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Substantiation of Réunion plume induced prolonged magmatic pulses (ca. 70.5–65.5 Ma) of the Deccan LIP in the Chhotanagpur Gneissic Complex, eastern India: Constraints from ^{40}Ar/^{39}Ar geochronology

Rajesh K Srivastava[1,*], Fei Wang[2,3,4] and Wenbei Shi[2]

[1] *Centre of Advanced Study in Geology, Institute of Science, Banaras Hindu University, Varanasi 221 005, India.*
[2] *State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, P.R. China.*
[3] *CAS Centre for Excellence in Tibetan Plateau Earth Sciences, Beijing 100 101, P.R. China.*
[4] *College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing 100 049, P.R. China.*
**Corresponding author. e-mail: rajeshgeolbhu@gmail.com*

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This study presents ^{40}Ar/^{39}Ar geochronology on the mafic dykes emplaced in the Damodar valley Gondwana sedimentary basins of the Chhotanagpur Gneissic Complex (CGC) to authenticate prolonged mafic magmatic activities during Maastrichtian period. A couple of earlier and one new ^{40}Ar/^{39}Ar plateau ages, which range in age from ca. 70.5 to 65.5 Ma, suggest prolonged ($\sim$5 myr) magmatic activities in the CGC. These syn- and pre-Deccan LIP magmatic intrusive activities in the CGC are supposedly related to the Réunion mantle plume. The reported age of 70.5 ± 0.9 Ma of a NE-trending mafic dyke emplaced within the Raniganj basin could probably be the earliest record of the Réunion mantle plume activity in the Indian shield. A number of other early magmatic rocks, related to the Réunion mantle plume induced Deccan LIP event, are also recorded elsewhere in the Indian shield and supportive of prolonged magmatic activities. Finally, this study also provides a better constraint on the initiation and lateral extent of the Réunion mantle plume induced Deccan LIP.

Keywords. ^{40}Ar/^{39}Ar geochronology; mafic dykes; Réunion plume; Deccan LIP; Chhotanagpur Gneissic Complex; eastern India.

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1. Introduction

Large Igneous Provinces (LIPs), recorded throughout the Earth's history, are large volume (>0.1 Mkm^3) outpouring of basaltic magma, mostly represented by Continental Flood Basalt Provinces, emplaced in an intraplate setting in a short period of time (<5 Ma; it could be <1 Ma in Phanerozoic) (e.g., Coffin and Eldholm 1994, 2005; Bryan and Ernst 2008; Bryan *et al.* 2010; Ernst 2014). The Deccan Flood Basalt Province is a prominent Phanerozoic LIP in the Indian Shield with a thick pile of basaltic flows (at places it is >2000 m) due to outpouring of a huge volume (512,000 km^3) covering an area of >500,000 km^2 (cf. Beane *et al.* 1986; Courtillot *et al.* 1986; Sen 2001; Jay and Widdowson 2008). The most important characteristic of this large volume magmatism is huge accumulations of basaltic flows over a short period of time (cf. Pande 2002; Chenet *et al.* 2007, 2008, 2009; Schoene *et al.* 2015, 2019; Parisio *et al.* 2016; Sprain *et al.* 2019 and references therein). Available geochronological and paleomagnetic data on Deccan basalts suggest that major part (>90%) of the Deccan LIP components were emplaced at <1 million year time (ca. 66.0–65.5 Ma), which is indistinguishable from the Cretaceous–Paleogene (K–Pg) boundary (e.g., Duncan and Pyle 1988; Vandamme and Courtillot 1992; Baksi 1994; Allègre *et al.* 1999; Hofmann *et al.* 2000; Chenet *et al.* 2007, 2008, 2009; Schoene *et al.* 2015, 2019; Parisio *et al.* 2016; Sprain *et al.* 2019 and references therein).

However, on the other hand, there are other evidences too which suggest that mafic magmatic activities also occurred just before and after the main Deccan event between 69 and 62 Ma and these are also supposed to be related to the Réunion plume magmatism (Widdowson *et al.* 2000; Pande 2002; Hooper *et al.* 2010; Chalapathi Rao and Lehman 2011; Shrivastava *et al.* 2015, 2017; Parisio *et al.* 2016). Some of these pre-Deccan volcanic flows and dykes activities include (i) alkaline intrusive igneous rocks exposed in the Cambay graben yield ^{40}Ar/^{39}Ar ages (of biotite grains) of 69.62 ± 0.08 and 69.58 ± 0.16 Ma (Basu *et al.* 1993); (ii) alkali-basaltic lava flows of the Anjar Traps, Kutch yield whole rock and plagioclase ages of 67.47 ± 0.30 and 67.67 ± 0.60 Ma, respectively (Courtillot *et al.* 2000); (iii) Lehmann *et al.* (2010) presented ^{40}Ar/^{39}Ar age for diamondiferous Mainpur kimberlites, Bastar craton, which yield 67.37 ± 0.80 Ma age; (iv) a feeder mafic dyke exposed near Betul area in the Satpura Mountain range, which yields ^{40}Ar/^{39}Ar age ca. 66.56 ± 0.42 Ma (Shrivastava *et al.* 2017); (v) many of the mafic dykes from the Nandurbar–Dhule swarms in the Deccan Traps yield ^{40}Ar/^{39}Ar ages ca. 67 Ma (Sheth *et al.* 2019).

Furthermore, a Réunion hotspot-related basaltic flow in the South Tethyan suture zone of Pakistan (see figure 1) have been dated by ^{40}Ar/^{39}Ar incremental heating method, which yields ages of 73.4–72.0 Ma (Mahoney *et al.* 2002); interestingly its isotopic and trace element geochemistry is very close to the Deccan basalts (Mahoney 1988). Other interesting fact is that basaltic lava flows exposed >400 km NE of the main Deccan flood basalts along India's eastern coast, near Rajahmundry, yield 64.7 ± 0.5 Ma, which is also thought to be part of the Deccan event (Knight *et al.* 2003). These observations are well supportive of a huge Réunion mantle plume head (White and McKenzie 1989), which was responsible for all these wide range volcanic eruptions, intrusive rocks and also continental break-up of greater India with the Seychelles (see figure 1; cf. Mahoney *et al.* 2002).

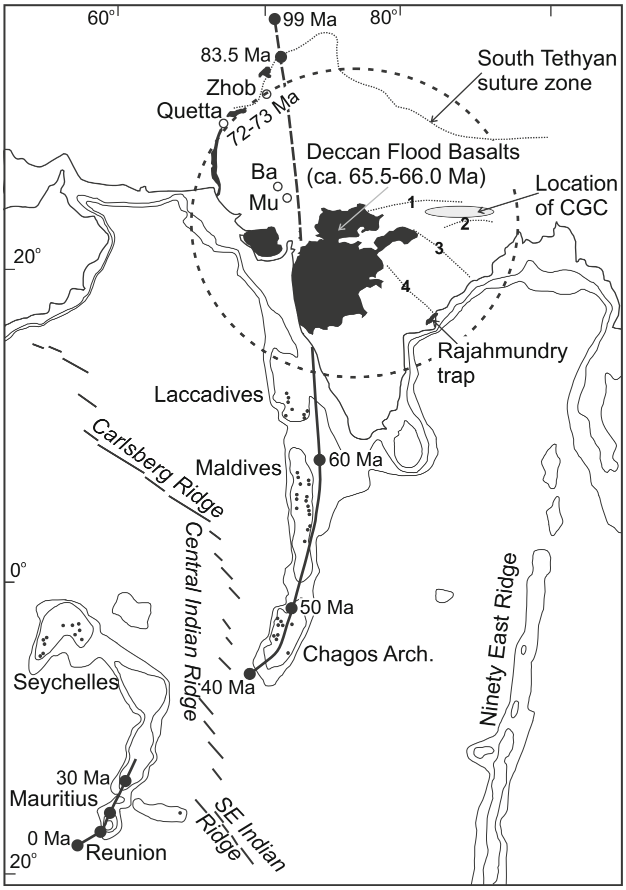

Figure 1. Geographic depiction of the west Indian ocean showing migration of the Indian shield over the static Réunion hotspot during 90–0 Ma (shown by thick line with 10 Ma increments) (modified from White and McKenzie 1989; Mahoney *et al.* 2002). The extended path (shown with dashed line) is based on plate reconstructions by Kent *et al.* (2002) and assumed by Mahoney *et al.* (2002). Dashed circle denotes hypothesized size of the Réunion mantle plume beneath the Indian shield during ca. 70–62 Ma (after White and McKenzie 1989; Cox 1989). Location of the Chhotanagpur Gneissic Complex (CGC) is also shown. Ba: Barmer; Mu: Mundwara; 1: Son–Narmada rift; 2: Singhbhum shear zone; 3: Mahanadi rift; 4: Godavari rift.

Mafic intrusive rocks, mostly dykes, associated with the Réunion plume induced magmatism, are well exposed in the Chhotanagpur Gneissic Complex (CGC), eastern India (Kent *et al.* 2002; Paul 2005; Srivastava *et al.* 2014). Reported ages of these intrusive igneous bodies range in age from 65.5 to 70.5 Ma (Kent *et al.* 2002; Srivastava *et al.* 2020). This work is exclusively aimed to validate presence of syn- and pre-Deccan (ca. 70.5–65.5 Ma) Réunion plume induced magmatic pulses in the CGC (eastern India) with the help of two existing

(Kent *et al.* 2002; Srivastava *et al.* 2020) and a new ^{40}Ar/^{39}Ar geochronology that mark the likely earliest magmatic activity associated with the Réunion plume derived Deccan LIP in the entire Indian shield.

2. Geology of the Chhotanagpur Gneissic Complex and mafic magmatic records

The Chhotanagpur Gneissic Complex (CGC) is an integral northern part of the Singhbhum craton and is considered to be a cratonized mobile belt of Archean age (cf. Naqvi and Rogers 1987; Kumar and Ahmad 2007; Sharma 2009; Srivastava *et al.* 2009, 2012). The southern part of the CGC is represented by the Singhbhum Mobile Belt (SMB) that separates CGC from the Singhbhum Granite Complex (SGC), whereas northern and eastern parts of the CGC is bounded by the ENE-trending Son–Narmada rift and Indo-Gangatic Plain, respectively (see figure 2a; cf. Naqvi and Rogers 1987; Sharma 2009; Ramakrishnan and Vaidyanadhan 2010; Srivastava *et al.* 2009, 2012, 2014). Presence of a number of ENE- to E-trending intracontinental rift/shear zones responsible for distinct magmatism in the region corroborates its cratonic nature (Ghose and Chatterjee 2008). The CGC consists of foliated granitoids which intrude amphibolites and granulite facies gneisses and schists. The eastward trending Carboniferous Gondwana sedimentary basins, also known as

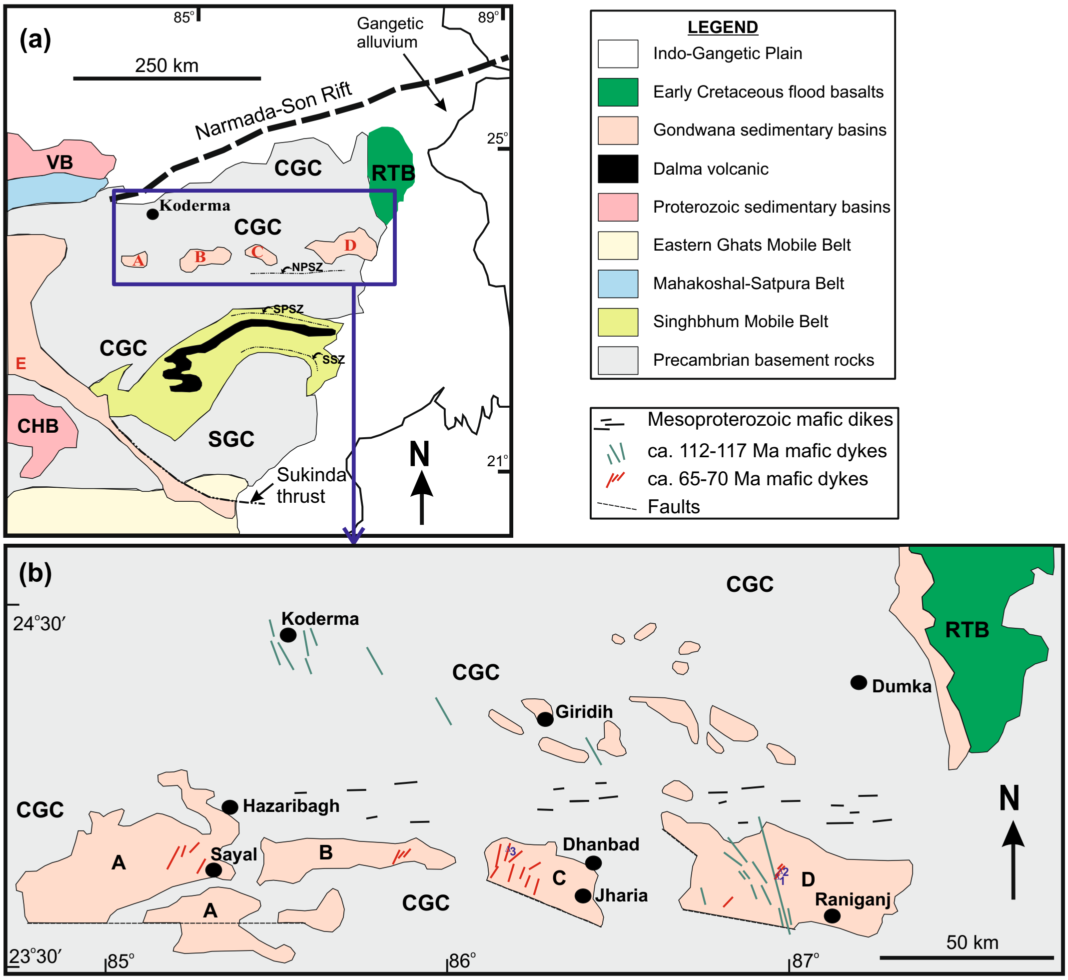

Figure 2. **(a)** Generalized geological map of the eastern and northeastern regions of the Indian Shield showing the Singhbhum craton, consisting of Chhotanagpur Gneissic Complex (CGC) and Singhbhum Granite Complex (SGC) (based and modified after Acharyya 2003; Melluso *et al.* 2012; Bhowmik *et al.* 2012; Srivastava *et al.* 2019, 2020). **(b)** Distribution of Mesoproterozoic and Cretaceous mafic dykes in the CGC (modified from Kumar and Ahmad 2007; Srivastava *et al.* 2014). CHB: Chhattisgarh basin; NPSZ: North Purulia Shear Zone; RTB: Rajmahal tholeiitic basalt; SPSZ: South Purulia Shear Zone; SSZ: Singhbhum Shear Zone; VB: Vindhyan Basin. A–E: Gondwana sedimentary basins (A: Karanpura; B: Bokaro; C: Jharia; D: Raniganj; E: Mahanadi). Δ shows locations of ^{40}Ar/^{39}Ar dated samples from the Raniganj (1 and 2) and Jharia (3) Gondwana sedimentary basins. ^{40}Ar/^{39}Ar age data: 1 (Kent *et al.* 2002); 2 (Srivastava *et al.* 2020); and 3 (present study).

Damodar Valley basins, are also an important geological feature present in the CGC (Mahadevan 2002; Chakraborty *et al.* 2003). Gabbros, massif anorthosites, peraluminous granite plutons, rapakivi granites, leptynites, komatiite and tholeiitic sills/dykes and flood basalts that range in age between Late Paleoproterozoic and Early Tertiary are other litho units present in the CGC (cf. Chatterjee *et al.* 2008; Ghose and Chatterjee 2008; Chatterjee and Ghose 2011). E- to ESE-trending South Purulia Shear Zone (SPSZ) and North Purulia Shear Zone (NPSZ) are other dominant features present in the CGC (cf. Bhowmik *et al.* 2012). This region is possibly the only geological domain in the entire Indian shield that has evidences of activities associated to the Kerguelen as well as Réunion plumes (cf. Srivastava *et al.* 2014).

A number of mafic and alkaline magmatic rocks of different ages (Mesoproterozoic to Cretaceous) are well recorded in the CGC and the Damodar Valley sedimentary basins (see figure 2b, cf. Kent *et al.* 2002; Srivastava *et al.* 2012, 2014, 2019, 2020; Srivastava 2020). These include: (i) ENE- to E-trending Mesoproterozoic mafic dykes intrude the basement gneisses of the CGC (cf. Kumar and Ahmad 2007; Srivastava *et al.* 2012); (ii) ca. 115–114 Ma ultrapotassic dykes are emplaced within the Damodar Valley Gondwana sedimentary basins (cf. Kent *et al.* 1998; Coffin *et al.* 2002; Srivastava *et al.* 2009; Chalapathi Rao *et al.* 2014); (iii) ca. 117–112 Ma mafic dykes, mostly trend in NNW to NW, intrude both the Damodar Valley sedimentary basins and Precambrian basement rocks (cf. Kent *et al.* 2002; Paul 2005; Srivastava *et al.* 2014, 2020); (iv) ca. 116–118 Ma Rajmahal tholeiitic basalts (cf. Kent *et al.* 1997, 2002; Ghatak and Basu 2011); and (v) ca. 70.5–65.5 Ma mafic dykes, mostly trend in NNE to NE, intrude only in the Damodar Valley sedimentary basins (Kent *et al.* 2002; Srivastava *et al.* 2014, 2020). The CGC is probably the only geological terrain in the Indian shield that possesses evidences of magmatic activities associated to the Kerguelen (serial number (ii), (iii) and (iv)) as well as Réunion (serial number (v)) plumes (cf. Srivastava *et al.* 2014).

3. Sampling, analytical techniques and ^{40}Ar/^{39}Ar dating

3.1 *Earlier dated samples*

Kent *et al.* (2002) have dated a ~50 km long NNW-trending mafic dyke (named Salma dyke), which cuts across the Raniganj basin, and placed it at 65.4 ± 0.3 Ma, which is close to the main Deccan LIP event, however, geochemistry of the Salma as well as other adjoining mafic dykes created doubt about its inferred emplacement age (Srivastava *et al.* 2014). Therefore, recently, Srivastava *et al.* (2020) have re-examined age of the Salma dyke and found its ^{40}Ar/^{39}Ar plateau age of 116.0 ± 1.4 Ma, which precisely suggest emplacement of Salma dyke ca. 116.0 Ma and not ca. 65.5 Ma. This is well supported by paleomagnetic age of ca. 117 Ma obtained for the Salma dyke by Patil and Arora (2008). There is no question on accuracy of the age, i.e., ca. 65.5 Ma, obtained by Kent *et al.* (2002), however, it is not of the NNW-trending Salma dyke but for one of the NE-trending mafic dykes present in the Raniganj basin (Srivastava *et al.* 2020). This conclusion is well supported by a new ^{40}Ar/^{39}Ar plateau age of 70.5 ± 0.9 Ma obtained for one of the NE-trending dykes, which is exposed very close to the Salma dyke in the Raniganj basin; the NE-trending dyke likely intersects the NNW-trending Salma dyke (Srivastava *et al.* 2020).

3.2 *Sampled dyke for the present work and ^{40}Ar/^{39}Ar dating*

The available two ^{40}Ar/^{39}Ar ages of late Cretaceous mafic dykes suggest their emplacement ca. 65.5–70.5 Ma (Kent *et al.* 2002; Srivastava *et al.* 2020). Both the samples were collected from the mafic dykes emplaced within the Raniganj basin. Therefore, in the present work, a sample from the NNE-trending mafic dyke (JH8/JD5) exposed in the Jharia sedimentary basin of the Damodar valley has been collected for ^{40}Ar/^{39}Ar dating. The sample was collected from Jogidih underground mine and its coordinates are N23°47′20″: E86°15′09″. It is very fresh and, under the polarizing microscope, shows ophitic texture and essentially composed of augite/titan augite and plagioclase. An appreciable amount of rutile and ilmenite are present as prominent accessories.

The whole rock fragments of 60–80 mesh (200–280 μm in diameter) were screened carefully under a binocular microscope to remove impurities, xenocrysts or phenocrysts to constrain the emplacement age and avoiding excess argon (see Srivastava *et al.* 2020 for more details). The final groundmass separates were dated at the Institute of Geology and Geophysics, Chinese Academy of

Table 1. *^{40}Ar/^{39}Ar data for CO$_2$ laser incremental step-heating of groundmass from JH8/JD5.*

Laser (W)	^{40}Ar/^{39}Ar	^{37}Ar/^{39}Ar	^{36}Ar/^{39}Ar	^{40}Ar*/^{39}Ar$_k$	^{40}Ar* (%)	^{39}Ar$_k$ (%)	Age (Ma)	±2σ
JH8/JD5 Groundmass $J = 0.00173300 \pm 0.00000867$								
1.60	143.594473	2.551748	0.447997	11.43903	7.95	3.12	35.50	± 17.78
1.70	66.777207	3.359922	0.159145	20.07472	29.98	3.38	61.84	± 7.18
1.80	41.022533	3.168960	0.068583	21.06497	51.21	5.13	64.84	± 3.47
1.90	34.056780	3.616501	0.042927	21.72606	63.60	7.02	66.84	± 2.45
2.00	30.172435	3.817872	0.030620	21.49751	71.02	7.26	66.14	± 2.02
2.10	28.422028	3.286706	0.023512	21.79653	76.47	9.25	67.05	± 1.62
2.20	26.958804	3.020108	0.020221	21.27819	78.73	9.74	65.48	± 1.50
2.30	25.800973	3.284571	0.015845	21.43979	82.86	9.74	65.97	± 1.36
2.40	25.897637	3.555580	0.013338	22.30644	85.87	11.10	68.59	± 1.28
2.50	24.951243	3.271124	0.012410	21.60411	86.34	10.63	66.47	± 1.26
2.60	24.440105	3.400295	0.011888	21.25884	86.73	10.45	65.42	± 1.26
2.70	24.639966	3.922388	0.012247	21.40416	86.58	13.18	65.86	± 1.14

Sciences (IGGCAS), Beijing. Selected sample, containing 10 grains, was wrapped in aluminum foil to form wafers, and stacked in quartz vials with the international standard YBCs (29.286 ± 0.045 Ma, Wang *et al.* 2014). Neutron irradiation was carried out in position H8 of 49-2 Nuclear Reactor (49-2 NR), Beijing (China), with a flux of $\sim 6.5 \times 10^{12}$ n (cm^2 s)$^{-1}$ for 24 hrs. The CO$_2$ laser fusion step-heating technique was used for ^{40}Ar/^{39}Ar analyses.

The Noblesse mass spectrometer at IGGCAS was used for isotopic measurements. Ca and K correction factors are $[^{36}\mathrm{Ar}/^{37}\mathrm{Ar}]_{\mathrm{Ca}} = 0.000261 \pm 0.0000142$, $[^{39}\mathrm{Ar}/^{37}\mathrm{Ar}]_{\mathrm{Ca}} = 0.000724 \pm 0.0000281$, $[^{40}\mathrm{Ar}/^{39}\mathrm{Ar}]_{\mathrm{K}} = 0.00088 \pm 0.000023$. All argon isotopes were measured using electron multipliers performing on ion-counting mode. Ages were calculated using the decay constant (5.531×10^{-10} yr^{-1}) reported by Renne *et al.* (2011), and all errors are quoted at the 2σ level. Plateau ages were determined from the contiguous steps that comprise more than 50% of the ^{39}Ar released, revealing concordant ages at the 95% confidence level. The age errors reported here are internal errors, including analytical errors and errors on blank, Ca and K correction factors, mass-discrimination and J-value; the error on the total decay constant is not propagated into the age error. Uncertainties on all data reported herein are at the 95% confidence level (2σ). The data were processed using ArArCALC (Koppers 2002). The detailed protocol of the ^{40}Ar/^{39}Ar analysis technique is described in Srivastava *et al.* (2020).

^{40}Ar/^{39}Ar data for the dated samples is presented in table 1, and age spectra and inverse isochron plots are shown in figure 3. It yields consistent plateau (66.4 ± 0.9 Ma) and inverse isochron (66.5 ± 1.5 Ma) ages within errors, which also suggest absence of excess argon residing in the sample. This is further substantiated by the trapped argon composition of 293.4 ± 23.5, which is within error of atmospheric Ar (295.5 ± 0.5).

4. Discussion

The three available ^{40}Ar/^{39}Ar ages (65.4 ± 0.3, 66.4 ± 0.9, and 70.5 ± 0.9 Ma) on the late Cretaceous mafic dykes emplaced in the Damodar valley Gondwana sedimentary basins of the Chhotanagpur Gneissic Complex evidently advocate following inferences:

(i) The Gondwana sedimentary basins of this region are intersected by a number of NNE- to NE-trending late Cretaceous (ca. 70.5–65.5 Ma) mafic dykes (cf. Kent *et al.* 2002; Srivastava *et al.* 2020 and present study). NNW- to NW-trending early Cretaceous (ca. 117–112 Ma) mafic dykes are intruded in the sedimentary basins as well (cf. Kent *et al.* 2002; Srivastava *et al.* 2020).

(ii) The ca. 70.5–65.5 Ma mafic dykes are supposed to be results of Réunion mantle plume related magmatism and associated to the Deccan LIP (cf. Kent *et al.* 2002; Paul 2005; Srivastava *et al.* 2014). This inference is well supported by characteristic geochemical signatures of these mafic dykes that match well with the Deccan basalts (cf. Srivastava *et al.* 2014).

(iii) The established geochronology of ca. 70.5–65.5 Ma mafic dykes clearly suggest

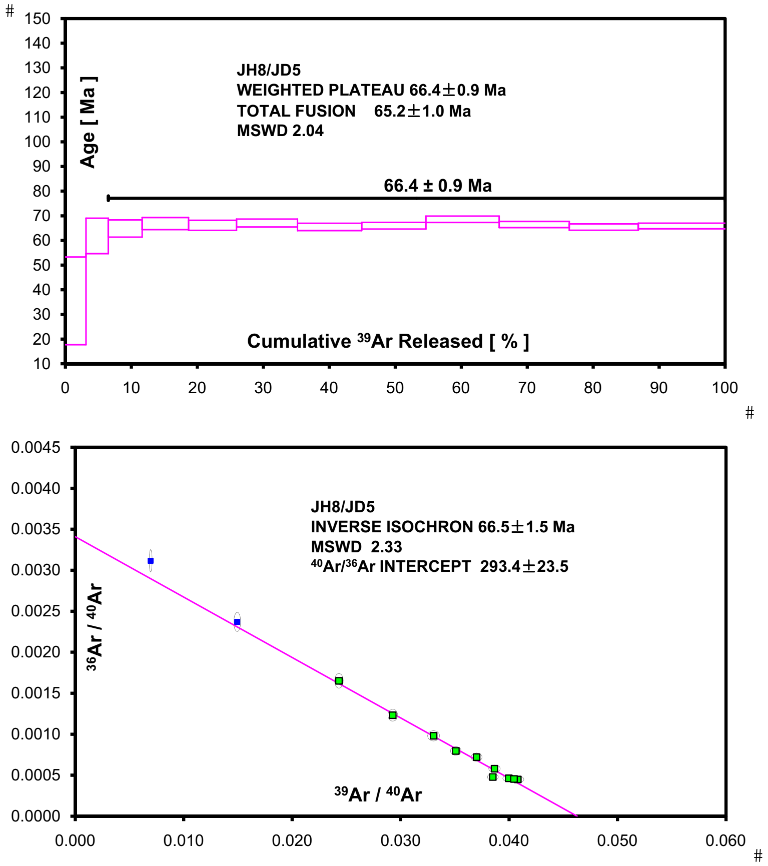

Figure 3. ^{40}Ar/^{39}Ar whole rock age spectra of JH8/JD5 (NNE-trending dyke exposed in the Jharia basin; location: N23°47′20″: E86°15′09″). Both plateau and inverse isochron ages are shown. In inverse isochron plots, green squares show plateau data points and blue squares represent non-plateau data points.

their emplacement during syn- and pre-Deccan event, which decisively suggest prolonged ($\sim$4.5–5.0 myr) magmatic activities in the region. Similar conclusions are also recorded elsewhere regions (cf. Shrivastava *et al.* 2015; Sheth *et al.* 2019; Kumar *et al.* 2020).

(iv) Biotite grains extracted from alkaline rocks from two complexes, i.e., Mundwara and Sarnu associated with the Deccan LIP, have been dated by ^{40}Ar/^{39}Ar method that yield 68.53 ± 0.16 and 68.57 ± 0.08 Ma, respectively, and considered as the first continental phase of Deccan magmatism (Basu *et al.* 1993); however, recent discovery of the 70.5 ± 0.9 Ma mafic dyke emplaced within the Raniganj basin (Srivastava *et al.* 2020) could be considered first record of the Réunion mantle plume activity in the Indian shield.

These inferences are splendidly supported by a number of observations on magmatic activities associated to the Réunion plume induced Deccan LIP. Early records (i.e., pre-Deccan) of basaltic flows and dykes, ranging in age ca. 69–66 Ma from different geographical locations are reported (Courtillot *et al.* 1988; Duncan and Pyle 1988; Pande *et al.* 1988; Basu *et al.* 1993; Bhattacharji *et al.* 1996; Pande 2002; Shrivastava *et al.* 2015; Sheth *et al.* 2019; Kumar *et al.* 2020). Anjar Traps of the Kutch region (ca. 67.5 Ma) and Mainpur kimberlites of the Bastar Craton (ca. 67 Ma), which are also thought to be related to the Deccan LIP event, also supports the above inference (Lehmann *et al.* 2010). Interestingly, a recent report suggests further evidence of early Deccan LIP record (ca. 70.5 Ma), probably earliest, in the CGC in the Indian shield (Srivastava *et al.* 2020). Although, further older age ca. 72 Ma was obtained for volcanic rocks of the South Tethyan suture zone, Pakistan (Mahoney *et al.* 2002), although its paleogeographic positions in the Indian shield is not straightforward to suggest direct connection with the Deccan LIP (Chatterjee *et al.* 2013), however, their incompatible element and Nd isotope ratios are very close to the modern Réunion lavas (Mahoney *et al.* 2002). Later, Kerr *et al.* (2010) have presented ^{40}Ar/^{39}Ar age of

69.7 ± 0.2 Ma for alkaline sills from the same region, which is slightly younger than the ages obtained by Mahoney *et al.* (2002). However, as basalt ages do have significantly larger errors than those for the sills, they infer that both rock units have probably emplaced almost at the same time (cf. Kerr *et al.* 2010).

Pande (2002) has reviewed geochronological data on the pre-Deccan magmatic rocks and, on the basis of available authentic and precise ^{40}Ar/^{39}Ar ages, concluded that although peak activity of the Deccan LIP occurred ca. 66.5–66.0 Ma, initial Deccan LIP pulses were started ca. 68.7 Ma. This inference is further corroborated by later and recent work on magmatic rocks from different locations and related to the Deccan LIP (cf. Shrivastava *et al.* 2015; Sen *et al.* 2016; Sheth *et al.* 2019; Srivastava *et al.* 2020; Kumar *et al.* 2020 and references therein).

Mantle plume origin of the Deccan LIP is well supported by a number of recent researches based on high quality geochronological, petrological, geochemical and geophysical data. Chalapathi Rao and Lehmann (2011) have reviewed all such data and suggested that the Deccan LIP was originated due to giant mantle plume, rather than a non-plume origin. This is not only true for main Deccan LIP event, but early and late pulses as well. Basu *et al.* (1993) have presented ^{3}He/^{4}He and ^{87}Sr/^{86}Sr ratios for the of ca. 68.5 Ma alkaline complexes and exclusively suggested that earlier phases of Deccan LIP were also derived from a high-^{3}He mantle plume as observed for the main Deccan LIP event. The mantle plume origin of the Deccan LIP and their protracted early and late magmatic pulses is also well supported by the size of the plume head. White and McKenzie (1989) were the first to postulate size of the Réunion plume head (see figure 1), responsible for the continental break-up of the Seychelles from western India, which was coinciding with rapid eruptions of the Deccan flood basalts at the KPgB. Figure 1 also shows path of movement of the Indian plate over the Réunion 'hotspot' during the Late Cretaceous (Morgan 1981), which produced large volume mafic magmatic melts emplaced as Deccan LIP. Mahoney (1988) has extrapolated the Réunion 'hotspot' path further north to incorporate earlier Deccan pulses (ca. 70 Ma) in the South Tethyan suture zone of Pakistan (see figure 1). The Rajahmundry Traps (^{40}Ar/^{39}Ar age ca. 65 Ma) of the east coast of southern India, far from the main exposed Deccan Traps, is also thought to be part of the Deccan LIP (figure 1; Knight *et al.* 2003). Considering all these extent of the Deccan magmatisms, which is also well supported by geomorphological as well as from sedimentologcal-stratigraphic records (cf. Cox 1989; Rainbird and Ernst 2001; Saunders *et al.* 2007; Chalapathi Rao and Lehmann 2011), an estimate of mantle plume head of 2000–2500 km in diameter is suggested (see figure 1; cf. White and McKenzie 1989).

5. Conclusions

- All these observations provide a better constraint on the initiation of the Deccan magmatism. At this point, it can be concluded that initial pulses of the Deccan LIP was started ca. 70.5 Ma, about 4.5–5.0 myr earlier to the main event at KPgB (ca. 66.0–65.5 Ma).
- Two earlier (65.4 ± 0.3 and 70.5 ± 0.9 Ma) and one new (66.4 ± 0.9 Ma) ^{40}Ar/^{39}Ar plateau ages on the late Cretaceous NNE- to NE-trending mafic dykes emplaced in the Damodar valley Gondwana sedimentary basins of the Chhotanagpur Gneissic Complex suggest their emplacement during syn- and pre-Deccan event.
- The ca. 70–65 Ma mafic dykes are supposed to be results of Réunion mantle plume related magmatism and associated to the Deccan LIP.
- The 70.5 ± 0.9 Ma mafic dyke emplaced within the Raniganj basin could probably be the earliest record of the Réunion mantle plume activity in the Indian shield.

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Corresponding editor: RAJNEESH BHUTANI