WERE THERE SIZE CONSTRAINTS ON BIOTIC EXCHANGES DURING THE NORTHWARD DRIFT OF THE INDIAN PLATE?

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Contrary to the geophysical data, which envisaged a long period (about 100 Ma) of physical isolation for the Indian subcontinent during its northward journey, the palaeontological data from the Upper Cretaceous continental sequences (Deccan infratrappean and intertrappean) of peninsular India unequivocally demonstrate the non-endemic nature of the biota with close biogeographic links to the southern as well as northern hemisphere continents. The Myobatrachinae frogs, pelomedusid turtles, titanosaurid and abelisaurid dinosaurs, and Sudamericiidae mammals exhibit distinct Gondwanan relationships. In marked contrast, the pelobatid and discoglossid frogs, anguid lizards, alligatorid crocodiles, palaeoecoid mammals, ostracodes, and charophytes indicate Laurussian connection. The Gondwanan taxa have been considered as representing an immigration event before 80 Ma (time of separation of Madagascar from India) and possibly between 85-90 Ma that facilitated the exchange of fauna between South America and Indo-Madagascar via Antarctica and Kerguelen Plateau. As far as the Laurussian connection is concerned, it has been shown that the size of organisms had a significant control on the biotic exchanges between the Indian subcontinent and the Laurussian landmasses. Only small-sized taxa could participate in the northern biotic interchanges through filter corridor-sweepstakes mode of dispersal involving the Trans-Himalayan Arc, Kohistan-Dras island arc complex and some oceanic volcanic islands which have been destroyed in due course of time at the subduction zone south of the Asian mainland/Trans-Himalayan Arc.

Key Words: Deccan; Lameta/Infratrappean; Intertrappean; Laurussian; Gondwanan; Non-Endemic; Cretaceous; Palaeobiogeography; India

Introduction

The northward drift of the Indian plate and its final collision with Asia has been a subject of considerable debate ever since the plate tectonics concept emerged on the earth science scene. Conventional palaeogeographic maps based on geophysical data have shown that the Indian plate after its break-up from the Gondwanan landmasses in the late Jurassic (about 150-160 Ma ago) and until its collision with the Asian mainland in the Early Eocene (about 55 Ma ago), drifted northwards as an island landmass within the Tethys1-6. Thus the Indian subcontinent was supposed to have remained physically cut off from other continental landmasses for over 100 Ma. The isolation of landmasses for such a long period of time would have a very dramatic effect on constituent populations. Following the continental separation, a progressive genetic isolation of populations would take place and the same would be reflected in morphological divergence over a geologically appreciable period of time. Australia and Madagascar are two such examples. In the light of geophysical data, it had been argued in the past that the mammals did not evolve on the Indian subcontinent7, rather they had immigrated from Asia once a physical contact was established between India and Asia in the Middle Eocene as exemplified by the mammalian fauna of Subathu Formation and subsequently evolved into the modern fauna and flora8. Whether the Indian subcontinent supported an endemic biota or not during its northward migration, particularly during the Late Cretaceous, can only be ascertained by an objective analysis of Late Cretaceous terrestrial fauna and flora as land living organisms are not expected to cross large bodies of sea water.
In the last two decades, focussed palaeontological studies on the Infra- and Inter-Trappean beds of Peninsular India, enhanced our knowledge of Late Cretaceous biota and allowed us to make a reasonable assessment of the Late Cretaceous palaeobiogeography of the Indian subcontinent. The current article is aimed to present a clear picture on the biogeographic links of the Indian subcontinent during the Late Cretaceous period by presenting some new insights in conjunction with a synthesis of earlier works. In the following sections, an account of various continental Late Cretaceous sequences of India, their fossil content and biogeographic relationships, and possible dispersal routes is given.

**Continental Upper Cretaceous Sequences of Peninsular India**

The continental Upper Cretaceous sediments have a wide geographic distribution in peninsular India spread across the political boundaries of eight states and occur either as thick sequences (<50 m) beneath the Deccan basaltic flows (infra-trappean/Lameta Formation) or as thin sedimentary strata (<5 m) sandwiched between the basaltic flows (intertrappean beds) (Fig. 1). The distribution of Infra and Intertrappean beds follows the outcrop pattern of Deccan Traps and their exposures are found on the western, eastern, northern, southern, and central parts of the Deccan volcanic province. Besides, continental vertebrate yielding Upper Cretaceous strata (Kallamedu Formation) are also known from distinctly shallow marine sequences of Tiruchirapalli District, Tamil Nadu.

The Infra-trappean (Lameta) sediments are primarily represented by sandstones, shales, limestones, mudstones, and siltstones, whereas the intertrappean beds consist of sandstones, cherts, cherty limestones, shales, mudstones, siltstones and marls. The Kallamedu Formation is predominantly represented by thick sandstone with subordinate clays and sandy clays. Some of these clay horizons have recently been identified as vitric tuff beds. Based on palaeontological evidences from the Infra and Intertrappean beds and geochrono-logical and paleomagnetic data from the Deccan basaltic flows, a Maastrichtian age for the Infra- and Intertrappean beds and a short duration of about 4 Ma for Deccan volcanism has been suggested.

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![Fig. 1 Sketch map showing the location of continental Upper Cretaceous fossil-yielding sites in peninsular India.](image-url)
The Ottakoval and Kallamedu Formations, which overlie Globotruncanana gansseri bearing Kallankurichchi Formation, have been considered as Late Maastrichtian in age. The faunal and floral list of the Infra- and Intertrappean beds and the Kallamedu Formation is given below.

**Lameta Formation**

The important localities from which the fossils have been recovered include Jabalpur, Pisdura-Dongargaoa-Nand, Rahiolis, and Marepalli-Auspalis.


**Intertrappean beds**

The most promising fossiliferous intertrappean localities are Gurmatal, Naskal, Rangapur, Asifabad, Nagpur, Bombay, Padwar, Ranipur, Anjara, and Mamoni.


**Kallamedu Formation**

A few poorly preserved bones and a tooth of a dinosaur were first reported by Blanford from Kallamedu village, Timichirappalli District, Tamil Nadu. These fossils were referred to Megalosaurus. Following this, Matley documented fragmentary limb and girdle bones from the same locality and assigned them to Titanosaurus sauropod and an unidentified stegosaur. Yadagiri et al. made some new collections of dinosaur bones from the Kallamedu Formation which included ilium, pubis, ischium, femur and tibia of a theropod dinosaur and a humerus, armour plates and a coracoid bone of a supposed stegosaur dinosaur. However, Chatterjee & Rudra doubted the presence of stegosaurian remains in the Kallamedu collection.

**Biogeographic Relationships**

Since only non-marine taxa are useful in understanding the contiguity or isolation of landmasses in the geological past, exclusively those Infra and Intertrappean taxa which have some biogeographic value are taken into account. The most important taxa from biogeographic point of view are lepisosteid and osteoglossid fishes, leptodactylid, pelobatid and discoglossid frogs, pelomedusid turtles, anguid lizards, alligatorid crocodiles, titanosaurid, abelisaurid, and ankylosaurid dinosaurs, palaeeoryctid and sudamericid mammals, ostracodes, and charophytes.
**Fishes**

The genus *Lepisosteus* is widely known from the Intrarapannae as well as Intertrapannae beds. Seven living species of gar fishes are confined to Central America, the Caribbean, and south-eastern North America. In the Cretaceous, the lepisosteids had a widespread distribution with fossil records from the Early Cretaceous of Niger and Congo, the Campanian/Early Maastrichtian Los Alamitos Formation, Upper Cretaceous Adamantina and Marilia Formations of Upper Bauru Group of Brazil, Upper Cretaceous rocks of Colombia, Upper Cretaceous (Maastrichtian) El Molino Formation of Bolivia, Albian Paluxy Formation, north-central Texas, Upper Cretaceous Lance Formation, Wyoming, Upper Cretaceous (Campanian) Blufftown Formation, Western Georgia, and Upper Cretaceous of India. In the Indian subcontinent, the gars had persisted into the early Middle Eocene (Kuldana Formation) of Pakistan. More recently, Gottfried & Krause reported *Lepisosteus* sp. from the Upper Cretaceous (Campanian) Maeverano Formation, Mahajanga Basin, Madagascar. Because of the wide geographic distribution of gars in the Cretaceous, it is assumed that this group must have evolved by the beginning of the break-up of Pangaea and had a Pangean distribution in the late Mesozoic.

The Intrarapannae osteoglossid fishes are known by squamules, whilst the Intertrapannae osteoglossids are represented by squamules, dental plates, and otoliths. Besides these reports, dental plates and squamules of these fishes have also been described from the Middle Eocene Subathu Formation, Kalakot, India. Similar fossils are also known from the early Middle Eocene Kuldana Formation, Pakistan. So far, the osteoglossomorph fishes have been recorded from the Aptian Araceo Formation, Brazil, Maastrichtian of Niger, Bolivia, Palaeocene Santa Lucia Formation, Tuipampa, Bolivia, Palaeocene of Australia and Europe, Late Palaeocene of Turkey, Eocene of Sumatra, marine Ypresian of Morocco. From the northern continents, the osteoglossids have been reported from the Upper Jurassic - Lower Cretaceous Guyang Formation of Guyang Basin, Inner Mongolia and Madongshan Formation, Liupanshan Group, Ningxia, North China, Upper Cretaceous (Campanian) Oldman Formation of Alberta, Canada, Palaeocene Paskapoo Formation of Alberta, Canada, the Eocene of North America, and the Middle Eocene Klondike Mountain Formation, Washington. Nelson hypothesised a Gondwanan (African) origin for OstegoGLOSSomorpha. Tavenor also arrived at a similar conclusion, but the attribution of Chinese *Lycoptera* to Hiodontiformes compelled Patterson to suggest East Asia (China-Mongolia) as the centre of origin for osteoglossomorphs. However, the widespread distribution of fossil osteoglossomorphs on the northern and southern continents points towards a possible cosmopolitan distribution of this group at the end of Mesozoic Era.

**Amphibians**

The fossil frog *Indobatrachus pusillus* reported from the Intrarapannae beds of Bombay is the only known fossil of the subfamily Myobatrachinae (Family Leptodactylidae) with extant members inhabiting Australia and New Guinea. *Indobatrachus* has been considered as a descendant of an older protodiscoglossid ancestor that reached India from a South American centre through northern Antarctica and South Africa.

In marked contrast to the Gondwanan relationship of *Indobatrachus*, two other families of frogs-Discoglossidae and Pelobatidae-described from the Intrarapannae beds of Naskal and Nagpur, respectively, indicate distinct Laurasian affinities. Mohabey & Udhoji have briefly mentioned the occurrence of Pelobatidae in the Upper Cretaceous Lameta sediments of Nand area. Since no descriptions or illustrations have been provided, the identification of Lameta pelobatids needs to be authenticated. The living members of the family Discoglossidae reside in Europe (*Discoglossus*, *Bombina*, *Alytes*, *Baleaephyrne*), Middle East (*Discoglossus*), North-western Africa (*Discoglossus*, *Alytes*), Asia (*Bombina*), and Southeast Asia (*Barbourula*). The fossil record of discoglossids is biased towards Laurasia with known occurrences from the Middle Jurassic of England (*Eodiscoglossus oxionensis*), Upper Jurassic (*E. sanjoniae*), and Hauterivian-Barremian (*Wealdenbattrachus juicarenis*) of Spain, Albion of Texas, Late Turonian-Coniacian of Asia (*Gobiates*, *Kizykuma antiqua*, *Aralobatrachus robustus*, *Saevesoederbergia egredia*, *Procobatrachus poulus*, *Estesina*).
elegans\textsuperscript{108}, Upper Cretaceous of Montana (Scotiophyrose \textit{pustulosa})\textsuperscript{109}, \textit{Paradiscoglossus americanus}\textsuperscript{110}, Spain\textsuperscript{111}, Baja California (Scotiophyrose)\textsuperscript{110}, Middle Palaeocene Tongue River Formation, Montana (cf. \textit{Scotiophyrose})\textsuperscript{112}, Upper Palaeocene of Cernay, France\textsuperscript{113}, and Miocene of North Caucasus.\textsuperscript{114} In the absence of a dorsal crest and in the development of dorsal tubercle and postero-dorsal extension of supra-acetabular expansion, the discoglossid ilia from the Intertrappean beds of Naskal resemble those of extant genus \textit{Atytes} and the Coniacian-Santonian discoglossid ilia from Uzbekistan\textsuperscript{108}. The extant and extinct members of the family Pelobatidae follow the same distribution pattern as the discoglossids except for the fact that the fossil record of the former group is known from the Cretaceous and living pelobatids also occur in North America. The pelobatids are known from the Upper Cretaceous rocks of Asia (\textit{Eopelobates leptocopa}l\textit{tus})\textsuperscript{115}, \textit{E. sosedkoli}\textsuperscript{116} and North America (\textit{Eopelobates sp.})\textsuperscript{117}, Middle Eocene of Europe (\textit{E. hinschii}), Oligocene of Asia (\textit{Macropelobates})\textsuperscript{118}, Lower Oligocene of South Dakota (\textit{E. grandis})\textsuperscript{119}, Upper Oligocene or Lower Miocene of Czechoslovakia (\textit{E. bayeri})\textsuperscript{119}, and Lower Miocene of Germany (\textit{E. anthracicus})\textsuperscript{120}.

The fossil record is, however, silent on the time of immigration of pelobatids and discoglossids from Eurasia to NW Africa, a small territory of which houses some living members of these groups. Recently, Asher & Krause\textsuperscript{121} indicated the presence of doubtful pelobatid frog remains in the Upper Cretaceous rocks of Madagascar if this identification is confirmed with additional well preserved material in future, our current view on the distribution of this group needs a revision. Prasad & Rage\textsuperscript{122} reported a humerus and ilium with morphology reminiscent of the family Hylidae from the Intertrappean beds of Naskal. Because of the poor state of preservation, these authors did not commit on the hylid assignment of these specimens. Before this find, hylids were definitively known from the Lower Oligocene of Canada\textsuperscript{122} and probably from the Middle Palaeocene of Brazil\textsuperscript{123}.

**Lizards**

Several vertebrae with morphology reminiscent of \textit{Anguis} (subfamily Annielinae) and \textit{Anniella} (subfamily Anniellinae) represent the lizard family Anguidae in the intertrappean fauna.\textsuperscript{124} Estes\textsuperscript{125} advocated a Laurasian (North American) origin for anguid lizards. Until now, the oldest anguid lizard has been reported from the Campanian of North America (\textit{Odaxosaurus})\textsuperscript{124}. In Asia, this group is known from the Upper Cretaceous Dajochotha Formation (\textit{Isodontosaurus gracilis})\textsuperscript{125}, Upper Eocene rocks of Mongolia (\textit{Placosaurus mongoliensis})\textsuperscript{126,127} and from China\textsuperscript{128} (\textit{Placosaurus sp.}). In Europe also, the members of this family first appear in the fossil record of Lower Eocene deposits (\textit{Campinosaurus woutersi})\textsuperscript{128}. The extant taxa of Anguidae occur in North America, Europe, Asia, North Africa, West Indies and South America.

**Turtles**

Pelomedusid turtles have been recorded from both \textit{Infra} (\textit{Schweboemys psidurensis})\textsuperscript{7,129} and Intertrappean beds (\textit{Schweboemys psidurensis}, \textit{S. leithii})\textsuperscript{130}. Drou\textsuperscript{131} was of the opinion that the Indian pelomedusids represent \textit{Schweboemys-Stereogenys} group of Podocnemidinae, a branch of common African-South American pelomedusid trunk, which persisted on the Indian subcontinent in isolation and had given rise to several post-Cretaceous pelomedusids. Hence the Indian pelomedusids may be considered as part of a Gondwanan stock that boarded the Indian plate before its separation from Africa contrary to the cosmopolitan distribution favoured for this group by Krause & Hartman\textsuperscript{132}.

**Crocodiles**

Dental remains of crocodiles referable to the family Alligatoridae are known to occur both in the Infra\textsuperscript{20} and Intertrappean beds.\textsuperscript{36,75} The fossil record shows that Alligatoridae is a Laurasian group with distribution in the Upper Cretaceous-Pliocene of Europe, Palaeocene, Miocene, and Recent of Asia, and Upper Cretaceous-Recent of North America. The most important fossil finds are from the Upper Cretaceous Oldman Formation, Canada (\textit{Albertochampsia langstoni)}, Hell Creek Formation, Montana, U.S.A. (\textit{Brachychampsia montana})\textsuperscript{133}, Upper Cretaceous of Europe\textsuperscript{134}, Palaeogene of North America (\textit{Allognathosuchus, Ceratosuchus}), China (\textit{Eoalligator})\textsuperscript{133}. Extant members of this group also inhabit North America and China.
Dinosaurs

Large bones belonging to titanosaurid (Titanosaurus indicus, T. blanfordi, T. colberti, T. madagascarense), abelisaurid (Indosuchus raptorus, Indosaurus matleyi), and possibly ankylosaurid (?Lametasaurus indicus) dinosaurs and sauropod and ornithopod eggs are known from the Lameta Formation, whereas few isolated bones, teeth and egg shells occur in the intertrappean beds. The Lameta titanosaurid eggs closely resemble those of France and Spain. Jain and Bandyopadhyay considered *Antarctosaurus septentrionalis* reported from the Lameta beds of Jabalpur as a junior synonym of *Titanosaurus indicus*. Similarly, *Laplataasaurus madagascarense* has also been transferred to *Titanosaurus madagascarense*. The titanosaurid dinosaurs have previously been reported from the Early and Late Cretaceous of Niger, Albion of Malawi (*Malawisaurus dixeyi*), Cenomanian of Egypt (*Aegyptosaurus*), and Sudan. Turonian and Santonian of Kenya, Albion-Cenomanian of Argentina (*Andesaurus delgadoi*), Upper Cretaceous rocks of Argentina and Uruguay (*Titanosaurus, Antarctosaurus, and Laplataasaurus*), *Saltasaurus loricatus*), Bauru Group of Brazil, and Madagascar (*Titanosaurus madagascarense*). Lower and Upper Cretaceous of South Africa and Upper Cretaceous of Morocco. Upper Cretaceous rocks of Fontllonga, Spain, Upper Cretaceous of Provence, southern France (*Titanosaurus indicus*), Spain (*T. indicus*), and Transylvania, and Late Maastrichtian of southwestern U.S.A. (*Alamosaurus*).

Similarly Abelisaurids have so far been recorded from the Albain (*Carnotaurus sastrei*), Senonian (*Xenotarsosaurus bonapartei*) and Early Maastrichtian (*Abelisaurus comahuensis*), Patagonia, Campanian Maevarano Formation of Madagascar (*Majungasaurus crenatissimus*), Upper Cretaceous Bauru Group of Brazil, Late Cretaceous of France (*Tarbosaurus bataaricus*), and Spain. Sampson et al. considered *Majungasaurus crenatissimus* from the Campanian of Madagascar as a sister taxon of *Indosuchus raptorius* of the Upper Cretaceous Lameta Formation (India). On the whole, the Upper Cretaceous titanosaurid and abelisaurid dinosaurs of India compare well with those of South America, Madagascar, and southern Europe.

Although megalosaurs have been reported from the Kallamedu Formation and the intertrappean beds, nothing can be said about their biogeographic relationship as the fossils are either fragmentary in nature or represented by isolated teeth. Moreover, the referral of isolated theropod teeth from India to "*Megalosaurus*" is based on close morphological similarity to "*Megalosaurus crenatissimus*" of Upper Cretaceous of Madagascar. But more recently, "*Megalosaurus crenatissimus*" has been transferred to *Majungasaurus crenatissimus*, associated with family Abelisauridae. Therefore, the presence of "*Megalosaurus*" in the Upper Cretaceous rocks of India is not firmly established.

The fossil record of titanosaurids and abelisaurids demonstrates that these two groups were dominant in the dinosaur fauna of the Gondwanan continents and were either absent or played a subordinate role to the hadrosaur, ceratopsian, and tyrannosaurid dominated fauna of Laurasia. There is nothing unusual about their occurrence in southern Europe as many faunal interchanges are supposed to have taken place between NW Africa and Iberia via Alboran and Apulian microplates during Late Cretaceous low sea levels. The presence of ziphodont mesosuchian crocodiles with close relationship to the South American and African Late Cretaceous trematochampsids in the European Ecocene has also been linked to this episode of faunal exchanges. Gheerbrant also invoked a Late Cretaceous/Early Tertiary episode of faunal interchange to explain the presence of Laurasian palaeocryptids in the Palaeocene of Morocco. Likewise, Bonaparte & Kielan-Jaworowska considered the occurrence of titanosaurid sauropods in the south-western U.S.A. as an evidences in support of Late Cretaceous faunal interchange with South America. Besides titanosaurids and abelisaurids, ankylosaurid remains have been documented from the Lameta sediments of Rahaol, but no descriptions or illustrations have been provided by these authors. The referral of *Lametasaurus indicus* from the Lameta beds of Jabalpur to ankylosaurs has been doubted. Even if their existence in the Late Cretaceous of India is established, ankylosaurs are of little biogeographic significance as this group of dinosaurs are known to occur in both Gondwanan and Laurasian landmasses. Baijai et al. described ornithoid egg shells with close affinities to Laevisoolithidae.
and Subtilolithidae families of Late Cretaceous Nemegt Formation, Mongolia from the intertrappean beds of Anjar.

**Mammals**

Until now, two groups of mammals - Palaeoryctidae and Sudamerididae have been documented from the Intrapreppean beds of India\(^{34,42-43,46,165}\). Palaeoryctidae is a Laurasian family of insectivore mammals with widespread distribution in the Upper Cretaceous-Palaeocene rocks of North America\(^{166-167}\) and the Upper Cretaceous strata of Mongolia\(^{168}\), and Cenomanian, Turonian, and Coniacian deposits of Uzbekistan\(^{169}\). The Indian Late Cretaceous palaeoryctid mammals (Deccamolestes hislop and D. robustus) are closer to North American Cimolestes and Procerberus in certain derived characters. The palaeoryctid mammals (Cimolestes, Palaeoryctes, Aboletyles) have also been recorded from the Upper Palaeocene (Thanetian) Adrar Mgorn locality, Ouarzazate Basin of Morocco\(^{166,167}\). Briggs\(^{172}\) misquoted Prasad and Sahn\(^{134}\) to show that a close relationship exists between the Moroccan and Indian palaeoryctids. Therefore, it needs to be stressed here that the Moroccan palaeoryctids compare with those of India in primitive characters only and no phylogenetic relationship has been established between the two. The Moroccan forms are supposed to have immigrated from North America via Southern Europe at about the Cretaceous-Tertiary boundary\(^{159}\). Krause et al.\(^{46}\) described a highly specialised group of mammals (Sudamerididae, Gondwanatheria) from the Upper Cretaceous (Campanian) Maevaran Formation of Madagascar and the Upper Cretaceous Intertrappean beds of Naskal in peninsular India. The gondwanatheres are multituberculate or multituberculate-like mammals previously known from the Late Cretaceous and Palaeocene of Argentina\(^{173}\).

Absence of gondwanatheres in other Gondwanan continents has been cited to show that these mammals are endemic to South America\(^{173}\). The latest reports from Madagascar and India refute this view and instead favour cosmopolitan distribution for this group of mammals in Gondwanan continents facilitated by biogeographic links between South America and Indo-Madagascar through Antarctica and Kerguelen Plateau\(^{46}\).

**Ostracodes**

The Intrapreppean non-marine ostracode assemblage includes many forms, such as Mongolicypris cf. M. gigantea, Altanicypris bhatiai, Eucypris sp., Candonia altamulaensis, Cyclucypris transitoria, Mongolianella palmosa, and ?Cypridopsis bugintisavica, similar to the Upper Cretaceous ostracode assemblage IV of Sifangtai and Mingshui Formations of Singliao Basin\(^{79}\).

The other members of the Lameta assemblage also exhibit close resemblance to contemporaneous fauna from Mongolia and China. The Lameta Eucypris is very close to Eucypris bugintisavica known from the Upper Cretaceous rocks of Bayshingtoav region of southeastern Mongolia, whereas Candonia cf. C. hubiensis approaches in its morphology the Upper Cretaceous C. hubiensis of Central Hubei, China\(^{15}\). Besides these taxa, Frambocythere tumiensis tumiensis, which has also been recorded from the intertrappean beds, was first recorded from the Upper Cretaceous of Spain and subsequently its other subspecies from the Montian of Belgium\(^{38}\). Likewise, the intertrappean ostracode fauna, which is remarkably similar to that of Lameta Formation, consists of many species, such as Candonia altamulaensis, C. bagmodica, Candoniella altanica, Altanicypris secechurae, Talicypridea bifomata, Cypridea cavernosa, ?Cypridopsis bugintisavica, Mongolianella palmosa, and M. khamariniensis, which are common to that of Upper Cretaceous Nemegt Formation of Mongolia\(^{38}\).

This assemblage is also identical to Talicypridea-Cypridea-Candonia assemblage from the Campanian-Maastrichtian Wangshi Group and from the Upper Cretaceous管理条例 Group, Southern Sichuan and northern Guizhou Provinces, China\(^{38}\). Similarly, Mongolicypris longa, Mongolianella khamariniensis, Candonia henaensis, Cypridea cavernosa, and Talicypridea sp. present in the intertrappean fauna were first documented from the Upper Cretaceous strata of Xining and Minhe Basins of China\(^{175}\). Paracandonia jabalpreensis of the Lameta Formation and Leiria jonesi and Cytheridella strangulata of the Intertrappean beds have been considered endemic species to peninsular India\(^{38}\).

However, according to these authors, the genus Leiria has wide distribution in the Late Mesozoic rocks of Europe and Asia. Similarly, Paracandonia is also known from the Late Cretaceous of Belgium (Paracandonia belgica)\(^{176}\). Timiriasevia and
Bisulocypris reported from the Intertrappean beds of Gurmatkal range from Jurassic to Late Cretaceous in age and may have cosmopolitan distribution. The latter genus has recently been documented from the Lameta sediments of Nand-Dongargaon area. Therefore, the freshwater ostracode fauna of the Infra and Intertrappean beds exhibits taxonomic relationship not only at generic level, but also overwhelmingly at species level to the Upper Cretaceous ostracode assemblages of Nemegt Basin, Mongolia and several inland lacustrine basins of China.

Charophytes

Bhatia et al. and Srinivasan et al. discussed the biogeographic affinities of the Intertrappean charophytes. According to these authors, Platychara rauoi, P. sahni, and P. rajahmundry are endemic to India. The genus Platychara is abundant in the Late Cretaceous lacustrine deposits of North America, Europe, South America, and possibly China. The genus Platychara perlata with known distribution from the Upper Cretaceous to Palaeocene of South America and Mexico is a cosmopolitan taxon. In contrast P. compressa has been recorded from the Upper Cretaceous to Palaeocene of U.S.A., Canada and Europe. The genus Peckichara occurs in the Maastrichtian of France and Spain, but its species P. varians has so far been documented from the Palaeocene - Early Eocene of Europe. Correspondingly, Harrisichara muricata and Stephanochara levis are confined to the Palaeocene of Europe (France and Belgium), but at generic level Harrisichara has been reported from the Upper Cretaceous rocks of Nemegt Basin, Mongolia. Similarly Grambastichara sp. is also comparable to Grambastichara bailanteensis described from the Cretaceous-Tertiary transitional sequences of the Shalamulim area of inner Mongolia. Bhatia et al. described a new species of Nemegtichara (N. grabasti) from the Intertrappean beds of Rangapur. This genus was first documented from the Palaeocene-Eocene rocks of Nemegt Basin, Mongolia and later on from the Turonian - Maastrichtian - Palaeocene - Eocene sequences of China. Similarly, the genus Microchara has a junior synonym in Gobichara reported from the Palaeocene of Mongolia.

From the foregoing discussion, it is apparent that the Infra and Intertrappean fossil assemblages do not indicate any marked endemism, rather they exhibit either Laurasian or Gondwanan connections. The Myobatrachinae frogs, pelomedusid turtles, titanosaurid and abelisaurid dinosaurs, and sudamerid mammals demonstrate Gondwanan affinities, whereas pelobatid and discoglossid frogs, anguid lizards, alligatorid crocodiles, palaeoryctid mammals, ostracodes, and charophytes suggest a Laurasian connection. So far, the strongest evidence for the Late Cretaceous Laurasian connection for India is offered by the ostracode fauna which includes many taxa identical at generic and even species level to those of Mongolia and China. On the other hand, the lepisosteid and osteoglossid fishes, and ankylosaurid dinosaurs had cosmopolitan distribution in the Late Cretaceous.

Possible Biogeographic Connections

There has been a general agreement among the palaeontologists and geologists on the non-endemicity of biota in the northward drifting Indian plate. However, a notable difference of opinion continues to prevail concerning the possible dispersal routes for the biotic interchanges. The presence of Gondwanan and Laurasian elements in the Late Cretaceous of India has been accounted in markedly different ways by different workers. Sahni and Sahni et al. discussed the entire gamut of Late Cretaceous faunal exchanges between Africa-India-Asia and came to the conclusion that Gondwanan taxa might have reached the Indian plate via Mascarene Plateau, Chagos and Laccadive ascismic ridges of the Indian Ocean. These authors also favoured dispersal of Laurasian taxa into India through Iran-Afghanistan microplates and Kohistan-Dras island arc systems that lay north of Greater India. But Chatterjee discounted the model suggested for the southern connection on the grounds that these volcanic island chains came into existence only from Tertiary to Recent times.

Alternatively, Briggs made an attempt to explain strong relationships of the Indian Late Cretaceous fauna and flora with those of Africa and Laurasia. He concluded that by Early Cretaceous India was isolated from Africa and Madagascar, and by Middle Cretaceous, it had moved close to North Africa (Somali peninsula); or alternatively it occupied the gap between Northeast Africa and
Eurasia, which facilitated a dispersal route involving a direct connection from India to North Africa and with an intermittent or sweeps stochastic passage across the Tethys to Eurasia. A somewhat similar conclusion was arrived at by Chatterjee\textsuperscript{183} to explain the African elements in the Late Cretaceous (65 Ma ago) of India. According to him, in the Late Cretaceous Karachi was adjacent to Socotra microcontinent at the northeast tip of Somalia and a greater part of south-western Arabia was emergent forming a dispersal corridor between India and Africa for terrestrial vertebrates. Regarding the Laurasian taxa, he suggested that the central part of Afghanistan (Dasht-i-Margo block) along with east central Iran (Lut block) formed a large microcontinent that maintained a land connection with Eurasia in the north and a dispersal corridor with Greater India through Kashmir region. The models advocated by Briggs\textsuperscript{172} and Chatterjee\textsuperscript{183} for the African connection of the fauna are not acceptable as the palaeogeographic reconstructions show that the Indian subcontinent was widely separated from Africa, moving in a northeastward direction during the Late Cretaceous period\textsuperscript{4,184-187}.

Krause & Maas\textsuperscript{188} maintained that the Indian subcontinent was adjacent to the eastern margin of Madagascar prior to magnetic anomaly 33b (Campanian) and Africa was faunistically linked with Madagascar at this time. These authors hypothesised that one or more groups of placental mammals boarded the Indian subcontinent in the Late Cretaceous from eastern Africa via Madagascar followed by a period of isolation during the Palaeocene when the Indian plate was drifting northeastswards through the Tethys. During this period of isolation, many groups of mammals, such as the Artiodactyla, Perissodactyla, Adapidae, Omomyidae, Hyaenodontidae and Anthracobunidae, had developed endemic taxa as evident from the Middle Eocene Kuldana and Domanda Formations of Pakistan and the Upper Subathu Formation of India. Contrary to most mammalian palaeobiogeographic reconstructions, which favoured mammalian immigrations from Central Asia to India after subaerial contact was established between India and Asian mainland in the early Eocene, Krause & Maas\textsuperscript{188} suggested that the dispersals were from India to Asia. This palaeobiogeographic model implies that the placental mammal Deccanolestes from the Upper Cretaceous Intertrappean beds was an immigrant from the African mainland via Madagascar. Besides immigrants, we cannot rule out the indigenous evolution of mamnals in the Mesozoic of India in the light of recent discoveries of triconodont mammals from the Upper Triassic\textsuperscript{189} and Lower Jurassic\textsuperscript{190} deposits of peninsular India. One of the author’s (GVRP) ongoing work on the early Jurassic mammals of India indicates much more diversity and the presence of euptothoerines cannot be ruled out. In a more recent paper, Krause \textit{et al.}\textsuperscript{46} justified the occurrence of highly derived Late Cretaceous South American mammal (Sudamericidae) in both India and Madagascar by invoking a late early Cretaceous (88-90 Ma) dispersal route from South America to India-Madagascar through Antarctica and Kerguelen Plateau which might have lasted as late as 80 Ma. The same biogeographic link might have been used by other Gondwanan elements, such as titanosaurid and abelisaurid dinosaurs, to make their appearance in the Late Cretaceous of India.

Contrary to the palaeobiogeographic models proposed by Briggs\textsuperscript{172} and Krause and Maas\textsuperscript{188}, Jaeger \textit{et al.}\textsuperscript{191} based on lack of significant endemism and the occurrence of Laurasian pelobatid frogs, palaeornithid mammals, and Mongolian charophytes in the Late Cretaceous of India, advanced a new hypothesis suggesting that the Indian subcontinent was close to Asia at the end of Cretaceous that facilitated the dispersal of non-marine biota across ephemeral land routes. The early India/Asia collision (Cretaceous/Tertiary boundary age) concept of Jaeger \textit{et al.}\textsuperscript{191} received an added impetus from the subsequent discoveries of alligatorid crocodiles\textsuperscript{30,75}, discoglossid frogs\textsuperscript{39}, anguid lizards\textsuperscript{44}, ostracodes\textsuperscript{38,59}, and charophytes\textsuperscript{31,37} of typical Laurasian affinity from the infra and intertrappean beds of peninsular India. Sahni and Bajpai\textsuperscript{192} and Prasad \textit{et al.}\textsuperscript{193} also favoured the early India/Asia collision model to account for the existence of Eurasian elements in the Late Cretaceous of India. Prasad \textit{et al.}\textsuperscript{193} while discussing the palaeobiogeographic significance of the Infra and Intertrappean biota observed that the Intertrappean biota have Gondwanan affinity possibly representing relics from former Gondwanaland, whereas the Intertrappean biota exhibit distinct Laurasian affinities. Based on the absence of Laurasian taxa in the Intertrappean beds, they concluded that the physical contact
between India and Asia was not achieved by the
time of deposition of Infracribrannian sediments. But
more recent works have shown that the
Infracribrannian biota also contains many Laurasian
elements, for instance ostracodes, charophytes,
alligatorid crocodiles, and a doubtful pelobatid
frog. Additional and more important evidence for
the early India/Asia collision model was
furnished by palaeomagnetic studies of southern,
central and northern parts of Ninetyeast Ridge in
the Indian Ocean. According to these authors,
Greater India was extended 650 km beyond the
present day outline of Northern Kohistan Suture
and Greater India's north-western margin crossed
the equator at or before 65 Ma and arrived in the
equatorial to low northern latitude belt. Further,
they concluded that reduction in the rate of India's
northward movement at 55 Ma coincides with
reduction in the spreading rate of the central Mid-
Indian ridge at magnetic anomaly MA24 and this
slow down in India's northward motion was taken
for completion of eastward propagating India/Asia
suturing process. Klootwijk et al. arrived at a
similar conclusion based on the palaeomagnetic
data from the Chitral region (Eastern Hindukush).

The Late Cretaceous-Early Tertiary India/Asia
collision model of Jaeger et al. was questioned
by some workers on the grounds that the
evidences from pelobatid and discoglossid frogs,
and palaeoryctic mammals are inadequate for
establishing a direct northern contact with Asia in
the Late Cretaceous. Rather they favoured the
traditionally accepted Early Eocene age for
achieving a definite subaerial contact between
India and Asia. Although some doubts have been
raised by these authors on the identifications of
anuran remains with Pelobatidae and Discoglossidae families, Rage and Jaeger convincingly defended the earlier taxonomic treatment of these taxa. According to Thewissen & McKenna and McKenna, the Lameta pelobatids might have reached the Greater India from Africa when the
former landmass maintained a connection with
Seychelles Block or the Horn of Africa on the west
or northwest via now destroyed island arcs or
Deccan basaltic pile itself. A somewhat similar
explanation has also been forwarded for the
Intertrappean Deccanolestes, in view of the
occurrence of palaeoryctic mammals in the Late
Palaeocene of Morocco and a primitive
therian mammal (Tribotherium africanum) with
alleged close relationship to Prokennalestes of
Mongolia in the Early Cretaceous of Morocco.
Contrary to McKenna's conclusion, no close
phylogenetic relationship has been shown to exist
between Tribotherium and the Early Cretaceous
Prokennalestes. Moreover, the current plate
kinematic reconstructions showed a wide body of
marine water separating the Greater India from
Africa throughout the former's northward
migration until its collision with mainland Asia.
Owing to these reasons, the palaeobiogeographic
models favouring a western connection for Greater
India with Africa are not sustainable. Further, it
needs to be emphasised that contrary to the views
held by Thewissen & McKenna and Krause &
Hartman, the fossil taxa of Laurasian affinities in
the Infra and Intertrappean beds include not only
anurans and mammals, but also anguid lizards,
alligatorid crocodiles besides the most important
ostracode and charophyte assemblages. In fact, the
ostracodes are identical to those of Upper
Cretaceous deposits of Mongolia and China even at
species. These fossil groups have been completely
overlooked by the above authors in their
biogeographic analysis of Late Cretaceous biota of
India.

In the light of existing fossil data from Africa,
the early India/Asia collision model of Jaeger et al.
appears highly attractive as it provides the
best possible explanation for the Laurasian taxa in
the Late Cretaceous of India. However, we cannot
ignore the fact that the fossil record of Africa is
incomplete and extensive field prospecting is
needed before arriving at meaningful
biogeographic conclusions. Moreover, conflicting
opinions exist on the date of initiation of collision
between India and Asia. Patriat and Achache postulated that the initial collision between India
and Asia took place at about 52-50 Ma ago as
inferred from the dramatic reduction in the
northward movement of Indian plate at this
time. Contrary to the palaeomagnetic results of
Klootwijk et al. which envisaged completion of
suturing along the entire Himalayan chain by 55
Ma after the collision being initiated around 65 Ma
ago, new structural and sedimentological data from
Zanskar shelf area favour a relatively younger age
for India/Asia collision. Searle et al. based on
structural and stratigraphic studies of the northern
continental margin of India, came to the conclusion
that all the ophiolitic belts along the northern
Indian plate margin were emplaced on this margin during the Late Cretaceous or at the Cretaceous-Tertiary boundary. Following the ophiolite obduction phase, stable shallow marine conditions prevailed not only along the Zanskar shelf, but also all along the Indus suture. As per these authors, the cessation of marine sedimentation with Kesi Formation and the onset of continental sedimentation with red beds and fluviatile conglomerates (Chulung-La Formation) at about 54 Ma (Ypresian) mark the closure of Tethys in this region. These continental beds conformably overlie the lowermost Eocene Nummulitic limestones which also occur all along northern Indian plate margin from Salt Range and Hazara to as far as southern Tibet. A similar age (54 Ma) has also been favoured for the final closure of Tethys in Ladakh and diachronous ages for collision from west to east on the basis sedimentary history along the northern Indian continental margin in Ladakh Himalaya. Treolar argued that the 65 Ma event identified by Klootwijk et al. does not necessarily date the initiation of India/Asia collision, instead marks a temporary hiatus in the northward path of India caused by the emplacement of ophiolites on to the leading edge of the Indian plate and collision must have occurred sometime between 65 and 55 Ma ago. On the basis subsidence history of the stratigraphic section on Zhevure Mountain on the northern flank of Everest, Rowley suggested that the initiation of collision began probably closer to 45 Ma or even later. In the Zanskar and Hazara regions of Indo-Pakistan, about 1200 km west of Zhevure Mountain along the India-Asia suture, the date for the initiation of collision is stratigraphically well constrained at 51.8 Ma. Further west of Zanskar and Hazara, extensive biostatigraphic analysis of sediments overlapping the suture between the Indian subcontinent and fragments of old oceanic terrains from Waziristan and Kurram in Northwest Pakistan led Beck et al. to suggest an age after 66 and before 55.5 Ma for the beginning of India/Asia collision. These new data favour diachronous initiation of collision from west to east along India-Asia suture zone and reject either collision at K/1 boundary or isochronous initiation of collision in the Early Eocene. Although cooling history of metamorphic rocks along Higher Himalaya-Swat and Hazara, Suru Valley, Zanskar, Tibet and eastern Nepal - indicates diachronous collision events from west to east, Searle et al. assumed that no diachronity occurs in view of the similarity in stratigraphic data from Waziristan (Pakistan) and Ladakh (India). Recently, Lee & Lawver suggested a Middle Palaeocene (58 Ma) land connection between India and Asia based on the reduction of drift rate from 17 cm/year in the Late Cretaceous to 11 cm/year in the Middle Palaeocene. Therefore, there is no unequivocal evidence to demonstrate that subaerial contact between the Indian plate and Asia (including microcontinental fragments accreted to its southern margin) was achieved by the end of Cretaceous.

New Insights

In view of the existing discordances in dating the India/Asia collision event, there is a need to consider alternative faunal dispersal mechanisms and/or routes which would provide a credible explanation for the presence of Laurasian taxa in the Late Cretaceous of the Indian subcontinent. Although it is not possible to make propositions regarding the dispersal mechanisms with a great degree of confidence, there are certain clearer pointers to some general conclusions. From the biogeographic point of view, one significant aspect the size control on dispersal of fauna and flora—has been grossly overlooked in the past. A detailed analysis of the Infra and Intertrappean fauna and flora demonstrates the presence of three important palaeocommunities viz., terrestrial, lacustrine/fluvial, and mixed (Table I). Of these, dinosaurs are the largest animals of the terrestrial community. The Lameta dinosaurs have been documented not only by large bones of titanosaurids, and abelisaurids, but also by sauropod and ornithoid egg clutches. In comparison, the Intertrappean dinosaurs are known only by a few isolated teeth, bones, and egg shell fragments whose taxonomic position is not clear, therefore are of uncertain biogeographic affinity. As discussed earlier, the Lameta titanosaurids and abelisaurids are of unmistakable Gondwanan affinity and are supposed to have arrived from South America making use of a dispersal route followed by sudamerid mammals (i.e. South America-Antarctica-Kerguelen Plateau-Indo-Madagascar). The presence of another Gondwanan vertebrate group, the pelomedusid turtles, in the Infra and
Table I

Important Palaeocommunities viz. terrestrial, lacustrine, fluvial, mixed and marine communities are classified as under:

<table>
<thead>
<tr>
<th>Terrestrial Community</th>
<th>Lacustrine/Fluvial Community</th>
<th>Mixed Community</th>
<th>Marine Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frogs:</td>
<td>Fishes:</td>
<td>Frogs:</td>
<td>Fishes:</td>
</tr>
<tr>
<td>?Hylidae</td>
<td>Lepisosteus indicus</td>
<td>Pelobatidae</td>
<td>Igdamabatis indicus</td>
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<tr>
<td>Lizards:</td>
<td>Osteoglossidae</td>
<td>Discoglossidae</td>
<td>Rhombodus sp.</td>
</tr>
<tr>
<td>Anguidae</td>
<td>Leiria jonesi</td>
<td>Myobatrachinae</td>
<td>Raja sudhakari</td>
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<tr>
<td>Dinosaurs:</td>
<td>Cytheridella strangulata</td>
<td>Crocodiles:</td>
<td>Rajiforme indet.</td>
</tr>
<tr>
<td>Titanosaurus indicus</td>
<td>Candonia altaunlaensis</td>
<td>Alligatoridae</td>
<td>Pycnodus lametii</td>
</tr>
<tr>
<td>T. madagascarensis</td>
<td>C. bagmodica</td>
<td>Turtles:</td>
<td>Pycnodontidae</td>
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<tr>
<td>T. colberti</td>
<td>C. henaensis</td>
<td>Shweboemys pisduensis</td>
<td>Eoserranus hislopi</td>
</tr>
<tr>
<td>Indosuchus raptorius</td>
<td>Candoniella altanica</td>
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<td></td>
</tr>
<tr>
<td>Indosaurus matleyi</td>
<td>sp. Alanicycpris szeczechurae</td>
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<tr>
<td>Megalosaurus</td>
<td>A. bhatiai</td>
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<tr>
<td>Mammals:</td>
<td>Talicypridea biformata</td>
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<tr>
<td>Deccanolestes hislop</td>
<td>Cypridea cavernosa</td>
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<td>D. robustus</td>
<td>Cypridea sp.</td>
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<tr>
<td>Sudamericanidae</td>
<td>Mongoloocypris longa</td>
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<td></td>
<td>Mongoloocypris cf. M. gigantea</td>
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<td></td>
<td>Mongolianella palmosa</td>
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<td></td>
<td>M. khamarinienis</td>
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<td></td>
<td>Frambogycpra tamiensis</td>
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<td></td>
<td>Cyclopcypris transitoria</td>
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<td></td>
<td>?Cypridopsis bugintavicus</td>
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<tr>
<td></td>
<td>Candonia cf. C. hubeinensis</td>
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<td></td>
<td>Eucypris cf. E. bajshintavica</td>
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<td></td>
<td>Bisutocypris sp.</td>
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<td></td>
<td>Timriasovia sp.</td>
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<td>Charophytes:</td>
<td>Platychora perlata</td>
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<td>P. compressa</td>
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<td>P. raoi</td>
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<td>P. sanhii</td>
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<td>P. rajahmunderca</td>
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<td></td>
<td>Peckichara varians</td>
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<td></td>
<td>Nemegticichara grambasti</td>
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<td></td>
<td>Harrisichara murieta</td>
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<td></td>
<td>Stephanochura cf. S. levis</td>
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<tr>
<td></td>
<td>Pseudoharriscichara cf. P.</td>
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<tr>
<td></td>
<td>baytikshahnensis</td>
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<tr>
<td></td>
<td>Grambastichara sp.</td>
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<tr>
<td></td>
<td>Microchara sp.</td>
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<td></td>
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<tr>
<td>Molluscs:</td>
<td>Physa prinsepii</td>
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<tr>
<td></td>
<td>Lymnaea subulata</td>
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<tr>
<td></td>
<td>Paludina normalis</td>
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<tr>
<td></td>
<td>Paludina sp.</td>
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<tr>
<td></td>
<td>Unio deccanensis</td>
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</table>

Intertrappean beds demands no explanation as the ancestral stock of this group was supposed to have boarded the Indian plate well before the separation of India from Africa. On the other hand, the Infra and Intertrappean taxa of Laurasian affinity, such as pelobatid and discoglossid frogs, anguid lizards, alligatorid crocodiles, palaeycyprid mammals, ostracodes and charophytes, are relatively very small in size. The individuals of all the vertebrate groups barring the alligatorid crocodiles could not have exceeded the size of a domestic rat. The crocodiles also appear to
be small in size as a vast majority of the teeth by which they have been identified is less than 5 mm in height. The ostracode carapaces are less than 2 mm and the ephippial gyrogonites are less than 1 mm in size. On the whole, very small-sized fauna and flora of terrestrial and lacustrine habitats were involved in the Late Cretaceous biotic interchanges between India and Asia. The question that now arises is what was the most likely reason behind the preferential dispersal of small-sized organisms? The most plausible explanation one could offer is that the kind of dispersal mechanism adopted by small-sized animals is not suitable for the migration of large-sized animals. Possibly there was no continuous land connection between India and Asia in the Late Cretaceous without which the large animals could not have crossed the marine barriers McKenna maintained that the past distribution of animals and plants is not governed by the time of separation or connection of continental blocks. Other factors may also play an important role in biotic distributions. As pointed out by McKenna within major bodies of marine water which act as strong barriers for land-based biota, there may exist a number of lesser barriers, such as aseismic elements, sea-floor spreading elements that act as an isthmus filter or intermittently maintained connection allowing some organisms to filter through (filter corridors). Alternatively, over long distances of water, sweepstakes dispersal may result in unbalanced and stray immigrants of usually small size rafting across the barrier. Therefore mixing of terrestrial biotas of two converging continental blocks would take place initially by sweepstakes mode of dispersal when their coasts are approaching each other, through a filter corridor when the landmasses made contact at some place, and through a continuous stable corridor finally when the contact is fully established.

The charophyte taxa exhibit affinities to those of Europe as well as Mongolia. However, the striking similarity of the ostracode fauna of the Infra- and Intertrappean beds to that of Mongolia and China even at specific level, the recovery of only a couple of these species from Europe, and their total absence from the African Cretaceous deposits do not favour any other dispersal route except the one directly from the north of Greater India. In view of the equivocal evidence for the end Cretaceous suturing of Indian and Asian landmasses, the only dispersal mechanisms which can provide a convincing explanation for the Central Asian and Chinese species in the Late Cretaceous of India are the filter corridors/sweepstakes. The Trans Himalayan Arc-Trench system represented by the Kohistan magmatic arc in Pakistan, Ladakh arc in India, and Gangdise arc in Tibet may have played an important role in providing a filter corridor for the Laurasian biota. These magmatic arcs had already established subaerial contact with Asia by the end of Cretaceous. But on the southern margin of these arc-trench systems, shallow marine conditions prevailed during the Late Cretaceous. However, subaerial exposure of Zanskas shelf sediments due to intermittent fall in sea level at a rate greater than the rate of subsidence has been noted at the Cretaceous-Tertiary boundary.

The latest report of sharks and rays from the Upper Cretaceous (Maasrichtian) Trem Formation at Suterranya and Fontlonga 6, south-central Pyrenees, Spain favours a close biogeographic link between India and Eurasia in the Late Cretaceous. The fossil fish assemblage from this locality includes the genus Igadabatis which was earlier reported from the Maastrichtian of Niger (Igadabatis sigmodon) and India (Igadabatis indicus). The new myliobatid dental material from Spain has been assigned to the Indian species, Igadabatis indicus (Prasad and Cappetta), because of identical morphology and is supposed to be very distinct from the African species, I. sigmodon. Likewise, Rhombodus sp., which represents the family Rhombodontidae, in the Spanish material compares well with Rhombodus sp. 2 of Prasad and Cappetta. Since the living members of rays have adopted to benthiic habits in shallow waters and are not known to cross deep oceanic barriers, the presence of two common species in India and Europe has been interpreted as an evidence for Late Cretaceous shelf connection between the two landmasses in the northern region. Hence the new data from Spain when viewed in conjunction with the data from India indicates that the Tethys Sea was probably very shallow and was reduced to a narrow channel in the Late Cretaceous enabling the dispersal of non-marine small-sized biota across intermittent and subaerially exposed landmasses. Soler-Gijón & López-Martínez favoured a dispersal route between Greater India, extending 1500 km to the north of it's present northern margin, and Asia through intermediate
continental fragments, such as Gondwanan Mount Victoria, Sikuleh, Natal Semitau, and Southwest Borneo, now part of Southeast Asia. This proposal is somewhat similar to one of the biogeographic models put forward by Prasad et al.\textsuperscript{193} to account for the Laurasian taxa in the Late Cretaceous of India. Prasad et al.\textsuperscript{193} speculated that Sundaland (South Yunnan, Indochina, Thailand and Shan Plateau), located north of Greater India before its displacement towards ESE over 1000 - 1500 km in the Tertiary\textsuperscript{218-219} in combination with the Trans-Himalayan Arc system may have formed an important dispersal route from north to south. However, the amount of extrusion involved is disputed\textsuperscript{220}. More recently, Huchon et al.\textsuperscript{221} opined that Indochina was never located north of the Indian subcontinent, rather it was situated northeast of the eastern syntaxis and thus the eastward extrusion should not exceed 600 km.

The Dras arc complex of the Indus Suture Zone (Ladakh Himalaya), comprising three structural units—Suru Unit, Naktul Unit and Nindam Formation—from west to east, has been interpreted as an oceanic volcanic arc that formed a larger arc assemblage along with Kohistan arc\textsuperscript{222}. Based on 79 Ma age deformation in Dras unit 1 in the Suru valley, the known accretion age of 80 Ma for the Kohistan arc with the southern margin of Asia, and lack of evidence for deformation in the eastern most Dras unit (Nindam Formation), these authors suggested that the Kohistan-Dras arc complex converged obliquely on the southern margin of Asia/Trans-Himalayan arc resulting in diachronous collision. Thus in the eastern part, the Nindam Formation, representing the distal fore arc apron was left as an offshore high and was only deformed after collision with the Indian plate in the early Tertiary\textsuperscript{222}. Recently, Sinha and Mishra\textsuperscript{253}

Fig. 2 Possible dispersal route between Greater India and Asia at the end of Cretaceous period (modified after Jaeger et al.\textsuperscript{191})
considered the tectonic blocks of volcanics and gabbro imbricated with turbidites along the melange zone between Shergol and Bodhkhari, western part of Ladakh, in the light of petrographic and geochemical parameters as relics of oceanic islands which had erupted in the Neotethys at about 75 Ma. According to these authors, when such volcanic islands reached the trench along the southern margin of Trans-Himalayan arc, initially there was temporary choking of the subduction zone, but continued convergence resulted in dismemberment of the oceanic island and
imbrication of island fragments with trench fill turbidites. The additional data from the Indus Suture Zone have tempted us to speculate that the Kohistan-Dras arc complex, which was welded in the western part to the southern margin of Asia/Trans-Himalayan arc, together with certain oceanic volcanic islands to its south in the shallower Tethys as suggested by Sinha and Misra facilitated the dispersal of Laurasian elements into the Indian plate by filter corridor/sweepstakes mode of dispersal (Fig. 2). Palynological data from the tuffaceous shales associated with Dras volcanics near Shergol also indicate proximity of this belt to the Indian subcontinent. Based on a palynological assemblage dominated by palm pollen, particularly Nipa, and rare Ephedra, Mathur and Jain suggested a coastal plain, brackish water environment and a common floral province extending from Tamil Nadu (southern India) through Kutch, Rajasthan (western India) as far north as Dras volcanics in the Palaeocene.

In conclusion, the palaeontological data from the Upper Cretaceous sequences of peninsular India demonstrated that the Indian subcontinent during its northward journey towards Asia maintained biogeographic links both with the Gondwana and Laurasian landmasses. After its separation from Africa around 150-160 Ma ago and subsequent divergence from Australia and Antarctica at about 125-130 Ma, a dispersal corridor was established between India/ Madagascar and South America via Antarctica and Kerguelen Plateau. This biogeographic connection, which was responsible for the faunal exchange between South America and Indo-Madagascar, such as the immigration of titanosaurid & abelisaurid dinosaurs, and Sudamericidae mammals, was achieved by 85-90 Ma and possibly maintained at least up to 80 Ma. At the Cretaceous/Tertiary boundary, the Indian plate, which had already undergone a fast rate of drift, moved farther northwards approaching the southern margin of Asia, but still a substantial body of shallow Tethys separated it from Asia. At this stage, many Mongolian, Chinese, North American and European biota of relatively small size reached India through filter corridor/sweepstakes mode of dispersal, making use of the Trans-Himalayan Arc-Kohistan-Dras island arc complex and some other oceanic islands south of these which have possibly been consumed at the subduction zone south of Asia. This biotic exchange preceded the final collision of India after 66 Ma and before 55 Ma (Fig. 3).

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