

Early Permian megaspores from Goutham Khani Open Cast Mine, Kothagudem Area, Godavari Graben, Telangana, India

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(Received 13 October, 2015; revised version accepted 28 November, 2015)

ABSTRACT

Joshi A & Tewari R 2015. Early Permian megaspores from Goutham Khani Open Cast Mine, Kothagudem Area, Godavari Graben, Telangana, India. The Palaeobotanist 64(2): 139–150.

Early Permian megaspores are reported for the first time from the Barakar Formation of Index Seam, Goutham Khani Open Cast Mine, Kothagudem Area, Godavari Graben, Telangana, India. The megaspore assemblage includes three genera and ten species, namely *Biharisporites spinosus*, *Biharisporites* sp. A (in Tewari *et al.*, 2009), *Biharisporites* sp., *Jhariatrilletes filiformis*, *Jhariatrilletes* sp., *Singhisporites indica*, *S. nautiyalii*, *S. radialis*, *S. surangei* and *Singhisporites* sp. Besides adding to the existing knowledge of megaspores from the Godavari Graben, the comparison of megaspores from the Goutham Khani Open Cast Mine with those of the other Indian Lower Gondwana basins, namely Damodar, Satpura, Wardha, South Rewa and other areas of the Godavari Graben reveals that majority of these differ in the presence of dense ornamentations on their exosporia. The previous records of megaspores from the late Permian of the Godavari Graben show dense spinate exosporia. Presence of such dense diverse spines on megaspores of this study indicates their early appearance during the Barakar Formation. An analysis of the developmental pattern of the exosporium architecture of Lower Gondwana megaspores in general, indicates that during the early Permian Talchir and Karharbari formations, the megaspores had simple outer layer with usually smooth, granulate, verrucate and sometimes baculate/connate ornamentations whereas, dense spinate exosporia were more common during Barakar and Raniganj formations indicating fresh water aquatic conditions. As such, the spinate megaspores of Kothagudem region also point towards terrestrial aquatic conditions.

Key-words—Megaspores, Barakar Formation, Palaeoenvironment, Kothagudem Area, Godavari Graben.

गौतम खनि विवृत खान, कोठागुडेम क्षेत्र, गोदावरी द्रोणिका, तेलंगाना, भारत से प्रारंभिक परमियन के स्थूल बीजाण

अरुण जोशी एवं रजनी तिवारी

सारांश

सूचक संस्तर, गौतम खनि, विवृत खान, कोठागुडेम क्षेत्र, गोदावरी द्रोणिका, तेलंगाना, भारत के बराकार शैलसमूह से पहली मरतिबा प्रारंभिक परमियन के स्थूल बीजाणु मिले हैं। स्थूल बीजाणु समुच्चय में तीन वंश एवं दस जाति नामतः *बिहारीस्पोरिटिस स्पाइनोसस*, *बिहारीस्पोरिटिस* जाति ए (तिवारी व अन्य 2009), *बिहारीस्पोरिटिस* जाति, *झरियाट्राइलिटिस फिलीफॉर्मिस*, *झरियाट्राइलिटिस* जाति, *सिंहीस्पोरिटिस* इंडिका, *एस. नौटियालाई*, *एस. रेडिएलिस*, *एस. सुरंगई* एवं *सिंहीस्पोरिटिस* जाति सन्निहित हैं। गोदावरी द्रोणिका से प्राप्त स्थूल बीजाणुओं की मौजूदा जानकारी को सम्मिलित करने के अलावा, अन्य भारतीय गोंडवाना द्रोणियों, नामतः दामोदर, सतपुड़ा, वर्धा, दक्षिण रीवा तथा गोदावरी द्रोणिका के अन्य क्षेत्रों की उनके साथ गौतम खनि, विवृत खान से स्थूल बीजाणुओं की तुलना खुलासा करती है कि एक्सओस्पोरिया पर सघन अलंकरणों की मौजूदगी में ये ज़्यादातर अलहदा हैं। आज की तारीख तक, गोदावरी द्रोणिका के विलंबित परमियन से अभिलिखित स्थूल बीजाणुओं में सघन शूल एक्सओस्पोरिया दर्शायी। इस अध्ययन के स्थूल बीजाणुओं पर सघन नानाविध शूलों की विद्यमानता बराकार शैलसमूह के दौरान उनका प्रारंभिक आविर्भाव दर्शाती है। सामान्यतः अधो गोंडवाना स्थूल बीजाणुओं पर एक्सओस्पोरियम स्थापत्य कला का विकासात्मक प्ररूप का विश्लेषण संकेत देता है कि प्रारंभिक परमियन के दौरान तल्वीर एवं करहरबाड़ी शैलसमूह में आमतौर पर चिकने, दानेदार, वेरूकेट तथा कभी-कभार बाकुलायुक्त/सहजात अलंकरणों सहित स्थूलबीजाणुओं की साधारण बाह्य परत थी, जबकि बराकार एवं रानीगंज शैलसमूहों के दौरान सघन शूल एक्सओस्पोरिया अति सामान्य थे। सघन शूल अलवर्णीय जल जलीय स्थितियाँ इंगित कर रहे हैं। तदनुसार, कोठागुडेम अंचल के शूल स्थूलबीजाणु स्थलीय जलीय स्थितियों की ओर भी इशारा करते हैं।

सूचक शब्द—स्थूलबीजाणु, बराकार शैलसमूह, पुरापर्यावरण, कोठागुडेम क्षेत्र, गोदावरी द्रोणिका।

INTRODUCTION

PERMIAN megaspores from Godavari Graben have been reported from Ramagundem, Chelpur (Jha & Srivastava, 1984), Rampuram (Patil & Premchand, 2001), Mailaram (Jha & Tewari, 2003), Gundala (Jha *et al.*, 2006) and Kachinapalli (Tewari *et al.*, 2007) areas. Palaeontological records from Goutham Khani Open Cast Mine are scarce. Bilwa *et al.* (2012) recorded palynotaxa, *Scheuringipollenites*, *Faunipollenites*, *Striatopodocarpites*, *Striatites*, *Tiwariaspores* and *Lunatisporites*, and Joshi *et al.* (2015) recorded *Vertebraria indica* from the Barakar Formation of this open cast mine. This is the first detailed systematic study of megaspores from the Barakar Formation (early Permian) of the Goutham Khani Open Cast Mine, Kothagudem Area, Godavari Graben, Telangana. Megaspore taxa identified in the assemblage include *Biharisporites spinosus*, *Biharisporites* sp. A (in Tewari *et al.*, 2009), *Biharisporites* sp., *Jhariatriteles filiformis*, *Jhariatriteles* sp., *Singhisporites indica*, *S. nautiyalii*, *S. radialis*, *S. surangei* and *Singhisporites* sp.

GEOLOGY OF THE AREA

The Godavari Valley Coalfield covers an area of about 17,000 sq. km bounded by 16°38' N and 19°32' N latitude and 79°12' E and 81°39' E longitude. The coalfield has an average width of 55 km, though there is a well-defined constriction in

the Paluncha–Kothagudem Area where it is only 6 km wide. The coal seams of economic value are mainly confined to the Godavari and Kothagudem sub-basins and the Yellandu outlier. The Kothagudem belt stretches for about 18 km from Kothagudem in the north and up to Pengadapa in the south. The Singareni Collieries Company Limited has established the following sequence (Raja Rao, 1982):

Top (queen) seam	6.7 to 13.5 m
Parting	42 m
King seam	2.1 to 31.3 m
Parting	0.91 to 6.3 m
Bottom (green) seam	4.2 to 8.4 m

Only the King Seam is of economic importance. It is 2.1 m in the Birly pit in the northern end of the belt and progressively increases to 31.3 m in the Goutham Khani mining block in the south. There are three collieries namely Goutham Khani, Venkatesh Khani and Padmawati Khani in the Kothagudem Area of which Goutham Khani (Fig. 1) is an Open Cast Mine, whereas, Venkatesh Khani and Padmawati Khani are underground mines. Two workable coal seams occur within the mine boundary. An Index Seam about 3 m thick exists over the Top Seam and consists of 30 cm thick coal band alternating with carbonaceous shale above and below. The gap between the Top Seam and the Index Seam is 60 m (Fig. 2). The mine is spread over a distance of up to 2.30 km in North–East and South–West direction and up to 1.30 km along North–West and South–East direction (Raja Rao, 1982).

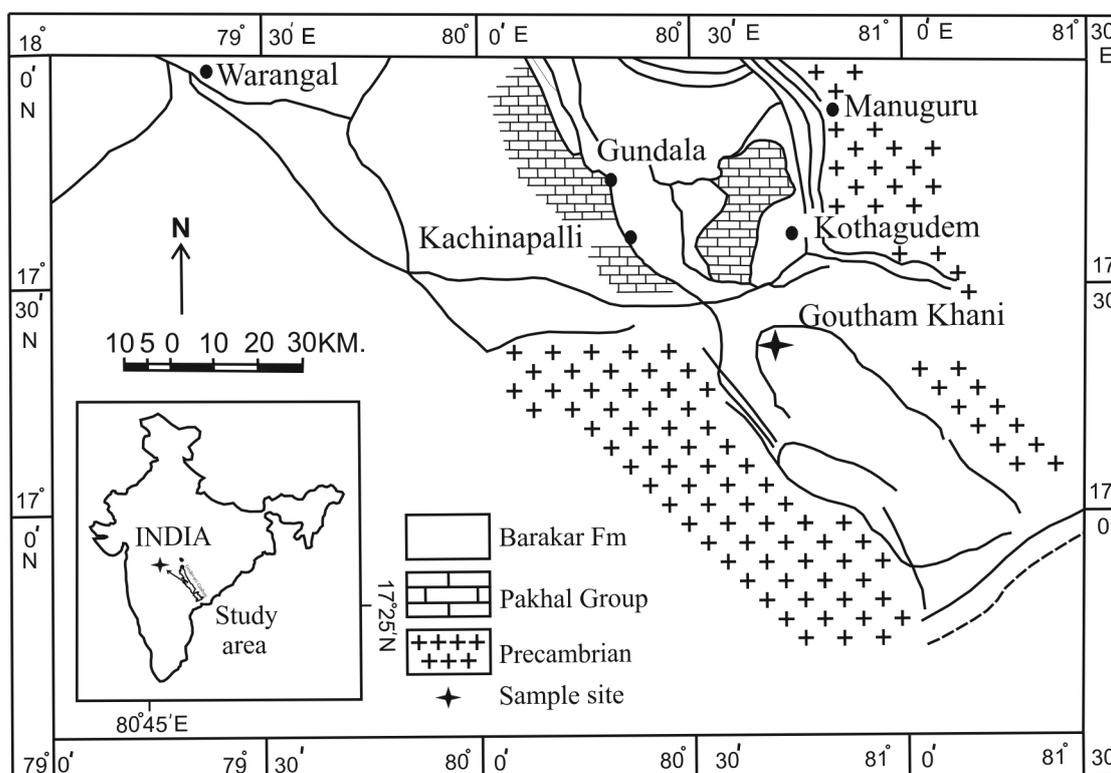


Fig. 1—Geological map showing the sample site (modified after SCCL, 2011).

MATERIAL AND METHOD

Megaspores were recovered from the carbonaceous shale samples collected from the Barakar Formation of Index Seam, Goutham Khani Open Cast Mine, Kothagudem Area, Telangana (Fig. 2). For the recovery of megaspores, the samples were processed with concentrate hydrofluoric acid for 5–7 days and washed thoroughly with water. Megaspores were picked individually and kept in conc. HNO_3 for 10–12 hours. A pinch of KClO_3 was added to catalyze the reaction. When the megaspores turned brown, they were thoroughly washed with water and then treated with 5% potassium hydroxide (KOH) solution which revealed the exosporium features like shape, nature of triradiate mark, contact ridges, ornamentation and the mesosporium. The taxa *Biharisporites* sp. and *Singhisporites* sp. were identified in SEM photographs. Since their mesosporium could not be studied, it was not possible to assign them to definite species. Hence, a detailed description of these is not given here. All the slides have been deposited in the repository of BSIP Museum vide BSIP Statement No. 1420.

LIST OF TAXA AND SYSTEMATIC DESCRIPTION

Genus: Biharisporites (Potonié, 1956) Bharadwaj & Tiwari, 1970

Biharisporites spinosus (Singh 1953 in Surange *et al.*, 1953) Bharadwaj & Tiwari, 1970 (Pl. 1.1, 2).

Biharisporites sp. A (in Tewari *et al.*, 2009) (Pl. 1.3).

Biharisporites sp. (Pl. 1.4–6).

Genus: Jhariatriletes Bharadwaj & Tiwari, 1970

Jhariatriletes filiformis Tewari & Maheshwari, 1992 (Pl. 2.1).

Jhariatriletes sp. (Pl. 2.2).

Genus: Singhisporites (Potonié, 1956) Bharadwaj & Tiwari, 1970

Singhisporites indica (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.3, 4).

Singhisporites nautiyalii (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.5, 6).

Singhisporites radialis Bharadwaj & Tiwari, 1970 (Pl. 3.1).

Singhisporites surangei (Potonié, 1956) (= *Triletes surangei* Singh, 1953 in Surange *et al.*, 1953) Bharadwaj & Tiwari, 1970 (Pl. 3.2–6, Pl. 4.1–4).

Singhisporites sp. (Pl. 4.5, 6).

Genus—Biharisporites (Potonié, 1956) Bharadwaj & Tiwari, 1970

Type species—Biharisporites spinosus (Singh, 1953 in Surange *et al.*, 1953) Bharadwaj & Tiwari, 1970

Biharisporites spinosus (Singh, 1953 in Surange *et al.*, 1953) Bharadwaj & Tiwari, 1970

(Pl. 1.1, 2)

Description—Megaspores circular to subcircular in proximo–distal orientation, trilete, azonate, tri–radiate and arcuate ridges probably dissolved during maceration, exosporium connate, coni with broad bases and pointed apices, sparsely distributed on exosporium. Differential maceration in conc. HNO_3 and KOH reveals circular, hyaline mesosporium devoid of cushions, occupying 1/2 of spore cavity.

Dimensions—Overall size 767–848 μm , length of spines 48–52 μm , width of spines at base 20–22 μm , width of spines at apex 8–11 μm , diameter of mesosporium 380–489 μm .

Remarks—Megaspores are identical to *Biharisporites spinosus* (Bharadwaj & Tiwari, 1970, Pl. 8, Figs 14–19, Pl. 9, Figs 1–5) in shape, nature of exosporium and mesosporium.

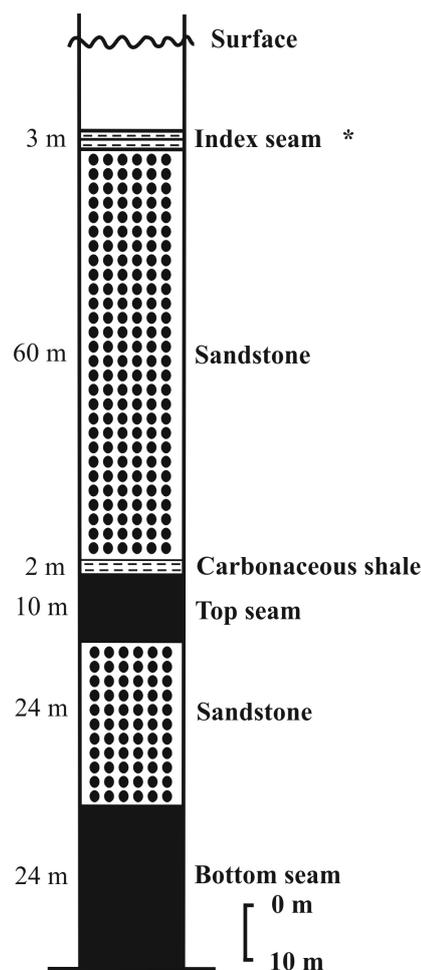


Fig. 2—Litholog of Goutham Khani Open Cast Mine, Kothagudem Area (after SCCL, 2011). * = Megaspores.

Biharisporites sp. A (in Tewari *et al.*, 2009) (Pl. 1.4–6)

Description—Megaspore azonate, oval, tri–radiate and arcuate ridges not clear, exosporium connate/spinate, conical spines more distinct on margin, dark circular, mesosporium occupying 1/3 of spore cavity is present.

Dimensions—Overall size 767 x 917 μm , length of spines 50–62 μm , width of spines at base 33–40 μm , width of spines at apex 11–17 μm , diameter of mesosporium 551 x 629 μm .

Remarks—Megaspore is identical in shape, nature of exosporium and mesosporium to *Biharisporites* sp. A recorded from late Permian of Ib River Coalfield, Mahanadi Basin, Odisha (Tewari *et al.*, 2009, Fig. 3.15).

Genus—*Jhariatriteles* Bharadwaj & Tiwari, 1970

Type species—*Jhariatriteles baculosus* Bharadwaj & Tiwari, 1970

Jhariatriteles filiformis Tewari & Maheshwari, 1992 (Pl. 2.1)

Description—Megaspore azonate, circular, tri–radiate ridges not clear; exosporium baculate with long, slender, thin, ribbon like appendages, tips of appendages blunt or tapering; differential maceration in conc. HNO_3 and KOH reveals thin, transparent mesosporium devoid of cushions.

Dimensions—Overall size 728 x 879 μm , length of spines 63–73 μm , width of spines at base 24–29 μm , width of spines at apex 11–14 μm , diameter of mesosporium 428 x 675 μm .

Remarks—Megaspore is identical to *Jhariatriteles filiformis* (Tewari & Maheshwari, 1992, Pl. 5, Figs 2, 4, 5) in shape and nature of mesosporium.

Jhariatriteles sp. (Pl. 2.2)

Description—Megaspore azonate, circular to sub–circular in shape, tri–radiate and arcuate ridges not clear, exosporium baculate, bacula of unequal length, sparsely distributed, longer bacula bifurcate with blunt tips, mesosporium thin, hyaline, folded, without cushions.

Dimensions—Overall size 772 x 849 μm , length of bacula 54–62 μm , width of bacula at base 42–51 μm , width of bacula at apex 17–23 μm , diameter of mesosporium 596 x 644 μm .

Remarks—The megaspore has baculate exosporium and the mesosporium is without cushions. Hence, it is placed here under the genus *Jhariatriteles*. However, the bacula are of unequal length, sometimes with bifurcate tips unlike those found in *Jhariatriteles* where they are long, slender, thin, blunt, obtuse or with tapering tips. Since only one megaspore is present we refrain to assign a specific circumscription to it.

Genus—*Singhisporites* (Potonié, 1956) Bharadwaj & Tiwari, 1970

Type species—*Singhisporites surangei* (Potonié, 1956) (= *Triletes surangei* Singh, 1953 in Surange *et al.*, 1953) Bharadwaj & Tiwari, 1970

Singhisporites indica (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.3, 4)

Description—Megaspore subcircular in proximo–distal orientation, trilete, azonate, tri–radiate ridges distinct, straight, end up at distinct arcuate ridges, contact area well–defined, exosporium covered with numerous thin, branched appendages distributed sparsely. Differential maceration in conc. HNO_3 and 5% KOH reveals a hyaline spherical mesosporium.

Dimensions—Overall size 807 x 849 μm , size of tri–radiate ridges 287–361 x 20–67 μm , length of spines 241–310 μm , width of spines at base 35–42 μm , width of spines at apex 15–22 μm , diameter of mesosporium 607 x 668 μm .

Remarks—Megaspore is identical to *Singhisporites indica* (= *Ramispinatispora indica*, Pant & Mishra, 1986, Pl. 6, Fig. 45, Pl. 9, Fig. 60, Text–Fig. 13 B) Glasspool, 2003 in shape, nature of arcuate ridges, exosporium ornamentation and mesosporium characteristics. However, the tri–radiate ridges are wavy in specimens of Pant and Mishra (1986, Pl. 6, Fig. 44) whereas, they are more or less straight in specimens described here.

Singhisporites nautiyalii (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.5, 6)

Description—Megaspore circular to subtriangular in shape, exosporium covered with uniformly distributed branched and unbranched spinate appendages, mesosporium not seen.

PLATE 1

(Scale bar = 100 μm)



1. *Biharisporites spinosus*, BSIP Slide No. 15434.
2. A portion of megaspore in 1 enlarged (x 4) to show ornamentation. BSIP Slide No. 15434.
3. *Biharisporites* sp. A (in Tewari *et al.*, 2009), BSIP Slide No. 15435.
4. *Biharisporites* sp., SEM photograph.
5. A portion of megaspore in 4 enlarged (x 3) to show ornamentation.
6. A portion of megaspore in 4 enlarged (x 7) to show ornamentation.

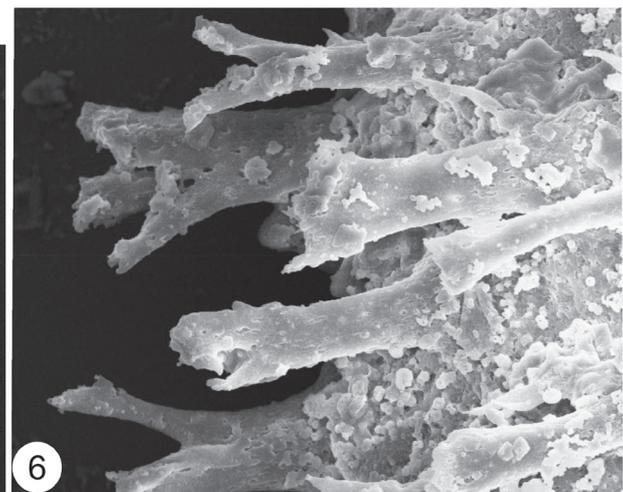
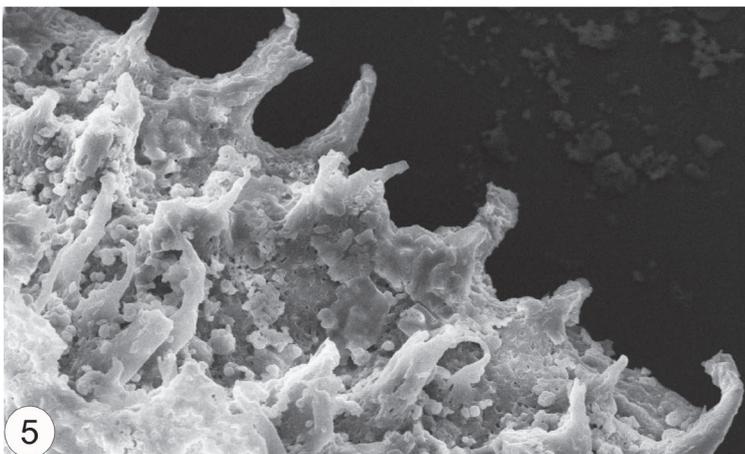
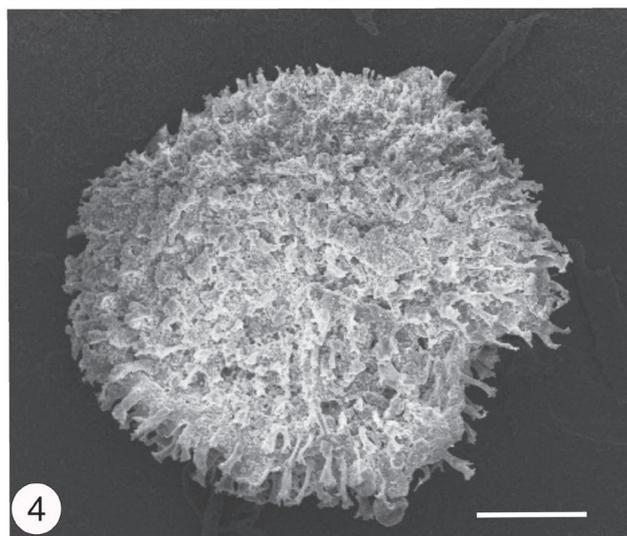
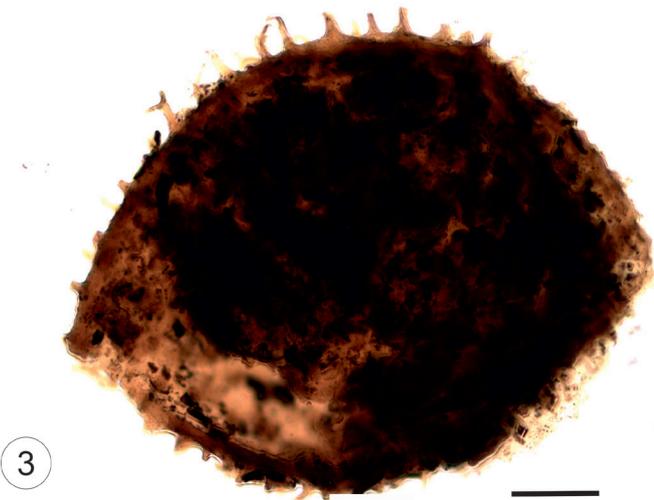
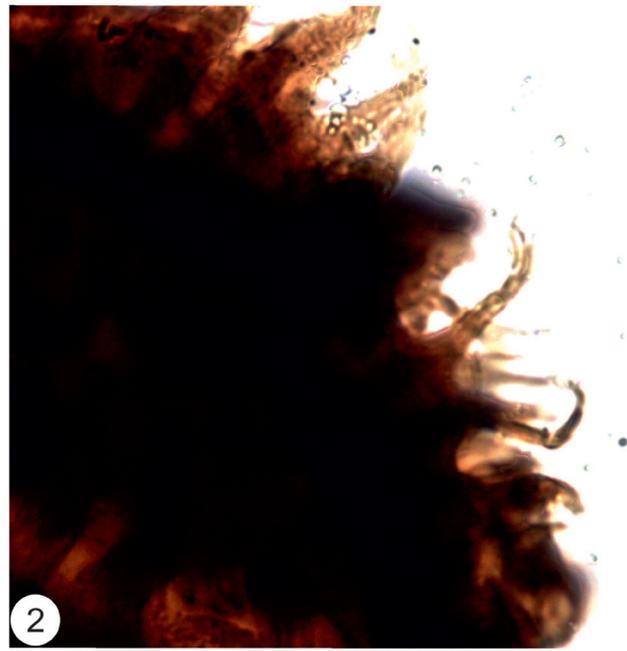
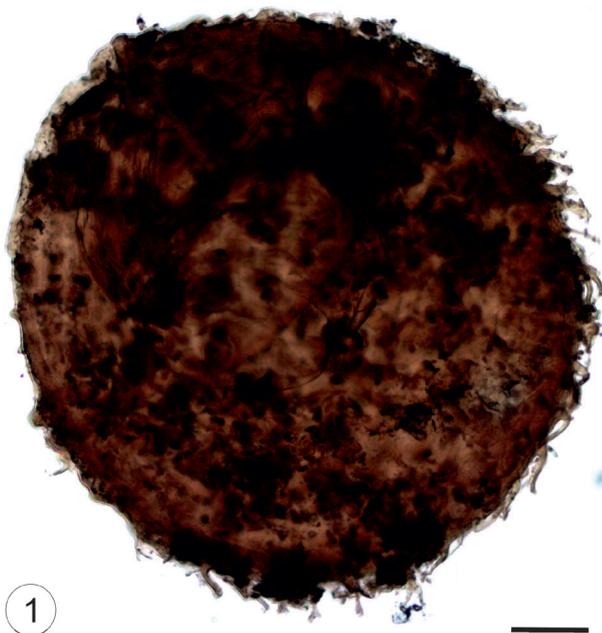


PLATE 1

Table 1—Distribution of megaspores of Goutham Khani Open Cast Mine in Indian Lower Gondwana basins.

Name of Taxa/ Formation	Indian Lower Gondwana basins								
	D	SR	S	G	D	D	G	M	G
	K	B	B	B	B	BM	R	R	KM
<i>Biharisporites spinosus</i>	+			+				+	
<i>Biharisporites</i> sp. A (in Tewari <i>et al.</i> , 2009)				+				+	
<i>Biharisporites</i> sp.				+					
<i>Jhariatrilletes filiformis</i>	+			+				+	
<i>Jhariatrilletes</i> sp.				+					
<i>Singhisporites indica</i>		+		+			+	+	
<i>Singhisporites nautiyalii</i>		+		+			+	+	
<i>Singhisporites radialis</i>			+	+		+		+	+
<i>Singhisporites surangei</i>				+	+			+	
<i>Singhisporites</i> sp.				+					

K: Karharbari Formation, B: Barakar Formation, BM: Barren Measures Formation, R: Raniganj Formation, KM: Kamthi Formation.

SR: South Rewa, S: Satpura, G: Godavari, D: Damodar, M: Mahanadi.

Dimensions—Overall size 687–775 μm , length of spines 60–61 μm , width of spines at base 31–32 μm , width of spines at apex 9–3 μm .

Remarks—Megaspore is identical to *Singhisporites nautiyalii* Glasspool 2003 (= *Ramispinatipora nautiyalii*, Pant & Mishra, 1986, Pl. 9, Fig. 62–64; Text–Fig. 14 A, B, D and E) in shape and exosporium ornamentation.

Singhisporites radialis (Potonié, 1956) Bharadwaj & Tiwari, 1970 (Pl. 3.1)

Description—Megaspore subcircular in proximo–distal orientation, contact area wide, tri–radiate ridges distinct, straight to wavy; 3/4 spore radius long, exosporium with long, fleshy, simple, sometimes furcate sparse processes, distributed radially, rare on contact area, dense near the margin, mesosporium faint.

Dimensions—Overall size 686 x 776 μm , size of tri–radiate ridges 174–575 \times 11–8 μm , length of spines 42–49 μm , width of spines at base 18–29 μm , width of spines at apex 4–11 μm .

Remarks—Megaspore is identical to *Singhisporites radialis* (Bharadwaj & Tiwari, 1970, Pl. 11, Figs 5–11, Pl. 12, Figs 1–4) in shape, nature of tri–radiate and arcuate ridges, nature of exosporium and mesosporium.

Singhisporites surangei Bharadwaj & Tiwari, 1970 (Pl. 3.2–6, Pl. 4.1–4)

Description—Megaspores trilete, azonate, circular to subcircular in proximo–distal orientation, tri–radiate ridges distinct, straight to curved, 3/4 spore radius long, end up at distinct arcuate ridges, exosporium covered with simple, furcate processes, more prominent near the margin. Differential maceration in conc. HNO_3 and KOH reveals thin,

PLATE 2

(Scale bar = 100 μm)



1. *Jhariatrilletes filiformis*, BSIP Slide No. 15436.

2. *Jhariatrilletes* sp., BSIP Slide No. 15437.

3. *Singhisporites indica*, BSIP Slide No. 15438.

4. A portion of megaspore in 3 enlarged (x 2) to show ornamentation,

BSIP Slide No. 15438.

5. *Singhisporites nautiyalii*, BSIP Slide No. 15439.

6. A portion of megaspore in 5 enlarged (x 4) to show ornamentation, BSIP Slide No. 15439.

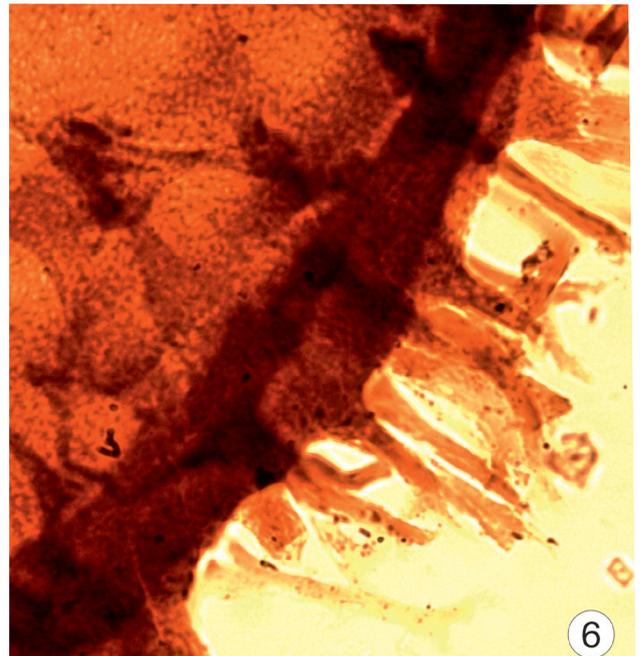
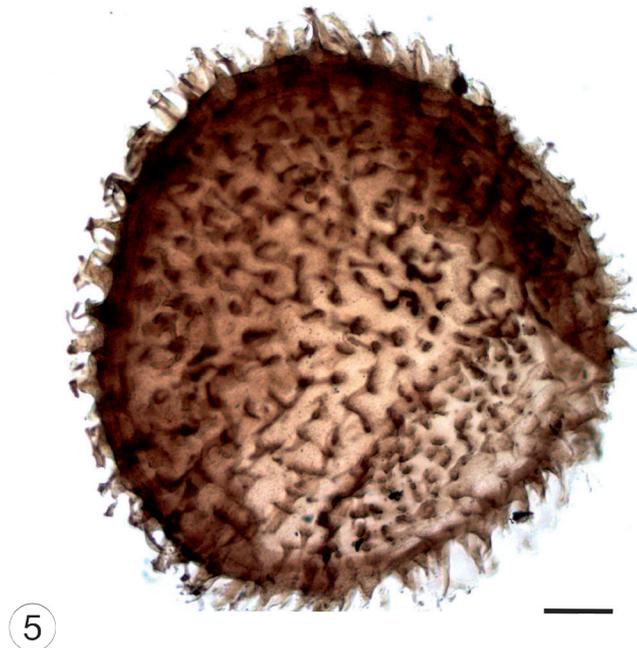
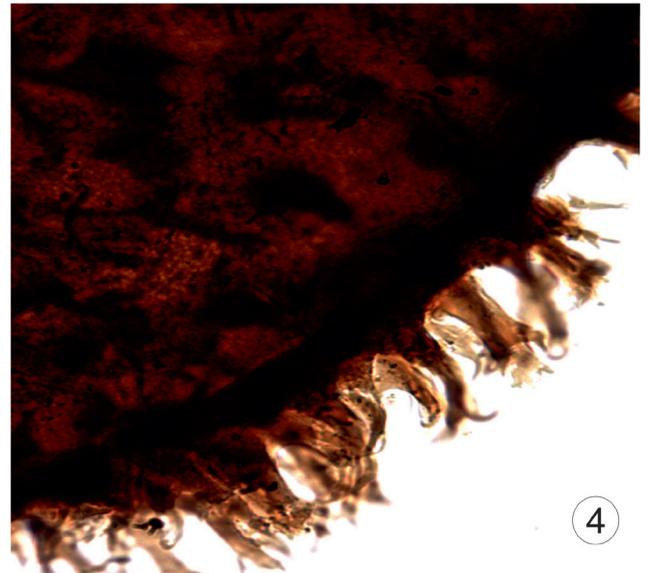
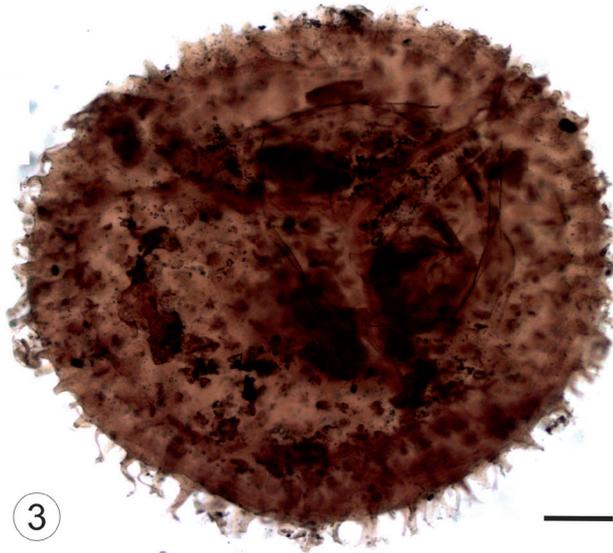
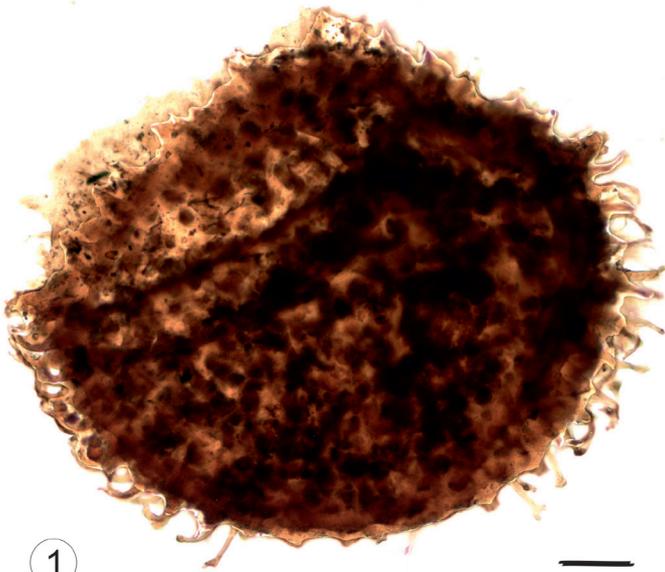


PLATE 2

Table 2—Distribution of megaspores of Goutham Khani Open Cast Mine in different areas of Godavari Graben.

Name of Taxa	Godavari Graben					
	Kothagudem	Kachinapalli		Mailaram	Chelpur	Ramagundem
	B	B	R	R	KM	KM
<i>Biharisporites spinosus</i>	*			*		
<i>Biharisporites</i> sp. A (in Tewari <i>et al.</i> , 2009)	*					
<i>Biharisporites</i> sp.	*		*			
<i>Jhariatriletes filiformis</i>	*					
<i>Jhariatriletes</i> sp.	*					
<i>Singhisporites indica</i>	*		*			
<i>Singhisporites nautiyalii</i>	*	*	*	*		
<i>Singhisporites radialis</i>	*	*	*	*	*	*
<i>Singhisporites surangei</i>	*		*			
<i>Singhisporites</i> sp.	*					

B: Barakar Formation, R: Raniganj Formation, KM: Kamthi Formation.

circular to subcircular mesosporium without cushions, about 2/3 of the spore diameter.

Dimensions—Overall size 176–864 μm , size of tri-radiate ridges 106–352 x 11–38 μm , length of spines 16–67 μm , width of spines at base 19–29 μm , width of spines at apex 8–14 μm , diameter of mesosporium 286–470 μm

Remarks—Megaspores are identical in shape, nature of tri-radiate ridges and nature of exosporium and mesosporium with *Singhisporites surangei* (Bharadwaj & Tiwari, 1970, Pl. 10, Figs 6–13, Pl. 11, Figs 1–4). One megaspore is small in size, i.e. < 200 μm (Pl. 4.1, 2) which is an exceptional case and sometimes happens due to the nature of preservation of the megaspores.

DISCUSSION

The megaspores described from the Barakar Formation of Goutham Khani Open Cast Mine comprise the taxa *Biharisporites spinosus*, *Biharisporites* sp. A (in Tewari *et al.*, 2009), *Biharisporites* sp., *Jhariatriletes filiformis*, *Jhariatriletes* sp., *Singhisporites indica*, *S. nautiyalii*, *S. radialis*, *S. surangei* and *Singhisporites* sp. Interestingly,

all of these show baculate and spinate exosporia. Laevigate megaspores have not been recovered in this assemblage. Bacula are mostly simple, sometimes bifurcate, whereas, spines are highly diversified being simple, bi and multifurcate, thin and stout, straight and curved. Megaspores from the Barakar Formation of other areas of the Godavari Graben namely Mailaram (Jha & Tewari, 2003), Kachinapalli (Tewari *et al.*, 2007), Gundala (Jha *et al.*, 2006), Chelpur, Ramagundem (Jha & Srivastava, 1984) and Rampuram (Patil & Premchand, 2001) include laevigate and verrucate megaspores as well (Table 3). An analysis of Table 1 showing distribution of Goutham Khani megaspores in different Indian Lower Gondwana basins mainly Damodar, Mahanadi, Satpura and South Rewa reveals that all the species of the genus *Singhisporites* are widely distributed whereas, *Biharisporites spinosus* and *Jhariatriletes filiformis* are less common and are known from the Karharbari Formation of the Damodar Basin and the Raniganj/Kamthi Formation of the Mahanadi Basin. Table 2 reveals wide distribution of *Singhisporites radialis* followed by *Singhisporites nautiyalii* in different areas of the Godavari Graben. Other megaspores are restricted to few areas.

PLATE 3

(Scale bar = 100 μm)



1. *Singhisporites radialis*, BSIP Slide No. 15440.
2. *Singhisporites surangei*, BSIP Slide No. 15441.
3. *Singhisporites surangei*, BSIP Slide No. 15442.
4. *Singhisporites surangei*, BSIP Slide No. 15443.

5. *Singhisporites surangei*, BSIP Slide No. 15444.
6. A portion of megaspore in 5 enlarged (x 3.5) to show ornamentation, BSIP Slide No. 15444.

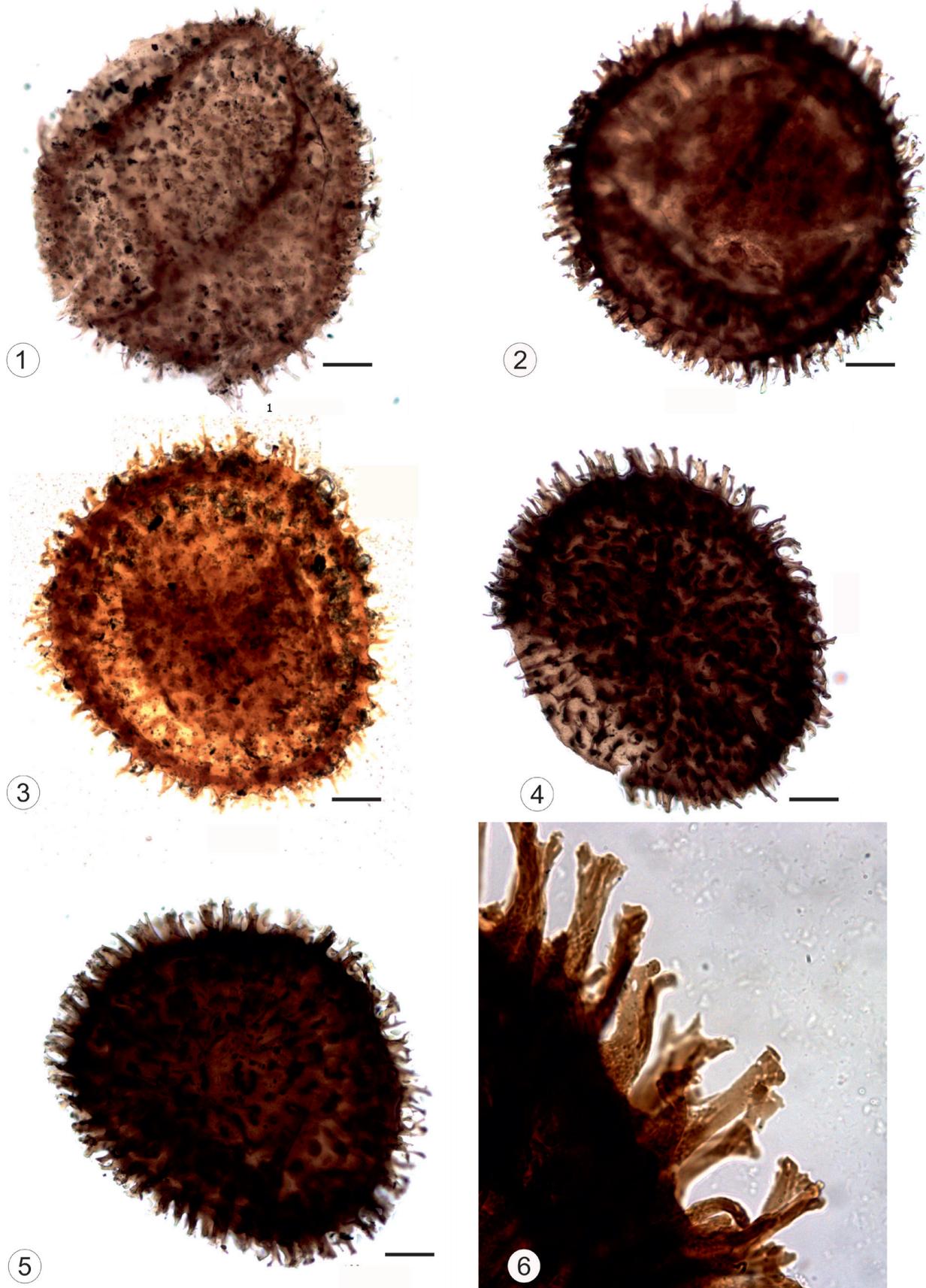


PLATE 3

Table 3—Distribution of megaspores in different areas of Godavari Graben.

Taxa	Rampuram B	Chelpur KM	Ramagundem KM	Kachinapalli B	R	Mailaram R	Gundala B	Kothagudem B
<i>Ancorisorites godavariensis</i>	+							
<i>Banksisorites utkalensis</i>				+	+	+	+	
<i>Biharisorites sparsus</i>					+			
* <i>Biharisorites spinosus</i>						+		+
* <i>Biharisorites</i> sp. A (in Tewari <i>et al.</i> , 2009)								+
<i>Biharisorites</i> sp. (in Tewari <i>et al.</i> , 2007)					+			
* <i>Biharisorites</i> sp.								+
<i>Bokarospores rotundus</i>				+		+	+	
<i>Bokarospores</i> sp. (in Tewari <i>et al.</i> , 2007)				+				
<i>Gundalasporea spinosus</i>							+	
<i>Jhariatriletes baculosus</i>					+			
<i>Jhariatriletes srivastavae</i>					+			
<i>Jhariatriletes damudicus</i>					+			
* <i>Jhariatriletes filiformis</i>					+			+
* <i>Jhariatriletes</i> sp.								+
<i>Kamthispora raniganjensis</i>						+		
<i>Kamthispora mailaramensis</i>						+		
<i>Kamthispora ramanamurthyi</i>						+		
<i>Penchiella</i> sp.					+			
* <i>Singhisporites indica</i>					+			+
* <i>Singhisporites nautiyalii</i>				+	+			+
<i>Singhisporites baculatus</i>						+		
<i>Singhisporites godavariensis</i>					+			
* <i>Singhisporites surangei</i>				+				+
* <i>Singhisporites radialis</i>		+	+	+	+	+		+
* <i>Singhisporites</i> sp.								+
<i>Talchirella trivedii</i>							+	

B: Barakar Formation, R: Raniganj Formation, KM: Kamthi Formation.

*Megaspores of present study.

PLATE 4
(Scale bar = 100 µm)



- | | |
|--|---|
| <p>1. <i>Singhisporites surangei</i>, BSIP Slide No. 15445.</p> <p>2. A portion of megaspore in 1 enlarged (x 3.5) to show ornamentation, BSIP Slide No. 15445</p> <p>3. <i>Singhisporites surangei</i>, SEM photograph.</p> | <p>4. A portion of megaspore in 3 enlarged (x 5) to show ornamentation.</p> <p>5. <i>Singhisporites</i> sp., SEM photograph.</p> <p>6. <i>Singhisporites</i> sp., SEM photograph.</p> |
|--|---|

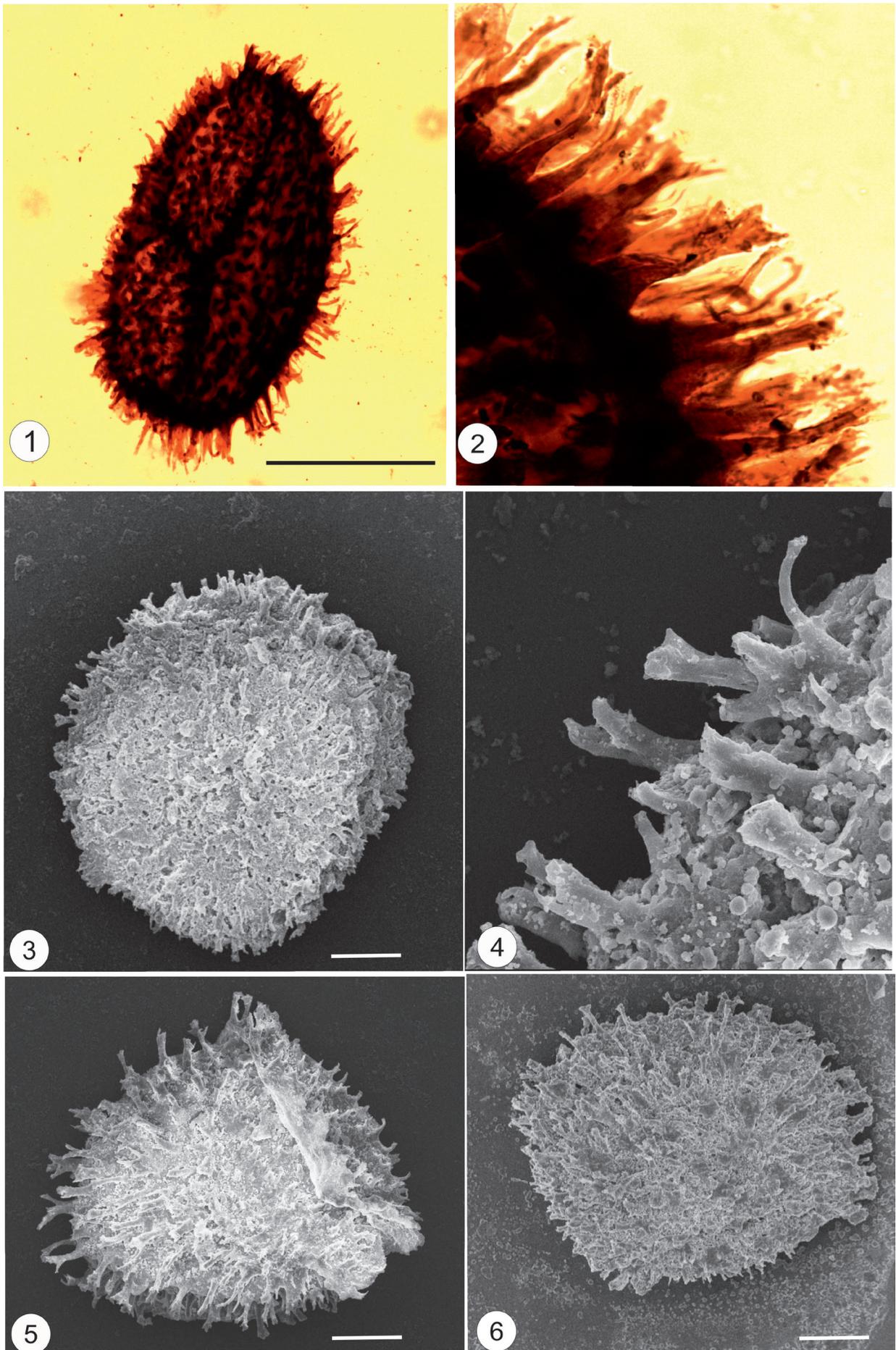


PLATE 4

Earlier records from the Godavari Graben reveal that megaspores from the Barakar Formation of this Graben were mostly laevigate, verrucate, sometimes spinate, whereas those of Raniganj/Kamthi Formation were by and large spinate, with highly diversified spines (Table 3). The present study indicates presence of dense spines in almost all the taxa recorded from the Barakar Formation of Goutham Khani OCM. Apparently, the megaspores with dense spinate exosporia appeared in the Barakar Formation and continued up to the late Permian. An analysis of the Lower Gondwana megaspores in general, reflects on the developmental pattern of their exosporia which are simple laevigate, verrucate, baculate, rarely spinate during the Talchir and the Karharbari formations and mostly spinate during the Barakar and the Raniganj formations. Since the spines help in floatation of megaspores, they indicate aquatic environmental conditions. Megaspores with different kinds of ornamentations such as coni, bacula, ribbon like appendages and simple, bi and multifurcate spines point towards presence of diverse heterosporous cryptogams (lycopsids, sphenopsids), the megafossils of which are not recorded from the entire Godavari Graben in general, and Kothagudem Area, in particular.

Acknowledgements—We thank Prof. Sunil Bajpai, Director, Birbal Sahni Institute of Palaeobotany (BSIP) for providing necessary facilities to carry out this research work and granting permission to publish the paper (BSIP/RDCC/Publication 61/2015); Mr K. Joshuva Jaidev, GM (Exploration), Exploration Division, Mr K. Ravi Shankar, General Manager (HRD), Mr Gurumurthy, Singareni Collieries Company Ltd. Kothagudem for granting permission to visit the colliery and for providing necessary help during field trip and Mr Shekhar, Area Survey Officer, Manuguru Area, Kothagudem region, for help in preparation of litholog and in sample collection. We are also thankful to Dr SSK Pillai, Scientist–C and Dr Deepa Agnihotri, Scientist–B, BSIP for their help during field trip and collection of samples. Thanks are due to the two reviewers for critically going through the manuscript.

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