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# Biodiversity during the Deccan volcanic eruptive episode

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## Abstract

This paper gives a detailed overview of biotic assemblages recovered from the Deccan trap intercalated sedimentary sequences (infra- and intertrappean beds) of peninsular India as a result of extensive research done during the last 20 years. The infra- and intertrappean beds contain remnants of Gondwanan forms such as myobatrachinae frogs, pelomedusid turtles, dinosaurs (i.e. titanosaurids and abelisaurids), and mammals. Apart from these Gondwanan elements, the infra- and intertrappean beds also contain forms of Laurasian affinity though recently doubt has been cast on such relationships. Based on previous fossil records, Laurasiatic forms were considered to be represented by a great variety of micro- and megavertebrate assemblages such as discoglossid and pelobatid frogs, anguid lizards, alligatorid crocodiles, palaeoryctid mammals, charophytes and ostracodes. The biotic assemblages show a remarkable similarity between the infra- and intertrappean beds indicating a short time period for the deposition of these Deccan volcano-sedimentary beds. The recovered biotic assemblages strongly indicate a Maastrichtian age for the initiation of Deccan volcanic activity and the sedimentary beds associated with it. The Cretaceous/Tertiary boundary as such remains to be defined in any known sections in sedimentary sequences in so far investigated localities of peninsular India. What have been identified are Maastrichtian age beds in the east-central and western Narmada river region on the basis of pollens, vertebrate assemblage and planktonic foraminiferas in infratrappian offshore sequences. A Palaeocene intertrappean bed at Lalitpur (Uttar Pradesh) that is among those lacking dinosaurian remains but having palynological assemblages similar to those from well established Palaeocene sequences, suggests the presence of Palaeocene intertrappeans, but the K/T boundary is yet to be properly defined. © 2002 Elsevier Science Ltd. All rights reserved.

*Keywords:* Biodiversity; Deccan traps; Infra- and intertrappeans; Maastrichtian; Palaeobiotas

## 1. Introduction

The Deccan Traps of peninsular India represent one of the most extensive continental flood basalts in the world, occupying an area of about half a million square kilometres in western, central and southern India. During the last two decades considerable work has been carried out on these Deccan volcanics, which has led to the sudden revival of interest in various aspects of this volcanic activity including its age and duration. Deccan basalts may have played a major role for biotic mass extinctions at the Cretaceous–Tertiary boundary (Officer and Drake, 1985; Courtillot et al., 1988), but various other workers (VonHof and Smit, 1997; Li and Keller, 1999; Barrera and Savin, 1999) have alternatively and more recently implicated Deccan volcanism in potentially forcing geochemical and biological shifts seen within the Maastrichtian (for detail see summaries in

Frank and Arthur, 1999; Barrera and Savin, 1999; MacLeod et al., 2000). The sedimentary beds (infra- and intertrappean) associated with Deccan basalts are highly fossiliferous and contain diverse biotic assemblages. The present paper is aimed to record almost all the biotic assemblages recovered from different infra- and intertrappean localities of peninsular India (Table 1). These Deccan volcano-sedimentary sequences are highly fossiliferous and have yielded diversified microfaunal and floral contents (Sahni et al., 1982; Jain and Sahni, 1983; Rana, 1984, 1988, 1990; Jain, 1986; Courtillot et al., 1986, 1988; Prasad, 1989; Prasad and Sahni, 1988, 1999; Vianey-Liaud et al., 1987, 2002; Sahni and Tripathi, 1990; Bajpai et al., 1990; Prasad and Rage, 1991, 1995; Rage and Prasad, 1992; Prasad and Cappetta, 1993; Prasad and Godinot, 1994; Khajuria et al., 1994; Prasad et al., 1994, 1995; Sahni and Khosla, 1994a,b,c; Sahni et al., 1994, 1996; Khosla and Sahni, 1995; Khosla, 1994, 1996, 2001; Prasad and Khajuria, 1990, 1995, 1996; Bhatia et al., 1990a,b,c, 1996; Mohabey, 1998; Loyal et al., 1996, 1998; Khajuria and Prasad, 1998; Bajpai and Prasad,

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Table 1

List of fauna and flora recovered from infra- and intertrappean localities of peninsular India. Important palaeocommunities, viz. terrestrial, lacustrine/fluviol, freshwater/brackish water and marine communities

Terrestrial community	Lacustrine/fluviol community	Freshwater/brackishwater community	Marine community
<b>Frogs</b> Leptodactylidae: <i>Indobatrachus pusillus</i>	<b>Fishes</b> <i>Lepisosteus indicus</i> <i>Lepidotes</i> sp. <i>Pycnodus bicresta</i> <i>Phareodus</i> sp. <i>Apateodus</i> sp. cf. <i>A. striatus</i> <i>Stephanodus lybicus</i> <i>Eotrigonodon indicus</i> <i>Eotrigonodon wardhaensis</i> <i>Pisdurodon spatulatus</i> <i>Indotrigonodon ovatus</i> <i>Palaeolabrus</i> sp. cf. <i>P. dormaalensis</i> <i>Dasyatis</i> sp. <i>Eoserranus</i> sp. <b>Fish otoliths</b> Lepisosteidae Elopidae Clupidae Serranidae Notopteridae Apogonidae	<b>Frogs</b> Pelobatidae Discoglossidae Myobatrachinae	<b>Fishes</b> <i>Igdabatis indicus</i> <i>Rhombodus</i> sp. <i>Raja sudhakari</i> <i>Rajiformeindet.</i> <i>Pycnodus lametae</i>
<b>Lizards</b> Anguidae <b>Dinosaurs</b> <i>Titanosaurus indicus</i> <i>T. blanfordi</i> <i>T. colberti</i> <i>Jainosaurus septentrionalis</i> <i>Indosaurus matleyi</i> <i>Indosuchus raptorius</i> <i>Megalosaurs</i> sp.	<b>Snakes</b> Nigerophiidae: <i>Indophis sahnii</i> <b>Ostracodes</b> <i>Leiria jonesi</i> <i>Cytheridella strangulata</i> <i>Candona altanulaensis</i> <i>C. bagmodica</i> <i>C. henaensis</i> <i>C (C)</i> sp. cf. <i>C. (C). hubeiensis</i> <i>Paracandona jabalpurensis</i> <i>Candoniella altanica</i> <i>Altanicypris szzechuriae</i> <i>Paracyprretta bhatiai</i> <i>Talicypridea biformata</i> <i>Cypridea cavernosa</i> <i>Cypridea (Pseudocypridina)</i> sp. <i>Mongolocypris longa</i> <i>Mongolocypris</i> sp. cf. <i>M. gigantea</i> <i>Mongolianella palmosa</i> <i>Mongolianella</i> sp. <i>M. khamariniensis</i> <i>Frambocythere tumiensis tumiensis</i> <i>Cyclocypris transitoria</i> <i>?Cypridopsis bugintsavicus</i> <i>?Cypridopsis</i> sp. <i>Candona</i> sp. cf. <i>C. hubeiensis</i> <i>Eucypris</i> sp. cf. <i>E. bajshintsavica</i> <i>Darwinula</i> sp. <i>Limnocythere falsicarinata</i> <i>Gomphocythere gomphomatos</i> <i>Pseudocypris ecotops</i> <i>Centrocypris megalopos</i>	<b>Foraminifera</b> Nodosariidae Gen. et. sp. Indet	<b>Foraminifera</b> <i>Abathomphalus mayaroensis</i> <i>Globotruncana arca</i> <i>G. stuartiformis</i> <i>Rugoglobigerina rugosa</i> <i>Pseudotextularia elegans</i>
<b>Dinosaur eggshell oospecies</b> <i>Megaloolithus cylindricus</i> <i>M. jabalpurensis</i> <i>M. mohabeyi</i> <i>M. baghensis</i> <i>M. dholiyaensis</i> <i>M. padiyalensis</i> <i>M. khempurensis</i> <i>M. dhoridungriensis</i> <i>M. megadermus</i> <i>Subtiliolithus kachchhensis</i> <i>Ellipsoolithus khedaensis</i>		<b>Crocodyles</b> <i>Alligatoridae</i> <b>Turtles</b> <i>Kurmademys kallamedensis</i> <i>Shweboemys pisdurensis</i> <i>S. lethii</i>	

Table 1 (continued)

Terrestrial community	Lacustrine/fluvial community	Freshwater/brackishwater community	Marine community
	<i>Zonocypris spirula</i>		
	<i>Cypria cyrtionidion</i>		
	<i>Cyprois rostellum</i>		
	? <i>Sarsicypridopsis</i> sp.		
	<i>Cetacella</i> sp.		
	<i>Talicypridea?</i> sp.		
	<i>Limnocypridea ecpymatos</i>		
<b>Mammals</b>	<b>Charophytes</b>		
<i>Deccanolestes hislopi</i>	<i>Platychara perlata</i>		
<i>D. robustus</i>	<i>P. compressa</i>		
<i>Sudamericidae</i>	<i>P. raoi</i>		
	<i>P. sahnii</i>		
	<i>P. rajahmundrica</i>		
	<i>Peckichara varians</i>		
	<i>Nemegtichara grambasti</i>		
	<i>Harrisichara muricata</i>		
	<i>Stephanochara</i> sp. cf. <i>S. levis</i>		
	<i>Grambastichara</i> sp.		
	<i>Microchara</i> sp.		
	<b>Molluscs</b>		
	<i>Physa prinseprii</i>		
	<i>Lymnaea subbulata</i>		
	<i>Paludina normalis</i>		
	<i>Unio deccanensis</i>		
	<b>Pollens and spores</b>		
	<i>Aquilapollenites bengalensis</i>		
	<i>Azolla cretacea</i>		
	<i>Ariadnaesporites</i> sp.		
	<i>Bacutripurites orluensis</i>		
	<i>Matanomadhiasulcites maximus</i>		
	<i>Spinizonocolpites baculatus</i>		
	<i>S. echinatus</i>		
	<i>Gabonisorites vigourouxii</i>		
	<i>Proxapertites</i> sp.		
	<i>Podocarpidites</i> sp.		
	<i>Lycopodiumsporites</i> sp.		
	<i>Tricolpites</i> sp.		
	<i>Triporetetes reticulatus</i>		
	<i>Ephedripites</i> sp.		
	<i>Dandotiaspora dilata</i>		
	<i>D. pseudoarticulata</i>		
	<i>Lakiapollis ovatus</i>		

2000; Whatley and Bajpai, 2000a,b; Bajpai and Whatley, 2001). These studies have been mostly carried out along the eastern margins of Deccan traps and have led to the discovery of biotic assemblages represented by fishes, frogs, lizards, snakes, turtles, crocodiles, dinosaurs, mammals, ostracodes and charophytes. In the last 10–15 years, palaeomagnetic and radiometric analysis have been carried out on the Deccan traps to provide further constraints on their age (Courtilot et al., 1986, 1988; Duncan and Pyle, 1988). At present there is not a general consensus over the age of the Deccan traps. Therefore, sundry workers have proposed different ages for the Deccan volcanic eruptions. Courtilot et al. (1986) and Duncan and Pyle (1988) suggested a very short span (i.e. 1 Ma) for Deccan basalts based on the fact that the bulk of Deccan trap activity centred around 29 R. However,  $^{40}\text{Ar}/^{39}\text{Ar}$  dates favour

a duration of about 2 Ma (Venkatesan et al., 1993) or about 4 Ma (Courtilot, 1990). These  $^{40}\text{Ar}/^{39}\text{Ar}$  ages and Re–Os isotopic data for Deccan basalts indicate that volcanic eruptions lasted between 1 and 4 Ma and the eruptive phase occurred around 67–64 Ma (Courtilot et al., 1986, 1988; Duncan and Pyle, 1988; Venkatesan et al., 1993; Baksi, 1994; Baksi et al., 1994; Bhattacharji et al., 1996; Sheth et al., 1997; Allegre et al., 1999; Mahoney et al., 2000). The  $^{40}\text{Ar}/^{39}\text{Ar}$  age data for the basaltic dykes exposed along the western region (i.e. Goa) reveal younger (Palaeocene) ages or clearly show a Danian age (i.e.  $62.8 \pm 0.2$  Ma) when compared with the current age range of Deccan basalts (Widdowson et al., 2000).

So far, no well-defined Cretaceous/Tertiary boundary has yet been delineated in any of the intertrappean sections of peninsular India. The post K/T boundary seems to be

present on the eastern banks of the Godavari river (i.e. Rajahmundry traps) showing normal magnetic polarity, indicating strong extrusion of Deccan basalts during chron 29 N (Baksi, 2001). Thus, the age of Rajahmundry Deccan traps is younger than that representing the Cretaceous/Tertiary boundary (Baksi, 1994; Widdowson et al., 2000). The only other possible intertrappean horizon containing the Cretaceous/Tertiary boundary is Kutch in Gujarat. The recent record of an Iridium anomaly in the intertrappean beds at Anjar (District Kutch, Western India) shows the possibility of the presence of Cretaceous/Tertiary boundary (Bajpai, 1996). Three layers of iridium-rich sediments have been identified in the (?) third intertrappean sequence occurring between basaltic Flows III and IV in the Anjar intertrappean section (Bhandari et al., 1995; Bajpai, 1996). The Anjar section contains a diverse record of fossils, i.e. sauropod (Titanosaurid) bones and eggshell fragments belonging to the oospecies namely, *Megaloolithus baghensis* (Khosla and Sahni, 1995); ornithoid eggshells (*Subtiliolithus kachchhensis* Khosla and Sahni, 1995); ostracodes (*Paracyprretta bhatiai* Khosla and Sahni, 2000 and *Mongolianella palmosa* Khosla and Sahni, 2000). All these forms have been found sandwiched between middle and upper iridium layers in this section (Bajpai, 1996).

The presence of a Late Cretaceous faunal assemblage (dinosaurs and ostracodes, etc.; Bajpai and Prasad, 2000) above the three iridium rich layers at Anjar implies that there 'is no Cretaceous/Tertiary boundary at Kutch' because of the fact that so far there is no record of Palaeocene beds or taxa above the last iridium level (Bajpai and Prasad, 2000). Some workers (Bhandari et al., 1996; Venkatesan et al.,

1996) claimed that these iridium levels represent the Cretaceous/Tertiary boundary, which is based mainly on  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of the basalts. Palynological data are still needed in order to define the Cretaceous/Tertiary boundary at Anjar (Bajpai, 1996; Bajpai and Prasad, 2000). However, due to the lack of biota like pollen, Palaeocene beds or taxa above the last Ir level, a precise Cretaceous/Tertiary boundary remains to be determined at Anjar.

More recently, Singh and Kar (2002) have recorded intertrappean beds of Palaeocene age from Papro village (Lalitpur District, Uttar Pradesh), India. The recovered palynological assemblage comprises Palaeocene marker species like *Dandotiaspora dilata*, *D. pseudoarticulata*, *Lakiapollis ovatus* and *Spinizonocolpites echinatus*. This pollen assemblage of Lalitpur Intertrappean beds indicates a definite Palaeocene age and shows that the latter phase of Deccan trap activity had occurred simultaneously in Western Ghats (Widdowson et al., 2000) as well as in the northernmost part of the Deccan trap province (Singh and Kar, 2002).

Recent palaeontological data indicate a Maastrichtian age for the infratrappean beds based on assemblages of fishes (Jain and Sahni, 1983; Sahni and Tripathi, 1990; Prasad and Cappetta, 1993; Mohabey, 1996), dinosaurs (Vianey-Liaud et al., 1987; Sahni and Khosla, 1994b; Sahni et al., 1994; Khosla and Sahni, 1995; Loyal et al., 1998; Khosla, 2001), and ostracodes (Khosla and Sahni, 2000). The marine subsurface infratrappean sections drilled by the Oil and Natural Gas Commission such as the Narsapur, Palakollu, Elamanchili and Modi wells (located 70 km southeast of Rajahmundry Deccan traps within the Krishna–Godavari basin, Fig. 1) are also Maastrichtian

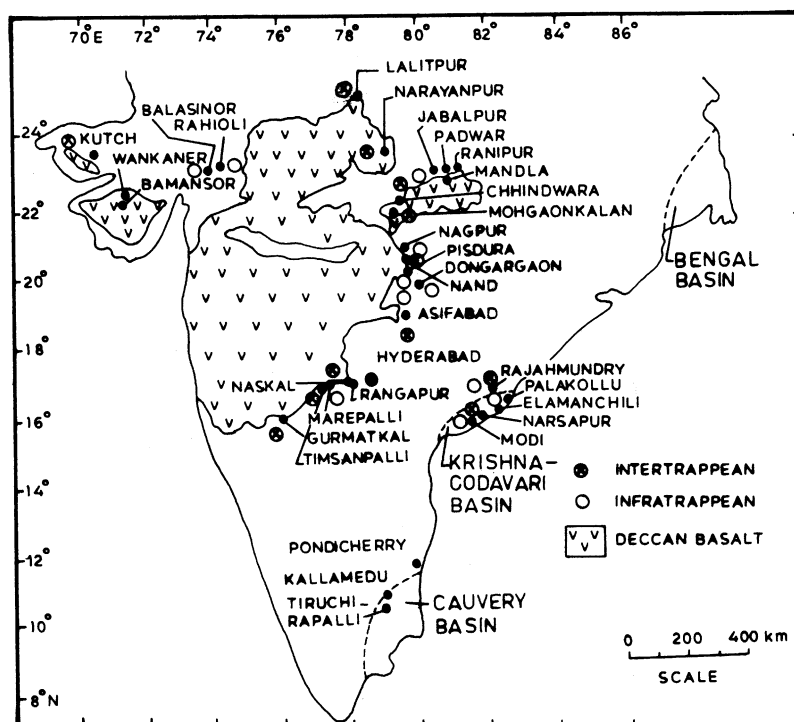


Fig. 1. Outcrop distribution of Upper Cretaceous Deccan volcanics showing the major infratrappean and intertrappean fossiliferous localities.

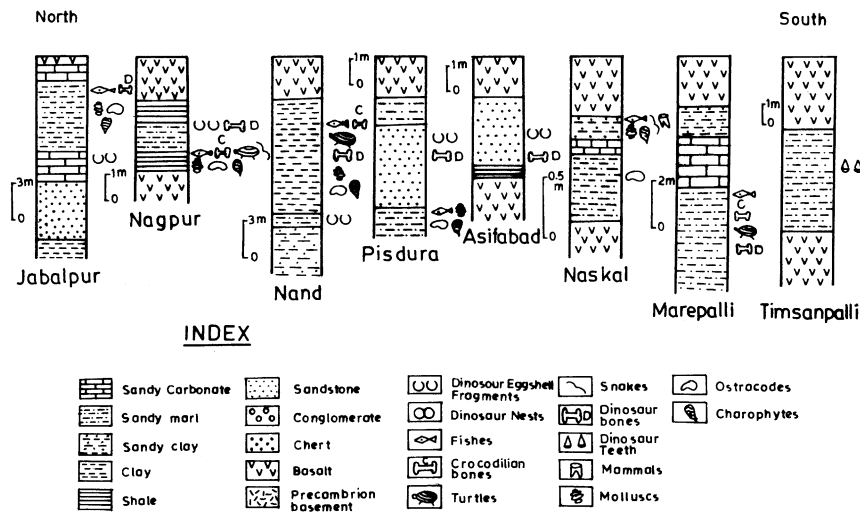


Fig. 2. Stratigraphic sections of Upper Cretaceous (central and southeastern) infra- and intertrappean localities showing various fossils.

in age due to the presence of planktonic foraminifers (Govindan, 1981; Raju et al., 1991; Jaiprakash et al., 1993). The intertrappean beds exposed in Naskal, Asifabad, Nagpur, Padwar, Ranipur and Mohgaon-Kalan have also been assigned a Late Cretaceous age, which are based on biotic assemblages like fishes (Prasad, 1989; Prasad and Cappetta, 1993), dinosaurs (Vianey-Liaud et al., 1987; Prasad, 1989; Khosla and Sahni, 1995; Khosla, 2001), mammals (Prasad and Sahni, 1988; Prasad et al., 1994; Khajuria and Prasad, 1998), palynofossils (Mathur and Sharma, 1990; Prakash et al., 1990; Prasad and Khajuria, 1996; Sahni et al., 1996; Kar and Srinivasan, 1998), and foraminiferal and palynological assemblages from marine Narsapur intertrappeans (Govindan, 1981; Venkatachala and Sharma, 1984).

## 2. Palaeobiotas from infra- and intertrappean beds

Extensive work has been carried out on microbiota, vertebrate and invertebrate bearing infra- and intertrappean beds of Jabalpur (Madhya Pradesh); Nand–Pisdura–Dongargaon (Maharashtra); Rahioli, Balasinor, Dohad (Gujarat); Marepalli, Naskal, Timsanpalli, Rangapur and Asifabad (Andhra Pradesh); Nagpur and Bombay (Maharashtra); Ranipur, Barela and Padwar (Madhya Pradesh); Anjar, Kachchh (Gujarat) and Mamoni in Rajasthan (Figs. 1–3). Diverse vertebrate and invertebrate fossils recorded by various workers (Table 1) are listed below.

**Fishes.** *Lepisosteus indicus* (Woodward, 1908), *Lepidotes* sp. (Prasad, 1989), *Raja sudhakari* (Prasad and Cappetta, 1993), *Rajiforme* indet. (Prasad and Cappetta, 1993), *Igdabatis indicus* (Prasad and Cappetta, 1993), *Rhombodus* sp. (Prasad and Cappetta, 1993), *Pycnodus lametae* (Woodward, 1908), *P. bicresta* (Kumar, 1983), *Phareodus* sp., *Apateodus* sp. cf. *A. striatus* (Woodward, 1901), *Eoserranus* sp. (Mohabey et al., 1993), *Stephanodus*

*lybicus*, *Eotrigonodon indicus* (Kumar and Loyal, 1987), *E. wardhaensis* (Jain and Sahni, 1983), *Pisdurodon spatulatus* (Jain and Sahni, 1983), *Indotrigonodon ovatus* (Jain and Sahni, 1983) *Palaeolabrus* sp. cf. *P. dormaalensis* (Casier, 1967) and fish otoliths belonging to the families Elopidae, Clupeidae, Lepisosteidae, Serranidae, Notopteridae and Apogonidae from infra- and intertrappean beds of Jabalpur, Pisdura–Nand–Dongargaon, Naskal, Rangapur, Asifabad and Kachchh (Sahni and Tripathi, 1990; Mohabey, 1996; Rana, 1988; Prasad, 1989; Prasad and Khajuria, 1990, 1995; Prasad and Cappetta, 1993; Bajpai et al., 1990).

**Amphibians.** The Bombay intertrappeans popularly known as ‘Frog Beds’ are known to contain the leptodactylid frogs (*Indobatrachus pusillus*, Spinar and Hodrova, 1985) belonging to the Subfamily Myobatrachinae (Family Leptodactylidae). Postcranial remains of pelobatid frogs (Family Pelobatidae, Sahni et al., 1982) and discoglossid frogs (Family Discoglossidae, Prasad and Rage, 1991) have been described from the intertrappean beds of Nagpur and Naskal.

Spinar and Hodrova’ (1985) advocated a Gondwanan (South America) origin for *Indobatrachus pusillus*.

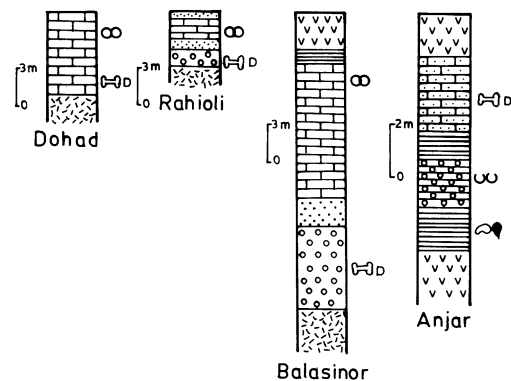


Fig. 3. Stratigraphic sections of Upper Cretaceous (Western India) intratrappean localities showing different fossils. Index for this figure is same as for Fig. 2.



The Myobatrachids reached India through northern Antarctica and South America (Spinar and Hodrova', 1985). Apart from Family Leptodactylidae, two groups of frog families, i.e. Discoglossidae and Pelobatidae have been documented from the intertrappean beds of Naskal (Prasad and Rage, 1991) and Nagpur (Sahni et al., 1982). Both discoglossid and pelobatid frogs suggest a Laurasian connection (Prasad et al., 1995; Prasad and Sahni, 1999).

**Lizards.** Several vertebrae belonging to the Family Anguidae have been reported from the intertrappean beds of Naskal (Prasad and Rage, 1995). The fossil record shows that the lizard family Anguidae is a Laurasian group (Estes, 1982) with the oldest occurrences in Campanian of North America (Armstrong-Ziegler, 1978).

**Crocodiles.** Crocodylian teeth belonging to the Alligatoridae Family are from the intertrappean beds of Rangapur (Rana, 1990; Rana and Sati, 2000) and Naskal (Prasad and Khajuria, 1990). Alligatoridae is a Laurasian family with widespread distribution in the Upper Cretaceous–Palaeogene rocks of Europe, China and North America (Buffetaut, 1980); Palaeocene, Miocene and Rest of Asia (Prasad and Sahni, 1999) but not Gondwana.

**Turtles.** Pelomedusoid turtles (*Shweboemys pisdurensis* Jain, 1986) are from the infratrappean beds of Pisdura (Jain, 1986) and intertrappean beds of Kachchh (Bajpai et al., 1990). More recently, a new type of pelomedusoid turtle *Kurmademys kallamedensis* (Gaffney et al., 2001) belonging to the Family Bothremydidae has been recovered from the Maastrichtian Kallamedu Formation of South India. Broin (1988) favoured a Gondwanan (Africa–South American) origin for Indian pelomedusoids belonging to *Schweboemys*–*Stereogenys* group of Podocnemidinae.

**Snakes.** *Indophis sahnii* (Family Nigerophiidae, Prasad and Rage, 1995) are reported from the intertrappean beds of Naskal. Boid snakes are known both from infra- and intertrappean beds (Prasad and Khajuria, 1995).

**Dinosaurs.** The dinosaurs are known mainly from the infratrappean beds of Jabalpur (Madhya Pradesh), Gujarat and Maharashtra. Dinosaur skeletal remains are represented by six species, i.e. *Titanosaurus indicus*, *T. blanfordi* (Huene and Matley, 1933); *T. colberti* (Jain and Bandyopadhyay, 1997) and *Jainosaurus septentrionalis* (Hunt et al., 1994), and abelisaurids (*Indosuchus raptorius* and *Indosaurus matleyi*, Chatterjee, 1978; Chatterjee and Rudra, 1996). Sauropod, ornithoid and theropod eggs and eggshells are known from the Lameta Formation, whereas, intertrappean beds are represented by pelvic bones of titanosaurids (Sahni et al., 1996), a few isolated teeth of *Megalosaurus* (Vianey-Liaud et al., 1987) and fragmentary eggshells (Khosla and Sahni, 1995; Khosla, 2001; Vianey-Liaud et al., 2002). Dinosaur eggs and eggshell fragments are represented by three oofamilies Megaloolithidae, Laevisoolithidae and Elongatoolithidae. Eleven distinct eggshell oospecies belonging to these three oofamilies are: *Megaloolithus cylindricus* (Khosla and Sahni, 1995), *M. jabalpurensis* (Khosla and Sahni, 1995), *M. mohabeyi* (Khosla

and Sahni, 1995), *M. padiyalensis* (Khosla and Sahni, 1995), *M. baghensis* (Khosla and Sahni, 1995), *M. dholiyaensis* (Khosla and Sahni, 1995), *M. dhoridungriensis* (Mohabey, 1998), *M. khempurensis* (Mohabey, 1998), *M. megadermus* (Mohabey, 1998), *Subtiliolithus kachchhensis* (Khosla and Sahni, 1995) and *Ellipsoolithus khedaensis* (Loyal et al., 1998; Mohabey, 1998).

The Late Cretaceous titanosaurid eggs from India are similar to the eggs and eggshells recorded from France, Spain, Romania, Peru and Argentina (Khosla and Sahni, 1995). Sauropods, principally *Titanosaurus*, have been reported earlier from the Late Cretaceous rocks of Argentina and Uruguay (Huene and Matley, 1933) and Madagascar (Huene and Matley, 1933). Abelisaurids have previously been reported from the Upper Cretaceous strata of South America (Sampson et al., 1996). Thus dinosaurs suggest a Gondwanan connection (Prasad and Sahni, 1999).

**Mammals:** Dental and postcranial remains of *Deccanolestes hislopi* (Prasad and Sahni, 1988) and *Deccanolestes robustus* (Prasad et al., 1994; Khajuria and Prasad, 1998) are well known from the intertrappean beds of Naskal (Andhra Pradesh). The fossil record shows that the family Palaeoryctidae is a Laurasian group with a distribution in the Upper Cretaceous–Palaeocene of North America (Clemens, 1973) and Upper Palaeocene of Morocco (Gheerbrant, 1990). The exact affinities of *Deccanolestes hislopi* (Prasad and Sahni, 1988) and *Deccanolestes robustus* (Prasad et al., 1994; Khajuria and Prasad, 1998) may need to be revised and reassessed. Prasad and Sahni (1999) were of the opinion that the Indian palaeoryctids may have been derived from Africa or evolved on the Indian subcontinent. More recently, mammals belonging to two families, i.e. Sudamericidae and Gondwanatheria, have been recorded from the Late Cretaceous Maevarano Formation of Madagascar and intertrappean beds of Naskal in Andhra Pradesh (Krause et al., 1997).

**Molluscs.** The pulmonate gastropods have been recorded in almost every infra- and intertrappean localities (Sahni and Tripathi, 1990; Prasad and Khajuria, 1990, 1995). Important forms are: *Paludina normalis* (Hislop, 1860), *Physa prinsepaii* (Hislop, 1860), *Lymnaea subbulata* and *Unio deccanensis* (Hislop, 1860).

**Ostracodes.** Lameta ostracodes are known only from Jabalpur (Madhya Pradesh) and the assemblage is large and taxonomically diverse which includes fifteen forms, such as *Paracyprretta bhatiai* (Khosla and Sahni, 2000), *Eucypris* sp. cf. *E. bajshintsavica* (Khand and Stankevitch, 1975; Sahni and Khosla, 1994a; Khosla and Sahni, 2000), *Mongolianella palmosa* (Galeeva, 1955; Sahni and Khosla, 1994a; Khosla and Sahni, 2000), *Mongolianella khamariniensis* (Ljubimova, 1956; Khosla and Sahni, 2000), *Mongolianella* sp. (Khosla and Sahni, 2000), *Mongolocypis* sp. cf. *M. gigantea* (Ye et al., 1977; Khosla and Sahni, 2000), *?Cypridopsis bugintsavicus* (Stankevitch, 1974; Khosla and Sahni, 2000), *?Cypridopsis* sp. (Szczuchura, 1978; Khosla and Sahni, 2000), *Candona altanulaensis*

(Szczechura and Blaszyk, 1970; Sahni and Khosla, 1994a; Khosla and Sahni, 2000), *Candona* (*Candona*) sp. cf. *C. (C.) hubeiensis* (Hou et al., 1978; Khosla and Sahni, 2000), *Paracandona jabalpurensis* (Sahni and Khosla, 1994a; Khosla and Sahni, 2000), *Cyclocypris transitoria* (Stankevitch, 1974; Khosla and Sahni, 2000), *Cypridea* (*Pseudocypridina*) sp. (Sahni and Khosla, 1994a; Khosla and Sahni, 2000) and *Darwinula* sp. (Khosla and Sahni, 2000).

An intertrappean ostracode assemblage from Asifabad, Nagpur, Mamoni and Kachchh is as diverse as that of the infratrapeans. The forms are more or less similar in both infra- and intertrappeans, which needs to be synonymized (Khosla and Sahni, work in progress) including some different forms described recently by Whatley and Bajpai (2000a,b) and Bajpai and Whatley (2001). In contrast to Mongolian and Chinese ostracode affinities suggested by Khosla and Sahni (2000), Whatley and Bajpai (2000a,b) and Bajpai and Whatley (2001) opined that the intertrappean ostracodes are highly endemic to the Indian landmass. The intertrappean ostracode forms are represented by *Leiria jonesi* (Bhatia and Rana, 1985), *Altanicypris szczechuriae* (Stankevitch, 1974), *Cytheridella strangulata* (Jones, 1860; Bhatia et al., 1996), *Candona altanulaensis* (Szczechura and Blaszyk, 1970), *C. bagmodica* (Shuvalov and Stankevitch, 1977; Bhatia et al., 1996), *Candona henaensis* (Hao et al., 1983; Bhatia et al., 1996) *Candoniella altanica* (Stankevitch, 1974; Bhatia et al., 1996), *Talicypridea biformata* (Szczechura and Blaszyk, 1970; Bhatia et al., 1996), *Cypridea cavernosa* (Galeeva, 1955; Bhatia et al., 1996), *Mongolocypris longa* (Hou et al., 1978; Bhatia et al., 1996), *?Cypridopsis bugintsavicus*, (Stankevitch, 1974; Khosla and Sahni, 2000), *Mongolianella palmosa* (Galeeva, 1955; Sahni and Khosla, 1994a; Khosla and Sahni, 2000), *Mongolianella khamariniensis* (Ljubimova, 1956; Khosla and Sahni, 2000), *Frambocythere tumiensis tumiensis* (Helmdach, 1978; Bhatia et al., 1996), *Limnocythere falsicarinata* (Whatley and Bajpai, 2000a), *Gomphocythere gomphomatos* (Whatley and Bajpai, 2000a), *Pseudocypris ecotops* (Whatley and Bajpai, 2000a), *Centrocypris megalopos* (Whatley and Bajpai, 2000a), *Zonocypris spirula* (Whatley and Bajpai, 2000a), *Cyprid cyrtonidion* (Whatley and Bajpai, 2000a), *Cyprois rostellum* (Whatley and Bajpai, 2000a), *?Sarsicypridopsis* sp. (Bajpai and Whatley, 2001), *Cetacella* sp. (Bajpai and Whatley, 2001), *Talicypridea* ? sp. (Bajpai and Whatley, 2001) and *Limnocypridea ephymatos* (Whatley and Bajpai, 2000b).

*Charophytes.* The infratrapean localities from which the charophytes have been recorded include Jabalpur (Sahni and Tripathi, 1990) and Nand–Dongargaon (Mohabey, 1996). Forms are: *Platychara raoi* (Bhatia and Mannikeri, 1976; Srinivasan et al., 1994), *P. perlata* (Peck and Reker, 1947; Srinivasan et al., 1994), *P. compressa* (Peck and Reker, 1948; Srinivasan et al., 1994), *P. rajahmundrica* (Rao and Rao, 1939; Srinivasan et al., 1994), *Nemegtichara grambasti* (Bhatia et al., 1990a), *Harrisichara muricata* (Grambast-Fessard, 1980; Srinivasan et al., 1994),

*Stephanochara* sp. cf. *S. levis* (Massieux, 1977; Srinivasan et al., 1994) and *Peckichara varians* (Massieux et al., 1981; Srinivasan et al., 1994).

An intertrappean charophyte assemblage of Gurmatkal (Srinivasan et al., 1994), Asifabad and Rangapur (Bhatia et al., 1990c) is much more diverse than infratrapeans. The forms are more or less similar in both infra- and intertrappeans including some different forms such as: *Platychara sahnii* (Rao and Rao, 1939; Bhatia and Mannikeri, 1976; Srinivasan et al., 1994), *P. raoi* (Bhatia and Mannikeri, 1976; Srinivasan et al., 1994), *P. perlata* (Peck and Reker, 1947; Srinivasan et al., 1994), *P. compressa* (Peck and Reker, 1948; Srinivasan et al., 1994), *P. rajahmundrica* (Rao and Rao, 1939; Srinivasan et al., 1994), *Nemegtichara grambasti* (Bhatia et al., 1990a), *Harrisichara muricata* (Grambast-Fessard, 1980; Srinivasan et al., 1994), *Grambastichara* sp. (Srinivasan et al., 1994), *Stephanochara* sp. cf. *S. levis* (Massieux, 1977; Srinivasan et al., 1994), *Peckichara varians* (Massieux et al., 1981; Srinivasan et al., 1994), *Chara* sp. (Srinivasan et al., 1994) and *Microchara* sp. (Sahni and Tripathi, 1990; Srinivasan et al., 1994).

### 3. Discussion

#### 3.1. Palaeoenvironments

The infra- and intertrappean biotic assemblages are represented by four palaeocommunities (Table 1). The majority of biotic elements, i.e. fishes, ostracodes, charophytes and molluscs, clearly point to a predominantly freshwater, lacustrine depositional setting, which developed under semi-arid conditions for the Lameta (infratrapeans) of Jabalpur (Khosla and Sahni, 2000) and Nand–Pisdura–Dongargaon–Dhamni–Pavana (Maharashtra, Mohabey, 1996). The intertrappean assemblages of Nagpur, Naskal, Kachchh and Gurmatkal (Rana, 1984; Prasad, 1989; Bajpai et al., 1990; Bajpai and Prasad, 2000), are also dominated by similar freshwater fauna and flora. Lithologically, the infra- and intertrappean beds show a variety of lithotypes ranging from marls, siltstones, mudstones, clays, claystones, calcrites and limestone which are strongly indicative of fluctuating lake levels (Mohabey et al., 1993; Khosla and Sahni, 2000).

*Terrestrial community.* The presence of terrestrial community, such as dinosaurs, mammals, frogs and lizards indicate fluvio-lacustrine conditions (Sahni and Khosla, 1994a,b; Prasad and Khajuria, 1990; Khosla and Sahni, 1995, 2000; Khajuria and Prasad, 1998). The dinosaur rich Lameta Limestone is a massive, palustrine calcrite, formed after the floodplain deposits. The Lameta Formation represents the relict of an ancient soil cover formed on various shield basements (i.e. Mahakoshal and Godhra Granites, Vindhyan and Gondwanas) ranging in age from Precambrian to Lower Cretaceous in peninsular India.

The calcrete horizon is 3–12 m in thickness. The presence of extensive dinosaur nesting sites (i.e. infratrappean sections of Jabalpur, Madhya Pradesh; Districts Dhar and Jhabua, Madhya Pradesh; Nand–Dongargaon, Dhamni–Pavna sections in Maharashtra and Kheda–Panchmahal district, Gujarat) in a single dominant lithology (pedogenically modified sandy carbonate) indicates that the calcritized palaeosol was deposited in an alluvial environment, comprising overbank, channel and back-swamp environments (Mohabey et al., 1993; Sahni and Khosla, 1994a,b; Tandon et al., 1990, 1995, 1998). The variation in the depositional conditions within the infratrappeans was due to a semi-arid climate with periodic dry cycles and seasonal rains, which influenced the sedimentation and preservation of the organisms (Mohabey et al., 1993). The dinosaur bearing infratrappeans show a number of sedimentological features related to pedogenesis such as the presence of high sand and pebble content like chert, jasper and quartz, representing repeated sheetflood events and different calcrete and palaeosol features like absence of bedding, mottling, pedotubules, desiccation cracks, bioturbation, rhizoconcretionary, pseudo-anticlinal, honeycomb, prismatic, brecciated and autobrecciated structures, etc. (Mohabey, 1991; Tandon et al., 1990, 1995, 1998; Sahni and Khosla, 1994b; Sahni et al., 1994; Khosla, 1994, 1996).

The solitary mammal bearing Naskal intertrappeans (Andhra Pradesh) were deposited in low-lying, shallow, floodplain alkaline lakes. The mammals, along with other microvertebrates, gathered in these lakes in search of food and water. Due to continuous drought conditions, the drying of the lakes led to the death of these animals. Furthermore, these intertrappeans became surficially exposed and experienced pedogenic modifications associated with calcritization (Prasad and Khajuria, 1996; Khajuria and Prasad, 1998).

*Lacustrine/fluviatile community.* The presence of fish taxa, i.e. clupeids, *Phareodus*, *Pycnodus*, *Lepidotus* are considered to have lived in lakes. Freshwater fishes includes *Dasyatis* sp., and *Lepisosteus* sp. (Mohabey et al., 1993) whereas *Eoserranus* inhabited paludal conditions (Mohabey et al., 1993; Khosla and Sahni, 2000). Increased alkalinity of these fish bearing sediments is due to the instantaneous and mass deaths of clupeids and *Eoserranus*, which is due to the excessive desiccation/evaporation of lakes (Mohabey et al., 1993). The ostracode assemblage listed herein (Table 1) comprises freshwater forms. A relatively high taxonomic diversity of the ostracode assemblage rules out the possibility of any form of extended transport by flowing water. The ostracod assemblage includes characteristic freshwater forms such as *Eucypris* and *Darwinula* and other taxa, such as *Candona*, *Cyclocypris* and *Cypridopsis*, which are highly sensitive to changes in environmental salinity. These genera are typical of shallow lacustrine environments and thrived in swamps, ponds or freshwater lakes. They include benthonic creepers and burrowers (*Candona*) while others, e.g. *Cypridopsis*, swam among

plants. The infra- and intertrappean ostracodes consists mostly of complete and closed ostracode carapaces (Khosla and Sahni, 2000). Further, a marked increase in the alkalinity of the environments is indicated by greater calcification of the thick-shell ostracodes (*Mongolocypris* cf. *M. gigantea*) and heavy ornamentation (e.g. in *Paracyprretta bhatiai* Khosla and Sahni, 2000; *Paracandona jabalpurensis* Sahni and Khosla, 1994a; *Frambocythere tumiensis tumiensis* Helmdach, 1978; Bhatia et al., 1996; *Darwinula* sp., Khosla and Sahni, 2000 and *Cypridea* (*Pseudocypridina*) sp., Khosla and Sahni, 2000). This increase in the precipitation of calcium carbonate was probably favoured by the presence of algae and tropical to sub-tropical climatic conditions. On the whole, the ostracod-bearing marl and siltstone bands were deposited in low energy environments (backswamps or lake, Khosla and Sahni, 2000; Srinivasan, 1991). The charophyte assemblage also clearly supports the prevalence of alkaline, shallow, freshwater conditions of deposition. The various pulmonate gastropods (*Physa*, *Paludina* and *Lymnaea* Hislop, 1860) as well as the pelecypod *Unio* provide further confirmation for this reconstruction (Khosla and Sahni, 2000). The vertebrate fauna such as snakes also indicate a lacustrine environment of deposition (Rage and Prasad, 1992; Prasad and Khajuria, 1996).

*Freshwater/brackishwater community.* The freshwater and brackish water fauna are represented by frogs of the Family Pelobatidae, Discoglossidae, crocodiles, turtles and some foraminifers (Nodosauridae Gen et. sp. indet., Prasad et al., 1986) indicate that the deposition of the infra- and intertrappean beds of Asifabad were influenced by freshwater to brackishwater conditions of deposition. The admixture of marine and non-marine assemblages in the Asifabad intertrappeans is indicative of the presence of coastal plain conditions in this region during the Upper Cretaceous period (Prasad et al., 1986).

*Marine community.* A marine community of fishes, i.e. *Igdabatis*, *Rhombodus*, *Raja sudhakari*, *Rajiforme* indet. and *Pycnodus lametae* (Table 1) along with freshwater taxa are known from the infratrappean beds of the Pisdura and Nand areas (Sati, 1999), and the Asifabad intertrappeans (Prasad and Khajuria, 1995). The fish taxa represent benthonic and neritic conditions where the climate was tropical, subtropical and warm. Such an admixture of marine and non-marine elements was explained by Sahni (1983) on the basis of the close proximity of the sea, from where certain fishes could make frequent upstream incursions.

### 3.2. Age of the Deccan volcano-sedimentary sequences

Based on dinosaurian remains, infratrappean beds were previously considered as Turonian in age (Huene and Matley, 1933). Several other workers (Chatterjee, 1978; Berman and Jain, 1982) proposed a Santonian to Maastichtian age for the infratrappean beds. Buffetaut (1987)



contradicted the Turonian age assigned by Huene and Matley (1933) for the Lameta dinosaurs and further compared the Indian infratrappean titanosaurids with Maastrichtian *Titanosaurus* known from Madagascar and Europe and favoured a Maastrichtian age for the infratrappean beds. The widespread occurrence of dinosaur eggs and eggshell fragments in the infratrappean sections of Jabalpur, Districts Dhar and Jhabua (Madhya Pradesh); Nand–Dongargaon, Dhamni–Pavna sections in Maharashtra and Kheda and Panchmahal districts in Gujarat indicates a Maastrichtian age for these beds and shows distinct affinities with the dinosaur fauna of France, Spain, Romania, Peru and Argentina (Sahni and Khosla, 1994b; Khosla and Sahni, 1995). The fish taxa, such as *Rhombodus*, *Apateodus* and *Stephanodus* in the infratrappean beds of Pisdura (Jain and Sahni, 1983), Jabalpur (Sahni and Tripathi, 1990), Marepalli and Narsapur (Prasad and Cappetta, 1993) and Nand–Dongargaon (Mohabey, 1996) indicate a Maastrichtian age (Prasad and Khajuria, 1995; Prasad and Sahni, 1999; Khajuria et al., 1994). The Myliobatid (*Igdabatis*) recovered from the infratrappean beds of peninsular India (Courtilot et al., 1986; Prasad and Cappetta, 1993; Mohabey, 1996) also supports a Maastrichtian age.

A Maastrichtian age can be assigned to the infratrappean sections of Jabalpur based mainly on the occurrence of a characteristic Late Cretaceous ostracode assemblage (*Altanicypris*, *Cypridea*, *Candona*, *Cypridopsis*, *Darwinula*, *Mongolianella* and *Mongolocypis*, Khosla and Sahni, 2000). The assemblage clearly has distinct affinities with Mongolian and Chinese forms (Khosla and Sahni, 2000). Similar ostracode assemblages have recently been recognized in the dinosaur-bearing Lameta Formation of Nand–Dongargaon and Dhamni–Pavna sections in Maharashtra, which also indicate a Maastrichtian age for these beds (Khosla and Sahni, 2000).

The infratrappean beds exposed along the southeastern coast of India have been assigned a Late Maastrichtian age, based on the presence of foraminiferal assemblages, recovered from four wells (i.e. Narsapur-1, Palakollu-A, Elamanchili-A, and Modi-A). The foraminiferal assemblage recovered from (depths of 3336 and 3339 m) infratrappean beds in the Narsapur well-1 are represented by a typical plankton *Abathomphalus mayaroensis* (Bolli, 1951) and other forms, such as *Globotruncana arca* (Cushman, 1926), *G. stuarti* (de Lapparent, 1918), *Globotruncanella citae* (Bolli) Reiss, 1957, *Rugoglobigerina rugosa* (Plummer, 1926), *Pseudotextularia elegans* (Rzehak, 1891; Nash, 1981) and *Racemiguembelina fructicosa* (Egger, 1902). In the Palakollu well, eight basaltic flows and intercalated sedimentary beds yielded typical Late Maastrichtian forms, such as *Globotruncana stuarti* (de Lapparent, 1918), *G. stuartiformis* (Dalbiez, 1955; Robaszynski et al., 1984) and *Racemiguembelina fructicosa* (Egger, 1902). The presence of *Gaudryina bronni* (Reiss) Loeblich and Tappan (1964) and *Globotruncana stuarti* (de Lapparent, 1918) in

the infratrappean beds of well Elamanchili-A has been recorded in support of a Late Maastrichtian age (Raju et al., 1991). Infratrappean beds of well Modi-A also contain a planktonic foraminiferal assemblage of the Late Maastrichtian *Abathomphalus mayaroensis* zone (Bronnimann, 1952; Raju et al., 1991). Radiometric dating ( $^{40}\text{Ar}/^{39}\text{Ar}$ ) of the lowermost basaltic flows, immediately overlying the infratrappean bed at Dongargaon, indicates an age of  $66.4 \pm 1.9$  Ma. The Narmada valley and Western Ghats indicate an age of  $66 \pm 2$  Ma (Courtilot et al., 1986, 1988).

Apart from infratrappeans, some Deccan intertrappean plant-bearing beds were earlier assigned an Early Tertiary age as it was considered that intertrappeans were devoid of dinosaurs (Lydekker, 1890). Extensive research during the last two decades led to widespread recoveries of dinosaur fossils (isolated teeth of Megalosaurids, broken eggshell fragments of sauropod, ornithoid and theropods and pelvic bones of titanosaurids) in the intertrappean beds of Nagpur (Rana, 1984; Vianey-Liaud et al., 1987); Kachchh (Bajpai et al., 1990; Sahni and Khosla, 1994b; Sahni et al., 1994; Khosla and Sahni, 1995; Bajpai and Prasad, 2000) and Ranipur (Prakash et al., 1990; Sahni et al., 1996). The Maastrichtian ichthyofauna (*Igdabatis* sp., *Rhombodus* sp., *Apateodus* sp., and *Stephanodus* sp., Prasad, 1989) recovered from the intertrappean beds of Naskal and Asifabad (Prasad, 1989; Prasad and Khajuria, 1990, 1995; Khajuria et al., 1994; Khajuria and Prasad, 1998); Nagpur (Rana, 1984) and Kachchh (Bajpai et al., 1990) also confirms the Maastrichtian age for these beds. The presence of mammals such as *Deccanolestes hislopi* (Prasad and Sahni, 1988) and *Deccanolestes robusti* (Prasad et al., 1994; Khajuria and Prasad, 1998) belonging to the family Palaeoryctidae from Naskal intertrappean beds also suggests a Maastrichtian age (Khajuria and Prasad, 1998). The Maastrichtian age is also supported for the intertrappean beds of Padwar (Prakash et al., 1990) by the presence of typical Maastrichtian markers including *Aquilapollenites bengalensis* (Baksi and Deb, 1981) and *Azolla cretacea* (Stanley, 1965). The intertrappean beds of Padwar, Ranipur and Mohgaon-Kalan (Mathur and Sharma, 1990; Prakash et al., 1990; Sahni et al., 1996; Kar and Srinivasan, 1998) contain other palynofossils of Maastrichtian age such as *Bacutripurites orluensis* (Jan du Chene et al., 1978), *Matanomadhiasulcites maximus* (Kar, 1985), *Spinizonocolpites baculatus* (Muller, 1968), *Gabonisorites vigourouxii* (Boltenhagen, 1967), *Proxapertites* sp. (Van der Hammen, 1956), *Podocarpidites* sp. (Cookson, 1947; Potonie', 1958), *Lycopodiumsporites* sp. (Thiergart, 1938), *Tricolpites* sp. (Erdtman, Cookson et Ross) Couper (1953), *Tripuroletes reticulatus* (Pocock) Playford (1971) and *Ephedripites* sp. (Bolkhovitina, 1953 ex Potonie', 1958). Additionally, the presence of palynofossils such as *Aquilapollenites bengalensis* (Baksi and Deb, 1981), *Azolla cretacea* (Stanley, 1965), *Gabonisorites vigourouxii* (Boltenhagen, 1967) and *Ariadnaesporites* sp. (Potonie', 1966; Tschudy, 1966) from Naskal and Mohgaon-Kalan intertrappeans also indicate

a Maastrichtian for these beds (Prasad and Khajuria, 1996; Sahni et al., 1996; Kar and Srinivasan, 1998) as these species are confined to the Maastrichtian all over the world (Kar and Srinivasan, 1998). In one instance, a pollen assemblage was more recently recovered from Lalitpur intertrappean beds and contain Palaeocene marker species represented by *Dandotiaspora dilata*, *D. pseudoarticulata*, *Lakiapollis ovatus* and *Spinizonocolpites echinatus* Singh and Kar, 2002).

A Late Maastrichtian age has also been assigned to the intertrappean beds of the southeastern coast on the basis of foraminiferal assemblage, recovered from the drilled well samples (depths ranging between 3310 and 3330 m) from the Narsapur-1. The foraminiferal assemblages are represented by *Globotruncana stuarti* (de Lapparent, 1918) and *Pseudotextularia browni* (Govindan, 1981). Apart from foraminifera, a recovered palynological assemblage represented by *Aquilapollenites bengalensis* (Baksi and Deb, 1981), *A. indicus* (Baksi and Deb, 1976) and *Azolla cretacea* (Stanley, 1965) also confirm a Late Maastrichtian age for the Narsapur intertrappean beds (Venkatachala and Sharma, 1984).

#### 4. Summary and concluding remarks

Concerted efforts during the last 20 years have provided much insight into the biota, age and facies of the sedimentary beds associated with Deccan Trap activity. However, the strides have also shown (Prasad and Khajuria, 1995; Sahni et al., 1996; Bajpai and Prasad, 2000) that there are certain constraints in working with these beds:

1. Firstly, continuous sequences across the Cretaceous, Late Cretaceous through Palaeocene sections are lacking.
2. The Cretaceous/Tertiary boundary has yet to be defined in a continuous sequence in beds associated with Deccan traps.
3. Sections, which are only 1–3 m in thickness either yield Maastrichtian biotas with dinosaurs and diagnostic pollen assemblages, or in a few cases, Palaeocene forms without the record of dinosaurs.
4. Although Iridium has been demonstrated in the Anjar sequence (Bajpai, 1996) presumably demarcating the Cretaceous/Tertiary boundary, current opinion by Bajpai and Prasad (2000) based on the presence of dinosaurs above the so called Iridium anomaly bearing beds has cast doubt on the authenticity of the Iridium layer.
5. A major constraint has been that most of the fossiliferous sedimentary horizons associated with Deccan traps lie on the eastern fringes of a province where the basalts are only 100 m in thickness, whereas most of the lava flow stratigraphy, geochemical characteristics and chronology are confined to the classic Western Ghats section. Hence it is sometimes not possible to correlate the sections on the eastern side with those to the west.
6. However the recent work by Widdowson et al. (2000) and Sen (2001) has shown that the Ambenali and Poladpur Formations of Western Ghats probably represent the eastern sections. Furthermore, it is difficult purely on a palaeontological basis to differentiate the presence of Maastrichtian–Danian beds because several of these freshwater taxa have long temporal ranges. There is only one recorded instance of the intertrappean beds at Lalitpur, which lack the *Aquilapollenites* assemblage, but show similarity with the palynological assemblages of the Madh Formation at Kutch (Palaeocene age), Gujarat (Kar, 1985) and the Lakadong Sandstone (Palaeocene) of Meghalaya (Kar and Kumar, 1986).

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#### References

- Allegre, C.J., Birck, J.L., Capmas, F., Courtillot, V., 1999. Age of the Deccan Traps using  $^{187}\text{Re}$ – $^{187}\text{Os}$  systematics. *Earth and Planetary Science Letters* 170, 197–204.
- Armstrong-Ziegler, G., 1978. An anilid snake and associated vertebrates from the Campanian of New Mexico. *Journal of Paleontology* 52, 480–483.
- Bajpai, S., 1996. Iridium anomaly in Anjar intertrappean beds and the K/T boundary. *Memoir Geological Society of India* 31, 313–319.
- Bajpai, S., Prasad, G.V.R., 2000. Cretaceous age for Ir-rich Deccan intertrappean deposits: palaeontological evidence from Anjar, western India. *Journal of the Geological Society of London* 157, 257–260.
- Bajpai, S., Whatley, R.C., 2001. Late Cretaceous non-marine ostracods from the Deccan intertrappean beds, Kora (western Kachchh, India). *Revista Espanola de Micropaleontologia* 33 (1), 91–111.
- Bajpai, S., Sahni, A., Jolly, A., Srinivasan, S., 1990. Kachchh intertrappean biotas: affinities and correlation. In: Sahni, A., Jolly, A. (Eds.), *Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar cum Workshop IGCP 216 and 245, Chandigarh*, pp. 101–105.
- Baksi, A.K., 1994. Geochronological studies on whole-rock basalts, Deccan Traps, India: evaluation of the timing of volcanism relative to the K–T boundary. *Earth and Planetary Science Letters* 121, 43–56.
- Baksi, A.K., 2001. The Rajahmundry Traps, Andhra Pradesh: evaluation of their petrogenesis relative to the Deccan Traps. *Proceedings of the Indian Academic Sciences, Earth Planetary Sciences* 110 (4), 397–407.
- Baksi, S.K., Deb, U., 1976. On new occurrence of *Aquilapollenites* from Eastern India. *Pollen Spores* 18 (3), 399–406.
- Baksi, S.K., Deb, U., 1981. Palynology of the Upper Cretaceous of the Bengal basin, India. *Revue of Paleobotany and Palynology* 31, 335–365.

- Baksi, A.K., Byerly, G.R., Chan, L.H., Farrar, E., 1994. Intracanyon flows in the Deccan province, India? Case history of the Rajahmundry Traps. *Geology* 22, 605–608.
- Barrera, E., Savin, S.M., 1999. Evolution of late Campanian–Maastrichtian marine climates and oceans. *Geological Society of America Special Paper* 332, 245–282.
- Berman, D.S., Jain, S.L., 1982. The braincase of a small Cretaceous sauropod dinosaur (Reptilia: Saurischia) from the Upper Cretaceous Lameta Group, Central India, with a review of Lameta Group localities. *Annals of Carnegie Museum Pittsburgh* 51 (21), 405–422.
- Bhandari, N., Shukla, P.N., Ghevariya, Z.G., Sundaram, S.M., 1995. Impact did not trigger Deccan volcanism: evidence from Anjar K/T boundary intertrappean sediments. *Geophysical Research Letters* 22 (4), 433–436.
- Bhandari, N., Shukla, P.N., Ghevariya, Z.G., Sundaram, S.M., 1996. K/T boundary layer in Deccan intertrappeans at Anjar, Kutch. *Geological Society of America Special Papers* 307, 417–424.
- Bhatia, S.B., Mannikeri, M.S., 1976. Some charophyta from the Deccan intertrappean beds near Nagpur, Central India. *Geophytology* 6 (1), 75–81.
- Bhatia, S.B., Rana, R.S., 1985. Palaeogeographic implications of the charophyta and ostracoda of the intertrappean beds of peninsular India. *Memoir Geological Society of France* 147, 29–35.
- Bhatia, S.B., Prasad, G.V.R., Rana, R.S., 1990a. Deccan volcanism, a Late Cretaceous event: conclusive evidence of ostracodes. In: Sahni, A., Jolly, A. (Eds.), *Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh*, pp. 47–49.
- Bhatia, S.B., Srinivasan, S., Bajpai, S., Jolly, A., 1990b. Microfossils from the Deccan intertrappean bed at Mamoni, District Kota, Rajasthan: additional taxa and age implication. In: Sahni, A., Jolly, A. (Eds.), *Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh*, pp. 118–119.
- Bhatia, S.B., Riveline, J., Rana, R.S., 1990c. Charophyta from the Deccan intertrappean beds near Rangapur, Andhra Pradesh, India. *Palaeobotanist* 37 (3), 316–323.
- Bhatia, S.B., Prasad, G.V.R., Rana, R.S., 1996. Maastrichtian nonmarine ostracodes from peninsular India: palaeobiogeographic and age implications. *Memoir Geological Society of India* 37, 297–311.
- Bhattacharji, S., Chatterjee, N., Wampler, J.M., Nayak, P.N., Deshmukh, S.S., 1996. Indian intraplate and continental margin rifting, lithospheric extension, and mantle upwelling in Deccan flood basalt volcanism near the K/T boundary: evidence from mafic dike swarms. *Journal of Geology* 104, 379–398.
- Bolkhovitina, N.A., 1953. Characteristic spores and pollen grains of Cretaceous of Central region of USSR. *Akademy Wiss UDSSR Geological Series* 154 (6), 1–184.
- Bolli, H.M., 1951. The genus *Globotruncana* in Trinidad. *BWI Journal of Palaeontology* 25 (2), 187–199.
- Boltenhagen, E., 1967. Spore et pollen du Cre'tace' superieur du Gabon. *Pollen Spores* 9, 335–355.
- Broin, F.de., 1988. Les tortues et le Gondwana. Examen des rapports entre le fractionnement du Gondwana et al dispersion ge'ographique des tortues pleurodires a' partir du Cretacee'. *Studia Palaeoichnologia* 2 (5), 103–142.
- Bronnimann, P., 1952. Globigerinidae from the Cretaceous (Cenomanian–Maastrichtian) of Trinidad. *BWI Bulletin of American Paleontology* 34 (140), 5–71.
- Buffetaut, E., 1980. Crocodylians from the continental Upper Cretaceous of Europe: new finds and interpretations. *Mesozoic Vertebrate Life* 1, 5–14.
- Buffetaut, E., 1987. On the age of the dinosaur fauna from the Lameta Formation (Upper Cretaceous) of Central India. *Newsletters in Stratigraphy* 18, 1–6.
- Casier, E., 1967. Le Landenien de Dormaal (Brabant) et sa faune ichthyologique. *Memoir Institute of Royal Science and Natural Belgium* 156, 1–66.
- Chatterjee, S., 1978. *Indosuchus* and *Indosaurus*, Cretaceous carnosaurus from India. *Journal of Palaeontology* 52 (3), 570–580.
- Chatterjee, S., Rudra, D.K., 1996. KT events in India: impact, rifting, volcanism and dinosaur extinction. *Memoir of the Queensland Museum* 39 (3), 489–532.
- Clemens, W.A., 1973. Fossil mammals of the type Lance Formation, part III: eutheria and summary. *Publications in Geological Sciences, University of California* 94, 1–102.
- Cookson, I.C., 1947. Plant microfossils from the lignites of Kerguelen Archipelago. *British, Australian and New Zealand Antarctic Research Expedition 1929–31 A2* (8), 129–142.
- Couper, R.A., 1953. Distribution of Proteaceae, Fugaceae and Podocarpaceae in some southern hemisphere Cretaceous and Tertiary beds. *New Zealand Journal of Scientific Technical Section B* 35 (3), 247–350.
- Courtilot, V., 1990. Deccan volcanism at the Cretaceous–Tertiary boundary: past climatic crisis as a key to future? *Palaeogeography, Palaeoclimatology and Palaeoecology* 89, 291–299.
- Courtilot, V., Besse, J., Vandamme, D., Montigny, R., Jaeger, J.J., Cappetta, H., 1986. Deccan flood basalts at the Cretaceous/ Tertiary boundary? *Earth and Planetary Science Letters* 80, 361–374.
- Courtilot, V., Feraud, H., Maluski, D., Vandamme, D., Moreau, M.G., Besse, J., 1988. Deccan flood basalts and the Cretaceous/Tertiary boundary. *Nature* 333 (6176), 843–846.
- Cushman, J.A., 1926. Some foraminifera from the Mendez Shale of eastern Mexico. *Contributions Cushman Laboratory of Foraminiferal Research* 2 (1), 16–28.
- Dalbiez, F., 1955. The genus *Globotruncana* in Tunisia. *Micropalaeontology* 1, 161–171.
- Duncan, R.A., Pyle, D.G., 1988. Rapid eruption of the Deccan flood basalts at the Cretaceous/Tertiary boundary. *Nature* 333, 841–843.
- Egger, J.G., 1902. Der Bau der Orbitolinen und verwandter Formen. *Abhandlungen der Bayerischen Akademie der Wissenschaften, Munchen, Math-Physical CI* 21 (3), 575–600.
- Estes, R., 1982. The fossil record and early distribution of lizards. In: Rhodn, A., Miyata, K. (Eds.), *Advances in Herpetology and Evolutionary Biology, Museum of Comparative Zoology, Cambridge*, pp. 365–398.
- Frank, T.D., Arthur, M., 1999. Tectonic forcings of Maastrichtian ocean-climate evolution. *Paleoceanography* 14 (2), 103–117.
- Gaffney, E.S., Chatterjee, S., Rudra, D.K., 2001. *Kurmademys*, a new side-necked turtle (Pelomedusoides: Bothremydidae) from the Late Cretaceous of India. *American Museum Novitates* 3321, 1–16.
- Galeeva, L.I., 1955. Ostrakody melovykh otlozhnii Mongol'ikoi Narodnoi Respubliki. *Geological Razved Neft. Institute Moscow*, pp. 1–63 (in Russian).
- Gheerbrant, E., 1990. On the early biogeographical history of African placentals. *Historical Biology* 4, 107–116.
- Govindan, A., 1981. Foraminifera from the infra- and intertrappean subsurface sediments of Narsapur Well-1 and age of the Deccan Trap flows. In: Khosla, S.C., Kachhara, R.P. (Eds.), *Proceedings of IXth Indian Colloquium on Micropalaeontology and Stratigraphy, Udaipur*, pp. 81–93.
- Grambast-Fessard, N., 1980. Les charophytes du Montien de Mons (Belgique). *Review of Palaeobotany and Palynology* 30, 67–88.
- Hao, Y.C., Ruan, P.H., Zhou, X.G., Song, Q.S., Yang, G.D., Cheng, S.W., Wei, Z.K., 1983. Middle Jurassic–Tertiary deposits and ostracode–charophyte fossil assemblage of Xining and Minhe basins. *Earth Science Wuhan College Geology* 23 (2), 1–31.
- Helmdach, F.F., 1978. Nichtmarine ostrakoden aus der Spanischen Oberkreide. *Berliner Geowiss Abhandungent* 3, 71–78.
- Hislop, S., 1860. Geology and fossils of Nagpur. *Quaternary Journal of the Geological Society of London* 16, 154–189.
- Hou, Y., Ho, J.D., Ye, C.H., 1978. The Cretaceous–Tertiary ostracodes from the marginal region of the Yangtze-Han river plain in Central Hubei. *Memoir Nanjing Institute of Geology and Palaeontology Academia Sinica* 9, 121–206. in Chinese.

- Huene, F.V., Matley, C.A., 1933. The Cretaceous Saurischia and Ornithischia of the central provinces of India. *Memoirs of the Geological Survey of India, Palaeontologica Indica*, New Series 21 (1), 1–74.
- Hunt, A.P., Lockley, M.G., Lucas, S.G., Meyer, C., 1994. The global sauropod fossil record. *Gaia* vol. 10, 261–279.
- Jain, S.L., 1986. New pelomedusid turtle (Pleurodira: Chelonia) remains from Lameta Formation (Maastrichtian) at Dongargaon, Central India, and a review of pelomedusids from India. *Journal of the Palaeontological Society of India* 31, 63–75.
- Jain, S.L., Bandyopadhyay, S., 1997. New titanosaurid (Dinosauria: Sauropoda) from the Late Cretaceous of central India. *Journal of Vertebrate Palaeontology* 17 (1), 114–136.
- Jain, S.L., Sahni, A., 1983. Some Upper Cretaceous vertebrates from Central India and their palaeogeographical implications. In: Maheshwari, H.K., (Ed.), *Cretaceous of India*, Indian Association of Palynostratigraphers Symposium BSIP, Lucknow, pp. 66–83.
- Jaiprakash, B.C., Singh, J., Raju, D.S.N., 1993. Foraminiferal events across K/T boundary and age of Deccan volcanism in Palakollu area, Krishna–Godavari basin, India. *Journal of the Geological Society of India* 41, 105–117.
- Jan du Chene, R.E., Onyike, M.S., Sowunmi, M.A., 1978. Some new Eocene pollen of the Ogwashi–Asabe Formation, south-eastern Nigeria. *Revista Espanola de Micropaleontologia* 10, 285–322.
- Jones, T., 1860. Notes on the fossil Cypride. *Quaternary Journal of the Geological Society of London* 16, 154–189.
- Kar, R.K., 1985. The fossil flora of Kachchh—IV. Tertiary Palynostratigraphy. *Palaeobotanist* 34, 1–279.
- Kar, R.K., Kumar, M., 1986. Palaeocene palynostratigraphy of Meghalaya, India. *Pollen and Spores* 28, 177–218.
- Kar, R.K., Srinivasan, S., 1998. Late Cretaceous palynofossils from the Deccan intertrappean beds of Mohgaon–Kalan, Chhindwara District, Madhya Pradesh. *Geophytology* 27 (1 and 2), 17–22.
- Khajuria, C.K., Prasad, G.V.R., 1998. Taphonomy of a Late Cretaceous mammal-bearing microvertebrate assemblage from the Deccan intertrappean beds of Naskal, peninsular India. *Palaeogeography, Palaeoclimatology and Palaeoecology* 137, 153–172.
- Khajuria, C.K., Prasad, G.V.R., Manhas, B.K., 1994. Palaeontological constraints on the age of Deccan Traps, peninsular India. *Newsletter in Stratigraphy* 31 (1), 21–32.
- Khand, E., Stankevitch, E.S., 1975. New ostracode species in Bain-Shiren suite from south-eastern Gobi (Upper Cretaceous). In: Kramarenko, N.N., Luwsandansan, B., Rozhdestvensky, A.K. (Eds.), *Fossil Fauna and Flora of Mongolia, Joint Soviet–Mongolian Palaeontological Expedition*, vol. 2. Nauka, Moscow, pp. 178–180.
- Khosla, A., 1994. Petrographical studies of Late Cretaceous pedogenic calcretes of the Lameta Formation at Jabalpur and Bagh. *Bulletin of the Indian Geologists Association* 27 (2), 117–128.
- Khosla, A., 1996. Dinosaur eggshells from the Late Cretaceous Lameta Formation along the east-central Narmada River region: biomineralization and morphotaxonomical studies. Unpublished PhD Thesis, Panjab University, Chandigarh, India, 197 pp.
- Khosla, A., 2001. Diagenetic alterations of Late Cretaceous dinosaur eggshell fragments of India. *Gaia* 16, 45–49.
- Khosla, A., Sahni, A., 1995. Parataxonomic classification of Late Cretaceous dinosaur eggshells from India. *Journal of the Palaeontological Society of India* 40, 87–102.
- Khosla, A., Sahni, A., 2000. Late Cretaceous (Maastrichtian) ostracodes from the Lameta Formation, Jabalpur Cantonment area, Madhya Pradesh, India. *Journal of the Palaeontological Society of India* 45, 57–78.
- Krause, D.W., Prasad, G.V.R., Koenigswald, W.V., Sahni, A., Grine, F.E., 1997. Cosmopolitanism among Gondwanan Late Cretaceous mammals. *Nature* 390, 504–507.
- Kumar, K., 1983. Palaeontological and palaeohistological investigation of Subathu vertebrates from Jammu and Kashmir and Himachal Pradesh. Unpublished PhD Thesis, Panjab University, Chandigarh, India, 438 pp.
- Kumar, K., Loyal, R.S., 1987. Eocene ichthyofauna from the Subathu Formation, Northwestern Himalaya, India. *Journal of the Palaeontological Society of India* 32, 60–84.
- de Lapparent, J., 1918. Etude lithologique des terrains cre'tace's de la region d' Hendaye. *Memoire pour servir a l' explication de la carte ge'ologique de la France*, 1–115. in French.
- Li, L., Keller, ., 1999. Variability in Late Cretaceous climate and deep waters: evidence from stable isotopes. *Marine Geology* 161, 171–190.
- Ljubimova, P.S., 1956. Ostracodes from the Cretaceous deposits of the eastern part of the Mongolian National Republic and their significance for stratigraphy. *Trudy vses neft nauchno-issled. Geological Razv Institute*, vol. 93, pp. 1–174 (in Russian).
- Loeblich, A.R.J.R., Tappan, H., 1964. *Treatise on Invertebrate Palaeontology; Part C—Protista 2, Sarcodina, Chiefly 'Thecamoebians' and Foraminiferida*, vol. 1 and 2. The Geological Society of America and the University of Kansas Press, Lawrence, pp. 1–900.
- Loyal, R.S., Khosla, A., Sahni, A., 1996. Gondwanan dinosaurs of India: affinities and palaeobiogeography. *Memoirs of the Queensland Museum, Brisbane, Australia* 39 (3), 627–638.
- Loyal, R.S., Mohabey, D.M., Khosla, A., Sahni, A., 1998. Status and palaeobiology of the Late Cretaceous Indian theropods with description of a new theropod eggshell oospecies, *Ellipsoolithus khedaensis*, from the Lameta Formation (District Kheda, Gujarat), Western India. *Gaia* 15, 377–386.
- Lydekker, R., 1890. Notes on certain vertebrate remains from the Nagpur District (with description of a fish skull by A.S. Woodward, F.G.S.). *Records of the Geological Survey of India* 23 (1), 20–22.
- MacLeod, K.G., Huber, B.T., Ducharme, M.L., 2000. Paleontological and geochemical constraints on the deep ocean during the Cretaceous greenhouse interval. In: Huber, B.T., MacLeod, K.G., Wing, S.L. (Eds.), *Warm Climates in Earth History*, Cambridge University Press, Cambridge, pp. 241–274.
- Mahoney, J.J., Sheth, H.C., Chandrasekharam, D., Peng, Z.X., 2000. Geochemistry of flood basalts of the Toranmal section, northern Deccan traps, India: implications for regional Deccan stratigraphy. *Journal of Petrology* 41 (7), 1099–1120.
- Massieux, M., 1977. Sur une nouvelle espece de charophyte du Thane'tien supe'rieur des Petites Pyre'ne'es. *Bulletin de la Socie'te' d' Histoire Naturelle de Toulouse* 113, 289–292.
- Massieux, M., Tambareau, Y., Villatte, J., 1981. Charophytes thane'tiennes et ilerdiennes de la couverture occidentale de Massif de Mouthoumet (Aude). *Ge'ologie Me'diterrane'enne* 8, 1–17.
- Mathur, Y.K., Sharma, K.D., 1990. Palynofossils and age of the Ranipur intertrappean bed, Gaur River, Jabalpur, MP. In: Sahni, A., Jolly, A. (Eds.), *Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata*, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh, pp. 58–59.
- Mohabey, D.M., 1991. Palaeontological studies of the Lameta Formation with special reference to the dinosaurian eggs from Kheda and Panchmahal District, Gujarat, India. Unpublished PhD Thesis, University of Nagpur, 124 pp.
- Mohabey, D.M., 1996. Depositional environments of Lameta Formation (Late Cretaceous) of Nand–Dongargaon Inland Basin, Maharashtra: the fossil and lithological evidences. *Memoir of Geological Society of India* 37, 363–386.
- Mohabey, D.M., 1998. Systematics of Indian Upper Cretaceous dinosaur and chelonian eggshell. *Journal of Vertebrate Palaeontology* 18 (2), 348–362.
- Mohabey, D.M., Udhoji, S.G., Verma, K.K., 1993. Palaeontological and sedimentological observations on non-marine Lameta Formation (Upper Cretaceous) of Maharashtra, India: their palaeontological and palaeoenvironmental significance. *Palaeogeography, Palaeoclimatology and Palaeoecology* 105, 83–94.
- Muller, J., 1968. Palynology of the Pedewan and Plateau Sandstone formations (Cretaceous–Eocene) in Sarwak, Malaysia. *Micropaleontology* 14 (1), 1–37.

- Nash, S., 1981. A neotype for the Cretaceous genus *Pseudotextularia* Rzehak, 1891. Journal of Foraminiferal Research 11 (1), 70–75.
- Officer, C.B., Drake, C.L., 1985. Terminal Cretaceous environmental events. Science 227, 1161–1167.
- Peck, R.E., Reker, C.C., 1947. Cretaceous and Lower Cenozoic charophyta from Peru. Novitates American Museum of Natural History 1369, 1–6.
- Peck, R.E., Reker, C.C., 1948. Eocene charophyta from North America. Journal of Palaeontology 22, 85–90.
- Playford, G., 1971. Palynology of basal Cretaceous (Swan River) strata of Saskatchewan and Manitoba. Palaeontology 14, 533–565.
- Plummer, H.J., 1926. Foraminifera of the Midway Formation in Texas. Texas University Bulletin (2644), 1–206.
- Potonié, R., 1958. Synopsis der Gattungen der *sporae dispersae* II. Teil: Nachträge Sporites, Saccites, Aletes, Praecolpites, Polyplacates, Monocolpates. Beih Geology Jahrbuch 31, 1–114.
- Potonié, R., 1966. Synopsis der Gattungen der *sporae dispersae* IV. Teil: Nachträge zu allen Gruppen (Turmae). Beih Geology Jahrbuch 72, 1–244.
- Prakash, T., Singh, R.Y., Sahni, A., 1990. Palynofloral assemblage from the Padwar Deccan intertrappeans (Jabalpur), MP. In: Sahni, A., Jolly, A. (Eds.), Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh, pp. 68–69.
- Prasad, G.V.R., 1989. Vertebrate fauna from the infra- and intertrappean beds of Andhra Pradesh: age implications. Journal of the Geological Society of India 34, 161–173.
- Prasad, G.V.R., Cappetta, H., 1993. Late Cretaceous selachians from India and the age of the Deccan traps. Palaeontology 36 (1), 231–248.
- Prasad, G.V.R., Godinot, M., 1994. Eutherian tarsal bones from the Late Cretaceous of India. Journal of Palaeontology 68 (4), 892–902.
- Prasad, G.V.R., Khajuria, C.K., 1990. A record of microvertebrate fauna from the intertrappean beds of Naskal, Andhra Pradesh. Journal of the Palaeontological Society of India 35, 151–161.
- Prasad, G.V.R., Khajuria, C.K., 1995. Implications of the infra- and intertrappean biota from the Deccan, India, for the role of volcanism in Cretaceous–Tertiary boundary extinctions. Journal of the Geological Society of London 152, 289–296.
- Prasad, G.V.R., Khajuria, C.K., 1996. Palaeoenvironment of the Late Cretaceous mammal-bearing Intertrappean beds of Naskal, Andhra Pradesh, India. Memoir Geological Society of India 37, 337–362.
- Prasad, G.V.R., Rage, J.C., 1991. A discoglossid frog in the Late Cretaceous (Maastrichtian) of India. Further evidence for a terrestrial route between India and Laurasia in the latest Cretaceous. Comptes Rendus de l'Académie des Sciences Paris 313 (II), 273–278.
- Prasad, G.V.R., Rage, J.C., 1995. Amphibians and squamates from the Maastrichtian of Naskal, India. Cretaceous Research 16, 95–107.
- Prasad, G.V.R., Sahni, A., 1988. First Cretaceous mammal from India. Nature 332, 638–640.
- Prasad, G.V.R., Sahni, A., 1999. Were there size constraints on biotic exchanges during the northward drift of the Indian plate? Proceedings of the Indian National Science Academy 65A (3), 377–396.
- Prasad, G.V.R., Sahni, A., Gupta, V.J., 1986. Fossil assemblages from infra- and intertrappean beds of Asifabad, Andhra Pradesh and their geological implications. Geoscience Journal 7 (2), 163–180.
- Prasad, G.V.R., Jaeger, J.J., Sahni, A., Gheerbrant, E., Khajuria, K., 1994. Eutherian mammals from the Upper Cretaceous (Maastrichtian) intertrappean beds of Naskal, Andhra Pradesh, India. Journal of Vertebrate Palaeontology 14 (2), 260–277.
- Prasad, G.V.R., Khajuria, C.K., Manhas, B.K., 1995. Palaeobiogeographic significance of the Deccan infra- and intertrappean biota from peninsular India. Historical Biology 9, 319–334.
- Rage, J.C., Prasad, G.V.R., 1992. New snakes from the Late Cretaceous (Maastrichtian) of Naskal, India. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 187, 83–97.
- Raju, D.S.N., Ravichandran, C.N., Dave, A., Jaiprakash, B.C., Singh, J., 1991. K/T boundary events in the Cauvery and Krishna–Godavari basins and age of Deccan volcanics. Geoscience Journal 12 (2), 177–190.
- Rana, R.S., 1984. Microvertebrate palaeontology and biostratigraphy of the infra- and intertrappean beds of Nagpur, Maharashtra. Unpublished PhD Thesis, University of Panjab (Chandigarh), India, 234 pp.
- Rana, R.S., 1988. Freshwater fish otoliths from the Deccan Traps associated sedimentary (Cretaceous–Tertiary transition) beds of Rangapur, Hyderabad, District, Andhra Pradesh, India. Geobios 21 (4), 465–493.
- Rana, R.S., 1990. Alligatorine teeth from the Deccan intertrappean beds near Rangapur, Andhra Pradesh, India: Further evidence of Laurasiatic elements. Current Science 59 (1), 49–51.
- Rana, R.S., Sati, K.K., 2000. Late Cretaceous–Palaeocene crocodylians from the Deccan Trap-associated sedimentary sequences of peninsular India. Journal of the Palaeontological Society of India 45, 123–136.
- Rao, K.S., Rao, S.R.N., 1939. Fossil charophyta of the Deccan intertrappean near Rajahmundry, India. Memoir Geological Survey of India, Palaeontologica Indica 29 (2), 1–14.
- Reiss, Z., 1957. Notes on foraminifera from Israel; 3—*Sigalia*, a new genus of foraminifera. Bulletin of Research Country Israel 6b, 239–244.
- Robaszynski, F., Caron, M., Gonzales Donoso, J.M., Wonders, A.H., 1984. Atlas of Late Cretaceous Globotruncanids. Revue du Micropalaeontology 26 (3/4), 305.
- Rzehak, A., 1891. Die foraminiferen-fauna der alttertiären Ablagerungen von Brunderndorf in Niederösterreich, mit Berücksichtigung des angeblichen Kreidevorkommens von Leitersdorf. Annalen des Naturhistorischen Hofmuseums, Wien 6 (1), 1–12. in German.
- Sahni, A., 1983. Upper Cretaceous Palaeobiogeography of the Peninsular India and the Cretaceous–Palaeocene Transition, Proceedings and Symposium on Cretaceous of India, IAP, Lucknow, pp. 128–140.
- Sahni, A., Khosla, A., 1994a. A Maastrichtian ostracode assemblage (Lameta Formation) from Jabalpur Cantonment, Madhya Pradesh, India. Current Science 67 (6), 456–460.
- Sahni, A., Khosla, A., 1994b. Palaeobiological, taphonomical and palaeoenvironmental aspects of Indian Cretaceous sauropod nesting sites. Gaia 10, 215–223.
- Sahni, A., Khosla, A., 1994c. The Cretaceous system in India: a brief overview. In: Okada, H., (Ed.), Cretaceous System in East and Southeast Asia, Research Summary 1994 Newsletter Special Issue IGCP 350, Kyushu University, Fukuoka, Japan, pp. 53–61.
- Sahni, A., Tripathi, A., 1990. Age implications of the Jabalpur Lameta Formation and intertrappean biotas. In: Sahni, A., Jolly, A. (Eds.), Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh, pp. 35–37.
- Sahni, A., Kumar, K., Hartenberger, J.L., Jaeger, J.J., Rage, J.C., Sudre, J., Vianey-Liaud, M., 1982. Microvertebre's nouveau des Traps du Deccan (Inde): mise en évidence d'une voie de communication terrestre probable entre la Laurasia et l'Inde à la limite Cretace'–Tertiaire. Bulletin de la Société Géologique de France 24 (5–6), 1093–1099.
- Sahni, A., Tandon, S.K., Jolly, A., Bajpai, S., Sood, A., Srinivasan, S., 1994. Upper Cretaceous dinosaur eggs and nesting sites from the Deccan-volcano sedimentary province of peninsular India. In: Carpenter, K., Hirsch, K.F., Horner, J.R. (Eds.), Dinosaur Eggs and Babies, Cambridge University Press, New York, pp. 204–226.
- Sahni, A., Venkatachala, B.S., Kar, R.K., Rajanikanth, A., Prakash, T., Prasad, G.V.R., Singh, R.Y., 1996. New palynological data from the Deccan intertrappean beds: implications for the latest record of dinosaurs and synchronous initiation of volcanic activity in India. Memoir Geological Society of India 31, 267–283.
- Sampson, S.D., Krause, D.W., Dodson, P., Forster, C.A., 1996. The premaxilla of *Majungasaurus* (Dinosauria: Theropoda), with implications for Gondwanan paleobiogeography. Journal of Vertebrate Palaeontology 16 (4), 601–605.
- Sati, K.K., 1999. Microvertebrates and associated microfossils from the infratrappan beds of Pisdura and Nand areas of Chandrapur and



- Nagpur districts of Maharashtra. Unpublished PhD Thesis, University of H.N.B. Garhwal (Srinagar, Garhwal), India, 176 pp.
- Sen, G., 2001. Generation of Deccan Trap magmas. *Proceedings of the Indian Academic Sciences, Earth Planetary Sciences* 110 (4), 409–431.
- Sheth, H.C., Duncan, R.A., Chandrasekharam, D., Mahoney, J.J., 1997. Deccan Trap dioritic gabbros from the western Satpura-Tapi region. *Current Science* 72, 755–757.
- Shuvalov, V.F., Stankevitch, E.S., 1977. Late Cretaceous Ostracoda and stratigraphy of Bayshingtoav region in south-eastern Mongolia. In: Tatarinov, L.P., (Ed.), *Mesozoic and Cenozoic Faunas, Floras and Biostratigraphy of Mongolia, Soviet–Mongolian Palaeontological Expedition, vol. 4.*, pp. 112–124, in Russian.
- Singh, R.S., Kar, R.K., 2002. Palaeocene palynofossils from the Lalitpur intertrappean beds, Uttar Pradesh, India. *Journal of the Geological Society of India*, 1–4, in press.
- Spinar, Z.V., Hodrova, M., 1985. New knowledge of the genus *Indobatrachus* (Anura) from the Lower Eocene of India. *Amphibia-Reptilia* 6, 363–376.
- Srinivasan, S., 1991. Geology and Micropalaeontology of Deccan Trap associated sediments of Northern Karnataka, Peninsular India. Unpublished PhD Thesis, University of Panjab (Chandigarh), India, 175 pp.
- Srinivasan, S., Bajpai, S., Sahni, A., 1994. Charophytes from Deccan intertrappean beds of peninsular India: implications for age and correlation of Deccan volcanics. *Geobios* 27 (5), 559–571.
- Stankevitch, E.S., 1974. Ostracoda from Upper Cretaceous deposits of continental water-basins in the northern Gobi (Mongolia). *Problemy Issledovaniya Drevnikh Ozer Evrazii, Leningard*, 57–70.
- Stanley, E.A., 1965. Upper Cretaceous and Palaeocene plant microfossils and Palaeocene dinoflagellates and hystichosphaerids from north Western Dakota. *Bulletin of American Palaeontology* 49 (222), 179–384.
- Szczuchura, J., 1978. Fresh-water ostracodes from the Nemegt Formation (Upper Cretaceous) of Mongolia. *Palaeontologica Polonica* 38 (8), 65–121.
- Szczuchura, J., Blaszyk, J., 1970. Fresh-water ostracoda from the Upper Cretaceous of Nemegt Basin, Gobi Desert. *Palaeontologica Polonica* 21 (2), 107–118.
- Tandon, S.K., Verma, V.K., Jhingran, V., Sood, A., Kumar, S., Kohli, R.P., Mittal, S., 1990. The Lameta Beds of Jabalpur, Central India: deposits of fluvial and pedogenically modified semi-arid fan-palustrine flat systems. In: Sahni, A., Jolly, A. (Eds.), *Cretaceous Event Stratigraphy and the Correlation of the Indian Nonmarine Strata, A Seminar Cum Workshop IGCP 216 and 245, Chandigarh*, pp. 27–30.
- Tandon, S.K., Sood, A., Andrews, J.E., Dennis, P.F., 1995. Palaeoenvironment of the dinosaur bearing Lameta Beds (Maastrichtian), Narmada Valley, Central India. *Palaeogeography, Palaeoclimatology and Palaeoecology* 117, 153–184.
- Tandon, S.K., Andrews, J.E., Sood, A., Mittal, S., 1998. Shrinkage and sediment supply control on multiple calcrete profile development: a case study from the Maastrichtian of Central India. *Sedimentary Geology* 119, 25–45.
- Thiergart, F., 1938. Die pollen flora der Niderlansitzer Braunkohle. *Jahrbuch Preusse Geology* 58, 282–351, in German.
- Tschudy, R.H., 1966. Associated megapores and microspores of the Cretaceous genus *Ariadnaesporites* Potonie', 1956, edmed. US Geological Survey Professional Paper 550, 76–82.
- Van der Hammen, T., 1956. A palynological systematic nomenclature. *Boln Geology Bogota* 4 (2 and 3), 63–101.
- Venkatachala, B.S., Sharma, K.D., 1984. Palynological zonation in subsurface sediments in Narsapur well No. 1, Godavari–Krishna Basin, India. *Proceedings of the X Indian Colloquium on Micropalaeontology and Stratigraphy*, 445–466.
- Venkatesan, T.R., Pande, K., Gopalan, K., 1993. Did Deccan volcanism pre-date the Cretaceous/Tertiary transition? *Earth Planetary and Science Letters* 119, 181–189.
- Venkatesan, T.R., Pande, K., Ghevariya, Z.G., 1996.  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of Anjar traps, western Deccan province (India) and its relation to the Cretaceous–Tertiary boundary events. *Current Science* 70 (11), 990.
- Vianey-Liaud, M., Jain, S.L., Sahni, A., 1987. Dinosaur eggshells (Saurischia) from the Late Cretaceous Intertrappean and Lameta Formations (Deccan, India). *Journal of Vertebrate Palaeontology* 7, 408–424.
- Vianey-Liaud, M., Khosla, A., Garcia, G., 2002. Relationships between European and Indian dinosaur eggs and eggshells of the oofamily megaloolithidae. *Journal of Vertebrate Palaeontology* in press.
- VonHof, H.B., Smit, J., 1997. High resolution late Maastrichtian–early Danian oceanic  $^{87}\text{Sr}/^{86}\text{Sr}$  record: implications for Cretaceous–Tertiary boundary events. *Geology* 25 (4), 347–350.
- Whatley, R., Bajpai, S., 2000a. A new fauna of Late Cretaceous non-marine ostracoda from the Deccan intertrappean beds of Lakshmipur, Kachchh (Kutch District), Gujarat, western India. *Revista Espanola de Micropaleontologia* 32 (3), 385–409.
- Whatley, R., Bajpai, S., 2000b. Further nonmarine ostracoda from the Late Cretaceous intertrappean deposits of the Anjar region, Kachchh, Gujarat, India. *Revue de Micropaleontologie* 43 (1–2), 173–178.
- Widdowson, M., Pringle, M.S., Fernandez, O.A., 2000. A post K–T boundary (Early Palaeocene) age for Deccan-type feeder dykes, Goa, India. *Journal of Petrology* 41 (7), 1177–1194.
- Woodward, A.S., 1901. Catalogue of the fossil fishes in the British Museum. *Britain Museum of Natural History* 38, 1–636.
- Woodward, A.S., 1908. On some fish remains from the Lameta beds at Dongargaon, central provinces. *Memoir Geological Survey of India Palaeontologica Indica (New series)* 3 (3), 1–6.
- Ye, C.H., Gou, Y.S., Hou, Y.T., Cao, M.Z., 1977. Mesozoic and Cenozoic Ostracoda Fauna from Yunnan, Mesozoic Fossils of Yunnan, China, Part II, Nanjing Institute of Geology and Palaeontology, Science Press, Beijing, pp. 153–330, in Chinese.