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Upper Gondwana palynoflora of Mahanadi Master Basin, Orissa, India

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ABSTRACT. Athgarh is the only Upper Gondwana Basin of Mahanadi Master Basin. Rich palynofloral diversity is recorded for this basin. For the first time, an Upper Gondwana palynoflora is reported from the shales of a megafossil locality, Saradia pahar, in the present paper. Till the date the Upper Gondwana palynofloral assemblage were recovered from four different localities including Saradia pahar. The assemblage is composed of about 138 species in 59 genera. This flora is dominated by gymnosperm pollen. Pteridophytic spores are meagrely represented. On the basis of palynology it is inferred that the Athgarh Sandstone is Lower Cretaceous in age. No angiosperm element has been recorded so far from this basin. Thus, its upper limit is within Albian.

KEY WORDS: palynoflora, Upper Gondwana, Athgarh Formation, Lower Cretaceous, Orissa, India

INTRODUCTION

The Upper Gondwana (Late Mesozoic) sediments exposed in the Mahanadi Master Basin of Orissa occupy a unique position in Indian stratigraphy. Blandford et al. (1859) used the term "Athgarh Basin" to demarcate the area over which the sandstones are exposed. Ball (1877) first investigated the area for the probable occurrence of coal and collected a few plant remains from the type locality Ghantikhal (Fig. 1). Athgarh Sandstone constitutes the northernmost exposure of the East Coast Upper Gondwana units of India (Patra & Sahoo 1996).

The Athgarh Basin is delimited by latitudes 20°15′ and 20°33′ N and longitudes 85°35′ and 85° 50′ E. It is exposed to the north, northwest and southwest of Cuttack and Bhubaneswar and covers an area of about 800 km^2 in the districts of Cuttack and Khurda. The river Mahanadi divides the basin into two unequal parts such that the southern portion is about three times greater than the northern one.

This Athgarh Basin in Orissa has received a few attention from palynologists. The first published palynological record from this Basin was by Maheshwari (1975). Subsequently, there are few more published accounts on micro-plant remains from this basin (Maheshwari 1975, Patra 1982, 1990, Jana & Tiwari 1986, Jana 1990, Sahoo 1993, Patra & Sahoo 1996, Goswami et al. 2006). But so far no analytical study has been carried out in this Upper Gondwana Basin.

For the first time, Upper Gondwana palynoflora is reported from the shales of the megafossil locality, Saradia pahar in the present study. In addition, palynofloral assemblages of Athgarh Sandstone were recovered mainly from three localities viz., Sidheswar Hill near Naraj, Jagannath Prasad, and Talbast (Fig. 1).

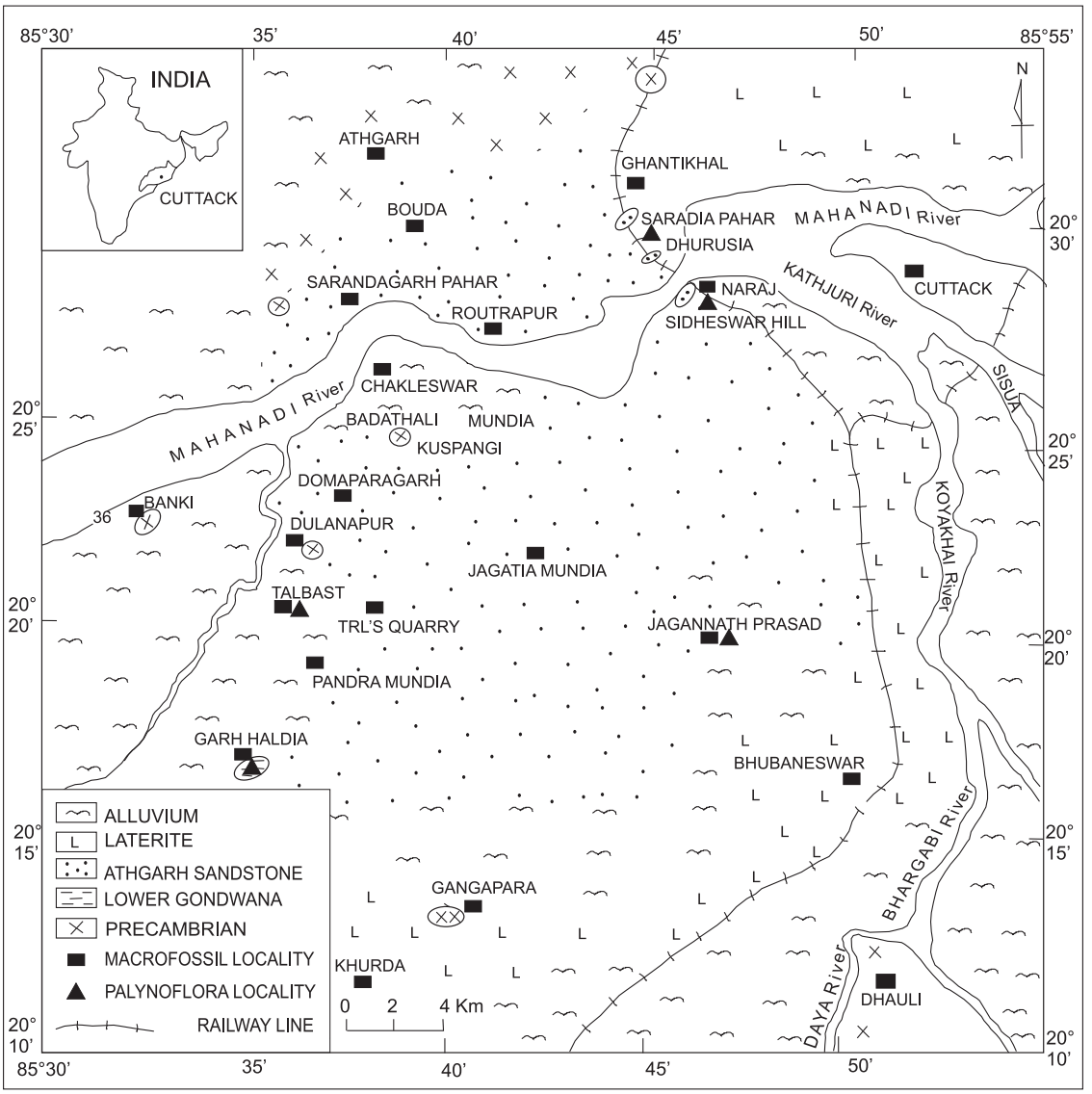


Fig. 1. Geological map of Athgarh Basin, Orissa, India (after Patra & Sahoo 1996)

The present study is a review of previous palynological works (Maheshwari 1975, Patra 1982, 1990, Jana & Tiwari 1986, Jana 1990, Sahoo 1993, Patra & Sahoo 1996, Goswami et al. 2006) and the present study.

PREVIOUS PALYNOLOGICAL STUDIES

LOWER GONDWANA PALYNOFLORAL ASSEMBLAGE

Tiwari et al. (1987) reported palynological findings from an isolated patch of brownish green shale of Lower Gondwana affinity near Garh Haldia in Athgarh Basin. This bed is the only Lower Gondwana exposure observed in this basin. Khaki green shale unit contains a palynoflora which is characterized by the presence of *Plicatipollenites gondwanensis* Lele 1964 and *P. indicus* Lele 1964 of the monosaccate genus, *Plicatipollenites* Lele 1964 and one alete genus *Leiosphaeridia* Eisenack 1958 along with few trilete spores *Leiotriletes* and few nonstriate disaccate pollen, *Vestigisporites*. Moreover, the assemblage consists of some black organic bodies namely *Legenochitina* and *Desmochitina*. Compositionally, this assemblage is of Talchir (early Lower Permian) affinity (Tiwari et al. 1987). The presence of only one monosaccate type, rarity of disaccates and absence of apiculate trilete spores apparently show the lack of the diversification in the assemblage. Possibly it suggests an affinity within the older Talchir palynoflora. Moreover, it is interesting to note that the specimens of

Plicatipollenites found here have a relatively smaller size range (50–85 μm) than those recorded from other palynofloras (124–160 μm) having older Talchir affinity (Lele 1975). This small size of monosaccate specimens suggests adaptability towards the extreme cold conditions in the early Talchir time. The Chitinozoa like bodies and *Leiosphaeridia* are indicators of shallow marine conditions of deposition.

UPPER GONDWANA PALYNOFLORAL ASSEMBLAGE

The Upper Gondwana palynoassemblage recovered from the following three localities:

Carbonaceous shales of Sidheswar Hill near Naraj (latitude 20°27′50″N and longitude 85°46′E)

Ash grey fireclay of Jagannath Prasad (latitude 20°20′N and longitude 85°46′50″E)

Black shales/clay of M/S Tata Refractories Ltd.'s Fireclay quarry near Talbast (latitude 20°20′30″N and longitude 85°36′E)

For the first time Maheshwari (1975) reported an Upper Gondwana palynofloral assemblage from Sidheswar Hill, Naraj and Jagannath Prasad in this basin. He recorded 45 species belonging to 29 genera of pollen and spores and has predominance of gymnosperm pollen, particularly *Araucariacites* and *Callialasporites.* In its quantitative composition the flora of Sidheswar Hill, Naraj, and Jagannath Prasad areas has overall resemblance with the miofloras of the Vermavaram and Upper Katrol beds of Indian Upper Gondwana.

Jana and Tiwari (1986) recorded a well preserved, diversified microflora consisting of 35 genera and 48 species from Sidheswar Hill, Athgarh Formation. The assemblage includes 14 genera not previously recorded by Maheshwari (1975). The microflora supports an Upper Jurassic to Lower Cretaceous age of the Athgarh Formation.

Jana (1990) recovered palynoassemblage from an outcrop of Athgarh Formation, near Talbast region in the southern part of Athgarh Basin. The assemblage comprises 23 genera and 33 species and is characterized by the dominance of the genus *Murospora* and the palynofloral composition, as a whole, shows its affinity with Upper Jurassic/Lower Cretaceous palynological assemblages.

Patra (1982) and Sahoo (1993) carried out palynological studies during their doctoral researches and recorded a number of Upper Gondwana palynoassemblages of Upper Jurassic – Early Cretaceous age from all the above mentioned localities.

GEOLOGY AND STRATIGRAPHY OF ATHGARH BASIN

The Athgarh Formation with an estimated thickness of 400 meters (Kumar & Bhandari 1973) rests unconformably over Eastern Ghats granulites (Precambrian), with dips of 3–10° to the S and SE (Pandya 1995), or on Permian rocks (Tiwari et al. 1987). It is mainly covered by rocks of the Upper Gondwana Group and is intruded by a single known basaltic dyke (dolerite) near Sidheswar Hill. Some portion of the Athgarh Sandstone is concealed by laterite and alluvium. However, Athgarh Sandstone has also been encountered in the subsurface, i.e. in the offshore region of coastal Orissa in the Bay of Bengal (Kaila et al. 1987). Athgarh Sandstone, as the name indicates, comprises various types of sandstones namely gritty, feldspathic, clayey, ferruginous etc. The Athgarh Formation consists of quartz arenite, sublithic arenite, lithic arenite and lithic wackes and those are characteristically lack feldspars (Mishra 1988, Pal 1990). Compositionally they vary from argillaceous to ferruginous. Other rock types include conglomerates, grits, carbonaceous shale, yellow shale, purple shale, white ash grey and brown colored fireclays. The sandstone hillocks occur as elevated topography of the area. The convex sides of the hillocks stretch in a south easterly direction having gentle slope. The north western side looks like a scarp and south eastern have gradual slope (Adyalkar 1962, 1965, Patra & Sahoo 1996, Kumar & Bhandari 1973, Chatterji et al. 1968, Mishra 1988, Singh Deo 1990).

It is observed that a basic igneous body namely dolerite has intruded into the Athgarh Sandstone at the Sidheswar Hill peak and it's surrounding, west of Naraj. It has come up through a fissure developed due to faulting and pushed up the carbonaceous, pink and yellowish shales to a higher position (Patra & Sahoo 1996). The dolerites have been studied by Acharya & Mahanti (1965) and Acharya & Ray (1969). Agrawal & Rama (1976) have radiometrically dated the intrusive to be 109 ± 3 my old. The lowest exposed section consists of coarse, loose textured conglomerate and ferruginous

Table 1. Stratigraphic nomenclature for the Athgarh Basin (after Patra & Sahoo 1996)

Age	Formation	Lithology	Thickness
Recent		Alluvium, Laterite	
Lower Cretaceous		Dolerite intrusive	
	Athgarh	Sandstone with intercalation of shale and clays	400 m
Unconformity			
Early Lower Permian	Talchir	Pale-green splintery shale	
Unconformity			
Precambrian		Charnockites, khondalites, basic granulites and quartzites	

sandstones while light coloured clays and sandstones occur near the top. This top sequence is perhaps co-eval with Dubrajpur sandstones of the Rajmahal Basin (Manjrekar et al. 2006). A generalized stratigraphic succession of the Athgarh Basin is given in Table 1.

MATERIAL

In the mean time, a palynoassemblage has been recorded by the authors from the shales exposed in the eastern flank of Saradia pahar. It is a small hillock near Ghantikhal. This locality is bounded by the latitude 20°30′20″N and longitude 85°44′20″E (Fig.1). Upper Gondwana palynoassemblage is recovered from this area in the present study. The present study includes the palynological analysis of about 60 shale samples from the said locality.

GEOLOGICAL SETTING

Saradia pahar is a small hillock near Ghantikhal and is in the eastern margin of the Athgarh Basin and to the north of the Mahanadi. A palynoassemblage has been recorded by the authors from the shales exposed in the eastern flank of Saradia pahar. The eastern flank of Saradia pahar Hillock exposes carbonaceous shale, siltstone, purple and yellow shale with laterite capping. Numerous spores and pollen grains are recorded from this locality. The geological section along Saradia pahar is presented in Fig. 2. The lithological succession observed along eastern flank is on the Table 2.

Table. 2. Litology

Rock types	Thickness in meters
Laterite	6
Purple shale	4
Yellow shale	3
Siltstone	3
Purple shale with black hue	2
Carbonaceous shale	5
Base is not exposed	

PALYNOASSEMBLAGE

List of spores and pollen grains recorded from the Saradia pahar locality in the present paper. Photographs of these spores and pollen are presented in the Figure 3.

Aequitriradites spinulosus Cookson & Dettmann 1958
A. verrucosus Cookson & Dettmann 1961
Araucariacites australis Cookson 1947
Boseisporites insignitus Venkatachala 1969
Callialasporites segmentatus (Balme 1957) Sukh-Dev 1961
Cicatricosisporites angustus Singh 1970
C. annulatus Archangelsky & Gamerro 1966
C. hughesii Dettmann 1963
C. ludbrooki Dettmann 1963
C. purbeckensis Norris 1969.
Cicatricosisporites sp.
Contignisporites cooksoniae Dettmann 1963
C. fornicatus Dettmann 1963
Contignisporites sp.
Coptospora cauveriana Venkatachala 1973
C. kutchensis Venkatachala 1969
C. microgranulosa Venkatachala & Sharma 1974
C. verrucosa Tripathi, Tiwari & Kumar 1990
Cycadopites couperi Kumar 1973
Impardecsispora indica Venkatachala 1969
Lycopodiacidites dettmannae Burger 1980
Lycopodiacidites sp.
Murospora florida Pocock 1961
Neoraistrickia truncate Kumar 1973
Pilosisporites notensis Cookson & Dettmann 1958
P. trichopapillosus Cookson & Dettmann 1958
Podocarpidites novus Sah & Jain 1965
Podosporites tripakshii Rao 1943
Properinopollenites monoalasporus (Sukh-Dev 1961) Maheshwari 1974
Santhalisporites sp.

The palynoassemblage of Saradia pahar is closely comparable with the top zone in

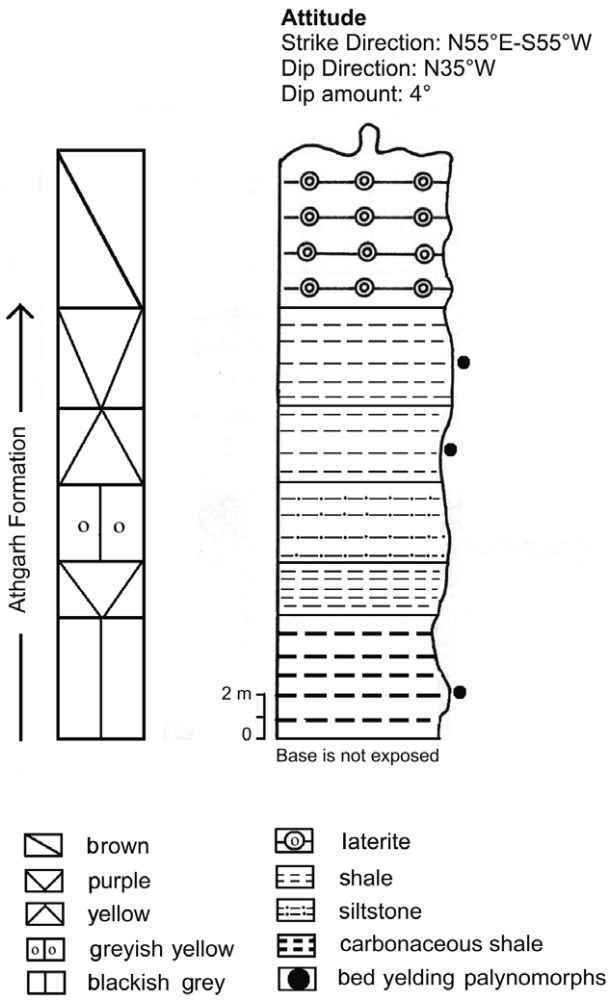
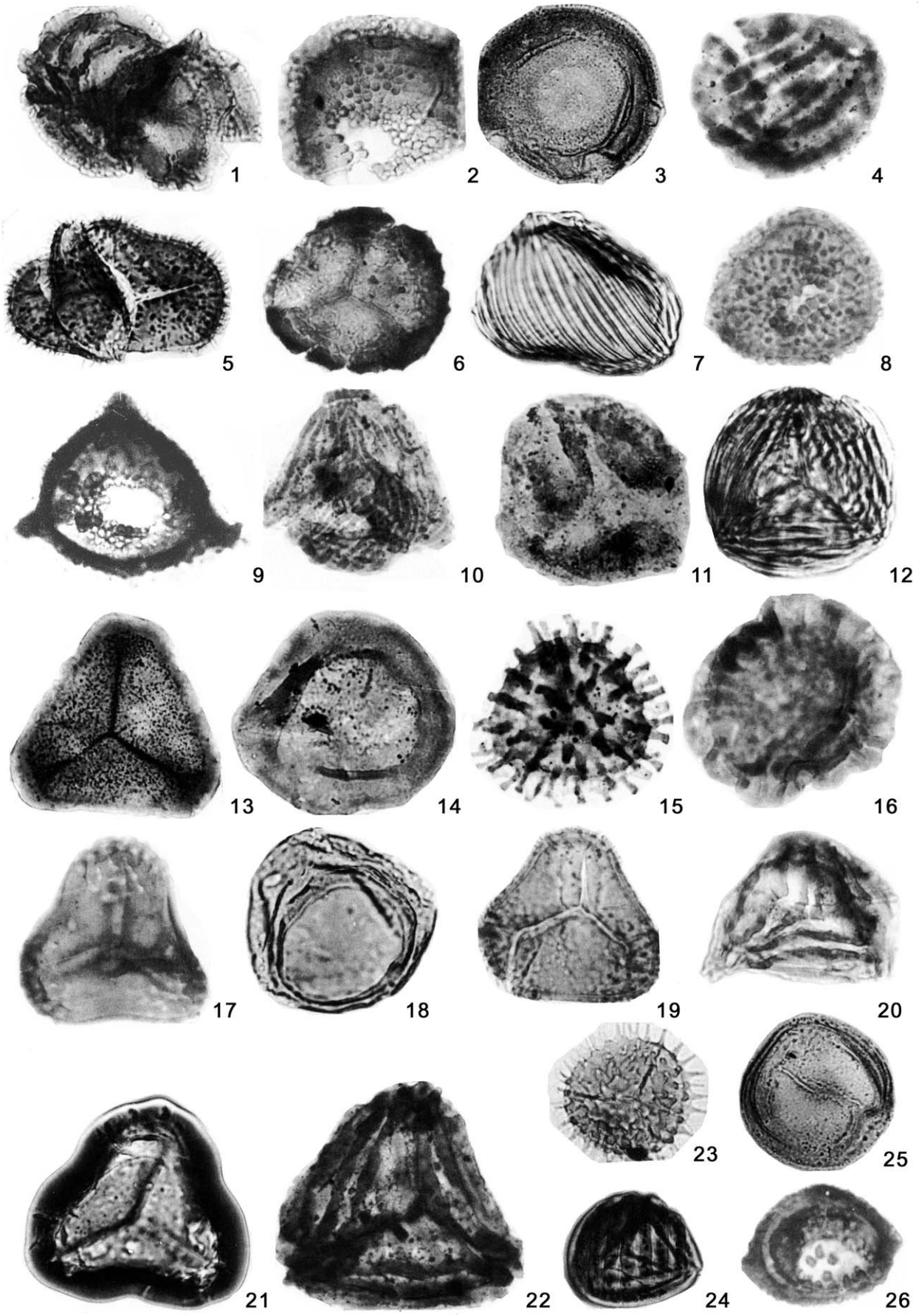


Fig. 2. Geological section along Saradia Pahar, Athgarh Basin, Orissa

Araucariacites complex of Bharadwaj (1969), whose composition is alete nonsaccates, prominent monocolpates, non-striated saccates, bisaccates, triletes, operculate and non-saccate elements. The typical Lower Cretaceous palyno-taxa namely *Coptospora cauveriana*, *C. kutchensis*, *C. microgranulosa*, *C. verrucosa*, and *Podosporites tripakshii* are recorded in this palynoassemblage. In addition, no angiospermic element has been recorded so far from this basin. Thus, this assemblage strongly affirms its age as Lower Cretaceous.

List of spores and pollen grains recorded by different authors from four Upper Gondwana palynofossil localities (Saradia pahar, Sidheswar Hill, Jagannath Prasad, Talbast) of the Athgarh Basin.

Abiespollenites sp.
Aequitriradites spinulosus Cookson & Dettmann 1958
A. verrucosus Cookson & Dettmann 1958
Aequitriradites sp.
Alisporites haradensis Kumar 1973
A. grandis Dettmann 1973
A. ovalis Kumar 1973
A. sehoraensis Kumar 1973
Alisporites sp.
Alsophyllidites bellus Venkatachala, Kar & Raza 1969
Araucariacites australis Cookson 1947
A. cooksoni Singh, Srivastava & Roy 1964
A. ghuneriensis Singh, Srivastava & Roy 1964
A. limbatus (Balme 1957) Habib 1969
Boseisporites insignitus Venkatachala 1969
B. minutus Venkatachala, Kar & Raza 1969
B. praeclarus Sukh-Dev 1961
Boseisporites sp.
Callialasporites trilobatus (Balme 1957) Sukh-Dev 1961
C. baculosus (Sukh-Dev 1961) Maheshwari 1974
C. dampieri (Balme 1957) Sukh-Dev 1961
C. discoidalis (Doring 1961) Bharadwaj & Kumar 1972
C. doering Kumar 1973
C. enigmatus (Singh & Kumar 1972) Kumar 1973
C. lametaensis Kumar 1973
C. lucidus (Pocock 1961) Maheshwari 1974
C. monoalasporus Sukh-Dev 1961
C. rudisacus Maheshwari 1974
C. segmentatus (Balme 1957) Sukh-Dev 1961
C. triletus Singh, Srivastava & Roy 1964
Callialasporites sp.
Cedripites nudis Kar & Sah 1970
Chordasporites sp.
Cicatricosisporites ludbrookii Dettmann 1963
C. angustus Singh 1970
C. annulatus Archangelsky & Gamerro 1966
C. hughesii Dettmann 1963
C. purbeckensis Norris 1969
Cicatricosisporites sp.
Classopollis indicus Maheshwari 1974
C. classoides Pocock & Jansonius 1961
Classopollis sp.
Concavisporites indicus Venkatachala 1969
C. crassus Venkatachala, Kar & Raza 1969
C. novicus Kumar 1973
Concavisporites sp.
Concavissimiporites crassatus (Delcourt & Sprumont 1955) Delcourt, Dettmann Hughes 1963
Concavissimiporites sp.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Contignispoites fornicatus Dettmann 1963
C. cooksoniae (Balme 1957) Dettmann 1963
C. dettmanii Singh & Kumar 1966
C. glebulentus Dettmann 1963
Contignisporites sp.
Coptospora cauveriana Venkatachala 1973
C. kutchensis Venkatachala 1969
C. microgranulosa Venkatachala & Sharma 1974
C. verrucosa Tripathi, Tiwari & Kumar 1990
Coptospora sp.
Crassimonoletes surangei Singh, Srivastava & Roy 1964
Crassimonoletes sp.
Cyathidites australis Couper 1953
C. concavus (Bolkhovitina 1953) Dettmann 1963
C. cutchensis Singh, Srivastava & Roy 1964
C. ghuneriensis Singh, Srivastava & Roy 1964
C. minor Couper 1953
Cyathidites sp. cf. *C. asper* Couper 1953
Cyathidites sp.
Cycadopites couperi Kumar 1973
Cycadopites sp
Deltoidospora sp.
Dettmannites sp.
Dictyophyllidites harrisii Couper 1958
Dictyophyllidites sp.
Faveosporites foveolus Venkatachala, Kar & Raza 1969
Faveosporites sp. cf. *F. canalis* Balme 1957
Faveosporites sp.
Foveotriletes sp.
Ginkgocycadophytus sp.
Gleicheniidites cercinidites (Cookson 1953) Dettmann 1963
Gleicheniidites sp.
Impardecispora indica Venkatachala 1969
I. apiverrucata (Couper 1958) Venkatachala, Kar & Raza 1969
I. uralensis (Bolkhovitina 1966) Venkatachala, Kar & Raza 1969
Inaperturopollenites sp.
Ischyosporites crateris Balme 1957
Ischyosporites sp.
Klukisporites pseudoreticulatus Couper 1958
K. areolatus Singh 1970
K. scaberis (Cookson Dettmann 1958) Dettmann 1963
K. variegatus Couper 1958
Klukisporites sp.
Laevigatosporites sp.
Lakhnavitriletes bansaensis Maheshwari 1974
Lametatriletes indicus Singh & Kumar 1972
Leschikisporis rudis Kar & Sah 1970
Leschikisporis sp.
Lycopodiumsporites circolumenus Cookson Dettmann 1958
L. austroclavatidites (Cookson 1953) Potonié 1956
Lycopodiacidites subtriangulus Venkatachala, Kar & Raza 1969
L. dettmannae Burger 1980
Lycopodiacidites sp.
Matonisporites crassiangulatus (Balme1957) Dettmann 1963
M. kutchensis Venkatachala 1969
Microcachryidites antarcticus Cookson 1947
Monolites intragranulosus Singh, Srivastava & Roy 1964
M. indicus Kumar 1973
Monosulcites ellipticus Kumar 1973
Murospora florida Pocock 1961
Neoraistrickia pallida Kumar 1973
Osmundacidites wellmanii Couper 1953
Osmundacidites sp.
Pilosisporites notensis Cookson & Dettmann 1958
Pilosisporites sp. cf. *P. notensis* Cookson & Dettmann 1958
P. trichopapillosus Cookson & Dettmann 1958
Platysaccus densus Kar 1968
Podocarpidites novus Sah & Jain 1965
P. ellipticus Cookson 1947
P. magnus Maheshwari 1974
P. vermiculatus Kumar 1973
Podocarpidites sp.
Podosporites tripakshii Rao 1943
P. raoi Singh, Srivastava & Roy 1964

←

Fig 3. 1. *Cicatricosisporites purbeckensis*, **2.** *Aequitriradites spinulosus*, **3.** *Coptospora microgranulosa*, **4.** *Contignisporites cooksoniae*, **5.** *Pilosisporites trichopapillosus*, **6.** *Lycopodiacidites* sp., **7.** *Cicatricosisporites angustus*, **8.** *Lycopodiacidites dettmannae*, **9.** *Aequitriradites verrucosus*, **10.** *Cicatricosisporites* sp., **11.** *Podosporites tripakshii*, **12.** *Cicatricosisporites annulatus*, **13.** *Boseisporites insignitus*, **14.** *Coptospora kutchensis*, **15.** *Neoraistrickia truncate*, **16.** *Callialasporites segmentatus*, **17.** *Impardecispora indica*, **18.** *Contignisporites* sp., **19.** *Pilosisporites notensis*, **20.** *Cicatricosisporites hughesii*, **21.** *Murospora florida*, **22.** *Cicatricosisporites ludbrooki*, **23.** *Santhalisporites* sp., **24.** *Contignisporites fornicatus*, **25.** *Coptospora cauveriana*, **26.** *Coptospora verrucosa*, (Magnification × 500)

Properinopollenites monoalasporus (Sukh-Dev 1961) Maheshwari 1974
P. singhii Maheshwari 1974
Psilospora sp.
Reticulatisporites pudens Balme 1957
Retitriletes circolumenus (Cookson & Dettmann 1958) Backhouse 1978
Santhalisporites sp.
Schizosporis sp.
? *Sehorapollenites* sp.
Todisporites major Couper 1958
T. minor Couper 1953
Todisporites sp.
Triletes sp.
Trilobosporites trioreticulatus Cookson & Dettmann 1958
Verrucosisporites sp.
Vitreisporites pallidus (Reissinger 1950) Nilsson 1958
Vitreisporites sp.

DISCUSSION AND CONCLUSION

Before discussing the palynoassemblage of Athgarh Formation/Athgarh Sandstone, the palynological assemblage zones of Mesozoic rocks of India as quoted by Bharadwaj (1969) should be discussed for better interpretation. According to him Lower Jurassic assemblage is dominated by *Classopollis* complex. Similarly, Middle to Upper Jurassic palynofloras are epitomized by varying proportions of *Araucariacites* and *Callialasporites* pollen complex. It is interesting to note that *Araucariacties* and *Callialasporites* pollen types continue to have the dominance during Lower Cretaceous. However, along with these pollen types, a number of distinct spore and pollen genera namely *Appendicisporites*, *Aequitriradites*, *Impardecispora*, *Lametatriletes*, *Cicatricosisporites*, and *Trilobosporites* are also found during Lower Cretaceous. These incoming palynomorphs have changed the palynospectra of Lower Cretaceous *vis-à-vis* the Jurassic. It is evident that the considerable number of spore and pollen taxa simply run through and be on both sides of the Upper Jurassic and Lower Cretaceous boundary. But the obvious appearance of above mentioned incoming characteristic cryptogamic sporomorphs heralds the bottom of Cretaceous.

The whole palynoassemblage of Athgarh Sandstone of above mentioned four localities can be intimately comparable to the top zone in *Araucariacites* complex of Bharadwaj (1969), whose composition is alete nonsaccates, prominent monocolpates, non-striated saccates, bisaccates, triletes, operculate, and non-saccate elements. Prominent spore and pollen genera are *Araucariacites*, *Cycadopites*, and *Podocarpidites*. The assemblage strongly affirms its age as Lower Cretaceous.

Maheshwari (1974) reported Upper Gondwana palynoassemblages from Rajmahal, Jabalpur and Bansa. According to him all these palynoassemblages belong to one biostratigraphic zone namely *Araucariacites-Callialasporites* assemblage zone. However, at the same time he postulated the existence of following three sub-zones.

Podocarpidites-Cyathidites-Gleicheniidites assemblage sub-zone of Rajmahal intertrappean beds;

Cycadopites-Podocarpidites-Classopollis assemblage sub-zone of Lametaghat, Hathnapur and Sehora;

Cycadopites-Podocarpidites-Properinopollenites assemblage sub-zone of Bansa.

The Athgarh palynofloral assemblage fits more appropriately to the assemblage subzone *Cycadopites-Podocarpidites-Properinopollenites* assemblage sub-zone of Bansa, though it has a significant number of *Murospora*. However Jana (1990) had categorically assigned *Murospora* rich assemblage of Talbast as Lower Cretaceous age. The Athgarh palynofloral assemblage can also be compared with pollen zones of Mahashwari and Jana (1988) of Jhuran and Bhuj formations. Interestingly assemblages from all three formations (Athgarh, Bhuj and Jhuran formations) have rich diversity of spores and pollen and have no marine elements. Athgarh assemblage firmly matches with the Palynozone II of Mahashwari & Jana (1988) of Bhuj Formation, where *Impardecispora, Bhujiasporites* and *Lycopodiumsporites* etc. are common.

On the basis of palynology it is inferred that the Athgarh Sandstone is of Lower Cretaceous age. While discussing the Wealdean palaeoflora of Gondwana basin, Borkar (1993) has placed the Athgarh, younger to the other East Coast basins. Tectonic set up suggests that all the East Coast Upper Gondwana basins are formed in Lower Cretaceous (Patra & Sahoo 1996). Furthermore, no angiospermic element

has been recorded so far from this basin. Thus, its upper limit is within Albian. In view of the above discussion it can be undoubtedly concluded that Athgarh Sandstone is of Lower Cretaceous age.

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