

Pollen showing angiospermoid characters from Late Permian of Peninsular India

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For the first time the angiospermoid character in Late Permian pollen exine from Raniganj sediments of Rajmahal Basin has been reported. A new genus *Daminites* has been described having infrareticulate-infrabaculate exine and two to three sulci on each face disposed along the longer axis, the sexine on terminal end thins out exposing the nexine. Pollen referable to *Cornetipollis* Pocock & Vasanthy 1988 and reticulate monosulcate pollen *Monocrinopollis* Cornet 1989 have also been recorded from the Late Permian sediments of Talcher Coalfield, Orissa.

Key-words—Pollen, Angiospermoid characters, Permian, India.

INTRODUCTION

THE ultrastructural studies of Permian pollen have provided finer internal details of exine structure facilitating identification of columellate tectate characters which in many cases is otherwise not distinct in Light Microscopy, even through "L-O" analysis. However, once a character has been substantiated with the Electron Microscopy, the finer morphographic structures may be easily observed and better understood in LM subsequently, with intentional search under the microscope. Cornet (1979), for the first time, reported very character-

istic pollen with angiospermoid characters—the *Crinopollis* Group from the Late Triassic-Chinle Formation in USA. After Cornet's report number of publications have appeared on similar findings (Litwin 1985; Cornet 1989; Zavada 1990; Pocock & Vasanthy 1988) although the angiosperm affinity has not been assigned to the most of these pollen.

During a palynological analysis of subsurface Late Permian sediments from Rajmahal area, Bihar and Talcher Colfield, Orissa (Figs. 1, 2), a group of pollen showing angiospermoid exine characters are recorded. This being the first report from India shall initiate further intensive search of angiospermoid exine characters. The palynological slides are stored in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Discussion on significant nonsaccate, sulcate pollen

A number of nonsaccate, striate and polyplcate pollen with one or many sulcus are on record from Late Permian and Mesozoic palynofloras, viz., *Ephedripites* Bolkhovitina 1953, *Welwitschiapites* Bolkhovitina 1953, *Gnetaceaepollenites* Thiergart emend. Jansonius 1962, *Praecolpatites* Bhardawaj & Srivastava 1969, *Singhia* Srivastava 1968, *Steevesipollenites* Stover 1964 and *Regalipollenites* de Lima 1980. The affinity of these pollen have been

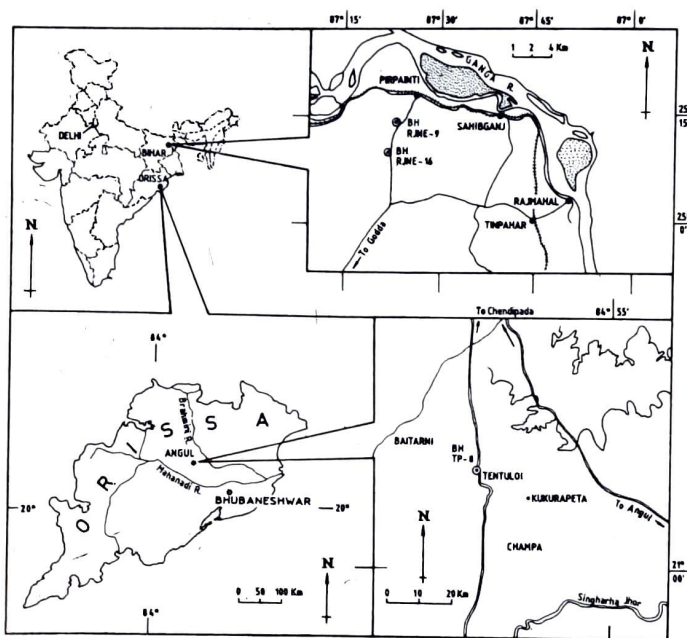


Fig. 1. Map showing location of bore holes in Rajmahal Basin, Bihar and Talcher Coalfield, Orissa, India.

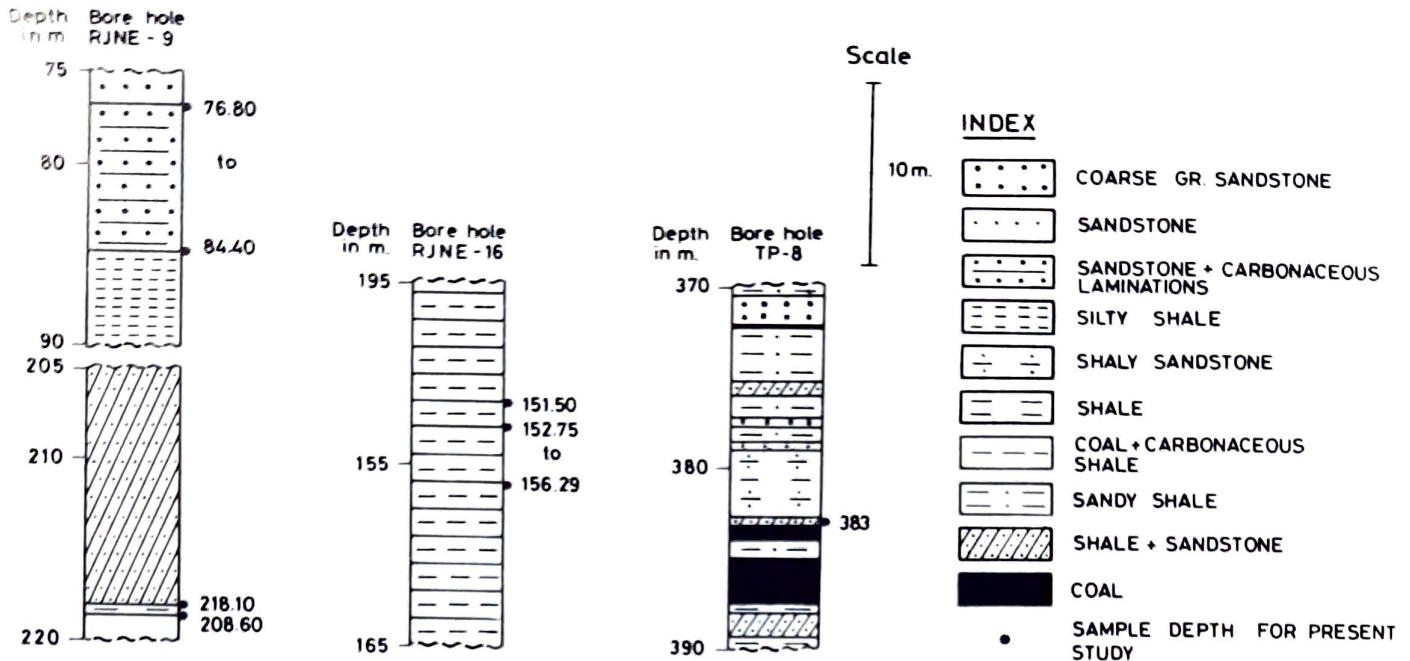


Fig. 2. Details of the depth of samples yielding the pollen with angiospermoid exine characters.

assigned to *Ephedra*, *Welwitschia* and *Gnetum* (Wilson 1959; Bharadwaj 1963; Osbon, Taylor & de Lima 1993). However, the pollen having distinct aperture and psilate or structured banded sexine and smooth unstructured psilate nexine, eg., *Equisetosporites* Daugherty emend. Pocock & Vasanthi 1988 and *Cornetipollis* Pocock & Vasanthi 1988 are described from Early Mesozoic palynoassemblages. The ultra-structural details of the columellate-TECTATE sexine,

which is difficult to observe in light microscope due to thick nature of bands (sexinal) and the tripartite nexine in *Equisetosporites* has been interpreted to be angiospermous by Pocock and Vasanthi (1988). The tripartite nexine has been considered as an important stage in the evolution of protoangiosperm exine. The other taxa *Cornetipollis* has been assigned an angiospermous affinity on the basis of foveoreticulate perforate and columellate nature of sexine

PLATE 1

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|--------------|--|-----------------|--|
| Figs 1-5 | <i>Daminites rajmabalensis</i> gen. et sp. nov. | 7 | Isotype. BSIP Slide No. 11749 (x500). |
| 1 | Holotype-showing two sulcus on one face and thinning of sexine on ends at the longer axis. BSIP Slide No. 11752 (x500) | 8 | Enlargement of part of specimen showing inframicroreticulate structure in surface view with complete meshes as well as loose ends of muri. BSIP Slide No. 11750 (x1500) |
| 2 | Enlargement of part of specimen showing columellate tectate exine structure in optical view. BSIP Slide No. 11753 (Ca x 2000). | 9 | Enlargement of part of specimen in Fig. 8 showing imperfect infrabaculate sexine structure in optical view and thick nexine. |
| 3 | Enlargement of portion of specimen in Fig. 1 showing the inframicroreticulate structure of exine in surface view (x1500). | 12 | Enlargement of part of specimen in Fig. 6 showing the thinning of sexine at the ends of the longer axis and thick nexine (x1500). |
| 4 | Enlargement of portion of specimen in Fig. 1 showing thinning of the sexine (arrow-head) and nature of infrabaculate exine structure (arrow) in optical view (x1500) | Figs 10, 11, 15 | Scanning Electron Micrographs of specimens of <i>Daminites</i> gen. nov. showing distinct sulcus along the longer axis in Figs. 10, 15 and exine pattern in surface view in Fig. 11 (bar measures 10 microns.) |
| 5 | Isotype. BSIP Slide No. 11753 (x500) | Fig. 13 | <i>Monocrinopollis</i> sp. BSIP Slide No. 11754 (x1000) |
| Figs 6-9, 12 | <i>Daminites indicus</i> gen. et sp. nov. | Fig. 14 | <i>Cornetipollis</i> sp. showing banded nature of exine and foveoreticulate structure of exine in surface view. BSIP Slide No. 11700 (x500) |
| 6 | Holotype-showing two distinct sulcus on one face and inframicroreticulate exine structure in optical view. BSIP Slide No. 11748 (x500) | | |

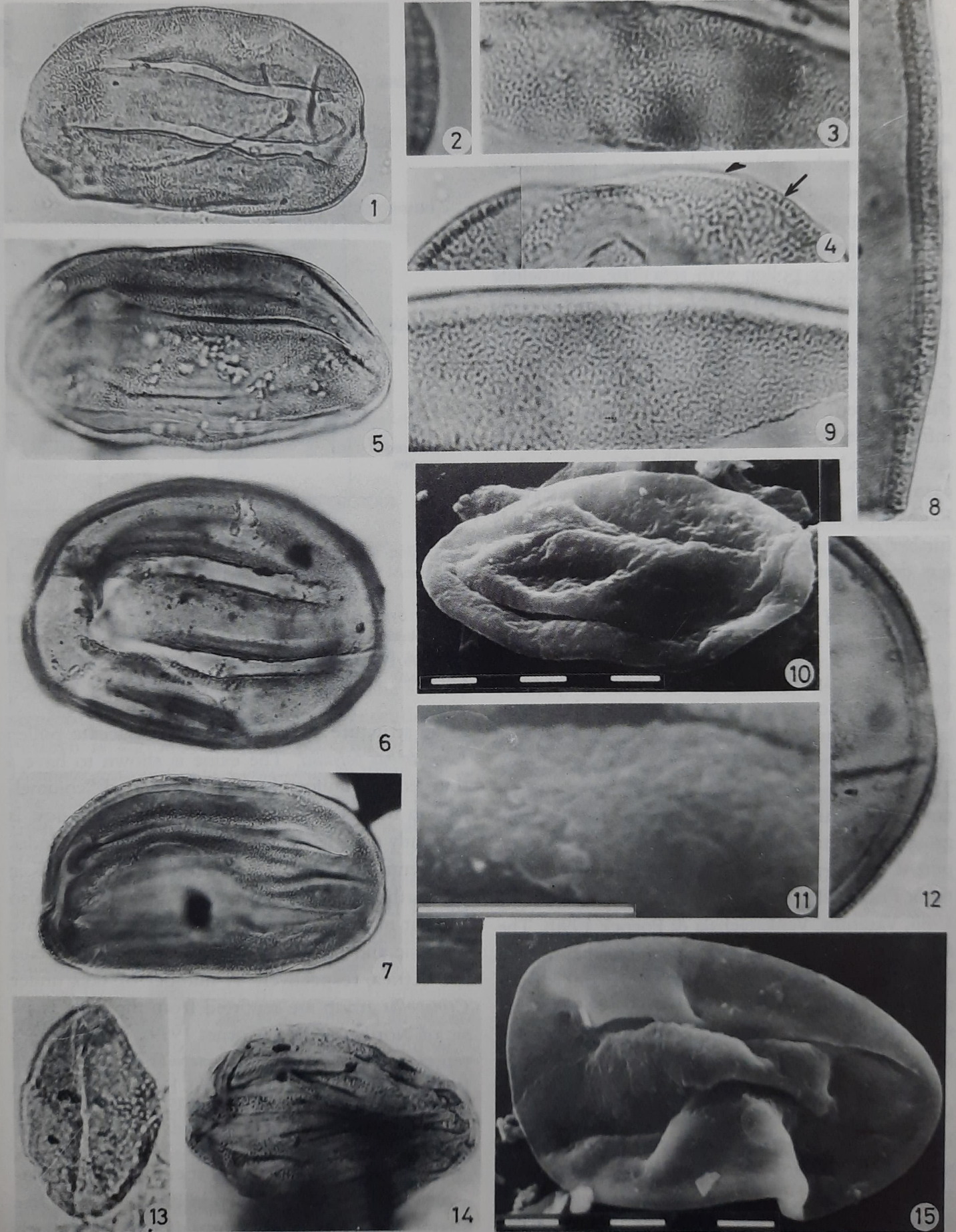


PLATE 1

(Pocock & Vasanthi, 1988) and partial exine homology have been defined between *Cornetipollis* and pollen of Trichanthereae tribe of Acanthaceae.

From the Late Triassic and Jurassic of the Newark Super Group of USA Cornet (1979) reported angiosperm-like pollen with tectate, columellate exine. Subsequently he (Cornet 1989) introduced *Crinopolles* group of pollen from Late Triassic deposits of Richmond rift Basin of Virginia. This group includes sulcate pollen with reticulate, columellate angiospermous exine, the reticulation being *Liliacidites* type, i.e., dimorphic in *Dicrinopollis*, *Monocrinopollis*, *Polycolpopollis*, *Tricrinopollis*. However, Cornet did not assign angiospermous affinity to these pollen. The occurrence of infrareticulate-infrabaculate exine in *Daminites rajmahalensis* gen. et. sp. nov. and *Cornetipollis* sp. with foveo-reticulate exine in the upper Raniganj assemblages from Rajmahal Basin and Talcher Coalfield of India adds further evidences of angiospermoid exine characters during Late Permian.

Evidences of Angiospermoid Exine Character through time

The palynologists generally believe that from the basic homogeneous solid sporoderm the granular, alveolar and columellar exine patterns evolved (Walker & Skvarla 1975; Walker & Walker 1984). The morphological features transcends the various taxonomic units the species, genus, families and groups. The granulo-columellar type of exine is reported from gymnosperms and angiosperms (Foster & Price 1981; Zavada 1984; Pocock & Vasanthi 1988; Vasanthi, Venkatachala & Pocock 1990). The alveolar sexine of gymnosperms are also shown to have resemblance with columellate sexine of angiosperms (Vasanthi, Venkatachala & Pocock 1990) through complexity or simplification of the sexine patterns.

The pre-Cretaceous occurrences of pollen having angiospermoid exine character are illustrated in Figure 3. It is observed that the differentiation of angiospermoid exine initiated during Upper Carboniferous recorded in the genus *Lasiostrobus* from North America. Taylor (1970) has illustrated the

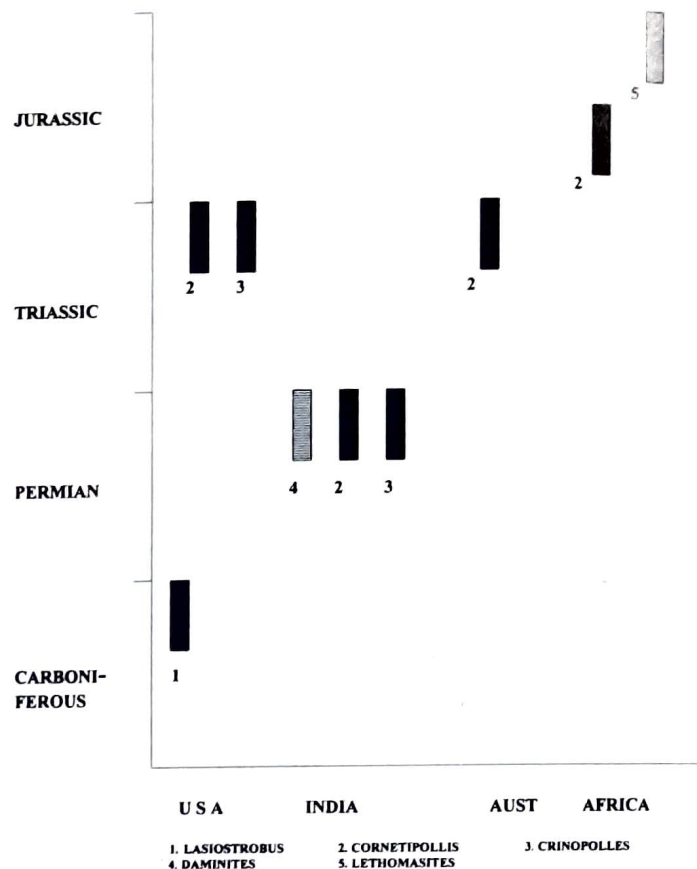


Fig. 3. Synthesis of data on appearance of pre-Cretaceous angiospermoid pollen in separate geographical areas, viz., North America, India, Australia and Africa. Index 1- *Lasiostrobus*, 2- *Cornetipollis*, 3- *Crinopolles*, 4- *Daminites*, 5- *Lethomasites*.

exine structure of Pennsylvanian bisaccate pollen *Lasiostrobus polysacci*. The exine is shown to have a thin tectum, uniformly thick nexine and "columellae" in between. The taxon *Daminites* gen. nov. is presently reported from the Late Permian of India. The genus *Cornetipollis* instituted from Upper Triassic of North America (Pocock & Vasanthi 1988) is also present in Late Permian strata of India and Late Triassic and Early Jurassic sediments of Australia and Africa, respectively. A number of taxa under *Crinopolles* group are reported from the Late Triassic of North America (Cornet 1989). This group is represented by genus *Monocrinopollis* in Indian Late Permian sequence reported here. The taxon *Lethomasites* is on record from Upper Jurassic sediments of Africa.

The occurrence of angiospermoid exine characters through time is shown in Fig. 4 in which five character manifestation steps (CMS) have been

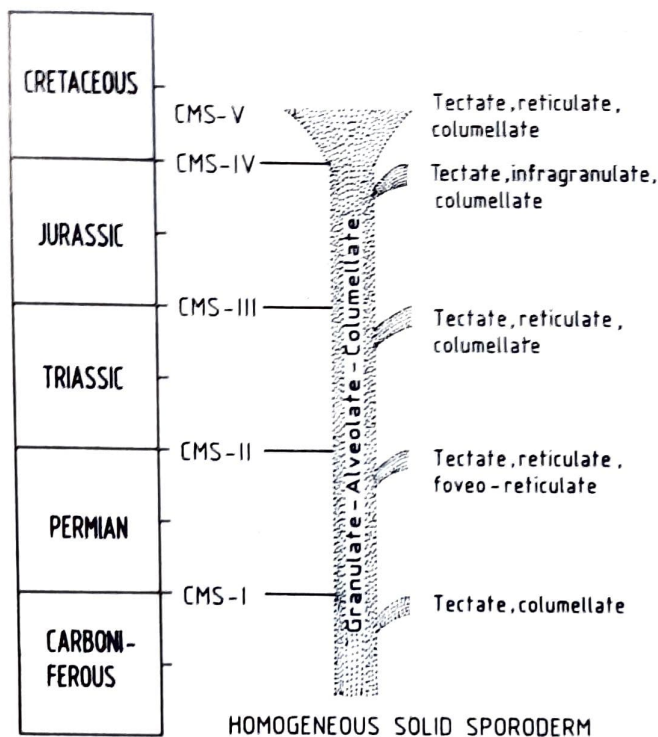


Fig. 4. Composite figure showing the appearance of pollen with angiospermoid exine characters at various time period identified as six Character Manifestation Steps.

identified. The first angiospermoid character, tectate columellate exine, is recorded in Late Pennsylvanian pollen-*Lasiostrobus polysacci* from USA. The second stage of CMS-tectate, reticulate-foveoreticulate pattern is signified in Late Permian pollen *Daminites* gen. nov. and *Cornetipollis* sp. from India. The occurrence of reticulate monosulcate pollen from Late Permian assemblage of India is also associated with the -CMS-II. *Crinopolles* group of pollen from Late Triassic of USA signifies the third stage of character manifestation-CMS-III by the presence of tectate reticulate columellate exine. The fourth stage of diversification – CMS-IV is evidenced by the occurrence of tectate infragranulate columellate exine of *Lethomasites* in the Late Jurassic assemblage from Morocco. The last and final stage- CMS-V, tectate reticulate columellate exine is recorded in Early Cretaceous assemblages globally. It appears that the angiospermoid exine pattern was experimented several times in the evolutionary history of land plants during Late Carboniferous, Late Permian, Late Triassic and Late Jurassic and finally established, diversified, and prolifer-

ated during Cretaceous.

The finding of pollen *Daminites* gen. nov. and *Cornetipollis* from Late Permian sediments is very significant. It points towards the differentiation of angiospermoid exine character at the Late Permian level. The plants producing these type of pollen might have represented the proangiospermous plexus and descendents of ancient Permo-Triassic alliance as proposed by Axelrod (1961). This also corroborates with the molecular data evidencing the diversification of angiospermous gene stalk during Permian (Martin, Gierl & Saedler 1989; Moldovan, Dahl, Huizinga, Fago, Hickey, Peackmen & Taylor 1994)

Material and Age of the Assemblage recording the new taxa

The material for the present study is from (Figs. 1, 2) : B.H. RJNE-29, Rajmahal Basin, Bihar, India (Tripathi 1986); B.H. RJNE-16, Rajmahal Basin, Bihar, India (Tripathi 1989); B.H. TP-8, Talcher Colfield, Orissa, India (Tripathi 1996). The assemblages from above material are dominated by striate biaccate pollen-*Striatopodocarpites*, *Faunipollenites*, *Crescentipollenites*. The age defining taxa present are *Navalesporites*, *Densipollenites*, *Gondisporites*, *Falcisporites*, *Satsangisaccites* and stray occurrences of *Arcuatipollenites*, *Lundbladispora* and *Densoisporites*. A Late Permian age has been assigned to the above palynofloras (Tripathi, 1986 1989, 1996).

DESCRIPTION

Daminites gen. nov.

Text-figs 1, 2; Pl. 1, figs. 1-12, 15

Type Species - *Daminites rajmahalensis* sp. nov.

Holotype - Pl. 1, Fig. 1, BSIP Slide No. 11752

Locality- Sample depth 218 to 218.60 m, Bore hole RJNE-9; Rajmahal Basin, Santhal Pargana, Bihar, India.

Age & Horizon - Late Permian, Raniganj Formation.

Diagnosis- Pollen oval in shape, bearing two to three thin areas-sulcus along the longer axis on each face, sulcus straight with smooth margin parallel to

each other. Exine inframicroreticulate in surface view and infrabaculate in optical view. Sexine thins out at two ends of longer axis exposing the smooth nexine.

Observation under SEM - Under Scanning Electron Microscope the 'sulci' are distinctly seen on the surface. The exine structure is not very clear but on surface the depressed areas are well seen which represent the lumen of reticulate pattern.

Remarks - The genus *Daminites* exhibits presence of many thin areas which might have functioned as germinal apertures. All the specimens observed are single pollen the monad and no specimen in tetrad condition is observed, therefore the poles and the distal and proximal face could not be precisely marked. In the dispersed pollen it is difficult to judge the proximal and distal face of the grain thereby the usage of term 'polycolpate' (restricted to the angiosperms only) or polysulcate. Therefore, presently the term sulcus is considered for the description.

Etymology - Named after the Damin Tribe of Santhal Pargana, Bihar, India.

Comparison- *Daminites* gen. nov. is characterised by infrareticulate-infrabaculate nature of sexine, thinning of the sexine on terminal ends of the longer axis and presence of two to three sulci-like structure on each face. A number of comparable genera are on record. *Daminites* differs from *Praecolpatites* Bharadwaj & Srivastava (1969) in the nature of exine structure and thinning at terminal ends, distinct sulci on both the faces, where as in *Praecolpatites* the exine is infrastructured with one sulcus, associated with exinal folds. *Welwitschiapites* Bolchowitina (1953) is monosulcate and longitudinally striate, striations may bifurcate and join the adjacent ones with structured exine. *Striatosporites* Bharadwaj (1954, 1955) possesses a monolete mark and the exine is striate, the striations being interconnected. *Gondwanaeaplicates* Kar (1969) is although a striate genus with infrapunctate exine structure has incipient zona-like structure hence different from *Daminites*. *Gnetaceapollenites*

Thiergart em. Jansonius (1962) differs from the present genus in having longitudinal ribs formed by exoexinal differentiation which may have grooves in them. *Cornetipollis* Pocock & Vasanthy 1988, is a costate pollen where the exinal bands alternate with furrows, bands having reticulate-foveoreticulate tectum and columellate stratum.

Distribution- *Daminites* gen. nov. is recorded in the Late Permian assemblages of Rajmahal Basin. Its presence is observed at 218 to 218.60 and 76.80 to 84.40 m depth in B.H. RJNE-9, 152.75 to 156.29 and 166.05 to 188.50 m depth in B.H. RJNE-16. Quantitatively this genus is rare. However, in all twenty five specimens (in 30 slides of 20x40 mm coverglass) have been studied under light microscope and six under Scanning Electron Microscope.

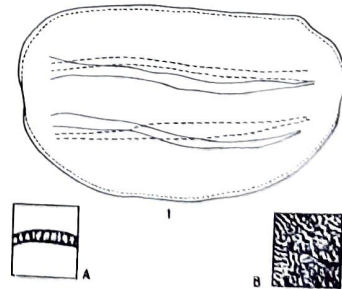
Daminites rajmahalensis sp. nov.

Text-fig. 1; Pl. 1, figs. 1-5

Holotype-Pl.1, fig. 1; Size 125x60 μ m, BSIP Slide No. 11752.

Age & Horizon - Late Permian, Raniganj Formation.

Area & Locality-Sample depth 218-218.60 m, Bore Hole RJNE-9, Rajmahal Basin, Santhal Pargana, Bihar, India.



Text-fig 1. Line drawing of *Daminites rajmahalensis* gen. et sp. nov. showing the exine differentiable into sexine and thin nexine and the two sulcus; A, illustrates the infrabaculate exine structure in optical view, B, illustrates the inframicroreticulate exine structure in surface view.

Etymology- Named after the Rajmahal Basin of Santhal Pargana, Bihar, India.

Diagnosis - Pollen grain conforming to the above generic diagnosis, sulci straight, narrow in the middle with diverging ends, sulci margin smooth. Exine inframicroreticulate, 1.5 to 2 μm thick, clearly identifiable into 1-1.5 μm thick sexine and less than 1 μm thick nexine. Sexine shows distinctly infrabaculae tectate columellate structure in optical view, columella fusing with the nexine, sexine thins out gradually at the terminal ends of longer axis, where smooth nexine is exposed in about 10 μm area.

***Daminites indicus* sp. nov.**

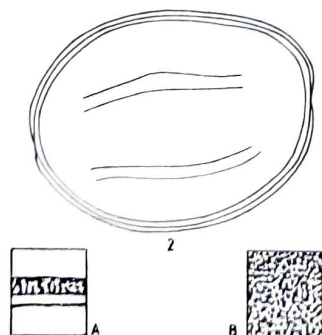
Text-fig. 2; Pl. 1, figs. 6-9

Holotype - Pl. 1, fig. 6; Size 87x75 μm , BSIP Slide No. 11748

Age & Horizon - Late Permian, Raniganj formation.

Locality- Sample depth 76.80-84.40 m, Bore Hole RJNE-9, Rajmahal Basin, Santhal Pargana, Bihar, India.

Diagnosis- Pollen oval in shape, exine two layered, 3-6 μm thick, sexine 1-3.5 μm and nexine 2-3 μm thick, exine structure inframicroreticulate



Text-fig. 2. Line drawing of Holotype of *Daminites indicus* sp. nov. showing thick exine differentiable into sexine and thick nexine and the two sulcus; A. illustrates the imperfect infrabaculate exine structure the columellae fuse with nexine, and hang half of the sexine thickness, B. illustrates the inframicroreticulate exine structure in surface view with meshes forming complete lumen as well as loose ends of muri.

to infrapunctate, meshes polygonal, muri enclosing complete lumen, at places loose free ends of muri also seen in surface view. In optical view sexine structured, infrabaculate tectate columellate, at places perfect columellate structure not seen, sexine shows columellae hanging half of the sexine thickness, nexine smooth, unstructured. Exine bears two to three sulci on each surface, sometimes on one face sulci not distinct only thinning is seen, sulci margin mostly well defined, sometimes indistinct on one face, straight to wavy. In some specimens verrucose and mud crack pattern seen in the central part in surface view. Sexine thins out at terminal ends of longer axis exposing the smooth nexine.

Comparison- *Daminites indicus* sp. nov. differs from *D. rajmahalensis* gen. et sp. nov. in having thicker exine differentiable into sexine and thick nexine with imperfect infrabaculate nature of sexine in optical view and sometimes with mudcrack pattern on the surface view.

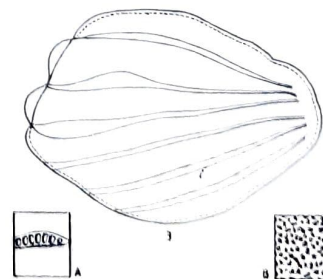
***Cornetipollis* Pocock & Vasanthi 1988**

Type Species - *Cornetipollis reticulatus* Pocock & Vasanthi 1988

***Cornetipollis* sp.**

Text-fig. 3; Pl. 1, fig. 14

Description-Pollen ellipsoid, 120x84 μm size. Exine bears bands and furrows, bands converge at



Text-fig. 3. Line drawing of *Cornetipollis* sp. showing the banded nature of exine; A. *infrabaculate* exine pattern as seen in optical view illustrating tectate-columellate pattern; B. foveo-reticulate exine structure seen in surface view.

the lateral ends, and have foveoreticulate structure which is very well seen under LM through LO analysis. Bands and furrows show slight twisting in one specimen. Sexine is very much reduced in the furrow region. However, on the bands the tectate columellate nature of sexine is distinct in optical view.

Distribution- These pollen are recorded in the Late Permian palynoflora at 383.00 m in B.H. TP-8 of Talcher Coalfield. Quantitatively these forms are very poor in the assemblage. In all, three specimens have been observed in four palynological slides of 20x40 mm coverglass.

Remarks- Pocock and Vasanthi (1988) have discussed the angiospermous affinity of *Cornetipollis* and form similarity with reference to exine character with extant pollen of genera *Bravaisia*, *Sachezia* and *Trichanthera* of family Acanthaceae. However, the difference is well marked due to the absence of two colporate aperture in *Cornetipollis*. The partial homology of exine character of these extinct and extant pollen is however remarkable.

Monocrinopollis Cornet 1989

Type Species - *Monocrinopollis reticulatus* Cornet 1989

Monocrinopollis sp.

Pl. 1, fig. 13

Description - Pollen spindle shaped. Exine 1 μm thick, double layered, 40x26 μm in size, inframicroreticulate, reticulation small near sulcus and big on other face, sulcus distinct, narrow, slightly diverging at ends.

Remarks- The occurrence of this taxon is very rare, only one specimen is recorded in 4 slides of 20x40 μm size coverglass. It is present at 383 m in B. H. TP-8, Talcher Coalfield, Orissa.

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