

Permian Gondwana megaspores from Wardha Basin, India

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ABSTRACT

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A rich megaspore assemblage has been recorded from the Early Permian Barakar Formation of Umrer Coalfield, Wardha Basin. The assemblage is represented by nine genera and thirteen species: *Bokarosporites rotundus*, *Banksisporites indicus*, *B. utkalensis*, *Duosporites congoensis*, *D. irregularis*, *Duosporites* sp., *Barakarella pantii*, *Talchirella trivedii*, *Jhariatriletes baculosus*, two new species—*Biharisporites umrerensis* and *B. waigaoensis* besides the taxa *Lagenosporites* sp. and *Setosisporites hirsutus*. The last two are reported for the first time from India. Preponderance of trilete and gulate megaspores indicates a dominance of Cryptogams and an association of gulate forms, in particular, suggests lycopsid affinity. The assemblage indicates prevalence of marshy and humid environmental conditions of deposition.

Key-words—Megaspores, Early Permian, Barakar Formation, Wardha Basin, India.

भारत के वर्धा द्रोणी से प्राप्त परमियन गोंडवाना गुरुबीजाणु

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सारांश

वर्धा द्रोणी के उमरेर कोयला क्षेत्र के प्रारंभिक परमियन बराकार शैलसमूह से प्राप्त एक प्रचुर गुरुबीजाणु समुच्चय अंकित किया गया है। इस समुच्चय को नौ वंशों तथा तेरह प्रजातियों जैसे—*बोकारोस्पोराइटीज रोटंडस*, *बैंकसीस्पोराइटीज इंडिकस*, *बी. उत्कलेन्सिस*, *डुओस्पोराइटीज कोंगोएन्सिस*, *डी. इरेगुलेरिज*, *डुओस्पोराइटीज* प्रजाति, *बराकारेला पन्तई*, *तालचीरेला त्रिवेदीयाई* तथा *झरियाट्राइलिटिज बेकुलोसस* के द्वारा निरूपित किया गया है। *लजेनोस्पोराइटीज* प्रजाति एवं *सीटोसीस्पोराइटीज हीरसुटस* के आलावा दो नयी प्रजातियों *बिहारीस्पोराइटीज उमरेन्सिस* तथा *बी. वायगाऊएन्सिस* को भी निरूपित किया गया है। *लजेनोस्पोराइटीज* एवं *सीटोसीस्पोराइटीज* प्रजातियों को भारत से प्रथम बार अभिलिखित किया गया है। त्रिअरीय तथा गुलेट गुरुबीजाणु की प्रचुरता क्रिप्टोगेम्स की प्रमुखता दर्शाता है और खासकर गुलेट रूप का साहचर्य लाइकोप्सिड की बंधुता को प्रदर्शित करता है। यह समुच्चय निक्षेपण की दलदली एवं आर्द्र पर्यावरणीय दशाओं की व्यापकता का संकेत करता है।

संकेत शब्द—गुरुबीजाणु, प्रारंभिक परमियन, बराकार शैलसमूह, वर्धा द्रोणी, भारत।

INTRODUCTION

THE Gondwana Sequence of India is known for its rich plant fossils: palynomorphs, leaves, fructifications, woods, roots and seeds (Lakhanpal *et al.*, 1976; Chandra &

Tewari, 1991; Tewari, 1991; Bajpai & Singh, 1994; Rajanikanth & Prakash, 1994).

Permian megaspores in India have been studied from different sedimentary basins in detail by Surange *et al.* (1953) and later by Bharadwaj & Tiwari (1970), Lele &

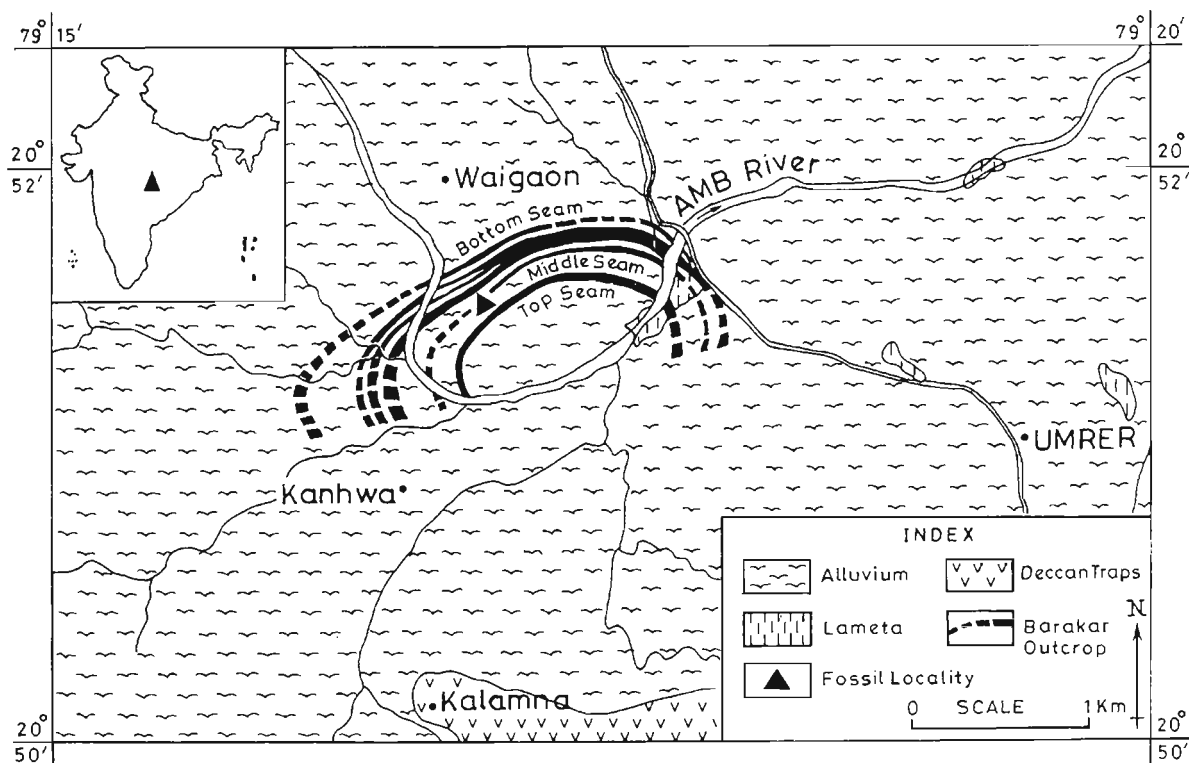


Fig. 1—Geological map of a part of Umrer Coalfield showing site of sample collection (after Raja Rao, 1982).

Srivastava (1983), Pant & Mishra (1986) and Tewari & Maheshwari (1992).

Also, during that period, studies on Permian megaspores were carried out in South America, Australia and South Africa (Trindade, 1954, 1959a, b, 1966; Trindade & Sommer, 1966; Dijkstra, 1955, 1971, 1972; Høeg *et al.*, 1955; Høeg & Bose, 1960; Pant & Srivastava, 1962; Piérart, 1959, 1975, 1978a, b; Piérart & Dijkstra, 1961). Further, such studies have gained

momentum in the last two decades and new megaspores are reported from South America (Arai & Rösler, 1980, 1984), Antarctica (McLoughlin, 2000), Australia (Glasspool, 2000, 2003a, b), South Africa (Glasspool, 2003b) and India (Agashe, 1979; Jha & Srivastava, 1984; Maheshwari & Tewari, 1989; Tewari, 1991; Tewari & Maheshwari, 1992; Tripathi, 1997, 1998a, b, 1999; Tripathi & Mishra, 1997, 2001; Patil & Premchand, 2001; Srivastava & Tewari, 2001, 2002; Jha & Tewari, 2003).

PLATE 1

1. *Bokarosporites rotundus*—Megaspore in wet condition showing smooth exosporium and mesosporium. BSIP Slide No. 12878. x 50.
2. *Banksisporites ukalensis*—Megaspore in wet condition showing granulate exosporium. BSIP Slide No. 12880. x 60.
3. *B. indicus*—Megaspore in wet condition showing granulate exosporium and mesosporium with dark contents. BSIP Slide No. 12882. x 70.
4. *Barakarella pantii*—Megaspore in wet condition showing baculate exosporium and mesosporium with numerous cushions. BSIP Slide No. 12887. x 70.
5. *Talchirella trivedii*—Megaspore in wet condition showing verrucate exosporium and mesosporium with numerous cushions. BSIP Slide No. 12885. x 70.
6. *Duosporites congoensis*—Megaspore in wet condition showing torn exosporium and mesosporium with biserially arranged cushions. BSIP Slide No. 12883a. x 50.
7. *Bokarosporites rotundus*—Megaspore in dry condition showing scabrate exosporium. x 85.
8. *Banksisporites ukalensis*—Megaspore in dry condition showing granulate exosporium. x 80.
9. *Bokarosporites rotundus*—Another megaspore in wet condition showing smooth exosporium and mesosporium. BSIP Slide No. 12879. x 50.
10. *Duosporites congoensis*—Triangular megaspore in dry condition. x 80.
11. *Duosporites congoensis*—Mesosporium enlarged to show cushions. BSIP Slide No. 12883a. x 150.
12. *Talchirella trivedii*—Megaspore in dry condition showing verrucate exosporium. x 80.

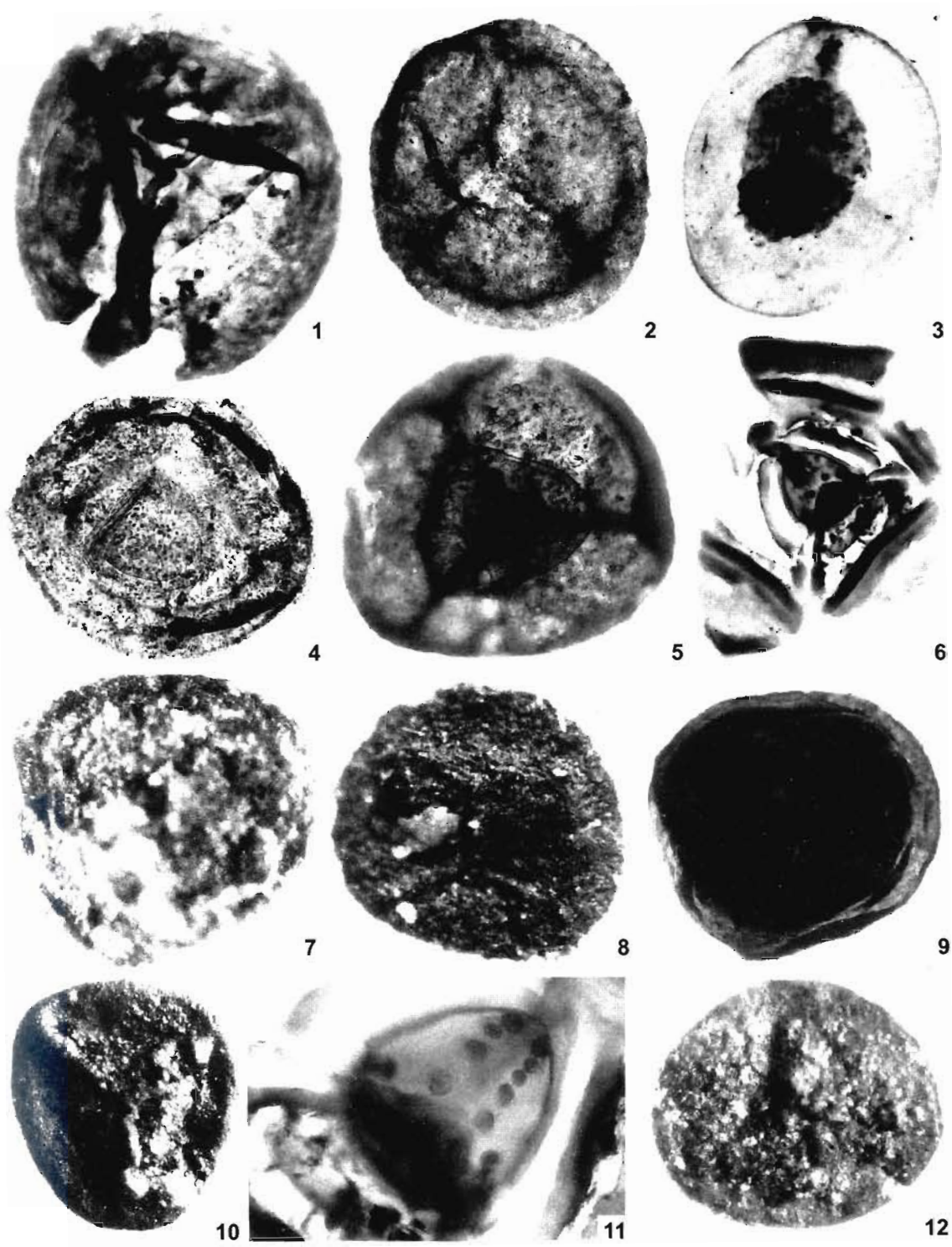


PLATE 1

The Indian Permian Gondwana megaspores are known from all the formations, viz., Talchir, Karharbari, Barakar, Barren Measures/ Kulti and Raniganj (Maheshwari & Tewari, 1988).

Prior to this work, Permian megaspores were reported from the Umrer Coalfield by Agashe (1979). In the present paper, additional taxa have been systematically described. The assemblage consists of 13 species belonging to 9 genera, viz., *Bokarsporites rotundus*, *Banksisporites indicus*, *B. utkalensis*, *Duosporites congoensis*, *D. irregularis*, *Duosporites* sp., *Barakarella pantii*, *Talchirella trivedii*, *Jhariatrilletes baculosus*, *Biharisporites umrerensis* sp. nov., *B. waigaonensis* sp. nov., *Lagenoisporites* sp. and *Setosisporites hirsutus* indicating diversity and richness of megaspores in Umrer Coalfield. This is the first report of these taxa from the area. Of these, two are new species and the taxa *Lagenoisporites* sp. and *Setosisporites hirsutus* are reported for the first time from India.

MATERIAL AND METHOD

The present megaspore assemblage has been recovered from carbonaceous shales of the Middle Seam, Umrer open cast project, Umrer Coalfield, Nagpur District, Maharashtra (Fig. 1). Samples were treated with conc. hydrofluoric acid for 5 to 10 days and then washed thoroughly with water. The specimens were then picked under low power binocular microscope, dried, measured and photographed for exosporium features like, the shape, the nature of tri-radiate mark and the contact ridges and ornamentation. Each specimen was then treated with conc. nitric acid and a pinch of potassium chlorate for one day and then with 5% potassium hydroxide. Differential controlled maceration in conc. HNO₃ and KOH revealed the mesosporium. Each specimen was again measured and photographed at this (wet/macerated) stage under transmitted light using a high power objective for details of ornamentation and mesosporium. The slides were finally mounted in canada balsam.

All the slides have been deposited at the repository of BSIP Museum.

GEOLOGY

The Gondwana succession in Indian subcontinent is characterised by mostly non marine deposits stretching through the peninsular region. The coal strata in the Wardha Valley are grouped into four areas viz., Kamptee, Umrer, Bandar and Wardha Valley coalfields. The present investigation is based on the samples collected from the Barakar Formation of Umrer OCP, Umrer Coalfield near the village Waigaon (Fig. 1). The coalfield is situated about 44 km south-west of Nagpur, Maharashtra in central India. It covers an area of about 5 sq km lying between latitudes 20°50'45" N and 20°52'50" N and longitudes 79°16' E and 79°18' 30" E. The coal bearing area lies on the west of Umrer Town and is covered by thick black-cotton-soil with sporadic occurrence of a few out crops of Lameta Formation. The stratigraphical sequence of the area is as follows (after Raja Rao, 1982):

Age	Formation	Lithology
Recent	—	Black soil migratory and derived
Cretaceous	Lameta	Limestones and sandstones
		Unconformity
Early Triassic	Kamthi	Reddish-brown sandstones, yellowish and brown shales
		Unconformity
	Barakar	Coarse-grained sandstones, carbonaceous shales (spore/pollen rich) and coal seams
Early Permian	Talchir	Greenish shales with occasional bands of sandstones
		Unconformity
Archaean	Metamorphics	Schists and phyllites

The total thickness of Barakar Formation is estimated to be about 200 m. Three different distinctive units have been recognized within this formation—Top, arenaceous section;

PLATE 2

1. *Duosporites irregularis*—Megaspore in dry condition showing verrucate exosporium and triradiate ridges extending beyond contact area. x 100.
2. *Duosporites irregularis*—Megaspore in wet condition showing folded mesosporium with cushions. BSIP Slide No. 12883b. x 64.
3. *Talchirella trivedii*—Megaspore in dry condition showing verrucate exosporium. x 90.
4. *Jhariatrilletes baculosus*—Megaspore in dry condition. x 97
5. *Talchirella trivedii*—Megaspore in wet condition showing circular mesosporium with numerous cushions. BSIP Slide No. 12886. x 60.
6. *Duosporites irregularis*—Mesosporium enlarged to show irregularly arranged cushions. BSIP Slide No. 12883b. x 100.
7. *Barakarella pantii*—Megaspore in dry condition showing baculate exosporium. x 85.
8. *Duosporites* sp.—Megaspore in dry condition showing verrucate exosporium. x 74
9. *Duosporites* sp.—Megaspore in wet condition showing verrucate exosporium and triangular mesosporium, cushions not clear. BSIP Slide No. 12884. x 60.
10. *Banksisporites indicus*—Megaspore in wet condition showing mesosporium with dark contents. BSIP Slide No. 12881. x 55.
11. *Barakarella pantii*—Megaspore in wet condition. BSIP Slide No. 12888. x 100.
12. *Jhariatrilletes baculosus*—Megaspore in wet condition. BSIP Slide No. 12882b. x 100.
13. *Jhariatrilletes baculosus*—A portion of megaspore in dry condition showing baculate exosporium. x 200.

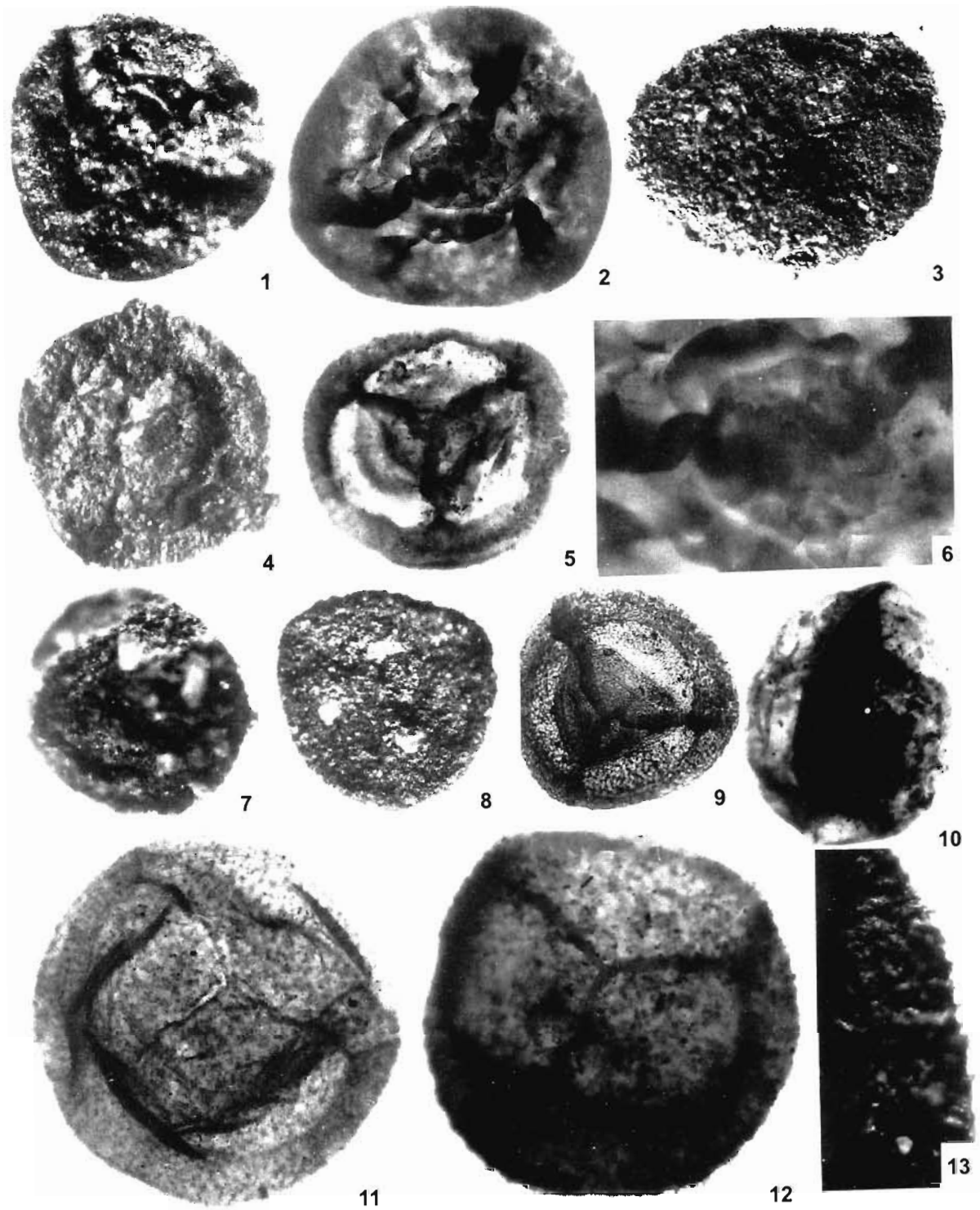


PLATE 2

Middle, carbonaceous section and Bottom, arenaceous/argillaceous section. The samples yielding megaspores belong to the middle carbonaceous section characterised by shale and sandstones partings. This section is about 70 m in thickness including 30-40 m of coal. Carbonaceous shales also showing equisetalean stem impressions yielded abundant megaspores.

SYSTEMATICS

Genus—**BOKAROSPORITES** Bharadwaj & Tiwari, 1970

Type species—**BOKAROSPORITES PSILATUS** Bharadwaj & Tiwari, 1970

BOKAROSPORITES ROTUNDUS Bharadwaj & Tiwari, 1970

(Pl. 1.1, 7, 9)

Description—Megaspores trilete, azonate, circular to subcircular in proximo-distal orientation; tri-radiate ridges well marked, arcuate ridges not clear; exosporium laevigate; differential maceration in conc. HNO_3 and KOH reveals thin, transparent, spherical mesosporium, almost $\frac{3}{4}$ of the spore diameter, devoid of cushions.

Dimensions—In (a) dry condition—overall size 550-900 x 500-900 μm , size of tri-radiate ridges 250-260 x 15-20 μm , (b) wet condition—overall size 840-1200 x 930-1200 μm , size of tri-radiate ridges 360-540 x 32-45 μm , size of mesosporium 630-900 x 600-840 μm .

Remarks—Megaspores are comparable with *Bokarosporites rotundus* (Bharadwaj & Tiwari, 1970, pl. 1, figs 9-10, 14) in shape, nature of exosporium and mesosporium which is usually transparent in this species. However, one of the specimens (Pl. 1. 9) has a dark mesosporium, yet it has been included here in this species because of its laevigate exosporium and absence of cushions in mesosporium.

Genus—**BANKSISPORITES** Dettmann 1961 emend. Banerji *et al.*, 1978

Type species—**BANKSISPORITES PINGUIS** (Harris) Dettmann, 1961

BANKSISPORITES UTKALENSIS (Pant & Srivastava) Tewari & Maheshwari, 1992

(Pl. 1.2, 8)

Description—Megaspores trilete, azonate, circular to subcircular in proximo-distal orientation, tri-radiate ridges straight to wavy, $\frac{3}{4}$ spore radius long in dry condition, more than $\frac{3}{4}$ spore radius long in wet condition, tapering toward ends where bounded by distinct arcuate ridges; exosporium verrucate, verrucae uniformly distributed; differential maceration in conc. HNO_3 and KOH reveals thin, transparent spherical, smooth mesosporium, sometimes folded, $\frac{3}{4}$ spore radius in extension, devoid of cushions.

Dimensions—In (a) dry condition—overall size 500-550 x 500-600 μm , size of tri-radiate ridges 150-300 x 20-30 μm , width of arcuate ridges 20 μm , size of verrucae 5-10 μm , (b) wet condition—overall size 680-900 x 700-840 μm , size of tri-radiate ridges 200-300 x 20-30 μm , width of arcuate ridges 30-60 μm , size of verrucae 5-10 μm , size of mesosporium 300-450 x 320-600 μm .

Comparison—Megaspores are comparable in shape, nature of exosporium and mesosporium with *Banksisporites utkalensis* (Tewari & Maheshwari, 1992, pl. 2, fig. 7; pl. 6, figs 1, 7).

BANKSISPORITES INDICUS (Singh) Tewari & Maheshwari, 1992

(Pl. 1.3, Pl. 2.10)

Description—Megaspores trilete, azonate, circular to subcircular in proximo-distal orientation; tri-radiate ridges straight, $\frac{3}{4}$ of the spore radius, ending up at distinct arcuate ridges; exosporium granulate in dry condition, grana, tri-radiate and arcuate ridges dissolve during maceration; differential maceration in conc. HNO_3 and KOH reveals subspherical mesosporium, filled with dark brown contents, devoid of cushions, folded in one of the megaspores (Pl. 2.10).

Dimensions—In (a) dry condition—overall size 500-550 x 600-650 μm , size of tri-radiate ridges 150-180 x 20 μm , width of arcuate ridges 20 μm , size of grana 2-2.5 x 1-2 μm , (b) wet condition—overall size 650-700 x 500-550 μm , 200-300 x 20-30 μm , size of mesosporium 250-300 x 250-450 μm .

PLATE 3

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| <p>1. <i>Biharisporites umrerensis</i> sp. nov.—Megaspore in dry condition. x 90.</p> <p>2. <i>Biharisporites umrerensis</i> sp. nov.—A portion of megaspore in wet condition showing coni on margin. BSIP Slide No. 12889. x 300.</p> <p>3. <i>Biharisporites umrerensis</i> sp. nov.—Holotype in wet condition, showing connate exosporium and triangular mesosporium. BSIP Slide No. 12889. x 127</p> <p>4. <i>Biharisporites waigaonensis</i> sp. nov.—Megaspore in wet con-</p> | <p>dition, showing subcircular exosporium and mesosporium. BSIP Slide No. 12890. x 91</p> <p>5, 7. <i>Biharisporites waigaonensis</i> sp. nov.—Portion of megaspores enlarged to show appendages. BSIP Slide No. 12890. 5. x 222, 7. x 666.</p> <p>6. <i>Biharisporites umrerensis</i> sp. nov.—Mesosporium enlarged. BSIP Slide No. 12889. x 230.</p> <p>8. <i>Biharisporites waigaonensis</i> sp. nov.—Holotype in dry condition. x 100.</p> |
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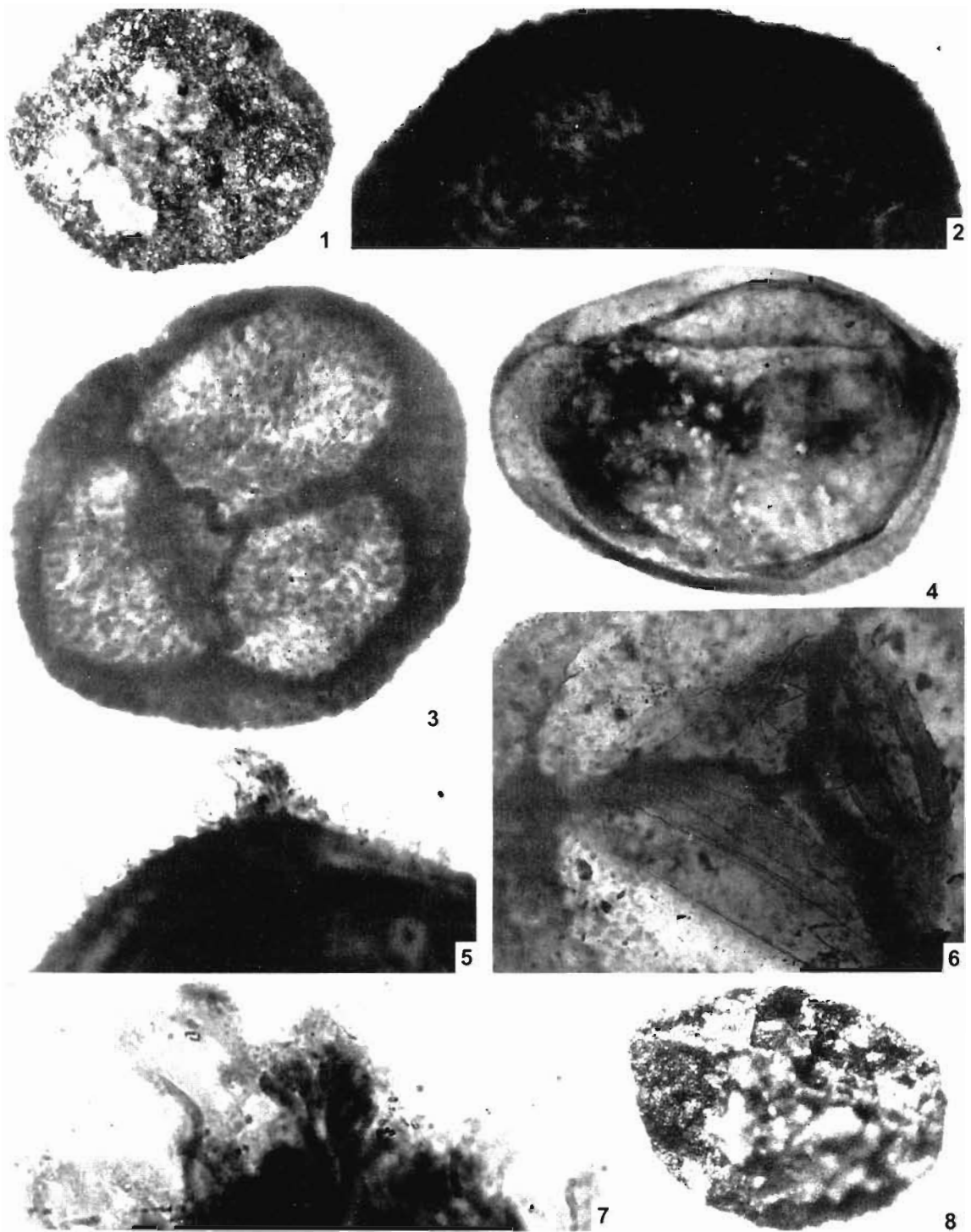


PLATE 3

Comparison—In presence of granulate exosporium and mesosporium the present megaspores resemble *Banksisporites indicus* (in Bharadwaj & Tiwari, 1970, pl. 3, figs 15, 16).

BANKSISPORITES SAHNII (Tripathi, 1997) comb. nov.

1997: *Srivastavaesporites sahnii* Tripathi, Journal of Palynology 33: 219-225. figs 1-6.

Holotype—Tripathi, 1997, pl. 1. fig. 1, Sl. No. 282, Palaeobotany Research Laboratory, Department of Botany, Govt. Autonomous College of Science, Rewa, Madhya Pradesh, India.

Locality—Chapha Colliery, Umaria Coalfield, Madhya Pradesh, India.

Horizon—Lower Gondwana (Lower Permian of India).

Remarks—The genus *Srivastavaesporites* Bharadwaj & Tiwari 1970, has already been merged with the genus *Banksisporites* Dettmann 1961 by Banerji *et al.* (1978) on the basis of similarity of morphological characters. Therefore, a new combination for the species *Srivastavaesporites sahnii* Tripathi 1997, viz., *Banksisporites sahnii* is proposed here.

Genus—**DUOSPORITES** Høeg *et al.*, 1955 emend. Bharadwaj & Tiwari, 1970

Type species—**DUOSPORITES CONGOENSIS** Høeg *et al.*, 1955

DUOSPORITES CONGOENSIS Høeg, *et al.*, 1955
(Pl. 1.6, 10, 11)

Description—Megaspore trilete, azonate, triangular in proximo-distal orientation, tri-radiate ridges straight to sinuous, more than $3/4$ spore radius long, narrow at tri-junction, broad at ends in wet condition, extending beyond arcuate area almost up to the margin, arcuate ridges distinct; exosporium verrucate, verrucae uniformly distributed; differential maceration in conc. HNO_3 and KOH tears exosporium, dissolves verrucae and reveals triangular, transparent mesosporium with few cushions arranged biserially along tri-radiate mark.

Dimensions—In (a) dry condition—overall size 500 x 500 μm , size of tri-radiate ridges 240-250 x 30-40 μm , width of arcuate

ridges 40 μm , size of verrucae 5 x 5 μm , (b) wet condition—overall size 650 x 700 μm , length of tri-radiate ridges 320-360 μm , width of tri-radiate ridges near tri-junction 40-50 μm , width of tri-radiate ridges near ends 80-90 μm , width of arcuate ridges 40 μm , size of mesosporium 200 x 250 μm , diameter of cushions 15-20 μm .

Comparison—Megaspore is comparable in triangular shape, nature of tri-radiate ridges, exosporium, mesosporium and arrangement of cushions with *Duosporites congoensis* (Høeg *et al.*, 1955, pl. 1, figs 1-3, pl. 2, figs 1-2, 4-5; Bharadwaj & Tiwari, 1970, pl. 12, figs 5, 6; Tewari & Maheshwari, 1992, pl. 3, figs 5, 7).

DUOSPORITES IRREGULARIS Bharadwaj & Tiwari, 1970
(Pl. 2. 1-2, 6)

Description—Megaspore trilete, azonate, subtriangular in proximo-distal orientation; tri-radiate ridges elevated, wavy in dry condition, sinuous in wet condition, extending beyond arcuate area up to the margin, arcuate ridges distinct; exosporium verrucate, verrucae uniformly distributed; differential maceration in conc. HNO_3 and KOH reveals subcircular, folded mesosporium in centre of the spore cavity with few irregularly arranged cushions.

Dimensions—In (a) dry condition—overall size 400 x 400 μm , size of tri-radiate ridges 100-170 x 30 μm , width of arcuate ridges 40 μm , size of verrucae 5-10 x 5-10 μm , (b) wet condition—overall size 810 x 900 μm , size of tri-radiate ridges 360-390 x 60 μm , width of arcuate ridges 30 μm , size of verrucae 30 x 15 μm , size of mesosporium 420 x 420 μm , diameter of cushions 30 x 20 μm .

Comparison—Megaspore compares well with *Duosporites irregularis* (Bharadwaj & Tiwari, 1970, pl. 12, figs 11-17) in shape, nature of tri-radiate ridges, exosporium ornamentation and nature of mesosporium.

DUOSPORITES sp.

(Pl. 2. 8, 9)

Description—Megaspore trilete, azonate, triangular in proximo-distal orientation; tri-radiate ridges straight to wavy, extending beyond arcuate ridges almost up to the margin, arcuate ridges distinct in wet condition; exosporium verrucate,

PLATE 4



1. *Lagenosporites* sp.—Megaspore in dry condition showing gula and laevigate exosporium. x 107.
- 2-11 *Setosisporites hirsutus*—BSIP Slide No. 12891
2. A portion of megaspore in dry condition showing appendages x 120.
3. Megaspore in wet condition. x 66.
4. Megaspore in wet condition showing smooth gula. x 67
5. Remaining part of megaspore showing spinate exosporium. x 64.
6. Megaspore in dry condition showing gula and spinate exosporium. x 79.
7. A portion of megaspore in dry condition enlarged to show spines. x 200.
- 8-11. Portions of megaspore in wet condition enlarged to show simple, bifurcate and trifurcate spines. 8. x 66, 9. x 141, 10. x 111, 11. x 333.

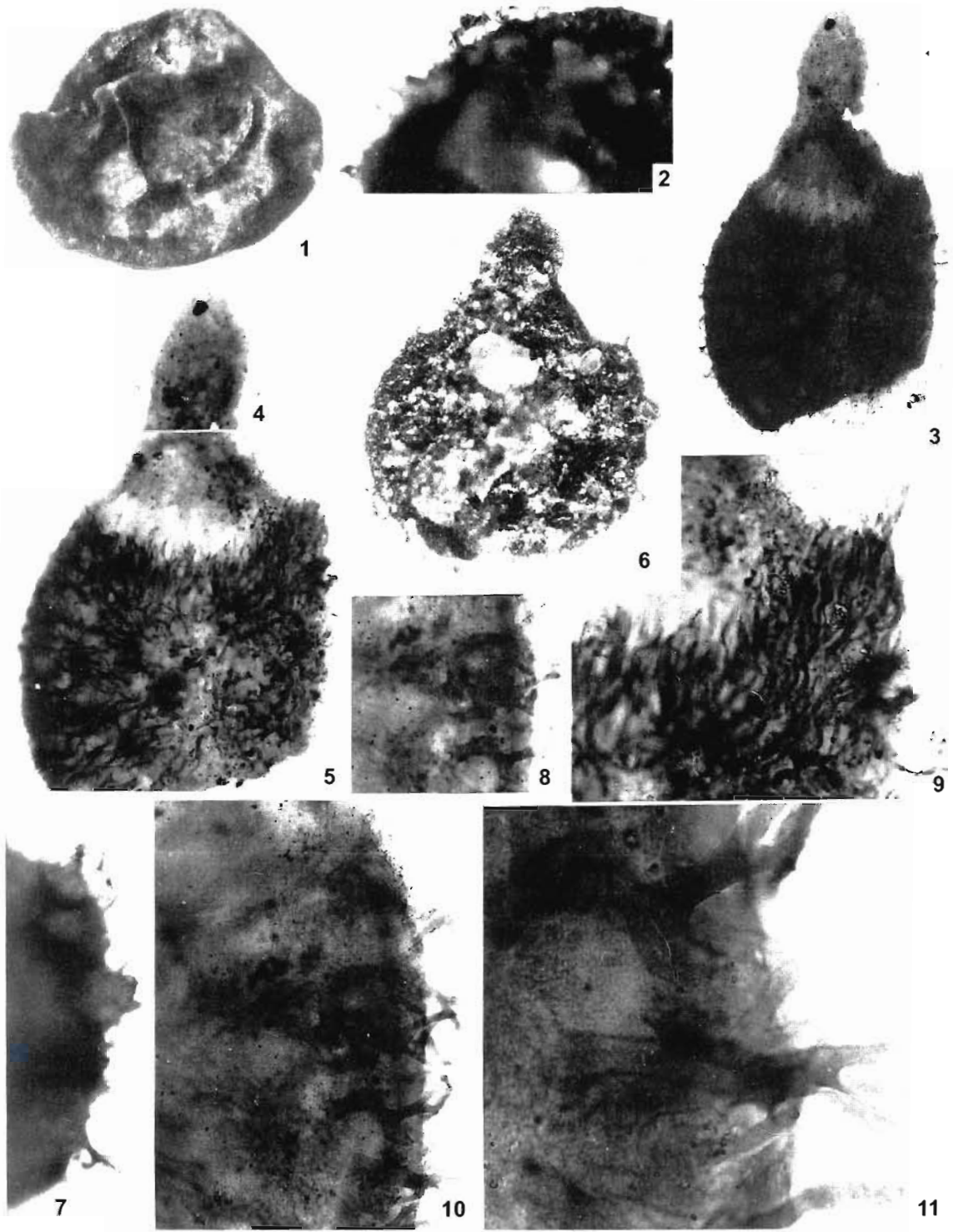


PLATE 4

Name of Taxa	Early Permian			Late Permian	
	Talchir	Karharbari	Barakar	Barren Measures/ Kulti Formation	Raniganj
<i>Duosporites dijkstrae</i> Bharadwaj & Tiwari, 1970	SR				
* <i>Banksisporites indicus</i> (Singh) Tewari & Maheshwari, 1992	SR	D, SR	D, W, M		
* <i>Duosporites congoensis</i> Høeg <i>et al.</i> , 1955	SR	D	D, S, W	D	D
<i>Talchirella nitens</i> (Dijkstra) Bharadwaj & Tiwari, 1970	SR	S	SR	D	D
<i>Ancorisporites venkatachala</i> Maheshwari & Tewari, 1989		D			
<i>Barakarella prakashii</i> Tewari & Maheshwari, 1992		S			
<i>Barakarella shuklae</i> Tewari & Maheshwari, 1992		D			
<i>Duosporites neerjajae</i> Tewari & Maheshwari, 1992		S			
<i>Jhariatriteles filiformis</i> Tewari & Maheshwari, 1992		SR			
<i>Saccarisporites ovalis</i> Pant & Srivastava, 1964		M			
<i>Saccarisporites varians</i> Pant & Srivastava, 1964		M			
<i>Shahdolia chaloneri</i> Pant & Mishra, 1986		SR			
<i>Surangeasporites karharbariensis</i> Bharadwaj & Tiwari, 1970		SR			
* <i>Banksisporites utkalensis</i> (Pant & Srivastava) Tewari & Maheshwari, 1992		D	D, S, W, M		G
* <i>Barakarella pantii</i> Lele & Srivastava, 1983		D	D, S, W		
<i>Duosporites multipunctatus</i> Høeg & Bose, 1960		D	S		
* <i>Talchirella trivedii</i> Pant & Srivastava, 1961 emend. Bharadwaj & Tiwari, 1970		D, SR, S	D, S, SR, W, M		
<i>Biharisporites spinosus</i> Bharadwaj & Tiwari, 1970		D	D		G
<i>Talchirella flavata</i> (Kar) Bharadwaj & Tiwari, 1970		D		D	
* <i>Bokarosporites rotundus</i> (Singh) Bharadwaj & Tiwari, 1970		D, SR, S	D, S, SR, W, M	D	G
<i>Ancorisporites binaensis</i> Pant & Mishra, 1986			SR		
<i>Ancorisporites godavariensis</i> Patil & Premchand, 2001			G		
<i>Aneuletes</i> sp. A Pant & Mishra, 1986			SR		
<i>Banksisporites dijkstrae</i> (Singh) Tewari & Maheshwari, 1992			D		
<i>Banksisporites endosporitiferus</i> (Singh) Tewari & Maheshwari, 1992			D		
<i>Banksisporites linearis</i> (Pant & Mishra) Tewari & Maheshwari, 1992		D, S, SR, M			
<i>Barakarella churuliaensis</i> Lele & Srivastava, 1983			D		
<i>Biharisporites arcuatus</i> Bharadwaj & Tiwari, 1970			SR		
<i>Biharisporites distinctus</i> Bharadwaj & Tiwari, 1970			D		
<i>Biharisporites papillaris</i> Agashe, 1979			W		
<i>Biharisporites</i> sp. Agashe, 1979			W		
* <i>Biharisporites umrerensis</i> sp. nov.			W		
* <i>Biharisporites waigaonensis</i> sp. nov.			W		
<i>Bokarosporites psilatus</i> Bharadwaj & Tiwari, 1970			D		
<i>Canaliculites triangularis</i> Pant & Mishra, 1986			SR		
<i>Cystosporites indicus</i> Trivedi, 1953			SR		
<i>Cystosporites</i> sp. Trivedi, 1953			SR		
* <i>Duosporites irregularis</i> Bharadwaj & Tiwari, 1970			D, W		
* <i>Duosporites</i> sp.			W		
<i>Hughesisporites variabilis</i> Dettmann, 1961			SR		
<i>Jhariatriteles binaensis</i> (Pant & Mishra) Tewari & Maheshwari, 1992			SR		
<i>Jhariatriteles densus</i> Lele & Srivastava, 1983			D		
<i>Lagenicula barakarensis</i> (Bharadwaj & Tiwari) Pant & Mishra, 1986			D		
<i>Lagenicula gondwanensis</i> Pant & Mishra, 1986			SR		
* <i>Lagenoisporites</i> sp.			W		
<i>Manumisporites crustata</i> Agashe, 1979			W		

<i>Manumisporites tuberculata</i> Agashe, 1979	W			
<i>Manumisporites distinctus</i> Bharadwaj & Tiwari, 1970	SR			
<i>Manumisporites hoegii</i> (Srivastava) Bharadwaj & Tiwari, 1970	SR			
<i>Penchiella barakarensis</i> Srivastava & Tewari, 2001	S			
<i>Pilatriteles mirzapurensis</i> Pant & Mishra, 1986	SR			
<i>Ramispinatispora indica</i> Pant & Mishra, 1986	SR			
<i>Ramispinatispora nautiyalii</i> Pant & Mishra, 1986	SR			G
<i>Saksenasporites rewaensis</i> Tripathi, 1999	SR			
<i>Satpurasporites gondwanensis</i> Srivastava & Tewari, 2002	S			
<i>Sethiaspora gondwanensis</i> Srivastava & Tewari, 2001	S			
* <i>Setosisporites hirsutus</i> (Loose) Ibrahim, 1933	W			
<i>Singhisporites fimbriata</i> Agashe, 1979	W			
<i>Singhisporites grandis</i> (Pant & Mishra) Glasspool, 2000	SR			
<i>Singhisporites surangei</i> (Singh) Potonie, 1954	D, R			
<i>Singraulispora saksenae</i> Tripathi & Misra, 1997	SR			
<i>Sporites granulata</i> Agashe, 1979	W			
<i>Jhariatriteles srivastavae</i> Bharadwaj & Tiwari, 1970	D	D		
<i>Duosporites katrinalaensis</i> Bharadwaj & Tiwari, 1970	D	D		
<i>Singhisporites baculatus</i> Bharadwaj & Tiwari, 1970	S	D		G
* <i>Jhariatriteles baculosus</i> Bharadwaj & Tiwari, 1970	W, SR	D		
<i>Singhisporites radialis</i> Bharadwaj & Tiwari, 1970	S	D		G
<i>Kamthispora raniganjensis</i> Jha & Tewari, 2003				G
<i>Kamthispora mailaramensis</i> Jha & Tewari, 2003				G
<i>Kamthispora ramanamurtyi</i> Jha & Tewari, 2003				G
<i>Noniasporites harrisii</i> Maheshwari & Bajpai, 1984				D
<i>Surangeasporites raniganjensis</i> Bharadwaj & Tiwari, 1970				D
<i>Talchirella densicorpa</i> Bharadwaj & Tiwari, 1970				D

(Asterisk indicates taxa reported in the present assemblage)

Legend: D- Damodar Basin; SR- South Rewa Gondwana Basin; W- Wardha Basin; G- Godavari Basin; M- Mahanadi Basin; S- Satpura Basin

Fig. 2—Distribution of megaspores in Permian Gondwana Sequence of India.

verrucae uniformly disposed, dissolve in wet condition; differential maceration in conc. HNO_3 and KOH reveals a triangular, dark, brownish-black mesosporium; cushions if present are not observed due to dark nature of mesosporium.

Dimensions—In (a) dry condition—overall size 450 x 500 μm , size of tri-radiate ridges 180-200 x 15 μm , width of arcuate ridges 15 μm , size of verrucae 5-10 x 5-10 μm , (b) wet condition—overall size 600 x 650 μm , size of tri-radiate ridges 280-300 x 30 μm , width of arcuate ridges 30 μm , size of mesosporium 300 x 300 μm .

Remarks—Exosporium of the megaspore is exactly similar to that of the genus *Duosporites* in being verrucate and also in tri-radiate ridges extending beyond the contact area. However, since cushions are not observable due to dark nature of mesosporium, the specific circumscription could not be determined. Moreover, according to Glasspool (2000) the granulate/dense ornamentation and folding of mesosporium or exosporium can mask the cushions or render them obscure.

Genus—**TALCHIRELLA** Pant & Srivastava 1961 emend. Bharadwaj & Tiwari, 1970

Type species—**TALCHIRELLA TRIVEDI** Pant & Srivastava, 1961

TALCHIRELLA TRIVEDI Pant & Srivastava 1961 emend. Bharadwaj & Tiwari, 1970

(Pl. 1.5, 12; Pl. 2.3, 5)

Description—Megaspores trilete, azonate circular or triangular in proximo-distal view, tri-radiate ridges straight to wavy, $3/4$ spore radius long, ending up at arcuate ridges, which are distinctly marked in wet condition; exosporium verrucate, verrucae uniformly distributed; differential maceration in conc. HNO_3 and KOH reveals thin, transparent, circular to triangular mesosporium, with numerous cushions arranged trigonally along the tri-radiate mark.

Dimensions—In (a) dry condition—overall size 500-550 x 500-550 μm , size of tri-radiate ridges 210-300 x 30-40 μm , size of verrucae 5 x 5 μm , (b) wet condition—overall size 660 x 740 μm , size of tri-radiate ridges 250-330 x 20-25 μm , width of arcuate ridges 20 μm , size of verrucae 10 x 10 μm , size of mesosporium 300 x 360 μm , diameter of cushions 10-10 μm .

Comparison—Megaspores compare well in shape, nature of exosporium and mesosporium with *Talchirella trivedii* (Bharadwaj & Tiwari, 1970, pl. 4, figs 1-12, pl. 5, figs 1, 2; Tewari & Maheshwari, 1992, pl. 1, figs 4, 6-7, 9-10).

Genus—**BARAKARELLA** Lele & Srivastava, 1983

Type species—**BARAKARELLA CHURULIAENSIS** Lele & Srivastava, 1983

BARAKARELLA PANTII Lele & Srivastava, 1983 emend. Tewari & Maheshwari, 1992

(Pl. 1.4; Pl. 2.7, 11)

Description—Megaspores trilete, azonate circular to subcircular; tri-radiate ridges straight to wavy, 3/4 spore radius long, ending up at distinct arcuate ridges; exosporium baculate; baculae thin, slender, uniformly distributed, more prominent on margin; differential maceration in conc. HNO₃ and KOH dissolves tri-radiate and arcuate ridges and reveals a thin, transparent, globular mesosporium which appears triangular due to folding on one side; cushions numerous, arranged trigonally along tri-radiate mark.

Dimensions—In (a) dry condition—overall size 450-700 x 400-750 µm, size of tri-radiate ridges 180-300 x 60 µm, width of arcuate ridges 60 µm, size of baculae 10-20 x 5-15 µm, (b) wet condition—overall size 700 x 750 µm, size of baculae 10-15 x 10 µm, size of mesosporium 300 x 310 µm, diameter of cushions 10-15 µm.

Comparison—Megaspores compare well in shape, nature of ornamentation, nature of mesosporium, presence and arrangement of cushions within the mesosporium with *Barakarella pantii* (Lele & Srivastava, 1983, pl. 3, figs 25-27; Tewari & Maheshwari, 1992, pl. 3, figs 2, 8, 10-11).

Genus—**JHARIATRILETES** Bharadwaj & Tiwari, 1970

Type species—**JHARIATRILETES BACULOSUS** Bharadwaj & Tiwari, 1970

JHARIATRILETES BACULOSUS Bharadwaj & Tiwari, 1970

(Pl. 2.4, 12-13)

Description—Megaspore trilete, circular, azonate; tri-radiate ridges straight to wavy, 3/4 spore radius long, extending up to arcuate ridges, tapering in dry condition, apparently uniformly wide in wet condition; arcuate ridges distinct; exosporium baculate, baculae more prominent on margin, sparser on the remaining part of spore body, tips of baculae blunt, obtuse or tapering; differential maceration in conc. HNO₃ and KOH reveals a thin, transparent mesosporium devoid of cushions.

Dimensions—In (a) dry condition—overall size 400 x 450 µm, size of tri-radiate ridges 180-300 x 15 µm, width of arcuate ridges 15 µm, size of baculae 5-10 x 5-15 µm, (b) wet condition—overall size 550 x 600 µm, size of tri-radiate ridges 250-300 x 30-µm, width of arcuate ridge 30 µm, size of baculae 5-10 x 5-10 µm, size of mesosporium 300 x 310 µm.

Comparison—Megaspore is comparable in shape, nature of tri-radiate and arcuate ridges, and nature of exosporium with *Jhariatriletes baculosus* (Bharadwaj & Tiwari, 1970, pl. 7, figs 1, 5, 14).

Genus—**BIHARISPORITES** Potonié, 1956 emend. Bharadwaj & Tiwari, 1970

Type species—**BIHARISPORITES SPINOSUS** (Singh) Bharadwaj & Tiwari, 1970

BIHARISPORITES WAIGAONENSIS sp. nov.

(Pl. 3.4-5, 7-8)

Holotype—BSIP Slide No. 12890.

Age—Early Permian, Barakar Formation.

Locality—Umrer Coalfield, near Waigaon Village, Nagpur District, Maharashtra, India.

Etymology—After Waigaon Village, adjacent to Umrer Coalfield.

Diagnosis—Megaspore trilete, azonate, subcircular to oval in proximo-distal orientation; tri-radiate ridges faint, straight, more than 3/4 spore radius long, ending up at arcuate ridges, which being faint, almost merged with margin; exosporium with spines and processes with bulbous apices, ornamentation more prominent on margin, sparse on rest of the spore body; mesosporium thin, subcircular, scabrate, without cushions.

Description—There is only one specimen, yet it is distinct enough for a new specific circumscription. In dry condition, it is subcircular to oval in shape, apparently verrucate with faint tri-radiate and arcuate ridges. However, differential maceration in conc. HNO₃ and 5% KOH reveals distinct spines on margin and peculiar appendages on one marginal spot which have broad bases, constricted middle portion and bulbous apices (Pl. 3.5, 8). Besides, a semispherical mesosporium is also revealed which is scabrate and devoid of cushions (Pl. 3.4). Tri-radiate and arcuate ridges retain their faint nature even after maceration. However, they are observable under high resolution.

Dimensions—In (a) dry condition—overall size 450 x 550 µm, size of tri-radiate ridges 180-200 x 20 µm, width of arcuate ridges 20 µm, (b) wet condition—overall size 560 x 800 µm, size of tri-radiate ridges 225-300 x 5 µm, width of arcuate ridges 10-15 µm, length of spines 15-30 µm, width of spines at base 15-20 µm, width of spines at apex 5 µm, length of appendages 15-45 µm, width of appendages at base 5-15 µm, width of appendages

in middle portion 5-10 μm , width of appendages at apex 10-15 μm , size of mesosporium 510 x 690 μm .

Comparison—*Biharisporites waigaonensis* sp. nov. differs from all the known species of the genus *Biharisporites*, viz., *B. distinctus*, *B. arcuatus*, *B. spinosus* (Bharadwaj & Tiwari, 1970, pl. 9, figs 6-13, pl. 10, figs 1-5, pl. 18, figs 14-19, respectively), *B. maiturensis* (Maheshwari & Banerji, 1975, pl. 7, figs 91-93) and *B. sparsus* (Banerji *et al.*, 1978, pl. 3, figs 24-25) in having additional appendages (besides spines) with bulbous apices. Further, *B. distinctus* is circular in shape with massive coni and setae sparsely distributed on contact area and densely distributed laterally and distally and in possessing circular mesosporium; *B. arcuatus* differs in having cylindrical setae with pointed to rounded tips and thin bases imparting a negatively reticulate appearance to the exosporium (Bharadwaj & Tiwari, 1970, pl. 10, figs 2, 5) and an indistinct mesosporium; *B. spinosus* is subtriangular in shape with spines and setae compactly and uniformly placed all over the spore body; *B. sparsus* and *B. maiturensis* differ in having connate ornamentation. *B. sparsus*, further differs in having an indistinct mesosporium while in *B. maiturensis*, mesosporium fills the entire spore cavity.

BIHARISPORITES UMRERENSIS sp. nov.

(Pl. 3. 1-3, 6)

Holotype—BSIP Slide No. 12889.

Age—Early Permian, Barakar Formation.

Locality—Umrer Coalfield, near Waigaon Village, Nagpur District, Maharashtra India.

Etymology—After Umrer Coalfield, the type locality.

Diagnosis—Megaspore trilete, azonate, subcircular to circular in proximo-distal orientation, deeply curved at margins against ray ends; tri-radiate ridges distinct, straight to sinuous, 3/4 of the spore radius in length, narrow at tri-junction, broad at ends, ending up at distinct arcuate ridges; exosporium connate, coni simple, more prominent on margin, stout with pointed apices; mesosporium thin, brown, triangular in shape, folded, half of the spore diameter, without cushions.

Description—The megaspore has been assigned a new specific status because of its distinct morphological features, viz., connate exosporium and triangular mesosporium. Additionally, due to highly curved nature adjacent to ends of tri-radiate ridges the megaspore appears semicircular. One of the tri-radiate ridges is straight, another one is wavy and the third is sinuous. They are narrow at tri-junction and gradually widen towards their ends near the arcuate ridges which are distinct and deeply curved adjacent to ray ends. Coni, though uniformly disposed, are more prominent on margin, simple, stout, broad at base with pointed apices. Differential maceration in conc. HNO_3 and 5% KOH reveals a much folded, triangular

mesosporium which is devoid of cushions. The mesosporium is brown in colour, centrally located and occupies half of the spore cavity.

Dimensions—In (a) dry condition—overall size 550 x 460 μm , size of tri-radiate ridges 190-240 x 20 μm , width of arcuate ridges 10-20 μm , length of coni 5-10 μm , width of coni at base 5-10 μm , width of coni at apex 5 μm ; (b) wet condition—overall size 560 x 600 μm , size of tri-radiate ridges 170-200 x 15-30 μm , width of arcuate ridge 20-30 μm , length of coni 5-10 μm , width of coni at base 10-11.5 μm , width of coni at apex 2.5-5 μm , size of mesosporium 260 x 300 μm .

Comparison—*Biharisporites umrerensis* sp. nov. is distinct from *B. spinosus*, *B. distinctus* and *B. arcuatus* (Bharadwaj & Tiwari, 1970) in having exclusively connate ornamentation. *B. spinosus* (pl. 8, figs 14-19, pl. 9, figs 1-5) has compactly and uniformly disposed spines and setae, and subcircular to subtriangular mesosporium. *B. distinctus* (pl. 9, figs 6-13) has both coni and setae, sparsely distributed on contact area. Besides, its mesosporium is circular. *B. arcuatus* (pl. 10, figs 1-5) differs in having setae and indistinct mesosporium. The present megaspore is comparable with *B. maiturensis* (Maheshwari & Banerji, 1975, pl. 3, figs 24-25) in having connate ornamentation. However, the latter differs in having indistinct arcuate ridges and mesosporium which is recognisable only by peripheral folds. *B. sparsus* differs in having indistinct mesosporium occupying almost whole of the spore cavity. From all these megaspores *B. umrerensis* differs in presence of triangular mesosporium occupying half of the spore cavity.

Genus—LAGENOISPORITES Potonié & Kremp, 1955
emend. Dybova-Jachowicz *et al.*, 1979

Type species—LAGENOISPORITES RUGOSUS (Loose)
Potonié & Kremp, 1955

LAGENOISPORITES sp.

(Pl. 4. 1)

Description—Megaspore gulate, tri-radiate ridges raised, extended into a small neck-like projection, form a tri-junction at the apex of smooth gula; contact area forming bulk of gula, exosporium laevigate; differential maceration in conc. HNO_3 and KOH dissolves tri-radiate ridges and arcuate ridges and does not reveal a mesosporium

Dimensions—In (a) dry condition—overall size 500 x 550 μm , size of gula 50 x 50 μm , size of tri-radiate ridges 420-450 x 30-60 μm , width of arcuate ridges 30 μm , (b) wet condition—overall size 600 x 600 μm , size of gula could not be measured because it disintegrated.

Remarks—The genus *Lagenoisporites* includes gulate megaspores with a laevigate exosporium. However, Dybova-Jachowicz *et al.* (1979) emended the genus to include both

unornamented and ornamented forms with very short appendages of various shapes. The megaspore described here is gulate and unornamented and hence included under the genus *Lagenosporites*. Moreover, since the mesosporium could not be recovered and other characters dissolved during maceration, specific circumscription is not given. Nevertheless, it resembles *Lagenosporites rugosus* (Loose) Potonié & Kremp (1955, pl. 4, fig. 22) in general structure except for exosporium which is punctuate/rugose in latter.

Genus—SETOSISPORITES Ibrahim, 1933 emend Potonié & Kremp, 1955

Type species—SETOSISPORITES HIRSUTUS (Loose) Ibrahim, 1933

SETOSISPORITES HIRSUTUS (Loose) Ibrahim, 1933
(Pl. 4.2-11)

Description—Megaspores gulate, gula smooth, raised into a dome-shaped, elongate structure with a broad base and a pointed apex, remaining part of the spore body circular in shape; tri-radiate and arcuate ridges not clear; exosporium of spore body except the gula, covered with long, stiff spines which are either simple or 2 to 3 times furcate, elongate, narrow with pointed apices, ornamentation dense; differential maceration in conc. HNO₃ and KOH does not reveal a mesosporium.

Dimensions—In (a) dry condition—overall size 550-850 x 650-670 µm, size of gula 120-180 x 150-180 µm, size of spines 20-50 x 5-10 µm, (b) wet condition—overall size 900 x 1290 µm, size of gula 510 µm (length), 510 µm (width of gula at base), 90 µm (width of gula at apex), length of spines 90-120 µm, width of spines at base 60 µm, width of spines at apex 5-30 µm.

Comparison—The megaspores are comparable with *Setosisporites hirsutus* (Loose) Ibrahim (Potonié & Kremp, 1955, pl. 4 figs 28, 29a, b) in shape, nature of gula and exosporium ornamentation.

DISCUSSION

The foregoing account suggests that a rich and diversified vegetation producing megaspores grew in the region during the deposition of these sediments. Most of the megaspores presently recovered, vary in their vertical distribution (Fig. 2). *Banksisporites indicus* extends from Talchir to Barakar formations; *Duosporites congoensis* from Talchir to Raniganj Formation, the taxa *Banksisporites utkalensis*, *Barakarella pantii* and *Talchirella trivedii* extend from Karharbari to Barakar Formation. *Bokarosporites rotundus* extends from Karharbari to Raniganj Formation. *Jhariatrilletes baculosus* extends from Barakar to Raniganj Formation. Other taxa like

Duosporites irregularis, *Duosporites* sp. are restricted to Barakar Formation. Besides, *Biharisporites umrerensis*, *B. waigaonensis*, *Lagenosporites* sp. and *Setosisporites hirsutus* are new to Indian records.

The present megaspore assemblage is comparable with that of Damodar, Mahanadi, Satpura and South Rewa Gondwana basins. Though nineteen species in total are known from Wardha Basin, six of these species occur in other basins of Early Permian and out of these, eleven species are exclusive to Barakar Formation, Umrer Coalfield and four species extend up to Late Permian (Fig. 2).

An analysis of Fig. 2 reveals that seventy three megaspore taxa are known from the Permian Gondwana of India. Interestingly, sixty seven species are recorded from Early Permian distributed in different basins and only eighteen species are known from Late Permian sediments. This possibly reflects stupendous growth of heterosporous plants during Early Permian time. Concerted efforts are required to draw any definite conclusion regarding paucity of megaspores during Late Permian.

Affinity of dispersed Gondwana megaspores is attributed mainly to Lycopsids (Pant & Mishra, 1986) on the basis of heterospory in that group, presence of spines on exosporium and existence of gulate megaspores. The presence of spinate taxa viz., *Biharisporites umrerensis* and *B. waigaonensis* as well as gulate taxa viz., *Lagenosporites* and *Setosisporites hirsutus* indicates prevalence of lycopsids during the deposition of Early Permian sediments in the Umrer Coalfield. Occurrence of such cryptogamic megaspores is indicative of marshy and humid environmental conditions at the time of deposition.

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