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EARLY CRETACEOUS PALYNOMORPHS, DINOFLAGELLATES AND PLANT MEGAFOSSILS FROM THE RAJMAHAL BASIN, JHARKHAND, INDIA

ARCHANA TRIPATHI[1*], B. N. JANA[1], OMKAR VERMA[2], RANJIT K. SINGH[3] and ASHOK K. SINGH[4]

[1]BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY, LUCKNOW – 226 007, INDIA
[2]DISCIPLINE OF GEOLOGY, SCHOOL OF SCIENCES INDIRA GANDHI NATIONAL OPEN UNIVERSITY, NEW DELHI – 110 068, INDIA
[3]DEPARTMENT OF GEOLOGY, SAHIBGANJ COLLEGE, SAHIBGANJ – 816 109, JHARKHAND, INDIA
[4]DEPARTMENT OF GEOLOGY, SNSRKS COLLEGE, SAHARSA – 652 201 BIHAR, INDIA
* Corresponding author, e-mail: tripathi_archana@hotmail.com

ABSTRACT

Palynomorphs, dinoflagellates and plant megafossils are recorded from the intertrappean beds of the Rajmahal Basin, Jharkhand, India. These beds are exposed at Moti Jharna, Sakrigali Ghat, Murali Pahar, Sonajuri and Kalkipara sites. The palynomorphs include *Araucariacites*, *Podocarpidites*, *Callialasporites*, *Coptospora, Cyathidites* and *Balmeisporites*. The dinoflagellate taxa observed are *Batiacasphaera* sp., *Dissiliodinium* sp. etc. Type A. The floral assemblage consists of *Elatocladus* sp., *Ginkgoites, Sphenopteris, Pachypteris* sp., *Pterophyllum*, *Araucaria* and *Ptilophyllum*. The composition of the present assemblage suggests the Early Cretaceous age for these intertrappen sites.

Keywords: Palynology, Megaflora, Early Cretaceous, Rajmahal Basin, India

INTRODUCTION

The Gondwana sediments of the Rajmahal Basin are a part of North-South trending Rajmahal-Purnea graben which extends over a large area of Jharkhand and West Bengal states, Eastern India. The associated intertrappean beds of Rajmahal Traps have been studied in detail due to its rich plant megafossil assemblage of *Ptilophyllum* flora (Sahni, 1932, 1948; Sahni and Rao, 1933; Rao, 1943; Vishnu-Mittre, 1956, 1958; Sharma, 1967, 1969, 1974, 1997; Sengupta 1988, Banerjee, 1993, 1995, 2000; Banerji and Jana 1998; Tiwari *et al*., 1984; Tiwari and Tripathi, 1995; Tripathi, 2008; Baksi *et al*., 1992). As a result, numerous genera of plant fossils belonging to the ferns, cycads and conifers have been reported from the Rajmahal Formation (Sengupta, 1988 and references therein). Among these *Ptilophyllum, Pterophyllum, Dictyozamites, Taeniopteris, Williamsonia, Brachyllum, Thinnfeldia* and *Cladophlebis* are the most common genera of plant fossils. The Rajmahal intertrappean beds are known with very poor animal fossil content, except one report of clupeiformes fish (*Jhingrania roonwali*) from the siliceous shales of an intertrappean bed exposed at Sakrighat (Mishra and Saxena 1964).

In the present study, an attempt has been made to undertake an integrated palynological and palaeobotanical study on the intertrappean sedimentary beds exposed in the northern and central part of the basin. The main aim of the present communication is to describe the new palynomorphs, dinoflagellate cysts and megafossil assemblage and discuss their implications for understanding the age of the intertrappean beds.

GEOGRAPHIC AND GEOLOGICAL SETTING

The Rajmahal Basin has one of the best developed sequence of the Upper Gondwana sediments which is known for its rich wealth of plant fossils since1850. The basin comprises a series of volcanic lava flows (Rajmahal Traps) and associated intertrappean sedimentary beds. It is located in eastern Jharkhand, dominantly composed of basalt, occupies a surface area of about 4100 km^2 and attains a maximum thickness of 600 meters (Fig. 1). Ball (1877) first conducted systematically geological mapping of the Rajmahal Basin and adjacent areas. Later, Sengupta (1988), Tiwari and Tripathi (1995), Tripathi (2008) presented a detailed account on litho- and biostratigraphic aspects of the Rajmahal Basin (Table 1).

Table 1. Geological succession exposed at The Rajmahal area, eastern Jharkhand (after Ball, 1877; Sengupta 1988; Tiwari & Tripathi 1995; Ghose *et al*., 1996).

Group	Formation	Lithology	Age
		Alluvium	Recent
		Laterite	
Upper Gondwana	Rajmahal	Basalt and acid volcanics with intertrappean beds of pyroclastic material, argillaceous, and arenaceous sediments often contain plant fossils (*Ptilophyllum* flora) and bentonite deposits in the lower sequence Igneous contact	Lower Cretaceous
	Dubrajpur	Pebbly ferruginous sandstone, conglomerate Triassic to and grit passing into siltstone and shale Usually forms high ridges and scarps Disconformity	Early Cretaceous
	Barakar	Sandstone, shale, and carbonaceous shale with coal seam Lower	Lower Permian Unconformity
	Talchir	Boulder bed, fine-grained sandstone, Yellow or green shale, highly-weathered	Lower Corboniferous Unconformity
	Proterozoic	Chhotanagpur gneiss-granulite complex	

The extent of the Rajmahal lava flow is not limited to the Rajmahal area only but drilling data have proved this to be extending up to the Burdwan, Galsi, Jalangi and Panagarh areas of West Bengal (Sengupta, 1988). Ramaswamy (1958) identified fifteen lava flows with eleven intertrappean beds in the Rajmahal Basin. Ghose *et al.* (1996) mentioned the occurrence of fifteen surface basaltic flows and twenty-eight subsurface lava flows that have been identified in the boreholes. The Rajmahal Formation is overlain at some places by the Dubrajpur Formation (Early Triassic-early Cretaceous), whereas in other places by the Barakar Formation (Early Permian) and with the Precambrian basement.

The intertrappean beds are very thin as compared to the thickness of individual lava flow in which thickness of intertrappen beds vary from a few centimeters to about 11m, whereas in subsurface these are up to 100m thick (Tripathi, 2008). These sedimentary beds are composed of sandstone, siltstone, arenaceous clay, white and grey colour baked shale, carbonaceous shale, tuffite and chert bed with *Ptilophyllum* flora. The intertrappean beds are well exposed in the southern, central and northern regions of Rajmahal areas.

For the present study, a number of intertrappean sites exposed at northern (e.g. Sakrigali Ghat, Mahadevganj, Moti Jharna, Mahrajpur, and Murli Pahar) and central (e.g. Malipara, Nipania, Sonajurui, Amtala, Kalkipara, Amarjola and Gumapahar) regions of the Rajmahal basin have been investigated (Fig. 1). During the investigation, samples for palynofossils and plant megafossils were collected. The

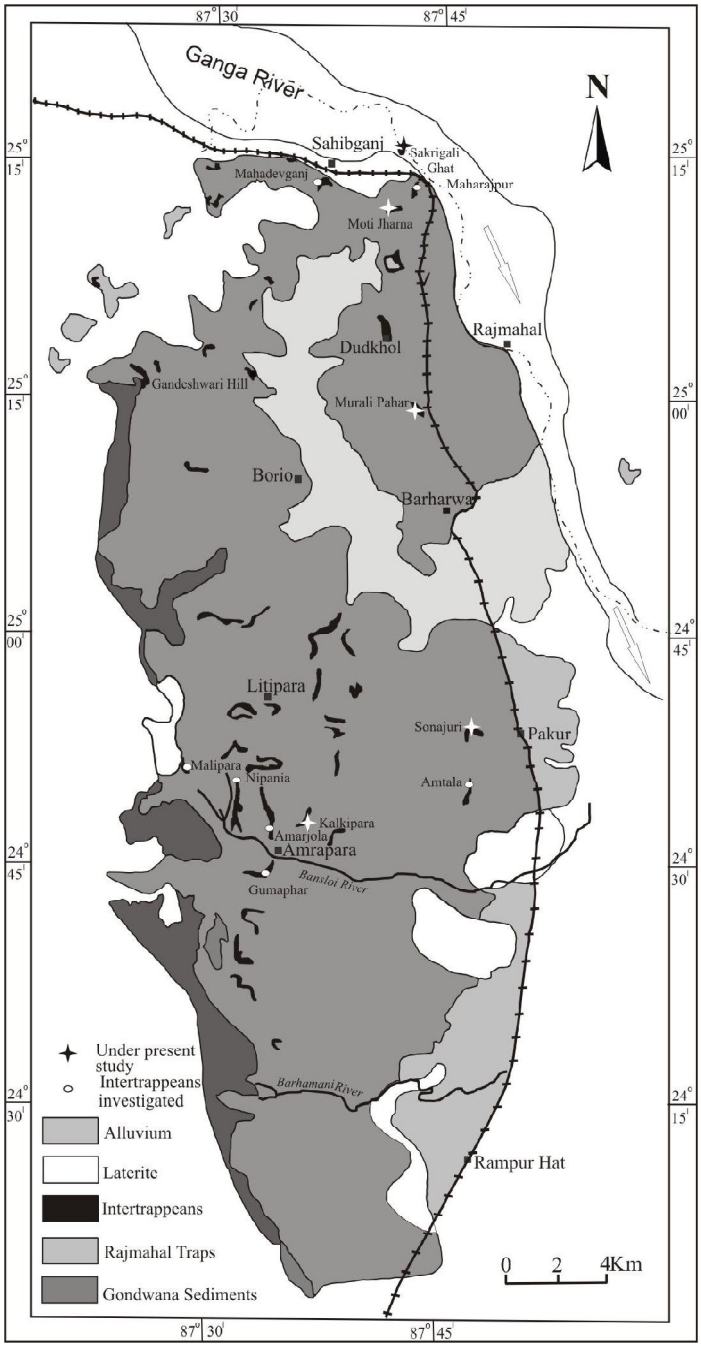

Fig. 1. Geological map of the Rajmahal Basin, eastern Jharkhand (after Ghose *et al.*, 1996).

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Plate I

EXPLANATION OF PLATE I

(A-F) Field photographs of the intertrappean beds associated with Rajmahal Traps, Rajmahal Basin, eastern Jharkhand. A, Field photograph of Moti Jharna; B, Sakrigali Ghat; C, Murali Pahar; and D, Kalkipara pahar intertrappean sections. E, Fossil wood found from the Kalkipara pahar and F, Close-up view of Kalkipara pahar intertrappean beds.

recovery of spore and pollen is rare and in few localities only. Similarly, the plant megafossils are either fragmentary, rare or totally absent. In none of the sections, fauna is observed. Table 2 gives the details of sections considered in the present study. The locality-wise details are described below.

Moti Jharna, northern Rajmahal basin

The scattered outcrops of the intertrappean beds are present near a locally famous Moti Jharna waterfall at Maharajpur village about 9.7 km southeast of Sahibganj town, Sahibganj District, Jharkhand. This section could be observed in the gorge at the Moti Jharna waterfall. It is difficult to find the base of the section and contact of trap and intertrappean bed. However, Ghose *et al.* (1996) observed two lava flows at Moti Jharna and an intervening intertrppean bed. A patch of greenish grey colour intertrappean consisting of green siltstone is exposed at a height of 102 m above the mean sea level (Pl. I, fig. A). The samples collected from the site have yielded some plant megafossils, palynomorphs, and dinoflagellate cysts.

Sakrigali Ghat, northern Rajmahal basin

The intertrappean section is exposed in a hillock under the Pir Baba's Mazar, near the Sakrigali Ghat, on the right bank of the River Ganga around 5.9 km from northeast of Sahibganj town. The small hillock at Sakrigali Ghat was traversed from both side, i.e. towards river and village. One intertrappean bed could be located in the section towards river side. The base of

Table 2: Details of intertrappean sites, Rajmahal Formation, Jharkhand considered for the present study.

S.No.	Locality	Elevation	Co-ordinates	Remarks
1	Moti Jharna	102 m	N 25°12?25.6? E 87°45?35.4?	Consist of khaki green siltstone, exact position of the beds is not clear, overlain and underlain by lava flows. Plant fossil present. One sample taken for palynology, rare yield
2	Sakrigali Ghat	------	N 25°22? E 87°15?	Five samples 1 from sandstone and 4 from siltstone were taken for palynology study
3	Murali Pahar	94 m	N 25°12?36.0? E 87°45?11.0?	Mudstone, clay, plant fossils present, 9 samples were taken for palynology
4	Sonajuri	-------	---------	Hard chert rich in petrified woods, appears as if forest is preserved
5	Kalkipara	132 m	N24°32?11.1? E 87°35?07.1?	Consist of medium to fine grained sandstone fossiliferous followed by hard siltstone, one sample for was collected for palynology

the intertrappean sequence is not exposed and overlain by the lava flow No. 2 (Pl. I, fig. B). The intertrappean beds consist of bluish grey siltstone, grey shales, and coarse grained grey sandstone (Fig. 2a). The grey siltstone of the sequence has yielded very few palynomorphs, but we could not find any megafloral remains from the site.

Murali Pahar, eastern Rajmahal basin

The Murali Pahar intertrappean site is located about 7.3 km east of Tinpahar village. Here intertrappean beds are exposed in front of Murali Mission Church (Pl. I, fig. C). The four lava flows with three intervening intertrappeans could be observed (Fig. 2b). The base of lava flow No. 1 is unexposed and is followed by 0.9 m thick sedimentary unit consisting of mudstone. The mudstone unit is succeeded vertically by basaltic lava flow No. 2 of about 8.5m thick. A thin, less than 1m thick sedimentary sequence is overlying the lava flow No. 2. This sequence is dominantly composed of clay and mudstone and overlain by very thin lava flow No. 3. A nearly 4.2m thick sedimentary sequence consisting of mudstone, siltstone and clay is intercalated within flows No. 3 and 4. Sediments from all these intertrappean beds were collected and processed; however, some palynomorphs and plant megafossils are recorded only from the clayey unit of the uppermost intertrappean bed.

Sonajuri, eastern Rajmahal basin

The Sonajuri locality is situated about 2.9 km west of Pakur town, Pakur Distict, Jharkhand. Here intertrappean beds, dominantly composed of hard chert have a very few scattered surface exposures. This site yields diverse remains of plant fossils and is especially rich in petrified woods.

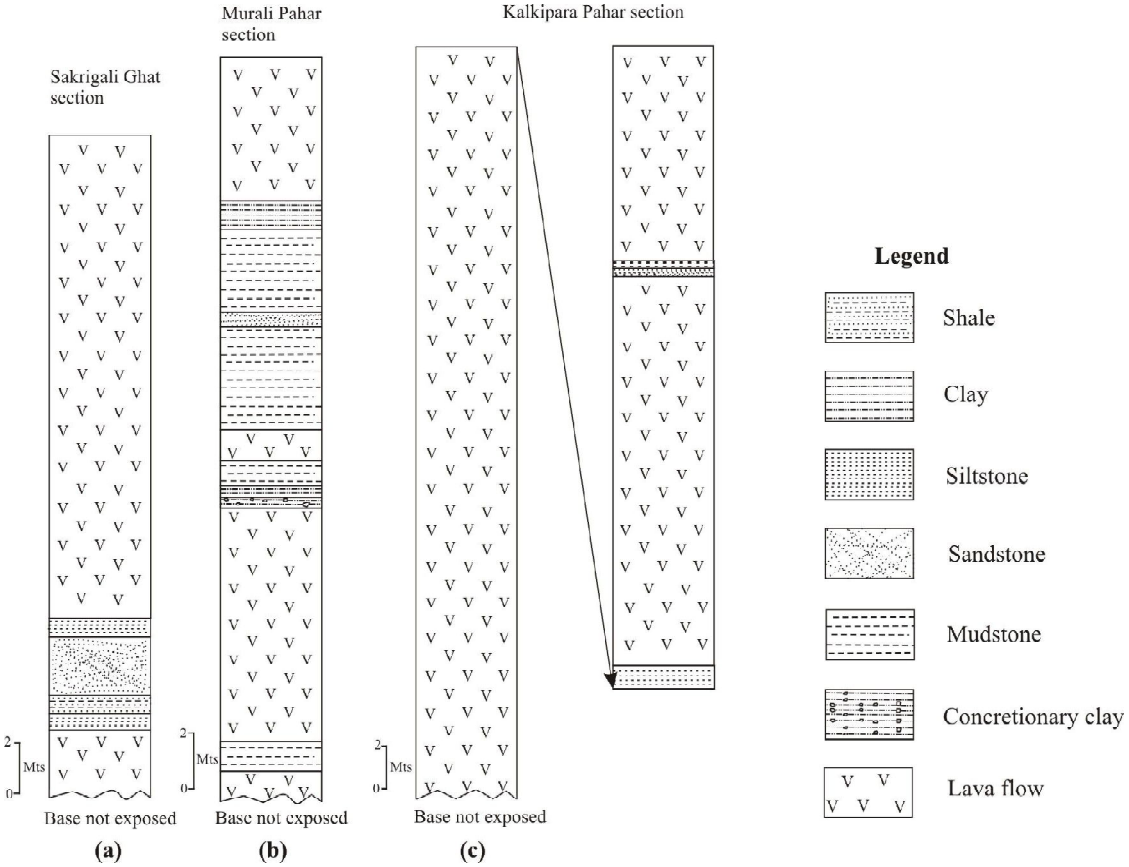
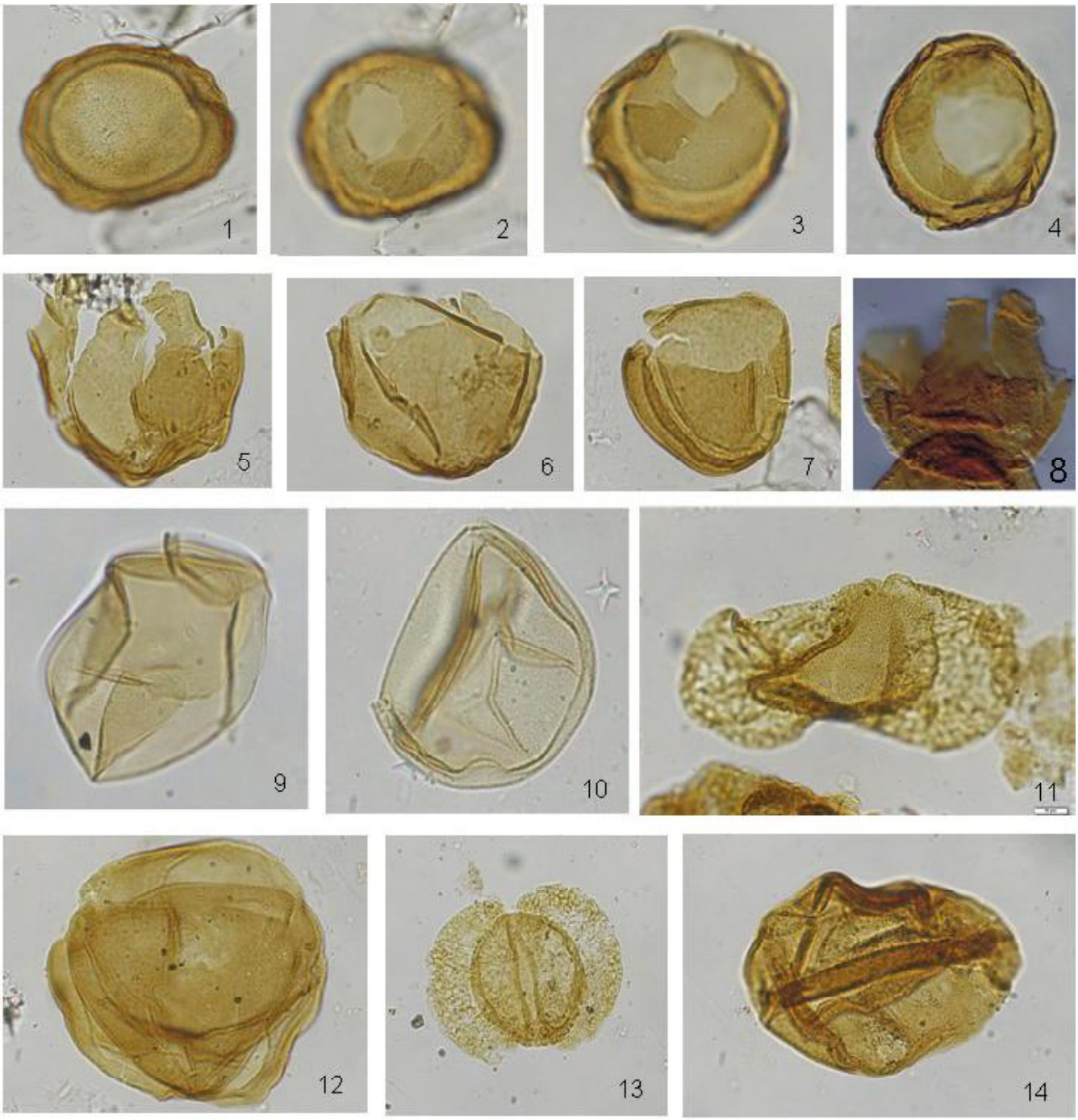


Fig. 2. Lithounits of the investigated sections of the Rajmahal Basin exposed at Sakrigali Ghat (a), Murali Pahar (b) and Kalkipara Pahar (c).

Plate II



EXPLANATION OF PLATE II

(All figures are ca 500X)

(1-14) Palynomorphs recovered from the intertrappean beds of Rajmahal Traps, Rajmahal Basin, eastern Jharkhand. 1-4, Type A; 1, showing granulose wall; 2, showing archaeopyle and the lid; 5-7, ***Batiacasphaera*** sp. 8, ***Dissiliodinium***; 9-10, ***Batiacasphaera levigata***; 11, ***Podocarpidites grandis***; 12, ***Callialasporites trilobatus***; 13, ***Podocarpidites ellipticus***; 14, ***Araucariacites australis***.

Kalkipara Pahar, southern Rajmahal basin

This section is exposed about 1 km north of Kalkipara village and is located about 2.8 km northeast of Amrapara, Pakur Distict, Jharkhand. At Kalkipara Pahar, three lava flows and two intertrappean beds could be recognized (Fig. 2c). The base of lava flow No 1 is not exposed (Pl I, figs. D-F). The intertrappean beds mainly comprise hard siltstone and medium to fine-grained fossiliferous sandstone. In this site, the plant fossils are very rare.

PALYNOLOGICAL AND PALAEOBOTANICAL OBSERVATIONS

The samples collected from various intertrappean beds are not rich in palynomorphs, dinoflagellates cysts and plant megafossils. The preservation of fossils is bad to fair. Following taxa are recoded in the present study.

Palynomorph Taxa

Cyathidites australis Couper, 1953
Cyathidites sp.
Callialasporites trilobatus (Balme) Dev, 1961
Callialasporites segmentatus (Balme) Srivastava, 1963
Podocarpidites ellipticus Cookson, 1947
Podocarpidites grandis Sah and Jain,1965
Podocarpidites multesimus (Bolkhovitina) Pocock, 1962
Podosporites sp.
Araucariacites australis Cookson, 1947
Coptospora kutchensis Venkatachala, 1969
Balmeisporites sp

Reworked Palynotaxa

Callumispora Bharadwaj & Saluja, 1969
Densipollenites Bhardwaj, 1962
Scheuringipollenites Tiwari, 1973
Faunipollenites Bhardwaj, 1962
Striatites Pant emend Bharadwaj, 1962
Striatopodocarpites Soritsch & Sedova emend Bharadwaj, 1962

Dinoflagellate Taxa

Batiacasphaera sp.
Batiacasphaera laevigata (Smelror) Feist-Burkhardt & Montell, 1997
Dissiliodinium sp.
Type A.

Plant Megafossils

Ginkgoites rajmahalensis Sah and Jain, 1965
Elatocladus sp.
Sphenopteris sp.
Pachypteris sp.
Pterophyllum Brongniart, 1828

The assemblages are locality wise described below.

Moti Jharna Intertrappean Site

This is the first report of palynomorphs, dinoflagellate cysts and plant megafossils from this locality.

Palynomorphs: The yield of palynomorphs is rare to common and is shown in Pl. II, figs. A-N. The taxa recorded are *Araucariacites australis* Cookson, 1947; *Callialasporites trilobatus* (Balme) Dev, 1961; *C. segmentatus* (Balme) Srivastava, 1963; *Podocarpidites ellipticus* Cookson, 1947; *P. grandis* Sah and Jain, 1965; *P. multesimus* (Bolkhovitina) Pocock, 1962; *Podosporites* sp., *Cyathidites australis* Couper, 1953. Besides palynomorphs, some dinoflagellate cysts are also observed. These taxa are described below.

Batiacasphaera Drugg emend Dorhoffer & Davies, 1980
(Type species: *Batiacasphaera compta* Drugg, 1970)

Batiacasphaera laevigata (Smelror) Feist-Burkhardt & Montell, 1997.

(Pl. II, figs. 9, 10).

Description : Size 60.5-550.5 X 55.5-50.5 µm, spheroidal cyst, smooth or with slightly wrinkle walled, without any inner body and observed opening, exine 1.5-2.0 µm thick.

Batiacasphaera sp.
(Pl. II, figs. 5-7)

Description : Size 73.5-70.5 X 66.5-60.5 µm, spheroidal cyst without any inner body, exine 2.8µm thick, scabrate and pitted, apical archaeopyle, paratabulation indicated along archaeopyle margin by zig-zag splitting.

Dissiliodinium Drugg, 1978
(Type species: *Dissiliodinium golobulus* Drugg, 1978)
Dissiliodinium sp.
(Pl II, fig. 8)

Description: Cyst spherical in shape, wall is thin less than 1 µm and granulate, sculptural elements less than1 µm, paratabulation lacking, compound archeopyle, apical paraplate remain attached to the hypocyst.

Remarks: Only one specimen is observed in the present assemblage.

Type A
(Pl. II, figs. 1-4)

Description: Size 76-100 µm, subspherical to lenticular in shape, single walled, with slight thickening on the margin, wall granulo-punctate, a subcircular to round angular archaeopyle is present on one side, a circular to sub-circular area present beneath the opening, in compressed specimens it may be centric or accentric.

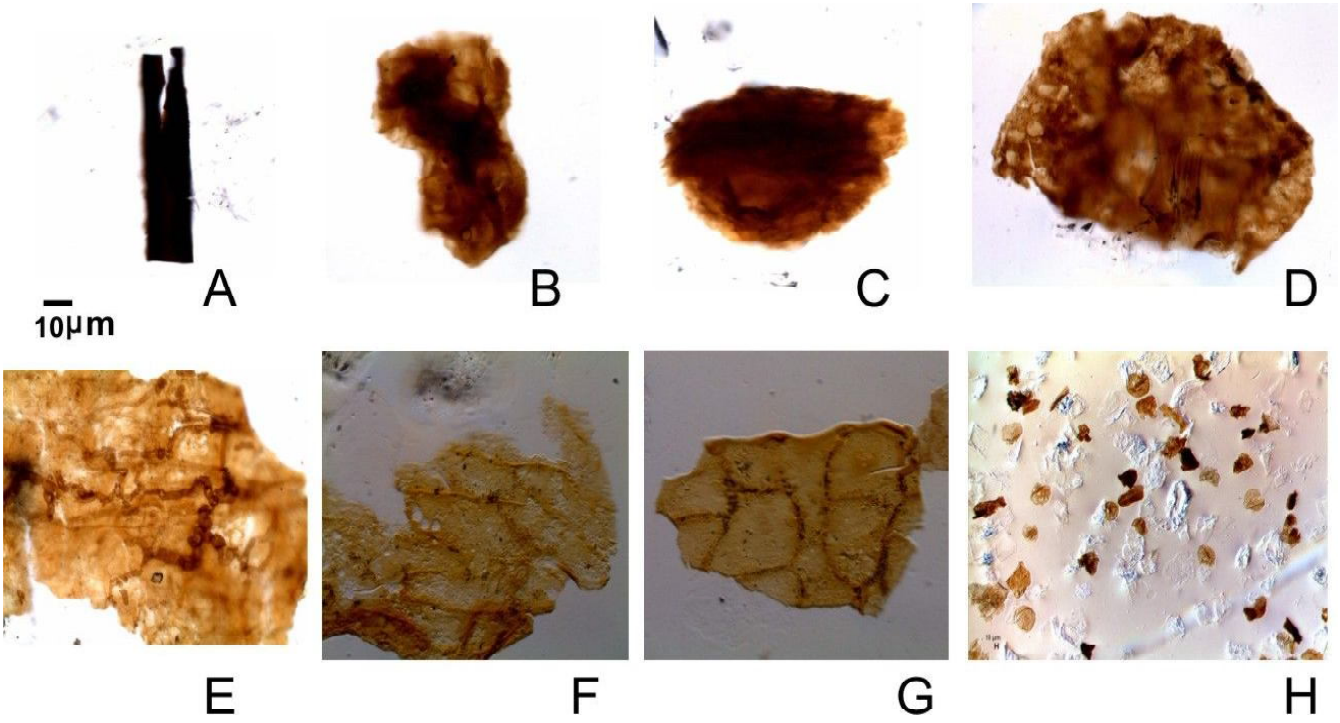
Plant megafossils: The plant fossils recorded from this intertrappean bed include leaf impression of *Ginkgoites rajmahalensis* Sah and Jain, 1965; and *Elatocladus* sp. (Pl. IV, figs. A, B) with carbonized cast. However, no cuticular details could be recovered from it. It represents the first report of plant fossils from this locality.

Discussion : The pollen taxa recorded here are long ranging and occur from Jurassic to Early Cretaceous. No significant age marker taxa could be observed. Hence, precise age could not be defined on the basis of spore and pollen. However, the dinoflagellate taxa (*Batiacasphaera, Dissiliodinium*) are recorded in abundance together with above-mentioned palynomorphs. These indicate Early Cretaceous age to the intertrappean beds exposed at Moti Jharna site.

Palynofacies analysis: In the present study, amongst the palynofacies constituents following types of organic matter debris were identified (Pl. III, figs. A-H)

1) *Black oxydized*: black opaque organic matter debris, also known as inertinite in coal maceral terminology is derived from the hard plant part, produced by oxidation of terrestrial plant tissues. On the basis of their mode of genesis they are of two types.
   i) *Unsorted semi-oxydized organic matter debris* : mostly of in-situ origin, formed due to intermittent aerial exposure of depositional surface, derived from the nearby vegetation source indicating proximity to the shoreline.
   ii) *Well-sorted equidimensional terrestrial woody particles*: indicates physical reworking during transportation process, undergoes mechanical abrasion and biotic degradation resulting in rounding and sorting of the particles. They signify long distance transport and high energy conditions.
2) *Brown degraded debris* : poorly oxydized translucent to opaque higher land plant tissue where the cellular structure is not clearly visible. It originates due to incomplete oxidation of terrestrial plant littre. They occur in abundance in the coal and lignite bearing lithofacies and are indicative

Plate III



EXPLANATION OF PLATE III

A-opaque black oxidized particle. B, C, D Brown degraded particle without any cellular structure (rounding of edges is very prominent in C is indicative of long distance transport. E, cuticular phytolclast showing partial degradation. F, G, well preserved plant cuticle. H, well sorted dispersed organic matter debris.

of terrestrial nature of the depositional environment.

3) *Structured, well-preserved organic matter debris*: It is usually derived from the cuticle of higher land plants. Light yellow fragments with clear cellular structures are commonly designated as cutinite in coal maceral terminology. Its dominance is indicative of proximal depositional environment, rapid burial and good accommodation potential.

Palaeoecology: In the present palynological assemblage, dinoflagellate cysts are present in large numbers along with terrestrially derived organic matter (Fig. 3) indicating shallow marine environment of deposition. Though they are present in abundance, their diversity pattern is low with only three morphotypes indicating restricted marine setting and highly stressful environment of deposition. The well-sorted, equi-dimensional particles occur in large proportion suggesting hydrodynamic conditions of river channels or long distance transport. However, presence of well-preserved cuticle in the assemblage points to proximity to shoreline.

Sakarigali Ghat Site

Palynomorphs: The samples collected from this site yielded rare spore and pollen. These are *Araucariacites australis* Cookson, 1947; *Podocarpidites ellipticus* Cookson, 1947 and *Callialasporites trilobatus* (Balme) Dev, 1961. All the palynomorphs are long ranging from Jurassic to Early Cretaceous. Hence precise dating could not be achieved. The intertrappean bed exposed in the section towards the river did

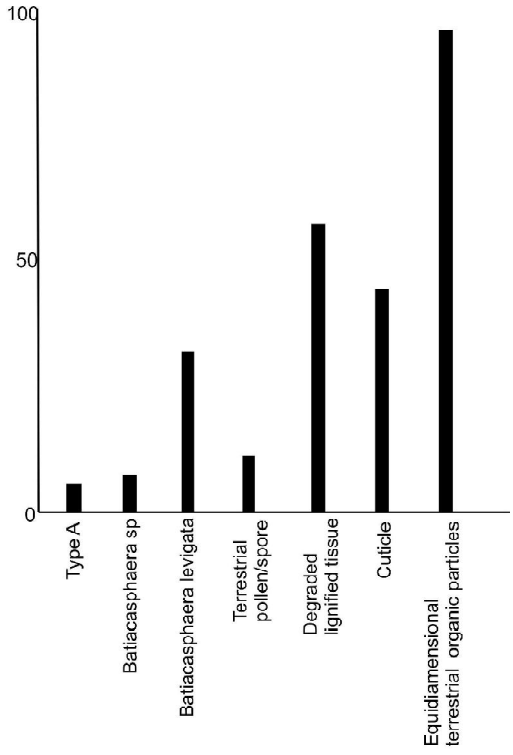


Fig.3. Distribution pattern of palynofacies constituents recorded in sample from the intertrappean bed at locality Moti Jharna.

not yield spore and pollen.

Remarks: Sah and Jain (1965) reported a rich assemblage of spores and pollen from the intertrappean bed exposed on the river side section. This has the composition of typical Early Cretaceous palynoassemblage consisting of taxa *Gleicheniidites mundus* Sah and Jain, 1965; *Deltoidospora triangularis* Sah and Jain, 1965; *Callispora baculoexinus* Sah and Jain, 1965; *Concavisimmisporites minor* Sah and Jain, 1965; *Ceratosporites* sp., *Paucibaculisporites increbscense* Sah and Jain, 1965; *Cicatricosisporites australiensis* (Cookson) Potonie, 1956; *Ischyosporites irregularis* Sah and Jain; *Trilobosporites purverrulentus* (Verbitskaya) Dettmann, 1963; *Foraminisporis* sp. cf. *asymmetricus* (Cookson and Dettmann) Dettmann, 1963, and species of *Callialasporites*, *Podocarpidites*, *Podosporites*, *Araucariacites*. It is to be noticed that the intertrappean beds analyzed by Sah and Jain (1965) is now under alluvium and the bed studied at present is quite high up in the succession.

Plant megafossils: The plant megafossils could not be observed in the presently traversed intertrappean beds.

Discussion: Sakrigali Ghat is one of the richest localities that yielded a variety of megafossils such as *Sphenopteris sakrigaliensis* Sah (Sah, 1966), *Ginkgoites* (Sah 1952), *Williamsonia santalensis* Sitholey and Bose (Sitholey and Bose 1953), and *Weltrichia santalensis* Sitholey and Bose (Sitholey and Bose, 1971). These megafossils have been recovered from a lower intertrappean bed adjacent to river water current. This fossiliferous bed is present under alluvium. The present intertrappean bed is younger to the one from where the plant megafossils were described by Sah (1966).

Murali Pahar Intertrappean Site

Palynomorphs: Rare yield of palynomorphs records taxa *Araucariacites australis* Cookson, 1947; *Podocarpidites ellipticus* Cookson, 1947; *P. grandis* Sah and Jain, 1965; *P. multesimus* (Bolkhovitina) Pocock, 1962; *Callialasporites trilobatus* (Balme) Dev, 1961; *Coptospora kutchensis* Venkatachala, 1969; *Cyathidites* sp., *Balmeisporites* sp. and microthyracious fungi. Again in the absence of marker taxa no precise age could be determined except the Early Cretaceous age.

Remarks: Besides above mentioned taxa, reworked Permian spore and pollen are also recorded. These are *Faunipollenites, Striatites, Striatopodocarpites, Scheuringipollenites, Densipollenites* and *Callumispora*.

Plant Megafossil: The strata in this bed are very uneven and with irregular surface. Here the assemblage consists of the taxa *Sphenopteris* sp., *Pachypteris* sp. and fragmentary pieces of *Pterophyllum* Brongniart (Pl. IV, fig. D). The details of venation are not distinct due to uneven surface and comparatively coarse nature of the sediments.

Remarks: From Murali Pahar Bose and Sah (1968) and Banerji (1995) recorded a fairly rich plant assemblage. It comprises of *Cladophlebis* sp., *Phyllopteroides laevis* Contrill and Web, *Coniopteris* sp., *Muralipaharopteris indica* Banerji, *Ptilophyllum acutifolium* Morris, *P. cutchense* Morris, *Otozamites gondwanensis, Taeniopteris spatulata* McClell, *Elatocladus conferta* (Oldham and Morris) Halle, *E. jabalpurensis* (Feistmantel) Sahni, *Desmiophyllum* sp. and scale leaf. The present fossil bearing intertrappean bed is overlying the one from where earlier workers described plant fossils.

Discussion: The above account does not provide precise age to the intertrappean bed except Early Cretaceous.

Sonajuri Intertrappean Site

Palynomorphs: The material did not yield spores and pollen.

Plant megafossils: The petrified ovulate *Araucarian* cones have been found from this locality in the present collection (Pl. IV, fig. C) The specimens of araucarian cones were small one and do not have enough scope to add further morphological details. The seed-bearing scales of *Araucaria* are not having any further detail than as described by Bohra and Sharma (1980) and Banerji and Jana (2003).

Discussion: The ovulate cones of Araucaria are known from Early Cretaceous. No precise age could be assigned to these beds.

Kalkipara Intertrappean Site

Palynomorphs: No palynomorphs could be seen.

Plant megafossils: From this area several petrified wood pieces were collected. But unfortunately in thin section none of the wood shows preservation. The taxa *Ptilophyllum* sp. is found here as impression from the Upper intertrappean bed.

Discussion : In the absence of palynomorphs and presence of woods and *Ptilophyllum* sp., no precise age could be assigned except broad Early Cretaceous age.

CONCLUSIONS

- This is the first report of palynomorphs, dinoflagellates and plant megafossils from Moti Jharna locality.
- Presence of taxa *Batiacasphaera* Dissliodinium indicates Early Cretaceous age.
- The palynofacies analysis indicates deposition at proximity to nearshore.
- Identification of a sequence of four traps and three intertrappean beds at Murali Pahar section and occurrence of fossils from third intertrappean bed was reported.
- Two interappean beds at Kalkipara were identified having scanty plant megafossils

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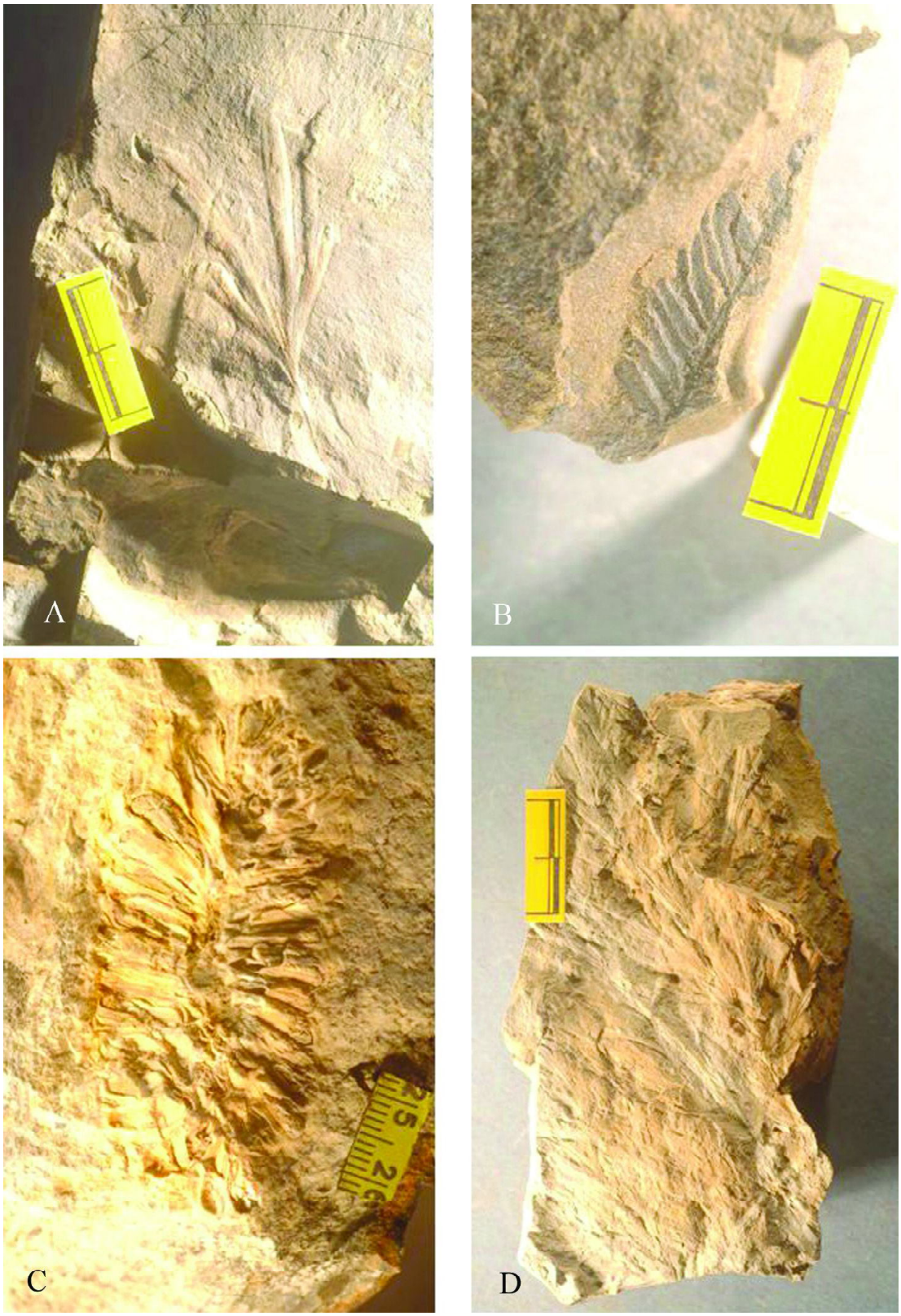
Plate IV



TRIPATHI, JANA, VERMA, SINGH AND SINGH

EXPLANATION OF PLATE IV

(A-D), Megaflora recovered from intertrappean beds of Rajmahal Traps, Rajmahal Basin, eastern Jharkhand. A-B, Megaflora from Moti Jharna; A, ***Ginkgoites rajmahalensis*** and B, ***Elatocladus*** sp. C, Araucarian ovulate cone from Sonajuri and D, ***Pterophyllum*** sp. from Murali Pahar.

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