly found with mantle plumes (e.g. Basu et al., 1993, 1995; Bell, 2001). It has been recognized that in some flood basalt provinces alkalic and carbonatitic magmatism occurred before and after the main pulse of tholeiitic volcanism (Basu et al., 1993, 1995; Bell, 2001; Heaman et al., 2002).

We report here the trace element and Nd–Sr–Pb isotopic analyses of 20 basalts and andesites from four different locations of the Rajmahal Traps, three mafic–ultramafic dikes of the Bokaro coal fields southwest of the Rajmahal Traps, and 56 alkalic, ultramafic, and carbonatitic rocks from four alkalic complexes around the Bengal Basin (Fig. 2). We use the geochemical data to document this widespread volcanism in eastern India by the Kerguelen plume that may approach an area of one million km^{2} (Fig. 1). Using the geochemical results and their interpretation we evaluate the petrogenesis of the tholeiitic traps and associated alkalic–mafic–ultramafic and carbonatitic magmatism in the context of Kerguelen plume volcanism.

2. GEOLOGICAL BACKGROUND OF ROCKS ANALYZED

2.1. Rajmahal Traps

The Rajmahal basalts exposed in the Rajmahal hills (Figs. 2b and A1–A4) of eastern India cover an area of