Sr-Nd isotope geochemistry of the early Precambrian sub-alkaline mafic igneous rocks from the southern Bastar craton, Central India

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Summary

Sr-Nd isotope data are reported for the early Precambrian sub-alkaline mafic igneous rocks of the southern Bastar craton, central India. These mafic rocks are mostly dykes but there are a few volcanic exposures. Field relationships together with the petrological and geochemical characteristics of these mafic dykes divide them into two groups; Meso-Neoarchaean sub-alkaline mafic dykes (BD1) and Paleoproterozoic (1.88 Ga) sub-alkaline mafic dykes (BD2). The mafic volcanics are Neoarchaean and have very close geochemical relationships with the BD1 type. The two groups have distinctly different concentrations of high-field strength (HFSE) and rare earth elements (REE). The BD2 dykes have higher concentration of HFSE and REE than the BD1 dykes and associated volcanics and both groups have very distinctive petrogenetic histories. These rocks display a limited range of initial $^{143}Nd/^{144}Nd$ but a wide range of apparent initial $^{87}Sr/^{86}Sr$. Initial $^{143}Nd/^{144}Nd$ values in the BD1 dykes and associated volcanics vary between 0.509149 and 0.509466 and in the BD2 dykes the variation is between 0.510303 and 0.510511. All samples have positive ε_{Nd} values; the BD1 dykes and associated volcanics have ε_{Nd} values between +0.3 and +6.5 and the BD2 dykes show variation between +1.9 to +6.0. Trace element and Nd isotope data do not suggest severe crustal contamination during the emplacement of the studied rocks. The positive ε_{Nd} values suggest their derivation from a depleted mantle source.

Overlapping positive ε_{Nd} values suggest that a similar mantle source tapped by variable melt fractions at different times was responsible for the genesis of BD1 (and associated volcanics) and BD2 mafic dykes. The Rb-Sr system is susceptible to alteration and resetting during post-magmatic alteration and metamorphism. Many of the samples studied have anomalous apparent initial $^{87}Sr/^{86}Sr$ suggesting post-magmatic interference of the Rb-Sr system which severely restricts the use of Rb-Sr for petrogenetic interpretation.

Keywords: Sr-Nd isotopes, Early Precambrian, Mafic, Sub-alkaline, Bastar craton.

Introduction

Early Precambrian mafic magmatic rocks have been reported from almost all Archaean terrains (Hall and Hughes, 1990; Ernst et al., 1995). These magmatic rocks show wide variations in composition from ultramafic (komatiites) to mafic (tholeiites) and occur as volcanics, dykes and layered complexes. There is an observed tendency for a temporal evolution from komatiitic to noritic magmatism that probably reflects changing crustal states: from mafic 'crust' prone to rapid recycling in the Archaean to a more stable continental crust in the early Proterozoic (Hall and Hughes, 1990). Detailed studies of early Precambrian mafic rocks can thus provide important constraints on the nature of magmatism at a time when Earth’s thermal budget may have been different from that of today.

Archaean cratons in the Indian Shield experienced a wide range of early Precambrian mafic magmatism (Naqvi and Rogers, 1987; Weaver, 1990; Ernst and Srivastava, 2008; Srivastava and Ahmad, 2008). However, except for those in the Dharwar craton (Drury, 1983; Rajamani et al., 1985; Weaver, 1990; Anand et al., 2003; Halls et al., 2007 and references therein), very few petrological and geochemical data are available on these rocks. Practically no isotopic data are available for the mafic igneous rocks exposed in the Bastar craton. The southern Bastar craton in central India (Fig.1b) has distinctive early Precambrian mafic dyke swarms and volcanic rocks whose petrological and geochemical characteristics are well characterised (Srivastava et al., 1996, 2004; Srivastava and Singh, 2003a, 2004; Srivastava, 2006a, b). Here we report new Sr and Nd isotope data that help to constrain further the petrogenesis of these rocks.

Geological setting

The central India Bastar craton is considered to have formed as part of an early supercontinent assembled around Archaean nuclei and known as 'Ur' or 'expanded Ur' (Rogers, 1996; Rogers and Santosh, 2003; Srivastava, 2008). The craton comprises a variety of granitoid, supracrustal, mafic, and unmetamorphosed late Proterozoic sedimentary rocks (Crookshank, 1963; Ramakrishnan, 1990). It is bounded on all sides by prominent structural features; the Godavari rift to the southwest, the Narmada rift to the northwest, the Mahanadi rift to the northeast and Eastern Ghat Belt to the southeast (Fig. 1a; Naqvi and Rogers, 1987). Crookshank (1963) described the general geology of southern Bastar craton but it is only recently that the petrology and geochemistry of the mafic rocks in the craton have been studied (Srivastava et al., 1996, 2004; Srivastava and Singh, 2003a, 2004; Srivastava, 2006a, b). The distribution of early Precambrian mafic rocks exposed in the southern part of the Bastar craton is shown in Figure 1b. Previous work has identified two groups of sub-alkaline mafic dykes (BD1 and BD2), a group of boninite-norite dykes (BN) and a variety of mafic volcanic rocks (Srivastava et al., 2004; Srivastava, 2006b; 2008). The two sets of sub-alkaline mafic dykes differ in age; BD1 dykes are Meso-Neoarchaean and BD2 dykes are Paleoproterozoic. This chronology is inferred from two important field relationships i.e. (i) a BN dyke cuts a dyke belonging to the BD1 swarm and (ii) veins of younger granite (2.3 Ga; Ramakrishnan, 1990) cut a dyke from the BN dyke swarm. It is, therefore, suggested that BN dykes are younger than BD1 but older than 2.3 Ga (Srivastava, 2006b, 2008). The BD2 dykes have been dated at 1883±1.4 Ma using the U-Pb isotope system in zircon and baddeleyite (French et al., 2004, 2008). None of the other mafic dykes have been radiometrically dated. However, on the basis of field relationships, the ages of granitoid rocks, and stratigraphic relationship between different rock units (Ramakrishnan, 1990; Sarkar et al., 1993; Srivastava et al., 1996; Srivastava and Singh, 2003b, 2004; Srivastava, 2006a), their approximate emplacement ages may be inferred. It is proposed that the BD1 swarm was emplaced in the Mesoarchaean and BD2 swarm in the Paleoproterozoic (1.88 Ga). Srivastava (2008) found that the geochemical characteristics of the boninite-norite (BN) dykes were similar to other Neoarchean-Paleoproterozoic (2.4-2.5 Ga) occurrences worldwide, an indication that boninitic magmatism may have been a common phenomenon at that time. This argument also supports the emplacement of BN dykes at around ~2.5 Ga. We suggest that the BD1 dykes were emplaced around 2.7 Ga which was the time at which worldwide mafic magmatism is reported from many Archaean cratons (Blichert-Toft and Albarède, 1994). Clearly, this is a circular argument but constraining the radiometric emplacement age for the medium-grade metamorphosed BD1 dykes is difficult given the absence of a primary igneous mineralogy. The age of the mafic volcanic rocks is also estimated as Neoarchaean (Srivastava et al., 2004). This is consistent with the observation that the volcanics share geochemical characteristics, and hence are likely to be genetically associated with the Neoarchaean BD1 dykes (Srivastava and Singh, 2003b). Thus, the isotope data will be age-corrected to 2.7 Ga. However, we also present initial isotope ratios corrected to 3.0 Ga in order to illustrate the significance of the uncertainty in age for the initial ratio calculation.

Analytical techniques

Samples for the isotope analyses were selected very carefully. All seventeen samples from the sub-alkaline mafic rocks (seven each from the BD1 and BD2 dykes and three from the mafic volcanic rocks) were extremely fresh and collected from the middle portion of the exposures (dykes/volcanic bodies). No evidence of any alteration, either in the field (hand specimen) or in thin section, was noticed in the analysed samples. All these samples were analysed for Sr and Nd isotopes at the Scottish Universities Environmental Research Centre (SUERC). Samples were weighed into PFA teflon screw-top beakers (Savillex®). ^{87}Rb and ^{84}Sr spikes were added quantitatively. Samples were then dissolved using ultra-pure reagents in a HF-HNO_3-HCl digestion. The dissolved sample was aliquoted (by mass) and the smaller (one third) fraction spiked with ^{145}Nd and ^{149}Sm spikes.

Rb and Sr were separated in 2.5 *N* HCl using Bio-Rad AG50W X8 200-400 mesh cation exchange resin. A rare earth element (REE) concentrate was collected by elution of 3*N* HNO_3. Nd and Sm were separated in a mixture of acetic acid (CH_3COOH), methanol (CH_3OH) and nitric acid (HNO_3) using Bio-Rad AG1x8 200-400 mesh anion exchange resin. Total procedure blanks for Rb, Sr, Sm and Nd were less than 0.5 ng.

Sr was loaded onto single Ta filaments with 1 N phosphoric acid, Rb onto triple Ta filaments and Sm and Nd onto triple Ta-Re-Ta filaments. Sr was analysed on a VG Sector 54-30 multiple collector mass spectrometer. A ^{88}Sr intensity of 1V (1 x 10^{-11}A) ± 10% was maintained. The ^{87}Sr/^{86}Sr ratio was corrected for mass fractionation using ^{86}Sr/^{88}Sr = 0.1194 and an exponential law. The mass spectrometer was operated in the peak-jumping mode with data collected as 15 blocks of 10 ratios. The Sr standard NBS987 gave $^{87}Sr/^{86}Sr$ = 0.710257±18 (2 SD, n =14). Rb was analysed on a VG54E single collector mass spectrometer. During each measurement 3 sets of 10 ratios were collected.

Sm and Nd isotope ratios were measured on a VG Sector 54-30 mass spectrometer. The $^{143}Nd/^{144}Nd$ ratios were measured with a ^{144}Nd beam of 1V (1 x 10^{-11}A). Each measurement consisted of 12 blocks of 10 ratios measured in the peak jumping mode and corrected for mass fractionation using an exponential law and $^{146}Nd/^{144}Nd$ = 0.7219. Repeated analyses of the internal laboratory standard (JM) gaves $^{143}Nd/^{144}Nd$ = 0.511511±9 (2 SD, n = 21) The spiked Nd and Sm runs were analysed as 3 blocks of 10 ratios with ion intensities of 5 x 10^{-13}A for ^{143}Nd and ^{149}Sm respectively.

Rb, Sr, Nd and Sm isotope ratios were corrected for mass fractionation and spike contribution and concentrations calculated using adaptations of the standard algorithms of Krough and Hurley, (1968). Rb-Sr and Sm-Nd isotopic data of BD1 dykes + mafic volcanics and BD2 dykes are presented in Tables 1 and 2, respectively.

Whole rock geochemistry

On the basis of whole rock chemistry the mafic rocks are classified as tholeiites (see TAS diagram; Fig. 2; Le Maitre, 2002; Irvine and Baragar, 1971). The BD1 and mafic volcanic samples vary from basaltic to basaltic-andesite compositions, whereas BD2 samples are basaltic. At similar MgO (5.25 – 6.25 wt%) and Cr (33 – 130 ppm) contents, the BD2 dykes have higher HFS and RE element concentrations (see Fig. 3a for REE patterns), an indication that the two groups were derived either from melting of different mantle sources or melting of similar mantle source but with variable melt fractions at different times. In other words both have had distinct petrogenetic histories. Chondrite normalized La^N/Lu^N and La^N/Sm^N in BD1 dykes are approximately 2 and 1.75 respectively, whereas in BD2 they are approximately 3 and 2. REE patterns of the mafic volcanic rocks (Fig. 3b) are similar to the BD1 dyke samples, suggestive of derivation from similar sub-alkaline parental magmas.

Sr and Nd isotope data

Initial $^{87}Sr/^{86}Sr$ and ε_{Nd} values for the BD1 dyke and associated volcanic samples were calculated assuming a 2.7 Ga emplacement age. Initial $^{87}Sr/^{86}Sr$ and ε_{Nd} values for the BD2 dyke samples were calculated for their 1.88 Ga emplacement age (French et al., 2008). The data are listed in Tables 1 and 2.

Initial $^{143}Nd/^{144}Nd_{2.7Ga}$ values of the BD1 dykes (0.509261 – 0.509466; $\varepsilon_{Nd2.7Ga}$ = +3.6 to +6.5) are similar to those of the associated volcanics (0.509149 – 0.509338; $\varepsilon_{Nd2.7Ga}$ = +0.3 to +4.0), consistent with the inference that they were derived from similar parental magmas. The $^{143}Nd/^{144}Nd_{1.88Ga}$ of the BD2 dykes are higher varying from 0.510303 to 0.510511 (ε_{Nd} = +1.9- +6.0). All samples have positive ε_{Nd} values, indicating that they derived from a mantle source that was variably depleted relative to the chondritic uniform reservoir model (CHUR; DePaolo and Wasserburg, 1976).

Initial $^{87}Sr/^{86}Sr_{2.7Ga}$ varies from 0.686372 to 0.711586 in BD1 dykes and 0.700542 to 0.722978 in the associated volcanics. The initial $^{87}Sr/^{86}Sr_{1.88Ga}$ of BD2 dykes shows a variation from 0.694018 to 0.719542. Values lower than 0.699 (the inferred solar system initial from the basaltic achondrite best initial ratio (Papanastassiou and Wasserburg, 1969) are clearly erroneous and indicate that the measured Rb/Sr is higher than the time integrated ratio leading to an over-correction for radiogenic in-growth. As it is difficult to ascertain which of these samples have had their Rb-Sr isotope systems disturbed the petrogenetic significance of the initial Sr isotope variations will not be discussed any further.

Correlation between initial $^{143}Nd/^{144}Nd$ and magmatic differentiation indices (SiO_2, MgO; Fig. 4) may be useful in constraining the extent of crustal contamination. In such plots, (Fig. 4a and b); BD1 (and associated volcanics) and BD2 dykes plot separately and display different trends. A broad correlation between $^{143}Nd/^{144}Nd$ and SiO_2 for the BD1 and mafic volcanic rocks is suggestive of crustal assimilation during magma differentiation. However, this is not substantiated by the $^{143}Nd/^{144}Nd$ – MgO relationship which shows no significant correlation. A detailed discussion on the possibility of crustal contamination to the studied mafic rocks was presented by Srivastava and Singh (2004). They concluded that mantle derived magmas were subjected to some degree to contamination during their ascent and/or temporary residence in crustal magma chambers. It is also important to note that dyke margins may be affected by crustal contamination but centres of dykes are little or un-contaminated (cf. Gill and Bridgewater, 1979; Kalsbeek and Taylor, 1986). Therefore, to minimize the possibility of crustal contamination, samples for the present study were collected from the centres of dykes and samples not containing inclusions/xenocrysts.

Srivastava and Singh (op. cit.) also evaluated trace element data to test the possibility of crustal contamination in these rocks. Element ratios such as Nb/La, Nb/Ce, and La^N/Sm^N, argue against crustal contamination. Fig. 5 plots ε_{Nd} against selected trace element ratios chosen for their predicted sensitivity to crustal contamination (Zr/Nb, La/Nb and Ba/La). For Zr/Nb the more crustal ratios are associated with high ε_{Nd}; La/Nb is not correlated with $^{143}Nd/^{144}Nd$; and the low ε_{Nd} samples tend also to be low in Ba/La which is not expected for crust. Thus, there is no systematic trend to crustal trace element characteristics with decreasing ε_{Nd}. Hence, it is concluded that crustal contamination plays little role in the petrogenesis of the Bastar tholeiitic mafic rocks. Their observed chemical characteristics are probably mantle derived.

The $^{143}Nd/^{144}Nd_{initial}$ versus $^{87}Sr/^{86}Sr_{initial}$ values are plotted on Fig. 4c.. This diagram reveals that BD1 and BD2 dyke samples plot separately due to different $^{143}Nd/^{144}Nd_{initial}$ values; the BD2 samples have higher $^{143}Nd/^{144}Nd_{initial}$ ratios than the BD1 and associated volcanic samples. Volcanic samples clearly show their genetic relationship with BD1 dykes. All the studied samples have positive ε_{Nd} values and most importantly overlapping ε_{Nd} values. (Fig. 4d). This suggests that they were derived from similar depleted sources. However, on the basis of whole rock geochemical data, BD1 and BD2 have different geochemical characteristics. Thus, it is possible that BD1 and BD2 rocks were derived from similar mantle sources, tapped at different times and by different degrees of partial melting and subsequent petrogenetic processes.

For further evaluation of the isotopic data isochron diagrams for the studied samples are presented in Fig. 6. A $^{147}Sm/^{144}Nd$ – $^{143}Nd/^{144}Nd$ isochron plot for BD1 samples (Fig. 6a) shows a correlation with a correlation coefficient that is much lower than required to define an isochron and somewhat steeper than a 2.7 Ga reference line – although inclusion of a single low Sm/Nd sample strongly affects the best-fit regression and the samples could be said to scatter around the 2.7 Ga reference line. BD2 samples do not show any correlation (Fig. 6b). Blichert-Toft and Albarède (1994) presented $^{147}Sm/^{144}Nd$ (ε_{Nd}) and $^{143}Nd/^{144}Nd$ data for 2.7 Ga mantle derived magmas and suggested small but significant isotopic heterogeneities for the Archaean mantle. These authors presented a density diagram showing the variation of $^{147}Sm/^{144}Nd$ and ε_{Nd} in the

2.7 Ga mantle-derived mafic rocks (Fig. 7). The data presented in this figure suggest that both long-term depleted and enriched mantle reservoirs had developed globally early in Earth history. For comparison, isotopic data for the BD1 samples presented in this study are also plotted on this diagram. The majority of samples fall in the range of mantle-derived Archaean mafic rocks. Variations in ε_{Nd} may therefore reflect compositional variations in the mantle. However, to the extent that the samples scatter around a 2.7 Ga reference line, the present day isotopic variation is, in part at least, a temporal response to variable $^{147}Sm/^{144}Nd$ which could reflect either source heterogeneity or variable melt fraction etc.

Conclusions

Sr and Nd isotope data presented here corroborate the recognition of two distinct (BD1 and BD2) dyke swarms in the southern Bastar craton. BD1 was likely emplaced during the Neoarchaean (~2.7 Ga), whereas BD2 was emplaced at 1.88 Ga. The isotopic data also support a genetic relationship between the BD1 dykes and the Neoarchaean mafic volcanics. Trace element and Nd isotope data argue against crustal contamination as an important petrogenetic process. Overlapping positive ε_{Nd} values suggest that these mafic rocks were derived from similar depleted mantle sources. ε_{Nd} and $^{147}Sm/^{144}Nd$ values of the BD1 samples from the southern Bastar craton show close similarities with other similar 2.7 Ga old mafic rocks reported worldwide. The present data are consistent with the suggestion that similar mantle sources sampled by different degrees of partial melting at different times were responsible for the petrogenesis of BD1 (+ associated volcanics) and BD2 mafic dykes. The lowest initial Sr isotope ratios are lower than the solar system initial value which is clearly erroneous and probably indicate that the measured Rb/Sr is higher than the time integrated ratio leading to an over-correction for radiogenic in-growth. Therefore, initial Sr isotope data are not appropriate for use in the interpretation of petrogenetic processes.

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Figure captions

Figure 1a: Major cratons and structural features of India (after Naqvi and Rogers, 1987). Major structural features are: 1. Small thrusts in western Dharwar craton; 2. Eastern Ghats front; 3. Sukinda; 4. Singhbhum; 5. Son Valley; and 6. Great Boundary fault. EGMB: Eastern Ghat Mobile Belt; NSRZ: Narmada-Son Rift Zone.

Figure 1b: Distribution of different mafic dykes and volcanics exposed in the southern part of the Cetral Indian Bastar craton (after Srivastava, 2006a, b). Width of dykes is exaggerated for clarity.

Figure 2: Total alkalis-silica (TAS) diagram (after Le Maitre 2002). Dotted line divides sub-alkaline basalts from alkaline basalts (after Irvine and Baragar 1971). Symbols: BD1 dykes (plus sign), BD2 dykes (open circles), and mafic volcanics (open diamonds).

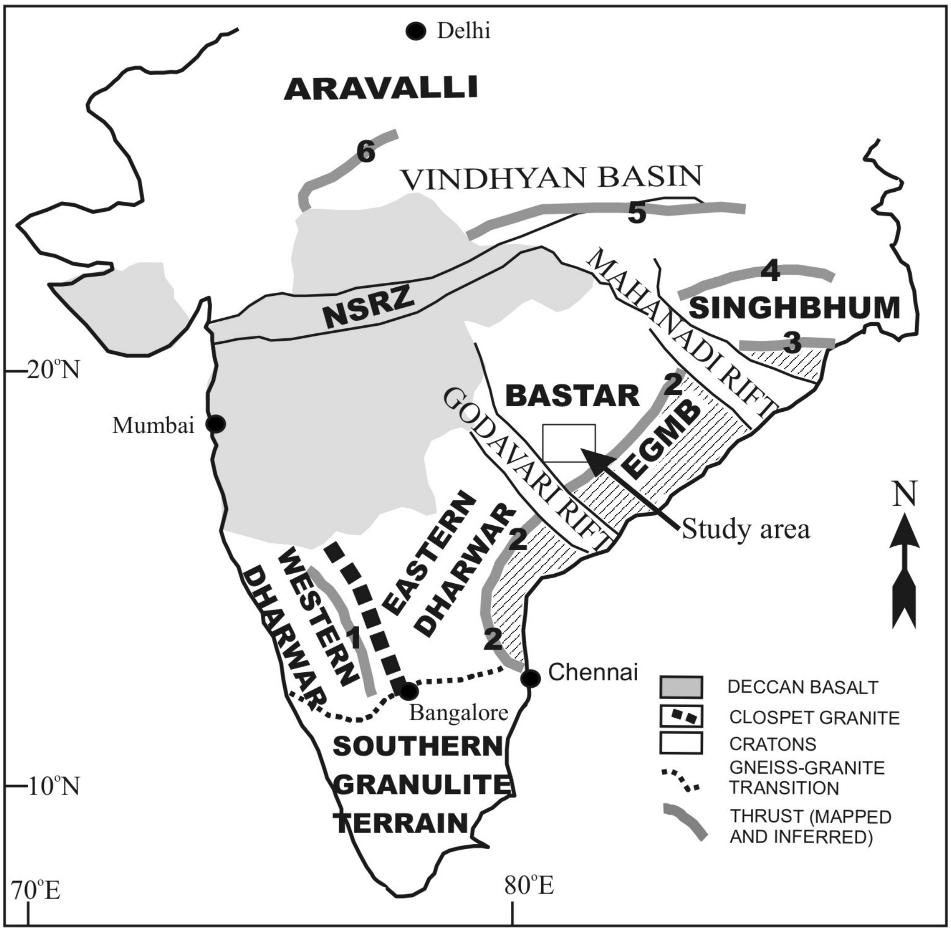
Figure 3: Chondrite normalized rare-earth elements patterns for studied samples. Chondrite values are taken from Evensen et al. (1978).

Figure 4: Variations of **(a)** $^{143}Nd/^{144}Nd_{initial}$ versus SiO_2 (wt%); **(b)** $^{143}Nd/^{144}Nd_{initial}$ versus MgO (wt%); **(c)** Isotope correlation plot between $^{143}Nd/^{144}Nd_{initial}$ and $^{87}Sr/^{86}Sr_{initial}$; **(d)** ε_{Nd} versus $^{87}Sr/^{86}Sr_{initial}$ plot. Symbols are as used in Fig. 2.

Figure 5: ε_{Nd} versus trace element ratios variations plots. Solid square and solid circle show chondrite and average crust values, respectively (taken from Rudnik and Fountain, 1995). Symbols are as used in Fig. 2.

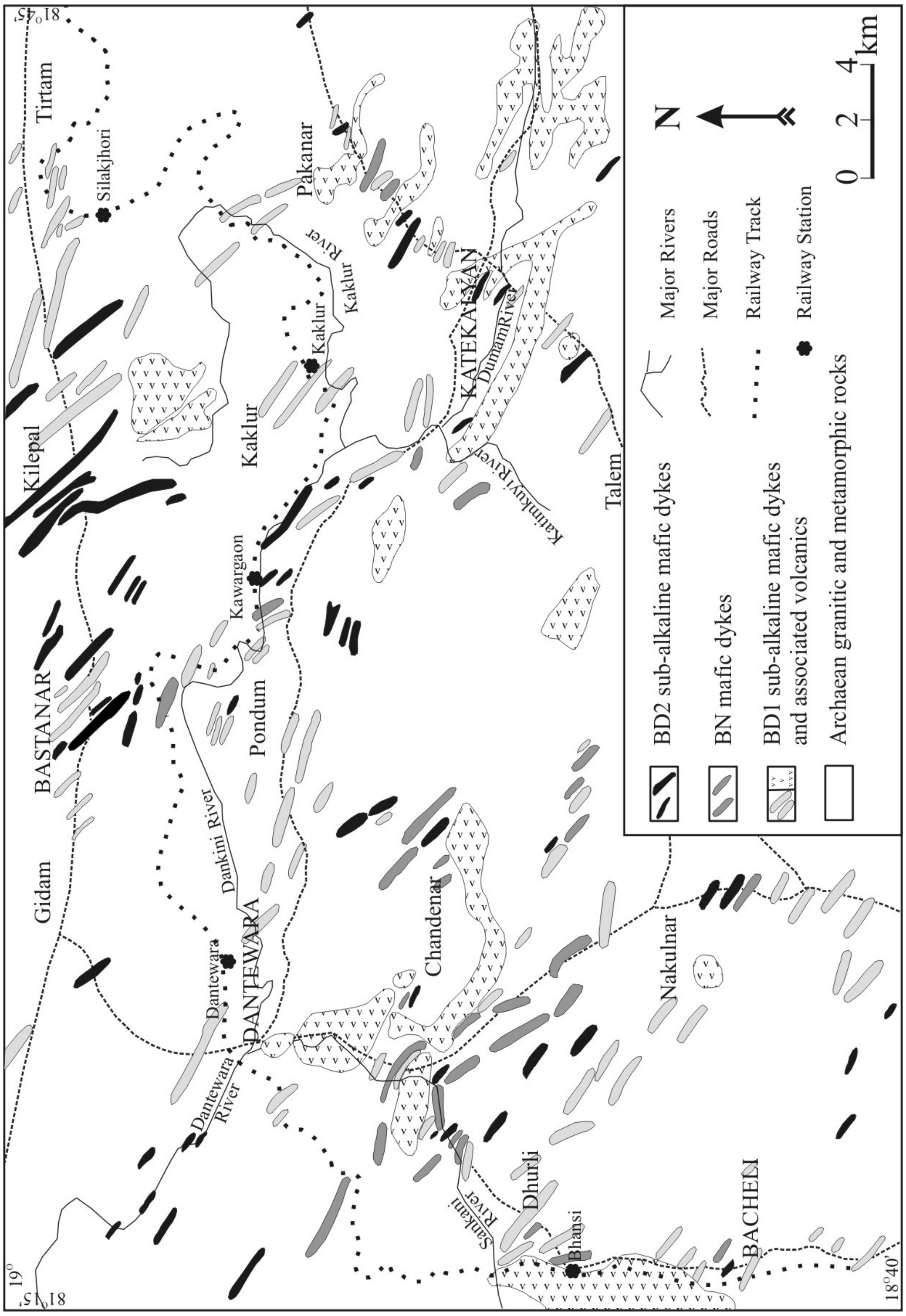
Figure 6: Sm-Nd isochron diagrams for the studied samples. Fig. 6a also shows 2.7 Ga reference line for comparison. Symbols are as used in Fig. 2.

Figure 7: Density diagram showing the variation in the isotopic composition $^{147}Sm/^{144}Nd$ ratio and ε_{Nd} in the late Archaean (2.7 Ga) mantle-derived mafic rocks (after Blichert-Toft and Albarède, 1994). The data presented in this figure suggest that both long-term depleted and enriched mantle reservoirs had developed globally early in Earth history. Mafic igneous rocks of present study are also plotted in this diagram for comparison. The majority of samples fall in the range of mantle-derived Archaean mafic rocks.



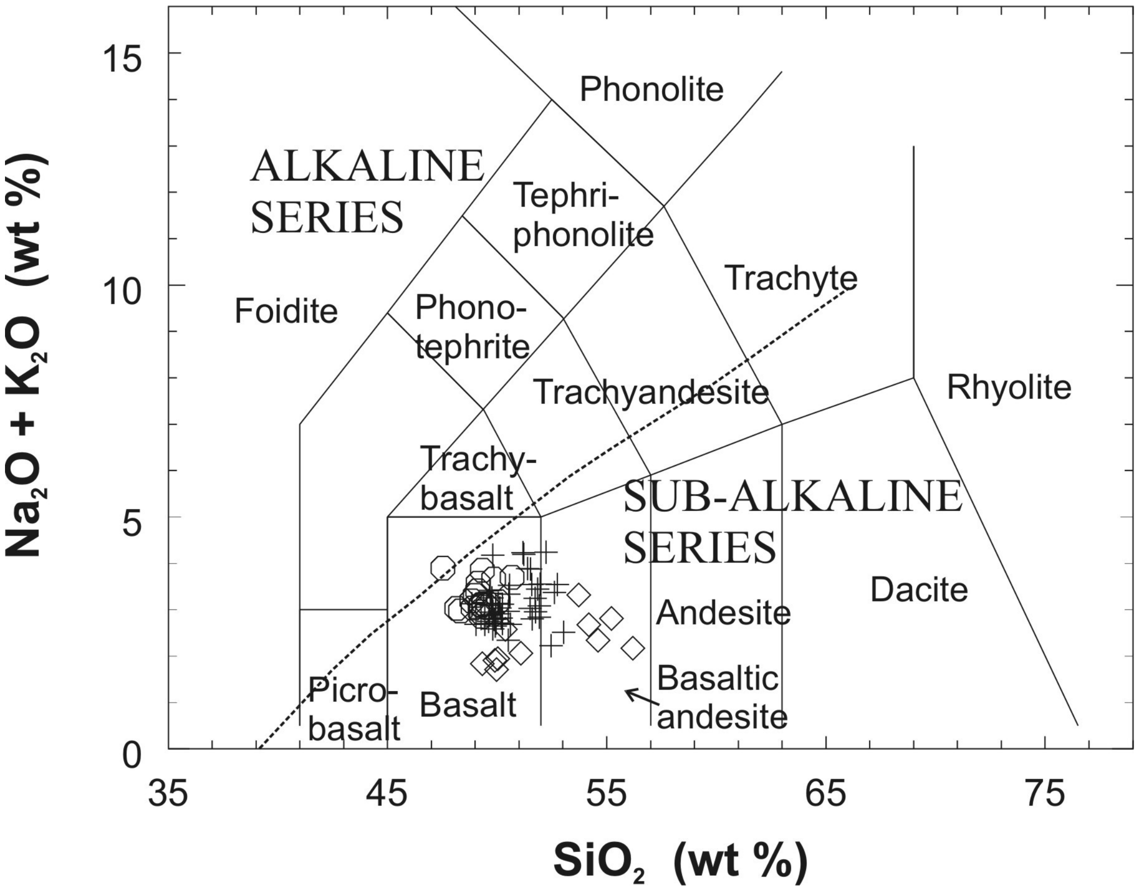
Delhi
ARAVALLI
6
VINDHYAN BASIN
5
4
NSRZ
MAHANADI RIFT
SINGHBHUM
3
20ºN
BASTAR
2
Mumbai
GODAVARI RIFT
EGMB
Study area
N
EASTERN DHARWAR
2
WESTERN DHARWAR
1
2
Chennai
Bangalore
SOUTHERN GRANULITE TERRAIN
10ºN
70ºE
80ºE
DECCAN BASALT
CLOSPET GRANITE
CRATONS
GNEISS-GRANITE TRANSITION
THRUST (MAPPED AND INFERRED)

Figure 1a



BD2 sub-alkaline mafic dykes
BN mafic dykes
BD1 sub-alkaline mafic dykes and associated volcanics
Archaean granitic and metamorphic rocks
Major Rivers
Major Roads
Railway Track
Railway Station
N
0 2 4 km
81°15'
81°45'
19°
18°40'
Tirtam
Silakjhori
Kilepal
Kaklur
Kaklur River
Pakanar
KATEKALYAN
Dumam River
Katmkuyi River
Talem
Kawargaon
BASTANAR
Pondum
Gidam
Dankini River
Dantewara
DANTEWARA
Dantewara River
Chandenar
Nakulnar
Dhurli
Sankani River
Bhansi
BACHELI

Figure 1b



15
10
5
0
35
45
55
65
75
Na2O + K2O (wt %)
SiO2 (wt %)
Phonolite
ALKALINE SERIES
Tephri-phonolite
Trachyte
Foidite
Phono-tephrite
Trachyandesite
Rhyolite
Trachy-basalt
SUB-ALKALINE SERIES
Andesite
Dacite
Basaltic andesite
Picro-basalt
Basalt

Figure 2

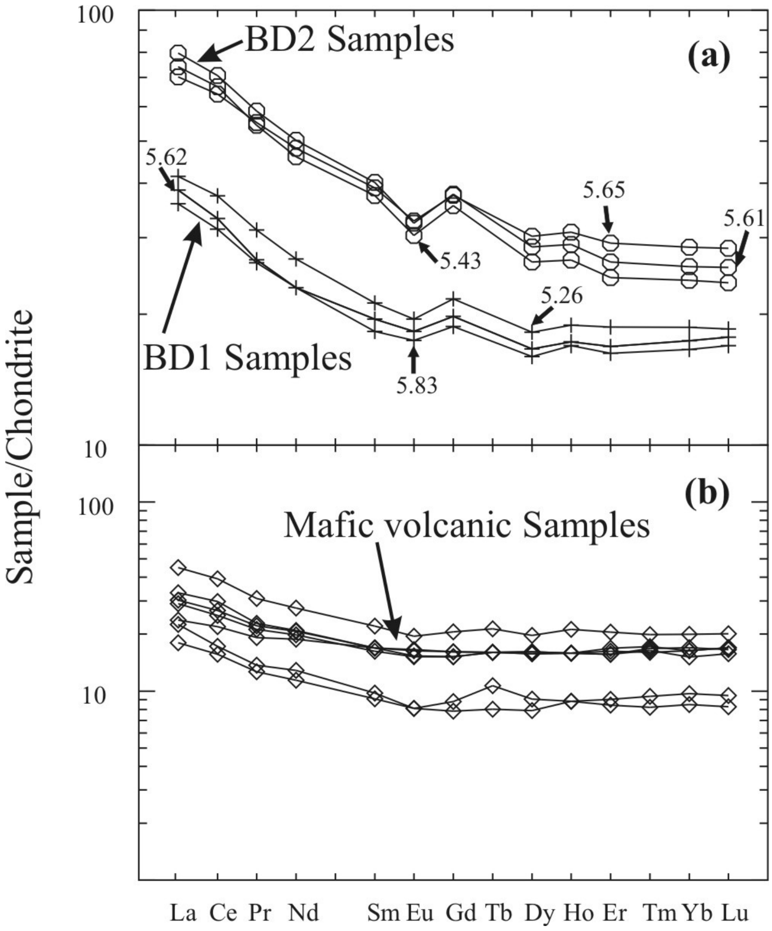

100
BD2 Samples
(a)
5.62
5.65
5.61
5.43
5.26
BD1 Samples
5.83
10
Sample/Chondrite
(b)
100
Mafic volcanic Samples
10
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

Figure 3

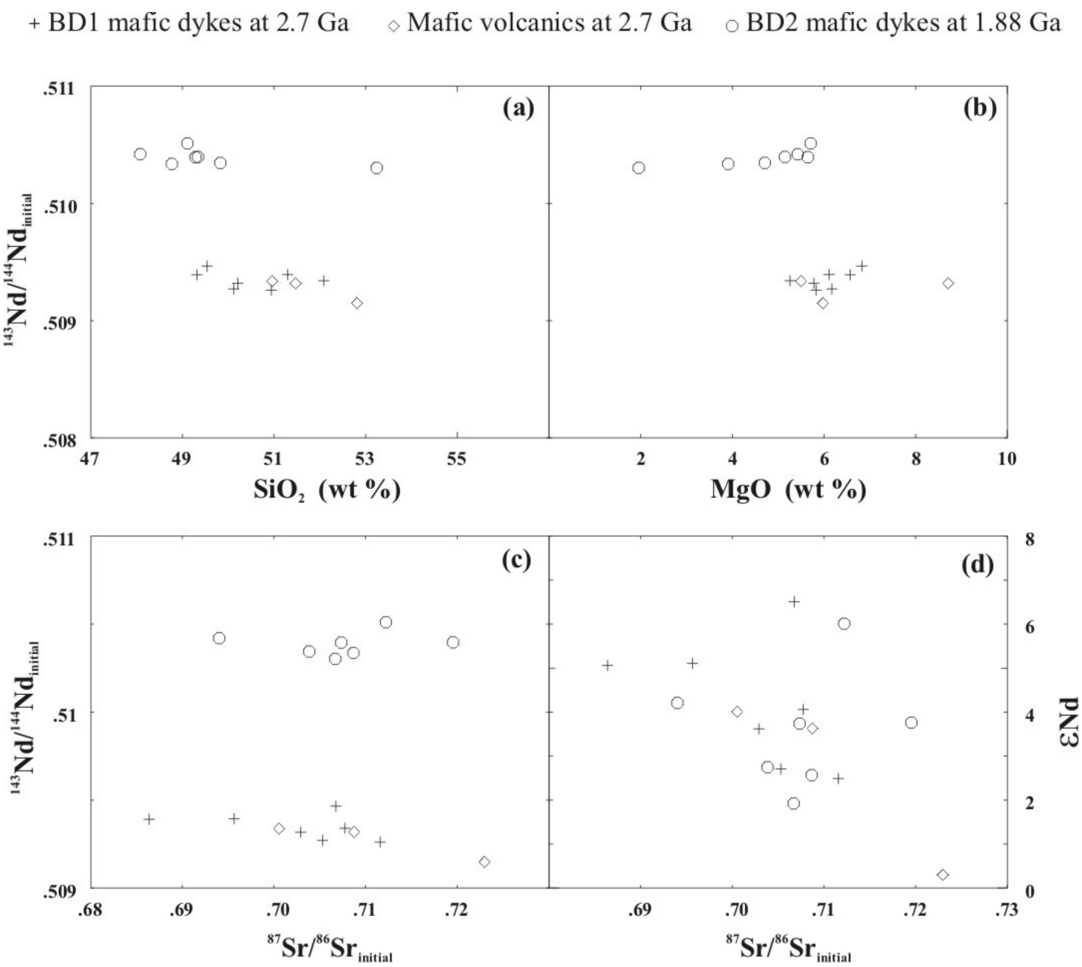

+ BD1 mafic dykes at 2.7 Ga
◇ Mafic volcanics at 2.7 Ga
○ BD2 mafic dykes at 1.88 Ga
(a)
(b)
(c)
(d)
143Nd/144Nd initial
SiO2 (wt %)
MgO (wt %)
87Sr/86Sr initial
εNd
.511
.510
.509
.508
.51
47
49
51
53
55
2
4
6
8
10
.68
.69
.70
.71
.72
.73
0

Figure 4

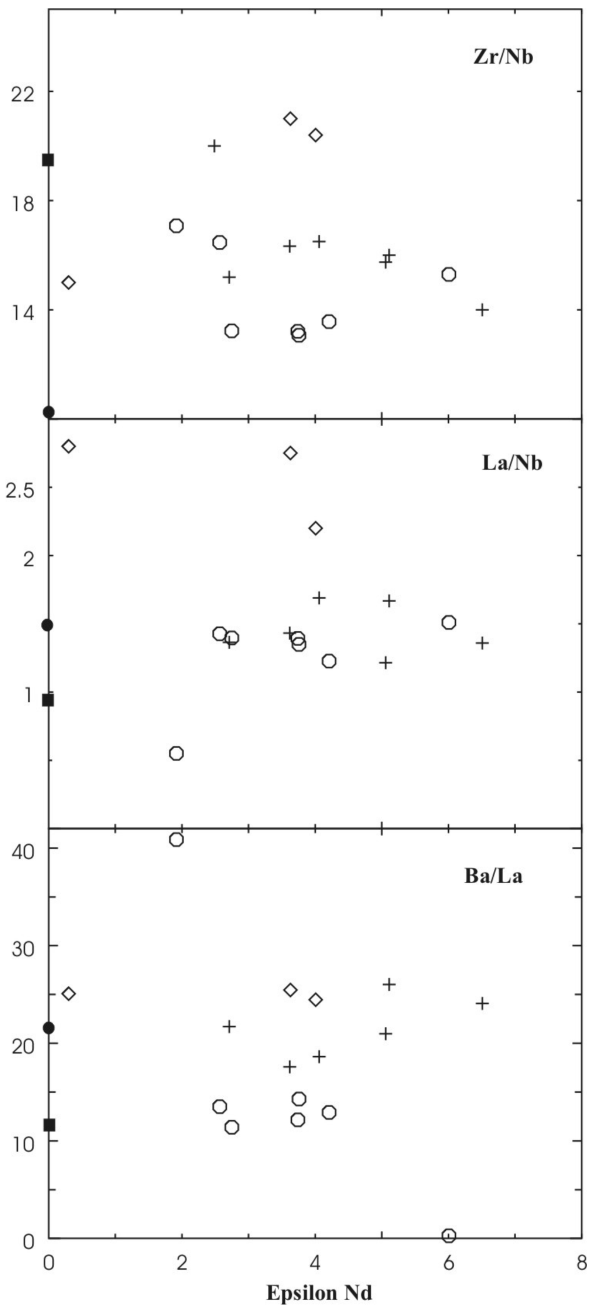


Figure 5

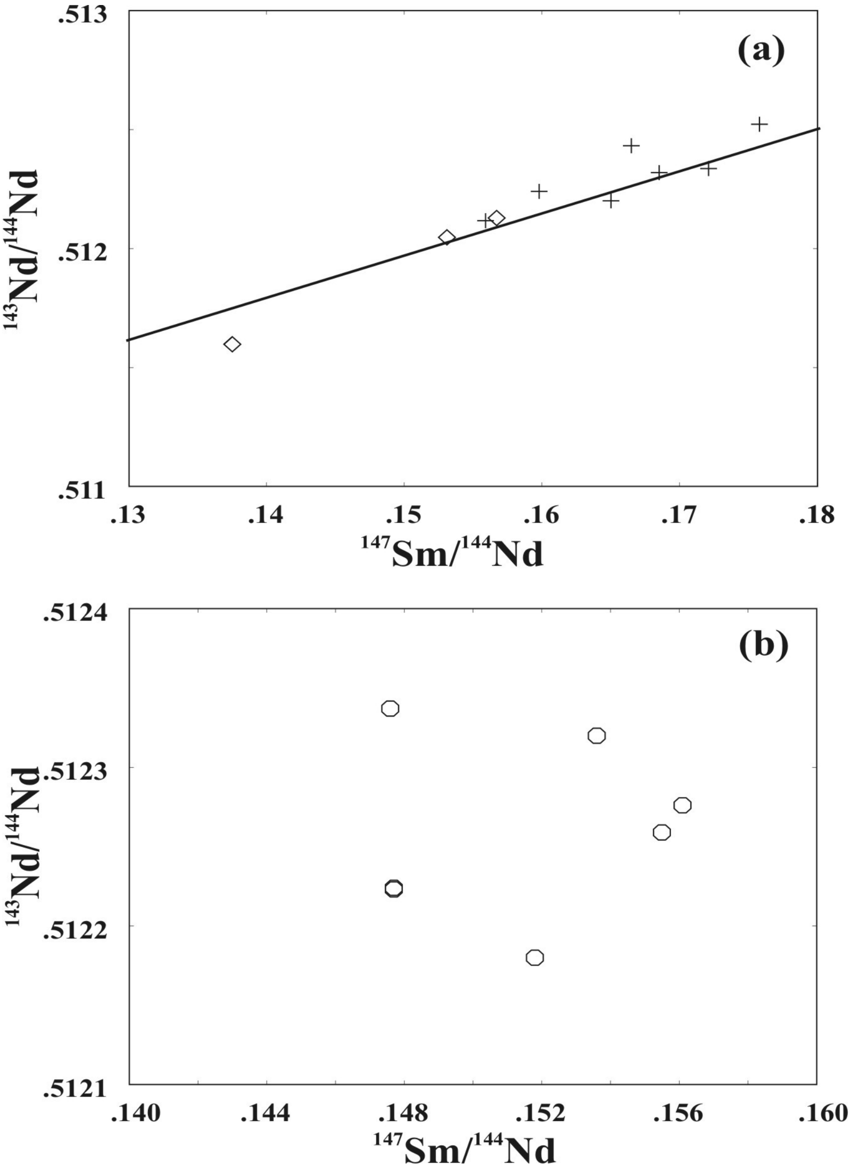

.513
(a)
.512
.511
.13
.14
.15
.16
.17
.18
$^{143}Nd/^{144}Nd$
$^{147}Sm/^{144}Nd$
.5124
(b)
.5123
.5122
.5121
.140
.144
.148
.152
.156
.160
$^{143}Nd/^{144}Nd$
$^{147}Sm/^{144}Nd$

Figure 6

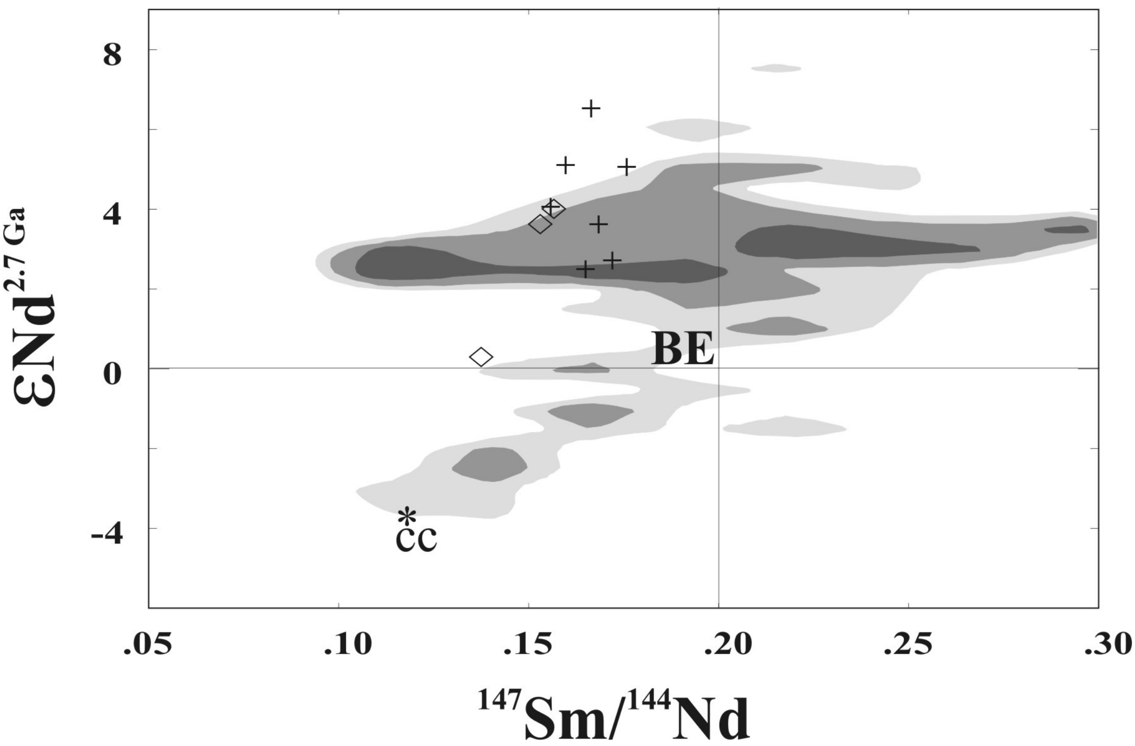


Figure 7

Table 1: Nd and Sr isotopic compositions in BD1 dyke and associated volcanic samples from the southern part of the central India Bastar craton.

Sample No. ↓	Sm (in ppm±error)	Nd (in ppm±error)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	% Std error	$^{143}Nd/^{144}Nd_{initial}$ at 3.0 Ga	$^{143}Nd/^{144}Nd_{initial}$ at 2.7 Ga	ε_{Nd} at 3.0 Ga	ε_{Nd} at 2.7 Ga
92/2 (D)	1.930 (0.0005)	7.009 (0.001)	0.1665	0.512432	0.0008	0.509133	0.509466	7.7	6.5
92/9 (D)	2.697 (0.0005)	10.205 (0.001)	0.1598	0.512241	0.0007	0.509075	0.509394	6.6	5.1
92/37 (D)	3.060 (0.001)	10.755 (0.001)	0.1721	0.512337	0.0006	0.508928	0.509272	3.7	2.7
92/44 (D)	3.739 (0.001)	13.417 (0.001)	0.1685	0.512320	0.0006	0.508981	0.509318	4.7	3.6
92/53 (D)	2.406 (0.001)	8.277 (0.001)	0.1758	0.512523	0.0007	0.509040	0.509391	5.9	5.1
93/302 (D)	3.073 (0.003)	11.259 (0.001)	0.1650	0.512201	0.0008	0.508931	0.509261	3.7	2.5
93/316 (D)	3.329 (0.001)	12.912 (0.001)	0.1559	0.512118	0.0006	0.509029	0.509341	5.7	4.1
97/190 (V)	3.470 (0.0003)	13.392 (0.001)	0.1567	0.512129	0.0007	0.509025	0.509338	5.6	4.0
97/331 (V)	1.551 (0.0005)	6.124 (0.001)	0.1531	0.512047	0.0009	0.509013	0.509319	5.4	3.6
97/343 (V)	2.712 (0.001)	11.929 (0.001)	0.1375	0.511598	0.0005	0.508875	0.509149	2.6	0.3
Sample No. ↓	Rb (in ppm±error)	Sr (in ppm±error)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	% Std error	$^{87}Sr/^{86}Sr_{initial}$ at 3.0 Ga	$^{87}Sr/^{86}Sr_{initial}$ at 2.7 Ga		
92/2 (D)	12.93 (0.02)	94.96 (0.12)	0.3945	0.722166	0.0014	0.704997	0.706747		
92/9 (D)	29.01 (0.03)	104.52 (0.13)	0.8046	0.727080	0.0016	0.692065	0.695634		
92/37 (D)	7.55 (0.01)	120.69 (0.12)	0.1811	0.712377	0.0013	0.704496	0.705300		
92/44 (D)	11.49 (0.02)	110.09 (0.21)	0.3022	0.714715	0.0014	0.701564	0.702905		
92/53 (D)	25.73 (0.01)	90.90 (0.08)	0.8198	0.718414	0.0013	0.682735	0.686372		
93/302 (D)	36.36 (0.05)	110.27 (0.13)	0.9579	0.749024	0.0011	0.707337	0.711586		
93/316 (D)	19.08 (0.04)	112.79 (0.15)	0.4904	0.726903	0.0011	0.705563	0.707738		
97/190 (V)	23.36 (0.05)	153.42 (0.27)	0.4410	0.717777	0.0013	0.698586	0.700542		
97/331 (V)	29.24 (0.02)	82.76 (0.07)	1.0263	0.748850	0.0012	0.704184	0.708736		
97/343 (V)	25.69 (0.04)	166.81 (0.22)	0.4470	0.740449	0.0011	0.720995	0.722978		

Initial Nd and Sr isotope ratios along with the epsilon values for BD1 dyke (D) and volcanic (V) samples were calculated at 3.0 Ga and 2.7 Ga emplacement ages. Epsilon values are calculated using present-day ratios of $^{87}Sr/^{86}Sr = 0.7047$ (Taylor and McLennan, 1985) for Bulk Silicate Earth (BSE) and $^{143}Nd/^{144}Nd = 0.512638$ (Goldstein et al., 1984) for Chondritic Uniform Reservoir (CHUR). T_{DM} values are calculated using present day $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ ratios given by Goldstein et al. (1984). Whole rock major (wt%) and trace element contents of BD1 dykes and volcanics is presented in Srivastava and Singh (2004) and Srivastava et al. (2004), respectively.

Table 2: Nd and Sr isotopic compositions in BD2 dyke samples from the southern part of the central India Bastar craton.

Sample No. ↓	Sm (in ppm±error)	Nd (in ppm±error)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	% Std error	$^{143}Nd/^{144}Nd_{initial}$	ε_{Nd}
92/7	5.566 (0.001)	21.911 (0.003)	0.1536	0.512320	0.0006	0.510420	4.2
92/51	4.956 (0.001)	20.284 (0.002)	0.1477	0.512223	0.0006	0.510395	3.7
92/56	3.514 (0.001)	14.399 (0.001)	0.1476	0.512337	0.0006	0.510511	6.0
92/59	15.045 (0.003)	59.949 (0.014)	0.1518	0.512180	0.0006	0.510303	1.9
92/65	5.389 (0.002)	22.056 (0.003)	0.1477	0.512224	0.0006	0.510396	3.8
93/273	7.249 (0.003)	28.198 (0.001)	0.1555	0.512259	0.0012	0.510336	2.6
93/301	5.265 (0.001)	20.395 (0.003)	0.1561	0.512276	0.0006	0.510345	2.8
Sample No. ↓	Rb (in ppm±error)	Sr (in ppm±error)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	% Std error	$^{87}Sr/^{86}Sr_{initial}$	
92/7	32.59 (0.03)	104.46 (0.12)	0.9036	0.718465	0.0012	0.694018	
92/51	19.12 (0.04)	105.78 (0.12)	0.5237	0.721542	0.0014	0.707374	
92/56	12.32 (0.02)	106.60 (0.15)	0.3348	0.721256	0.0011	0.712197	
92/59	39.22 (0.01)	144.65 (0.20)	0.7860	0.727942	0.0017	0.706676	
92/65	30.42 (0.03)	127.26 (0.17)	0.6937	0.738310	0.0012	0.719542	
93/273	25.82 (0.06)	117.24 (0.14)	0.6383	0.725935	0.0018	0.708665	
93/301	19.57 (0.02)	97.68 (0.21)	0.5803	0.719545	0.0016	0.703844	

Initial Nd and Sr isotope ratios along with the epsilon values for BD2 dykes were calculated at 1.88 Ga emplacement age.

For calculation parameters please see Table 1.

Whole rock major (wt%) and trace element contents of BD1 dykes are presented in Srivastava and Singh (2004).