BULL. BOT. SURV. INDIA
Vol. 39, Nos. 1-4 : pp.157-178, 1997

MEGASPORE SUCCESSION THROUGH THE RANIGANJ-PANCHET TRANSITION IN THE RANIGANJ COALFIELD, INDIA

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ABSTRACT

Megaspores from the uppermost horizon of Raniganj Formation and the lowermost strata of Panchet Formation exposed in the Raniganj Coalfield, West Bengal, have been analysed both qualitatively and quantitatively. The assemblage recovered from the Raniganj Formation qualitatively comprises *Banksisporites psilatus* (Bharadwaj & Tiwari) *comb. nov.*, *B. panchetensis* (Maheshwari & Banerji) Banerji *et al.*, *Biharisporites maiturensis* Maheshwari & Banerji, *B. raniganjensis sp. nov.* and *Maiturisporites indicus* Maheshwari & Banerji. The genus BIHARISPORITES is the most commonly occurring from in this assemblage. The Maitur Member of Panchet Formation yields *Banksisporites panchetensis* (Maheshwari & Banerji) Banerji *et al.*, *B. gondwanensis* Maheshwari & Banerji, *B. granulosus* Maheshwari & Banerji, *Biharisporites maiturensis* Maheshwari & Banerji, *B. luguensis* Pal *et al.*, *Verrutriletes obscurus* (Maheswari & Banerji) Banerji *et al.*, *V. distinctus* (Maheshwari & Banerji) Banerji *et al.*, *Talchirella sinuata* Maheshwari & Banerji, *T. dubia* Maheshwari & Banerji, *T. flavata* (Kar) Bharadwaj & Tiwari, *Pantiella bosei* Maheshwari & Banerji, *P. bharadwajii* Maheshwari & Banerji, *P. maheshwarii sp. nov.*, *Maiturisporites indicus* Maheshwari & Banerji, *M. distinctus* Maheshwari & Banerji, *M. spinotriletus* Maheshwari & Banerji and *M. banerjii sp. nov.* Some abnormal forms with tetralete sutures have also been recovered from this horizon. Maitur assemblage is characterized by the preponderance of the genus MAITURISPORITES followed by BANKSISPORITES.

INTRODUCTION

The Raniganj Formation of Damodar Valley Basin is believed to be of Upper Permian age. The study of megaspores from this formation has remained greatly neglected in comparison to that of the underlying Barakar Formation. From a bore hole sample of Raniganj Formation, Bharadwaj and Tiwari (1970) reported five species of megaspores belonging to four genera *viz.* *Jhariatriletes baculosus* Bharadwaj & Tiwari, *Talchirella densiocarpa* Bharadwaj & Tiwari, *T. raniganjensis* Bharadwaj & Tiwari, *Surangeaesporites ranigangenesis* Bharadwaj & Tiwari and *Biharisporites spinosus* (Sing) Bharadwaj & Tiwrai. Later,

Date of receipt : 29.1.98. Date of acceptance : 17.11.99.

Maheshwari and Bajpai (1984) described a new genus NONIASPORITES based on *N. harisii* Maheshwari & Bajpai recovered from the Seam-IX of Raniganj Formation in Raniganj Coalfield. Both of the above works are based on morphotaxonomic study and quantitative analysis of megaspore taxa has not been attempted so far.

Overlying the Raniganj Formation, in Damodar Valley Basin, there is the Panchet Formation which has been dated as Lower Triassic on the basis of palaeontological remains. The Panchet Formation has been classified into two members, the older Maitur Member and the younger Deoli Member. Qualitatively well diversified megaspore assemblages have been reported from both the Maitur Member (Maheshwari and Banerji, 1975) and Deoli Member (Pal, Ghosh and Sannigrahi, 1997).

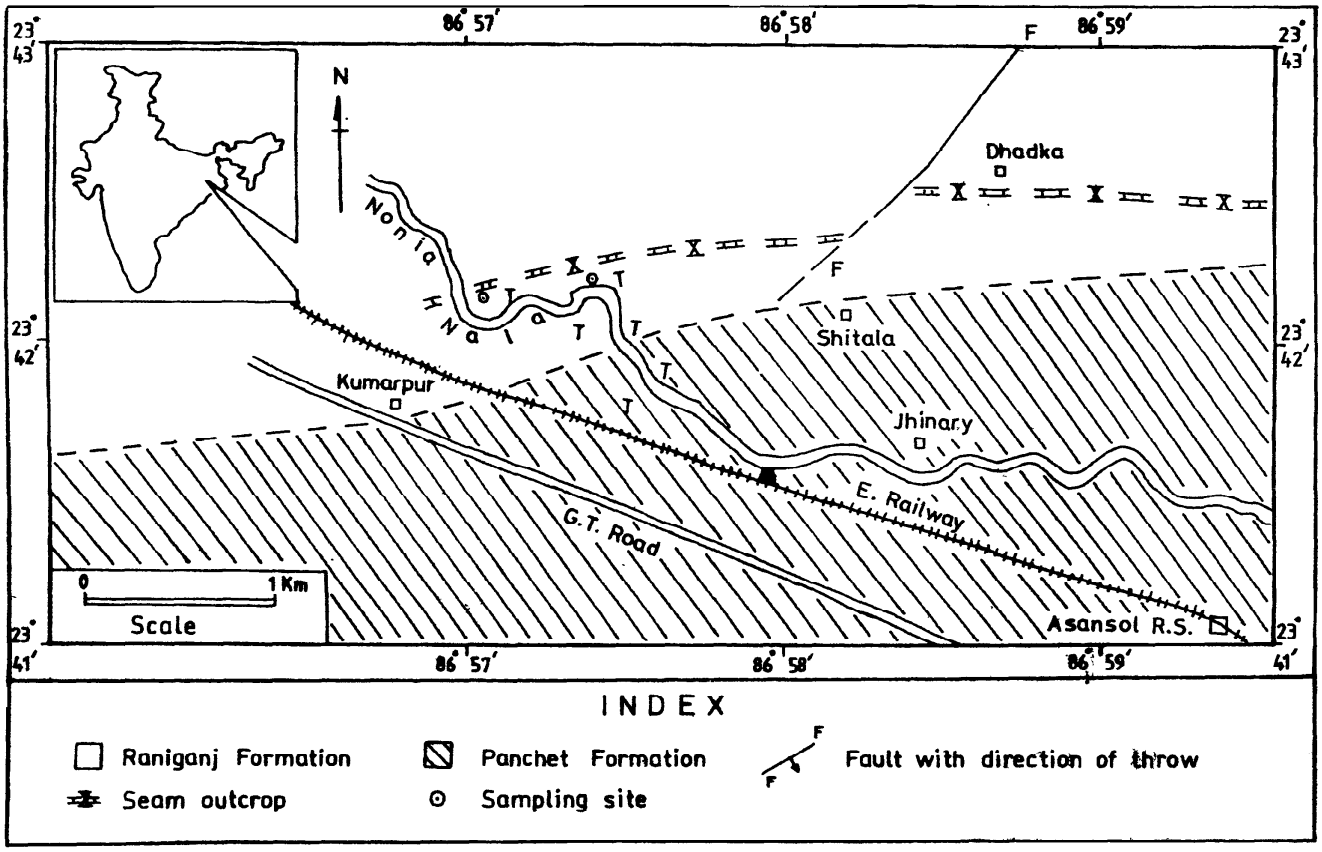
From the Maitur Member Maheshwari and Banerji (1975) described *Banksisporites gondwanensis* Maheshwari & Banerji, *B. granulosus* Maheshwari & Banerji, *B. minuticorpus* Maheshwari & Banerji, *B. panchetensis* (Maheshwari & Banerji) Banerji, Kumaran & Maheshwari, *Biharisporites maiturensis* Maheshwari & Banerji, BIHARISPORITES sp., *Verrutriletes distinctus* (Maheshwari & Banerji) Banerji, Kumaran & Maheshwari, *V. obscurus* (Maheshwari & Banerji) Banerji, Kumaran & Maheshwari, *Talchirella dubia* Maheshwari & Banerji, *T. sinuata* Maheshwari & Banerji, *Pantiella bosei* Maheshwari & Banerji, *P. bharadwajii* Maheshwari & Banerji, *Maiturisporites indicus* Maheshwari & Banerji *M. distinctus* Maheshwari & Banerji, *M. spinotriletus* Maheshwari & Banerji and ? NATHORSTISPORITES sp. However, the frequency distributions of the taxa were not studied by them.

In the Nonia Nala Section, about 3.5 km. North-West of Asansol Railway Station, the younger horizon of Raniganj Formation is well exposed. It is represented here by sandstone, siltstone, grey shale, carbonaceous shale and coal seam (Seam-X). The Raniganj sequence in this section is overlain by the greenish yellow to khaki green facies of the Maitur Member of Panchet Formation. The contact between the two formations appears to be conformable (Dutta *et al.* 1977).

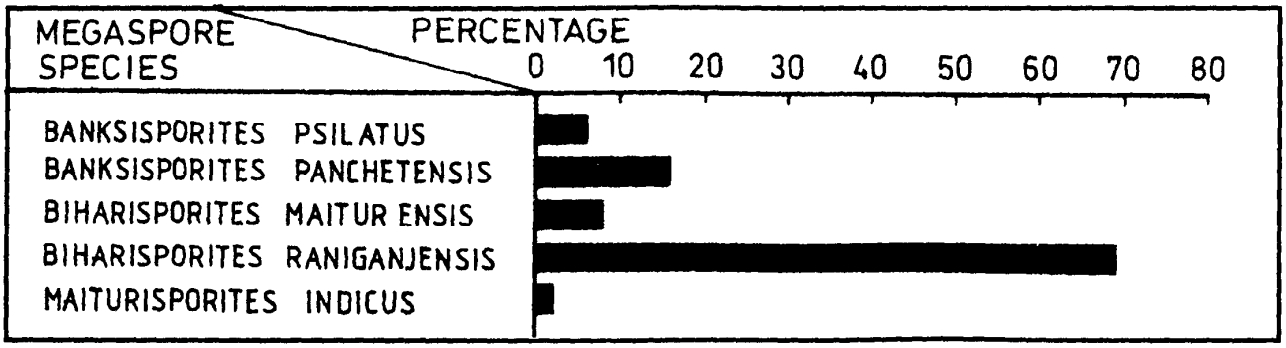
With a view to understand megaspore succession through the Permo-Triassic transition in Damodar Valley Basin rock samples belonging to the uppermost Raniganj and the Lowermost Panchet sequence exposed in the Nonia Nala section near Asanso (Text-fig. 1) were analysed.

MATERIAL AND METHODS

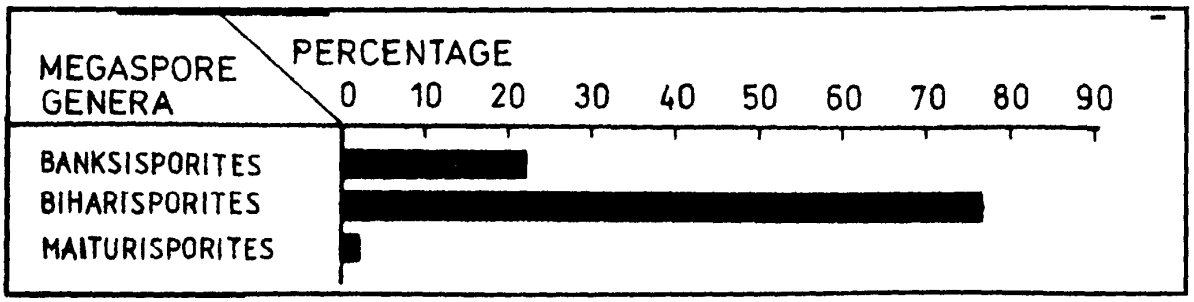
Two samples of carbonaceous shales associated with Seam-X, the youngest seam of Raniganj Formation, yielded well preserved megaspores on maceration and altogether 118 specimens were recovered. From the Maitur Member of Panchet Formation only one sample of khaki green



Text-fig. 1. Geological map of part of the Raniganj Coalfield area showing the sampling sites.



Text-fig. 2. Bar-diagram showing the percentage frequencies of megaspore species recovered from Raniganj Formation.



Text-fig. 3 .Bar-diagram showing the percentage frequencies of megaspore genera collected from Raniganj Formation.

shale was found to contain megaspores. 176 well preserved megaspores were isolated from this sample. The megaspores were studied by Bright Field Microscopy with incident as well as transmitted light and also by Scanning Electron Microscopy. All the megaspores isolated were morphotaxonomically analysed for determining the percentage frequencies of taxa in an assemblage.

All types and figured specimens, slides, SEM-stubs and negatives are preserved in the Palaeobotany and Palynology Section, Botany Department, Burdwan University.

DESCRIPTION

Megaspore assemblage from the upper horizon of Raniganj Formation:

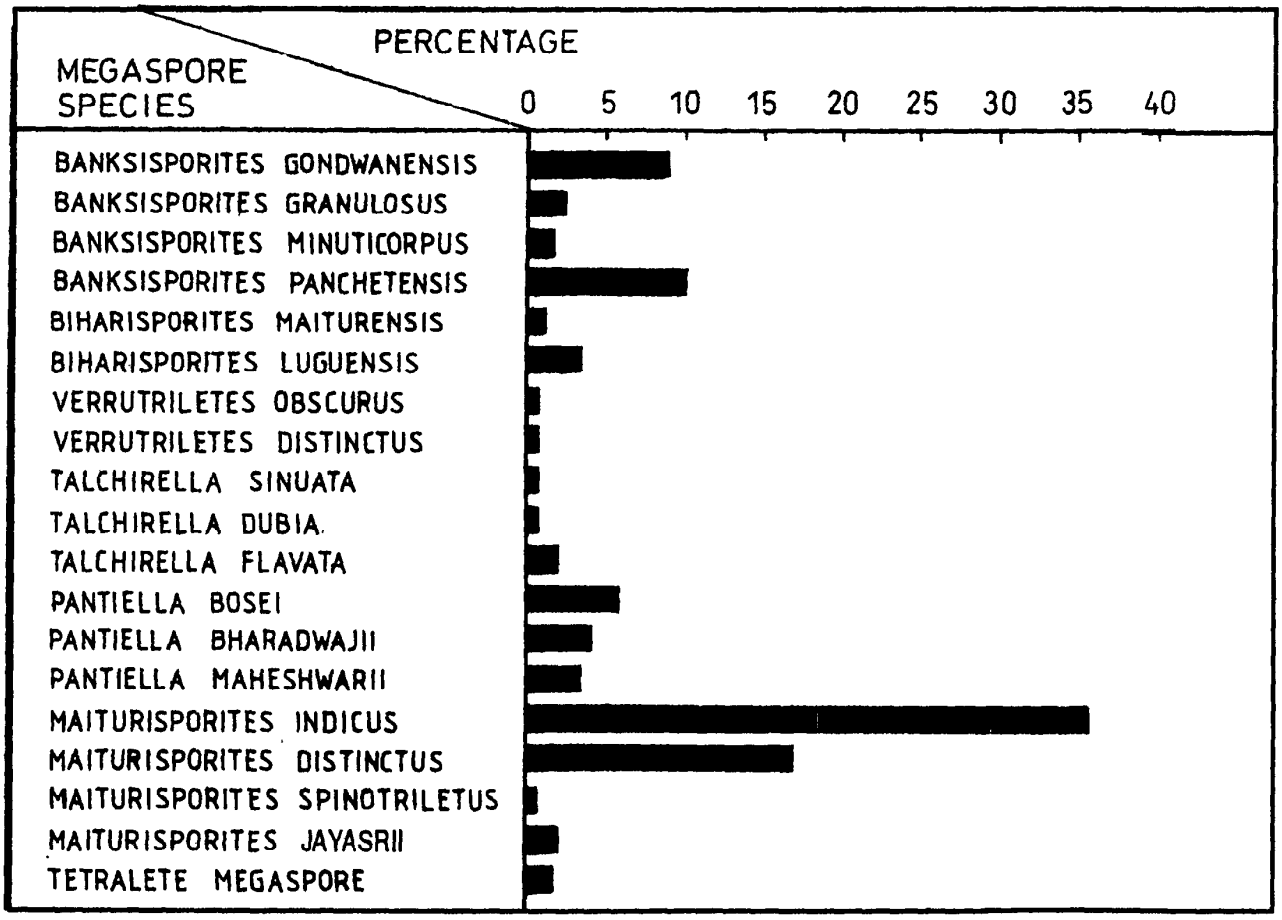
Qualitative as well as quantitative analysis of megaspores recovered from the two samples of this sequence reveal that the samples yield more or less similar megaspore assemblage. The overall assemblage comprises following taxa.

BANKSISPORITES Dettmann emend. Banerji *et al.* 1978.

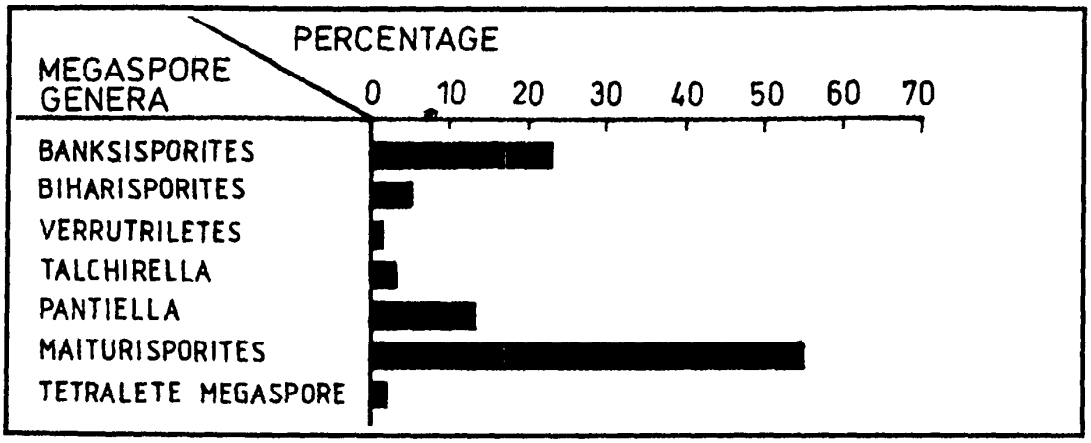
The genus BANKSISPORITES was instituted by Dettmann (1961) for cavate trilete megaspores having smooth to granulose exosporium and cushionless mesosporium. Bharadwaj and Tiwari (1970) created two new genera, viz. SRIVASTAVAESPORITES and BOKAROSPORITES, based on specimens from Parmian strata of India. While doing so they did not compare their genera with the then existing genus BANKSISPORITES Dettmann. Out of those two new genera of Bharadwaj and Tiwari (1970) the genus SRIVASTAVAESPORITES has already been included as a junior synonym of BANKSISPORITES by Banerji *et al.* (1978). The second genus BOKAROSPORITES as circumscribed by Bharadwaj and Tiwari is characterised by smooth exosporium with contact areas mostly ill defined, sometimes marked by faint arcuate rims and mesosporium without cushions. In BANKSISPORITES the exosporium is smooth to granulose, mesosporium is devoid of cushions and in several species of the genus (*B. dettmannae*, *B. kachchhensis*, *B. panchetensis*) arcuate ridges are present whereas in other species (*B. pinguish*, *B. sinuosus*, *B. granulosus*) arcuate ridges are absent and contact areas are ill defined. As such, in all its essential features the genus BOKAROSPORITES is indistinguishable from the genus BANKSISPORITES and therefore, BOKAROSPORITES has been treated here as a junior synonym of BANKSISPORITES (I. C. B. N. Art. 57.1)

Banksisporites psilatus (Bharadwaj & Tiwari) Sannigrahi & Pal *comb. nov.* Basionym *Bokarosporites psilatus* Bharadwaj & Tiwari, Palaeontographica B129, 1970, p. 19-20 PI. 1 figs 1-8 text figs. 3-5. (Pl. 1, figs. 10, 11).

Diagnosis : Trilete megaspores, subcircular in polar view (equatorial diameter 345-390 μm in dry state and 470 504 μm in wet condition); trilete rays distinct, laesurae



Text-fig. 4. Bar-diagram showing the percentage frequencies of megaspore species recovered from Panchet Formation.



Text-fig. 5 .Bar-diagram showing the percentage frequencies of megaspore genera collected from Panchet Formation.

straight, extending about $^2/_3$ of the spore radius; contact areas indistinct, arcuate ridges absent ; exosporium laevigate, exine wall ±10 μm thick; mesosporium large, thin, filling almost whole of the spore cavity (recognizable only by peripheral folds).

Comparison and Remarks : The present specimens are closely comparable with *Banksisporites psilatus* described as *Bokarosporites psilatus* by Bharadwaj and Tiwari (1970) from Barakar Strata of West Bokaro Coalfield, India. The species is quite common in the present assemblage being represented by seven specimens out of altogether 118 megaspore specimens.

Banksisporites panchetensis (Maheshwari & Banerji) Banerji *et al.* 1978.

(PI.1, figs 2, 3)

Nineteen specimens of the presently recovered assemblage are assignable to this species. *Banksisporites panchetensis* has been described from the Maitur Member of Panchet Formation and the Tiki Formation of India (Banerji, Kumaran and Maheshwari, 1978).

BIHARISPORITES Potonié emend. Bharadwaj & Tiwari 1970.

Biharisporites maiturensis Maheshwari & Banerji 1975 (PI. 2, figs 1, 3)

Biharisporites maiturensis has earlier been described from the Maitur Member of Panchet Formation by Maheshwari and Banerji (1975). In the presently recovered assemblage this species is represented by nine specimens.

B. raniganjens Sannigrahi Pal *sp. nov.*

(PI. 2, figs 4-6)

Diagnosis : Megaspores trilete, *amb* ± circular (equatorial diameter 428 560 μm in dry state and 560 888 μm in wet condition) ; trilete laesurae well developed, little undulated, in dry state 30-35 μm high and 20-25 μm wide near the trijunction, gradually tapering towards the ends, extending nearly up to the equator; contact areas broad, well marked by sharp arcuate rims (6 - 10 μm high in dry state); exosporium covered with closely set low coni (5 8 μm high and 10 - 16 μm broad in dry spores), coni occasionally intermingled with verrucae of about same size, exosporium ± 10 μm thick; mesoporium indistinct.

Holotye : Slide No. B. U. 26.

Locality : Nonia Nala Section, North East of Kumarpur, Burdwan District, West Bengal, India.

Horizon and Age : Raniganj Formation; Upper Permian.

Comparison and Remarks : *Biharisporites raniganjensis* is the most predominant form in the present assemblage. Altogether 81 specimens of this species have been recovered. The species is characterised by its coniate-verrucate exosporium, prominent arcuate ridges, broad contact areas and indistinct mesoporium. In having coniate exosporium *Biharisporites maiturensis* described from Raniganj (present paper) and Panchet (Maheswari and Banerji, 1975) formations and *Biharisporites sparsus* described from Tiki Formation (Banerji, Kumaran and Maheshwari, 1978) resemble

the present species. But *B. maiturensis* differs from *B. raniganjensis* in having weakly developed arcuate ridges and distinct mesosporium. *B. sparsus* is distinguishable by its sparse distribution of coni and indistnict arcuate ridges.

MAITURISPORITES Maheshwari & Banerji 1975

Maiturisporites indicus Maheshwari & Banerji 1975. (PI. 4, figs 2,3)

The species being represented by only two specimens is rather rare in the present assemblage. In all available features those are similar to the specimens of *Maiturisporites indicus* described by Maheshwari and Banerjee (1975) from the Maitur Member of Panchet Formation.

Quantitative analysis of the assemblage:

Quantitative analysis of altogether 118 specimens recovered from the samples shows that the assemblage is overwhelmingly dominated by *Biharisporties raniganjensis* (68.6%). *Banksisporites panchetensis* (16.1%), *B. psilatus* (5.9%) and *Biharisporites maiturensis* (7.6%) are commonly occurring elements whereas *Maiturisporites indicus*(1.7%) is rather rare in occurrence. (Text-fig.2)

At generic level (text-fig.3). BIHARISPORITES having the frequency of 76.2% is the most predominant form, followed by the genera BANKSISPORITES (22.0%) and MAITURISPORITES (1.7%).

Megaspore assemblage from the lower horizon of panchet formation :

An assemblage of megaspores consisting of 18 species belonging to 6 genera has been recovered from the sample of the older horizon of the Panchet Formation.

BANKSISPORITES Dettmann emend. Banerji *et al.* 1978.

Banksisporites gondwanensis Maheshwari & Banerjee 1975. (Pl.1, figs.4,5)

This species has earlier been reported from these beds by Maheshwari and Banerji (1975). Our collection includes 16 specimens of this species out of altogether 176 specimens of megaspores.

B. panchetensis (Maheshwari & Banerji) Banerji *et al.* 1978. (Pl.1, fig.1)

Banksisporites panchetensis is one of the most frequently occurring elements in the present assemblage. This species was originally described from the Maitur beds by Maheshwari and Banerji (1975) under the genus SRIVASTAVAESPORTIES Bharadwaj and Tiwari (1970). Later, Banerji, Kumaran and Maheshwari (1978) while marging SRIVASTAVAESPORITES described it as *B. panchetensis* with the genus BANKSISPORITES.

B. granulosus Maheshwari & Banerji 1975. (Pl.1, figs.8,9)

Four specimens of the present assemblage are similar to those of *Banksisporites granulosus* described earlier by Maheshwari and Banerji (1975) from the same beds.

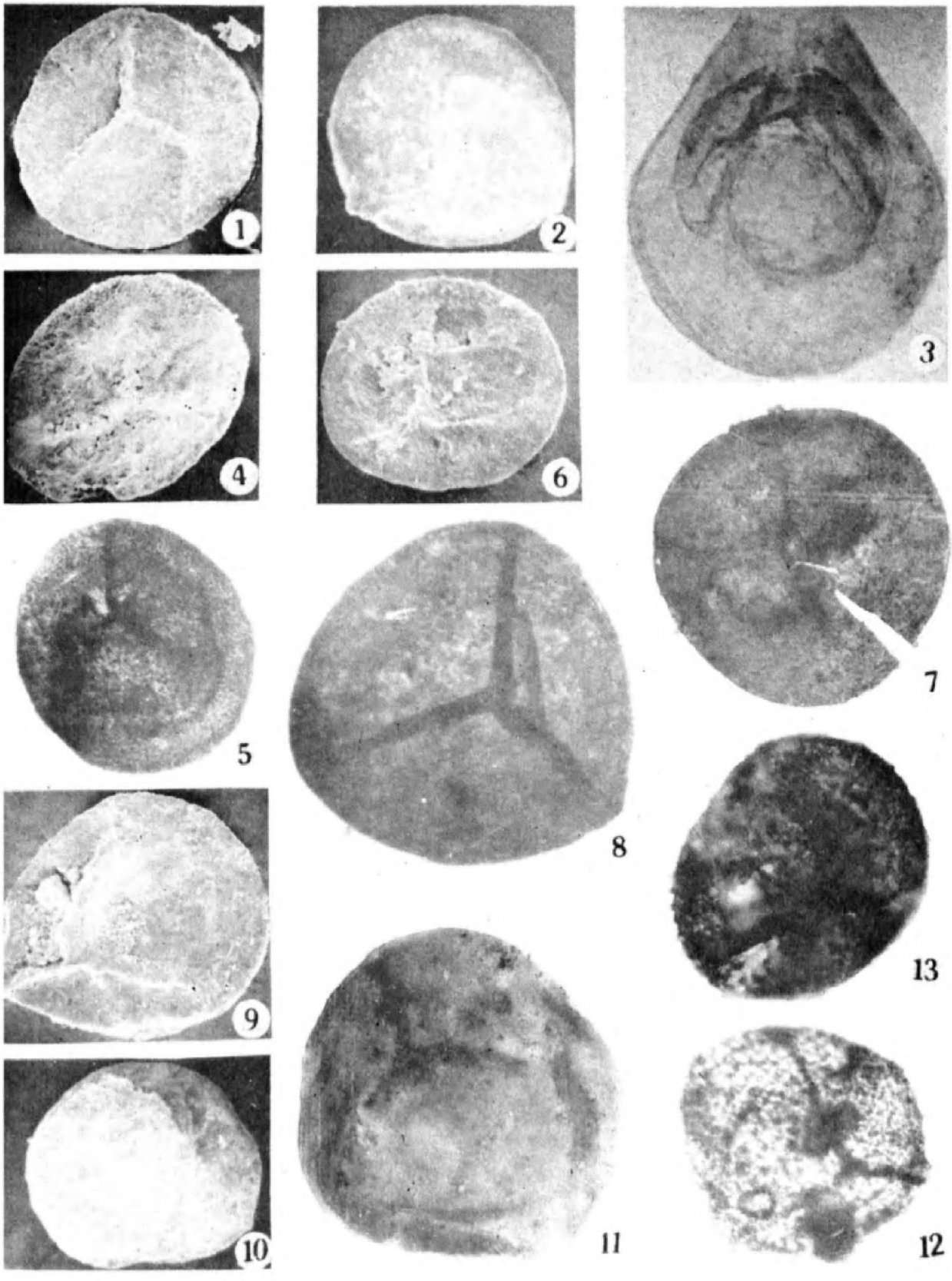


Plate-1

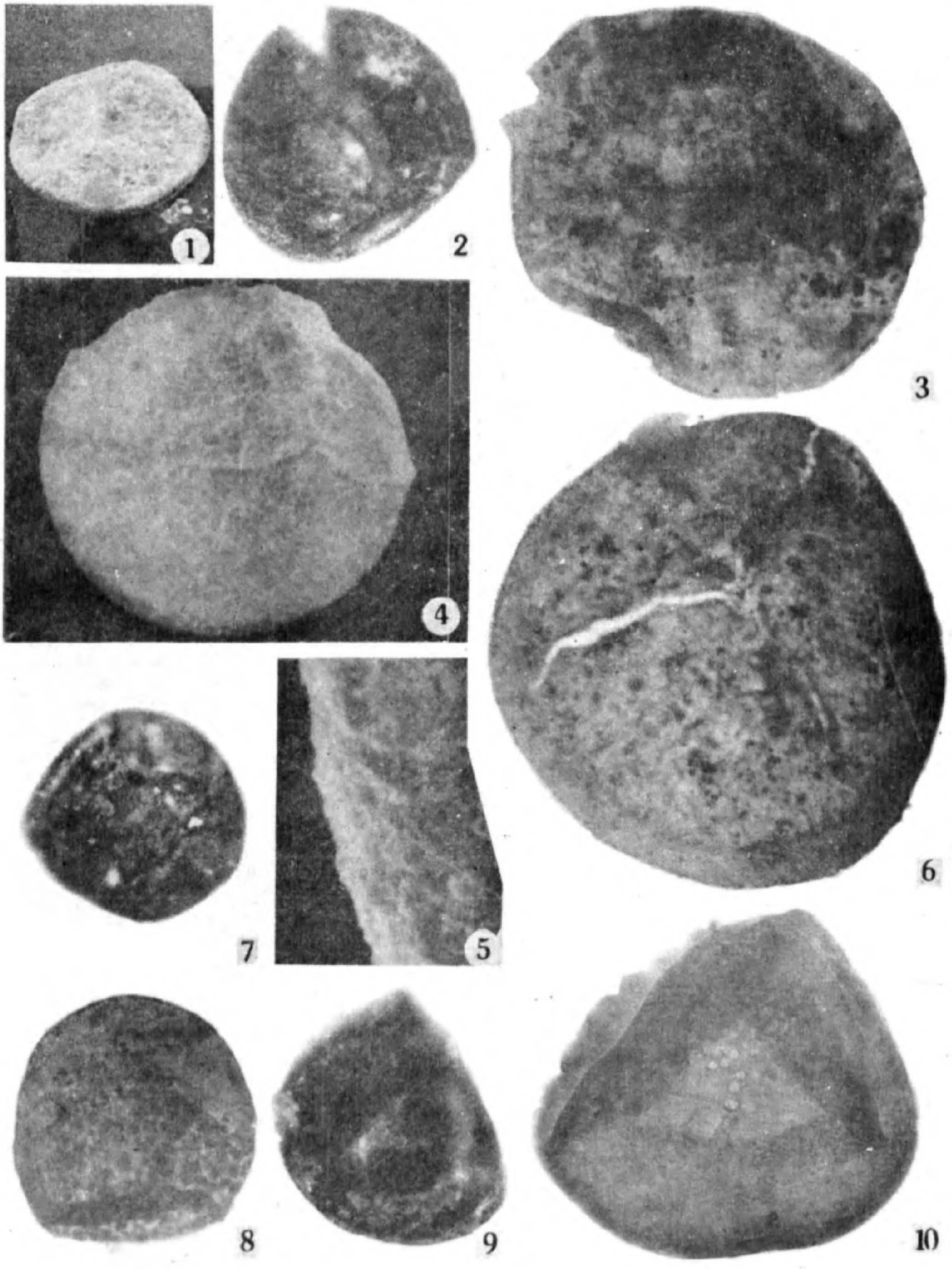


Plate-2

EXPLANATION OF PLATES

(All figures × 100, unless otherwise mentioned)

PLATE-1

1-3 *Banksisporites panchetensis* (Maheshwari & Banerji) Banerji *et al.*

1, Scanning Electron Micrograph of a spore collected from Panchet Formation showing finely granulose exosporium, SEM Stub No. - 2/1.

2, Scanning Electron Micrograph of a specimen from Raniganj Formation showing weakly developed arcuate ridges ; SEM Stub No. 1/4.

3, A macerated megaspore of Raniganj Formation showing distinct mesosporium. Slide No. - B. U. 25.

4, 5. *B. gondwanensis* Maheshwari & Banerji.

4, Scanning Electron Micrograph of a dry specimen showing its microverrucose exosporium; SEM Stub No. - 2/2.

5, Macerated megaspore with distinct mesosporium in wet condition; Slide No. B. U. 29.

6,7. *B. minuticorpus* Maheshwari & Banerji.

6, Scanning Electron Micrograph of a megaspore showing its granulose exosporium ; SEM Stub No. - 2/3.

7, Megaspore in wet condition showing a thin subcircular mesosporium and ill-developed trilete rays. Slide No. - B. U. 31.

8, 9. *B. granulosus* Maheshwari & Banerji.

8, A megaspore in wet condition with a thin subtriangular mesosporium ; Slide No. - B. U. 30.

9, Scanning Electron Micrograph of a specimen showing granulose exosporium, SEM Stub No. - 2/4.

10, 11. *B. psilatus* (Bharadwaj & Tiwari) Sannigrahi & Pal comb. nov.

10, Scanning Electron Micrograph of a megaspore showing smooth exosporium ; SEM Stub No. 1/5.

11, Megaspore in wet condition, Slide No. - B.U. 24.

12, 13. *Biharisporites luguensis* Pal, Ghosh & Sannigrahi (in press).

12, Megaspore in wet condition showing small coniate exosporium and a thin mesosporium, Slide No. - B.U. 34.

13, Another megaspore in dry condition showing sharp arcuate ridges.

PLATE-2

1-3 *Biharisporites maiturensis* Maheshwari & Banerji.

1, Scanning Electron Micrograph of a dry megaspore from Raniganj Formation showing distinct coniate exosporium, SEM Stub No. -1/3.

2, A specimen in dry condition collected from Panchet Formation showing feeble arcuate ridges ; Slide No. - B.U. 33.

3, Megaspore from Raniganj Formation in wet condtion; slide No. - B. U. 27.

4-6. *B. raniganjensis* Sannigrahi & Pal sp. nov.

4, Scanning Electron Micrograph of a dry megaspore showing well developed arcuate rims and trilete rays, SEM Stub No. 1/1.

5, Part of megaspore in fig. 4 magnified showing coniate-verrucate exosporium × 700

6, Megaspore in wet condition ; slide No. - B.U. 26.

7,8 *Verrutriletes obscurus* (Maheshwari & Banerji) Banerji *et. al.*

7, A megaspore in dry condition.

8, Same megaspore in wet condition showing distinct verrucae on the exosporium; Slide No. - B.U. 35.

9, 10. *Talchirella flavata* (Kar) Bharadwaj & Tiwari.

9, Megaspore in dry condition.

10, Same specimen in wet condition showing a distinct traingular mesosporium with irregularly arranged cushions below the laesurae trijunction, Slide No. - B. U. 36.

B. minuticorpus Maheshwari & Banerjee 1975. (Pl.1, figs.6,7)

This species has been described earlier from these beds by Maheshwari and Banerji (1975). Our collection includes three specimens of this species.

BIHARISPORITES Potonié emend. Bharadwaj and Tiwari 1970

Biharisporites maiturensis Maheshwari & Banerjee 1975. (Pl.2, fig.2)

Two specimens of the present assemblage have been identified as *Biharisporites maiturensis*. In all available features those are indistinguishable from *B. maiturensis* described by Maheshwari and Banerji (1975) from Maitur beds.

B. luguensis Pal, Ghosh & Sannigrahi 1997. (Pl.1, figs. 12, 13)

Six specimens of the present assemblage in all characteristic features are similar to those of *Biharisporites luguensis* described by Pal *et al.* (1997) from the Deoli Member of Panchet Formation in East Bokaro Coalfield. This species is hereby recorded for the first time from the Maitur Member.

VERRUTRILETES van der Hammen ex Potonié 1956

Verrutriletes obscurus (Meheshwari & Banerji) Banerji *et al.* 1978.

(Pl. 2, figs. 7, 8)

This species is extremely rare in the present collection, only one specimen has been recovered. Maheshwari and Banerji (1975) originally dscribed this species from Maitur beds under the genus JHARIATRILETES. Subsequently, Banerji *et al.* (1978) transferred it to VERRUTRILETES because it possesses verrucae instead of baculae over the exosporium.

TALCHIRELLA Pant and Srivastava emend. Bharadwaj and Tiwari 1970

Talchirella flavata (Kar) Bharadwaj & Tiwari 1970. (Pl. 2, figs. 9, 10)

This species is hereby reported for the first time from the Maitur sequence. *Talchirella flavata* is rather rare in Maitur, respresented by only three specimens in present collection. The specimens closely resemble those of *T. flavata* described by Bharadwaj and Tiwari (1970) from the Kulti Formation of Jharia Coalfield.

PANTIELLA Maheshwari and Banerji 1975 emend.

The genus PANTIELLA was instituted by Maheshwari and Banerji (1975) based on megaspore specimens from the Maitur rocks. The authors circumscribed the genus as having 'coniate, spinose or setose' ornamentation of exosporium. However, critical examination of several specimens of PANTIELLA recovered from Maitur beds (*locus typicus*), using Bright Field as well as Scanning Electron Microscopy reveals that the exosporium is fundamentally reticulate with a coniate projection at each muri-trijuncture. The figures of Maheshwari and Banerji (1975; text figs 5, 6A, 6C; Plate 8,

fig 112; Plate 9, fig. 114) also show the reticulate nature of exosporium, a fact already mentioned by Pant and Basu (1979, p. 205). Hence, the generic diagnosis of the genus is emended hereby.

Emended diagnosis : Megaspores trilete, trilete rays well developed; contact areas large, bounded by strongly developed equatorial or subequatorial arcuate ridges; exosporium reticulate, muri sharp with well developed coniate projection at each trijuncture; mesosporium distinct, subtriangular with circular to oval cushions arranged in two rows along the trilete laesura.

Type species : *Pantiella bosei* Maheshwari and Banerji 1975.

Comparison : In its ornamentation of exosporium PANTIELLA resembles MAITURISPORITES Maheshwari and Banerji 1975. But the mesosporium of the latter is devoid of cushions. As in PANTIELLA mesosporium with cushions is known to occur in several megaspore genera like DUOSPORITES Hoeg, Bose and Manum 1955, TALCHIRELLA Pant and Srivastava 1961, SURANGEAESPORITES Bharadwaj and Tiwari 1970, BARAKARELLA Lele and Srivastava 1983. But PANTIELLA can readily be distinguished from all these genera by its reticulate exosporium with coniate projections at trijunctures of muri.

Pantiella bosei Maheshwari & Banerji 1975 emend. (Pl. 3, figs. 1, 2)

Emended diagnosis : Trilete megaspores, *amb* subtriangular (equatorial diameter 315 390 μm in dry state and 380 - 456 μm in wet condition); trilete laesurae well developed (20-30 μm high at trijunction in dry spores), sharp at top, little wavy, extending nearly up to the equator; contact areas well marked by narrow arcuate ridges (±20 μm high); exosporium reticulate, muri sharp, having a 10 25 μm long (including the height of the muri) coniate projection at each trijunction, projections more well developed in the proximal contact areas; lumina hexagonal to polygonal in outline (8 25 μm wide); mesosporium distinct, subtriangular, 180 220 μm wide, having two rows of oval to circular cushions (7 10 μm in diameter) below each laesura.

Remarks *Pantiella bosei* has earlier been described from these beds by Maheshwari and Banerji (1975). The species is rather common in the present assemblage. Altogether 10 specimens have been referred to this species.

P. bharadwajii Maheshwari & Banerji 1975 emend. (Pl. 3, figs. 3 5)

Emended diagnosis : Megaspores trilete, *amb* subcircular to subtriangular (equatorial diameter 300 - 437 μm in dry state and 512 615 μm in wet condition); trilete rays distinct (30 - 40 μm high and ±20 μm wide near the trijunction in dry state), little wavy, upper edge sharp, gradually tapering towards ends, extending nearly up to the equator; contact areas well defined, broad, bounded by distinct, sharp, almost equatorial arcuate ridges (15 25 μm high in dry spores); exosporium reticulate, muri sharp, having a

15 30 μm long (including the height of the muri) coniate projection at each trijunction, projections uniformly developed all over the spore surface, lumina hexagonal to polygonal, 8 - 30 μm wide; mesosporium distinct, dense, subtriangular, 200 250 μm wide, margin folded, provided with oval to circular (7 10 μm in diameter) cushions in two rows below each laesura.

Remarks : *Pantiella bharadwajii* is represented by seven specimens in the present assemblage. This specimen was reported previously by Maheshwari and Banerji (1975) from Maitur beds.

Pantiella maheshwarii Sannigrahi & Pal *sp. nov.* (Pl. 3, figs. 6, 7)

Diagnosis : Trilete megaspores, *amb* subcircular to subtriangular (equatorial diameter 315 380 μm in dry state and 430 620 μm in wet condition), contact facets slightly convex; trilete rays well developed, ±30 μm high and 20 μm broad in dry state, wavy; contact areas well marked by distinct, sharp, subequatorial arcuate ridges (10 15 μm high); exosporium reticulate, muri sharp with a coniate projection at each muri-trijunction (10 - 25 μm high including muri), lumina hexagonal to polygonal, 10 35 μm wide, projections relatively weakly developed (5 - 12 μm high) in proximal contact areas; mesosporium distinct, subtriangular (230 - 420 μm in diameter), margin devoid of folding, provided with a row of circular to oval cushions (±10 μm in diameter) flanking below each arm of the laesurae, cushions in a row are interconnected by a thread like structure giving rise to a bead and string appearance.

The specific name is after Dr. H.K. Maheshwari.

Holotype : Slide No. B. U. 39.

Locality : Nonia Nala Section, East of Kamarpur, Burdwan District, West Bengal, India.

Horizon and Age : Panchet Formation, Lower Triassic.

Comparison and remarks : *Pantiella maheshwarii* can be distinguished from *P. bosei* by its weakly developed sculptural elements in the proximal contact areas whereas, it is just reverse in case of *P. bosei.* Moreover, unlike *P. bosei,* the mesosporium in *P. maheshwarii* is relatively large and devoid of marginal folding. *P. bharadwajii* differs from *P. maheshwarii* in having uniformly developed sculptural elements all over the exine surface. *P. maheshwarii,* in comparison to other two species, is rather infrequent at Maitur, represented by only six specimens in our present collection.

MAITURISPORITES Maheshwari and Banerji 1975.

Maiturisporites indicus Maheshwari and Banerji 1975 (Pl. 4, fig. 1)

Maiturisporites indicus is the most dominant element in the presently recovered assemblage. Altogether 64 well preserved

specimens have been referred to this species.

Maiturisporites distinctus Maheshwari and Banerji 1975. (Pl. 3, figs. 8, 9)

Maiturisporites distinctus was previously described by Maheshwari and Banerji (1975) from this horizon. This species is quite common in the Maitur assemblage and 30 well preserved specimens have been referred to it.

M. jayasrii Sannigrahi and Pal *sp. nov.* (Pl. 4, figs. 4-6)

Diagnosis : Megaspores trilete, *amb* subcircular (equatorial diameter 400 - 450 μm in dry state and 600 - 645 μm in wet condition); trilete laesurae distinct, slightly curved but not sinuous, ±35 μm high and 20 μm wide in dry spores, reaching nearly up to the equator, laesurae at its highest altitude in middle part, two ends gradually becoming low; contact areas well defined by distinct subequatorial arcuate ridges (15 - 20 μm high); exosporium rather thin and fragile, surface reticulate, muri low (10 - 15 μm wide and 5 8 μm high) and blunt at top with a verrucose projection at each trijuncture; lumina hexagonal to polygonal, 10 - 30 μm wide; mesosporium indistinct.

The species has been named after Dr.(Miss) Jayasri Banerji.

Holotype : Slide No. B. U. 42.

Locality : Nonia Nala Section, East of Kumarpur, Burdwan District, West Bengal, India.

Horizon and Age : Panchet Formation, Lower Triassic.

Comparison and remarks : *Maiturisporites jayasrii* can be distinguished from all other known species of the genus (viz. *M. indicus*, *M. distinctus* and *M. spinotriletus*) by its low blunt muri with verrucate projections at trijunctures. This species is quite infrequent in the present assemblage being represented by only three specimens.

Tetralete megaspores (Pl. 4, figs. 7, 8)

Description : Megaspores tetralete, *amb* subcircular (equatorial diameter 250 - 270 μm in dry state and 500 575 μm in wet condition); tetralete rays well developed, almost straight, extending up to 2/3 3/4 of spore radius, ± equal in length, tetrajunction slightly broader, gradually tapering towards ends; contact areas indistinct, arcuate ridges absent; exosporium coarsely granulose, grana relatively sparsely distributed at contact faces than elsewhere; mesosporium indistinct.

Comparison and remarks : The occurrence of abnormal tetralete megaspores has been reported previously by Maheshwari and Bajpai (1987) from Lower Permian Coal Measures of Zaire. Mishra and Tripathi (1989) also reported fossil tetralete megaspores from the Lower Gondwana Coal samples of Umaria Coalfield, Madhya Pradesh, India. The Zaire specimens differ from the present specimens by their smooth exosporium and slightly elevated contact areas. The Umaria form has granulose surface

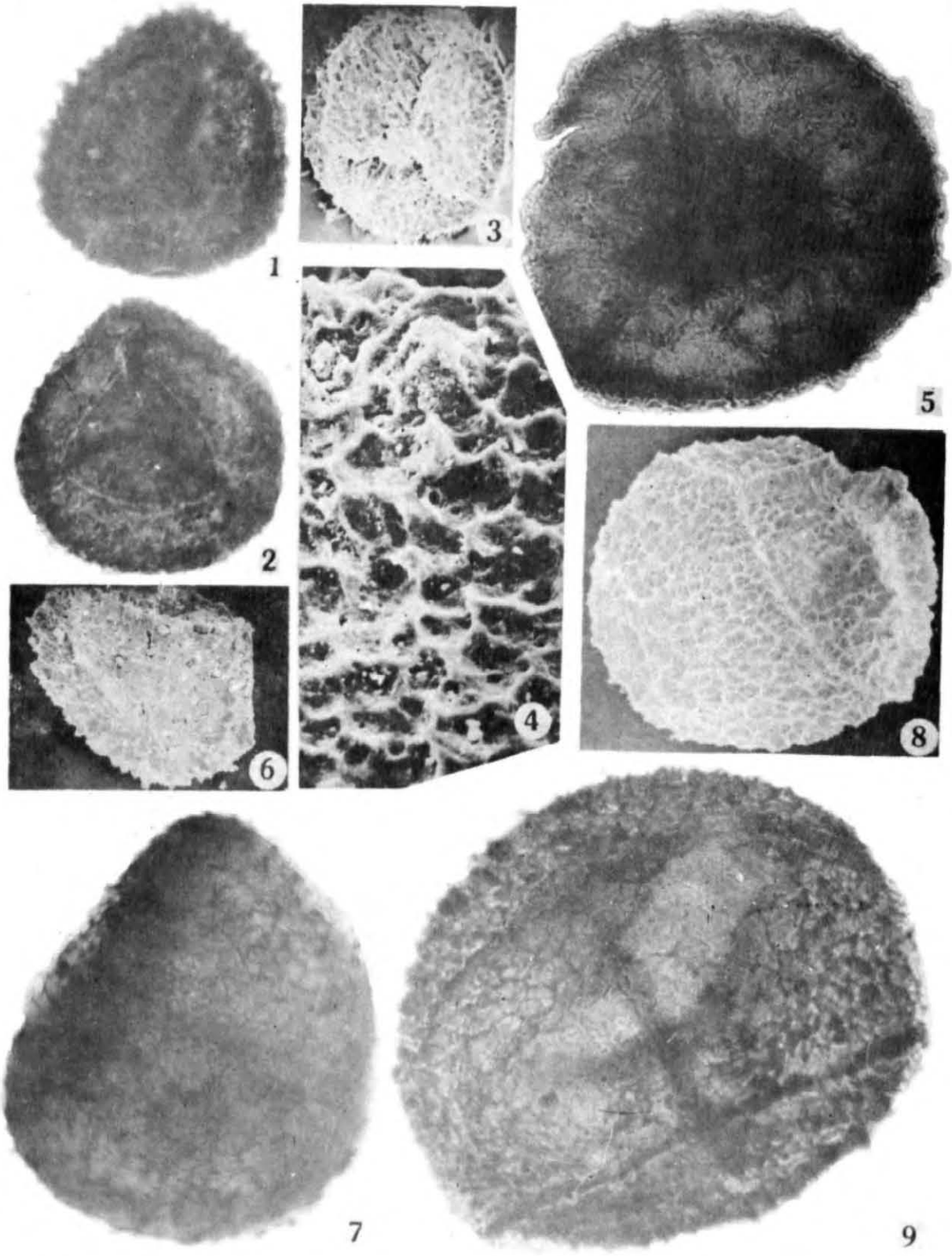


Plate-3

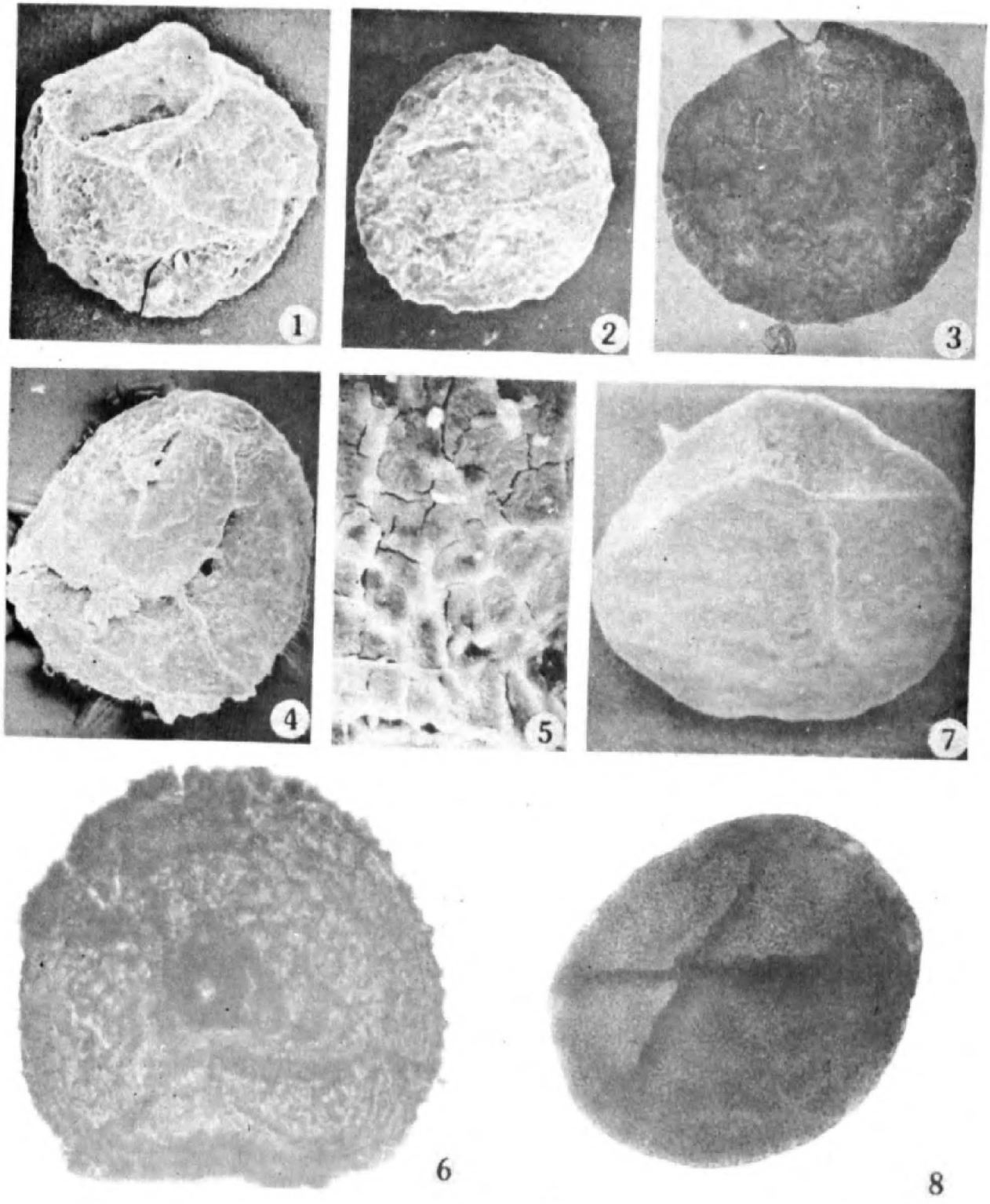


Plate-4

EXPLANATION OF PLATES

(All figures ×100, unless otherwise mentioned)

PLATE-3

1,2. *Pantiella bosei* Maheshwari & Banerji.

1, Megaspore in dry condition.

2, Same spore in wet condition showing subtriangular mesosporium with faint cushions and relatively bigger sculptures just above the mesosporium; Slide No.- B.U. 37.

3-5. *P. bharadwajii* Maheshwari & Banerji

3, Scanning Electron Micrograph of a dry megaspore ; SEM Stub no. - 2/7.

4, Same spore of fig. 3 magnified to show distinct reticulate exosporium with coniate processes at each muri trijuncture ×500.

5, Megaspore in wet condition showing triangular mesosporium with biseriately arranged cushions, trilete rays slightly shifted from its original position leaving very prominent cushions. Slide No. - B.U. 38.

6,7. *P. maheshwari* Sannigrahi & Pal sp. nov.

6, Scanning Electron Micrograph of a dry specimen showing relatively developed sculptural processes at the equatorial distal part than the contact faces. SEM Stub No. - 2/8.

7, Holotype showing large mesosporium with faint cushions below the trilete laesurae. Slide No. - B.U. 39.

8,9. *Maiturisporites distinctus* Maheshwari & Banerji.

8, Scanning Electron Micrograph of a dry megaspore showing high sharp trilete laesurae and arcuate ridges. SEM Stub No. - 3/3.

9, Megaspore in wet condition Slide No. - B.U. 41.

PLATE-4

1-3. *Maiturisporites indicus* Maheshwari & Banerji.

1, Scanning Electron Micrograph of a dry specimen recovered from Panchet Formation showing arcuate ridges and the nature of reticulation, SEM Stub No. - 3/2.

2, Scanning Electron Micrograph of a dry megaspore of Raniganj Formation. SEM Stub No. 1/2.

3, A megaspore of Raniganj Formation in wet condition; Slide No. B.U. - 28.

4-6. *M. jayasrii* Sannigrahi & Pal. sp. nov.

4, Scanning Electron Micrograph of a dry megaspore showing trilete laesurae and arcuate ridges ; SEM Stub No. - 2/6.

5, Part of a spore in figure 4 magnified to show the verrucate nature of muri trijuncture × 700.

6, Holotype in wet condition. Slide No. - B.U. 42.

7, 8. *Tetralete megaspore.*

7, Scanning Electron Micrograph of a dry spore showing distinct tetralete rays. SEM Stub No. - 3/1.

8, Another specimen in wet condition showing tetralete laesurae and granulose exosporium. Slide No. - B.U. 43.

like the present one but the former differs by the presence of distinct arcuate rims. Pant and Srivastava (1962), Srivastava *et al.* (1992) and Srivastava *et al.* (1995) reported the formation of tetralete megaspores in living plants of *Isoetes indica* Pant and Srivastava, *I. dixitei* Shende, *Pteris aspericaulis* Wall. ex Ag. and *P. biaurita* L. From the observations in extant taxa they concluded that such spores are rather rare abnormal forms, majority of spores are with normal trilete sutures.

In the present assemblage, tetralete forms are rather rare in occurrence. Only three well preserved specimens have been collected. In all available features the specimens resemble *Banksisporites granulosus* except their abnormal tetralete marks. For this reason, the specimens have been treated here as an abnormal form, rather being described as a new species.

Quantitative analysis of the assemblage: In the presently recovered megaspore assemblage from Maitur, most of the species previously described by Maheshwari and Banerji (1975) from these beds have also been met with. However, a few previously reported forms are totally missing in the present assemblage. Those are *Verrutriletes distinctus, Talchirella dubia, T. sinuata* and *Maiturisporites spinotriletus.* In spite of our repeated attempts to recover these taxa we failed. We concluded that these species occur at Maitur with extremely low frequencies. In our assemblage the mininum frequency of occurrence is of *Verrutriletes obscurus* which is represented by solitary specimen. While making the quantitative analysis we presume the minimum frequency for the species which were described by Maheshwari and Banerji (1975) but are missing in our assemblage. In course of the present investigation 176 specimens have been collected from the Maitur beds and four are added for the above species making total number of specimens to 180 for calculating frequency distribution of taxa.

The overall assemblage has been found to be dominated by *Maiturisporites indicus* (35.6%), followed by *M. distinctus* (16.7%), *Banksisporites panchetensis* (10.0%), *B. gondwanenis* (8.9%) and *Pantiella bosei* (5.6%). *P. bharadwajii* (3.9%), *P. maheshwarii* (3.3%) and *Biharisporites luguensis* (3.3%) are commonly occurring forms. *Banksisporites granulosus* (2.2%), *B. minuticorpus* (1.7%), *Talchirella flavata* (1.7%), *Maiturisporites jayasrii* (1.7%), *Biharisporites maiturensis* (1.1%), *Verrutriletes obscurus* (0.6%), *V. distinctus* (0.6%), *Talchirella sinuata* (0.6%), *T. dubia* (0.6%) and *Maiturisporites spinotriletus* (0.6%) are rather rarely occurring elements (Text-fig.4).

At generic level (Text-fig.5) MAITURISPORITES (54.6%) is most predominant. BANKSISPORITES is next in abundance (22.8%). PANTIELLA (12.8%) and BIHARISPORITES (4.4%) are also quite common in occurrence. TALCHIRELLA (2.9%) and VERRUTRILETES (1.2%) are rather rare in the

present assemblage. Moreover, abnormal specimens with tetraradiate suture occur at a low frequency (1.7%).

DISCUSSION

The megaspore assemblage as recovered from the youngest strata of Raniganj Formation in the Raniganj Coalfield qualitatively comprises *Banksisporites psilatus* (Bharadwaj and Tiwari) Sannigrahi and Pal *comb. nov.*, *B. panchetensis* (Maheshwari and Banerji) Banerji, Kumaran and Maheshwari, *Biharisporites maiturensis* Maheshwari and Banerji, *B. raniganjensis* Sannigrahi and Pal *sp. nov.* and *Maiturisporites indicus* Maheshwari and Banerji. Quantitatively the genus BIHARISPORITES is the most predominent form, BANKSISPORITES is a commonly occurring element whereas MAITURISPORITES is rather rarely met with.

The megaspore assemblage recovered from the Maitur Member of Panchet Formation is represented by *Banksisporites gondwanensis* Maheshwari and Banerji, *B. minuticorpus* Maheshwari & Banerji, *B. panchetensis* (Maheshwari and Banerji) Banerji, Kumaran and Maheshwari, *Biharisporites maiturensis* Maheshwari and Banerji, *B. luguensis* Pal, Ghosh and Sannigrahi (in press), *Verrutriletes obscurus* (Maheshwari and Banerji) Banerji, Kumaran and Maheshwari, *V. distinctus* (Maheshwari and Banerji) Banerji, Kumaran and Maheshwari, *Talchirella sinuata* Maheshwari and Banerji, *T. dubia* Maheshwari and Banerji, *T. flavata* (Kar) Bharadwaj and Tiwari, *Pantiella bosei* Maheshwari and Banerji, *P. bharadwajii* Maheshwari and Banerji, *P. maheshwarii* Sannigrahi and Pal *sp. nov.*, *Maiturisporites indicus* Maheshwari and Banerji, *M. distinctus* Maheshwari and Banerji, *M. spinotriletus* Maheshwari and Banerji and *M. jayasrii* Sannigrahi and Pal *sp. nov.* in addition to a tetralete form. Quantitatively MAITURISPORITES is the most predominant form. BANKSISPORITES, PANTIELLA are found abundantly. BIHARISPORITES is a commonly occurring element whereas TALCHIRELLA and VERRUTRILETES are rather rare in occurrence.

The Lower Gondwana megaspore flora was most diversified at Barakar Formation and it gradually declined in the overlying Kulti and Raniganj Formations (Bharadwaj and Tiwari 1970). The megaspore assemblage of youngest strata of Raniganj Formation also corroborates this. Only five species belonging to three genera have been recorded from this horizon. Most of the genera reported from the Barakar, Kulti and lower horizon of Raniganj formations viz. JHARIATRILETES, SINGHISPORITES, SURANGEAESPORITES, DUOSPORITES, MANUMISPORITES and NONIASPORITES have not been found in the upper beds of Raniganj. However, a few genera, viz. BANKSISPORITES and BIHARISPORITES, which made their first appearance in older formations, still persist

in the youngest Raniganj strata, though their species are different. The present work reveals that the uppermost horizon of Raniganj Formation is characterised by last occurrence of *Banksisporites psilatus* and first appearance of *Banksisporites panchetensis, Biharisporites maiturensis, B. raniganjensis* and *Maiturisporites indicus*. The genus MAITURISPORITES made its first appearance in the upper Raniganj strata and subsequently becomes the most dominant form in the Panchet Formation. *Banksisporites panchetensis, Biharisporites maiturensis* and *Maiturisporites indicus* which are present at Raniganj Formation also continue in the Panchets. The genera PANTIELLA and VERRUTRILETES appear for the first time in the Panchet Formation. TALCHIRELLA is generally a common element in Barakar, Kulti and the Lower Horizon of Raniganj formations. The genus has also been recorded from the Panchet Formation but strikingly missing in the upper strata of Raniganj Formation.

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