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Megaspore assemblages from the Tiki Formation of India and their Stratigraphic Significance

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ABSTRACT

Megaspore assemblages from three different localities belonging to the Triassic of Tiki Formation in India have been analysed both qualitatively and quantitatively. The assemblages are represented by the species belonging to the genera *Banksisporites, Biharisporites, Verrutriletes, Bacutriletes, Maiturisporites, Horstisporites, Hughesisporites, Erlansonisporites, Minerisporites, Nathorstisporites* and *Aneuletes*. All the three assemblages are characterised by the predominance of the genus *Banksisporites*. The genera *Biharisporites* and *Maiturisporites* were present only during the deposition of lower part of the Formation, while *Horstisporites* and *Minerisporites* had their appearance during the deposition of the upper reaches of the Formation. The megaspore remains reveal a Upper Triassic age for the Tiki Formation.

Key-words: Megaspore, Tiki Formation, Upper Triassic, India

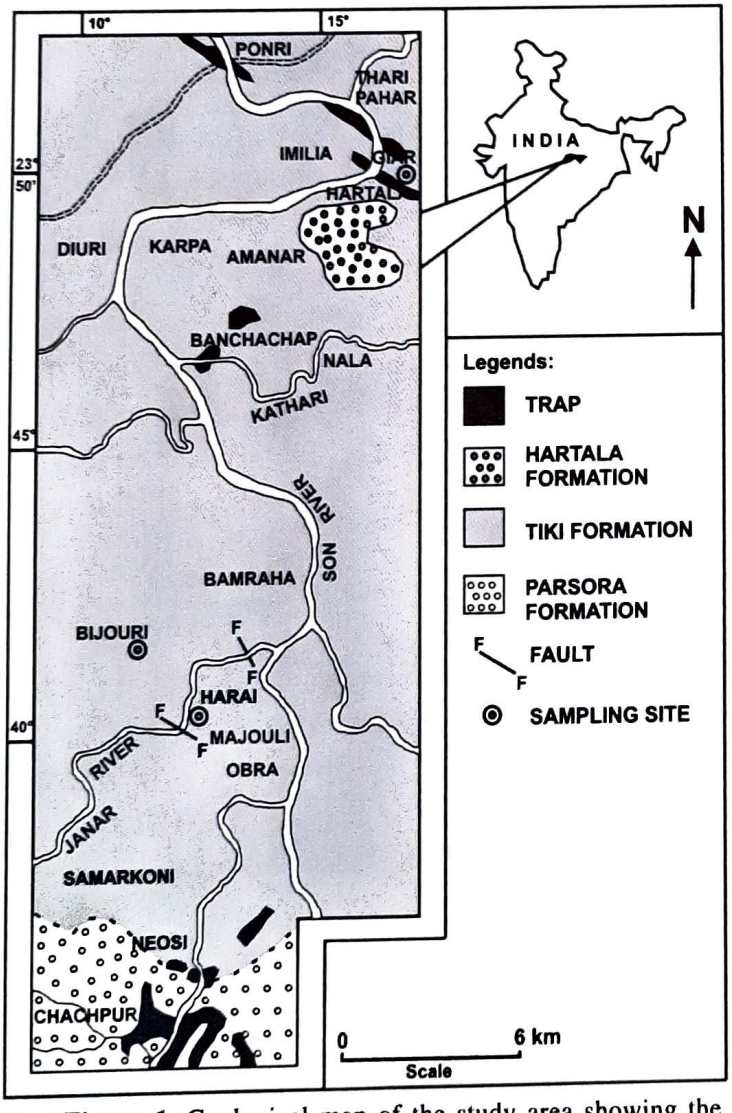
INTRODUCTION

The rocks of Tiki Formation occur in the Son Valley Basin of the Shahdol District, Madhya Pradesh. Exposed in the low-lying vast tract between Neoi and Tiki, the Tiki Formation is characterised by white to pinkish white and yellowish sandstone, loose green sandstone, rubbly grey calcareous sandstone, greyish micaceous shale, green sandy shale and red clay. The sandstones are often associated with clay galls. Earlier, megaspore assemblage has been recorded by Banerji et al. (1978) from the Tiki Formation. They described megaspores of *Trileites* sp., *Bokarosporites janarensis* Banerji et al., *Banksisporites dettmannae* Banerji et al., *B. panchetensis* (Maheshwari & Banerji) Banerji et al., *B. pinguis* (Harris) Dettmann, *B. sinuosus* Dettmann, *B. tenuis* (Dijkstra) Dettmann, *Banksisporites* sp., *Biharisporites sparsus* Banerji et al., *Biharisporites* sp., *Verrutriletes minuticorpus* Banerji et al., *V. obscures* (Maheshwari & Banerji) Banerji et al., *Bacutriletes* sp., *Horstisporites areolatus* (Harris) Potonie', *Erlansonisporites triassicus* Banerji et al., *Erlansonisporites* sp., *Hughesisporites variabilis* Dettmann, *Nathorstisporites hopliticus* Jung and *Nathortisporites* sp. from a locality on the east bank of Janar River, south-west of Harai Village. Their account only involves morphotaxonomy of megaspore taxa. Quantitative analysis had not been attempted in the previous study. The present work is based on systematic collection of samples through the entire sequence of Tiki Formation and both qualitative as well as quantitative analyses of megaspores of the productive samples.

MATERIAL AND METHODS

Samples, with their respective lithologies, from the three following localities of Shahdol District, Madhya Pradesh yielded well preserved megaspores: i) greyish

micaceous fine grained sandy and silty shales exposed on the east bank of Janar River, 1.25 km south-west of Harai Village [from this locality, Banerji et al. (1978) earlier described their assemblage], ii) dark-grey micaceous silty shales exposed on the northern bank of Janar River, 0.3 km east of Bijouri Village and iii) green sandy micaceous shales exposed on the east bank of Son River, north-west of Giar Village (Text-Figure 1). Each sample was treated with Hydrofluoric acid for 2 days. Then it was washed thoroughly in distilled water to make acid free by using a 150 mesh standard sieve. From the organic residue megaspores were sorted out one by one under a WILD M3B Stereobinocular microscope and allowed to dry at room temperature. Individual megaspore was first studied and photographed under strong incident light using Leitz Labourlux S Bright Field Light microscope with Leica DFC 295 digital camera. Later on, the megaspore was gradually macerated with concentrated Nitric acid followed by a treatment with dilute alkali (2-5% NaOH). When the specimen became sufficiently translucent its further details were studied under the bright field light microscope using transmitted light. Microphotographs were also taken at different stages of progressive maceration. For scanning electron microscopic studies dry specimens were first coated with gold and then studied and photographed under Hitachi S-530 Scanning Electron Microscope with digital camera attachment. Text-figures have been drawn from the slides by using a camera lucida and also with the help of enlarged photographs. Quantitative analysis of each assemblage has been carried out on at least two hundred specimens of megaspores, however, in samples with very low frequency of megaspores, at least one hundred specimens were counted.



Text-Figure 1. Geological map of the study area showing the sampling sites.

OBSERVATIONS

Systematic Description of Megaspores Recovered from Harai and Bijouri Localities of Janar River Section

Genus - *Banksisporites* Dettmann emend. Banerji et al. 1978

Banksisporites pinguis (Harris) Dettmann 1961. (Pl. 1, fig. 2; Text-Figure 2A)

Description: Trilete megaspores, *amb* ± spherical (equatorial diameter 260-340 µm in dry state and 325-430 µm in wet condition); trilete laesurae distinct, ± 15µm high and 10µm wide near the trijunction in dry spores, ± straight, extending ± 3/4 of the spore radius; contact areas indistinct, arcuate ridges absent; exosporium smooth to finely granulose; mesosporium distinct ± circular, 210-260 µm diameter in wet specimens.

Remarks: Banksisporites pinguis is a preponderant element in both the localities. Out of altogether 134 specimens of megaspores from the Harai locality 55 specimens belong to this species. Banerji et al. (1978) reported this species from Harai locality. In Bijouri locality, 72 specimens of this species have been identified out of 129 specimens.

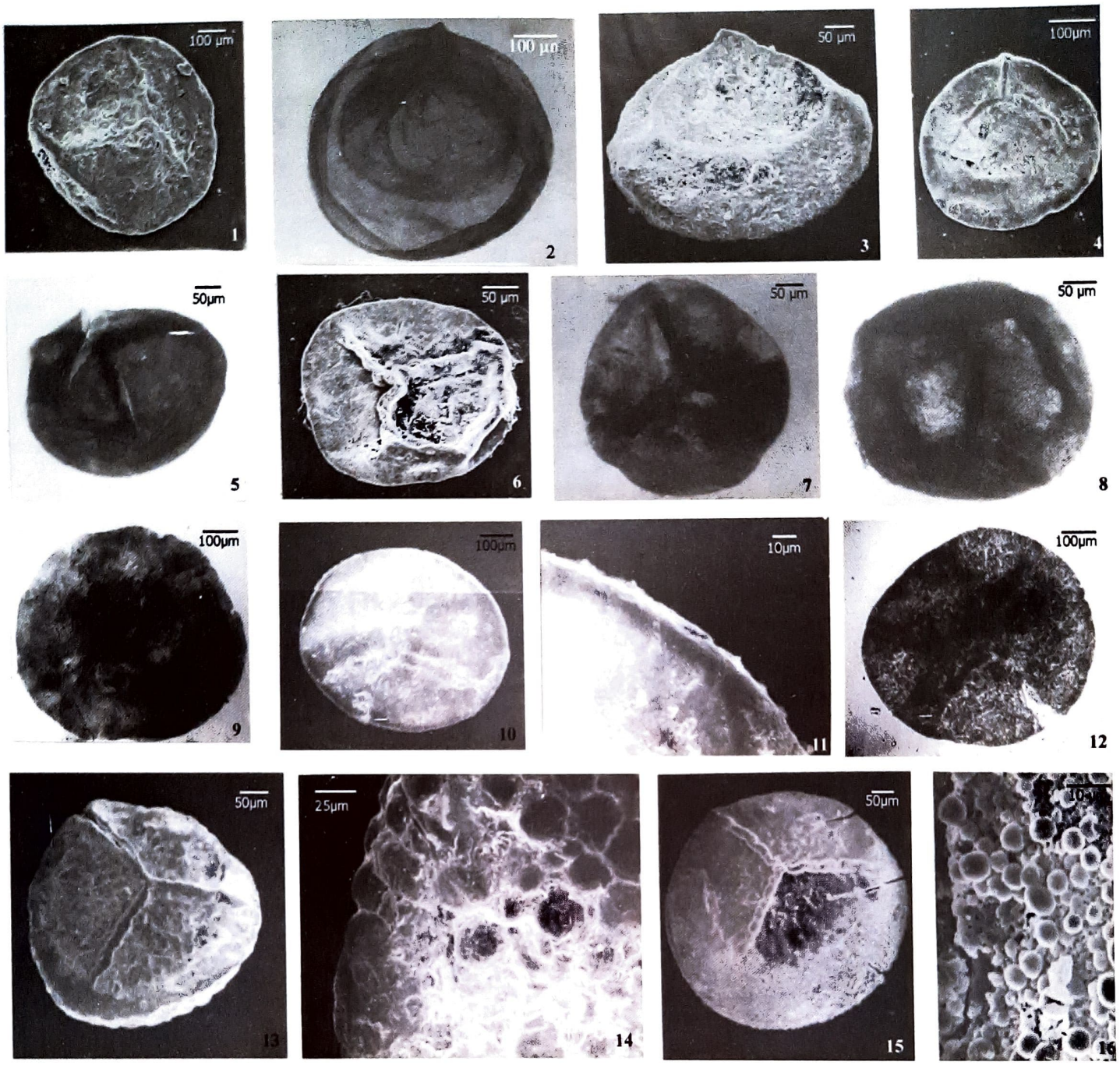


PLATE 1

Figs 1 & 2. *Banksisporites pinguis* (Harris) Dettmann. 1. scanning electron micrograph of a dry specimen from Giar locality, showing its smooth to finely granulose exosporium. SEM Stub No. BU 11/1. 2. a specimen in wet condition from Harai locality. **Fig. 3.** *Banksisporites dettmannae* Banerji *et al.*, Scanning Electron Micrograph of a dry megaspore recovered from Bijouri locality showing coarsely granulose exosporium and arcuate ridges. SEM Stub No. BU 6/7. **Figs 4 & 5.** *Banksisporites panchetensis* (Maheshwari & Banerji) Banerji *et. al.* 4. scanning electron micrograph of a specimen recovered from the Bijouri locality showing granulose exosporium and arcuate rims. SEM Stub No. BU 6/6. 5. a megaspore in wet condition collected from the Harai beds showing mesosporium. Slide No. BU 65. **Figs 6 & 7.** *Banksisporites sinuosus* Dettmann. 6. scanning electron micrograph of a dry megaspore of Giar locality showing sinuous trilete rays and finely granulose exosporium. SEM Stub No. BU 11 /2. 7. Same megaspore in wet condition showing a thin subcircular mesosporium. **Fig. 8.** *Banksisporites gondwanensis* Maheshwari & Banerji, a megaspore recovered from the Bijouri locality in wet condition showing its microverrucose exosporium and a mesosporium. Slide No. BU 54. **Fig. 9.** *Banksisporites janarensis* (Banerji, Kumaran & Maheshwari) comb. nov., A megaspore from Harai locality in wet condition showing a faint mesosporium and the broad trilete ray ends. Slide No. BU 67. **Figs 10-12.** *Biharisporites sparsus* Banerji *et al.* 10. scanning electron micrograph of a dry megaspore from Harai locality. SEM Stub No. BU 5/4. 11. a part of exosporium of the specimen in Fig. 4 magnified to show the sparse distribution of coni over exine surface. 12. same specimen in wet condition facing the distal view. **Figs 13 &14.** *Verrutriletes minuticorpus* Banerji *et al.* 13. scanning electron micrograph of a megaspore from Harai locality. SEM Stub No. BU 5/3. 14. a part of exosporium of the specimen in Fig. 1 magnified to show the nature of the verrucae. **Figs 15 & 16.** *Verrutriletes carbunculus* (Dijkstra) Potonié recovered from Bijouri locality. 15. scanning electron micrograph of a specimen showing its almost smooth contact faces and trilete rays. SEM Stub No. BU 6/1. 16. a part of exosporium magnified to show the gammae like verrucae.

Banksisporites dettmannae Banerji et al. 1978. (Pl. 1, fig. 3)

Description: Megaspores trilete, *amb* circular to subcircular (equatorial diameter 280-430 µm in dry state and 430-640 µm in wet condition); laesurae well developed (15-20 µm high and of ± same width in dry state), straight or at places little undulated, extending upto the margin of the contact areas; contact areas marked by distinct equatorial arcuate ridges; exosporium uniformly granulose, occasionally folded; mesosporium distinct, spherical, occupying about 2/3 of the spore cavity, diameter of mesosporium 280-430 µm in wet condition.

Remarks: Banksisporites dettmannae has been described earlier from Harai by Banerji et al. (1978). In the present collection this species is represented by 17 specimens from Harai and 20 specimens from Bijouri locality.

Banksisporites panchetensis (Maheshwari & Banerji) Banerji et al. 1978 (Pl. 1, figs. 4 & 5)

Description: Trilete megaspores, *amb* ± circular (equatorial diameter 335-410 µm in dry state and 400-450 µm in wet condition); trilete mark distinct, laesurae almost straight or at places little undulated, ± 30 µm high and 20 µm wide in dry state, extending 2/3 to 3/4 of the spore radius, gradually tapering towards the ends; contact areas clearly bounded by mediumly developed arcuate ridges; exosporium granulate, grana uniformly distributed throughout the surface; mesosporium distinct, filling almost 1/2 to 2/3 of the spore cavity (mesosporium 200-310 µm in diameter in wet condition).

Remarks: Twelve specimens from Harai and 10 specimens from Bijouri localities have been identified as *Banksisporites panchetensis*. In all available features those are indistinguishable from *B. panchetensis* described by Banerji et al. (1978) from Harai locality and also from Maitur Member of Panchet Formation (Sannigrahi and Pal 2000).

Banksisporites sinuosus Dettmann 1961 (Text-Figure 2B)

Description: Megaspores trilete, *amb* ± circular (equatorial diameter 260-270 µm in dry state and 295-320 µm in wet condition); trilete rays distinct, sinuous, extending ±3/4 of the spore radius; contact areas indistinct, arcuate rims absent; exosporium granulose; mesosporium very thin, ± circular (215-225 µm diameter in wet condition).

Remarks: Banerji et al. (1978) earlier reported this species from Harai locality. In the present work five specimens of *B. sinuosus* have been recovered from Harai beds, however, the megaspore assemblage from Bijouri is totally devoid of this species.

Banksisporites gondwanensis Maheshwari & Banerji 1975 (Pl. 1, fig. 8)

Description: Trilete megaspores, *amb* subcircular (equatorial diameter 300-370 µm in dry state and 350-480 µm in wet condition); trilete rays distinct, ± 25 µm high and 18 µm wide in dry state, slightly wavy; contact areas indistinct, arcuate rims absent; exosporium microverrucose, verrucae densely packed, uniformly distributed throughout the surface, exine wall 8-15 µm thick; mesosporium distinct, thin, 200-280 µm in diameter in wet specimens.

Remarks: This species is hereby reported for the first time from the Tiki Formation. The solitary specimen from Bijouri, in all available features, resembles *Bankisporites gondwanensis* described by Maheshwari and Banerji (1975) and Sannigrahi and Pal (2000) from the Panchet Formation.

Banksisporites janarensis (Banerji et al.) comb. nov. (Pl. 1, fig. 9; Text-Figure 2C).

Basionym- Bokarosporites janarensis Banerji et al., *Palaeobotanist* 25, P. 3; Pl. 1 , fig. 2; Text-Figure 1.

Diagnosis: Megaspores trilete, *amb* ± circular (equatorial diameter 530-550 µm in dry state and 625-655 µm in wet condition); trilete rays distinct with slightly broad ends, extending ±2/3 of the spore radius; contact faces indistinct, arcuate rims absent; exosporium almost smooth; mesosporium distinct, thin, 400-450 µm in diameter in wet specimens.

Remarks: This species is represented by seven specimens in the assemblage recovered from Harai, but has been found to be absent at Bijouri. Banerji et al. (1978) described this species as *Bokarosporites*

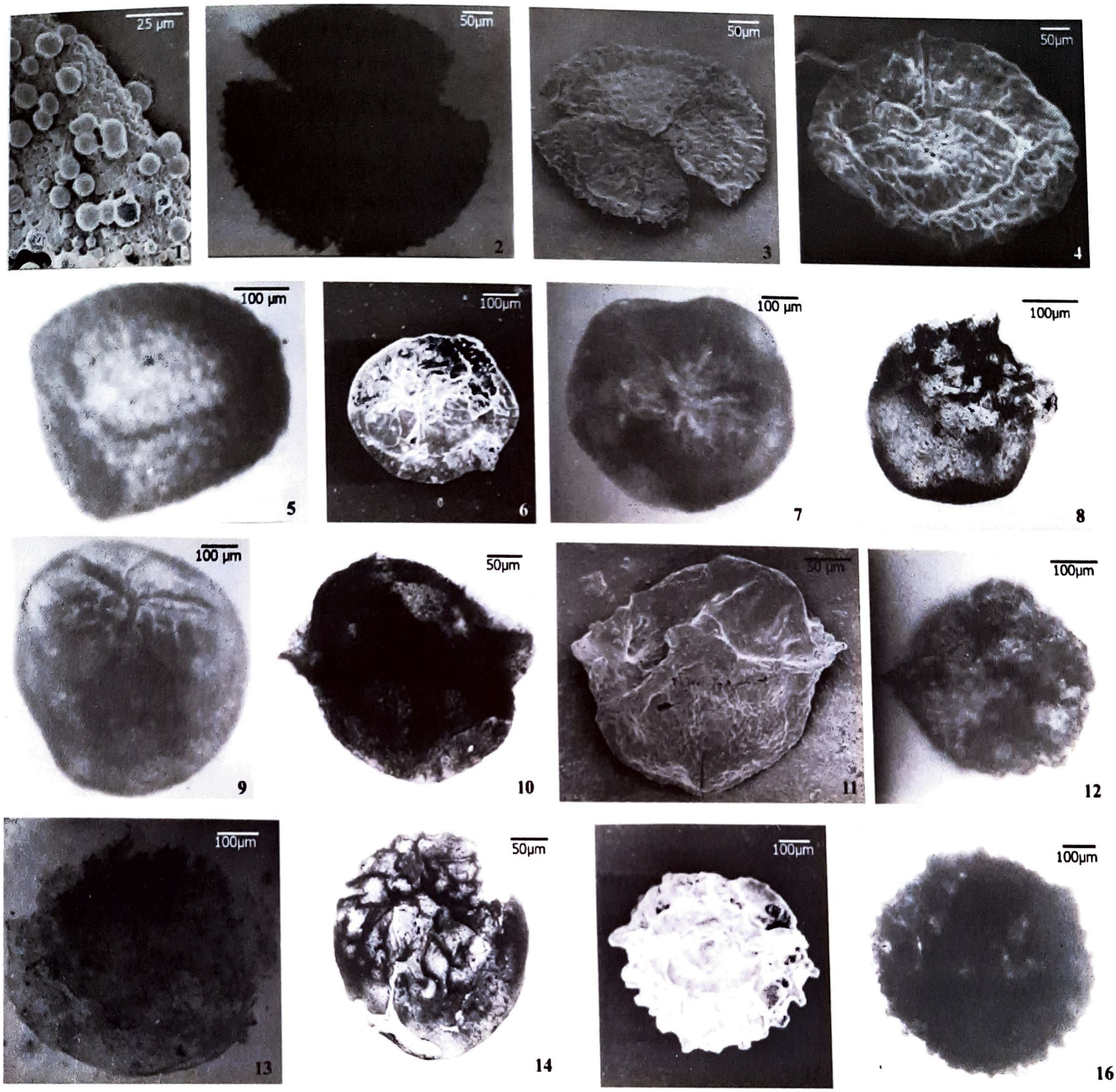


PLATE 2

Fig. 1. *Verrutriletes carbunculus* (Dijkstra) Potonie[1], A part of exosporium of magnified to show the gammae like nature of the verrucae from Giar locality. **Figs 2 & 3.** *Bacutriletes* sp. cf. *B. tylotus* (Harris) Potonie[1] from Giar locality. 2. a specimen in wet condition. 3. scanning electron micrograph of the same specimen showing cylindrical baculae over the exosporium. SEM Stub No. BU 11 /3. **Figs 4 & 5.** *Maiturisporites indicus* Maheshwari & Banerji. 4. Scanning Electron Micrograph of a specimen of Bijouri locality showing. distinct arcuate ridges and reticulate exosporium. SEM Stub No. BU 6/2. 5. another specimen of Harai locality in wet condition. Slide No. BU 69. **Figs 6-8.** *Hughesisporites singhii* Banerji, Jana & Maheshwari. 6. scanning electron micrograph of a megaspore collected from the Bijouri locality. SEM Stub No. BU 6/3. 7. a specimen of Harai locality in wet condition showing ridges over the contact faces. Slide No. BU 68. 8. a specimen in wet condition from Giar locality. **Fig. 9.** *Hughesisporites spinosus sp. nov.,* Holotype in wet condition; the projections disappear after maceration. Slide No. BU 59 from Bijouri locality. **Figs 10 & 11.** *Minerisporites variabilis* sp. nov. from Giar locality. 10. a Holotype in wet condition.. 11. scanning electron micrograph of the holotype showing microreticulate exosporium, equatorial zona and smooth contact faces. SEM Stub No. BU11/6x200. **Figs 12 & 13.** *Erlansonisporites triassicus* Banerji *et al.* from Harai locality. 12. a megaspore in dry condition. 13. a specimen in wet condition showing high muri like appendages in proximal face and a smooth distal face of exosporium in sub-equatorial view. Slide No. BU 70. **Fig.14.** *Erlansonisporites triassicus* Banerji, Kumaran & Maheshwari., a specimen of Giar locality in wet condition showing high muri in proximal part and a smooth distal face of exosporium. Slide No. BU 75. **Figs 15 & 16.** *Erlansonisporites robustus* sp. nov. from Harai locality. 15. scanning electron micrograph of a dry megaspore showing robust muri over exosporium and trilete rays. SEM Stub No. BU 5/2. 16. Holotype in wet condition. Slide No. BU 63.

janarensis. However, *Bokarosporites* has been considered as a junior synonym of *Banksisporites*. Therefore, the specimens have been treated here as *Banksisporites janarensis*.

Genus - *Biharisporites* Potonié emend. Bharadwaj & Tiwari 1970

Biharisporites sparsus Banerji et al. 1978 (Pl. 1, figs. 10-12)

Description: Trilete megaspore, *amb* ± circular (equatorial diameter 650 µm in dry state and 720 µm in wet condition); trilete rays distinct, straight, uniformly high throughout, extending almost up to the equator; contact areas indistinct, arcuate rims indiscernible; exosporium covered with sparsely distributed small coni (6-10 µm high in dry state); mesosporium not visible.

Remarks: This species is rarely represented in the Harai assemblage and totally absent at Bijouri.

Genus - *Verrutriletes* Van der Hammen ex. Potonié 1956

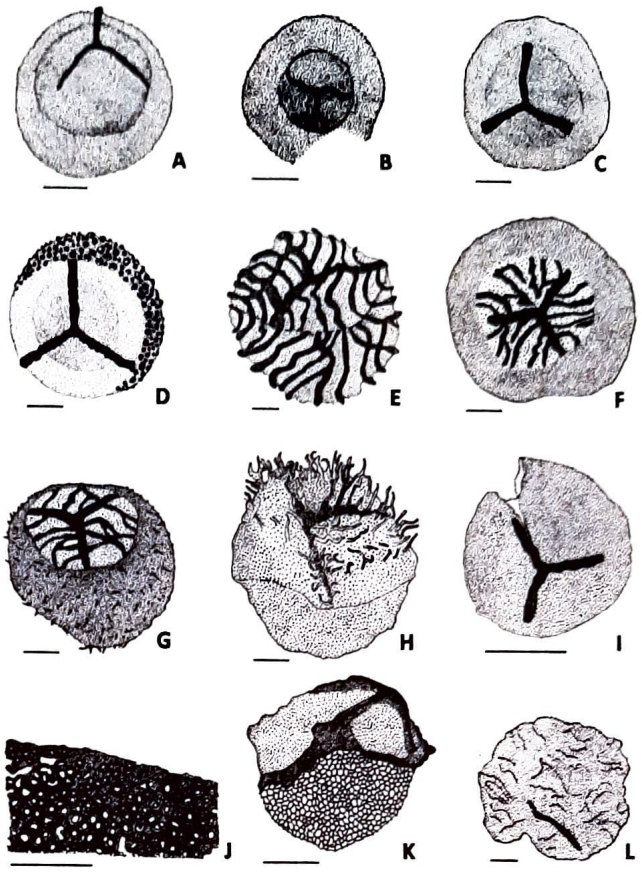
Verrutriletes minuticorpus Banerji et al. 1978 (Pl. 1, figs. 13 & 14)

Description: Trilete megaspores, *amb* subcircular (equatorial diameter 450-510 µm in dry state and 520-600 µm in wet condition); trilete mark well developed, almost straight, upper edge little wavy, extending nearly up to the equator; contact faces indistinct, arcuate rims absent; exosporium ornamented with closely set broad verrucae; 12-20 µm high as well as wide in dry state; exine thick, general surface granulate; mesosporium distinct but faintly visible due to thick exosporium, mesosporium 300-350 µm diameter in wet condition.

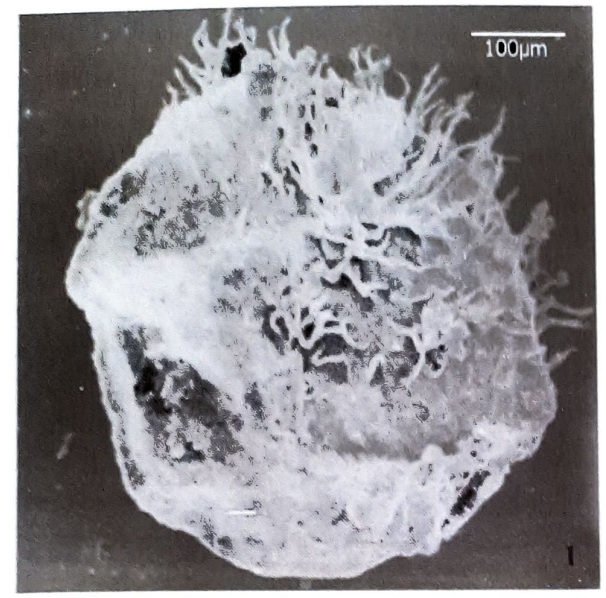
Remarks: In the present collection this species is represented only by two specimens from Harai locality.

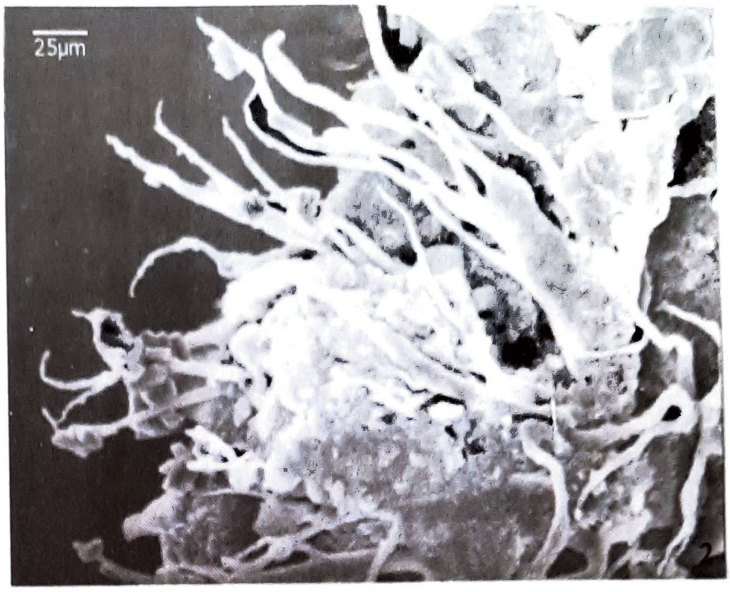
Verrutriletes carbunculus (Dijkstra) Potonié 1956 (Pl. 1, figs. 15 & 16; Text-Figure 2D)

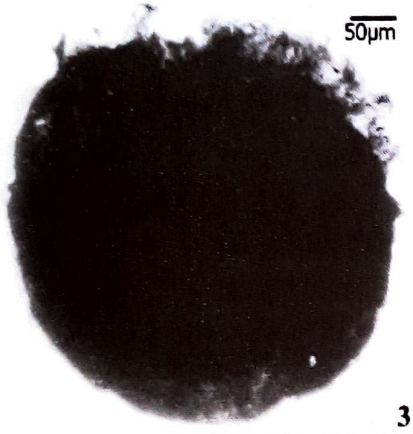
Description: Trilete megaspores, *amb* ± circular (equatorial diameter 510-550 µm in dry state and 580-600 µm in wet condition); trilete rays distinct, ± 20 µm high as well as wide in dry state, laesurae straight to little sinuous, or rather coily in appearance, rounded, uniformly high throughout, extending ± 3/4 of the spore radius; contact areas distinct due to differential distribution of the sculptural elements, arcuate ridges

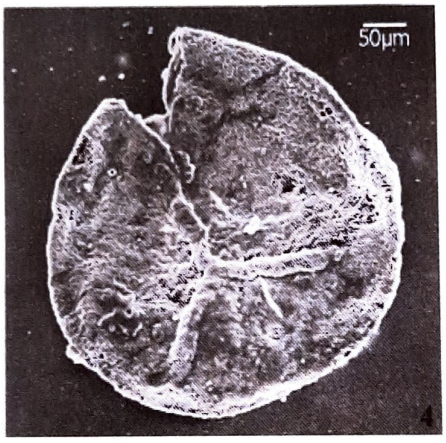


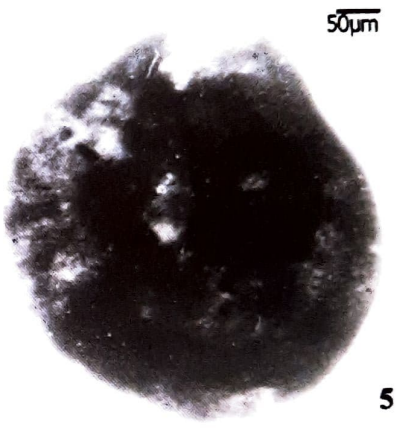
Text-Figure 2: A. *Banksisporites pinguis* (Harris) Dettmann. Megaspore in wet condition showing smooth to finely granulose exosporium and the mesosporium. **B.** *Banksisporites sinuosus* Dettmann. Megaspore at wet condition showing finely granulose exosporium, sinuous trilete rays and mesosporium. **C.** *Banksisporites janarensis* (Banerji, Kumaran & Maheshwari) comb. nov. Megaspore at wet condition showing smooth exosporium, trilete rays with broad ends and the mesosporium. **D.** *Verrutriletes carbunculus* (Dijkstra) Potonié. Megaspore at wet condition showing glossy gammae-like projections over exosporium excepting the contact faces and a small mesosporium. **E.** *Erlansonisporites robustus* sp. nov. Holotype in wet condition showing sparsely placed robust muri over exosporium and little wavy trilete rays. **F.** *Hughesisporites singhii* Banerji, Jana & Maheshwari. Megaspore at wet condition showing characteristic wavy projections in proximal contact areas and smooth distal face of the exosporium. **G.** *Hughesisporites spinosus* sp. nov. Holotype in dry condition showing wavy projections in proximal contact areas and rest of the exosporium with sparsely distributed spinose-setose projections. **H.** *Nathorstisporites hopliticus* Jung. Megaspore in dry condition showing capilli like projections over contact faces including the trilete rays and smooth distal face of exosporium. **I.** *Horstisporites foveolatus* sp. nov. Holotype in dry condition showing trilete rays and pitted exosporium. (0.1 mm/100 µm). **J.** part of exosporium magnified showing reticulate ornamentation and lumina provided with central pits. (0.025 mm/25 µm). **K.** *Minerisporites variabilis* sp. nov. Holotype in dry condition (equatorial view) showing almost smooth contact faces,distal face of exosporium microreticulate and well developed equatorial zona. **L.** *Aneuletes psilatus* sp. nov. Holotype in dry condition showing smooth exosporium with foldings. (Scale bar = 1mm, until otherwise mentioned).

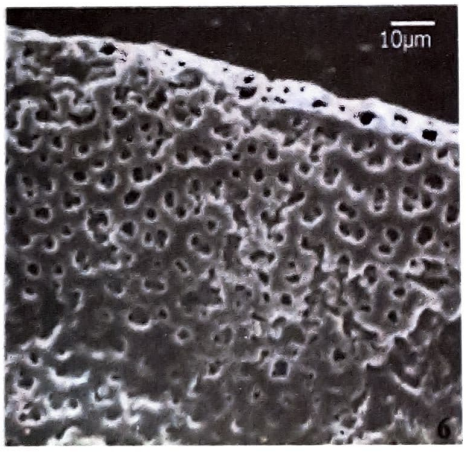












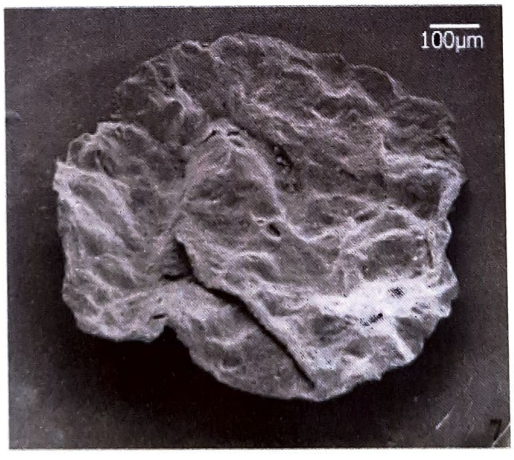


PLATE 3

Figs 1-3. *Nathorstisporites hopliticus* Jung. 1. scanning electron micrograph of a megaspore of Harai locality showing capilli like projections over trilete rays, on the contact faces and a smooth distal face of exosporium. SEM Stub No. BU 5/1. **2.** a part of exosporium of the specimen in fig. 1 magnified to show the nature of projections. **3.** a megaspore from Giar locality in wet condition showing capilli like projections in proximal face and a smooth distal part of exosporium. Slide No. BU 76. **Figs 4-6.** *Maexisporites giarensis* sp. nov. from Giar locality. 4. scanning electron micrograph of the holotype showing trilete rays and finely pitted exosporium.. 5. Holotype in wet condition.. 6. a part of exosporium of the holotype magnified to show that each mouth of the pit is boarded by low muri like thickening.. **Figs 7 & 8.** *Aneuletes psilatus* sp. nov. from Giar locality. 7. scanning electron micrograph of the holotype showing psilate exosporium and minute folds. SEM Stub No. BU 11/8. 8. another specimen in wet condition. After maceration the smooth exosporium gives a pseudo-microrugulate sculpture. Slide No. BU 77.

not recognizable; exosporium covered with densely packed almost spherical glossy verrucae (6-12 μm high in dry state), contact areas almost smooth, rarely bearing small verrucae; verrucae firmly attached with exosporium and not dissolved in maceration; mesosporium distinct, dense, ± circular, ± 350 μm diameter in wet specimens.

Remarks: The present specimen resembles *Verrutriletes carbunculus* (Dijkstra) Potonié in its exosporium ornamentation. However, the present specimen shows little undulating trilete rays in contrast to more or less straight laesurae of *V. carbunculus*. The nature of the verrucae of this specimen is quite controversial. Potonié (1956) suggested that the substance of the ornamentation of *V. carbunculus* appears as resinous exudates of the spore wall. Dijkstra (1949) proposed that each of these structures has a great resemblance to a ruby. Marcinkiewicz (1979) regarded the exine sculptural elements as saprophytic fungi attached to the exine. She has assigned these elements to a separate fungal taxa *Reymanella globosa*. Banerji et al. (1984) described similar specimens from the Lower Cretaceous Bhuj Formation of Kachchh Basin. They stated that the spherical verrucae-like structures over exosporium of their specimens of *V. carbunculus* quickly dissolved in acid maceration and for this reason they supported Marcinkiewicz's conclusion that the spherules are not elements of sculptures. Huber (1982) supported the view of Potonié (1956) that the gammae are type of resinous exudates. He studied the structures under higher magnification under SEM and concluded that each gamma possesses a smooth thin film covering foam like inner layer and the whole structure is subtended by a papilla of the outer spore wall. We studied the Tiki specimens under light microscope and SEM. The exosporium of the present specimens of the Tiki Formation are ornamented with dark black glossy spherical verrucae which remain firmly attached with the exine and do not dissolve during acid and alkali treatments. Thus, we conclude that at least in case of the specimens of *V. carbunculus* from Tiki Formation, the spherical verrucae-like structures are the integral part of exosporium sculpture.

Genus - *Maiturisporites* Maheshwari & Banerji 1975

Maiturisporites indicus Maheshwari & Banerji 1975 (Pl. 2, figs. 4 & 5)

Synonym - 1978 *Horstisporites areolatus* (Harris) Potonié: Banerji et al. *Palaeobotanist*, 25, p.1 0, 11 ; Pl. 6; figs. 39 & 40; Text-Figure 7.

Description: Trilete megaspores, subcircular in equatorial view (equatorial diameter ±352 μm in dry state and ±405 μm in wet condition); trilete rays well developed, 25-30 μm high at trijunction in dry spores, laesurae ± straight, sharp towards the crest, gradually becoming low towards the ends, extending almost upto the equator; contact areas always surrounded by sharp subequatorial arcuate rims (7-10 μm high in dry state); exosporium reticulate, muri sharp, in dry state 6-10 μm high and 4-6 μm wide, muri trijunction slightly broader than elsewhere, muri not much projecting at the equator; lumina polygonal to hexagonal (8-40 μm wide in dry spores); mesosporium indistinct.

Remarks: In all available features the present specimens resemble *Maiturisporites indicus* described from the Raniganj and Panchet formations by Maheshwari and Banerji (1975), Pal et al. (1997) and Sannigrahi and Pal (2000). Banerji et al. (1978) described similar specimens under *Horstisporites areolatus* from Harai beds. The present specimens as well as those figured by Banerji et al. 1978 (p. 10-11; Pl. 6, figs. 39, 40) possess distinct arcuate ridges and sharp muri with irregular-polygonal lumina. These features conform with the genus *Maiturisporites*. It may be noted that unlike *Maiturisporites*, *Horstisporites* is devoid of arcuate rims and the muri are quite blunt at top instead of being sharp like those of *Maiturisporites*. The species is of common occurrence at both the localities of Janar River Section.

Genus-*Erlansonisporites* Potonie[1]1956

Erlansonisporites trissicus Banerji et al. 1978 (Pl. 2, figs. 12 & 13)

Description: Trilete megaspores, *amb* subcircular, varying in diameter from 350-425 μm in dry state and 460-630 μm in wet condition; trilete laesurae well developed, raised, 35-45 μm high in dry state, almos

straight, extending almost up to the equator; contact areas indistinct, arcuate rims not recognisable; exosporium proximally ornamented with high muri like appendages, 10-20 μm high in dry specimens, distal surface of exine devoid of such appendages; mesosporium indistinct.

Remarks: Erlansonisporites triassicus is a frequently occurring element in the present collection from Harai. Altogether 10 specimens have been assigned to it. This species was earlier reported by Banerji et al. (1978) from the same locality.

Erlansonisporites robustus sp. nov. (Pl. 2, figs. 15 & 16; Text-Figure 2E)

Diagnosis: Trilete megaspores, *amb* subcircular (equatorial diameter 580-600 μm in dry state and 715-735 μm in wet condition); trilete rays distinct, laesurae little wavy, 30-40 μm high throughout in dry state, extending ± 2/3 of the spore radius, difficult to separate trilete rays from the high muri of exosporium; contact faces recognizable by the suppressed nature of the contact areas; arcuate ridges indistinct; exosporium ornamented with high, sparsely placed thick muri (40-65 μm high and 8-15 μm wide in dry state), muri forms an incomplete reticulum throughout the surface, occasionally muri anastomosing with each other, exosporium surface granulate; mesosporium not seen.

Derivation of species name: The specific name refers to the robust nature of muri over exosporium.

Holotype: Slide No. BU 63.

Locality: East bank of Janar River, 1 .25 km south-west of Harai Village, Shahdol.

District, Madhya Pradesh, India.

Horizon & Age: Tiki Formation; Upper Triassic.

Comparison & Remarks: In having identifiable trilete rays, the present species is closely comparable with *E. indicus* Banerji et al. (1984). But the present species possesses sparsely distributed robust thick muri in contrast to closely packed thin membranous lamellate muri over exosporium of *E. indicus. E. singhii* (Singh) Banerji et al. and *E. erlansonii* (Miner) Potonié differs by their indistinct trilete mark and thin membranous muri over exosporium. *Erlansonisporites robustus* is represented here by five specimens recovered from Harai.

Genus - *Hughesisporites* Potonié 1956

Hughesisporites singhii Banerji et al. 1978. (Pl. 2, figs. 6 & 7; Text-Figure 2F)

Description: Trilete megaspores, *amb* ± circular (equatorial diameter ±480 μm in dry state and ±600 μm in wet condition); trilete rays distinct, sinuous or patchy in appearance, ± 20 μm high and 15 μm wide in dry state, extending ± 2/3 of the spore radius, uniformly high throughout; contact areas distinct, provided with characteristic wavy ridges, arcuate rims absent; exosporium almost smooth; mesosporium indistinct.

Remarks: The present specimens, in all characteristic features resemble those described as *Hughesisporites singhii* by Banerji et al. (1984) from the Lower Cretaceous Bhuj Formation; Kachchh Basin. The species is recorded from both localities and represented by four specimens from Harai and three specimens from Bijouri.

Hughesisporites spinosus sp. nov. (Pl. 2, fig. 9; Text-Figure 2G)

Diagnosis: Trilete megaspores, subcircular in polar view, varying in equatorial diameter, 570-600 μm in dry state and 690-740 μm in wet condition; trilete rays distinct, uniformly high throughout (20-30 μm high and 15-20 μm wide in dry spores), almost straight, extending ± 2/3 of the spore radius; contact faces distinct, slightly grooved, bears irregular low wavy ridges, arcuate rims not recognisable; exosporium covered with sparsely distributed spinose-setose projections, 15-35 μm long in dry state; mesosporium indistinct.

Derivation of species name: The specific name is derived from the spinose-setose projections over exosporium.

Holotype: Slide No. BU 59.

Locality: North bank of Janar River Section, near Bijouri Village, Shahdol District, Madhya Pradesh, India.

Horizon & Age: Tiki Formation; Upper Triassic.

Comparison & Remarks: Hughesisporites spinosus sp. nov. differs from all the known species of

the genus in having spinose-setose projections over exosporium. The species is found only from the north bank of Janar River locality near Bijouri Village and altogether six specimens have been referred to it.

Genus - *Nathorstisporites* Jung 1958

Nathorstisporites hopliticus Jung 1958 (Pl. 3, figs. 1 & 2; Text-Figure 2H)

Description: Trilete megaspores, *amb* subcircular (equatorial diameter 520-540 μm in dry state and 590-640 μm in wet condition); trilete laesurae thin, membranous, bears raised branched or unbranched long capilli or filamentous projections, processes 30-100 μm long in dry specimens; contact areas also possess such projections; exosporium almost smooth on distal surface; mesosporium not seen.

Remarks: The present specimens are indistinguishable from those described earlier by Banerji et al. (1978) from Harai locality. *N. hopliticus* has been recovered both from Harai and Bijouri localities. Four specimens from Harai locality and five specimens from Bijouri have been assigned to this species.

Systematic Description of Megaspores Recovered from The Giar Locality of Son River Section

Genus - *Banksisporites* Dettmann emend. Banerji et al. 1978

Banksisporites pinguis (Harris) Dettmann 1961 (Pl. 1; fig. 1)

The present specimens are similar to those of *Banksisporites pinguis* described previously in the present contribution from the Harai and Bijouri localities of Tiki Formation. This species is most predominant in the present assemblage and is represented by 46 specimens out of 106 specimens.

Banksisporites sinuosus Dettmann 1961 (Pl. 1, figs. 6 & 7)

Altogether 12 specimens have been assigned to this species. Those are indistinguishable from *Banksisporites sinuosus* described from the Harai locality of Tiki Formation.

Genus - *Verrutriletes* Van der Hammen ex Potonie[1] 1956

Verrutriletes carbunculus (Dijkstra) Potonié 1956 (Pl. 2, fig. 1)

In all available features six specimens from Giar resemble those of *Verrutriletes carbunculus* described from the Bijouri locality of Tiki Formation. However, the verrucae in the present specimens are little larger than the Bijouri specimens.

Genus - *Bacutriletes* (Van der Hammen) Potonié 1956

Bacutriletes sp. cf. B. *tylotus* (Harris) Potonié 1956 (Pl. 2, figs. 2 & 3)

Description: Megaspores trilete, *amb* ± cricular (equatorial diameter 350-400 μm in dry state and 390-460 μm in wet condition); trilete rays distinct, ± straight, laesurae sometimes open; contact faces indistinct, arcuate rims absent; exosporium covered with closely placed baculae with rounded apices (baculae 12-20 μm long in dry state), mesosporium indistinct.

Remarks: Four specimens in the present collection resemble *Bacutriletes tylotus* described from the Upper Triassic of Greenland (Harris, 1935). But the baculae of the Giar specimens have rounded apices, whereas, in *B. tylotus* those are with truncated ends.

Genus – *Horstisporites* Potonié 1956

Horstisporites foveolatus sp. nov. (Pl. 3, figs. 4-6; Text-Figure 2 I & J)

Diagnosis: Megaspores trilete, subcircular in polar view, equatorial diameter 350-365 μm in dry state and 415-450 μm in wet condition; trilete rays well developed (in dry state ±15 μm high as well as wide), laesurae little wavy, extending upto ±2/3 of the spore radius; contact areas indistinct, arcuate rims absent; exosporium reticulate, muri blunt at top, lumina polygonal, each lumen with a central pit (2-4μm wide in dry state); mesosporium indistinguishable. The specific name refers to the foveolate nature of the exosporium.

Holotype: SEM Stub No. BU 11/7.

Locality: East bank of Son River, about 150 m north-west of Giar Village.

Horizon & Age: Tiki Formation; Upper Triassic.

Comparison & Remarks: The present species can readily be distinguished from other known species of

Horstisporites by its characteristic foveolate nature of the exosprium. *H. foveolatus*, represented by only two well preserved specimens in the present collection, is rather uncommon at Giar.

Genus - *Hughesisporites* Potonié 1956

Hughesisporites singhii Banerji et al. 1984 (Pl. 2, fig. 8)

Description: Six specimens in the Giar assemblage are very closely comparable with *Hughesisporites singhii* described from the Harai and Bijouri localities of Tiki Formation. The present specimens are comparatively smaller in size than that of Harai and Bijouri specimens.

Genus - *Minerisporites* Potonié 1956

Minerisporites variabilis sp. nov. (Pl. 2, figs. 10 & 11; Text-Figure 2K)

Diagnosis: Megaspores trilete, zonate, subtriangular in polar view (equatorial diameter 250-310 μm in dry state and 300-400μm in wet condition); trilete rays distinct, low, ± straight, extending upto the margin of the zona; zona equatorial, more or less equally wide (±35μm in dry state) all round the spore, slightly raised at the ray ends; exosporium microreticulate, lumina polygonal (4-6 μm wide in dry state), contact faces devoid of reticulation and almost smooth; mesosporium indistinct.

Holotype: SEM Stub No. BU 11/6.

Locality: East bank of Son River, about 150 m north-west of Giar Village.

Horizon & Age: Tiki Formation; Upper Triassic.

Comparison & Remarks: In having an indistinct mesosporium the present species resembles *Minerisporites mineri* (Dev) Banerji et al. (1984) and *M. reticulatus* (Singh, Srivastava & Roy) Banerji et al. (1984). But the present species differs from the latter two species in having microreticulate exosporium and smooth contact faces. *Minerisporites variabilis* is rather a frequently occuring species in the present assemblage being represented by 12 specimens.

Derivation of species name: The species name is after the variations in the exosporium ornamentation.

Genus - *Erlansonisporites* Potonié 1956

Erlansonisporites triassicus Banerji et al. 1978 (Pl. 2, fig. 14)

Description: Five specimens are assignable to *Erlansonisporites triassicus* Banerji et al. This species has earlier been described in the present work from the Harai locality of Tiki Formation. However, the present specimens are comparatively smaller in size.

Genus - *Nathorstisporites* Jung 1958

Nathorstisporites hopliticus Jung 1958 (Pl. 3, fig. 3)

Description: The present specimens are similar to *Nathorstisporites hopliticus* Jung described previously from the Harai and Bijouri localities of Tiki Formation. This species is rather common in the Giar locality and is being represented by 11 specimens.

Genus - *Aneuletes* Harris 1961

Aneuletes psilatus sp. nov. (Pl. 3, figs. 7 & 8; Text-Figure 2L)

Diagnosis: Alete megaspores, subcircular to oval in outline, varying in diameter from 835-900 μm in dry state and 1050-1100 μm in wet condition; exosporium smooth, often folded; mesosporium indistinct.

Derivation of species name: The specific name refers to the smooth nature of exosporium.

Holotype: SEM Stub No. BU 11/8.

Locality: East bank of Son River, about 150 m north-west of Giar Village.

Horizon & Age: Tiki Formation; Upper Triassic.

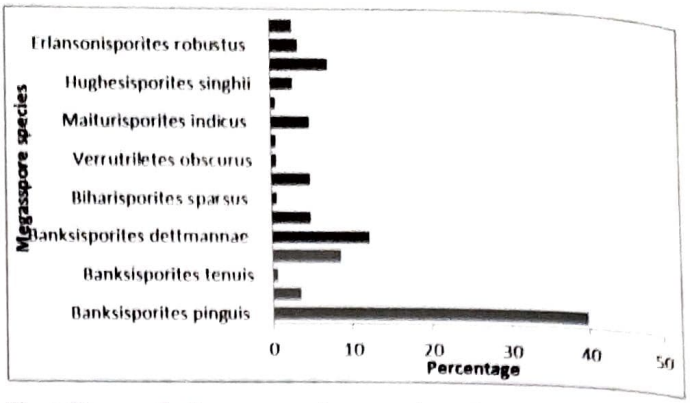
Comparison & Remarks: Aneuletes psilatus sp. nov. differs from *A. petera* described by Harris (1961) from Yorkshire Jurassic in having a smooth exosporium without pits and bulgings. *Aneuletes* sp. described from the Pali Formation in the present contribution is distinguishable by the possession of distinct microreticulate-rugulate sculpture of exosporium. This type of spores are rare in the present assemblage and are represented by only two specimens.

Quantitative Analysis of the Assemblage Recovered from the Harai Locality of Janar River Section:

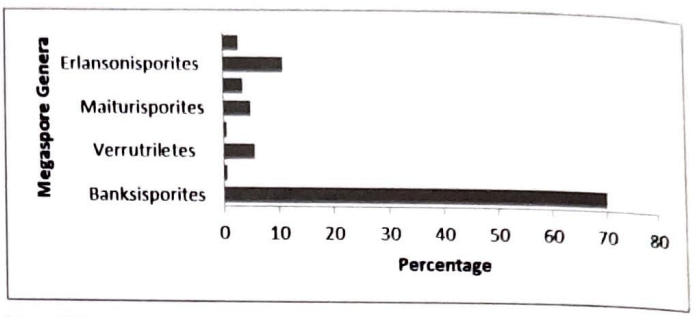
During the present work most of the species previously described from Harai by Banerji et al. (1978)

have been met with in addition to some species which were hitherto unknown from this locality. However, a few previously reported forms are totally absent in the present collection. Those are *Banksisporites tenuis*, *Verrutriletes obscurus*, *Bacutriletes* sp. and *Hughesisporites variabilis*. In all probablities, these species occur with extremely low frequencies. Banerji et al. (1978) mentioned that each of *Banksisporites tenuis* and *Bacutriletes sp.* is represented by solitary specimen but the specimen numbers of other two missing taxa have not been mentioned by them. In the present assemblage the minimum frequency of occurrence is of *Biharisporites sparsus* which is represented by solitary specimen. While making the quantitative analysis it has been presumed that the minimum frequency for the species which were described by Banerji et al. (1978) but are missing in the present assemblage. In course of the present investigation 134 specimens have been collected and four are added for the above species making the total number of specimens 138 for calculating the frequency distribution of the taxa. The overall assemblage is dominated by *Banksisporites pinguis* (39.9%) followed by *B. dettmannae* (12.3%), B. *panchetensis* (8.7%), *Erlansonisporites triassicus* (7.3%), *Maiturisporites indicus* (5.0%), *Verrutriletes minuticorpus* (5.0%), *Banksisoorites janarensis* (5.0%), *B. sinuosus* (3.6%), *Erlansonisporites robustus* (3.6%), *Nathorstisporites hopiiticus* (2.9%) and *Hughesisporites singhii* (2.9%), *Banksisporites tenuis* (0.7%), *Biharisporites sparsus* (0.7%), *Bacutriletes* sp. (0.7%), *Verrutriletes obscurus* (0.7%) and *Hughesisporites variabilis* (0.7%) are extremely rare in the present assemblage (Text-Figure 3).

At generic level (Text-Figure 4) *Banksisporites* (70.2%) is the most predominant. *Erlansonisporites* (10.9%) is quite common in occurrence. *Verrutriletes* (5.7%) and *Maiturisporites* (5.0%) are frequently occurring elements. *Hughesisporites* (3.6%) and *Nathorstisporites* (2.9%) are found in considerable frequency, whereas, *Biharisporites* (0.7%) is rarely met with.



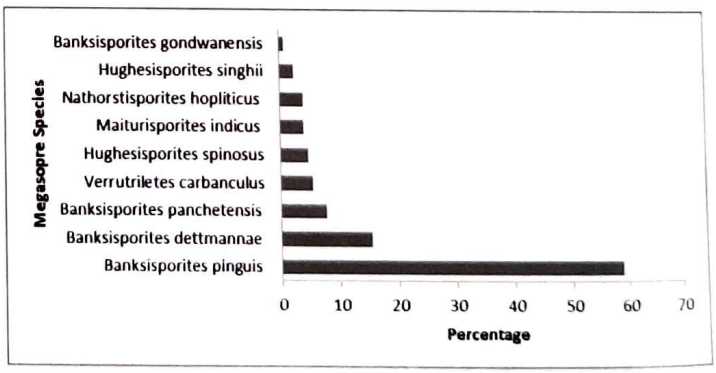
Text-Figure 3. Percentage frequencies of megaspore species recovered from Harai locality.



Text-Figure 4. Percentage frequencies of megaspore genera recovered from Harai locality.

Quantitative Analysis of the Assemblage Recovered from the Bijouri Locality of Janar River Section:

The megaspore assemblage is dominated by *Banksisporites pinguis* (55.8%) followed by *B. dettmannae* (15.5%), *B. panchetensis* (7.8%), *Verrutriletes carbunculus* (5.4%), *Hughesisporites spinosus* (4.7%), *Maiturisporites indicus* (3.9%), *Nathorstisporites hopliticus* (3.9%) and *Hughesisporites singhii* (2.3%). *Banksisporites gondwanensis* (0.8%) is extremely rare in this assemblage (Text-Figure 5). At generic level (Text-

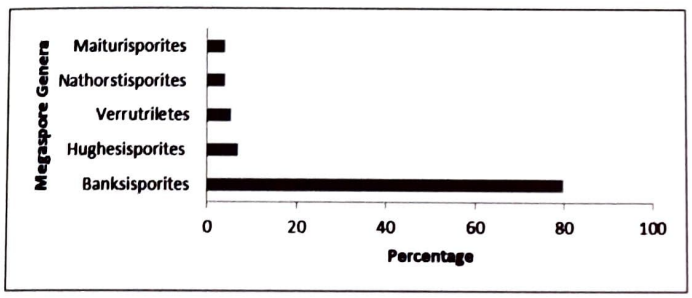


Text-Figure 5. Percentage frequencies of megaspore species recovered from Bijouri locality.

Figure 6) *Banksisporites* (79.9%) is the most preponderant form in association with *Hughesisporites* (7.0%), *Verrutriletes* (5.4%),*Nathorstisporites* (3.9%) and *Maiturisporites* (3.9%).

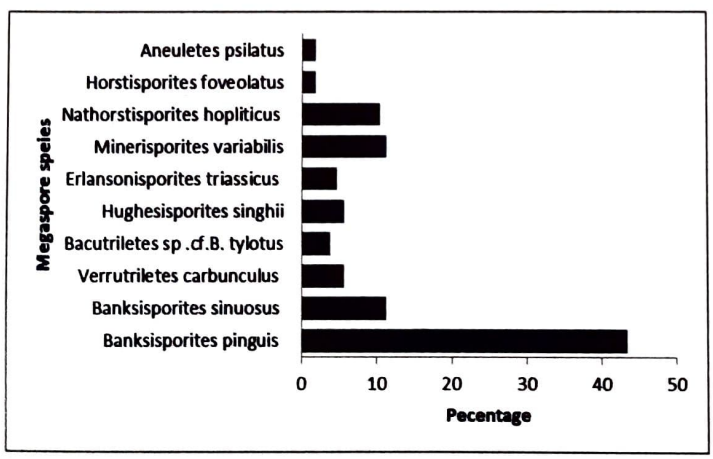
Quantitative Analysis of the Assemblage Recovered from The Giar Locality of Son River Section:

The megaspore assemblage recovered from the Giar plant beds is found to be dominated by *Banksisporites pinguis* (43.4%). *Banksisporites sinuosus* (11.3%), *Minerisporites variabilis* (11.3%) and *Nathorstisporites hopliticus* (10.4%) are commonly occuring elements. *Verrutriletes*

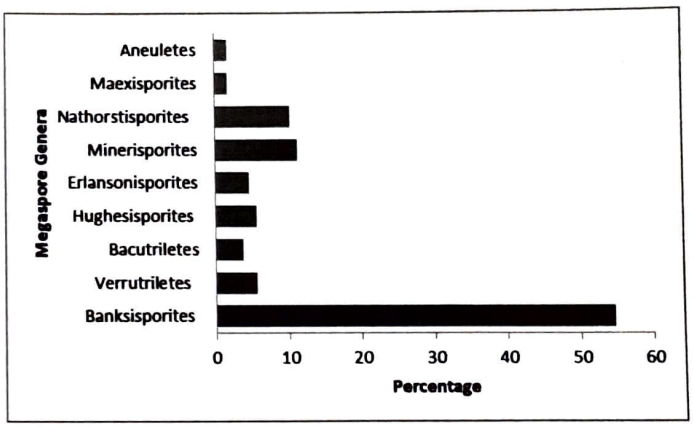


Text-Figure 6. Percentage frequencies of megaspore genera recovered from Bijouri locality.

carbunculus (5.7%), *Hughesisporites singhii* (5.7%), *Erlansonisporites triassicus* (4.7%) and *Bacutriletes* sp. cf. B. *tylotus* (3.8%) are found with more or less low frequency (Text-Figure 7). *Horstisporites foveolatus* (1.8%) and *Aneuletes psilatus* (1.8%) are rather rare in occurrence. Percentage frequencies at generic level (Text-Figure 8) shows that the genus *Banksisporites* (54.7%) is overwhelmingly dominant



Text-Figure 7. Percentage frequencies of megaspore species recovered from Giar locality.



Text-Figure 8. Percentage frequencies of megaspore genera recovered from Giar locality.

in the assemblage followed by *Minerisporites* (11.3%) and *Nathorstisporites* (10.4%).

DISCUSSION

The megaspore assemblage recovered from the Harai Locality of Tiki Formation exposed on the east bank of Janar River near Harai village comprises *Banksisporites pinguis* (Harris) Dettmann, *B. dettmannae* Banerji et al., *B. sinuosus* Dettmann, *B. panchetensis* (Maheshwari & Banerji) Banerji et al., *B. tenuis* (Dijkstra) Dettmann, *B. janarensis* (Banerji et al.) comb. nov., *Biharisporites sparsus* Banerji et al., *Verrutriletes minuticorpus* Banerji et al., *V. obscurus* Banerji et al., *Bacutriletes* sp., *Maiturisporites indicus* Maheshwari & Banerji, *Erlansonisporites triassicus* Banerji et al., *E. robustus* sp. nov., *Hughesisporites variabilis* Dettmann, *H. singhii* Banerji et al. and *Nathorstisporites hopliticus* Jung. Out of those, *Hughesisporites singhii* and *Erlansonisporites robustus* are described for the first time. Samples from Bijouri locality, exposed on the north bank of Janar River near Bijouri Village yielded a megaspore assemblage comprising *Banksisporites pinguis* (Harris) Dettmann, *B. dettmannae* Banerji et al., *B. panchetensis* (Maheshwari & Banerji) Banerji et al., *B. Gondwanensis* Maheshwari & Banerji, *Verrutriletes carbunculus* (Dijkstra) Potonie, *Maiturisporites indicus* Maheshwari & Banerji, *Hughesisporites singhii* Banerji, Jana & Maheshwari, *H. Spinosus* sp. nov. and *Nathorstisporites hopliticus* Jung. Both qualitatively and quantitatively the above two assemblages are closely related. In fact, all the genera

are common in both the localities, except *Erlansonisporites* and *Bacutriletes*. The species diversity was more in Harai locality than Bijouri. Both are dominated by *Banksisporites*. But the absence of the genus *Biharisporites* as well as the presence of *Verrutriletes carbunculus* in the Bijouri locality possibly indicates a little younger aspect than the Harai locality. Pant and Basu (1979b) published a Middle Triassic megaspore assemblage exposed on the bank of Gopad River near Nidpur Village, Sidhi District, Madhya Pradesh, India. The assemblage is characterised by *Banksisporites triassicus* (= *Srivastavisporites triassicus)* Pant & Basu, *Banksisporites major* (= *Srivastavisporites major*) Pant & Basu, *Grambastisporites nidpurensis* Pant & Basu, *Trikonia emarginata* Pant & Basu, *Mamillaespora sidhiensis* Pant & Basu, *Lagenicula spinosa* (= *Nidhitriletes spinosa)* Pant & Basu. Out of those only the genus *Banksisporites* is common to the present assemblage. However, the species of the genus in the two assemblages are different. In fact, all the species described from the Nidpur were new and none of them has later been recorded elsewhere. Moreover, the presence of characteristic Upper Triassic megaspores viz., *Banksisporites pinguis, B. sinuosus, Bacutriletes* sp., *Erlansonisporites triassicus, E. robustus, Hughesisporites variabilis, H. singhii, H. spinosus, Verrutriletes carbunculus* and *Nathorstisporites hopliticus*, reveals that the present assemblage is younger than Nidpur beds. On the basis of megaspore composition, the age of the outcrops of Harai and Bijouri localities appears to be Upper Triassic. Pal (1984) also suggested an Upper Triassic age for these outcrops based on megafloral evidences.

Megaspore assemblage recovered from the Giar locality of Tiki Formation is represented by *Banksisporites pinguis* (Harris) Dettmann, *B. sinuosus* Dettmann, *Verrutriletes carbunculus* (Dijkstra) Potonie, *Bacutriletes* sp. cf. *B. tylotus* (Harris) Potonie, *Erlansonisporites triassicus* Banerji et al., *Hughesisporites singhii* Banerji et al., *Minerisporites variabilis* sp. nov., *Nathorstisporites hopliticus* Jung, *Maexisporites giarensis* sp. nov. and *Aneuletes psilatus* sp. nov. The megaspore assemblage closely resembles the underlying Harai and Bijouri assemblages. The common genera between them are *Banksisporites, Verrutriletes, Bacutriletes, Hughesisporites, Erlansonisporites* and *Nathorstisporites*. Quantitatively, all the three assemblages from Tiki Formation are dominated by *Banksisporites pinguis*. But the presence of *Horstisporites* and *Minerisporites* in the Giar assemblage clearly indicates an younger aspect. The genera *Horstisporites* and *Minerisporites* occur abundantly in the Lower Cretaceous beds of Bhuj, Jabalpur and Athgarh formations (Banerji et al. 1984; Dev 1961; Jana and Ghosh 1997). Moreover, the total absence of the genus *Maiturisporites* as well as the relative abundance of *Banksisporites sinuosus, Hughesisporites singhii* and *Nathorstisporites hopliticus* at Giar indicates an younger age for the outcrop of Giar locality than the outcrops at Harai and Bijouri. The presently recovered megaspore assemblage also suggests an Upper Triassic age for the outcrop at Giar locality and corroborates with the megafloral evidences of Pal (1984a).

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