(Corallina sp.) along with green algae Ovulites and Halimeda are present in this lithounit. This generic variation may be due to variation of salinity during the deposition of this limestone. The high diversity of the foraminiferal forms also suggests variable salinity conditions of the sea, which possibly suppressed the growth of algae during this period. Abundance of Lithothamnion in this assemblage indicates relatively greater water depth (~40 m). However, udoteaceans and halimeds, which are abundant in this lithounit prefer shallow water depth. Therefore, probably the Umutlahad Limestone was deposited in fluctuating water conditions with slightly moderate energy environment.

The uppermost unit, i.e. the Prang Limestone Member is dominated by the mastophoroid non-geniculate corallines, e.g. Lithoporella and Spongiotes. These algal forms occur mostly in encrusting condition with Orbitoid foraminifera. Dasyycladacean green algae (Actinoporella sp.) are also found in this lithounit. Presence of dasyyclads along with mastophoroid and melobesiod non-geniculate corallines indicates a shallow water depth with more or less low to moderate energy condition.

A perusal of the foregoing account reveals that all the three algal assemblages show an overall dominance of corallinaceans along with sporolithaceans. In all probability the limestone was deposited under shallow, warm shelf environment of normal salinity with some minor sea-level changes within the transgressive phase.


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Palynological constraints on the age of mammal-yielding Deccan intertrappean beds of Naskal, Rangaredi district, Andhra Pradesh

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A palynological assemblage recovered from the Deccan intertrappean sediments of Naskal, Rangaredi district, Andhra Pradesh on the southern margin of Deccan volcanic province is reported here. The assemblage contains taxa assigned to Ariadnae, Trigonia, Triploptera. Mulleripollis, Azolla and Minerisporites, favouring a Maastrichtian age for the eutherian mammal-bearing intertrappean beds of Naskal. Freshwater ferns dominate this assemblage, which indicates a lacustrine environment of deposition and a warm and humid climate.

Keywords: Deccan intertrappean bed, eutherian mammals, Maastrichtian age, Naskal, palynology.

DECCAN Traps encompassing the Cretaceous–Tertiary (K/T) boundary1,2 with estimated duration of volcanism varying from 0.5 to 5 Ma3,5 have attracted worldwide

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attention. Thin sedimentary (intertrappean) beds intercalated with volcanic flows, deposited during the dormant stages of volcanism, preserve the signatures of the then biotic communities. Palaeontological and palaeobotanical studies of the outcrops and subsurface intertrappean sections have brought many new vertebrate, invertebrate and plant taxa of Gondwanan and Laurasian affinities to our knowledge. In this respect, the most promising among the intertrappean outcrops is the section exposed near the village Naskal, Rangareddi district, Andhra Pradesh. This intertrappean horizon has been a source of diverse vertebrate groups, including the eutherian mammals. Earlier, all the placentals mammals of the Indian subcontinent were considered as immigrants from Eurasia following the collision between India and Asia. Therefore, precise dating of these intertrappean beds is essential before making any attempt to explain this biogeographic anomaly. Based on a preliminary study of the microvertebrate assemblage from the intertrappean beds of Naskal, a Late Cretaceous age was suggested for these beds. Pollens and spores are the most reliable dating tools compared to other intertrappean fauna and flora. Keeping this in view, samples from different levels of the Naskal intertrappean sequence have been processed for the recovery of pollens and spores.

Dutt provided a detailed geological map of the Deccan Trap terrain of Pargi–Vikarabad–Tandur areas, Rangareddi district and also discussed the lava-flow stratigraphy of the area. He has identified nine volcanic flows and five intertrappean beds in this area. The mammal-bearing intertrappean beds of Naskal exposed 2 km NE of Naskal village (Survey of India toposheet no. 56 G/15, 16) occur between volcanic flows 4 and 5, and comprise gleyed-mudstone, yellow mudstone, marlstone, impure marlstone, chert and calcareous mudstone in the order of ascendance. In physical continuation of the mammal-yielding intertrappean section of Naskal, another intertrappean section occurs about 1.5 km northwest of it. The sedimentary succession of this section includes basal finely laminated yellow mudstone, followed upwards by pinkish-white marl, brownish-red chert, brownish-white mudstone and carbonaceous shale (Figure 1). The latter contains leaf remains beyond identification and the palynomorphs reported here. The mudstones underlying the carbonaceous shale do record few palynomorphs, but are rich in organic matter.

The samples were treated with dilute nitric acid after crushing them to small pieces of about 5 mm size. The samples were kept under normal temperature and occasionally stirred until the organic matter was oxidized. Some samples required heating for about 1 h for complete oxidation. Samples were decanted several times (4–6 rinses) using distilled water to remove traces of acid. The residue obtained was spread over a thin glass cover-slip by mixing equal amount of polyvinyl alcohol and dried before being mounted on slides using Canada balsam. The mounted slides are deposited in the museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

The following palynomorphs were recovered along with dispersed organic remains (Figure 2):

- *Azolla cretacea* Stanley, 1965
- *Ariadnaespites intermedius* Hall, 1967
- *Triporoletes reticulatus* (Pocock) Playford, 1971
- *Gabonisporites vigourouxi* Boltenhagen, 1967
- *Minerisporites triradiatus* Kar & Singh, 1986
- *Cyathidites minor* Couper, 1953
- *Cyathidites australis* Couper, 1953
- *Todisporites major* Couper, 1958
- *Polyphidiisporites* sp.
- *Maculatospora* sp.
- *Cycadopites* sp.
- *Mulleripollis bolpurenensis* Baks & Deb, 1981
- *Mulleripollis* sp.
- *Lithoparaphysa* sp.
- *Spinizonocolpites echinatus* Muller, 1968
- *Proxapterites curvis* van Hoeken-Klinkenberg, 1966
- *Lilliciades* sp.
- ‘Porate’ and ‘tetrad’ angiosperm pollen
- Algal and fungal spores
- Diatom cysts with pinnate diatoms
- Dinoflagellate cysts.

In a preliminary study, the presence of *Ariadnaespites* sp. and *Gabonisporites* cf. *G. vigourouxi* from the intertrappean beds of Naskal was documented. The above listed palynological assemblage, recovered in the present study, consisting of *M. bolpurenensis*, *A. intermedius*, *G. vigourouxi*, *M. triradiatus*, *T. reticulatus* and *A. cretacea* records a well-diversified assemblage from the intertrappean beds of Naskal. Many of these taxa are index fossils for the Maastrichtian throughout the world. In India,
Figure 2. a. Mulieripollis holporensis, slide no. BSIP 13097; b. Mulieripollis sp., slide no. BSIP 13099; c. Tricolpites sp., slide no. BSIP 13113; d. Polyplepisporites sp., slide no. BSIP 13103; e. Dinoflagellate cyst, slide no. BSIP 13098; f. Maculatastypora sp., slide no. BSIP 13101; g. Gabonisporites vigourovii, slide no. BSIP 13098; h. Cyathidites minor, slide no. BSIP 13097; i. Lithoparaphyses sp., slide no. BSIP 13114; j. Masulae of Acolia cretacea, slide no. BSIP 13109; k. l. Porate angiospermic pollen, slide no. BSIP 13098; n. Lillicolletes sp., slide no. BSIP 13107; m. Diatom cyst, slide no. BSIP 13108; o. Minorisporites triradiatus, slide no. BSIP 13111; p. Cyathidites australis, slide no. BSIP 13096; q. Algal spore, slide no. BSIP 13101; r. Cyclospores sp., slide no. BSIP 13105; s. Angiospermic pollen tetrad, slide no. BSIP 13104, and t. Ariadnaesporites intermedius, slide no. BSIP 13110.
these taxa have also been recorded from the Late Cretaceous subsurface sediments of Bengal Basin\(^{14}\); the Deccan intertrappean beds of Mohgaon-Kalan, Chhindwara district, Madhya Pradesh\(^{15}\); the subsurface Deccan intertrappean sediments at Padwar, Jabalpur district, Madhya Pradesh\(^{16}\); Ranipur, Gaur River section, Jabalpur district, Madhya Pradesh\(^{17}\) and from the intertrappean beds of Anjar, Kutch district, Gujarat\(^{18}\).

It has been observed that *Aquilapollenites* plays a significant role in the correlation of Upper Cretaceous subsurface and surface sediments of India\(^{16}\) and that both *Aquilapollenites indicus* and *A. bengalensis* occur in the Upper Cretaceous sediments\(^{14}\). But the intertrappean sediments of Padwar, Ranipur, and Mohgaon-Kalan lack *A. indicus*, whereas it has been reported from the Anjar intertrappean section\(^{18}\). Srivastava\(^{19}\) proposed four Late Cretaceous physogeographical provinces, among which *Aquilapollenites* and Normapolles Provinces are confined to the northern hemisphere, and placed India along with Brazil and West Africa under *Constantisporites* Physogeographical Province. Normapolles group of pollen has also recently been recorded from the Late Cretaceous outcrops of Meghalaya\(^{20}\) and the subsurface Early Palaeocene sediments of Ganga Basin\(^{21}\). Presence of *Aquilapollenites* and Normapolles pollen, typical Laurasian taxa, in the Late Cretaceous and Early Palaeocene of India is a biogeographic anomaly\(^{21,22}\), as is the case with eutherian mammals.

*G. vigourouxii*, first reported from the Late Cretaceous of Gabon, West Africa\(^{23}\), is common in the Maastrichtian sediments of India and has not been reported from sediments younger than Late Cretaceous. *Ariadnaesporites* and *Minerisporites* are cosmopolitan in distribution, having been reported from the Upper Cretaceous sediments of North America, Europe, India and all the other continents. Therefore, the new palynological assemblage favours a definitive Maastrichtian age for the intertrappean beds of Naskal.

Grains of *Ariadnaesporites* vary in size from 40 to 200 μm, but have similar morphology and seem to have been produced by heterosporous water fern which could disperse over wide geographical areas within a short span of time. The presence of this species reflects a uniform global climate during the Late Cretaceous. Presence of terrestrial ferns such as *Cyathidites, Todisporites, Triporoletes, Gabonisporites, Polypondisporites* and fungal remains favour warm and humid conditions at the time of deposition of the sediments.

The present palynological assemblage is dominated by freshwater fern (Salviniaaceae) spores, viz. *Ariadnaesporites, Azolla* and *Minerisporites* and also contains some freshwater diatom cysts. This indicates a lacustrine environment of deposition, not very far from the sea, as indicated by the presence of pollen of a mangrove palm *Nipa* (Spinizonocolpites), paraphyses of a mangrove fern *Acrostichum* (Lithoparasphyceae) and some dinoflagellate cysts. Based on sedimentology, fauna and taphonomy of the microvertebrate fauna, deposition in shallow, freshwater, alkaline, flood-plain lakes distal to the sea coast, which were intermittently subjected to subaerial exposure leading to the development of palaeosols was inferred for these intertrappean beds\(^{8}\). Proximity of marine body of water is also indicated by the presence of *Igdabatis*, a Maastrichtian ray fish in the microvertebrate fauna of these intertrappean beds. *Igdabatis* is known from Upper Cretaceous shallow marine sequences of Niger\(^{24}\) and Spain\(^{25}\). But the rarity of *Igdabatis* and the predominance of freshwater elements in the microvertebrate assemblage of Naskal, does suggest that these sediments were deposited in a freshwater lacustrine basin distal to the sea coast.

Algal, bryophytic, pteridophytic, gymnospermic and angiospermic remains present in the Naskal palynological assemblage show that all the extant plant groups were well developed during the Late Cretaceous. Presence of terrestrial pollen represented by *Mulleripollis, Proxapertites, Tricolpites, Spinizonocolpites, Liliacidites* and other ‘porate’ and ‘tetrad’ forms, suggests that the plant community in the vicinity of the lake was considerably advanced as it includes the higher angiospermic group. This group gained complete dominance on land since the terminal Cretaceous. In India, during the last phase of volcanism, the palynotaxa were replaced by *Dandiotiaspora dilata, D. plicata, D. pseudouriculata* and *Lakiapolis ovatus*\(^{26}\), but some forms like *Spinizonocolpites, Proxapertites, Lycopodiumsporites* and *Matanomadhasialis* continued, developed more rapidly and became dominant during the Palaeocene.

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10. Sahni, A., Venkatashala, B. S., Kar, R. K., Rajanikanth, A., Prakash, T., Prasad, G. V. R. and Singh, R. Y., New palynological data from the Deccan intertrappeans: implications for the latest records of dinosaurs and synchronous initiation of the volcanic acti-
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