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Palynostratigraphy and palaeoenvironment of the Permian sediments in Mand Coalfield, Mahanadi Basin, Chhattisgarh, India

SAURABH GAUTAM*, MADHUMITA DAS AND BHASKAR BEHERA

Fakir Mohan University, Vyasa Vihar, Nuapadhi, Balasore 756020, (Odisha), India.
**Corresponding author: sbhgtm@rediffmail.com*

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ABSTRACT

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Palynological investigation of 483.00 m deep subsurface Permian sediments of borehole MSK–1, in Sithra–Kurekela Block of Mand Coalfield, revealed four distinct palynoassemblage zones. These palynoassemblages belong to Lower and Upper Barakar (Early Permian), Barren Measures and Raniganj (Late Permian) palynofloras of Indian Gondwana. The oldest Palynoassemblage–I, (*Scheuringipollenites barakarensis*) recorded between 483.60–309.00 m depths, shows dominance of non–striate bisaccate pollen grains chiefly — *Scheuringipollenites* followed by *Faunipollenites* in association with *Indotriradites, Dentatispora, Verrucosispora* and *Microbaculispora* related to Lower Barakar palynoflora. Palynoassemblage–II, (*Faunipollenites varius*) recorded between 303.40–139.40 m depths, showing the dominance of *Faunipollenites* in association with *Scheuringipollenites, Striatopodocarpites, Brevitriletes, Horriditriletes* and *Striamonosaccites*, indicates Upper Barakar palynoflora. Palynoassemblage–III, (*Densipollenites indicus*) recorded between 135.55 to 92.50 m depths, showing the prominence of enveloping monosaccate pollen (*Densipollenites*) in association with *Faunipollenites, Microfoveolatispora, Striatopodocarpites* and *Verticipollenites*, indicates Barren Measures palynoflora. Palynoassemblage–IV, (*Densipollenites magnicorpus*) recorded between 90.90–27.00 m depths, is characterized by the dominance of striate bisaccate pollen taxa chiefly *Striatopodocarpites* and *Faunipollenites* along with *Densipollenites, Navalesporites, Distriatites, Hamiapollenites, Crescentipollenites* and *Guttulapollenites* indicating late Permian (Raniganj) age. Raniganj palynoflora has been demarcated in lithologically designated Barren Measures Formation. This is the first report of Late Permian (Raniganj) palynoflora from Sithra–Kurekela area of this coalfield. The age correlation also gets support from comparative studies with similar palynoassemblages known from Indian Gondwana. Palynofloral evidences indicate the prevalence of warm and humid conditions. Dominance of gymnosperms represented by glossopterids, conifers and cordaites along with low percentage of trilete spores (filicopsids and sphenopsids) suggests that the sediments were deposited under fresh to brackish water environment.

Key–words—Palynology, Permian, Palaeoenvironment, Mand Coalfield, Chhattisgarh.

भारत में छत्तीसगढ़ की महानदी द्रोणी के मंड कोयलाक्षेत्र में पर्मियन अवसादों का परागाणु स्तरक्रमविज्ञान एवं पुरापर्यावरण

सौरभ गौतम, मधुमिता दास एवं भास्कर बेहरा

सारांश

मंड कोयलाक्षेत्र के सिथरा–कुरेकेला खंड में वेध–छिद्र एमएसके–1 के 483.00 मी. गहरी उपपृष्ठीय पर्मियन अवसादों के परागाणविक अन्वेषण ने चार विशिष्ट परागाणु समुच्चय मंडलों का खुलासा किया। ये परागाणु समुच्चयें भारतीय गोंडवाना की निचली और ऊपरी बराकार (प्रारंभिक पर्मियन), बंजर संस्तर और रानीगंज (विलंबित पर्मियन) की हैं। 483.60–309.00 मी. गहराइयों के मध्य अभिलिखित प्राचीनतम परागाणुसमुच्चय–I, (*स्युरिंगीपॉलेनाइट्स बराकारेन्सिस*) अधो बराकार परागाणु वनस्पति–जात से संबंधित *इंडोट्रिरेडाइट्स, देंडेटीस्पोरा वेर्रुकोसीस्पोरा* और *माइक्रोबेकुलीस्पोरा* के साहचर्य में गैर–रेखीय द्विसपुट पराग मुख्यतः – *फॉनीपॉलेनाइट्स* के अनुगामी *स्युरिंगीपॉलेनाइट्स* की प्रभुत्वता दर्शा रहा है। 303.40–139.40 मी. गहराइयों के मध्य अभिलिखित परागाणुसमुच्चय–II, ऊपरी बराकार वनस्पति–जात इंगित करते हुए *स्युरिंगीपॉलेनाइट्स, स्ट्रीऐटोपोडोकार्पाइट्स, ब्रेविट्रीलेट्स, हार्रीडिट्रीलेट्स* एवं *स्ट्रिमोनोसैक्काइट्स* के साहचर्य में *फॉनीपॉलेनाइट्स,* की प्रभुत्वता दर्शा रहा है। 135.55 से 92.50 मी. गहराइयों के मध्य अभिलिखित परागाणु समुच्चय–III (*डेन्सीपॉलेनाइट्स इंडिकस*), बंजर

संस्तर परागाणु वनस्पति–जात इंगित करते हुए *फॉनीपॉलेनाइट्स, माइक्रोफोबियोलेटिस्पोरा, स्ट्रिएटोपोडोकार्पाइट्स* एवं *वर्टिसीपॉलेनाइट्स* के साहचर्य में अवगुंठित करते हुए एकल सपुट पराग (*डेन्सीपॉलेनाइट्स*) की उत्कृष्टता दर्शा रहा है। 90.90–22.00 मी. गहराइयों के मध्य अभिलिखित परागाणुसमुच्चय–IV (*डेन्सीपॉलेनाइट्स मैग्नीकार्पस*), *डेन्सीपॉलेनाइट्स, नेवलेस्पोराइट्स, डिस्ट्रीएटाइटिस, हैमियापॉलेनाइट्स, क्रिसेंटीपॉलेनाइट्स* और *गुट्टुलापॉलेनाइट्स* के साथ रेखीय द्विसपुट पराग मुख्यतः *स्ट्रिऐटोपोडोकार्पाइट्स* एवं *फॉनीपॉलेनाइट्स* की प्रभुत्वता से अभिलक्षणित विलंबित पर्मियन (रानीगंज) काल व्यंजित करती है। रानीगंज परागाणु वनस्पति–जात आश्मिक रूप से नामित बंजर संस्तर शैलसमूह से सीमांकित है। इस कोयलाक्षेत्र के सिथरा–कुरेकेला क्षेत्र से प्राप्त विलंबित पर्मियन (रानीगंज) परागाणु वनस्पति–जात का प्रथम वर्णन है। काल सहसंबंध भारतीय गोंडवाना से प्राप्त ज्ञात सदृश परागाणु समुच्चयों के साथ तुलनात्मक अध्ययनों से भी संबल प्राप्त होता है। परागाणु पुष्पी प्रमाण कोष्ण एवं आर्द्र स्थितियों की व्यापकता व्यंजित करते हैं। त्रिअरीयों (फिलिकॉप्सिड व स्फैनोप्सिड) की अल्प प्रतिशतता के साथ ग्लॉसोप्टेरिडों, शंकुवृक्षों एवं कॉर्डाइटों से रूपायित अनावृतबीजियों की प्रबलता जताती है कि अलवण से नुनखरा जल पर्यावरण के अंतर्गत अवसाद निक्षेपित हो गए थे।

सूचक शब्द—परागाणुविज्ञान, पर्मियन, पुरापर्यावरण, मंड कोयलाक्षेत्र, छत्तीसगढ़।

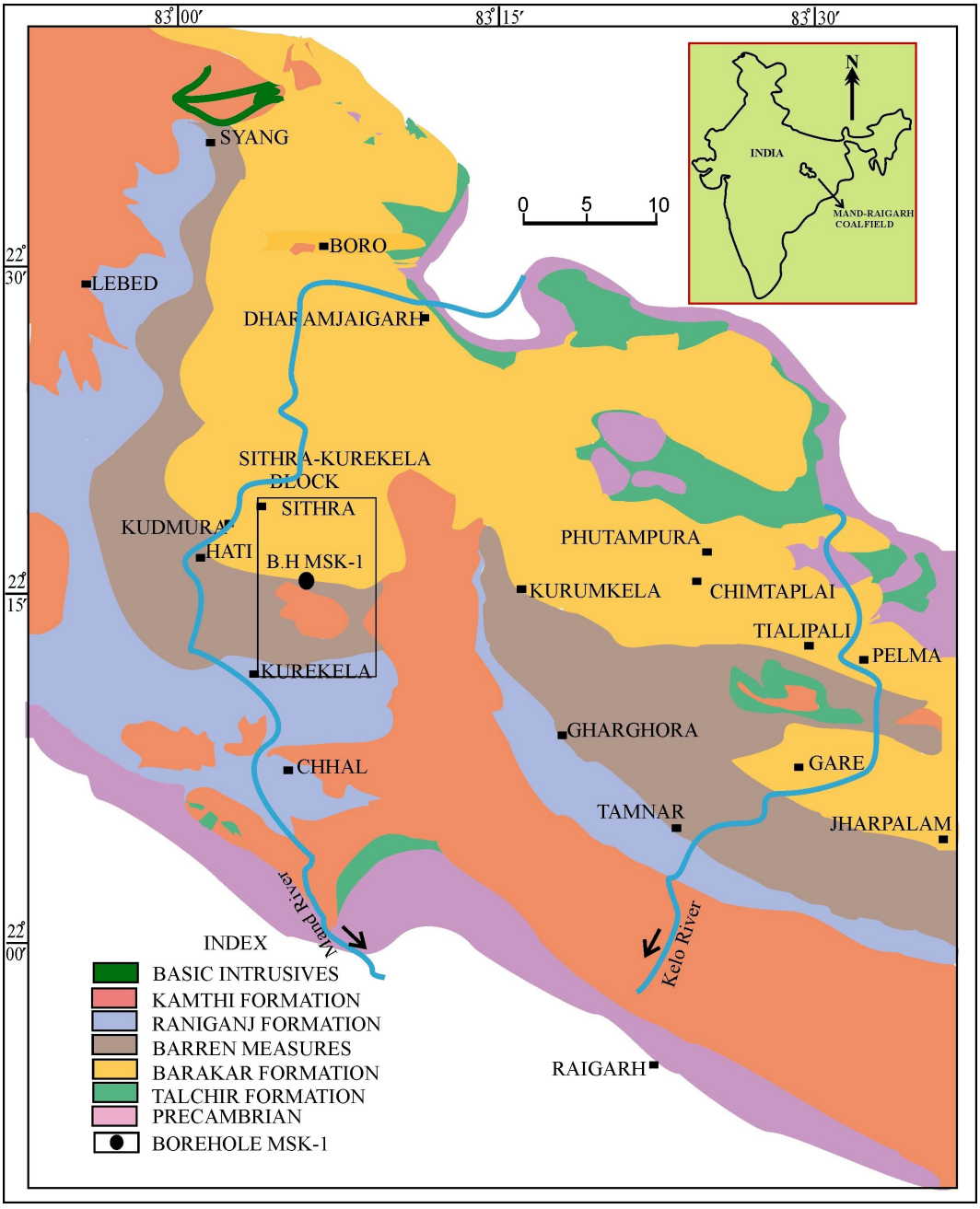

Fig. 1—Geological Map of the Mand–Raigarh Coalfield, showing location of Borehole MSK–1 (after Naik *et al.*, 2016).

INTRODUCTION

THE Mand–Raigarh Coalfield is located in the central part of the Upper Mahanadi Gondwana Master Basin and extends over a vast stretch from Sambalpur District, Odisha in the southeast, to the Surguja District of Chhattisgarh in the northwest. The Gondwana sediments are subdivided into different coalfields/ basins like Ib–River, Mand–Raigarh, Korba and Hasdo–Arand, mainly on the state or geographic boundaries. The state boundary between Chhattisgarh and Odisha is considered for the demarcation of the south eastern limit of Mand–Raigarh Coalfield. This coalfield covers the

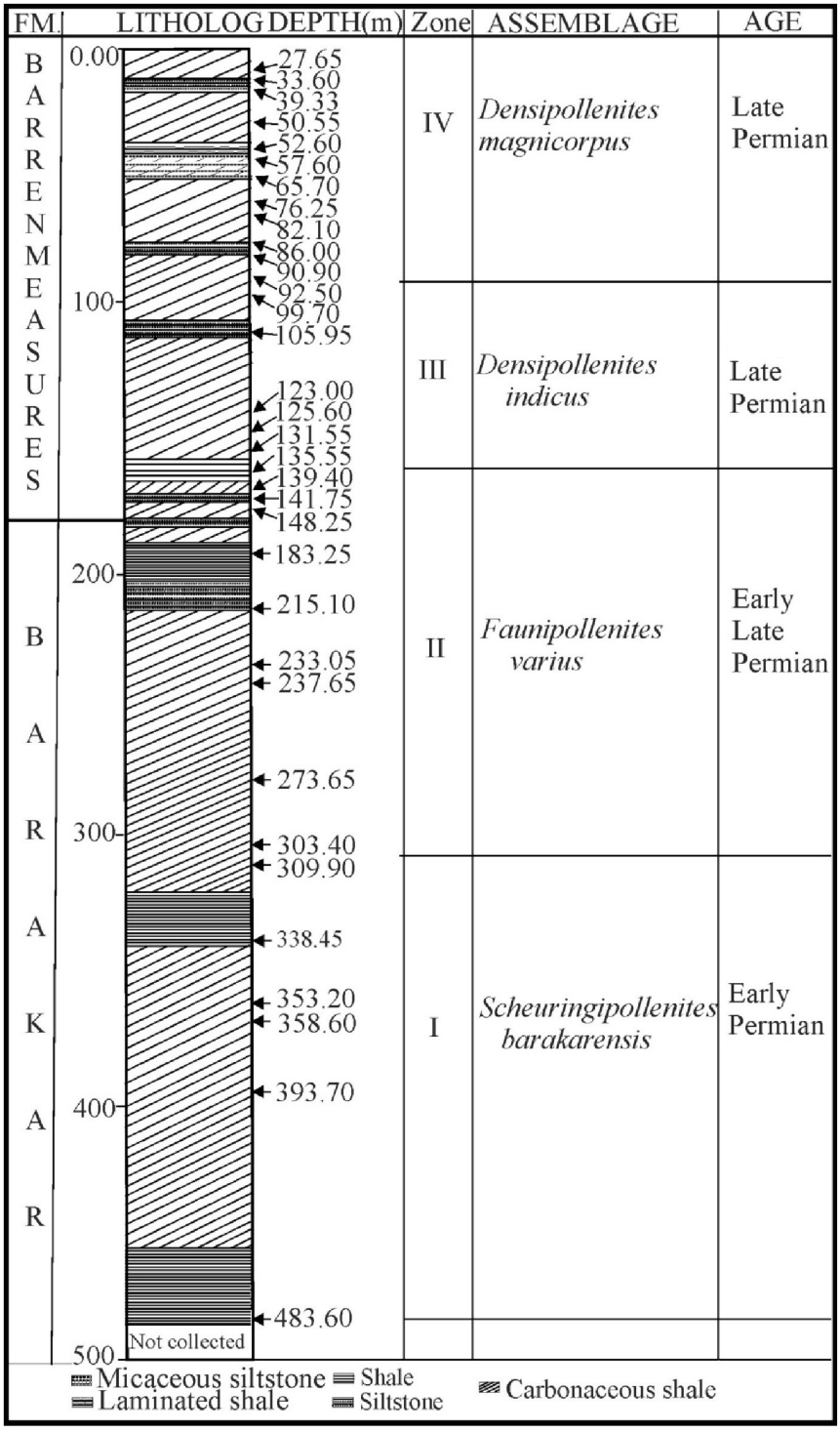

Fig. 2— Litholog showing position of samples and palynoassemblages identified in Borehole MSK–1.

		Depth (m)	Quantitatively Important taxa	Qualitatively Important taxa	Other taxa	Palyno-zones	Age
PALYNOASSEMBLAGES	(IV)	27.65-90.90	*Striatopodocarpites* (20-25-%), *Crescentipollenites* (12-15%) *Faunipollenites* (5-7%).	*Densipollenites* (5-6%), *Distriatites* (2-5%), *Guttulapollenites* (1-2%), *Hamiapollenites* (1-5%), *Horriditriletes* (1-2%), *Lahirites* (2-5%), *Lunatisporites* (5-7%), *Microbaculispora* (1-2%), *Navalesporites* (1-2%), *Praecolpatites* (1-2%), *Striatites* (2-3%), *Stroter*sporites (2-5%) and *Verticipollenites* (1-2%).	*Brevitriletes* (2-3%), *Cuneati-sporites* (1-2%) and *Latosporites* (1%).	Raniganj	Late Permian
	(III)	92.50-135.55	*Densipollenites* (25-30%) *Faunipollenites* (10-15%) *Striatopodocarpites* (8-10%).	*Crescentipollenites* (2-7%), *Distriatites* (5-8%), *Hamiapollenites* (1-2%), *Horriditriletes* (1-4%), *Lacinitriletes* (1-2%), *Lahirites* (1-5%), *Latosporites* (1-2%), *Lunatisporites* (2-5%), *Microbaculispora* (1%), *Primuspollenites* (1%), *Scheuringipollenites* (1-2%), *Striatites* (2-6%) and *Verticipollenites* (1-5%).	*Brevitriletes* (1-2%), *Corisaccites* (1%), *Cuneatispo-rites* (1-2%), *Sahnites* (1%), *Rhizomaspora* (1-2%), and G*inkgocyca-dophytus* (1%).	Barren Measures	Early Late Permian
	(II)	139.40-303.40	*Faunipollenites* (25-30%), *Striatopodocarpites* (5-10%) *Scheuringipollenites* (10-20%)	*Brevitriletes* (2-4%), *Caheniasaccites* (1%), *Crescentipollenites* (5-10%), *Cuneatisporites* (3-5%), *Distriatites* (3-5%), *Dentatispora* (2-4%), *Horriditriletes* (1-2%), *Ibisporites* (2-3%), *Indotriradites* (1-2%), *Latosporites* (1-2%), *Lunatisporites* (1-2%), *Parasaccites* (2-5%), *Primuspollenites* (2-3), *Rhizomaspora* (1-3%), *Striatites* (3-5%) and *Verticipollenites* (2-5%)	*Circumstria-tites* (1-2%), *Cyclograni-sporites* (1%), *Leiosphae-ridia* (1-2%), *Sahnites* (1-2%), *Tetraporina* (1-2%) and *Ginkgocyca-dophytus* (1-2%).	Upper Barakar	Late Early Permian
	(I)	309.90-483.60	*Scheuringipollenites* (25-35%) *Faunipollenites* (15-20%) *Striatopodocarpites* (10-15%)	*Brevitriletes* (2-3%), *Circumstriatites* (1-2%), *Corisaccites* (1-2%), *Crescentipollenites* (5-7%), *Cuneatisporites* (3-5%), *Latosporites* (1-2%), *Lunatisporites* (1-2%), *Primuspollenites* (2-3%), *Parasaccites* (8-10%), *Striatites* (2-3%), *Verticipollenites* (2-3%)	*Cyclograni-sporites* (1-3%), *Sahnites* (1-2%) and *Ginkgocyca-dophytus* (2-3%).	Lower Barakar	Early Permian

Fig. 3—Showing palynocomposition and palynoassemblages identified in Borehole MSK–1.

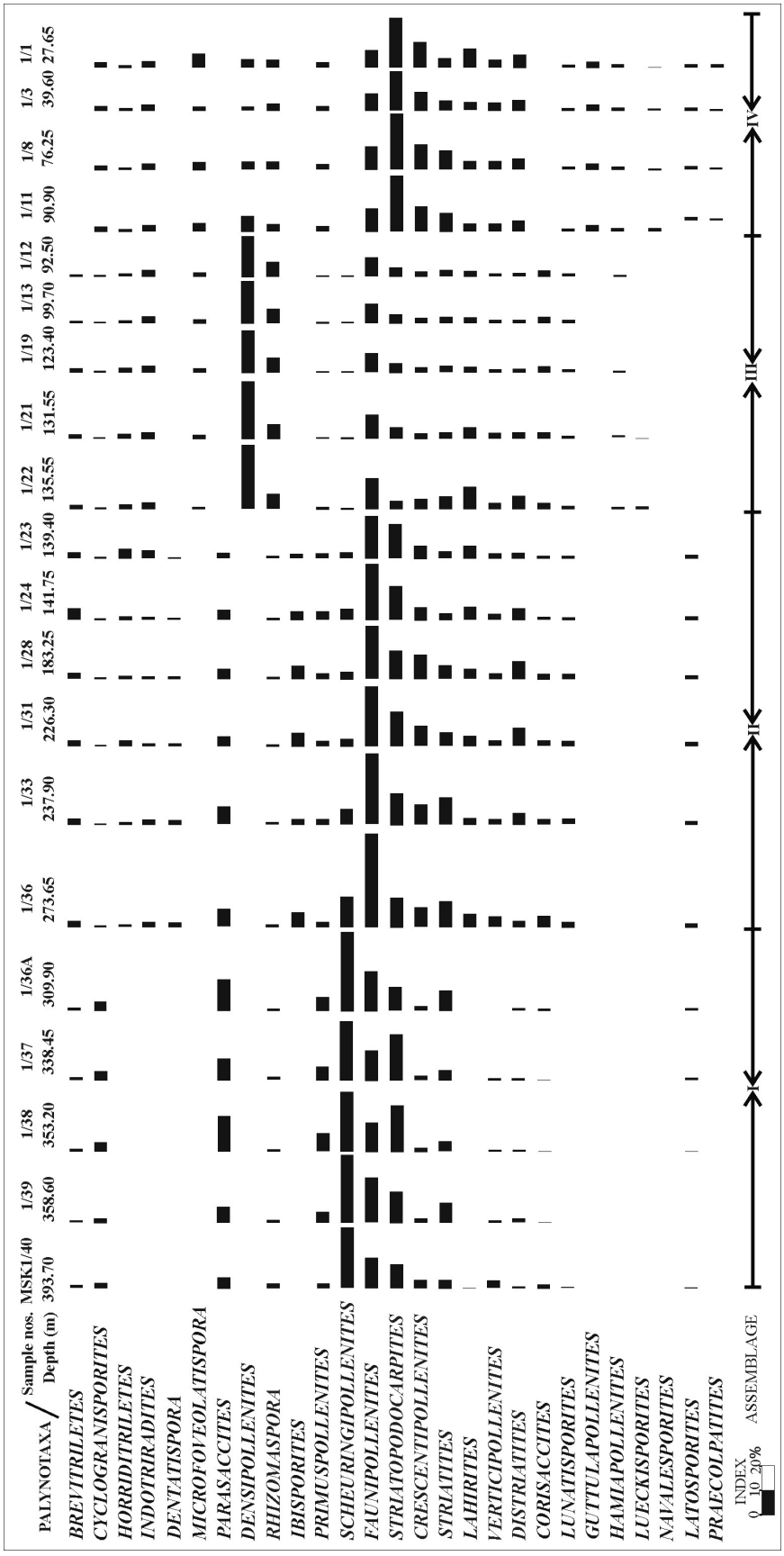

Fig. 4—Histogram showing vertical distribution of palynotaxa in Borehole MSK–1.

areal extents of three initially assigned coalfields namely, North Raigarh, South Raigarh and Mand River coalfields (Raja Rao, 1983). Later, on the basis of tectonic and lithostratigraphic modelling Chakraborti (2001) suggested the subdivision of Mahanadi Master Basin into–Talcher, Raigarh, IB, Mand, Korba and Hasdo–Arand coalfields. The north and western parts of the Mand–Raigarh Coalfield have been referred to Mand sub–basin. It is separated from Raigarh, Ib–River Basin in the east by N–S to NNE–SSW trending lineament passing the Konkori–Gersa–Sirsinga area. On the west it is separated from Korba Basin by NW–SE trending Mauhari–Machida lineament and from Hasdo–Arand Basin in the north by well defined E–W trending Dhirpada–Kedma–Chornai shear zone. The boundaries the Mand sub–basin acquire NNW–SSE to NW–SE trending asymmetrical shape with an aerial extent of about 2000 sq km and bounded by latitudes 22°05'00" to 22°47'00" N and longitudes 82°55'00" to 83°15'00" E (Fig. 1).

Palaeobotanical data from Mand–Raigarh Coalfield are meagre and scattered. However, different species of *Glossopteris indica, Vertebraria indica* and *Schizoneura* sp. have been reported from the Barakar and Kamthi formations of Raigarh Basin (Raja Rao, 1983). Pal (1984) reported *Glossopteris indica, G. raniganjensis, G. gondwanensis, G. angustifolia, Vertebraria indica, Phyllotheca* sp. and *Schizoneura* sp. from the Kamthi Formation of Raigarh Coalfield around Bichpahari and Paharphore areas and assigned late Permian age. Subsequently, Bandhopadhyay (1989) also recorded *Glossopteris* and *Samaropsis* sp. in association with fossil fauna–fenestillid *Bryozoa* and non–calcareous fresh to brackish water estherids (*Palaeoliminia diopsis*) from the marlstone bed exposed near Baronakund area and equated it to late Permian age. Chakraborti (2001) has also recorded mega plant fossils like–*Glossopteris indica, G. gondwanensis, G. angustifolia, Vertebraria indica, Phyllotheca* sp., *Schizoneura* sp*., Elatocladus helle* and *Sphenopteris* sp. from the Lower Kamthi bed of the Raigarh Coalfield. Chakraborti and Chakraborty (2001) have recorded Early to Middle Triassic plant megafossils *Baiera* and *Pterophyllium,* and microfossils *Alisporites, Falcisporites, Klausipollenites* and *Weylandites* from the Kamthi Formation, near Baronakund area, Raigarh Coalfield. In addition, Jana *et al.* (2002), Chakraborty (2003), Chakraborti and Ram–Awatar (2006), Ram–Awatar (2007) have recorded early to late Permian palynoflora from this coalfield. Besides, Murthy *et al*. (2014a) have recorded early and late Permian palynofossils from Mand Basin. They also discussed the phytogeographic provincialism on the basis of *Guttulapollenites*. Recently, Mahesh *et al.* (2017) have recorded the macroscopic charcoal remains from the Mand Coalfield and suggested a positive evidence of wildfire in late Permian Gondwana sediments of this basin. Further, on the basis of petrological study, they suggested that these charcoals are formed at a temperature of more than 500°C, and nature of deposition of these charcoals was hypo–autochthonous.

In the present investigation, an early and Late Permian palynofossils have been recorded from Borehole MSK–1, which is an important finding for correlating the coal seams in the area. The late Permian (=Raniganj) equivalent palynoflora recovered from the lithologically designated Barren Measures strata is a major outcome of the present study.

GEOLOGY OF THE AREA

The Gondwana sediments of Mand sub basin are juxtaposed against the quartzite of Chandrapur Group (Chhattisgarh Supergroup) in the southwest and the meta–igneous and igneous rocks of Raigarh–Sundargarh schist belt in the northwest. The geology of the Mand–Raigarh Basin has undergone a major change when regional exploration and large scale mapping was carried out over a large part of the basin by Chakraborti *et al.* (2002). On the basis of lithological attributes, the total sedimentary package of the basin has been re–categorized into Talchir, Barakar, Barren Measures, Raniganj and Kamthi formations. The stratigraphic sequence of the Mand Coalfield is shown in Table 1 (after Chakraborti *et al*., 2002).

MATERIAL AND METHODS

The materials for the present investigation were provided by the GSI, camping at Dharanjaygarh, district

PLATE 1

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1. *Horriditriletes curvibaculosus* Bharadwaj & Salujha, 1964; Slide no. MSK1–39/1, coordinates 14 × 107.
2. *Navalesporites spinosus* Sarate & Ram–Awatar, 1984; Slide no. MSK1–1/1, coordinates 17 × 112.
3. *Trabeculosporites gopadensis* Trivedi & Misra emend. Tiwari & Ram–Awatar, 1992; Slide no. MSK1–38/1, coordinates 09 × 112.
4. *Densipollenites indicus* Bharadwaj, 1962; Slide no. MSK1–5/3, coordinates 12 × 120.

5,7. *Densipollenites invisus* Bharadwaj & Salujha, 1964; Slide nos. MSK1–12/1, coordinates 06 × 129, MSK1–22/2, coordinates 07 × 109.

6. *Densipollenites magnicorpus* Tiwari & Rana, 1981; Slide no. MSK1–5/2, coordinates 15 × 120.
8. *Lueckisporites virkkiae* Potonié & Klaus, 1954; Slide no. MSK1–24/1, coordinates 12 × 122.
9. *Scheuringipollenites barakarensis* (Tiwari) Tiwari, 1973; Slide no. MSK1–37/1, coordinates 17 × 117.
10. *Parasaccites* sp. cf. *P. densicorpus* Lele, 1975; Slide no. MSK1–23/1, coordinates 07 × 117.
11. *Corisaccites alutus* Venkatachala & Kar, 1966; Slide no. MSK1–32/2, coordinates 12 × 112.
12. *Faunipollenites varius* Bharadwaj, 1962 emend. Tiwari *et al.,* 1989; Slide no. MSK1–32/ 2, coordinates 06 × 113.

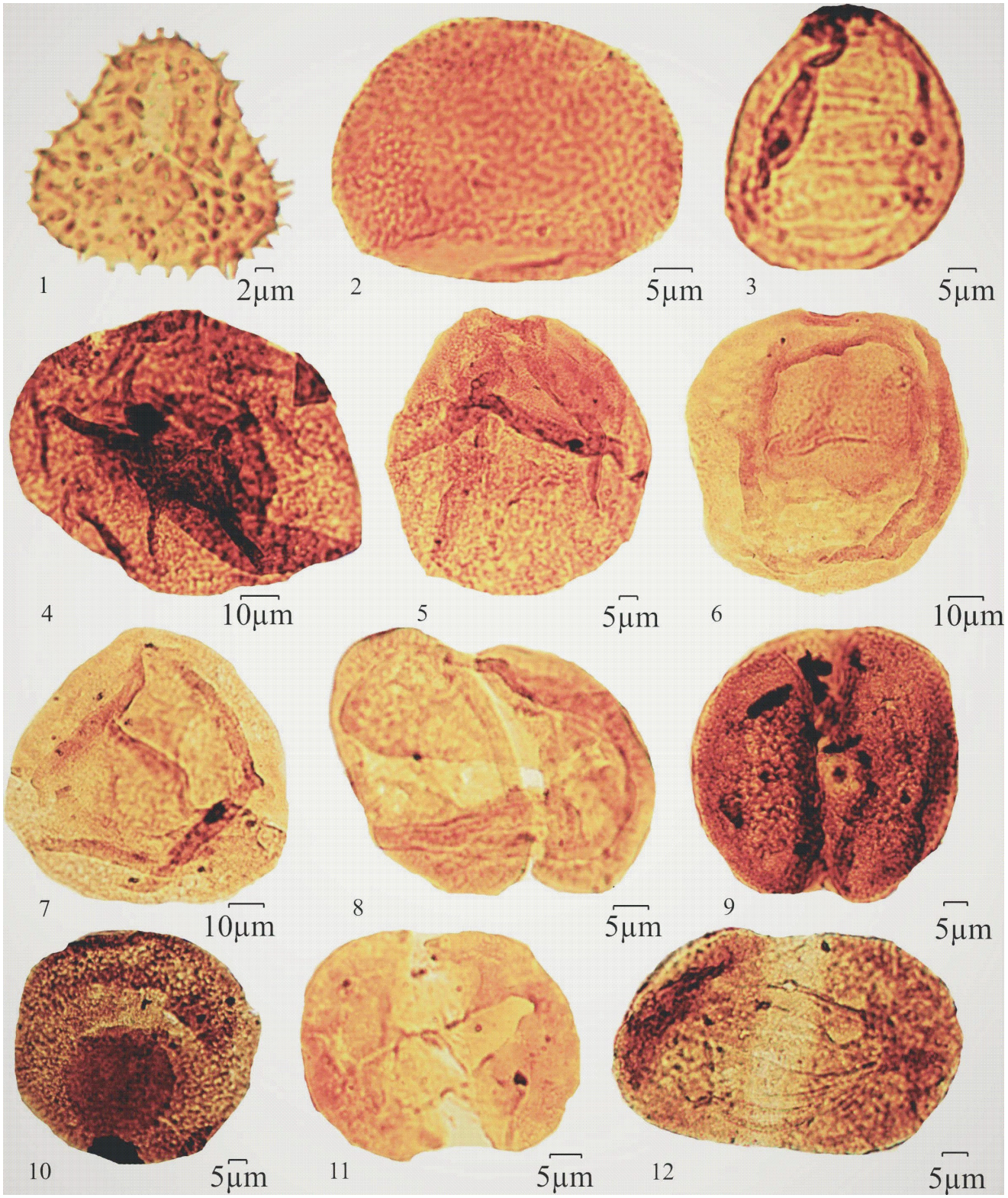
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PLATE 1

Raigarh, Chhattisgarh, India (Fig. 1). The lithological details of productive samples are given in Table 2. For recovery of spores and pollen grains, samples (5–10 g) were first crushed into small pieces (1–2 mm in size). Thereafter, these samples were treated with hydrofluoric acid (40% concentration) for 3–4 days to dissolve the siliceous components, followed by concentrated nitric acid (HNO_3) treatment for 2–4 days to digest the organic matter and finally 5–10% (KOH) to remove the humus. The samples were washed thoroughly with water after each step. Throughout the procedure, the maceration process was carefully monitored under a microscope. After through wash, the residue was mixed with polyvinyl alcohol, smeared over cover glass and kept for drying at room temperature. After complete drying, the cover glasses were mounted with canada balsam. Eight slides of each sample were prepared and dried in an oven. The quantitative and qualitative studies of productive samples and photomicrographs were taken with the help of high power Olympus Microscope (B.H. 2 Model, No. 216294). The productive slides have been deposited in the Department of Biosciences and Biotechnology, FM University, Balasore, Odisha.

PALYNOSTRATIGRAPHY

Out of 44 rock samples, only 32 were productive (Table 2). On the basis of the quantitative and qualitative distribution of various palynotaxa, four distinct palynoassemblages have been identified in borehole MSK–1 (Fig. 3). Some of the stratigraphically significant taxa have been illustrated in Pls 1, 2. The relative occurrences of the taxa considered in the assemblage are; rare (<1%), common (2–5%), fair (6–10%), subdominant (11–20%) and dominant (21–60%). The vertical distribution and percentage frequency of various palynotaxa have been shown in histogram (Fig. 4) and a complete check list of identified spore/pollen grains is given in Table 3.

PALYNOASSEMBLAGE–I

The Palynoassemblage–I has been marked at depth of 483.60–309.90 m (sample nos. 43–37A), lithologically represented by carbonaceous shale and shale units. It shows the dominance of non striate bisaccate pollen grains, viz. *Scheuringipollenites* (25–35%) and sub–dominance of striate bisaccate pollen grains, *viz. Faunipollenites* (15–20%) and *Striatopodocarpites* (10–15%). Other associated taxa present in the assemblage are–*Brevitriletes* (2–3%), *Circumstriatites* (1–2%), *Corisaccites* (1–2%), *Crescentipollenites* (5–7%), *Cuneatisporites* (3–5%), *Cyclogranisporites* (1–3%), *Distriatites* (1–2%), *Latosporites* (1–2%), *Lunatisporites* (1–2%), *Primuspollenites* (2–3%),*Parasaccites* (8–10%), *Striatites* (2–3%), *Sahnites* (1–2%), *Verticipollenites* (2–3%), *Verrucosisporites* (1%) and *Ginkgocycadophytus* (2–3%).

PALYNOASSEMBLAGE–II

The Palynoassemblage–II has been demarcated at depth of 303.40–139.40 m (sample nos. 36–23) lithologically represented by carbonaceous shale, siltstone and shale units. It shows the dominance of striate bisaccate pollen grains, viz. *Faunipollenites* (25–30%), *Striatopodocarpites* (5–10%) and sub–dominance of non–striate bisaccate pollen grains, *viz*. *Scheuringipollenites* (10–20%). Other associated taxa present in the assemblage are–*Brevitriletes* (2–4%), *Caheniasaccites* (1%), *Circumstriatites* (1–2%), *Crescentipollenites* (5–10%), *Cuneatisporites* (3–5%), *Cyclogranisporites* (1%), *Distriatites* (3–5%), *Dentatispora* (2–4%), *Horriditriletes* (1–2%), *Ibisporites* (2–3%), *Indotriradites* (1–2%), *Latosporites* (1–2%), *Leiotriletes* (1%), *Leiosphaeridia* (1–2%), *Lunatisporites* (1–2%), *Parasaccites* (2–5%), *Primuspollenites* (2–3%), *Rhizomaspora* (1–3%), *Sahnites* (1–2%), *Striatites* (3–5%), *Tetraporina* (1–2%), *Verticipollenites* (2–5%) and *Ginkgocycadophytus* (1–2%).

PALYNOASSEMBLAGE–III

The Palynoassemblage–III has been distinguished at depth of 135.55–92.50 m (sample nos. 22–12) lithologically represented by carbonaceous shale, siltstone and shale units. It shows the dominance of enveloping monosaccate viz. *Densipollenites* (25–30%) , sub–dominance of striate bisaccates, viz. *Faunipollenites* (10–15%) and *Striatopodocarpites* (8–10%). Other associated taxa present in the assemblage are −*Brevitriletes* (1–2%), *Corisaccites* (1%), *Crescentipollenites* (2–7%), *Cuneatisporites* (1–2%), *Distriatites* (5–8%), *Hamiapollenites* (1–2%), *Horriditriletes* (1–4%), *Lacinitriletes* (1–2%), *Lahirites* (1–5%), *Latosporites* (1–2%), *Lunatisporites* (2–5%), *Microbaculispora* (1%), *Microfoveolatispora* (1–2 %), *Primuspollenites* (1%), *Rhizomaspora* (1–2%), *Sahnites* (1%), *Scheuringipollenites* (1–2%), *Striatites* (2–6%), *Verticipollenites* (1–5%) and *Ginkgocycadophytus* (1%).

PALYNOASSEMBLAGE–IV

The Palynoassemblage–IV has been discriminated in carbonaceous shale, micaceous siltstone, laminated shale and siltstone samples between depth 90.90–27.65 m (sample nos. 11–1). The assemblage is characterized by the dominance of striate bisaccate pollen grains, viz. *Striatopodocarpites* (20–25%), *Crescentipollenites* (12–15%) and *Faunipollenites* (5–7%). Other associated taxa present in the assemblage are −*Brevitriletes* (2–3%), *Cuneatisporites* (1–2%), *Densipollenites* (5–6%), *Distriatites* (2–5%), *Guttulapollenites* (1–2%), *Hamiapollenites* (1–5%), *Horriditriletes* (1–2%), *Lahirites* (2–5%), *Latosporites* (1%), *Lunatisporites* (5–7%), *Microbaculispora* (1–2%), *Navalesporites* (1–2%), *Praecolpatites* (1–2%), *Striatites*

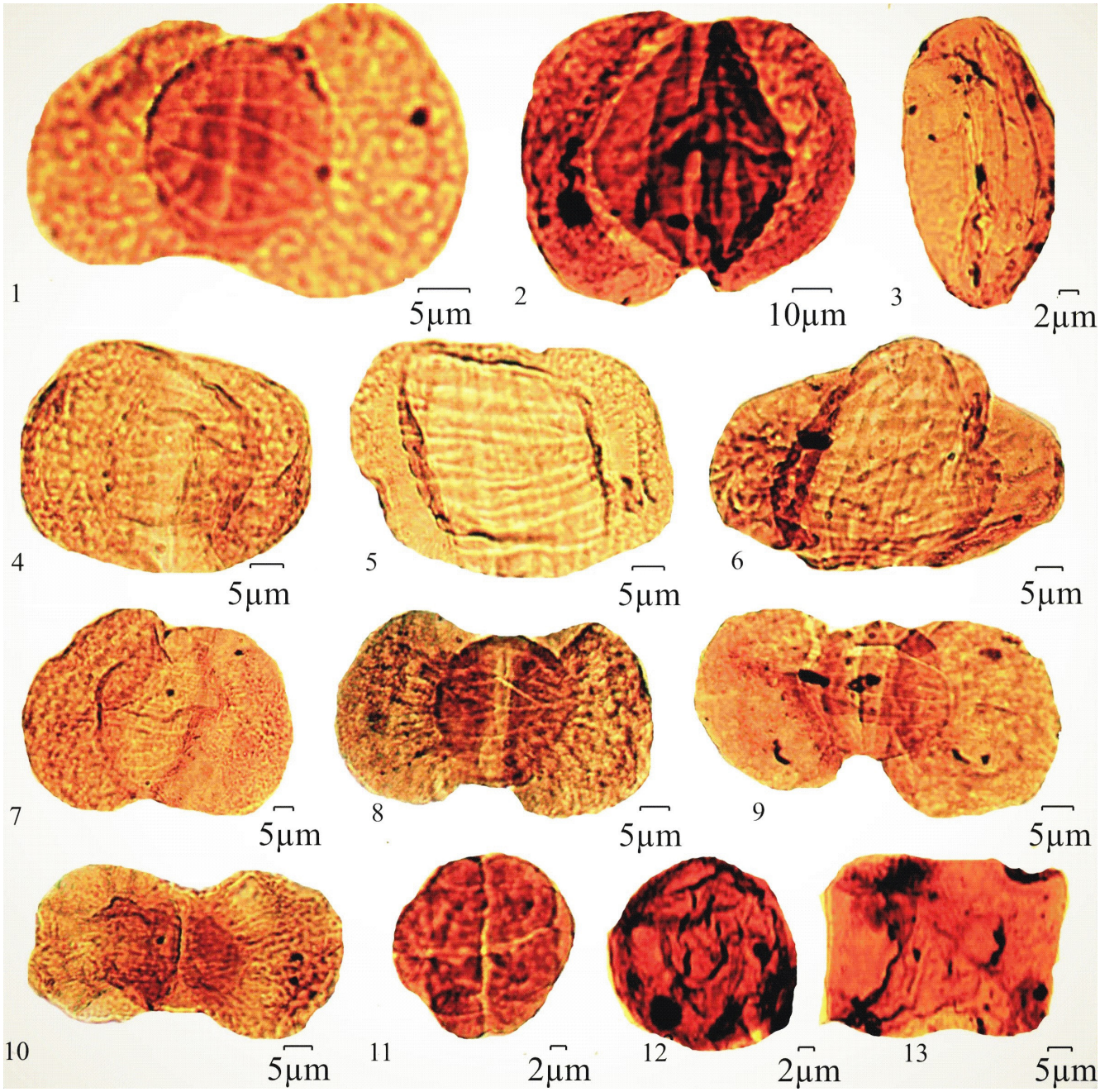

PLATE 2

1. *Lunatisporites ovatus* (Goubin) Maheshwari & Banerji, 1966; Slide no. MSK1–30/ 1, coordinates 07 × 120.
2. *Crescentipollenites fuscus* (Bharadwaj) Bhardwaj *et al.,* 1974; Slide no. MSK1–18/ 4, coordinates 17 × 119.
3. *Praecolpatites nidpurensis* Bharadwaj & Srivastava, 1969; Slide no. MSK1–32/1, coordinates 05 × 118.
4. *Faunipollenites perexiguus* Bharadwaj emend. Tiwari *et al.,* 1989; Slide no. MSK1–33/1, coordinates 10 × 105.
5. *Distriatites insolitus* Bhardwaj & Salujha, 1964; Slide no. MSK1–33/ 1, coordinates 11 × 118.
6. *Hamiapollenites insolitus* Bharadwaj & Salujha, 1964; Slide no. MSK1–24/ 2, coordinates 17 × 126.
7. *Striatopodocarpites magnjficus* Bharadwaj & Salujha, 1964; Slide no. MSK1–30/ 1, coordinates 21 × 117.
8. *Striatites communis* Bharadwaj & Salujha, 1964; Slide no. MSK1–1/ 13/1, coordinates 10 × 104.
9. *Lahirites raniganjensis* Bharadwaj, 1962; Slide no. MSK1–36/1, coordinates 08 × 121.
10. *Verticipollenites crassus* Bharadwaj & Salujha, 1964; Slide no. MSK1–18/1, coordinates 05 × 126.
11. *Guttulapollenites hannonicus* Goubin, 1965; Slide no. MSK1–18/1, coordinates 09 × 127.
12. *Leiosphaeridia simplex* Sinha, 1969; Slide no. MSK1–12/1, coordinates 12 × 112.
13. *Tetraporina tetragona* (Pant & Mehra) Kar & Bose, 1976; Slide no. MSK1–25/1, coordinates 11 × 119.

Table 1—Generalized lithostratigraphy of the Mand–Raigarh Coalfield, Chhattisgarh (after Chakraborti *et al.*, 2002).

Age	Formation	Thickness	Lithology
Recent to sub–Recent			Alluvial soil, pebbly to bouldery bed with silty clay band, laterite, etc.
Cretaceous	Deccan Trap	200 m+	Basaltic and doleritic flows, dykes and sills.
Lower to Middle Triassic	Supra–Panchet /Kamthi	280 m+	Buff coloured, coarse to pebbly, cross bedded, reworked shaly clasts bearing sandstone with abundant ferruginous sandstone bands with/ without red claystone to siltstone or white marl bed at the base.
	Raniganj	180–250 m	Cyclic sequence of fine to medium grained sandstone, grey shale, claystone, carbonaceous shale and two coal seams.
Upper Permian	Barren Measures	280–350 m	Interbedded sequence of sideritic claystone, grey shale, siltstone and fine grained sandstone; carbonaceous shale and some medium grained sandstone bands in the east to dominantly medium to coarse grained sandstone with interbanded sequence of sideritic claystone, grey shale, siltstone and fine grained sandstone; carbonaceous shale and light green siltstone to sandstone bands.
To	B A R A K A R — Upper	180–220 m	Mostly medium to coarse grained sandstone with subordinate very coarse to pebbly massive arkosic sandstone. This fining upward sequence includes five regional coal seams (No. V to IX) and one local coal seam (No. VIIL). Grey claystone to siltstone bands are common at the top and bottom.
	— Middle	140–200 m	Mostly coarse to very coarse grained sandstone with granule to pebbly sandstone at the base of each depositional sequence. Fine grained sandstone and siltstone are rarely present. It contains five to six local seams (Nos./ bands IVL1 TO IVL6).
Lower Permian	— Lower	280–400 m	Mostly very coarse grained to granule sized arkosic sandstone with pink quartz and garnet grains and also with subordinate medium to coarse grained sandstone. It includes four regional coal seams (No. I IV). Pebbly to matrix–based conglomerate bands are common. Basal 40–50 m zone is fine to medium grained with minor siltstone.
Lowermost Permian to Upper Carboni–ferous	Talchir	200 m	Khaki to brownish green, siltstone, shale and fine grained sandstone with two boulder
			Unconformity
Late Proterozoic Group	Chandrapur		Variegated quartzite sandstone, calcareous, variegated shale.
			Unconformity
Early Proterozoic	Bilaspur, Raigarh, Sundargarh Complex.		Vein quartz, pegmatite, granite gneiss, massive granite, etc.

(2–3%), *Strotersporites* (2–5%) and *Verticipollenites* (1–2%). Palynocomposition of these four distinct palynoassemblages are summarized in Fig. 3.

DISCUSSION AND CONCLUSIONS

The foregoing account of the palynological study of the Lower Gondwana strata in Mand Coalfield suggests that rich and diversified vegetation grew in the region during the formation of these sediments. The palynoflora recovered from different formations has been assigned to thirty five genera and seventy seven species (Table 3). The quantitative analysis of various taxa at generic and species level shows a marked change in palynoflora from Barakar to Raniganj Formation. A total of four distinct palynoassemblages have been identified in coal bearing horizons of Lower Gondwana succession in the Sithra–Kurkela Block of Mand Coalfield, Mahanadi Basin, out of which Palynoassemblages–I and II belongs to Lower Coal horizons (Lower and Upper Barakar formations–early and late early Permian), Palynoassemblage–III belongs to Barren Measures–late Permian and youngest Assemblage–IV belongs to Upper Coal horizon (Raniganj Formation–late Permian; Fig. 2).

The Palynoassemblage–I, marked in the borehole MSK–1 (between 483.60–309.90 m depth) has yielded the dominance of nonstriate disaccate pollen taxa mainly *Scheuringipollenites* and striate disaccate pollen taxa *Faunipollenites* and *Striatopodocarpites* in association with *Brevitriletes, Circumstriatites, Crescentipollenites, Corisaccites, Cyclogranisporites, Cuneatisporites, Distriatites, Latosporites, Lunatisporites, Primuspollenites, Parasaccites, Striatites, Striatopodocarpites, Sahnites, Verticipollenites* and *Ginkgocycadophytus*. Dominance of *Scheuringipollenites* and sub–dominance *Faunipollenites* and palynoassemblage recorded in Borehole MSK–1 can be correlated with known Lower Barakar palynofloral assemblages recorded from other coalfields of India, namely Korba Coalfield (Zone–3 of Bharadwaj & Srivastava, 1973); Giridih Coalfield (Zone 2 of Srivastava, 1973); Johilla Coalfield (Zone 3 of Anand–Prakash & Srivastava, 1984); Umaria Coalfield (Zone 3 of Srivastava & Anand–Prakash, 1984); Sohagpur Coalfield (Palynoassembalge–II of Ram–Awatar 1996; Palynoassemblage–I of Gautam *et al.*, 2014); Pathakhera Coalfield (Assemblage–II of Sarate, 1986; Zone–2 of Srivastava & Sarate, 1989); Raniganj Coalfield (Zone–4 of Tiwari, 1973; Assemblage–II of Murthy *et al*., 2010); Jharia Coalfield (Tiwari *et al*., 1981; Tripathi & Tiwari, 1982); South Karanpura Coalfield (Zone–A of Bhardwaj & Tripathi, 1978); Talcher Coalfield (Assemblage–II of Tripathi, 1997; Assemblage–2 of Tripathi & Bhattacharya, 2001); Ib River Coalfield (Palynozone–II of Meena, 2000); Mand–Raigarh Coalfield (Assemblage–C of Jana *et al*., 2002; Assemblage–II of Chakraborty, 2003; Assemblage–A of Chakraborti & Ram–Awatar, 2006; Palynoassemblage–III of Murthy *et al*., 2014a); Singrauli Coalfield (Assemblage III of Vijaya *et al*., 2012); Pench Valley Coalfield (Assemblage–I of Murthy *et al*., 2013); Godavari Valley Coalfield ─ (Assemblage–C of Ramagundam area, Srivastava & Jha, 1989; Palynozone–4 of Ramakrishnapuram area, Srivastava & Jha, 1992; Budharam area, Srivastava & Jha, 1995; Palynozone–2 of Koyagudem area, Srivastava & Jha, 1996; Palynozone–3 of Mailaram area, Jha & Aggarwal, 2012; Palynozone–4 of Aggarwal & Jha, 2013). All the assemblages mentioned above are dominated by *Scheuringipollenites* and show sub dominance of *Faunipollenites* and *Striatopodocarpites* within the *Scheuringipollenites barakarensis* Assemblage Zone IV of Tiwari and Tripathi (1992).

The Palynoassemblage–II, identified in the borehole MSK–1 (between 303.40–139.40 m depth) represents the Upper Barakar palynoflora due to high incidence of striate disaccate pollen taxa mainly *Faunipollenites* and *Striatopodocarpites* along with sub–dominance of *Scheuringipollenites*. The other palynoflora recorded in the assemblage are ─*Brevitriletes, Caheniasaccites, Circumstriatites, Cuneatisporites, Crescentipollenites, Cyclogranisporites, Distriatites*, *Dentatispora*, *Horriditriletes, Ibisporites, Indotriradites, Lacinitriletes*, *Lahirites*, *Latosporites*, *Lunatisporites, Primuspollenites*, *Parasaccites*, *Rhizomaspora*, *Striatites* and *Verticipollenites*. The palynoassemblage compares well with the Upper Barakar palynoassemblages of different coalfields, viz. Raniganj Coalfield (Khudia Nala Section, Zone–5 of Tiwari, 1973); North Karanpura Coalfield (Zone–2C of Venkatachala & Kar, 1968); South Karanpura Coalfield (Zone–6 of Kar, 1973; Bharadwaj & Tripathi, 1978); Pench–Kanhan Coalfield (Bharadwaj *et al*., 1974); Johilla Coalfield (Zone–4 of Anand–Prakash & Srivastava, 1984; Zone–E of Tiwari & Ram–Awatar, 1989); Umaria Coalfield (Zone–4 of Srivastava & Anand–Prakash, 1984); Talcher Coalfield (Assemblage 3 of Tripathi & Bhattacharya, 2001); Sohagpur Coalfield (Assemblage–1 of Ram–Awatar *et al*., 2004); Mand–Raigarh Coalfield (Palynozone–D of Jana *et al*., 2002; Palynozone–III of Chakraborty, 2003 and Palynozone–B of Chakraborti & Ram–Awatar, 2006; Palynoassemblage–II of Murthy *et al*., 2014a); Tatapani–Ramkola Coalfield (Assemblage II of Tripathi *et al*., 2012); Singrauli Coalfield (Assemblage IV of Vijaya *et al*., 2012). The upper Barakar palynoflora mentioned above are dominated by *Faunipollenites* and *Striatopodocarpites* and sub–dominance of *Scheuringipollenites* within the *Faunipollenites varius* Assemblage Zone (V) of Tiwari and Tripathi (1992).

The Palynoassemblage–1II, identified in borehole MSK–1 (between 135.55–92.50 depth m) shows the prominence of enveloping monosaccate pollen chiefly *Densipollenites* and sub–dominance striate disaccate pollen like S*triatopodocarpites* and *Faunipollenites.* High incidence of *Densipollenites* along with striate disaccates is characteristic of Barren Measures Formation.

The other significant taxa recorded in the assemblage are ─ *Brevitriletes, Corisaccites, Crescentipollenites, Distriatites, Hamiapollenites, Horriditriletes, Lacinitriletes, Lahirites, Latosporites, Lunatisporites, Microbaculispora, Primuspollenites, Rhizomaspora, Striatites* and *Verticipollenites* (Fig. 3). The Palynoassemblage–III, correlates with the Barren Measures palynoflora of different coalfields, viz. Jharia Coalfield (Bharadwaj *et al.,* 1965, Kar, 1966); North Karanpura Coalfield (Kar, 1969, 1973); Brahmani Coalfield (Srivastava & Maheshwari, 1974); Auranga Coalfield (Lele & Srivastava, 1977); Hutar Coalfield (Assemblage 5 of Shukla, 1983); Godavari Graben (Palynozone VI, Ramagundam and Ramakrishnapuram areas of Srivastava & Jha, 1989); Singrauli Coalfield (Assemblage V of Vijaya *et al*., 2012). All the assemblages mentioned above are dominated by *Densipollenites* and show sub–dominance of *Striatopodocarpites* within the *Densipollenites indicus* Assemblage Zone–VI of Tiwari and Tripathi (1992). This is the first record of Barren Measures palynoflora identified in the area.

The younger Palynoassemblage–IV, marked in borehole MSK–1 (between 90.90–27.65 m depth) shows prominence of striate bisaccate taxa–*Crescentipollenites, Faunipollenites* and *Striatopodocarpites* in association with *Brevitriletes, Densipollenites, Distriatites, Guttulapollenites, Hamiapollenites, Horriditriletes, Lahirites, Lunatisporites, Microbaculispora, Striatites, Stroterspories* and *Verticipollenites*. Besides, some younger taxa like *Navalesporites* and *Praecolpatites* is also present in the Palynoassemblage–IV which distinguishes it from Barren Measures palynoflora. Hence, Palynoassemblage–IV represents Raniganj equivalent palynoassemblage in borehole MSK–1 in the study area. The Palynoassemblage–IV, compares well with the Late Permian palynoassemblages known from different coalfields, viz. Raniganj Coalfield (Bharadwaj, 1962; Bharadwaj *et al*., 1979; Assemblage–I of Vijaya, 2004); Satpura Basin (Palynozone–5 of Bharadwaj *et al*., 1978; Sarate & Patil, 1994); Talcher Coalfield (Assemblage–II of Tiwari *et al.,* 1991; Assemblages 5, 6 of Tripathi & Bhattacharya, 2001); Singrauli Coalfield (Assemblage–I of Tripathi *et al*., 2005; Assemblage VI of Vijaya *et al*., 2012); Tatapani–Ramkola Coalfield (Assemblage V of Tripathi *et al.,* 2012); Sohagpur Coalfield (Assemblage II of Ram–Awatar *et al.,* 2004, Assemblage II of Gautam *et al*., 2014); Mand–Raigarh Coalfield (Palynozone–D of Jana *et al*., 2002; Palynozone VII of Chakraborty 2003 and Zone–C of Chakraborti & Ram–Awatar, 2006; Assemblage–1 of Murthy *et al*., 2014a); Tatapani–Ramkola Coalfield (Assemblage 1 of Srivastava & Kar, 2001, Assemblage III of Tripathi *et al.,* 2012); South Karanpura Coalfield (Assemblage II of Murthy *et al*., 2014b); Pachwara Coalfield, Rajmahal (Tripathi & Ray, 2005); Godavari Valley Coalfield ((Palynozone–9 of Budharam area, Srivastava & Jha, 1995; Palynoassemblage–V of Mamakannu area, Jha & Aggarwal, 2010; Palynozone–7 of Mailaram area, Jha & Aggarwal, 2012; Palynoassemblage–II of Chintalapudi area, Jha *et al*., 2012, and Palynozone VI of Lingala–Koyagudem area Coalbelt, Aggarawal & Jha, 2013). All the assemblages mentioned above are dominated by *Striatopodocarpites, Crescentipollenites* and *Faunipollenites* in association with sub–dominance of *Densipollenites* correlate with the *Densipollenites magnicorpus* Assemblage Zone (IX) of Tiwari and Tripathi (1992). Raniganj palynoflora has been demarcated in lithologically designated Barren Measures Formation for the first time in this area.

PALAEOENVIRONMENTAL INTERPRETATIONS

The palynoassemblage analysis reveals that the major constituent of the Mand Coalfield flora corresponds to gymnosperm pollen chiefly glossopterids, conifers, cordaits and peltasperms. The striate bisaccates are the most important group of the assemblage represented by *Striatopodocarpites, Faunipollenites, Distriatites, Crescentipollenites, Striatites, Verticipollenites, Stroterosporites, Lahirites, Hamiapollenites* and *Lunatisporites* indicating presence of conifer in the peat forming vegetation (Knoll & Nicklas, 1987). Conifers are considered to be extra basinal or hinterland elements which typically show several adaptations for survival in drier habitats. Monosaccates are represented by mainly *Parasaccites* and *Densipollenites* suggestive of Cordaites in the peat forming flora (Taylor & Taylor, 1993). According to Taylor and Taylor (1993), Cordaites pollen prefers mesophilous palaeoenvironment near the mire and palaeoecologically inhabit well drained and low land substrates. The nonstriate bisaccate pollen represented by glossopterids include *Scheuringipollenites, Cuneatisporites* and *Ibisporites* indicating prevalence of peat forming vegetation (Taylor & Taylor, 1993). Glossopterids grew in mesophylous to xerophylous palaeoenvironment, flourished in lowland peats while conifers survived in distant areas to the mires (Knoll & Nicklas, 1987). The trilete spores represented in the assemblage by algal (*Leiosphaeridia* and *Tetraporina*), filicopsids (*Horriditriletes, Brevitriletes, Microbaculispora*, *Horriditriletes, Cyclogranisporites* and *Cyclobaculisporites*), lycopsid (*Indotriradites*) and sphenopsids (*Latosporites* and *Navalesporites*) are also present in the peat forming vegetation, and are related to herbaceous and arborescent groups flourishing in hygrophilous and mesophillous environments (Cazzulo–Klepzig *et al.,* 2005). The conifer pollen in the present assemblage suggests the dominance of arborescent vegetation in the form of a forest swamp probably in a small distant marginal part of the mire. The high representation of glossopterids and conifers co–occurring with filicopsids and sphenopsids are indicative of a hypautocthonous sedimentation (Birks & Birks, 1980). The overall palynological analysis suggests that the Mand Coalfield palaeomire occupied inland areas of the basin and

Table 2— List of samples collected from Borehole MSK–1, Mand Coalfield.

Sr. No.	Sample No.	Depth (m)	Lithology	Frequency
1.	MSK1/1*	27.65	Carbonaceous shale	+ (Top sample)
2.	MSK1/2*	33.60	Siltstone	+
3	MSK1/3*	39.60	Siltstone	+++
4.	MSK1/4*	50.55	Carbonaceous shale	+
5.	MSK1/5*	52.60	Carbonaceous shale	++
6.	MSK1/6*	65.70	Carbonaceous shale	++
7.	MSK1/7*	76.25	Carbonaceous shale	++
8.	MSK1/8*	82.10	Carbonaceous shale	+++
9.	MSK1/9*	86.00	Carbonaceous shale	+
10.	MSK1/10*	90.90	Siltstone	+
11.	MSK1/11*	92.50	Siltstone	+
12.	MSK1/12*	99.70	Carbonaceous shale	++
13.	MSK1/13*	103.30	Carbonaceous shale	+++
14.	MSK1/14	105.95	Carbonaceous shale	—
15.	MSK1/15*	112.60	Siltstone	++
16.	MSK1/16	115.30	Siltstone	—
17.	MSK1/17	121.00	Carbonaceous shale	—
18.	MSK1/18	123.40	Carbonaceous shale	—
19.	MSK1/19*	125.60	Carbonaceous shale	+++
20.	MSK1/20*	131.55	Carbonaceous shale	++
21.	MSK1/21*	135.55	Carbonaceous shale	+++
22.	MSK1/22*	139.40	Shale	++
23.	MSK1/23*	141.75	Carbonaceous shale	+++
24.	MSK1/24*	148.25	Siltstone	+++
25.	MSK1/25*	33.60	Carbonaceous shale	++
26.	MSK1/26	151.75	Siltstone	—
27.	MSK1/27	178.25	Carbonaceous shale	—
28.	MSK1/28*	183.25	Shale	+++
29.	MSK1/29	195.10	Shale	—
30.	MSK1/30	215.10	Siltstone	—
31.	MSK1/31*	226.30	Carbonaceous shale	+++
32.	MSK1/32*	233.05	Carbonaceous shale	++
33.	MSK1/33*	237.90	Carbonaceous shale	+++
34.	MSK1/34	269.20	Carbonaceous shale	—
35.	MSK1/35*	273.65	Carbonaceous shale	++
36.	MSK1/36	303.40	Carbonaceous shale	—
37.	MSK1/36A*	309.90	Shale	++
38.	MSK1/37*	338.45	Carbonaceous shale	++
39.	MSK1/38*	353.20	Carbonaceous shale	++
40.	MSK1/39*	358.60	Carbonaceous shale	+++
41.	MSK1/40*	393.70	Carbonaceous shale	++
42.	MSK1/41	435.90	Carbonaceous shale	—
43.	MSK1/42	471.80	Carbonaceous shale	—
44.	MSK1/43	483.60	Shale	—(Bottom sample)

Indicate: Productive* ; (—Barren; + poor; ++fair +++ well preserved palynomorphs)

Table 3─Check list of palynotaxa identified in Borehole MSK–1

Trilete spores

Brevitriletes communis Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
B. levis (Balme & Hennelly) Bharadwaj and Srivastava, 1969
B. unicus (Tiwari) Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
Cyclobaculisporites indicus Bharadwauj and Salujha,1964
Cyclogranisporites gondwanensis Bharadwaj and Salujha, 1964
Dentatispora indica Tiwari, 1964
Horriditriletes rampurensis Tiwari, 1968
H. curvibaculosus Bharadwaj and Salujha, 1964
Indotriradites sparsus Tiwari, 1965
Lacinitriletes minutus Venkatachala and Kar, 1968
Leiotriletes rectus Bharadwaj and Salujha, 1964
Microbaculispora barakarensis Tiwari and Singh,1981
Microfoveolatispora foveolata (Tiwari) Tiwari and Singh, 1981

Monolete spores

Latosporites colliensis Balme and Hennelly, 1956
Navalesporites spinosus Sarate and Ram Awatar, 1984

Monosaccate pollen grains

Caheniasaccites distinctus Lele and Makada, 1972
C. ovatus Bose and Kar, 1966
Densipollenites densus Bharadwaj and Srivastava, 1969
D. indicus Bharadwaj, 1962
D. invisis Bharadwaj and Salujha, 1964
D. magnicorpus Tiwari and Rana, 1980
Parasaccites korbaensis Bharadwaj and Tiwari, 1964
P. obscurus Tiwari, 1965
P. distinctus Tiwari, 1965
P. diffusus Tiwari, 1965

Non–striate disaccate pollen grains

Cuneatisporites exiguus Salujha, 1965
Cuneatisporites rarus Kar, 1968
Ibisporites diplosaccus Tiwari, 1968
Scheuringipollenites barakarensis (Tiwari) Tiwari, 1973
S. maximus (Hart) Tiwari, 1973
S. tentulus (Tiwari) Tiwari, 1973
Sahnites sp. Pant emend. Tiwari and Singh, 1984

Striate disaccate pollen grains

Circumstriatites obscurus Lele and Makada, 1972
Crescentipollenites amplus (Balme and Hennely) Tiwari and Rana, (1980
C. fuscus (Bharadwaj) Bhardwaj *et al.*, 1974
C. *gondwanensis* (Maheshwari) Bhardwaj *et al.*, 1974
C. *notabilis* (Tiwari) Bhardwaj *et al.*, 1974
Distriatites bilateris Bharadwaj, 1962
D. indicus Sinha, 1972
Faunipollenites congoensis (Bose & Kar) Tiwari *et al.,* 1989
F. perexiguus Bharadwaj emend. Tiwari *et al.,* 1989
F. varius Bharadwaj 1962 emend. Tiwari *et al.,* 1989
F. singrauliensis Sinha, 1972
Lahirites raniganjensis Bharadwaj, 1962
L. rarus Bharadwaj and Salujha, 1964
L. singrauliensis Sinha, 1972
Primuspollenites levis Tiwari, 1964
P. lintrus Tiwari, 1965
P. singrauliensis Sinha, 1972
Rhizomaspora indica Tiwari, 1965
R. fimbriata Tiwari, 1965
R. singula Tiwari, 1965
Striatopodocarpites brevis Sinha, 1972
S. decorus Bharadwaj and Salujha, 1964
S. diffusus Bharadwaj and Salujha, 1964
S. globosus (Maheshwari) Bharadwaj and Dwivedi, 1981
S. labrus Tiwari, 1965
S. magnjficus Bharadwaj and Salujha, 1964
S. ovatus (Maheshwari) Bharadwaj and Dwivedi, 1981
S. *subcircularis* Sinha, 1972
Striatites communis Bharadwaj and Salujha, 1964
S. levistriatus Bharadwaj and Tiwari, 1977
S. solitus Bharadwaj and Salujha, 1964
S. tectus Venkatachala and Kar, 1968
S. varius Kar, 1968
Stroterosporites decorus Kar, 1968
S. lentisaccutus Kar, 1968
Verticipollenites crassus Bharadwaj and Salujha, 1964
V. debilis Venkatachala and Kar, 1968
V. gibbosus Bharadwaj, 1962
V. oblongus Bharadwaj, 1962

Taeniate pollen grains

Corisaccites alutus Venkatachala and Kar, 1966
Guttulapollenites hannonicus Goubin, 1965
Hamiapollenites insolitus Bharadwaj and Salujha, 1964
Lunatisporites diffusus Bharadwaj and Tiwari, 1977
L. ovatus (Goubin) Maheshwari and Banerji, 1966
Lueckisporites virkkiae Potonie & Klaus, 1954
Trabeculosporites gopadensis Trivedi and Misra emend. Tiwari and Ram–Awatar, 1992

Others

Ginkgocycadophytus korbaensis Tiwari, 1965
Praecolpatites nidpurensis Bharadwaj and Srivastava, 1969
Leiosphaeridia Eisenach emend. Downie and Sarjeant, 1963
Tetraporina sp. Banerjee and D'Rozrio, 1988

probably deposited under fresh (presence of *Leiosphaeridia* and *Tetraporina*) to brackish water environment.

CONCLUSIONS

From the palynological data presented here, it is possible to draw the following conclusions:

Palynologically four distinct palynoassemblages (I–IV) have been identified in borehole MSK–1. Recovered palynoassemblages (I–IV) represent Lower Barakar, Upper Barakar, Barren Measures and Raniganj palynofloras respectively.

Raniganj palynoflora has been identified in lithologically designated Barren Measures Formation.

The palynological study suggests two coal horizons during the Permian period, one belonging to the early Permian (Lower Coal Measures, i.e. Lower Barakar and Upper Barakar formations), and other belonging to the late Permian (Upper Coal Measures, i.e. Raniganj Formation). The palynological study would be helpful for the coal exploration in the Mand sub–basin.

The peat forming palynoflora is characterized by the dominance of gymnosperm pollen chiefly glossopterids, conifers (striate bisaccate and non–striate bisaccate) and cordaites, i.e. monosaccates. Trilete spores are subordinate and represent by lycopsids, sphenopsids and filicopsids. The palaeovegetational studies depict the dominance of subarborescent /arborescent vegetation along with the low percentage of algal and pteridophytic spores. The climate during deposition of the Permian sediments was very warm with high humidity.

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