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Palaeobotanical evidence for Artinskian wildfire in the Talcher Coalfield, Mahanadi Basin, India

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The present endeavour documents the evidence of Artinskian wildfire from the Indian geological record by means of analysing macroscopic fossil charcoal fragments embedded in the coal bearing succession of Bharatpur Coal-mine in Talcher Coalfield, Mahanadi Basin, India. The palynological and SEM analyses record palaeobotanical evidence of this wildfire. The *Scheuringipollenites barakarensis* palynoassemblage of the present contribution assigns an Early Permian (Artinskian) age to the studied section and it also shows the dominance of glossopteridales, sub dominance of coniferales followed by cordaitales and filicales plant groups. The SEM study of macroscopic charcoal fragments exhibits anatomical features like homogenized cell walls, uniseriate simple, biseriate simple as well as alternate pitting patterns present on tracheid walls and also rays of varying heights signifying gymnospermous wood affinities. The good preservation and large size as well as almost unabraded edges of the charcoal fragments are indicative of a parautochthonous origin.

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INTRODUCTION

The Gondwana sediments of Mahanadi Basin have been deposited in the Chhattisgarh and Odisha states of India. This basin comprises five main coalfields namely Mand-Raigarh, Hasdo-Arnad, Korba, Talcher and Ib-River. Among these coalfields, Talcher Coalfield is situated on the south eastern part of the Mahanadi Basin and occupies the Brahmani River valley. It is spread over an area of 1800 km^2. The major part of this coalfield lies in Dhenkanl and Angul districts while some part in the Sambalpur District, Odisha. This coalfield lies between latitudes 20º 50' - 21º 15'N and longitudes 84º 20' - 85º 33'E (Fig. 1). The Precambrian rocks comprising granites, gneisses, schists, phylites and amphibolites (Table 1) form the basement for the deposition of the overlying Lower Gondwana sedimetary succession. There lies an angular unconformity between the contact of Lower Gondwana succession and underlying Precambrian basement rocks. The Lower Godwana sediments are more or less striking in the E-W direction. Lithostratigraphically, the lowermost Lower Gondwana sediments resting immediately above the underlying Precambrian basement rocks belong to the Talchir Formation. The Talchir Formation constitutes the oldest lithostratigraphic unit of the Gondwana Supergroup. It is further followed-up by coal-bearing Karharbari and Barakar formations of Early Permian age. The successively younger non-coal bearing Barren Measures Formation (early Late Permian) overlies Barakar Formation. The youngest Lower Gondwana rocks of this coalfield belonging to the Kamthi Formation range in age from Late Permian to Early Triassic (Raja Rao, 1982; Manjrekar *et al*., 1995, 2006; Goswami and Singh, 2013) (Table 1). The Bharatpur coalmine section under present investigation corresponds to the Barakar Formation. Lithologically, the Barakar Formation is mainly consisting of medium to fine or even coarse-grained feldspar bearing white colour sandstones, grey/carbonaceous shale and thick coal seams mostly interbanded with shale and clay bands.

Palynological assemblages are known from all formations (Talchir to Kamthi) in the Talcher Coalfield. Bharadwaj and Srivastava (1969) reported two palynoassemblages belonging to Early Permian age from a 19 boreholes study in the Talcher Coalfield. Navale and Srivastava (1971) recognised upper Barakar palynoassemblage of Late Permian age from the Gopalprasad seam in the Talcher Coalfield. Tiwari *et al*. (1991) reported the Upper Permian (Late Permian) Raniganj Formation has been identified in the Supra Barakar sequence in western part of the Talcher coalfield. Tripathi (1993) identified three distinct palynozones viz. *Parasaccites korbaensis* Assemblage Zone (Upper Talchir), *Scheuringipollenites barakarensis* Assemblage Zone (Lower Barakar) and *Faunipollenites varius* Assemblage Zone (Upper Barakar) from the borehole TEW-25 in the north-western part of this coalfield. Tripathi (1996a) recorded Early and Late Triassic palynoassemblages from the Barakar and Suprabarakar sediments of the borehole TP-8 in the eastern region of the Talcher Coalfield and she observed a distinct and sharp palynological break in the Suprabarakar sequence. Tripathi (2001) has also distinguished a Permian-

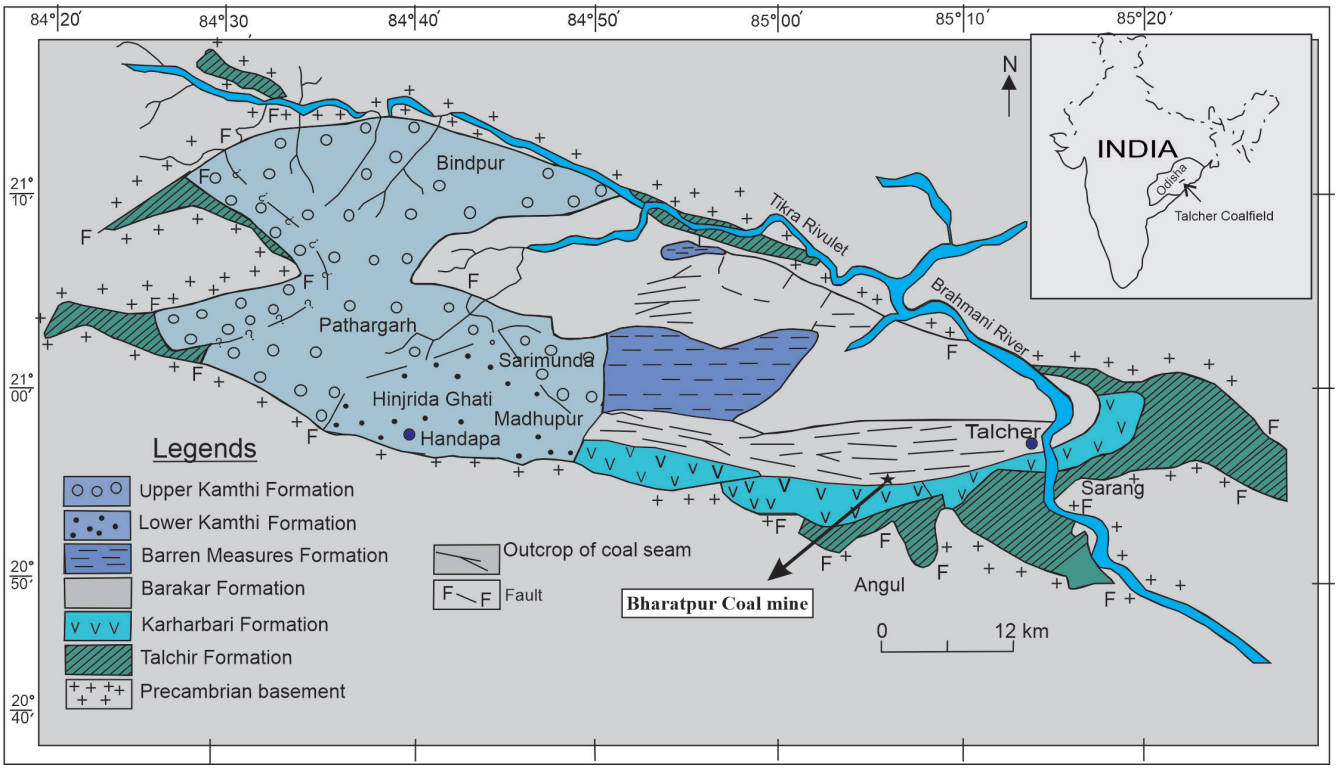


Fig. 1. Geological map of Talcher Coalfield showing the location of study area Bharatpur coalmine, Talcher Coalfield, Mahanadi Basin.

Triassic palynological boundary from the same borehole. Srivastava (1969) documented Lower Barakar, late Early Permian palynoassemblage from Gopalprasad area in Talcher Coalfield. Bhattacharyya *et al*. (2001) recovered a Triassic miofloral assemblage of non-striated bisaccates from the Kamthi Formation of this coalfield. Meena (2003) recorded late Early Triassic and Early Permian palynoassemblages from the boreholes TP-9 and TP-10 of the Talcher Coalfield. Recently, Sahoo *et al*. (2020a,b) have recorded two palynoassemblages from Late Permian sediments of this coalfield near Angul District.

The occurrence of fossil charcoal in sedimentary rocks is widely accepted as direct evidence of palaeofire in the geological past (Scott and Jones, 1994, Scott 2000; Scott and Glasspool, 2006). Most of the charcoal findings from the Permian coal and associated sediments are of gymnospermous origin (Jasper *et al*., 2013, 2017; Benicio *et al*., 2019; Murthy *et al*., 2020, 2021). In comparison with Northern Hemisphere, there are very few macroscopic charcoal studies from Upper Palaeozoic sediments in Southern Hemispheres particularly in Indian subcontinent. So far, the evidences of palaeo-wildfire in India are known from the Late Permian Raniganj Coalfield, Damodar Basin (Jasper *et al*., 2012) and from the Barren Measures Formation in the South Karanpura Coalfield, Damodar Basin (Mahesh *et al*., 2015). Subsequently, Mahesh *et al*. (2017) reported Late Permian macroscopic charcoal from the Raniganj Formation in the Mand-Raigarh Coalfield, Mahanadi Basin. In addition, Jasper *et al*. (2016) have found Late Permian charcoal fragments (tracheids) from Zewan Formation in the Kashmir region, North West Himalaya. Further, Jasper *et al*. (2017) have also recorded Early Permian charcoal from the Dhanpuri coalmine section in the Sohagpur Coalfield, South Rewa Gondwana Basin. Recently, Murthy *et al*. (2020, 2021) have documented Early Permian (Artinskian) macroscopic charcoal fragments respectively from Auranga Coalfield in the Damodar valley and Dulia Block in the Rajmahal Basin.

The present palynological study mainly deals with the formulation of palynostratigraphic zones and providing the precise age for the Bharatpur coalmine section (belonging to Barakar Formation) of the Talcher Coalfield. This work also incorporates the involvement of SEM study in the context of analyzing the anatomical features of macroscopic charcoal present in the carbonaceous shale (samples No. BP-6A, BP-7 & BP-8).

MATERIAL AND METHODS

Palynology - Each sample of approximately fifty g of sediments were crushed and then proccessed by using hydrofluoric acid (40% HF) for two days for removal of silicates and other mineral impurities. These were oxidized with concentrated nitric acid (63.1% HNO_3) to remove the humic units. The residue was sieved by 400 mesh sieves and five slides were prepared for each sample. The palynofossils were examined under a standard light microscope (Olympus BX61) with DP-25 camera using Cell A software.

Charcoal - The macroscopic charcoal fragments embedded in carbonaceous shales (BP-6A, BP-7 & BP-

Table 1. Generalized stratigraphy of Talcher Coalfield, Odisha (modified after Manjrekar *et al*., 2006).

Age	Formation	Lithology and fossil content	Thickness
Recent to	Upper	Alluvium and laterite	250+
Triassic	Kamthi	Triassic Upper Kamthi Upper bed (Late Triassic): ferruginous, hard and quartzitic sandstones, bands of compact brown, grey and yellow shales and clasts of lavender and creamy white shales. Palynoassemblage includes *Striatopodocarpites*, *Satsangisaccites*, *Falcisporites*, *Weylandites*, *Muraticavea*, *Lundbladispora*, *Arcuatipollenites*, *Playfordiaspora* and *Alisporites*	
Late Permian	Lower Kamthi	Medium- to coarse-grained, pebbly cross-bedded ferruginous sandstones, clasts of greenish-white and greyish-white shales, pink clays. Megafloral assemblage is dominated by medium and broad mesh forms Glossopteris species with plenty of ferns and arthrophytes. Palynoassemblage is dominated by *Striatopodocarpites*, *Faunipollenites* and *Crescentipollenites*.	
Middle Permian	Barren Measures	Coarse- to medium-grained greenish grey feldspathic sandstones with shreds and lenses of chocolate coloured clay, micaceous siltstone, dark grey shale, carbonaceous shale, purple brown shale and clay ironstone. Palynofloral assemblage is dominated by *Densipollenites* and *Striatopodocarpites*.	317+
Early Permian	Barakar	Fine- to coarse-grained feldspathic whitish sandstones, siltstone, grey shale, sandy shale, fireclay and coal seams with polymictic conglomerate at the base. Megafloral assemblage is dominated by narrow and medium mesh forms Glossopteris species with a few ferns and arthrophytes. Palynoassemblage is dominated by *Scheuringipollenites*, *Faunipollenites* and *Striatopodocarpites*.	600
Early Permian	Karharbari	Medium- to coarse-grained whitish arkosic sandstones, carbonaceous shale, grey shale and coal seams. Megafloral assemblage is dominated by Buriadia, Gangamopteris, Euryphyllum and Noeggerathiopsis. Palynoassemblage is dominated by *Parasaccites*, *Microbaculispora* and *Brevitriletes*.	270
Early Permian	Talchir	Diamictites, rhythmites, turbidites, conglomerate, fine- to medium-grained greenish sandstones, olive coloured needle shales, turbidite, tillites and tilloids etc. Megafloral assemblage comprises Noeggerathiopsis, equisetaceous stems, Gangamopteris, Arberia and Ottokaria. Palynoassemblage is dominated by *Plicatipollenites*, *Potonieisporites* and *Caheniasaccites*.	170+
		----------Unconformity----------	
	Precambrian	Granites, gneisses, amphibolites, migmatites, quartzite and pegmatites etc.	

8) of Bharatpur coalmine section (Fig. 2) were extracted mechanically with the help of tweezers, surgical knife and needles under an illuminated magnifier. The fragments were then mounted on stubs with adhesive carbon tape and coated with gold-palladium coater (JEC 3000PC). These were observed and also photographed under Scanning Electron Microscope (SEM) JEOL 7610F.

Repository - The palynotaxa documented in this paper are deposited in the repository of Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow vide statement no. 1564 with museum slide numbers 16898-16907.

RESULTS

Palynological study

The preservation of palynotaxa is inconsistent within the samples, but recovery is very low and specimens are yellowish-dark brown in colour and distorted. Out of twelve samples, only seven samples (BP-1, 3, 4, 5, 6, 8 and 9) yielded palynomorphs together with uneven dark plant debris. Other two samples (BP-3A & BP-7) have yielded very few palynomorphs along with degraded organic matter, dark colour woody flinters and uneven dark plant debris. The remaining three samples (BP-2, BP-6A & BP-10) are found barren of palynomorphs and comprise lath-shaped woody splinters and uneven shaped dark debris. Based on quantitative, qualitative analysis as well as marker speices one distinct palynoassemblage has been identified. The vertical distribution of different palynotaxa is shown in Table 2 and 3. Stratigraphically significant marker palynotaxa are presented in Plate-I. The list of palynotaxa recovered from the Bharatpur coal mine section and their botanical affinities are shown in Table 4.

The palynomorphs recovered from present palynoassemblage have low taxonomical diversity and consisting 24 genera and 28 species belonging to trilete spores and pollens. These are Filicales (2 taxa), Cordaitales (5 taxa), Glossopteridales (11 taxa) and Coniferales (7 taxa) and 3 unknown taxa (Table 4). The statistical analysis of the studied sequence reveals that the pollen grains are dominant constituents over the spores. In pollen grains, the non striate bisaccate genus *Scheuringipollenites* (0-31 grains) is dominating and the striate bisaccate genus *Faunipollenites* (1-22 grains) is a subdominating taxon. The other striate bisaccate pollens included in the palynoassemblage are *Striatopodocarpites* (0-2 grains), *Rhizomaspora* (0-1 grain), *Crescentipollenites* (0-1 grain), *Diastriatites* (0-1 grain) and *Verticipollenites* (0-1 grain). The other non striate bisaccate genus is *Platysaccus* (0-1 grain). The palynoassemblage also consists of other palynomorphs such as taeniate bisaccate *Lunatisporites* (0-1 grain), *Chordasporites* (0-1 grain), *Guttulapollenites* (0-1 grain), monosaccate pollen- *Barakarites* (0-2 grains), *Striomonosaccites* (2-9 grains), *Parasaccites* (0-2 grains), *Densipollenites* (0-10 grains), *Striasulcites* (0-1 grain), *Striapollenites* (0-1 grain), sulcate pollen- *Weylandites* (0-1 grain), trilete spores- *Microbaculispora* (0-1 grain), *Callumispora* (0-2 grains), *Maculatasporites* (0-1 grain), *Praecolpatites* (0-1 grain) and *Tetraporina* (0-1 grain).

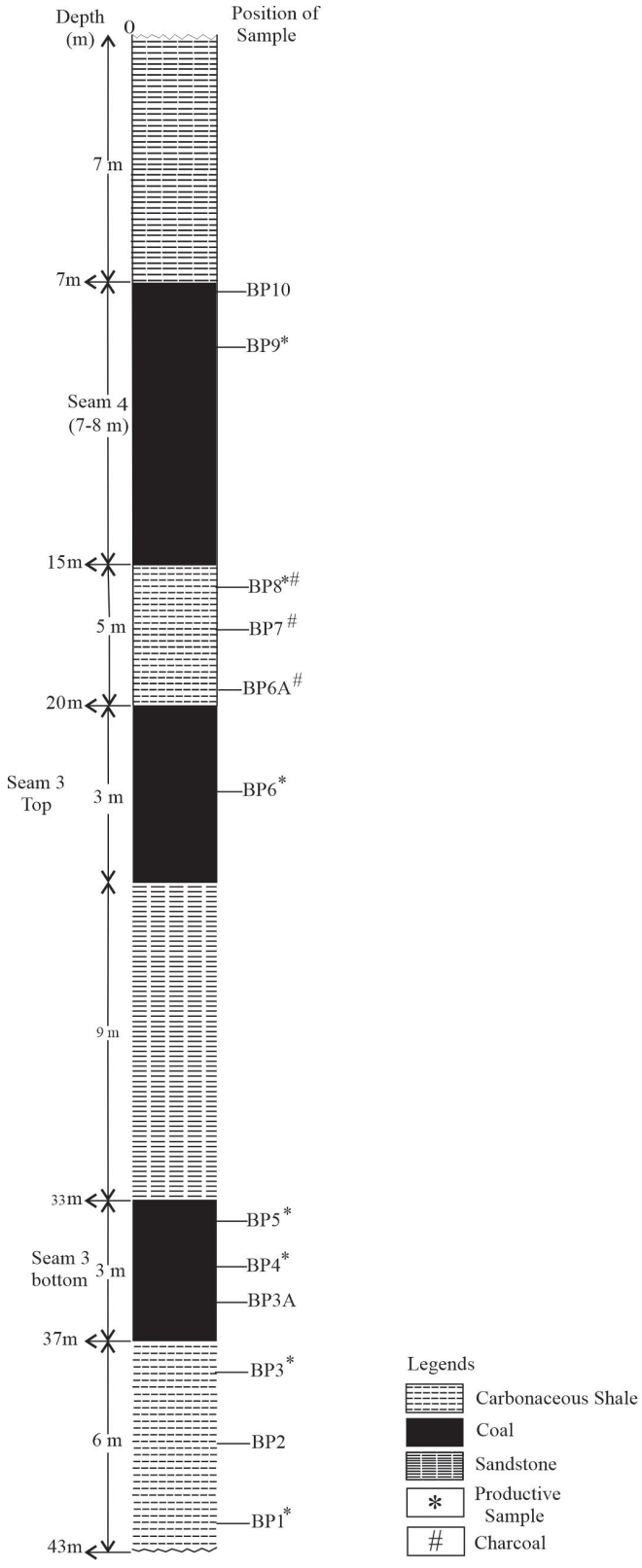


Fig. 2. Litholog of the Bharatpur coalmine section, Talcher Coalfield, Mahanadi Basin.

Anatomical characteristics of charcoal

Jones and Chaloner (1991) and Scott (2000, 2010) proposed the criteria for identification of fossil charcoal as black colour, silky lustre, homogenized cell walls and well preserved anatomical features. Three samples were collected from three levels in the Bharatpur coalmine section from the Talcher Coalfield, Son-Mahanadi Basin (Fig. 2). Many well preserved fragments of charcoal embedded in the carboniferous (encircled) shale exhibit the size range from 10- 20 mm in width and 15- 40 mm in length (Plate II).

In all charcoal specimens (hand specimen), the charred woody tissues are not three-dimensionally preserved. In almost all samples homogenized cell walls are clearly visible in tracheids (Plate III, Fig. 5; Plate IV, Fig.3). The tracheid walls represent biseriate alternating border pits (Plate III, Fig 3; Plate IV, Fig. 2). Most of the pits are oval shape with a diameter of 4-6.5 µm (Plate III, Fig. 3) while some are small and circular with a diameter of 2.0-2.5µm (Plate IV, Fig. 2). Rays are observed in various heights such as rays of three- cell height with diameter range of 23-25µm (Plate IV, Fig.1), and rays of eight – cell height with a diameter range of 15-30 µm (Plate III, Fig.2). It has been noticed that the palynological slides (from the charcoal embedded sediment) contain microcharcoal (opaque phytoclasts) rich in lath shaped particles with or without pits (Plate I, Fig. 18; Plate IV, Figs. 5-8).

DISCUSSION

In the present study, the recovery of palynotaxa in ca 43 m thick studied Gondwana sequence consists both palynotaxa and palynodebris. The palynodebris containing organic matter includes dark brown woody splinters and amorphous matter (Plate-I, Fig. 18). Generally, late Early Permian (Artinsian) sediments of the Barakar Formation in Gondwana succession are characterized by dominance of non-striate bisaccate mainly *Scheuringipollenites* and striate bisaccate *Faunipollenites* pollens.

The Glossopteridales elements dominate in the present palynoassemblage constituting 33% of the total plant assemblage and represented by eleven species such as three species of *Scheuringipollenites*, two species of *Faunipollenites* and one species each of *Striatopodocarpites, Verticipollenites, Weylandites, Striapollenites, Striasulcites* and *Platysaccus*, followed by sub-dominance of Coniferales acconting to 29% of the total plant assemblage consisting seven species such as one species each of *Guttulapollenites, Crescentipollenites, Distriatites, Chodasporites, Alisporites, Arcuatipollenites* and *Rhizomaspora*. Other plant groups of this assemblage constitute 17 % of the total plant assemblages and includes five species of cordaitales viz. two species of *Densipollenites* and one species each of *Striomonosaccates*, *Barakarites* and *Parasaccites*; spores are meagre represented with only two species of Filicales comprising 8% of the total plant assemblage viz. one species each of *Callumispora* and *Microbaculispora*. Three species of unknown plant group with an account 12% of the total plant assemblage are of *Tetraprina*, *Maculatisporites* and *Precolatites* (Table 4).

The palynoassemblage is showing the dominance (in number) of *Scheuringipollenites* and sub-dominance

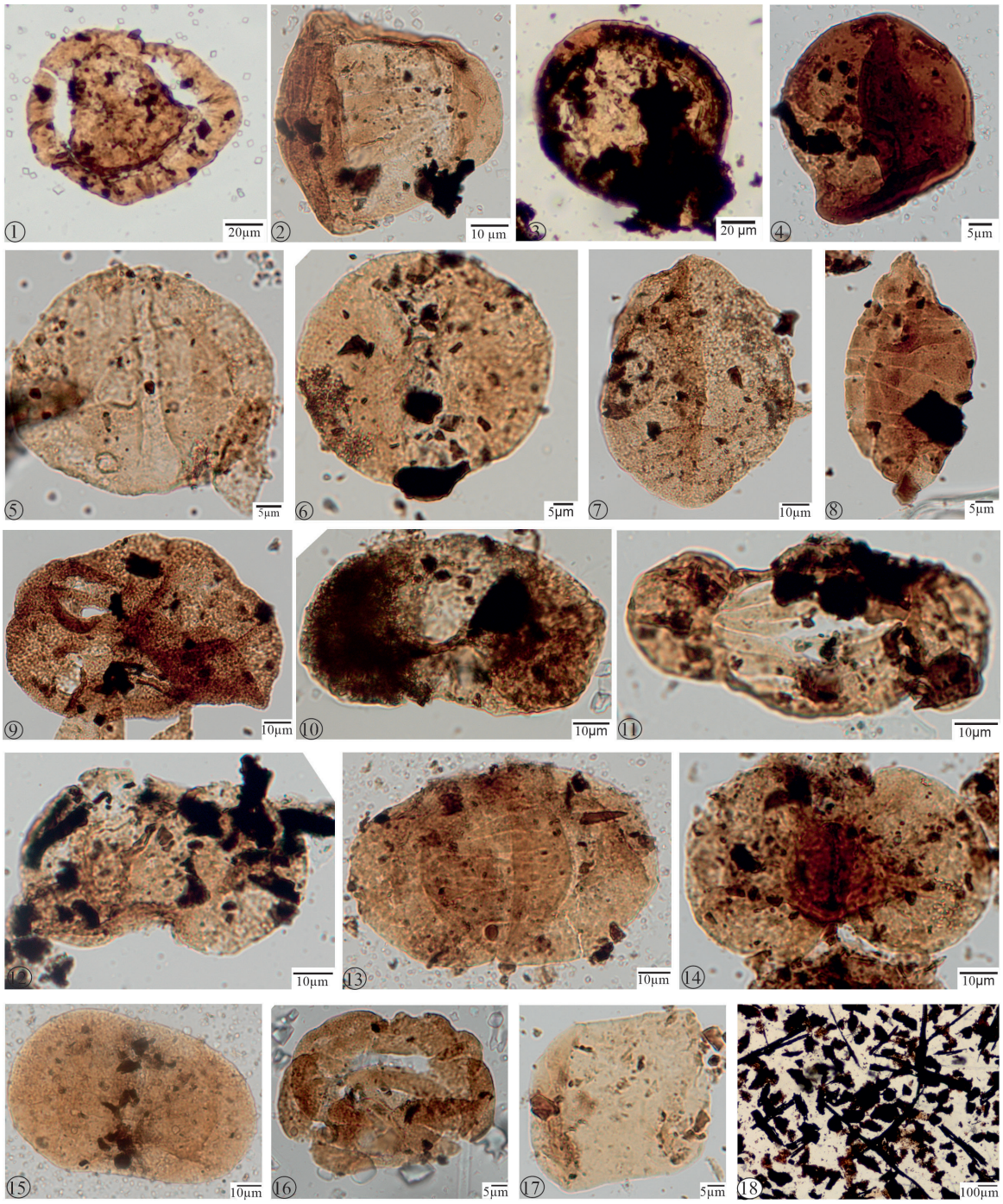
Table 2. Distribution of palynotaxa at each sample in the investigated section of Bharatpur coalmine, Talcher Coalfield, Mahanadi Basin. Note: The numbers do not correspond to percentages.

Genera	BP-1	BP-2	BP-3	BP-3A	BP-4	BP-5	BP-6	BP-6A	BP-7	BP-8	BP-9	BP-10
Callumispora	--	--	--	--	--	1	--	--	--	--	--	--
Microbaculispora	1	--	--	--	1	--	--	--	--	--	--	--
Striomonosaccites	--	--	7	--	--	2	--	--	--	--	--	--
Densipollenites	--	--	10	--	--	1	--	--	--	1	--	--
Barakarites	--	--	2	--	--	1	1	--	--	2	--	--
Parasaccites	--	--	1	--	--	2	--	--	--	--	1	--
Faunipollenites	7	--	22	--	---	5	2	--	--	9	2	--
Crescentipollenites	--	--	1	--	--	1	1	--	--	--	--	--
Striatopodocarpites	1	--	--	--	1	1	1	--	--	--	--	--
Verticipollenites	1	--	1	--	--	--	--	--	--	--	1	--
Alisporites	--	--	--	--	--	--	1	--	--	--	--	--
Distriatites	--	--	--	--	--	--	--	--	--	1	--	--
Chordasporites	--	--	1	--	--	1	--	--	--	--	--	--
Striapollenites	--	--	--	--	--	1	--	--	--	--	--	--
Striasulcites	--	--	--	--	--	1	--	--	--	--	--	--
Lunatisporites	--	--	--	--	--	1	--	--	--	--	1	--
Platysaccus	--	--	--	--	1	--	--	--	--	--	--	--
Maculatisporites	--	--	--	--	1	1	--	--	--	--	--	--
Guttulapollenites	--	--	--	--	--	3	--	--	--	--	--	--
Scheuringipollenites	14	--	30	--	---	2	3	--	--	6	--	--
Weylandites	--	--	--	--	--	--	1	--	--	--	--	--
Tetraporina	--	--	--	--	--	--	1	--	--	--	--	--
Rhizomaspora	--	--	--	--	--	--	1	--	--	--	--	--

Table 3. Distribution of palynotaxa (species level) in the investigated section of Bharatpur coalmine, Talcher Coalfield, Mahanadi Basin.

	BP-1	BP-2	BP-3	BP-3A	BP-4	BP-5	BP-6	BP-6A	BP-7	BP-8	BP-9	BP-10
Callumispora fungosa	---	---	---	---	---	P	---	---	---	---	---	---
Microbaculispora gondwanensis	P	---	---	---	P	---	---	---	---	---	---	---
Striomonosaccites ovatus	---	---	P	---	---	P	---	---	---	---	---	---
Densipollenites invisus	---	---	P	---	---	P	---	---	---	---	---	---
Densipollenites sp.	---	---	---	---	---	---	---	---	---	P	---	---
Barakarites decorus	---	---	P	---	---	P	---	---	---	P	---	---
Parasaccites korbaensis	---	---	P	---	---	P	---	---	---	---	P	---
Faunipollenites varius	P	---	P	---	---	P	P	---	---	P	P	---
Faunipollenites singraulensis	P	---	P	---	---	---	P	---	---	---	---	---
Crescentipollenites fuscus	---	---	P	---	---	---	P	---	---	---	---	---
Striatopodocarpidites magnicorpus	P	---	---	---	P	P	P	---	---	---	---	---
Verticipollenites sp.	P	---	---	---	---	---	---	---	---	---	P	
Distriatites bilateris	---	---		---	---	---	---	---	---	P	---	---
Chordasporites sp.	---	---	P	---	---	P	---	---	---	---	---	---
Striapollenites sp.	---	---	---	---	---	P	---	---	---	---	---	---
Striasulcites tectus	---	---	---	---	---	P	---	---	---	---	---	---
Lunatisporites ovatus	---	---	---	---	---	---	---	---	---	---	P	---
Platysaccus sp.	---	---	---	---	P		---	---	---	---	---	---
Maculatisporites sp.	---	---	---	---	P	P	---	---	---	---	---	---
Guttulapollenites hunnonicus	---	---	---	---	---	P	---	---	---	---	---	---
Scheuringipollenites barakarensis	P	---	P	---	---	P	---	---	---	---	---	---
Scheuringipollenites maximus	P	---	P	---	---	P	P	---	---	P	---	---
Scheuringipollenites tentulus	P	---	P	---	---	P	P	---	---	---	---	---
Weylandites minutus	---	---	---	---	---	---	P	---	---	---	---	---
Tetraporina sp.	---	---	---	---	---	---	P	---	---	---	---	---
Rhizomaspora indica	---	---	---	---	---	---	P	---	---	---	---	---
Alisporites sp.	---	---	---	---	---	---	P	---	---	---	---	---
Praecolpatites	---	---	---	---	---	---	---	---	---	P	---	---

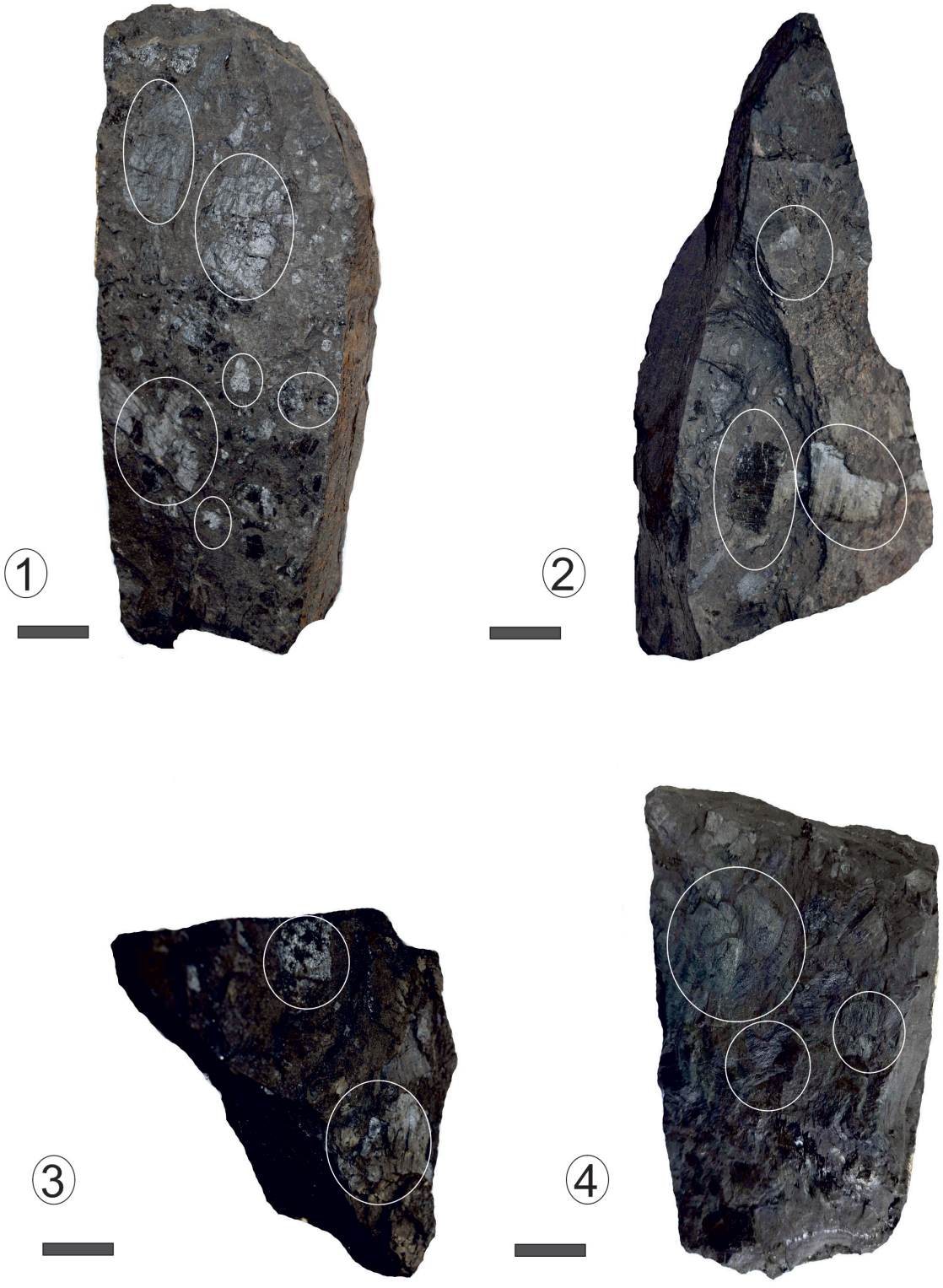
Plate I



EXPLANATION OF PLATE I

1. *Parasaccites korbaensis* Bharadwaj and Tiwari (BSIP Museum Slide No. 16904, P60/4); 2. *Striomonosaccites ovatus* Bharadwaj 1962 (BSIP Museum Slide No. 16903, R37/1); 3. *Barakarites decorus* Tiwari 1965 (BSIP Museum Slide No. 16900,T49/4); 4. *Callumispora fungosa* Balme 1973 (BSIP Museum Slide No. 16903, O53-P53); 5. *Scheuringipollenites barakarensis* Tiwari 1973 (BSIP Museum Slide No. 16899, X43); 6. *Scheuringipollenites maximus* Tiwari 1973 (BSIP Museum Slide No. 16901, S61/3); 7. *Scheuringipollenites tentulus* Tiwari 1973 (BSIP Museum Slide No. 16902, Z64/2); 8. *Striasulcites tectus* Venkatachala & Kar 1968 (BSIP Museum Slide No. 16904, M66/4); 9. *Densipollenites invisus* Bharadwaj and Salujha 1964 (BSIP Museum Slide No. 16905, M44/4-N44/2); 10. *Chordasporites* sp. (BSIP Museum Slide No. 16901, T41/4-T42/3); 11. *Striotopodocarpites magnicorpus* Bharadwaj and Tiwari 1964 (BSIP Museum Slide No. 16907, L61/2); 12. *Verticipollenites* sp. (BSIP Museum Slide No. 16907, N49); 13. *Crescentipollenites fuscus* (Bharadwaj), Tiwari and Kar 1974 (BSIP Museum Slide No. 16906, Q45/3); 14. *Rhizomaspora indica* Tiwari 1964 (BSIP Museum Slide No. 16906, N36/4); 15. *Faunipollenites varius* Bharadwaj 1962 (BSIP Museum Slide No. 16898, Q38/3); 16. *Guttulapollenites hannonicus* Goubin 1965 (BSIP Museum Slide No. 16903, R54/1); 17. *Tetraporina* sp. (BSIP Museum Slide No. 16906, W32/2-W33/1); 18. Showing microscopic charcoal in palynological slide.

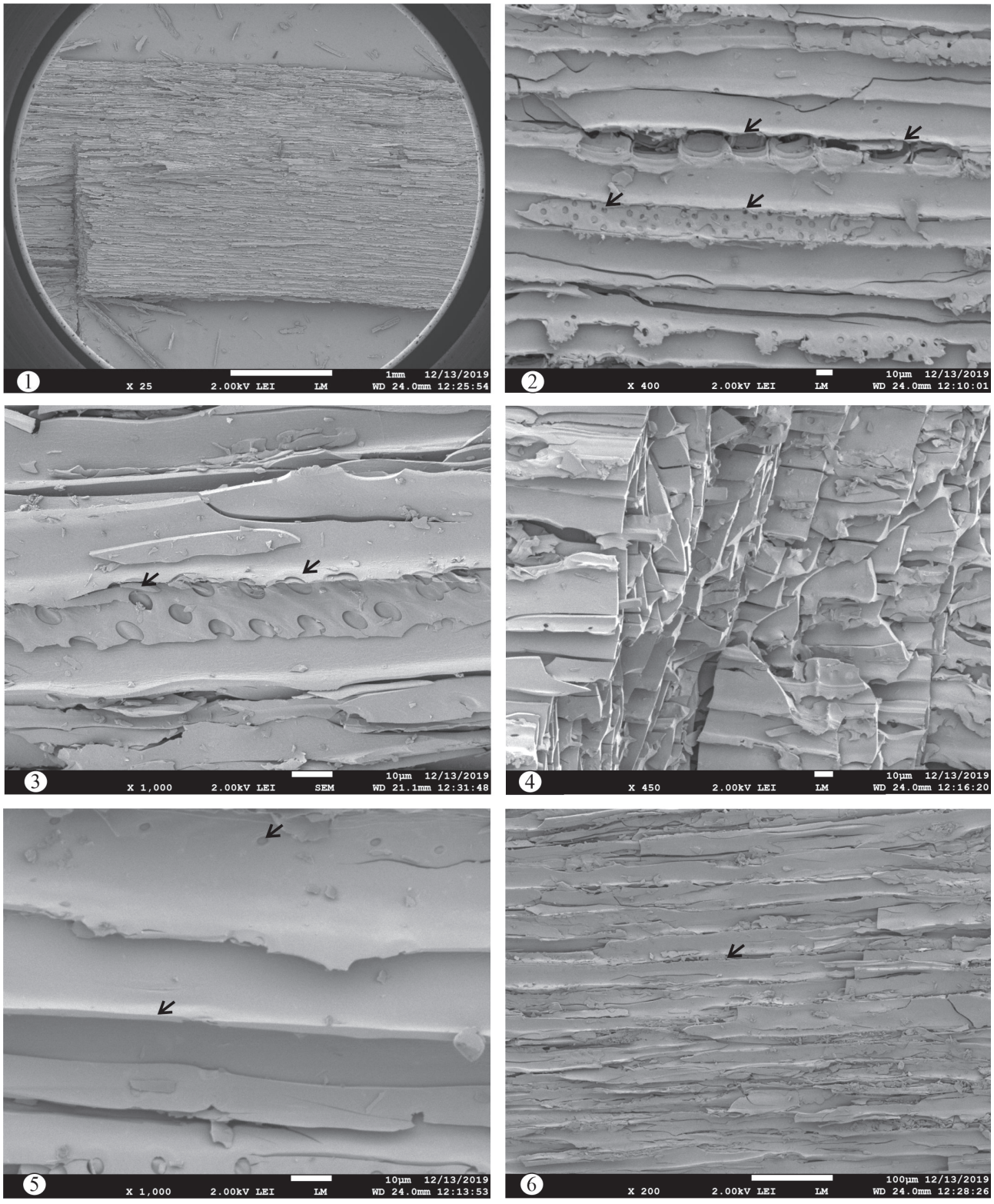
Plate II



EXPLANATION OF PLATE II

Photographs showing the macroscopic fossil charcoal fragments embedded in the carbonaceous shale in the Bharatpur coalmine and displaying the silky lustre (marked in circles). 1. Charcoal fragments showing the sharp edges bigger in size and it is recovered from the sample BP6A; 2. Charcoal fragments showing the sharp edges and relatively smaller in size, it recovered from the sample BP 7; 3 and 4. Charcoal fragments showing the serrated edges and less silky lustre and it recovered from the sample BP 8 (scale 2.5 cm).

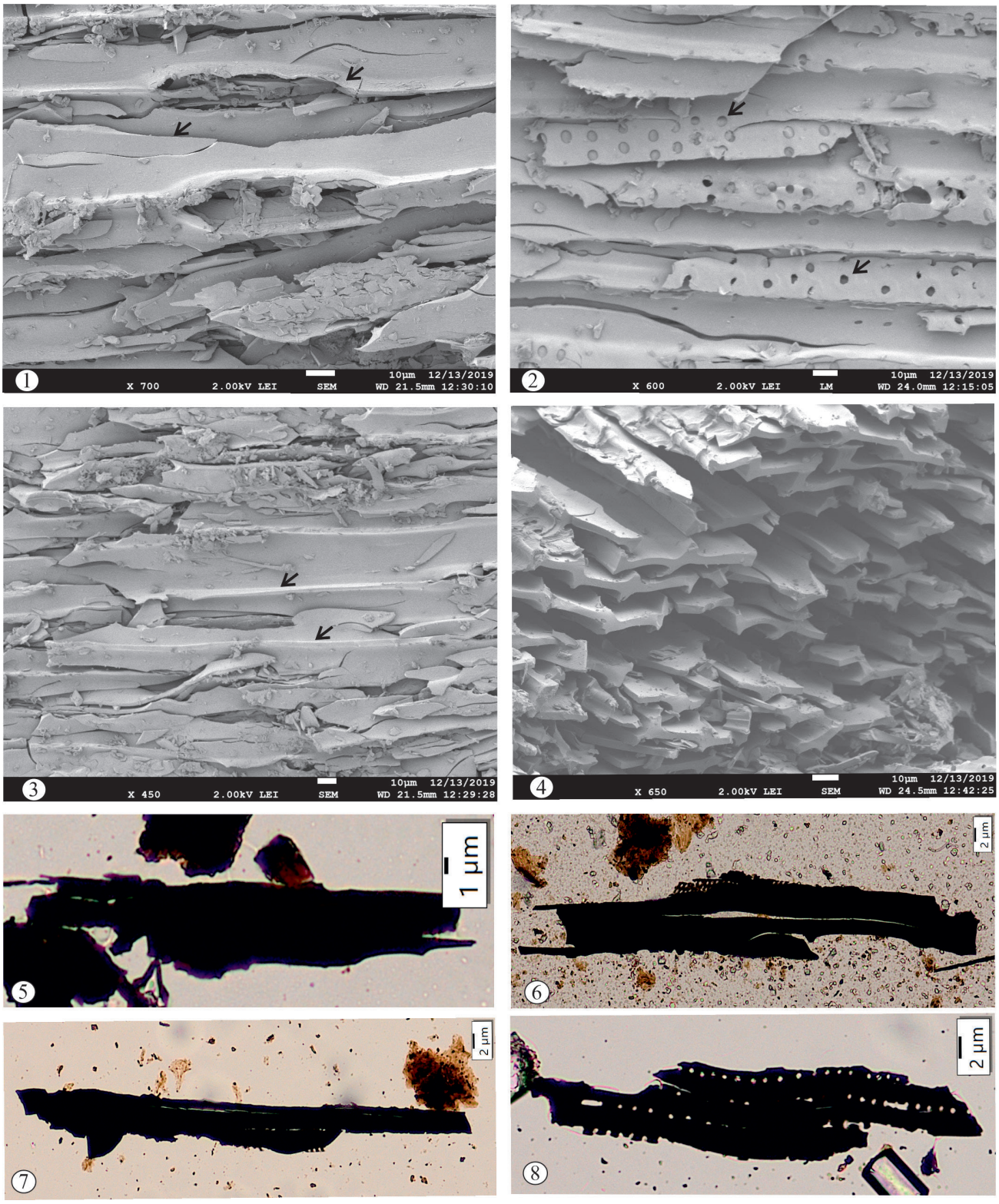
Plate III



EXPLANATION OF PLATE III

Field Emission Scanning Electron Microscopic photographs of Bharatpur open cast mine, Talcher Coalfield, Mahanadi Basin. 1. Showing charcoal fragment; 2. Charred tracheid exhibiting uniseriate rays of eight-cell heights (arrow); 3. Charred tracheids exhibiting multiseriate pitting with oval shape aperture; 4. Exhibiting shattered tracheids in oblique view; 5. Charred exhibiting homogenized cell walls (arrow); 6. Showing charcoal tracheids.

Plate IV



EXPLANATION OF PLATE IV

Field Emission Scanning Electron Microscopic photographs of Bharatpur open cast mine, Talcher Coalfield, Mahanadi Basin. 1. Charred tracheids exhibiting uniseriate ray of four-cell highs; 2. Charred tracheids exhibiting multiseriate, alternate and circular smaller in size relatively pits; 3. Charred tracheids exhibiting homogenized cell walls (arrow); 4. Exhibiting anatomical details of heavily shattered tracheids due to compaction and also showing homogenized cell wall and so called "Bogenstrukturen"; 5-8. Showing .microcharcoal photographs from the palynological slide (BP-7).

Table 4. List of palynotaxa recorded in the investigated section of Bharatpur coalmine, Talcher Coalfield, Mahanadi Basin (based on Balme 1995; Lindström and McLoughlin 2007; di Pasquo and Grader 2012; Mishra *et al*., 2017).

Palynotaxa identified in this study	Botanical affinities
Callumispora fungosa	Filicales
Microbaculispora gondwanensis	Filicales
Striomonosaccites ovatus	Cordaitales
Densipollenites invisus	Cordaitales
Densipollenites sp.	Cordaitales
Barakarites decorus	Cordaitales
Parasaccites korbaensis	Cordaitales
Faunipollenites varius	Glossopteridales
Faunipollenites singraulensis	Glossopteridales
Striatopodocarpites magnicorpus	Glossopteridales
Verticipollenites sp.	Glossopteridales
Scheuringipollenites barakarensis	Glossopteridales
Scheuringipollenites maximus	Glossopteridales
Scheuringipollenites tentulus	Glossopteridales
Weylandites minutus	Glossopteridales
Striapollenites sp.	Glossopteridales
Striasulcites tectus	Glossopteridales
Platysaccus sp.	Glossopteridales
Guttulapollenites hunnonicus	Coniferales
Crescentipollenites fuscus	Coniferales
Distriatites bilateris	Coniferales
Chordasporites sp.	Coniferales
Alisporites sp.	Coniferales
Arcuatipollenites ovatus	Coniferales
Rhizomaspora indica	Coniferales
Tetraporina sp.	Unknown
Maculatisporites sp.	Unknown
Praecolpatites	Unknown

of *Faunipollenites* pollens along with stratigraphically significant marker species viz., *Scheuringipollenites* (*S. barakaensis, S. maximus* and *S. tentulus*), *Faunipollenites varius, Faunipollenites singrauliensis, Rhizomaspora indica, Striasulcites tectus, Verticipollenites* sp., *Barakarites* sp., *Densipollenites* sp. and *Barakarites* sp. Thus, this palynoassemblage compares well with the *Scheuringipollenites barakarensis* assemblage zone in the lower part of the Barakar Formation of the Damodar Basin (Tiwari and Tripathi, 1992).

The identified macroscopic charcoal fragments are embedded in the carbonaceous shales. These are collected from three levels (samples BP-6A, BP-7 & BP-8) in the Bharatpur coal mine section (Fig. 2) and suggest the repeated occurrence of repetition of wildfire during deposition of these sediments. In most of the specimens, the edges of fragments are not abraded. Large sizes, sharp edges and beautifully preserved anatomical features demonstrate that these sediments have been transported only over a short distance (parautochthonous/autochtonous origin) before deposition (Scott, 2000; Abu Hamad *et al*., 2012 and Jasper *et al*., 2016). The typical "Bogenstrukturen" are observed in cross-section (Plate IV, Fig. 4) depicting in-situ shattered charcoal in siliciclastic sediments (Sander and Ghee, 1990; Scott, 2000; Uhl *et al*., 2004 and Kubik *et al*., 2015). The homogenized cell walls and well preserved anatomical details in the samples confirm that the charred woody fragments are fossil charcoal and thus served as direct evidence for palaeo wildfire (Jones and Chaloner, 1991 and Scott, 2000) during the deposition of Barakar sediments (Artinskian) in Talcher Coalfield, Mahanadi Basin. The FESEM analysis of charcoal has revealed anatomical details such as axial tracheids exhibiting uniseriate, simple and biseriate, alternating pitting patters and homogenized cell wall diagnostic of gymnospermous wood. All the charcoal fragments embeded in the carbonaceous shales it reflects sediments diposits over low energy condition in the proximal part of the deposition site.

CONCLUSIONS

Scheuringipollenites barakarensis palynoassemblage is identified in the coal-bearing sediments from the Bharatpur coal mine in the Talcher Coalfield, Mahanadi Basin and it is assigned an Early Permian (Artinskian) age. The palynoassemblage shows dominance of Glossopterid elements accounting for 33% of total plant assemblage representing eight species of Glossopteridales; three species of *Scheuringipollenites*, two species of *Faunipollenites* and one species each of *Striatopodocarpites, Verticipollenites, Weylandites, Striapollenites, Striasulcites* and *Platysaccus*.

Studied fossil charcoal fragments exhibit anatomical details such as homogenized cell walls, uniseriate simple, biseriate alternate pitting patterns and rays of varings heights on tracheid walls pointing to gymnospermous wood affinity. Preserved large sizes, sharp edges and excellent anatomical features are indicating short distance transport of sediments before burial of the charcoal specimens.

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