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DEPOSITIONAL ENVIRONMENT OF INTERTRAPPEAN AND INTRATRAPPEAN BEDS OF THE ANJAR AREA, KACHCHH DISTRICT, INDIA: FORAMINIFERAL EVIDENCE

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ABSTRACT

The intertrappeans associated with the Deccan volcanics of Jhilmili and Rajahmundri were reported to be marine, but the Anjar intertrappeans were previously advocated to have deposition in lacustrine or freshwater environment. The present investigation carried out on 26 samples collected from infratrappean, intertrappean and intratrappeans beds in and around Viri village, Anjar area, Kachchh district, India. The infratrappean (L-1), intratrappeans at the bottom as well as on the top (L-2 and L-6) are considered non-marine in origin as no foraminifera are recorded within these beds. Samples from the central portion of the area documented foraminiferal population which was not described earlier. Foraminiferal assemblages consisting of mainly *Rotalia*, *Elphidium*, *Quinqueloculina*, *Nonion* group of species within the intermediate intertrappean and intratrappeans (L-3 to L-5) are inferred to be deposited under shallow marine or ocean connected lacustrine environment. Presence of siliciclastic grains, rock-fragments, peloids and bioclasts also clearly indicate shallow water deposition. Increased abundance of *Nonion* spp., *Quinqueloculina* spp. as well as presence of planktic foraminifera (*Pseudogloborotalia ranikotensis* and *Globigerina triloculinoides*) within the intertrappean bed (L-3) is suggestive of relatively higher water depth at the site during deposition. Changes in deposition environments from non-marine to marine and finally non-marine sequence from older to younger indicate events of marine transgression followed by a regression phase.

Keywords: Deccan volcanics, Intertrappean and intratrappean, foraminifera, marine environment

INTRODUCTION

The Deccan volcanics were erupted at the Cretaceous–Tertiary (K-T) boundary within a short period of time and covered large areas of western, central and southern India (Vaidyanadhan and Ramakrishnan, 2010). Fossiliferous intertrappean and intratrappean beds within Deccan basalts bear significant characteristics of the Late Cretaceous - Early Palaeocene geological history of India. Till date intertrappeans and intratrappeans from the K-T boundary have been described from some parts of India, like the late Maastrichtian to early Danian sequence in the Jhilmili area (Chindwara district, Madhya Pradesh) (Keller *et al*., 2009; Khosla, 2015), late Maastrichtian of the Mumbai Island Formation (Cripps *et al*., 2005; Vaidyanadhan and Ramakrishnan, 2010), the uppermost Maastrichtian sediments around Naskal, (Ranga Reddy district, Telengana) (Prasad and Khajuria, 1990; Vaidyanadhan and Ramakrishnan, 2010), the Danian Rajahmundry beds (Prasad and Khajuria, 1990; Malarkodi *et al*., 2010), the Maastrichtian Lameta beds of Jabalpur (Shukla and Saha, 2012), the Mamoni intertrappean in Kota district of Rajasthan (Whatley *et al*., 2003), and the infra- and inter-trappean beds of Asifabad district of Andhra Pradesh (Prasad and Sahni, 1987).

Several intertrappean beds were studied in Naredi, Kora, Lakshmipur, Dayapar and Anjar sections of Kachchh district, Gujarat. Algal, fungal and palynofossil assemblages of early Palaeocene age have been described from the Naredi section situated on Naliya-Narayan Sarovar Road. It is inferred that sediments of this area were deposited in a shallow depression over the trap within a short interval, in tropical to subtropical climate (Saxena and Ranhotra, 2009). Many species of non-marine ostracods and gastropods of late Cretaceous to Palaeocene age were recorded from Lakshmipur, Dayapar and Kora region in western Kachchh (Whatley and Bajpai, 2000a; Samant and Bajpai, 2005; Bajpai *et al*., 2013). Several studies were also carried out on the intertrappean sediments of the Anjar area using geochemical and biological (e.g. ostracod, dinosaur fossils) proxies. These studies demonstrate deposition of intertrappean sediments during late Maastrichtian to early Danian (supported by K-Ar ages of traps) in non-marine to lacustrine environment (Bhandari *et al*., 1995; Shukla *et al*., 1997; Khadkikar *et al*., 1999; Whatley and Bajpai, 2000b; Bajpai and Prasad, 2000; Courtillot *et al*., 2000; Dogra *et al*., 2004). However, no clear cut signature of exclusive marine environment was recorded within the intertrappeans and intratrappeans of Kachchh including Anjar. Also no report of foraminifera, a group of unicellular eukaryotic test bearing marine protozoan, from the Anjar area is available till date.

The present study was carried out on the intertrappean, intratrappean and infratrappean sediments in and around Viri village, close to Anjar town, Kachchh district, India. Sediment samples from seven locations were collected from six areas and foraminiferal investigation was carried out on these samples. An attempt has also been made to infer the palaeodepositional environment of these infra-, intra- and inter-trappean beds using foraminiferal and sedimentological proxies.

MATERIALS AND METHODS

The Viri village and its adjacent areas in Kachchh District have outcrops of seven lava flows with respective intertrappean and intratrappean beds (Fig. 1) (Ghevariya, 1988; Courtillot *et*

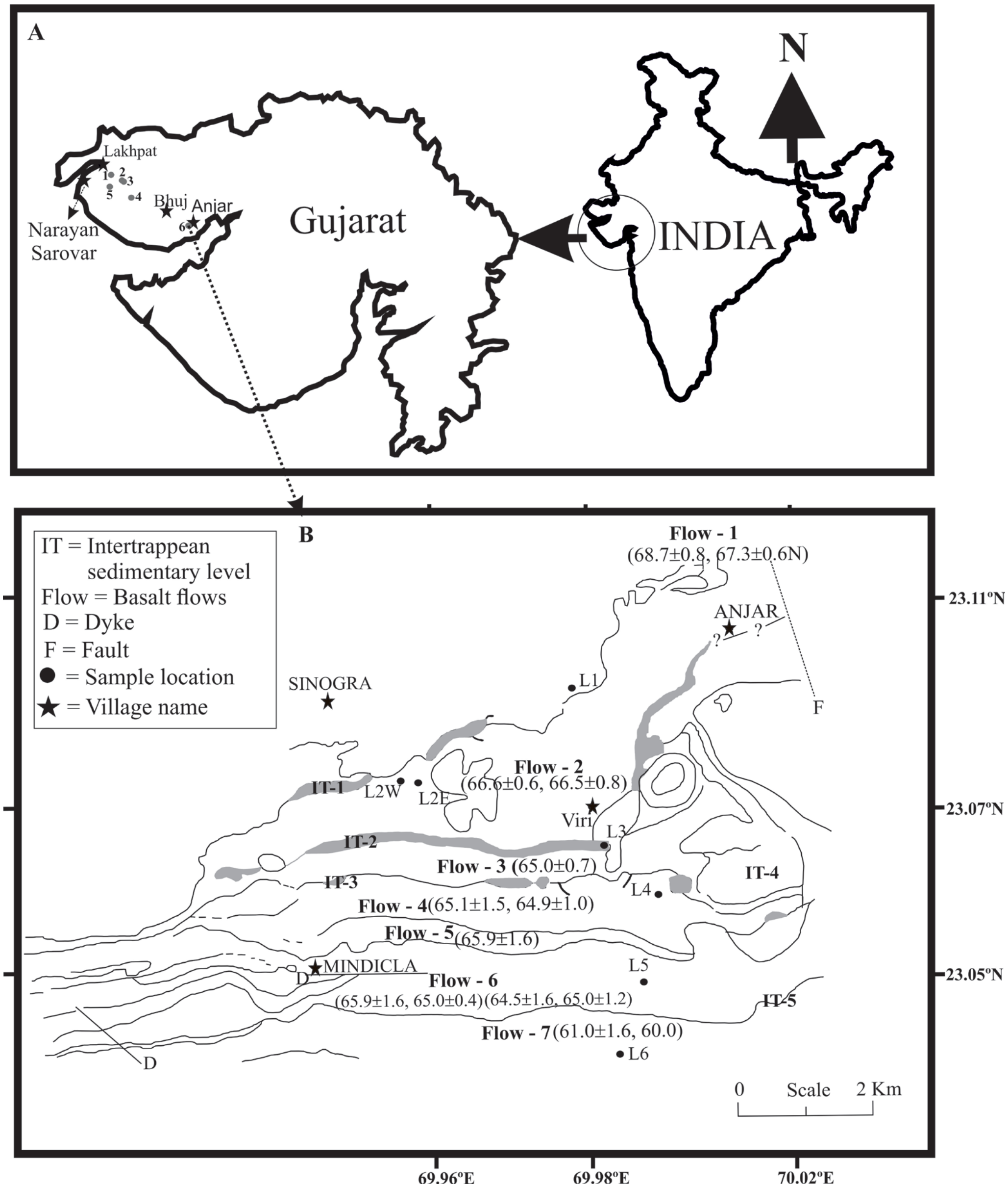

Fig. 1. A. Geographical outline map of India and Gujarat, showing positions of the studied area. Numbers 1, 2, 3, 4, 5 and 6 represent already studied sections at Naredi, Kora, Dayapar, Lakshimipur, Naliya-Narayan Sarovar Road and Viri, respectively. B. Location map of sampling sites near Viri village, Anjar. Sampling locations are numbered as L-1 to L-6. The map is redrawn with flow numbers and flow ages (Ma) after Ghevariya (1988), Shukla *et al*. (1997), Courtillot *et al*. (2000) and Shukla *et al*. (2001). Gray colour bands represent intertrappean beds. Solid stars represent the name of villages in and around the study area. Solid circles indicate sampling sites.

al., 2000; Shukla *et al*., 1997; Shukla *et al*., 2001). Intratrappean beds were identified based on the published field photograph by Keller *et al*. (2008). All these beds provide us an excellent opportunity for foraminiferal investigation. Total 26 samples were collected from seven locations (22 samples were collected from five locations, L-2 to L-6, positioned within flows 2 to 7 and remaining 4 samples were collected from the infratrappean, L-1). The location-wise sampling details are given in Figs. 1, 2 and Table 1.

The first location (L-1) is situated in the infratrappean beds on the SE of the NH-8A, NW of the Viri village (Fig. 1). Total four samples were collected from a section of

EXPLANATION OF PLATE I

SEM and light microscopic (only 6 and 7) images of major benthic and planktic foraminifera documented in inter- and intratrappeans of Anjar. Scale bar represent 100 µm length. 1. ***Elphidium*** sp.1 (Umbilical view), 2. ***Elphidium*** sp.1 (Apertural view), 3. ***Elphidium*** sp.2 (Umbilical view), 4. ***Elphidium*** sp.2 (Apertural view), 5. ***Globigerina triloculinoides*** (Apertural view), 6. ***Nonion costiferum*** (Umbilical view), 7. ***Nonion costiferum*** (Apertural view), 8. ***Pseudogloborotalia ranikotensis*** (Umbilical view), 9. ***Pseudogloborotalia ranikotensis*** (Spiral view), 10. ***Pseudogloborotalia ranikotensis*** (Apertural view), 11. ***Quinqueloculina*** sp. (Side view), 12. ***Quinqueloculina*** sp. (opposite side view), 13. ***Quinqueloculina*** sp. (Apertural view), 14. ***Rotalites trochidiformis*** (Umbilical view), 15. ***Rotalites trochidiformis*** (Spiral view), 16. ***Rotalites trochidiformis*** (Apertural view).

Plate I

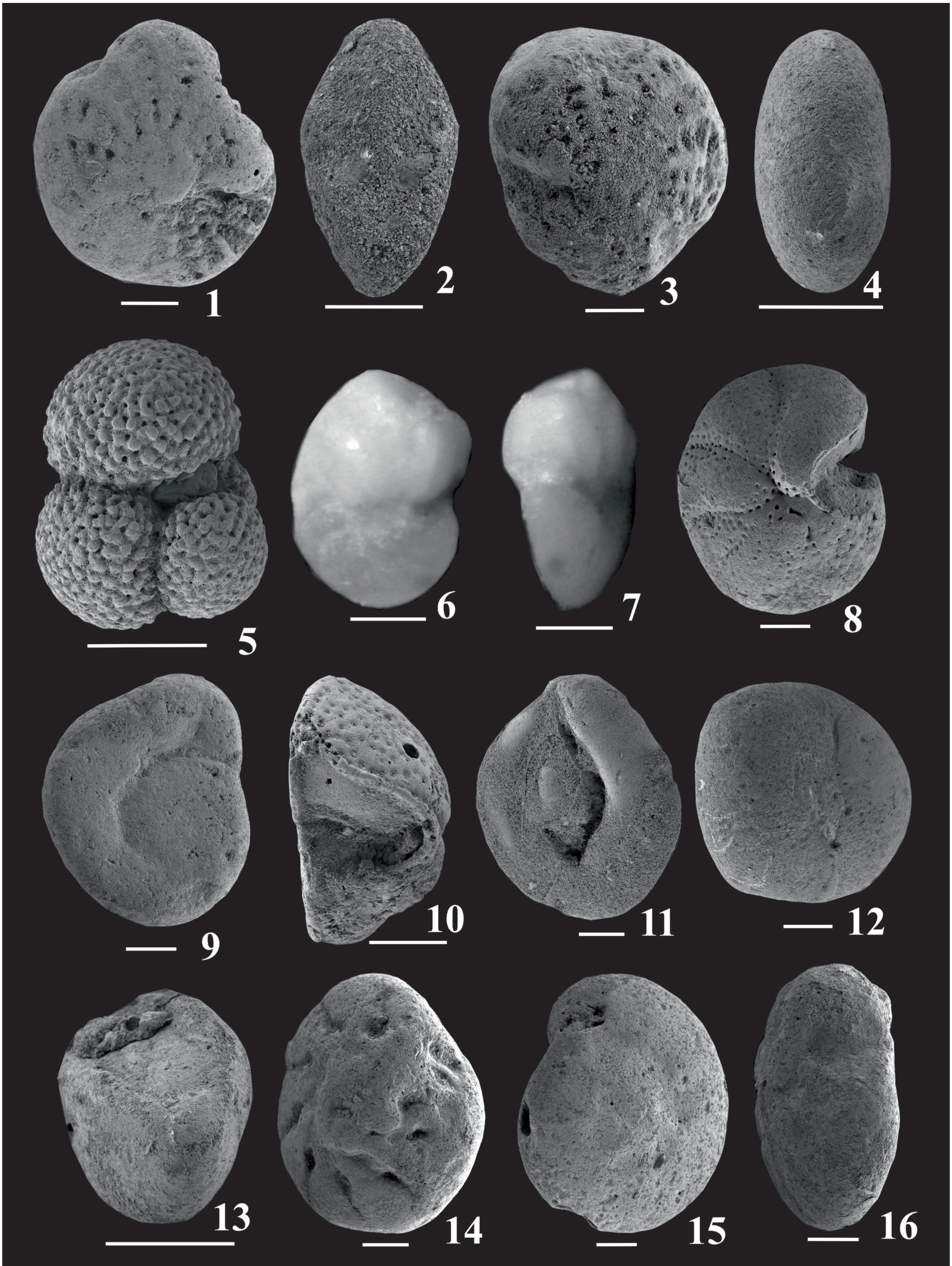

Table 1. Sample locations with stratigraphic positions and coordinates. Basalt flow numbers are adopted from the published literatures (Ghevariya, 1988; Courtillot *et al*., 2000; Shukla *et al*., 1997; Shukla *et al*., 2001).

Location numbers	Lithostratigraphic position	Coordinates	No. of studied samples
L-1	Below flow 2	23^0 05' 47.99″N; 69^0 59' 26.82″E	04
L-2W	Within flow 2	23^0 05'16.95″N; 69^0 57' 33.63″E	02
L-2E		23^0 05' 9.8″N; 69^0 57' 43.82″E	04
L-3	Between Flow 2 and 3	23^0 04.5'24″ N; 69°59.939″ E	03
L-4	Within flow 4	23^0 04' 4.31″N; 70^0 00' 9.5″E	06
L-5	Within flow 6	23^0 02' 59.19″N; 69^0 59' 58.32″ E	04
L-6	Within Flow 7	23^0 02' 16.98″N; 69^0 59' 37.47″E	03

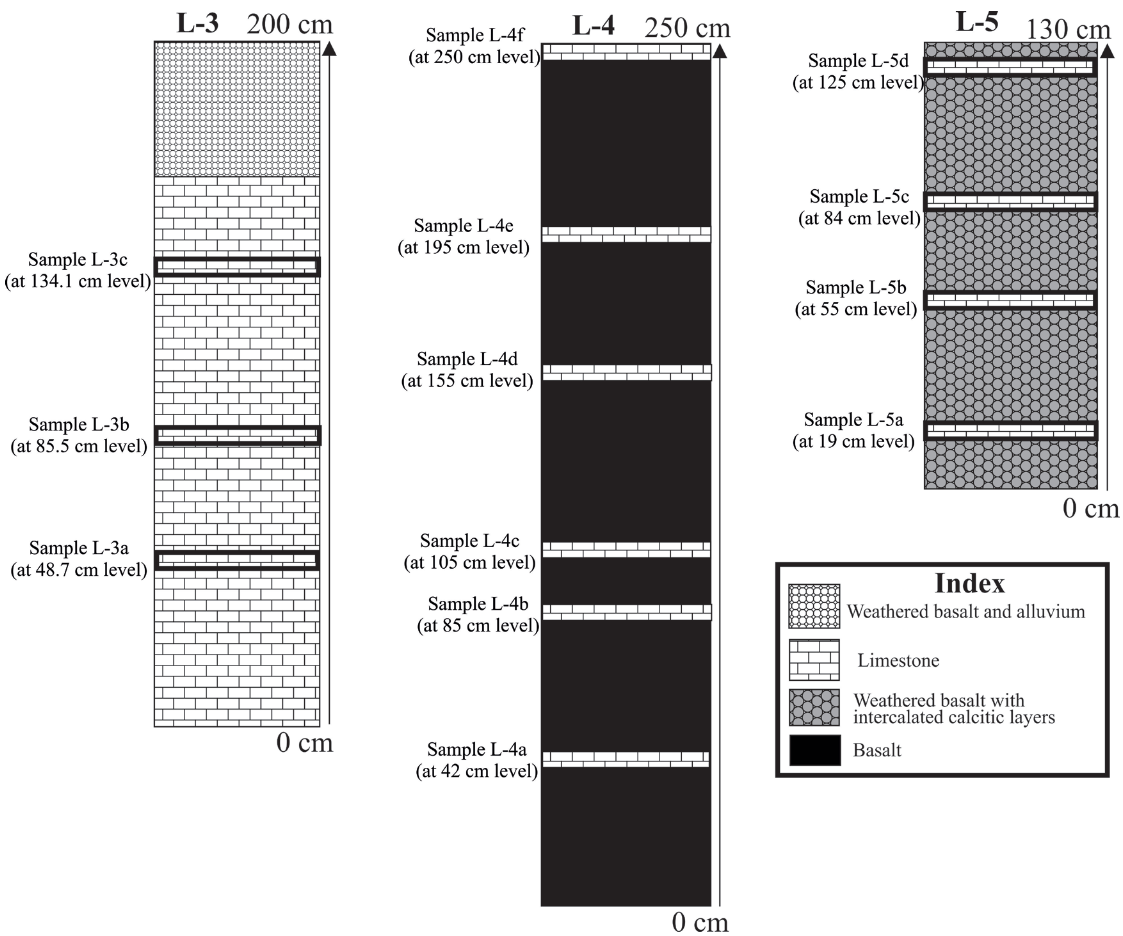

Fig. 2. Schematic representation of sampling sections at L-3, L-4 and L-5 in which foraminifera are documented. Base of each sampling section is designated as 0 cm and shows younging direction upward. Section L-3 is oldest and L-5 is the youngest one. Position of each sampling level from base within calcareous layers are marked with sample identification numbers.

~2 m consisting of carbonaceous cement rich reddish to white colour cross stratified sandstone. This sandstone belongs to the upper part of the Bhuj Formation (Shukla *et al*., 2001) which lies unconformably below the basalt flow 2. The first sampling position of the second area (L-2W) is positioned in the Flow 2 along a small nala section north of NH-8A, west of Viri (Fig. 1). Two intratrappean samples were collected from a 65 cm thick fractured basalt section containing calcareous layers. The second sampling location of this area (L-2E) is situated towards E of L-2W near the bridge on NH-8A along the same nala (Fig.

EXPLANATION OF PLATE II

SEM and light microscopic (only 2, 3 and 4) images of benthic foraminifera which are less in abundance in inter- and intratrappeans of Anjar. Scale bar represent 100µm length. 1. ***Amphistegina*** sp., 2. ***Anomalinoides pseudowelleri*** (Umbilical view), 3. ***Anomalinoides pseudowelleri*** (Spiral view), 4. ***Anomalinoides pseudowelleri*** (Apertural view), 5. ***Bolivina*** sp. (Apertural view), 6. ***Buliminoides williamsoniana*** (Apertural view), 7. ***Buliminoides williamsoniana*** (Side view), 8. ***Cibicides simplex*** (Umbilical view), 9. ***Cibicides simplex*** (Spiral view), 10. ***Cibicides Simplex*** (Apertural view), 11. ***Cribroelphidium vadescens*** (Umbilical view), 12. ***Discorotalia*** sp. (Umbilical view), 13. ***Dobrogelina discorbiformis*** (Umbilical view), 14. ***Ellipsoidella kugleri*** (side view), 15. ***Nodosaria*** *sp.* (Side view), 16. ***Notoplanulina rakauroana*** (Umbilical view), 17. ***Spiroloculina*** sp. (Side view).

Plate II

1). Total four intratrappean samples were collected from a 1.4 meter thick section containing layers of limestone embedded within fractured basalt. The third sampling location (L-3), within flow 2 and 3 (intertrappean-2 or IT-2), is the thickest one and is exposed south of Viri along the western side of the road connecting villages Viri and Devadiya (Fig. 1). This section consists of 1.6 m thick layer of white, brown to off-red coloured impure limestone overlain by weathered basalt and alluvium. Total three samples were collected from this location (Fig. 2). The fourth sampling area (L-4) is situated in flow 4 (Fig. 1). This section is located along the east side of the same road (connecting Viri and Devadiya villages). Thin intercalations of calcareous layers (intratrappeans) are present within a 2.5 m thick highly fractured basalt. Six samples were collected from this section (Fig. 2). The fifth sampling area (L-5) is located along the east side of the same road (Fig. 1). Here calcareous intratrappean beds are observed within highly weathered basalt section (1.3 m) in flow 6. Total four samples were collected from this section (Fig. 2). The sixth sampling area (L-6) is situated along the west side of same road in a basalt quarry within flow 7 (Fig. 1). Intratrappeans of calcareous materials are observed within a 1.77 m thick sequence of weathered basalt section. Total 3 samples were collected from this section. Overall SE dip direction of the Viri area as well as estimated ages of lava flows (Ghevariya, 1988; Courtillot *et al*., 2000; Shukla *et al*., 1997; Shukla *et al*., 2001) indicates sediments of L-1 to be the oldest and L-6 to be the youngest.

Approximately 20 gm of each sample was used for the foraminiferal analysis. Foraminiferal separation was done followed by the process describe in Bhaumik *et al*. (2011). Only repetition of the separation process was followed as the samples are consolidated in nature. Generated foraminiferal data is presented in terms of absolute abundance which is already used as a convention for representing foraminiferal data set (Hayward *et al*., 2010a,b). This convention is followed as only a few forms are dominant and there are few samples where only one to three specimens are documented. Thin sections of the intertrappean were also made and observed microscopically to characterise the constituents and depositional environment.

RESULTS AND DISCUSSION

All the 26 samples were microscopically analysed to document foraminiferal abundance. Among these, only 13 samples from location numbers L-3 to L-5 are productive in terms of foraminifera. Samples from L-3 bear significant number of foraminiferal specimens (113 to 253 foraminifers / 20 gm). Foraminiferal abundances are less (<50 foraminifers / 20 gm) in locations L-4 and L-5 (Fig. 3). Rest 13 samples from L-1, L-2W, L-2E and L-6 are completely barren in terms of foraminifera. The most abundant benthic foraminifera groups are *Rotalia* spp., *Elphidium* spp., *Nonion* spp., *Quinqueloculina* spp. and planktic foraminifera *Pseudogloborotalia ranikotensis* (Fig. 3; Plate 1). The other foraminiferal groups (*Amphistegina* sp., *Anomalinoides pseudowelleri*, *Astacolus* sp., *Bolivina* spp., *Buliminoides williamsoniana*, *Cibicidoides simplex*, *Cribroelphidium vadescens*, *Dobrogelina discorbiformis*, *Discorotalia* sp., *Ellipsoidella kugleri*, *Nodosaria* sp., *Notoplanulina rakauroana*, *Spiroloculina* sp.) are less in abundance (Plate 2). We also documented single specimen of

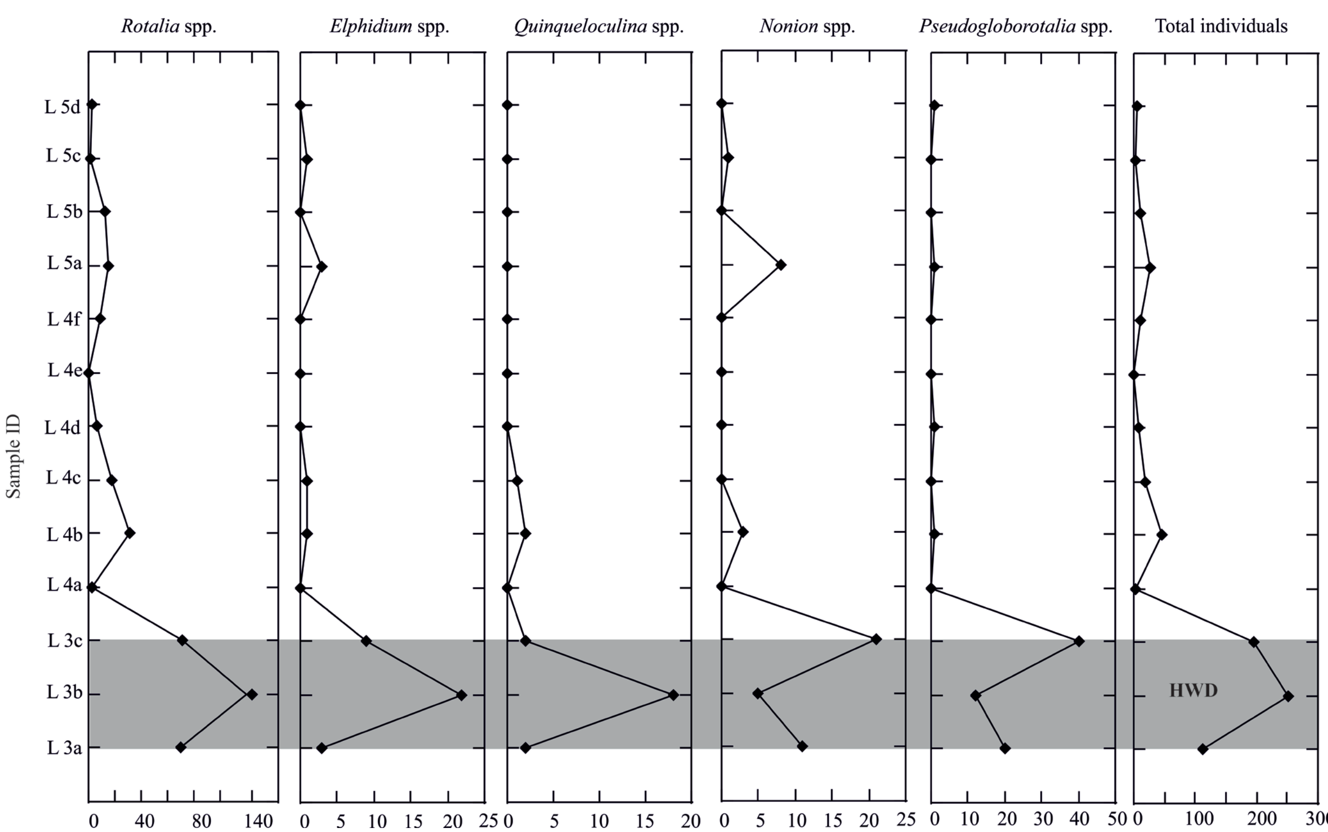

Fig. 3. Composite plot of foraminiferal absolute abundance (number of foraminifera/20gm sediments) in sample locations L-3 to L-5. Higher abundance of foraminiferal population in L-3 marked by grey bar indicates relatively higher water depth (HWD).

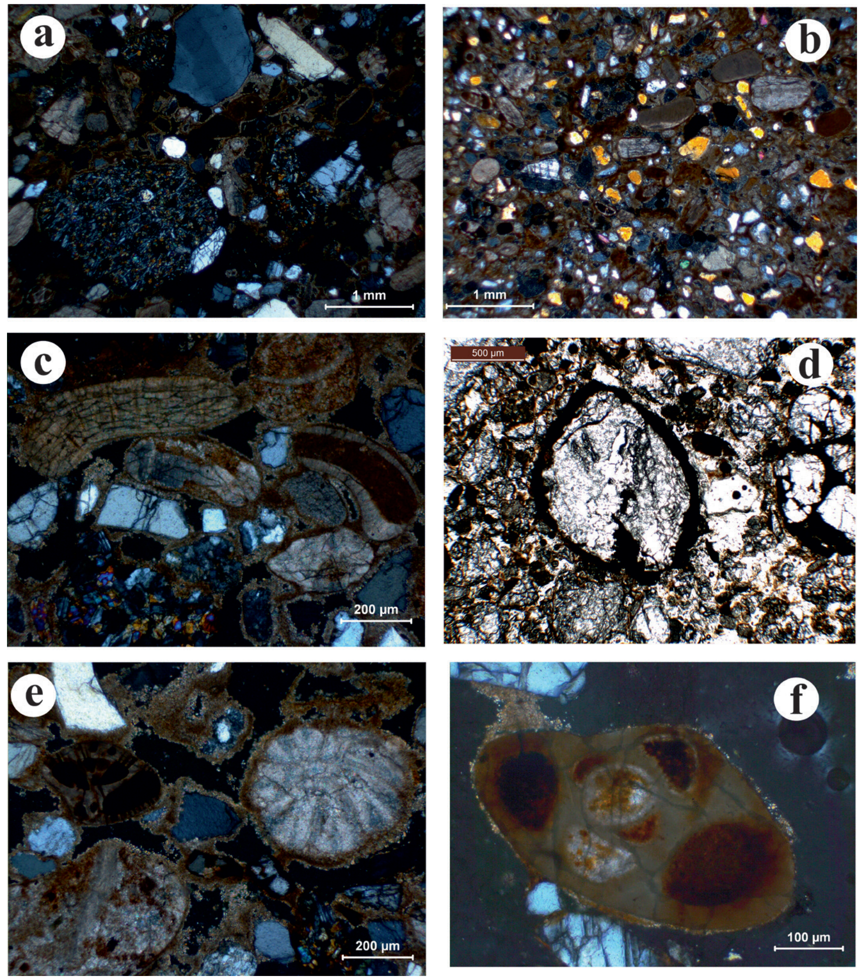

Fig. 4. Thin section of impure polymictic limestone from L-3. (a) grainstone with quartz, feldspar and fragments of basalts. Elliptical micritic peloids are present. (b) wackestone with siliciclast (quartz, feldspar), and bioclast grains. Elliptical micritic peloids are also present. (c) enlarged portion of wackestone with rock fragments of quartz, feldspar and fragments of basalts. Micrite coating around the bioclasts and lacking of internal structure indicates effect of sea floor diagenesis. (d) wackestone with rock fragments and recrystallised ostracoda carapace boundary (e) thin section of *Rotalia* and *Nonion* within the rock (f) thin section of *Quinqueloculina*.

another planktic foraminifera *Globigerina triloculinoides* from L-3b (Plate I).

It is assumed that the foraminifera present in the intertrappean bed are not reworked from upper Bhuj Formation (exposed in L-1) as this is barren in terms of foraminifera. Also presence of two planktic foraminifera *Globigerina triloculinoides* (FAD at C29n or 65.6 Ma; Berggren *et al*., 1995; Ogg, 2012) and *Pseudogloborotalia ranikotensis* (FAD at Paleocene; Loeblich and Tappan, 1988) indicates that they were not reworked forms from the pre-Deccan sediments as they evolved since early Paleocene.

Thin section study of sediments from L-3 shows the limestone to be impure in nature and fabrics range from grainstone to packstone (Fig. 4). The impure limestone contain siliciclastic clasts (quartz, feldspar), rock fragments (basalts) along with carbonate bioclasts (foraminiferal test, ostracoda carapace, algae, bryozoan fragments) within calcareous matrix. Documentation of basalt fragments within the sedimentary section indicate it is an intertrappean. This litho-unit also contain peloids and micritic coating on bioclasts probably generated by seafloor diagenesis (Fig. 4).

Till date several palaeontological works have been done on Anjar intertrappeans. These studies documented preservation of gastropods, bivalves (Khadkikar *et al*., 1999), ostracods (Bhandari *et al*., 1995; Khadkikar *et al*., 1999; Whatley and Bajpai, 2000b; Courtillot *et al*., 2000) and dinosaur remains (Ghevariya, 1988; Khadkikar *et al*., 1999). Peloids (Khadkikar *et al*., 1999), fish remnants (Bajpai and Srinivasan, 1996), and palynofossils (Dogra *et al*., 2004) are also reported from these intertrappeans. No foraminiferal record is published on the intertrappeans as well as intratrappeans of Anjar till date. Hence, this is the first foraminiferal documentation within the Anjar intertrappean and intratrappeans.

Members of the *Rotalia* group are commonly found in shallow shelf environment (Sander, 2012; Kundal, 2014). Study of Gräfe (2005) shows that *Rotalities trochidifirmis* is abundant in inner ramp (10-50m water depth) facies. *Elphidium* group of foraminifera are typically confined to shallow water environment within inner shelf depth (Murray, 2006). Members of the genus *Quinqueloculina* are generally found within shelf environment and may be present occasionally in bathyal depth (Murray, 2006). Generally association of *Nonion* group is common with above mentioned species and many researches documented their higher abundance in relatively deeper depth in shelf region (Murray, 2006; Villanueva-Guimerans and Canudo, 2008) in intermediate warm muddy environment (Murray, 2006; Saidova, 2010). Ecological preference of species *Pseudogloborotalia ranikotensis* is not well established. This species is considered under planktic group by several workers (Pokorný, 1963; Rincón *et al*., 2007). However, studies reveal that population of planktic foraminifera gradually increases with depth as well as distance from the coast (van der Zwaan *et al*., 1990).

The overall benthic foraminiferal assemblages (*Rotalia*, *Elphidium*, *Quinqueloculina*, *Nonion*) recorded within intertrappean and intratrappeans of this study suggest existence of near shore to shallow water inner shelf (may be inner neritic or lagoonal) environment at the time of deposition (Fig. 3). The thin section study also documented polymictic detrital clasts, peloids and bioclasts (ostracoda and bryozoan) within these impure limestone (Fig. 4) which clearly support deposition of sediments in tropical to subtropical high energy shallow marine conditions (Flügel, 2004). However, several palaeontological and geochemical works have been done on third intertrappean (IT-3 lying between flows -3 and 4) whereas the other intertrappeans/intratrappeans remain untouched. All these works suggested that deposition of IT-3 took place either in lacustrine (Shukla *et al*., 1997; Khadkikar *et al*., 1999; Bajpai and Prasad, 2000; Courtillot *et al*., 2000) or in freshwater (Dogra *et al*., 2004) environment. Documentation of foraminifera within intertrappean-2 and intratrappeans within flows - 4 and 6 thus strongly indicates influence of marine water during deposition. However, concept of lacustrine environment as suggested by several workers may be accepted with a consideration that the palaeo-lake existed over this area possibly had close proximity to shore line with an open connection to ocean for the invasion of marine water. It is important to note that a part of the intertrappean of Jhilmili section is also considered as brackish marine in origin based on foraminiferal abundance (Keller *et al*., 2009; Khosla, 2015). Study of Malarkodi *et al*. (2010) also inferred the depositional environment of intertrappean of Rajahmundri as shallow inner shelf to brackish marine environment based on foraminiferal abundance.

Sediments of L-3 (Intertrappean-2) is typically characterised by the increased absolute abundance of benthic foraminifera *Nonion* spp. and *Quinqueloculina* spp. along with planktic form *Pseudogloborotalia ranikotensis* (Fig. 3). This litho-unit also contains another planktic form *Globigerina triloculinoides*. Thus, these benthic and planktic assemblage together indicates existence of relatively higher water depth during deposition of sediments within inner shelf/lacustrine environment. Development of thick bed (1.6 m) of impure limestone and input of detrital grains (quartz, feldspar and fragments of basalts) in L-3 also corroborate this observation.

Sediments from L-1, L-2E and L-2W are devoid of foraminifera. We assume that these sediments were developed in fresh water condition. Sediments of L-3 (relatively higher water depth), L-4 and L-5 were deposited in shallow water inner shelf/lacustrine environment. Thus from the above discussion it may inferred that there was a marine transgression initiated with higher water depth during which the L-3 bed was developed (Fig. 3). The regression phase started after the formation of L-3 and continued up to the development of sediments of L-5. Finally, the depositional environment of the area had freshwater condition at the time of deposition of sediments of L-6.

CONCLUSIONS

The present foraminiferal investigation pursued on inter- and intra-trappean beds of Anjar area documented significant numbers of foraminifera in the central part of the study area. The major benthic and planktic foraminifera are *Rotalia* spp., *Elphidium* spp., *Quinqueloculina* spp., *Nonion* spp., and *Pseudogloborotalia ranikotensis* respectively with some other less abundant benthic forms.

Preservation of foraminifera within central portion with detrital sediments, bioclasts and peloids clearly indicate that the studied site was under the influence of shallow inner shelf and/or ocean connected lacustrine environment. The bottom infra- and intra-trappeans as well as top intertrappeans are barren in foraminifera whereas the central portion is rich in foraminifera suggesting event of marine transgression over fluvial deposits which was followed by a regression phase.

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REFERENCES

Bajpai, S. and Srinivasan, S. 1996. Fish otoliths from the Deccan intertrappean beds of Kachchh, pp. 471–475. In: Contributions to XV Indian Colloquium on Micropalaeontology and Stratigraphy (Eds. Pandey *et al*.), Dehradun, India. Wadia Institute of Himalayan Geology.

Bajpai, S. and Prasad, G. V. R. 2000. Cretaceous age for Ir-rich Deccan intertrappean deposits: Palaeontological evidence from Anjar, Western India. *Journal of Geological Society of London*, **157**: 257-260.

Bajpai, S., Holmes, J., Bennett, C., Mandal, N. and Khosla, A. 2013. Palaeoenvironment of Northwestern Indian during the late cretaceous Deccan volcanic episode from trace-element and stable-isotope geochemistry of Intertrappean ostracod shell. *Global. Planet. Change*, **107**: 82-90.

Berggren, W. A., Kent, D. V., Swisher III, C. C. and Aubry, M. P. 1995. A revised Cenozoic geochronology and chronostratigraphy, p. 129-212. *In*: Berggren, W. A. (Eds.) Geochronology, Time scale and Global Stratigraphic Correlation. *SEPM Special Publication*, **54**.

Bhandari, N., Shukla, P. N., Ghevariya, Z. G. and Sundaram, S. 1995. Impact did not trigger Deccan volcanism: evidence from Anjar K/T boundary intertrappean sediments. *Geophysical Research Letters*, **22**: 433-436.

Bhaumik, A. K., Gupta, A. K. and Thomas, E. 2011. Blake Outer Ridge: Late Neogene variability in paleoceanography and deep-sea biota. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **302**: 435–451.

Courtillot, V., Gallet, Y., Rocchia, R., Feraud, G., Robin, E., Hofmann, C., Bhandari, N. and Ghevaria, Z. G. 2000. Cosmic markers, $^{40}Ar/^{39}Ar$ dating and palaeomagnetism of the KT section in the Anjar area of the Deccan large igneous province. *Earth Planetary Science Lett*ers, **182**: 137-156.

Cripps, J. A., Widdowson, M., Spicer, R. A. and Jolley, D. W. 2005. Coastal ecosystem responses to late stage Deccan Trap volcanism: the post K-T boundary (Danian) palynofacies of Mumbai (Bombay) West India. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **216**: 303-332.

Dogra, N. N., Singh, Y. R. and Singh, R.Y. 2004. Palynological assemblage from the Anjar intertrappeans, Kutch district, Gujarat: Age implications. *Current Science*, **86**:1596-1597.

Flügel, E. 2004. Microfacies of carbonate rocks: Analysis, interpretation and application. Springer, Berlin, pp: 114.

Ghevariya, Z. G. 1988. Intertrappean dinosaurian fossils from Anjar area, Kutch, Gujarat. *Current Sciience*, **57**: 248-251.

Gräfe, K. U. 2005. Late Cretaceous benthic foraminifera from Basque-Cantabrian Basin, Northern Spain. *Journal of Iberian Geology*, **31**: 277-298.

Hayward, B. W., Johnson, K., Sabaa, A. T., Kawagata, S. and Thomas, E. 2010a. Cenozoic record of elongate, cylindrical, deep-sea benthic foraminifera in the North Atlantic and equatorial Pacific Oceans. *Marine Micropaleontology,* **74**: 75–95.

Hayward, B. W., Sabaa, A. T., Thomas, E., Kawagata, S., Nomura, R., Schröder-Adams, C., Gupta, A. K. and Johnson, K. 2010b. Cenozoic record of elongate, cylindrical, deep-sea benthic foraminifera in the Indian Ocean (ODP Sites 722, 738, 744, 758, and 763). *Journal of Foraminiferal Research*, **40**(2): 113–133.

Keller, G., Adatte, T., Gardin, S., Bartolini, A. and Bajpai, S. 2008. Main Deccan volcanism phase ends near the K–T boundary: Evidence from the Krishna–Godavari Basin, SE India. *Earth and Planetary Science Letters,* **268**: 293–311.

Keller, G., Khosla, S. C., Sharma, R., Khosla, A., Bajpai, S. and Adatte, T. 2009. Early Danian planktic foraminifera from Cretaceous-Tertiary intertrappean beds at Jhilmili, Chhindwara district, Madhya Pradesh, India. *Journal of Foraminiferal Res*earch, **39**: 40-55.

Khadkikar, A.S., Sant, D.A., Gogte, V. and Karanth, R. V. 1999. The influence of Deccan volcanism on climate: Insights from lacustrine intertrappean deposits, Anjar, western India. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **147**: 141-149.

Khosla, A. 2015. Palaeoenvironmental, palaeoecological, palaeogeographical implications of mixed fresh water and brackish marine assemblages from the Cretaceous-Palaeogene Deccane intertrappean beds at Jhilmili, Chhindwara District, Central India. *Revista Mexicana de Ciencias Geológicas*, **32**: 344-357.

Kundal, M. P. 2014. Foraminifera from the Late Middle Eocene to Early Middle Miocene sequence of the Kachchh Offshore Basin, Western India: Paleoenvironmental Significance. *J. Palaeontological Society of India*, **59**: 219-226.

Loeblich, A. R. and Tappan, H. 1988. Foraminiferal genera and their classification. Nostrand Reinhold, New York, **1**: 484.

Malarkodi, N., Keller, G., Fayazudeen, P. J. and Mallikarjuna, U. B. 2010. Foraminifera from the Early Danian intertrappean beds in the Rajahmundry quarries, Andhra Pradesh. *Journal of Geological Society of India*, **75**: 852-863.

Murray, J. W. 2006. Ecology and applications of benthic foraminifera. Cambridge University Press, New York, pp: 1-426.

Ogg, J. G. 2012. Geomagnetic polarity time scale. In: Gradstein F. M., Ogg, J. G., Schmitz, M. D. and Ogg, G. M. (Eds.) The Geological Time scale 2012, *Elsevier*: **1**: 85-114.

Pokorný, V. 1963. Principles of Zoological Micropalaeontology. Pergamon Press, Oxford, pp: 517.

Prasad, G. V. R. and Sahni, A. 1987. Coastal-plain microvertebrate assemblage from the terminal Cretaceous of Asifabad, Andhra Pradesh. *Journal of Palaeontological Society of India*, **32**: 5-19.

Prasad, G. V. R. and Khajuria, C. K. 1990. A record of microvertebrate fauna from the intertrappean beds of Naskal, Andhra Pradesh. *Journal of Palaeontological Society of India*, **35**: 151–161.

Rincón, D. A., Arenas, J. E., Cuartas, C. H., Cárdenas, A. L., Molinares, C. E., Caicedo, C. and Jaramillo, C. 2007. Eocene-Pliocene planktonic foraminifera biostratigraphy from the continental margin of the southwest Caribbean. *Stratigraphy*, **4**: 261-311.

Saidova, K. M. 2010. Benthic Foraminifer Communities of the Persian Gulf. *Marine Biology*, **50**: 61–66.

Samant, B. and Bajpai, S. 2005. Palynoflora from the Lakshmipur intertrappean deposits of Kutch, Gujarat: Age implications. *Journal of Paleontological Society of India*, **50**, 169-176.

Sander, N. J. 2012. Paleontologic and stratigraphic overview of the Paleogene in eastern Saudi Arabia. *Carnets de Géologie*, **2012/04** (CG2012_A04).

Saxena, R. K. and Ranhotra, P. K. 2009. Palynofloral study of the Intertrappean bed exposed at a new locality in Kutch District, Gujarat and its implications on palaeoenvironment and age. *J. Geol. Soc. India*, **74:** 690-696.

Shukla, A. D., Bhandari, N., Kusumgar, N., Shukla, P. N., Ghevariya, Z. G., Gopalan, K. and Balram, V. 2001. Geochemistry and Magnetostratigraphy of Deccan flows at Anjar, Kutch. *Proceedings of the Indian Academy of Sciences. Earth and planetary sciences*, **110**: 110-132.

Shukla, P. N., Shukla, A. D. and Bhandari, N. 1997. Geochemical characterization of the Cretaceous-Tertiary boundary sediments at Anjar, India. *Palaeobotanist*, **46:** 127-132.

Shukla, U. K. and Saha, O. 2012. Fossil evidence for dinosaur egg raider lizard from Lametaghat, Jabalpur, Central India. *International Journal of Advanced Earth Science*, **1**: 9-12.

Vaidyanadhan, V. and Ramakrishnan, M. 2010. Geology of India. *Geological Society of India*, **2**: 557-997.

Van der Zwaan, G. J., Jorissen, F. J. and De Stitger, H. C. 1990. The depth dependence of planktonic/ benthic foraminiferal ratios: Constraints and applications. *Marine Geology*, **95**: 1-16.

Villanueva-Guimerans, P. and Canudo, I. 2008. Assemblages of recent benthic foraminifera from the northeastern gulf of Cádiz. *Geogaceta*, **44**: 139–142.

Whatley, R. and Bajpai, S. 2000a. A new fauna of late cretaceous non–marine ostracoda from the deccan intertrappean bed of Lakshmipur Kachchh (Kutch District), Gujarat, Western India. *Revista española micropaleontología*, **32:** 385-409.

Whatley, R. and Bajpai, S. 2000b. Further non–marine ostracoda from the late Cretaceous Deccan intertrappean deposits of Anjar region, Kachchh, Gujarat, Western India. *Revista micropaleontología*, **43**: 173-178.

Whatley, R., Bajpai, S. and Whittaker, J, E. 2003. Freshwater ostracoda from the Upper Cretaceous Intertrappean beds at Mamoni (Kota district), Southern Rajasthan, India. *Revista española micropaleontología*, **35**: 75-86.

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