The Palaeobotanist 66(2017): 177–189
0031–0174/2017

Early Permian micro and megaspores from the Nand–Besur Block, Bandar Coalfield, Wardha Basin, Maharashtra, India

SRIKANTA MURTHY, OMPRAKASH S. SARATE, S. SURESH KUMAR PILLAI AND RAJNI TEWARI*

Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226 007, India.
**Corresponding author: rajni_tewari@bsip.res.in*

(Received 26 May, 2017; revised version accepted 02 August, 2017)

ABSTRACT

Murthy S, Sarate OS, Pillai SSK & Tewari R 2017. Early Permian micro and megaspores from the Nand–Besur Block, Bandar Coalfield, Wardha Basin, Maharashtra, India The Palaeobotanist 66(2): 177–189.

The sub–surface samples of bore core NP–75 drilled near Nand Village, a part of Nand–Besur Block of Bandar Coalfield, Wardha Basin, Maharashtra have yielded palynomorphs which include spores/pollen grains and megaspores. The pollen assemblage shows the dominance of the genus *Scheuringipollenites* and sub–dominance of *Faunipollenites* (=*Protohaploxypinus*) along with *Caheniasaccites*, *Plicatipollenites*, *Potonieisporites, Barakarites, Arcuatipollenites, Striatopodocarpites,* etc. Megaspores are represented by three genera and nine species comprising *Bokarosporites rotundus*, *Bokarosporites* sp., *Jhariatriletes filiformis*, *Singhisporites baculatus, S. indica, S. nautiyalii, S. radialis, S. surangei* and *Singhisporites* sp. The palynomorph assemblage indicates an early Permian age equivalent to the lower Barakar Formation.

Key–words—Palynomorphs, Barakar Formation, Nand–Besur Block, Bandar Coalfield, Wardha Basin, Maharashtra.

भारत में महाराष्ट्र की वर्धा द्रोणी के नंद–बेसुर खंड, बंदर कोयलाक्षेत्र से प्राप्त प्रारंभिक पर्मियन सूक्ष्म एवं स्थूल बीजाणु

श्रीकांत मूर्ति, ओमप्रकाश एस. सराटे, एस. सुरेश कुमार पिल्लै एवं रजनी तिवारी

सारांश

महाराष्ट्र की वर्धा द्रोणी में बंदर कोयलाक्षेत्र के नंद–बेसुर खंड भाग के नंद ग्राम के नजदीक स्थित बोर कोर एन पी–75 के उपपृष्ठीय नमूनों से बीजाणुओं/पराग दानों एवं स्थूलबीजाणुओं सहित परागाणुसंरूप प्राप्त हुए हैं। पराग समुच्चय *स्युरिंगीपोलेनाइटिस* वंश की प्रभुत्वता तथा *केहनियासेक्काइटिस, प्लिकाटीपोलेनाइटिस, पोटोनीस्पोराइटिस, बराकेराइटिस, आर्कुएटीपोलेनाइटिस, स्ट्रिएटोपोडोकार्पाइटिस,* इत्यादि के साथ–साथ *फॉनीपोलेनाइटिस* (=*प्रोटोहेप्लोझायपीनस*) की प्रभुत्वता दर्शाता है। स्थूलबीजाणु के तीन वंश तथा *बोकारोस्पोराइटिस रोटंडस, बोकारोस्पोराइटिस* जाति, *झरियाट्रायलेटीस फिलीफॉर्मिस, सिंहीस्पोराइटिस बेकुलेटस, एस. इंडिका, एस. नौटियालयाई, एस. रेडिएलिस, एस. सुरंगेआई* एवं *सिंहीस्पोराइटिस* जाति सन्निहित नौ जातियों से रूपायित हैं। यह परागाणुसंरूप समुच्चय अधो बराकार शैलसमूह के समतुल्य प्रारंभिक पर्मियन आयु द्योतित करता है।

सूचक शब्द—परागाणुसंरूप, बराकार शैलसमूह, नंद–बेसुर खंड, बंदर कोयलाक्षेत्र, वर्धा द्रोणी, महाराष्ट्र।

INTRODUCTION

THE Wardha Basin is one of the important Lower Gondwana basins of India and is confined to the north–eastern part of the Maharashtra State. It includes four coalfields (Raja Rao, 1982) namely, Wardha Valley of Chandrapur District, Umrer and Kamptee of Nagpur District and the Bandar Coalfield which is situated towards the north of the Wardha Valley Coalfield and spreads over a part of both Nagpur and Chandrapur districts, Maharashtra. Plant macro

fossils are well documented from all the coalfields (Bunbury, 1861; Feistmantel, 1881; Varadpande, 1977a, b; Chitnis & Vagyani, 1979; Chandra & Prasad, 1981; Raja Rao, 1982; Sundaram & Nandi, 1984; Agashe & Prasad, 1989; Agashe & Shashi Kumar, 1996; 2001; Agashe, 2001; Tewari & Rajanikanth, 2001; Agarwal *et al.,* 2007; Tewari, 2007, 2008; Singh *et al*., 2005; Tewari *et al*., 2012a, b). Palynological studies from early Permian Barakar Formation have been

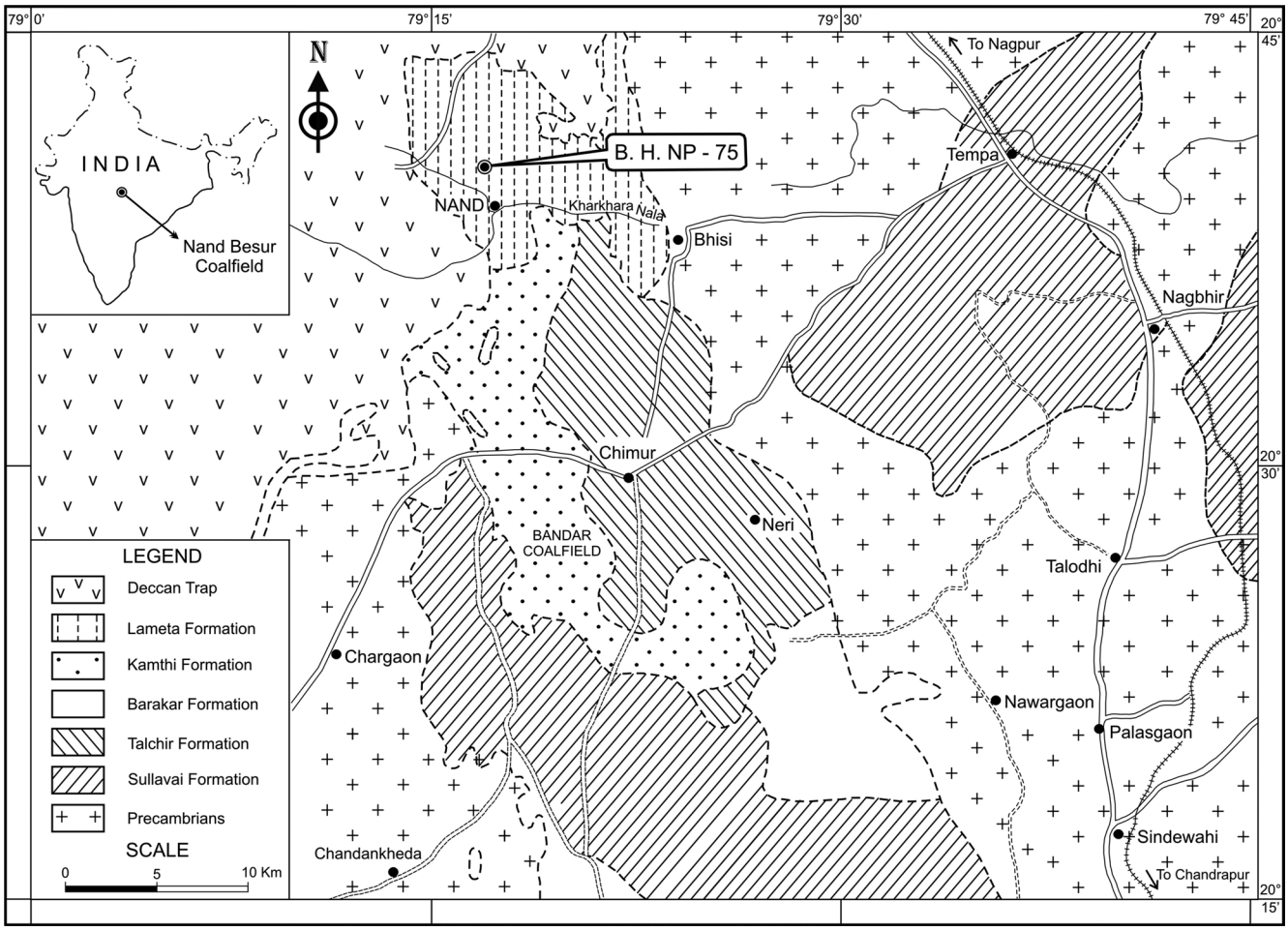

Fig. 1—Geological map showing location of bore–core No. NP–75, Nand–Besur Block, Bandar Coalfield, Maharashtra.

PLATE 1

1. *Microfoveolatispora foveolata* Tiwari 1965. BSIP Slide No. 16204.
2. *Parasaccites korbaensis* Bharadwaj & Tiwari 1964. BSIP Slide No. 16204.
3. *Parasaccites obscurus* Tiwari 1965. BSIP Slide No. 16204.
4. *Striasulcites ovatus* Venkatachala & Kar 1968. BSIP Slide No. 16206.
5. *Parasaccites perfectus* Bose & Maheshwari 1968. BSIP Slide No. 16206.
6. *Plicatipollenites gondwanensis* (Balme & Hennely) Lele 1964. BSIP Slide No. 16205.
7. *Tuberisaccites tuberculatus* Maheshwari 1969. BSIP Slide No. 16208.
8. *Potonieisporites magnus* Lele & Karim 1970. BSIP Slide No. 16205.
9. *Potonieisporites jayantiensis* Lele & Karim 1970. BSIP Slide No. 16206.
10. *Caheniasaccites distinctus* Lele & Makada 1972. BSIP Slide No. 16205.
11. *Caheniasaccites decorus* Lele & Makada 1972. BSIP Slide No. 16205.
12. *Faunipollenites singrauliensis* Sinha (1972), BSIP Slide No. 16204.
13. *Faunipollenites varius* Bharadwaj 1962, BSIP Slide No. 16207.
14. *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.* 1974, BSIP Slide No. 16203.
15. *Striatopodocarpites magnificus* Bharadwaj & Salujha 1964, BSIP Slide No. 16206.
16. *Rhizomaspora indica* Tiwari 1964, BSIP Slide No. 16208.
17. *Verticipollenites gibbosus* Bharadwaj (1962), BSIP Slide No. 16205.
18. *Striatites multistriatus* (Balme & Henn.) Tiwari 1964, BSIP Slide No. 16203.
19. *Corisaccites alutas* Venkatachala & Kar 1966, BSIP Slide No. 16208.
20. *Corisaccites vanus* Venkatachala & Kar 1966, BSIP Slide No. 16204.
21. *Arcuatipollenites ovatus* (Goubin) Tiwari & Vijaya (1995), BSIP Slide No. 16206.
22. *Scheuringipollenites barakarensis* (Tiwari) Tiwari (1973), BSIP Slide No. 16204.
23. *Scheuringipollenites maximus* (Hart) Tiwari (1973), BSIP Slide No. 16204.
24. *Scheuringipollenites tentulus* (Tiwari) Tiwari (1973), BSIP Slide No. 16204.

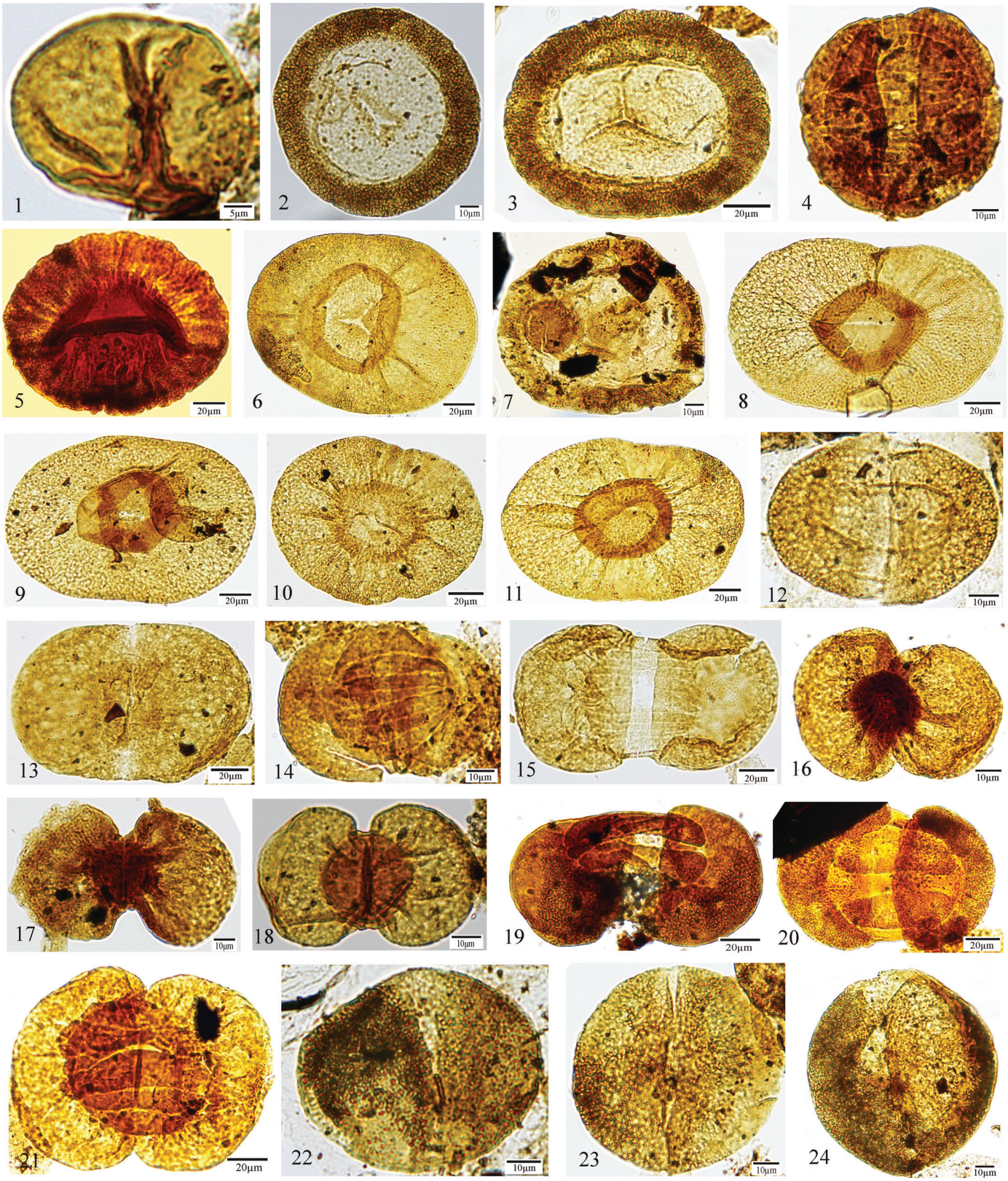
1
5µm
2
10µm
3
20µm
4
10µm
5
20µm
6
20µm
7
10µm
8
20µm
9
20µm
10
20µm
11
20µm
12
10µm
13
20µm
14
10µm
15
20µm
16
10µm
17
10µm
18
10µm
19
20µm
20
20µm
21
20µm
22
10µm
23
10µm
24
10µm

PLATE 1

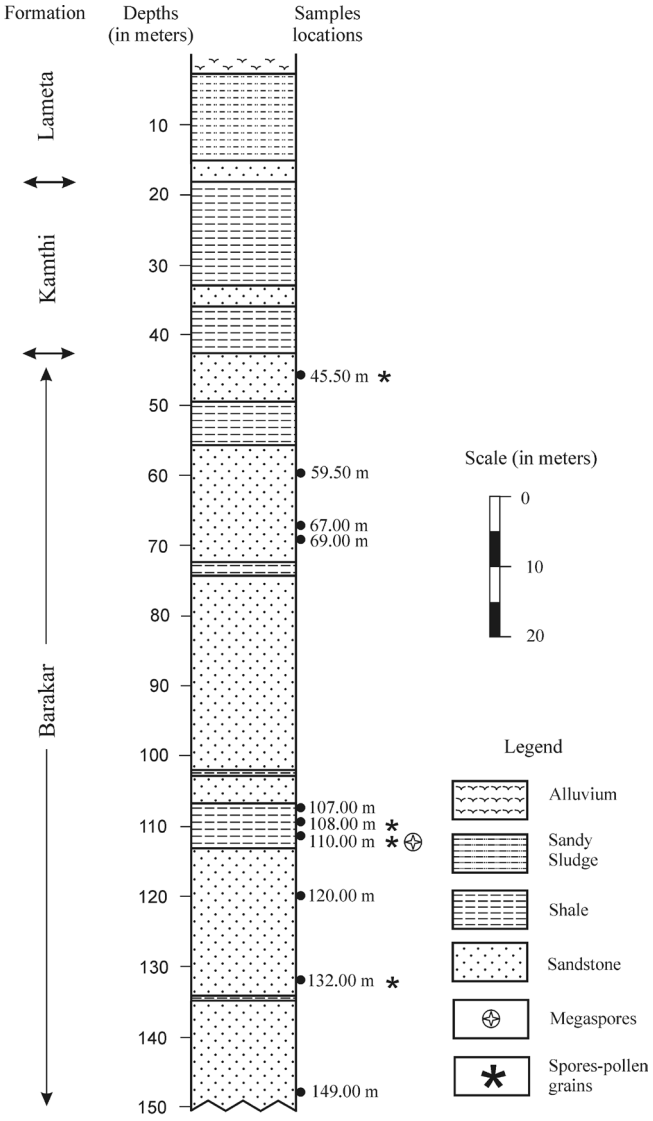

Fig. 2—Litho column of bore–core No. NP–75, Nand–Besur Block, Bandar Coalfield, Maharashtra showing position of samples.

carried out by Bharadwaj and Anand Prakash (1974), Jha *et al.* (2007) and Kalkar *et al.* (2010) from the Makardhokada area in Umrer Coalfield, Nagpur District, by Bhattacharyya (1997), Mahesh *et al.,* (2008, 2011, 2014) and Jha *et al.,* (2011) from the Wardha Valley Coalfield, Chandrapur District and by Pauline Sabina *et al.,* (2007) from the Gokul Block (Nagpur District), Bandar Coalfield. Late Permian palynomorph assemblages have been recorded from Chalburdi area (Murthy & Sarate, 2016) and bore core No.WG–22 near Sekapur, Wardha Valley Coalfield, Chandrapur District in Wardha Basin (Sarate *et al.,* 2016). Besides, Permian–Triassic (Srivastava & Bhattacharyya, 1996) and, early and late Triassic (Kumar & Jha, 2000) palynomorph assemblages have been recorded from Bazargaon and Katol area, respectively, of Nagpur District of the Wardha Basin. Previous records of megaspores from the Wardha Basin are by Agashe (1980) and Tewari *et al.,* (2004) from the Umrer Coalfield. In the present communication, micro–and megaspores are recorded for the first time, from the early Permian Barakar Formation of the Nand–Besur Block, Bandar Coalfield, Nagpur District, Wardha Basin, Maharashtra.

GEOLOGY OF THE AREA

The Bandar Coalfield is one of the prominent coalfields located in Vidarbha region of Maharashtra. It was first discovered by Hughes (1877) who reported the existence of Barakar Formation here. The coal–bearing blocks established through exploration from south to north are Bandar, Murpar, Surmanjiri, Bhagwanpur, Gokul, Nand and Khandalzari (CMPDI, unpublished report). The Bandar Coalfield is named after the Bandar Village and is located at a distance of nearly 42 km NE of Warora Town. It is situated towards the north of the main Wardha Valley Coalfield and is detached from it by the Archaean metamorphic rocks as well as the Vindhyan sediments. It spreads over a part of Nagpur and Chandrapur districts of the Maharashtra State. The Lower Gondwana sediments in the Bandar Coalfield occur in an area of 295 sq. km within the latitudes 20° 20' to 20°38'N and longitudes 79°14' to 79°30'E (CMPDI, unpublished report) and are deposited in a depression with metamorphic rocks exposed on

PLATE 2

1. *Singhisporites radialis* Bharadwaj & Tiwari, 1970, BSIP Slide No. 16211.
2. *Singhisporites radialis* Bharadwaj & Tiwari, 1970, BSIP Slide No. 16209.
3. *Singhisporites baculatus* (Kar, 1968) Bharadwaj & Tiwari, 1970, BSIP Slide No. 16213.
4. *Jhariatriletes filiformis* Tewari & Maheshwari, 1992, BSIP Slide No. 16213.
5. *Singhisporites indica* (Pant & Mishra,1986) Glasspool, 2003, BSIP Slide No. 16210.
6. *Jhariatriletes filiformis* Tewari & Maheshwari, 1992, BSIP Slide No. 16210.
7. *Singhisporites surangei* (Singh, 1953) Bharadwaj &Tiwari, 1970 BSIP Slide No. 16213.
8. *Bokarosporites rotundus* Bharadwaj & Tiwari, 1970, BSIP Slide No. 16210.
9. *Singhisporites nautiyalii* (Pant & Mishra, 1986) Glasspool, 2003 BSIP Slide No. 16211.
10. *Singhisporites radialis* Bharadwaj & Tiwari, 1970, BSIP Slide No. 16212.
11. *Singhisporites nautiyalii* (Pant & Mishra, 1986) Glasspool, 2003 BSIP Slide No. 16212.
12. *Singhisporites nautiyalii* (Pant & Mishra, 1986) Glasspool, 2003 BSIP Slide No. 16211.

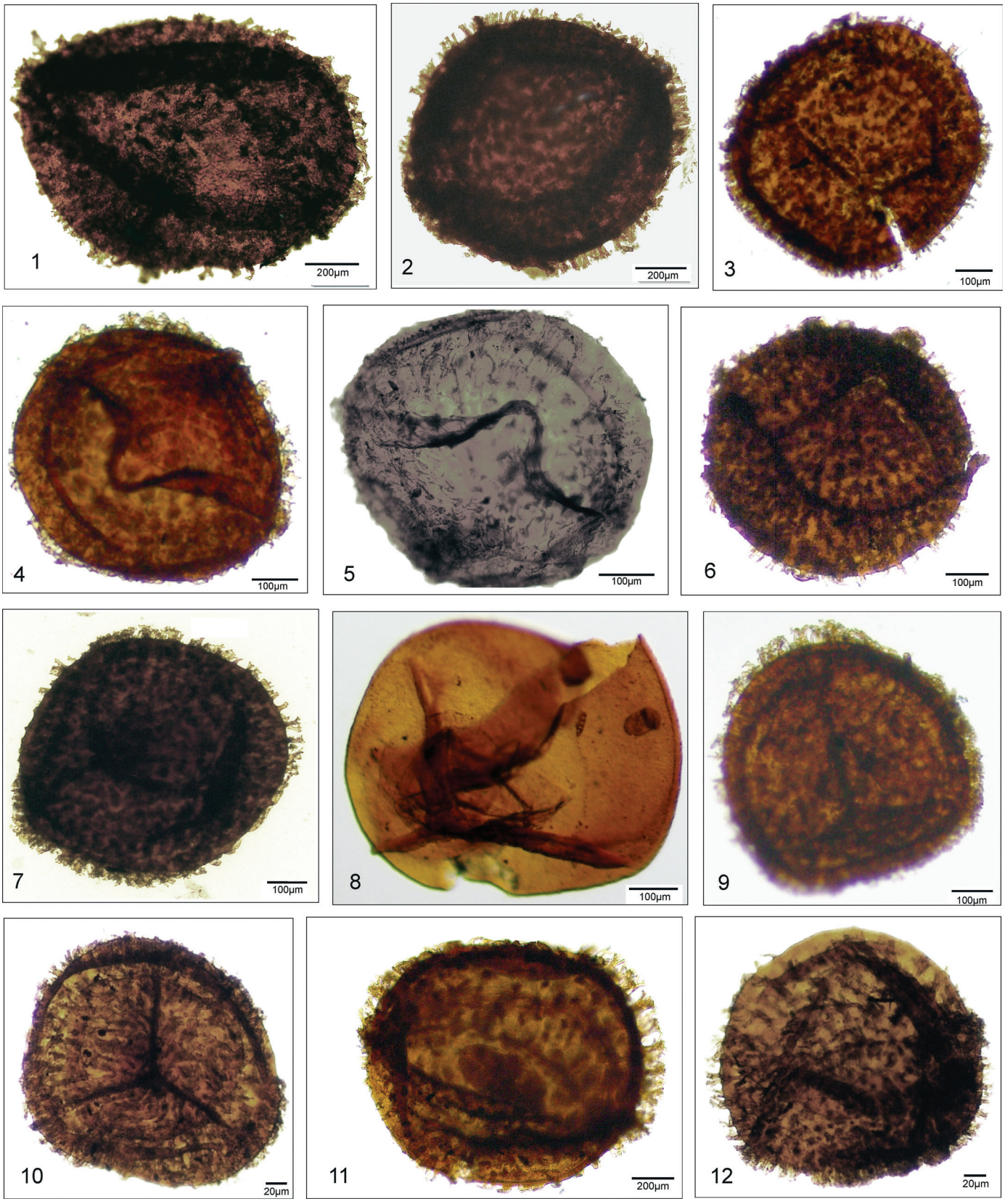
1
200µm
2
200µm
3
100µm
4
100µm
5
100µm
6
100µm
7
100µm
8
100µm
9
100µm
10
20µm
11
200µm
12
20µm

PLATE 2

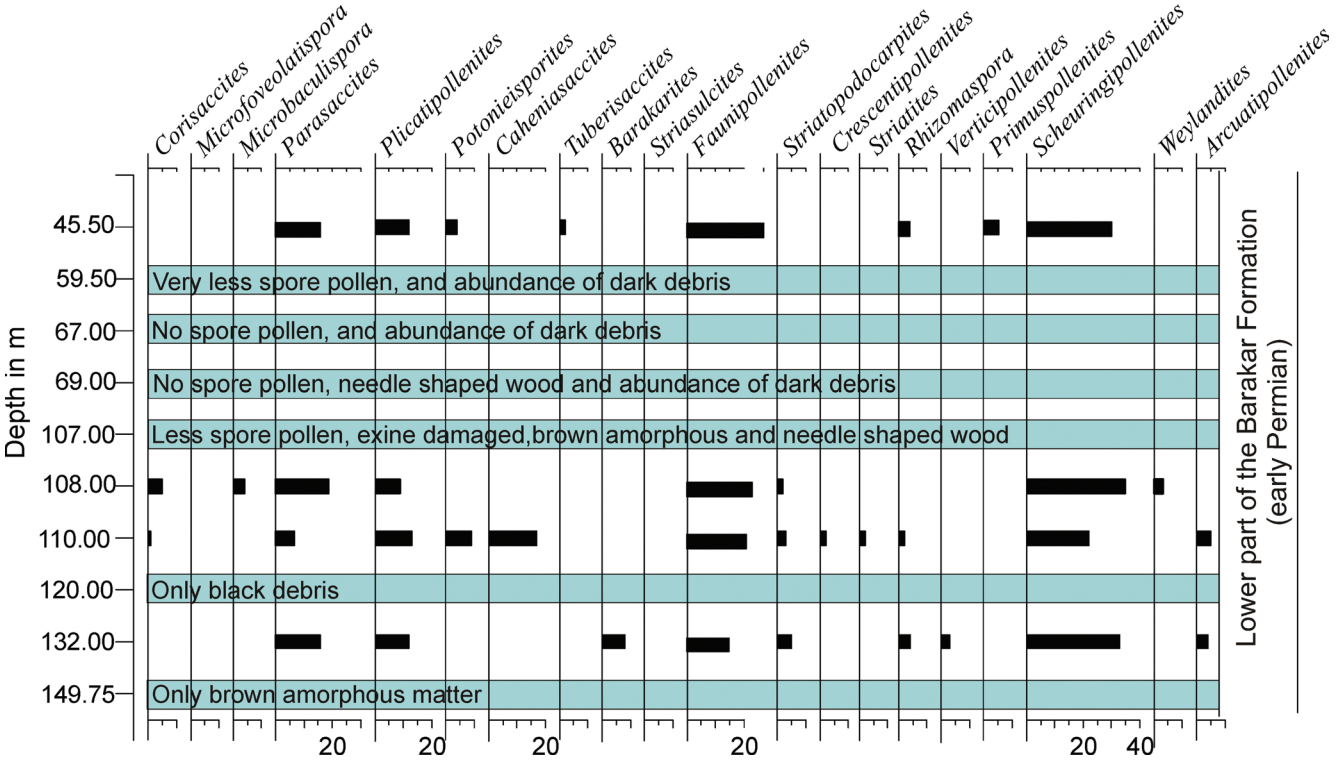

Fig. 3—Frequency distribution of the palynomorphs recorded from bore–core No. NP–75, Nand–Besur Block, Bandar Coalfield, Wardha Basin.

eastern and western sides. On the southern side, the Gondwana sediments are exposed on a hilly region formed by the rocks of Sullavai Group and on the northern side they are capped by the Lameta Formation and Deccan Traps. The Gondwana sediments in general display rolling topography and are marked by a general slope towards the south. The southern boundary of the coalfield lies about 10 km west of Chimur Town. The coalfield extends towards the north for about 27 km with a width of about 10 km. The study area represents north–eastern continuity of the main Bandar Coalfield known as the Nand–Besur Block and displays similar geographical features as witnessed in the Bandar Coalfield (Table 1). The Nand Block is adjacent to and lies on the northern margin of the Gokul Block. Both these blocks are spread in the Nagpur District of Maharashtra (CMPDI, unpublished report and personal communication with the sub–area manager). The two blocks are separated by the Besur–Piraya Village Road. Part of the Nand Block containing about 9.50 m thick coal seam lies between Nand nalla and Besur–Piraya Village road. According to CMPDI (unpublished) report, Nand nalla is the separating boundary between the two blocks. Detailed exploration in the Nand Block has established the existence and continuity of the prominent coal seams encountered in the Bandar and Murpar blocks. Accordingly, three coal seams namely, Seam–II, Seam–V and Seam VII with an average thickness of four, two and one metres, respectively, are present in the Nand Block. The average thickness of the parting between seams–II and V is about forty meters. Seam VII is inconsistent and less than 1 m thick, and hence not considered for proposed mineable reserves. Therefore, there are only two important seams, i.e. Seam II and Seam V in this block (CMPDI, unpublished report), belonging to the Barakar Formation. The thickness of the Barakar Formation, as intersected in various bore cores of the Bandar Coalfield, ranges from 9.15 to 76.77 m.

MATERIAL AND METHODS

Well preserved micro and megaspores were retrieved from 11 samples of the sub–surface sedimentary sequence ranging between the depth 30 m and 149 m of bore core NP–75. This borehole is located at distance of 4 km north of Nand Village in Bhiwapur Tehsil of Nagpur District, Maharashtra. The Lower Gondwana sedimentary sequence underlies the Lameta Formation (Figs 1 & 2) and comprises sandy sludge, sandstone and shale sequence. For maceration, approximately 50 gms of crushed sample was processed

PLATE 3

1–5, 7–9. *Singhisporites* sp.

6. *Bokarosporites* sp.

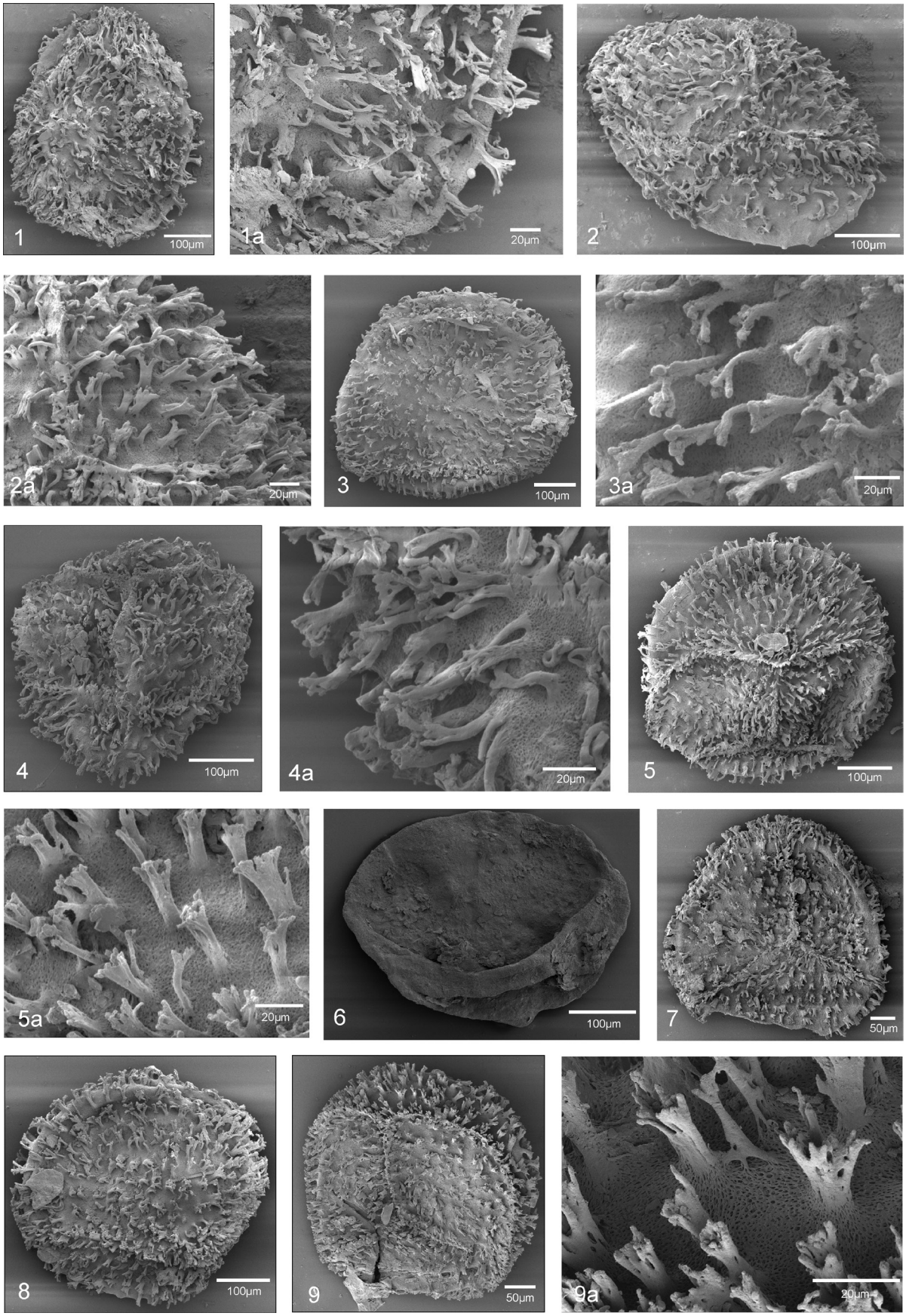
1
100µm
1a
20µm
2
100µm
2a
20µm
3
100µm
3a
20µm
4
100µm
4a
20µm
5
100µm
5a
20µm
6
100µm
7
50µm
8
100µm
9
50µm
9a
20µm

PLATE 3

Age	Formation	Lithology
Recent	–	Alluvial gravel, soil
Eocene	Deccan Trap	Tholeiitic basalt
	—————— Unconformity ——————	
Cretaceous	Lameta	Predominantly chert, cherty limestone and silicified sandstone
	—————— Unconformity ——————	
Late Permian/Early Triassic	Kamthi	Brownish yellow medium to coarse grained ferruginous sandstone with clay beds
	—————— Unconformity ——————	
Early late Permian	Barren Measures	Variegated clay, fine to coarse grained, chloritic sandstone and shale, etc.
Early Permian	Barakar	Fine to coarse grained sandstone, grey shales and coal seams
Early Permian	Talchir	Greenish shale, siltstone and sandstone
	—————— Unconformity ——————	
Proterozoic	Sullavai	Quartzites
	—————— Unconformity ——————	
Archaean		Metamorphites

Table 1—General lithostratigraphic succession of the Bandar Coalfield based on sub–surface data (modified from Raja Rao, 1982 and CMPDI, unpublished report).

following the standard palynological techniques. For the removal of silicates from the shaly and sandy sequence, the samples were kept in hydrofluoric acid (HF) for two to three days. Subsequently, the resultant acid–free residue was treated with concentrate nitric acid (HNO_3) followed by alkali treatment (10% KOH solution) to remove the humic contents. Five slides per sample were prepared from each productive sample. A maximum of 200 palynomorphs were counted per sample for ascertaining their percentage frequency distribution (Fig. 3). 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 potassium chlorate ($KClO_3$) 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 and contact ridges, ornamentation and the mesosporium. Light microscopic studies and the micro photography were carried out with Olympus BX61 microscope with DP–20 camera attachment. For SEM study the specimens were picked and mounted over stubs with double–sided adhesive carbon tape, coated with gold palladium and examined using Field Emission Electron Microscope (Model JEOL 7610F). Some megaspores belonging to the taxa *Bokarosporites* and *Singhisporites* were identified in the SEM photographs. Since their mesosporium could not be studied, it was not possible to assign them to definite species. Though, this is the first record of the megaspores from the early Permian Barakar Formation of the Bandar Coalfield, all of them are well known. 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. 1467.

MICROSPORES

The palynomorph assemblage recorded from the bore core NP–75 at a depth of 108–110 m shows the dominance of non–striate bisaccate genus *Scheuringipollenites* (22–35%) along with sub dominance of striate bisaccate *Faunipollenites* (15–27%). However, *Caheniasaccites* (17%) is reported only from one sample, at a depth of 110 m. The other stratigraphically significant pollen taxa include radial monosaccate genera *Parasaccites* (7–14%), *Plicatipollenites* (9–13%), *Potonieisporites* (4–9%), *Barakarites* (8%), *Arcuatipollenites* (4–5%), *Striatopodocarpites* (2–5%), *Primuspollenites* (5%), *Corisaccites* (1–5%), *Rhizomaspora* (2–4%), *Verticipollenites* (3%), *Weylandites* (3%), *Tuberisaccites* (2%) and *Straisulcites* (2%). Trilete spores are meagre in this assemblage and are mainly represented by the genera *Microbaculispora* (4%) and *Microfoveolatispora* (2%) (Pl.1).

Name of Taxa/ Formation	Barakar	
	Umrer Coalfield	Bandar Coalfield (Present study)
Barakarella pantii (Lele & Srivastava, 1983) Tewari & Maheshwari, 1992	*	–
Bokarosporites rotundus Bharadwaj & Tiwari, 1970	*	*
Bokarosporites sp.	–	*
Banksisporites indicus (Singh, 1953) Tewari & Maheshwari, 1992	*	–
Banksisporites sahnii (Tripathi, 1997) Tewari *et al.*, 2004	*	–
Banksisporites utkalensis (Pant & Srivastava, 1961) Tewari & Maheshwari, 1992	*	–
Biharisporites papillaris Agashe, 1980	*	–
Biharisporites umrerensis Tewari *et al.*, 2004	*	–
Biharisporites waigaonensis Tewari *et al.*, 2004	*	–
Biharisporites sp. Agashe, 1980	*	–
Duosporites congoensis Høeg, *et al.,* 1955	*	–
Duosporites irregularis Bharadwaj & Tiwari, 1970	*	–
Duosporites umrerensis Agashe, 1980	*	–
Duosporites sp. (in Tewari *et al.,* 2004)	*	–
Jhariatriletes baculosus Bharadwaj & Tiwari, 1970	*	–
Jhariatriletes filiformis Tewari & Maheshwari, 1992	–	*
Lagenoisporites sp. (in Tewari *et al.,* 2004)	*	–
Manumisporites crustata Agashe, 1980	*	–
Manumisporites tuberculata Agashe, 1980	*	–
Singhisporites baculatus (Kar, 1968) Bharadwaj & Tiwari, 1970	–	*
Singhisporites indica (Pant & Mishra, 1986) Glasspool, 2003	–	*
Singhisporites nautiyalii (Pant & Mishra, 1986) Glasspool, 2003	–	*
Singhisporites fimbriata Agashe, 1980	*	–
Singhisporites radialis Bharadwaj & Tiwari, 1970	–	*
Singhisporites surangei (Singh, 1953) Bharadwaj & Tiwari, 1970	–	*
Singhisporites sp.	–	*
Setosisporites hirsutus (Loose) Ibrahim, 1933	*	–
Sporites granulata Agashe, 1980	*	–
Talchirella trivedii (Pant & Srivastava, 1961) Bharadwaj & Tiwari, 1970	*	–

Table 2—Distribution of megaspores in the Wardha Basin (* = present, – = absent).

PALYNOLOGICAL CORRELATION

The miofloral assemblage compares broadly with that recorded from the Barakar Formation of the Hindustan Lalpeth Colliery, Wardha Valley Coalfield by Agashe and Chitnis (1970, 1972) considering the dominance of bisaccate pollen

grains *Scheuringipollenites* and *Striatopodocarpites* followed by trilete *Acanthotriletes, Retusotriletes* and *Gondisporites*. The palynological investigation carried out from bore–holes MWS–23 and MWS–33 of Wardha Valley Coalfield (Bhattacharyya, 1997) has revealed two palynoassemblage zones. The Palynoassemblage Zone A indicates affinity with that of the Karharbari Formation of Damodar Basin, whereas, Palynoassemblage Zone B is assigned to the Lower Barakar Formation. The Palynoassemblage Zone B compares well with the present assemblage as it shows the dominance of non–striate bisaccate *Scheuringipollenites* and sub dominance of striate bisaccate *Faunipollenites* along with radial monosaccate pollen *Parasaccites*. The other palynomorphs present in the assemblage include *Caheniasaccites, Rhizomaspora*, *Primuspollenites, Lunatisporites, Striatopodocarpites* and *Weylandites.*

The present assemblage shows a close similarity with the Palynoassemblage–2 of bore–core CMWNM–57, Majri Open Cast Mine (Jha *et al.,* 2011), Palynoassemblage A retrieved from the bore core MGE–15 (Mahesh *et al.,* 2008) and palynomorphs recorded from the sediments of New Majri Open Cast Mine (Mahesh *et al.,* 2014) of Wardha Valley Coalfield, and the bore core MBG–23 of Gokul block of Bandar Coalfield **(**Pauline Sabina *et al.,* 2007) in presence of *Scheuringipollenites–Faunipollenites* complex and other palynomorphs including *Plicatipollenites, Potonieisporites*, *Caheniasaccites*, *Tuberisaccites*, *Barakarites*, *Striasulcites*, *Striatopodocarpites, Rhizomaspora, Verticipollenites*, *Primuspollenites*, *Corisaccites*, *Weylandites*, *Arcuatipollenites*. *Microbaculispora* and *Microfoveolatispora* indicating affinity with the lower part of the Barakar Formation.

The palynomorph assemblage recorded presently is younger than the biozones II & III reported from the early Permian sediments of Umrer Coalfield by Bharadwaj and Anand–Prakash (1974). The biozones II & III contain the dominance of *Parasaccites* along with sub–dominance of *Sulcatisporites (Scheuringipollenites)* which resemble with the palynoflora of the Karharbari Formation. The other palynomorphs recorded from the assemblage mainly include *Leiotriletes, Lophotriletes, Brevitriletes, Horriditriletes, Virkkipollenites, Caheniasaccites, Crucisaccites, Platysaccus, Rhizomaspora, Striatites, Faunipollenites, Vesicaspora,* etc. Jha *et al.* (2007) have also reported palynoflora from the Umrer Coalfield indicating an early Permian age. This assemblage shows the existence of *Indotriradites, Jayantisporites, Microbaculispora, Divarisaccus, Striatopodocarpites, Scheuringipollenites* and *Tiwariasporis* which were not recorded in the assemblage of Bharadwaj and Anand–Prakash (1974). Mahesh *et al.* (2011) recovered two assemblages from the borehole CMWY–95 from the Wardha Valley Coalfield. Assemblage 1 contains the dominance of *Parasaccites* and sub–dominance of *Plicatipollenites*, whereas, Assemblage 2 is marked by the dominance of *Parasaccites* and sub–dominance of *Callumispora* along with *Plicatipollenites*. The other genera of common occurrence in the assemblages include *Vesicaspora, Crescentipollenites, Sahnites, Jayantisporites, Scheuringipollenites, Horriditriletes, Dentatispora, Divarisaccus, Caheniasaccites, Lophotriletes* and *Microbaculispora*. These palynoassemblages also indicate an early Permian age equivalent to the lower part of the Barakar Formation. Pauline Sabina *et al.,* (2016) carried out palynological study from the Umrer Coalfield of Wardha Basin. This palynoflora is characterized by the dominance of *Parasaccites* and sub–dominance of *Scheuringipollenites* and it also shows presence of *Crucisaccites, Callumispora, Caheniasaccites, Brevitriletes, Tiwariasporis* and *Primuspollenites*. This palynomorph association has been assigned an early Permian age.

MEGASPORES

A list of the megaspores recorded in the present study from the bore core NP–75 at a depth of 110 m (Fig. 2) is provided below. Since all the megaspores are well known, we refrain from providing their detailed description.

Genus—BOKAROSPORITES Bharadwaj & Tiwari, 1970

Bokarosporites rotundus Bharadwaj & Tiwari, 1970 (Pl. 2.8)
Bokarosporites sp. (Pl. 3.6)

Genus—JHARIATRILETES Bharadwaj & Tiwari, 1970

Jhariatriletes filiformis Tewari & Maheshwari, 1992 (Pl. 2.4, 6)

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

Singhisporites baculatus (Kar, 1968) Bharadwaj & Tiwari, 1970 (Pl. 2.3)
Singhisporites indica (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.5)
Singhisporites nautiyalii (Pant & Mishra, 1986) Glasspool, 2003 (Pl. 2.9, 11, 12)
Singhisporites radialis Bharadwaj & Tiwari, 1970 (Pl. 2.1, 2, 10)
Singhisporites surangei (Singh, 1953) Bharadwaj & Tiwari, 1970 (Pl. 2.7)
Singhisporites sp. (Pl. 3.1–5, 7–9)

DISCUSSION

The palynomorph assemblage recorded, herein, is comparable with those known from the early Permian Barakar

Formation of Wardha Valley Coalfield **(**Agashe & Chitnis, 1970, 1972; Bhattacharyya, 1997; Mahesh *et al.,* 2008, 2014; Jha *et al.,* 2011) and Bandar Coalfield (Pauline Sabina *et al.,* 2007) in presence of *Scheuringipollenites–Faunipollenites* complex, besides *Plicatipollenites*, *Potonieisporites*, *Caheniasaccites*, *Tuberisaccites*, *Barakarites*, *Striasulcites*, *Striatopodocarpites*, *Rhizomaspora*, *Verticipollenites*, *Primuspollenites*, *Weylandites*, *Arcuatipollenites (=Lunatisporites)* and trilete spores such as *Microbaculispora* and *Microfoveolatispora.*

Permian megaspores are recorded from almost all the Lower Gondwana basins of India namely, Damodar, Satpura, Mahanadi and Godavari (Tewari, 2008 and references cited, therein; Tewari *et al.,* 2009; Govind *et al.,* 2014; Joshi *et al.,* 2014). However, there are only two records from the Barakar Formation of the Umrer Coalfield, Nagpur District from the Wardha Basin, (Agashe, 1980; Tewari *et al.,* 2004). An analysis of the Table 2 reveals that the megaspore assemblage of the Umrer Coalfield is rich and diversified and that of the Bandar Coalfield with three genera and nine species is relatively, impoverished. Twelve genera and twenty nine species are present in the Wardha Basin (including previous work and present study), of which, eleven genera and eighteen species including *Bokarosporites rotundus, Banksisporites indicus, B. utkalensis, Duosporites congoensis, D. irregularis, D. umrerensis, Duosporites* sp., *Barakarella pantii, Talchirella trivedii, Jhariatriletes baculosus, Manumisporites crustata, M. tuberculata, Biharisporites umrerensis, B. waigaoensis, Biharisporites* sp., *Lagenoisporites* sp., *Setosisporites hirsutus* and *Sporites granulata* are recorded from the Umrer Coalfield and *Bokarosporites rotundus*, *Bokarosporites* sp., *Jhariatriletes filiformis*, *Singhisporites baculatus, S. indica, S. nautiyalii, S. radialis, S. surangei* and *Singhisporites* sp. are presently recorded from the Bandar Coalfield. Interestingly, except for *Bokarosporites rotundus,* none of the other taxa are common to both the coalfields. Though, the genus *Jhariatriletes* is found in both these, the species are different. *Singhisporites* reported from the Bandar Coalfield is absent in the Umrer Coalfield and the taxa *Banksisporites*, *Biharisporites, Manumisporites, Lagenoisporites, Setosisporites, Talchirella* and *Sporites* of the Umrer Coalfield are absent in the Bandar Coalfield. In both these coalfields, the megaspores with both laevigate and spinate exosporia are common. Diversity in the ornamentations of the exosporia including smooth (*Bokarosporites, Lagenoisporites*), granulate/ verrucate (*Banksisporites, Duosporites, Talchirella*), baculate (*Barakarella, Jhariatriletes*), connate (*Biharisporites*), spinate with multifurcate spines (*Manumisporites, Singhisporites, Setosisporites*) indicates presence of different kinds of source vegetation mainly the lycopsids, the megafossils of which are not, so far, known from the Umrer and Bandar coalfields. The spinate outer walls indicate presence of aquatic conditions which facilitate fertilization. The occurrence of trilete spores and pollen taxa, in addition to a rich *Glossopteris* floral assemblage recorded from the Nand Block of the Bandar Coalfield by Singh *et al.,* (2005), indicates presence of conducive aquatic and humid climatic conditions necessary for the formation of thick coal seams in the area.

CONCLUSIONS

- The palynofloral assemblage recorded in the present study indicates an age equivalent to the early Permian Barakar Formation.
- The palynoassemblage compares well with those of the early Permian sequence of Umrer and Wardha Valley coalfields.
- First record of the megaspores from the lower part of the Barakar Formation indicates presence of lycopsids in the area and hence aquatic conditions
- The diverse palynomorphs and earlier records of megafossils indicates presence of pteridophytes and gymnosperms which were responsible for the formation of coal in the area.

Acknowledgements*—We thank Prof. Sunil Bajpai, Director, Birbal Sahni Institute of Palaeosciences (BSIP) for providing necessary facilities to carry out this research work and granting permission to publish the same* **(***Permission No. BSIP/RDCC/26/2–17–18). The authors are thankful to the Director, Directorate of Geology and Mining, Nagpur, Government of Maharashtra, for helping in collection of samples and providing relevant details and Mr Indrajeet Tripathi, Sub Area Manager, Gokul OCP, Nagpur District and Mr JVSP Rao, Sub Area Manager, Murpar OCP, Chandrapur District are thanked for providing geological details of the area. Critical comments and suggestions of Prof. SK Pandita of Geology Department, Jammu University, Drs Deepa Agnihotri and Neha Aggarwal, scientists C of BSIP are gratefully acknowledged.*

REFERENCES

Agarwal A, Tewari R & Rajanikanth A 2007. A gymnospermous (Araucariaceae) wood from the Kamthi Formation, Wardha Valley Coalfield. Gondwana Geological Magazine 22: 103–107.

Agashe SN 1980. Megaspores from the Permian coal seams (Lower Gondwana) of Umrer Colliery, Nagpur District, Maharashtra, India. *In:* Proceedings of IV International Palynological Conference 2: 627–634. Birbal Sahni Institute of Palaeobotany. Lucknow, India.

Agashe SN 2001. Studies in fossil gymnospermous woods—Part X; Three new species of *Araucarioxylon* from Lower Gondwana strata of Chandrapur District of Maharashtra, India. Palaeobotanist 50: 381–393.

Agashe SN & Chitnis SR 1970. Palynological investigation of coal seams of Lower Gondwana strata from Maharashtra, India–A preliminary report. Palynological Bulletin 6: 6–9.

Agashe SN & Chitnis SR 1972. Palaeopalynology of a Permian coal seam from the Hindustan Lalpeth Colliery, Chandrapur District, Maharashtra, India. *In:* Ghosh AK *et al.,* (Editors)–Proceedings of Seminar on Palaeopalynology Indian Stratigraphy, Calcutta: 21–29.

Agashe SN & Prasad KR 1989. Studies on fossil gymnospermous

woods–Part VII: Six new species of Lower Gondwana (Permian) gymnospermous woods from Chandrapur District of Maharashtra State, India. Palaeontographica B 212: 71–102.

Agashe SN & Shashi Kumar MS 1996. Studies in fossil gymnospermous woods–Part VIII: A new species of *Araucarioxylon* i.e. A. *wejgaoense* from Lower Gondwana strata of Chandrapur District of Maharashtra, India. Palaeobotanist 45: 15–19.

Agashe SN & Shashi Kumar MS 2001. Studies in fossil gymnospermous woods–Part X; Three new species of *Araucarioxylon* from Lower Gondwana strata of Chandrapur District of Maharashtra, India. Palaeobotanist 50: 381–393.

Bharadwaj DC 1962. The miospore genera in the coals of Raniganj Stage (Upper Permian), India. Palaeobotanist 9: 68–106.

Bharadwaj DC & Anand–Prakash 1974. Palynostratigraphy of Lower Gondwana sediments from Umrer Quarry, Nagpur, Maharashtra, India. Geophytology 4: 130–94.

Bharadwaj DC & Salujha SK 1964. Sporological study of seam VIII in Raniganj Coalfield, Bihar, (India) Part I–Description of *Sporae dispersae*. Palaeobotanist 12: 181–215.

Bharadwaj DC & Tiwari RS 1964. On two new monosaccate genera from Barakar Stage of India. Palaeobotanist 12: 139–146.

Bharadwaj DC & Tiwari RS 1970. Lower Gondwana megaspores–A Monograph. Palaeontographica B129: 1–70.

Bharadwaj DC, Tiwari RS & Kar RK 1974. *Crescentipollenites* gen. nov.: a new name for hitherto known *Lunatisporites* Leschik from the Lower Gondwanas. Geophytology 4: 141–146.

Bhattacharyya AP 1997. Palynological recognition of the Karharbari–Barakar Formation in the sub–surface sediments of Wardha Coalfield, Maharashtra, India. Palaeobotanist 46: 217–219.

Bose MN & Maheshwari HK 1968. Palaeozoic *Sporae disperse* from Congo–VII. Coal measures near lake Tanganyika, south of Albertville. Annis Musee Royal De L' Afrique Centrale–Tervuren, Belgique Annales–Serie In 8º–Sciences geologiques–nº 60: 1–116.

Bunbury CJF 1861. Notes on a collection of fossil plants from Nagpur, Central India. Quarterly Journal of Geological Society of London 17: 325–346.

Chandra S & Prasad MNV 1981. Fossil plants from the Kamthi Formation of Maharashtra and their biostratigraphic significance. Palaeobotanist 28/29: 99–121.

Chitnis SR & Vagyani BA 1979. Additions to the *Glossopteris* flora from the Kamthi beds near Satnavri, District Nagpur, (M.S.). Geophytology 9: 62–64.

Feistmantel O 1881. The fossil flora of the Gondwana System. The flora of the Damuda–Panchet divisions. Memoirs of the Geological Survey of India, Palaeontologia indica 12(3): 78–149.

Glasspool IJ 2003. A review of Permian Gondwana megaspores. With particular emphasis on material collected from coals of the Witbank Basin of South Africa and the Sydney. Review of Palaeobotany and Palynology 124: 227–296.

Govind N, Tewari R, Pillai SSK & Joshi A 2014. IGMIS–a computer–aided information system on Indian Gondwana megaspores. Current Science 106: 434–439.

Høeg OA, Bose MN & Manum S 1955. On double walls in fossil megaspore, with description of *Duosporites congoensis* n. gen. n. sp. Nytt Magasin for Botanik 4: 101–107.

Hughes TWH 1877. The Wardha Valley Coalfield. Memoirs of the Geological Survey of India. 13: 1–154.

Ibrahim A. 1933. Sporenformen des Aegirhorizonts des RuhrReviers. Diss. zur Erlangung der Worde eines Doktor–Ingenieurs der Technischen Hochschule zu Berlin 1–47.

Jha N, Pauline Sabina K, Tewari R & Mehrotra NC 2011. Palynological dating and correlation of surface and subsurface sediments from Wardha Valley Coalfield, Maharashtra. Journal of the Geological Society of India 77: 137–148.

Jha N, Tewari R & Rajanikanth A 2007. Palynology of Permian Gondwana sequence of Umrer Coalfield, Maharashtra. Journal of the Geological Society of India 69: 851–857.

Joshi A, Tewari R & Agnihotri D 2014. Plant diversity in the Kamthi Formation of India: A Review. Palaeobotanist 63: 127–136.

Kalkar SA, Bhute SD & Sarate OS 2010. Palynoflora recorded from Makardhokada area, Nagpur District, Maharashtra. Palaeobotanist 59: 63–70.

Kumar P & Jha N 2000. Subsurface palynological succession from Katol area, Nagpur, Maharashtra. Geophytology 29: 65–68.

Lele KM 1964. Studies in the Talchir flora of India: 2. Resolution of the spore genus *Nuskoisporites* Potonie and Klaus. Palaeobotanist 12: 147–168.

Lele KM & Karim R 1970. Studies in the Talchir flora of India–6. Palynology of the Talchir Boulder beds in Jayanti Coalfield, Bihar. Palaeobotanist 19: 52–69.

Lele KM & Makada R 1972. Studies in the Talchir flora of India–7. Palynology of the Talchir Formation in the Jayanti Coalfield, Bihar. Geophytology 2: 41–73.

Mahesh S, Pauline Sabina K & Bilwa ML 2008. Permian palynomorphs from the subsurface sediments of lower Gondwana of Wardha Valley Coalfield, Maharashtra, India. Gondwana Geological Magazine 23: 63–67.

Mahesh S, Pauline Sabina K & Bilwa ML 2011. Palynodating and correlation of subsurface sediments from bore–hole CMWY–95 of Wardha Valley Coalfield, Maharashtra, Central India. Palaeobotanist 60: 299–307.

Mahesh S, Pauline Sabina, K & Bilwa ML 2014. Palynology and depositional facet of lower Permian (Artinskian) sediments from New Majri Open Cast Mine, Wardha Basin, India. Journal of the Geological Society of India 83: 697–708.

Maheshwari HK 1969. Palaeozoic *Sporae dispersae* from Congo–X. Microfossils from a cliff section at the confluence of Lufupa and Mushyashya rivers, South Katanga. Annales Musee Royal de l'Afrique Centrale, (Tervuren, Belgium) Serie in 8, Sciences Geologiques 63: 115–168.

Murthy S & Sarate OS 2016. Late Permian palynoassemblage from Chalburdi area, Chandrapur District, Maharashtra. Palaeobotanist 65: 85–95.

Pauline Sabina K, Bilwa ML & Mahesh S 2007. A palynostratigraphic study of lower Gondwana sediments from Bandar Coalfield, Nagpur District, Maharashtra. Journal of the Geological Society of India 69: 834–840.

Pauline Sabina K, Mahesh S, Bilwa ML & Bernardes–de–Oliveira MEC 2016. A palynostratigraphic study of the Umrer Coalfield of Wardha Basin, Maharashtra State, Central India and its putative correlation with Indian and other Gondwanan areas. Geological USP, Série cientifica, São Paulo 16: 99–117.

Raja Rao CS 1982. Coalfields of India–2. Coal resources of Tamil Nadu, Andhra Pradesh, Orissa and Maharashtra. Bulletin of the Geological Survey of India Series A 45: 9–40.

Sarate OS, Murthy S & Kalkar SA 2016. Late Permian palynoassemblage from Borehole No. WG–22 near Sekapur, Wardha District, Maharashtra, India. Palaeobotanist 65: 177–187.

Sinha V 1972. *Sporae dispersae* from Jhingurdah Seam, Singrauli Coalfield (MP), India. Palaeobotanist 9: 175–201

Singh KJ, Sarate OS, Bhattacharyya AP & Goswami S 2005. Record of Lower Gondwana megafloral assemblage from the Nand Coalfield, Wardha Basin, Nagpur District, Maharashtra. Journal of the Geological Society of India 66: 293–302.

Srivastava SC & Bhattacharyya AP 1996. Permian–Triassic palynofloral succession in sub surface from Bazargaon, Nagpur District, Maharashtra. Palaeobotanist 43: 10–15.

Sundaram D & Nandi A 1984. Palaeobotanical study of Umrer Coalfield, Nagpur, Maharashtra, with special reference to biostratigraphy. In Symposium on Evolutionary Botany & Biostratigraphy, Calcutta 1979. Sharma AK *et al*. (Editors)—Today & Tomorrow's Printers & Publishers, New Delhi: 315–321.

Tewari R 2007. The *Glossopteris* flora from the Kamptee Coalfield, Wardha Basin, Maharashtra, India. Palaeontographica B 277: 43–64.

Tewari R 2008. Morphological evolution of Indian Gondwana megaspores. Palaeobotanist 51: 89–98.

Tewari R & Maheshwari HK 1992. Megaspores from Early Permian of India. Geophytology 21: 1–19.

Tewari R, Mehrotra NC, Meena KL & Pillai SSK 2009. Permian megaspores from Kuraloi Area, Ib–River Coalfield, Mahanadi Basin, Orissa. Journal

of Geological Society of India 74: 669–678.

Tewari R, Mehrotra NC, Pillai SSK, Pandita SK & Agnihotri D 2012a. Gymnospermous seeds from the Barakar Formation of Umrer Coalfield, Wardha Basin, Maharashtra. Palaeobotanist 61: 123–130.

Tewari R, Pandita SK, Agnihotri D, Pillai SSK & Bernardes–de–Oliveira MEC 2012b. An Early Permian *Glossopteris* flora from the Umrer Coalfield, Wardha Basin, Maharashtra, India. Alcheringa: 1–18.

Tewari R & Rajanikanth A 2001. Occurrence of *Glossopteris* flora, Pisdura Nand Dongargaon Sub–Basin. Palaeobotanist 50: 411–414.

Tewari R, Rajanikanth A & Jha N 2004. Permian Gondwana megaspores from Wardha Basin. India. Palaeobotanist 53: 35–50.

Tiwari RS 1964. New miospore genera in the coals of Barakar Stage (Lower Gondwana) of India. Palaeobotanist 12: 250–259.

Tiwari RS 1965. Miospore assemblage in some coals of Barakar Stage (Lower Gondwana) of India. Palaeobotanist 13: 168–214.

Tiwari RS 1973. *Scheuringipollenites,* a new name for the Gondwana sporomorphs so far assigned to *"Sulcatisporites* Leschik 1955" Senckenb. Leth. 54: 105·117.

Tiwari RS & Vijaya 1995. Differential morphographic identity of Gondwana palynomorphs. Palaeobotanist 44: 62–115.

Varadpande DG 1977a. *Dadoxylon satnauriense*, a new species of petrified gymnosperm wood from the Lower Gondwanas of India. Journal of the University of Poona, Science and Technology 50: 157–162.

Varadpande DG 1977b. Fossil plants from Kamthi beds of Lower Gondwanas of India. Journal of the University of Poona, Science and Technology 50: 227–234.

Venkatachala BS & Kar RK 1966. *Corisaccites* gen. nov., A new saccate genus from the Permian of Salt Range, West Pakistan. Palaeobotanist 15: 107–109.

Venkatachala BS & Kar RK 1968. Palynology of the Karanpura sedimentary Basin, Bihar, India–I Barakar Stage at Badam. Palaeobotanist 16: 66–90.