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Palaeoenvironmental and stratigraphical implications of the palynoflora and macro–charcoal from the early Permian of the Chuperbhita Coalfield, Rajmahal Basin, Jharkhand, India

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ABSTRACT

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Palynological and macro–charcoal studies have been carried out on fossiliferous material from the upper seam of the Barakar Formation of Simlong Open Cast Mine (OCM), Chuperbhita Coalfield, India. The palynoassemblage exhibits a dominance of non–striate bisaccate pollen, mainly *Scheuringipollenites,* and a subdominance of striate bisaccate pollen assignable to *Faunipollenites*, suggesting an early Permian age (Artinskian). The presence of macro–charcoal indicates the occurrence of wildfire at the time of deposition of the Barakar Formation at Simlong OCM. The composition of the palynological assemblage, as well as anatomical details of the macro–charcoal, indicate that the source vegetation was dominated by gymnosperms. The non–abraded edges of many charcoal fragments suggest that the charcoal has not been transported over a long distance, indicating local to regional fires. Together with previous records of macro–charcoal, and the high inertinite contents of many Permian coals from India, this study further supports the widespread occurrence of palaeo–wildfires as frequent sources of disturbance in continental ecosystems in this part of Gondwana during the early Permian.

Key–words—Macro–charcoal, Palynology, Palaeowildfire, Early Permian, Rajmahal Basin, India.

INTRODUCTION

THE Gondwana sediments, which have been deposited from the latest Carboniferous up to the early Cretaceous in Eastern Gondwana (i.e., Australia and India) are well exposed in different sedimentary basins of peninsular India (e.g., Gee, 1932; Veevers, 2006; Mukhopadhyay *et al.*, 2010). In the Rajmahal Basin, lower Gondwana sediments are known by the Talchir and the coal–bearing Barakar formations (Permian). The Upper Gondwana sediments are well exposed and divided into Dubrajpur (late Triassic to Jurassic) and Rajmahal (early Cretaceous) formations. Based on the occurrence of coal deposits, the Rajmahal Basin has been divided into five coalfields in the western part, stretching along the north–to–south directions, namely the Hura, Chuperbhita, Pachhwara, Mahuagarhi and Brahmani coalfields (Murthy *et al.*, 2020b).

Palynology plays an important role in the biostratigraphy of continental deposits (e.g., Traverse, 2007), as other reliable index–fossils are often missing in such deposits. In the Rajmahal Basin, palynological studies have been carried out from various Upper Gondwana (Rao, 1936, 1943; Vishnu Mittre, 1953, 1954; Tiwari *et al.,* 1984; Tripathi *et al.*, 1990, 2013; Bakshi *et al.,* 1992; Tiwari & Tripathi, 1995; Tripathi, 2001, 2002, 2004, 2008; Tripathi & Ray, 2006; Murthy *et al.*, 2018, 2020b) and Lower Gondwana (Maheshwari, 1967; Srivastava & Maheshwari, 1974; Murthy *et al.*, 2018, 2020b, 2021; Pillai *et al.*, 2020) formations in different coalfields. However, so far palynological records from the Chuperbhita Coalfield are scarce.

From this coalfield Ghosh *et al.* (1984) reported an upper Barakar palynoassemblage from the Chattagram area, including dominant striate bisaccate pollens (*Faunipollenites*, *Striatites*, *Strotersporites* and *Lahirites*) and trilete spores (*Punctatisporites* and *Psilalacinites*) in sub–dominance, with only sporadic occurrence of monosaccate pollen grains (mainly *Densipollenites*), suggesting a late early Permian age. Bharadwaj and Srivastava (1986) described a lower Barakar palynoassemblage from the Gomani River section of the Chuperbhita Coalfield. Banerjee and D'Rozario (1990, 1988) studied three cores (RCH–1, RCH–2 and RCH–3) from the Chuperbhita Coalfield and identified three palynoassemblage zones, namely the *Plicatipollenites–Parasaccites zone* belonging to the early Permian age (equivalent to Karharbari Formation), the non–striated bisaccate *Scheuringipollenites* zone, representing a late early Permian age (equivalent to the Barakar Formation), and the striate bisaccate *Striatopodocarpites–Striatites* zone, denoting a late early Permian age (equivalent to the upper part of the Barakar Formation). Later, Tripathi (2001) carried out a palynological study on samples from core RCH 151 from the Chuperbhita Coalfield and assigned Permian, Jurassic and early Cretaceous ages to the different horizons of this core. Five palynoassemblage zones *Scheuringipollenites barakarensis*, *Faunipollenites varius*, *Densipollenites densus*, *Gondisporites raniganjensis* and *Densipollenites magnicorpus* were identified from the coal–bearing sequence, indicating the strata equivalent to the Barakar, Barren Measures and Raniganj formations and interpreted as representing the Barakar Formation based on lithological criteria.

Fire is a common source of disturbance in many terrestrial ecosystems, not only in the present times, but also during large parts of the Phanerozoic (Scott *et al.*, 2014). The oldest records of charcoal produced by wildfires come from the Silurian (Glasspool *et al.*, 2004; Scott *et al.*, 2014; Glasspool & Gastaldo, 2022, 2023) and since then there is more or less continuous fossil records of charcoal and other products of wildfires (e.g., Scott, 2000, 2010; Brown *et al.*, 2012; Abu Hamad *et al.*, 2012; Scott *et al.*, 2014; Jasper *et al.*, 2021; Lu *et al.*, 2021). From Gondwana, the first evidence of palaeowildfire, in the form of micro–and meso–charcoal, has

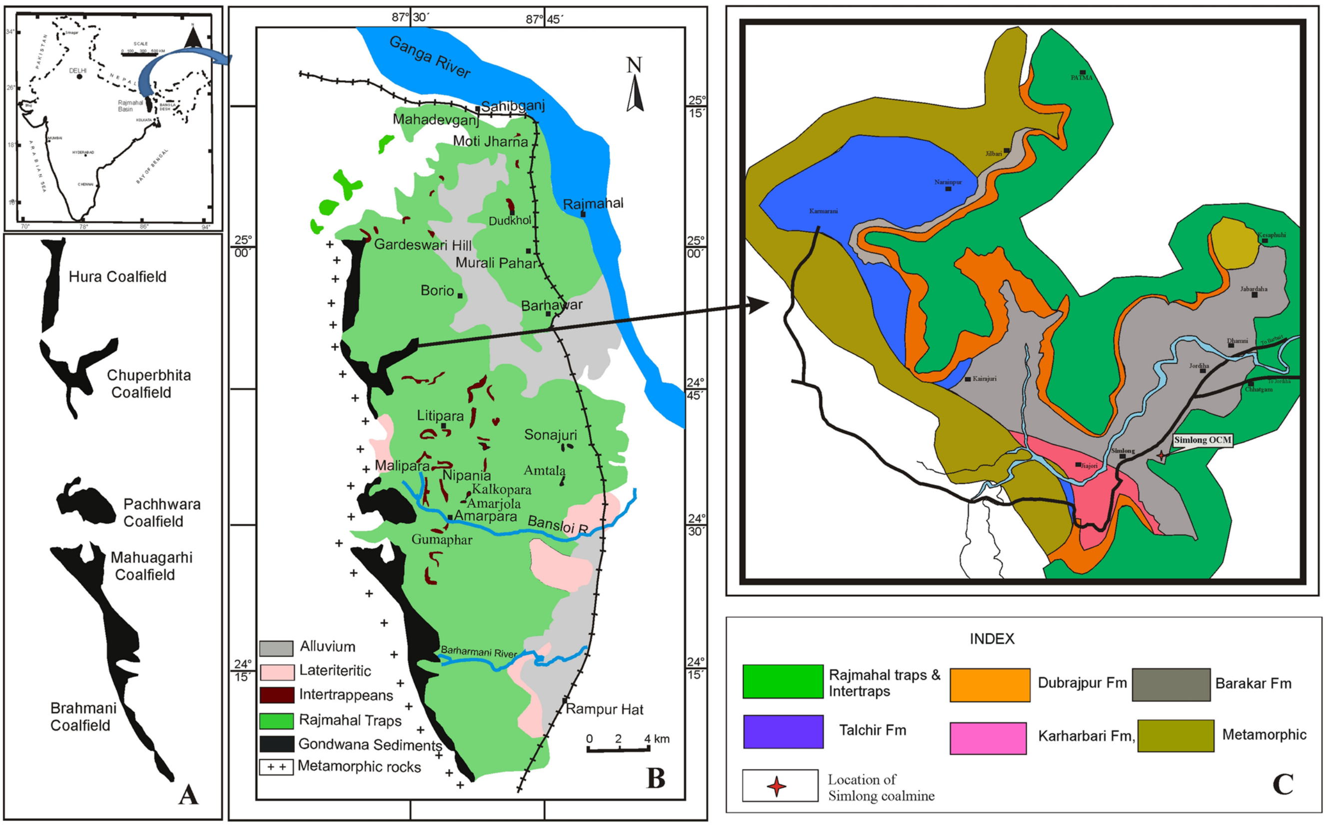

Fig. 1—(A) Overview of coalfields in the Rajmahal Basin, (B) Geological map of the Rajmahal Basin, (C) Geological map of the Chuperbhita Coalfield showing location of the sample.

been published from the late Permian of the Sydney Basin, Australia (Glasspool, 2000). However, it should be noted that abundant occurrence of pyrogenic inertinites (i.e. fusinite, semifusinite and inertodetrinite) have earlier been reported from a number of Indian coal deposits (e.g., Diessel, 2010; and citations therein), but mostly without specifically connecting these inertinites to the occurrence of palaeowildfires. Later on, macro–charcoal has been discovered by different workers in the Permian sequences of South Africa (e.g., Glasspool, 2003; Jasper *et al.*, 2013), Brazil (e.g., Jasper *et al.*, 2008, 2011a, b, c, 2013; Degani–Schmidt *et al.*, 2015; Manfroi *et al.*, 2015; Kauffmann *et al.*, 2016; Benício *et al.*, 2019; Kubik *et al.*, 2020), Australia (e.g., Mays & McLoughlin, 2022), the Arabian Plate (e.g., Uhl *et al.*, 2007); and Antarctica (e.g., Holdgate *et al.*, 2005; Slater *et al.*, 2015; Tewari *et al.*, 2015). The first verified (by means of SEM analysis) records of macro–charcoal from the Indian subcontinent, were published by Jasper *et al.* (2012), who reported the existence of wildfire at the time of deposition of the late Permian Raniganj Formation in the Raniganj Coalfield of the Damodar Basin. Later on, Mahesh *et al.* (2015, 2017) identified macro–charcoal from the late Permian Barren Measures and Raniganj formations of the South Karanpura Coalfield, Damodar Basin and the late Permian (Lopningian) of the Mand–Raigarh Coalfield, Mahanadi Basin. Jasper *et al.* (2016) reported the occurrence of palaeowildfire from the Zewan Formation of the late Permian age of the Kashmir region. The first published macro–evidence of wildfire from the early Permian sediments of India came from the VI seam of the Barakar Formation of Dhanpuri OCP of Sohagpur Coalfield (Jasper *et al.*, 2017). Subsequently, early Permian wildfire records have been published for the Auranga Coalfield, Damodar Basin (Murthy *et al.*, 2020a), the Talchir Coalfield, Mahanadi Basin (Mishra *et al.*, 2021, 2022), and the Wardha Valley Coalfield, Wardha Basin (Murthy *et al.*, 2022). In the Rajmahal Basin, the occurrence of palaeowildfire was identified by Murthy *et al.* (2021) in the form of macro–charcoal from the Barakar Formation (early Permian) of the Dulia Block in the Rajmahal Basin, Jharkhand.

The present paper deals with additional palynological studies and the first report of macro–charcoal from the Barakar Formation of the Simlong Open Cast Mine (OCM) in Chuperbhita Coalfield, Rajmahal Basin, Jharkhand. It provides an additional record of macroscopic charcoal from the Indian Gondwana sediments, strengthening the interpretation that palaeowildfires, fuelled mainly by gymnospermous vegetation, occurred rather frequently in this part of Gondwana during the early Permian.

GEOLOGY OF THE AREA

The Gondwana formations of the Rajmahal Basin, contain coal deposits arranged in an NNW–SSE trending linear belt along the western side of the Rajmahal hills, which are known from North to South as Hura, Chuperbhita, Pachhwara, Mahuagarhi and Brahmani coalfields (Fig. 1). The

Table 1—General Stratigraphic Succession in Rajmahal Basin (Raja Rao, 1987).

Age	Group	Formation	Litho type
Recent/ Quaternary		Soil/ Alluvium	Yellow to maroon sandy, pebbly soil and clay
——Unconformity——			
Early Cretaceous to Late Jurassic	Upper Gondwana	Rajmahal Formation	Basic volcanics and intertrappeans (medium to fine–grained sandstone, dark grey claystone, grey shale and siltstone with oolites)
——Unconformity——			
Jurassic to Late Triassic	Upper Gondwana	Dubrajpur Formation	Medium–grained sandstone, pebbly sandstone, grey siltstone, mottled shale and claystone
——Unconformity——			
Early Permian	Lower Gondwana	Barakar Formation	Coarse–grained to pebbly sandstone, very fine to medium–grained feldspathic sandstone, grey shale, carbonaceous shale and coal seams
Early Permian to Late Carboniferous	Lower Gondwana	Talchir Formation	Conglomerate and pebbly sandstone, greenish fine–grained sandstone, greenish shale and silt-stone
——Unconformity——			
Precambrian		Chhotanagpur Gneissic Complex	Granite gneiss, chlorite biotite schist

Archaean granitic complex is the basalmost stratigraphic unit of the basin and is overlain by the Talchir, Barakar, Dubrajpur and Rajmahal formations in ascending stratigraphic order (Raja Rao, 1987).

The Chuperbhita Coalfield is situated between 24º43'−24º47'N latitude and 87º28'–87º30'E longitude and lies south of the Hura Coalfield. It is the second largest coalfield among the five coalfields of the Rajmahal Basin. The generalized stratigraphy of the Gondwana sediments of the Chuperbhita Coalfield is given in Table. 1. The Barakar coals are well developed in this coalfield, resting partly on the Talchir Formation and partly on the undulating Archaean basement.

The coal–bearing Barakar Formation is 550 m thick and divided into lower and upper parts. The 260 m thick lower part comprises few coal seams, as well as shales with coarse–grained sandstones, followed by a 100 m barren zone that, in turn, passes into the 190–200 m thick upper coal–bearing part. The upper part contains coal seams alternating with medium to coarse–grained sandstones. The Barakar Formation is flanked on the north by a thin capping consisting of deposits assigned to the Dubrajpur Formation, overlain by traps and Intertrappean beds of the early Cretaceous Rajmahal Formation. In the south and east, coal measures are covered directly by Rajmahal traps (Guha *et al.*, 1978; Singh & Singh, 1996).

Simlong Open Cast Mine (OCM), located in the Chuperbhita Coalfield, is in the Pakur sub–division of Sahibganj District of Jharkhand State (India) and is worked by the Eastern Coalfields Limited. It is located between latitudes 24º44'33"−24º45'55"N and longitudes 87º26'30"−87º28'38"E. The Simlong Open Cast block stretches in an area of about 2.40 km² and is covered in the Survey of India Toposheet no.72 P/5.

Based on sub–surface data recorded by exploratory drilling and surface geological mapping, a total of nine seams (seven regionally correlatable and two local coal seams) have been identified in this area. The coal–bearing sequences of the Simlong OCM block are trending in the NW–SE direction and dipping towards the northeast. The dip in this block is generally 8º−10º (CMPDI report on Simlong OCP, 2011).

MATERIAL AND METHODS

Palynological and macro–charcoal studies have been carried out on a sample associated to the upper seam of the Barakar Formation of Simlong OCM (Fig. 1C), Chuperbhita Coalfield, Rajmahal Basin, Jharkhand, India.

Palynology—For palynological studies, approximately 50 g of the sample was crushed and treated with hydrofluoric acid (40% HF) to remove silica and other minerals for two days. Thereafter, the samples were oxidized with concentrated nitric acid (HNO_3) to remove the humic matter. The residue was sieved with a 400 mesh sieve and six slides were prepared for the sample. The slides were scanned under an Olympus BX61 light microscope with a DP–25 camera. All six palynological slides (BSIP Museum Slide No. 17007−17012) were deposited in the repository of the Museum of Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow, vide Museum Statement No. 1619.

Macro–charcoal—Macro–charcoal fragments were extracted mechanically with the help of needles and a dissecting knife under a low–power binocular. The charcoal fragments were mounted on standard SEM–stubs with double–sided adhesive tape and sputter–coated with gold (JEC 3000PC). These gold–coated charcoal fragments were studied under a JEOL 7610F Field Emission Scanning Electron Microscope (FESEM) at the Birbal Sahni Institute of Palaeosciences.

PLATE 1 (Palynology) ⟶

Selected palynomorphs from the early Permian of the Chuperbhita Coalfield, Rajmahal Basin, Jharkhand (India).

1. *Plicatipollenits indicus* Lele 1964, BSIP Museum Slide No. 17008, K48/1.
2. *Densipollenites densus* Bharadwaj & Srivastava 1969, BSIP Museum Slide No. 17007, S41/2–4.
3. *Potonieisporites novicus* Bharadwaj emend BSIP Museum Slide No. 17009, J50/2–4.
4. *Parasaccites bilateralis* Tiwari 1965, BSIP Museum Slide No. 17010, K36–37.
5. *Scheuringipollenites barakarensis* Tiwari 1973, BSIP Museum Slide No. 17007, Q35/1.
6. *Scheuringipollenites maximus* Tiwari 1973, BSIP Museum Slide No. 17007, S46–47.
7. *Scheuringipollenites tentulus* Tiwari 1973, BSIP Museum Slide No. 17009, L56/1.
8. *Faunipollenites varius* Bharadwaj emend. Tiwari *et al.* 1989, BSIP Museum Slide No. 17009, N64–65.
9. *Striatopodocarpites* sp., BSIP Museum Slide No. 17010, S40.
10. *Sahnites barrelis* (Tiwari) Tiwari & Singh 1984, BSIP Museum Slide No. 17011, T50.
11. *Primuspollenites levis* Tiwari 1964, BSIP Museum Slide No. 17012, G63/4.
12. *Crescentipollenites fuscus* Bharadwaj, Srivastava & Kar 1974, BSIP Museum Slide No. 17010, P49/1.
13. *Tiwariasporis novus* (Srivastava) Bharadwaj & Dwivedi 1981, BSIP Museum Slide No. 17008, T54.
14. *Rhizomaspora* sp., BSIP Museum Slide No. 17009, P43/2–4.
15. *Verticipollenites oblongus* Bharadwaj 1962, BSIP Museum Slide No. 17007, K62.

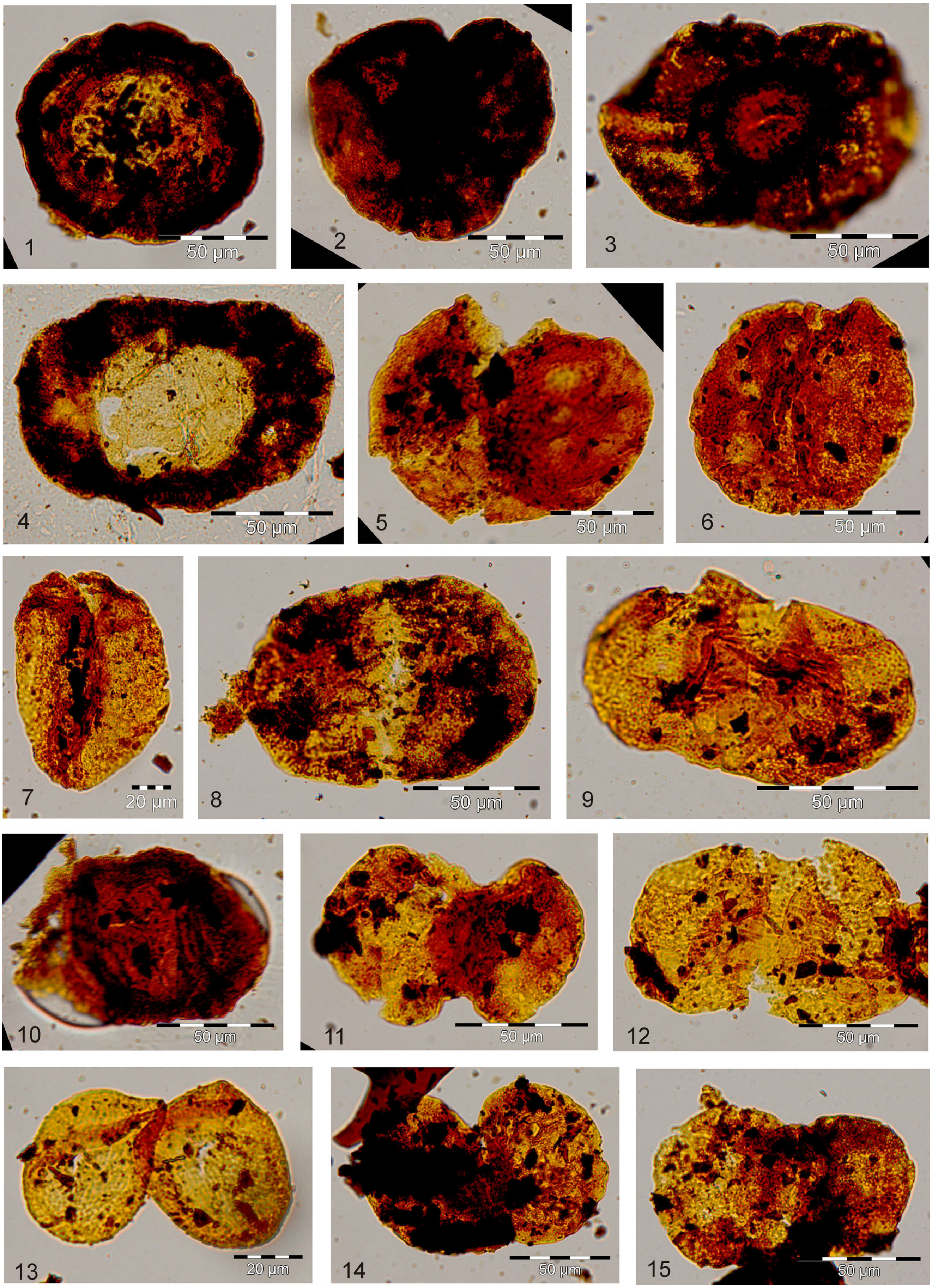
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PLATE 1

RESULTS

Palynology

Palynomorphs from the early Permian of the Chuperbhita Coalfield, Rajmahal Basin, Jharkhand (India) are figured on Pl. 1. The palynoassemblage exhibits a dominance of non–striate bisaccate pollen, mainly *Scheuringipollenites* (38%) and sub–dominance of striate bisaccate pollen, chiefly *Faunipollenites* (25%). The other palynotaxa recovered in this palynoassemblage are *Parasaccites* (15%), *Plicatipollenites* (2%), *Densipollenites* (3%), *Tiwariasporis* (2%), *Striatopodocarpites* (6%), *Crescentipollenites* (2%), *Rhizomaspora* (5%), *Verticipollenites* (1%) and *Primuspollenites* (1%), as well as individual grains of *Potonieisporites* and *Sahnites* (Fig. 2).

Macro–charcoal description

Fragments of macro–charcoal, ranging between 3–5 mm in width and 3–4 mm in length, were recovered from the studied material. The fragments are compressed, exhibiting so–called "Bogenstrukturen" (Pl. 2.1) (cf. Scott, 2000) and exhibit non–abraded edges, well–preserved anatomical details (Pl. 2), and homogenized cell walls (Pl. 2.1–2.2); characters considered as typical for charcoal (e.g., Scott, 2000, 2010). Tracheids present uniseriate (Pl. 2.4–2.5) or uni–to biseriate (Pl. 2.3) pitting. When biseriate, pits are oppositely to sub–oppositely arranged (Pl. 2.3). Pits are bordered and vary from elliptical to narrow elongate elliptical (Pl. 2.3–2.5). Rays are poorly preserved and seem to be homocellular and uniseriate (Pl. 2.6). Cross–field pits and growth rings have not been observed.

DISCUSSION

The palynoassemblage recovered from the Simlong OCM of the Chuperbhita Coalfield is characterized by the dominance of non–striate bisaccate pollen mainly *Scheuringipollenites* spp. and sub–dominance of striate bisaccate pollen mainly *Faunipollenites* along with index species, *viz. Scheuringipollenites tentulus*, *Scheuringipollenites barakarensis*, *Scheuringipollenites maximus*, *Faunipollenites varius*, *Faunipollenites singrauliensis*, *Rhizomaspora indica*,

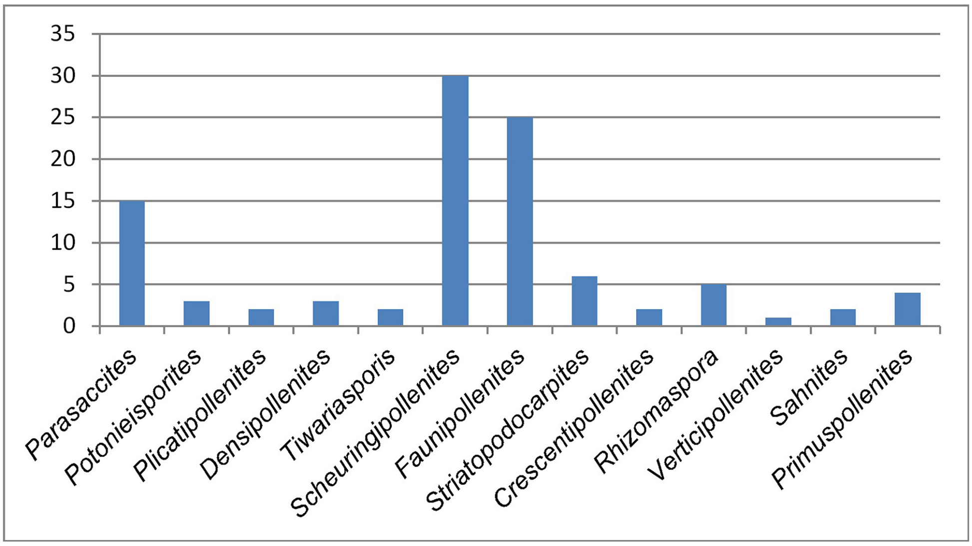

Fig. 2—Distribution of palynotaxa recovered from the sample containing charcoal specimens.

PLATE 2 (Macro–charcoal) →

SEM images of charcoal from the early Permian of the Chuperbhita Coalfield, Rajmahal Basin, Jharkhand (India).

1. Shattered tracheid walls in cross–section, forming the so–called "Bogenstrukturen".
2. Remnant of a ray in tangential view, exhibiting homogenized cell walls (arrow).
3. Overturned radial tracheid walls with uni–to biseriate bordered pits. Pits not touching.
4. Slightly oblique view of radial and tangential tracheid walls with uniseriate, touching bordered pits on the left and not touching pits on the right side of the image.
5. Detail of shattered tracheid walls with uniseriate, not touching pits.
6. Tangential view of charcoal with remnants of three rays, ray cells seem to be filled with debris of shattered cell walls.

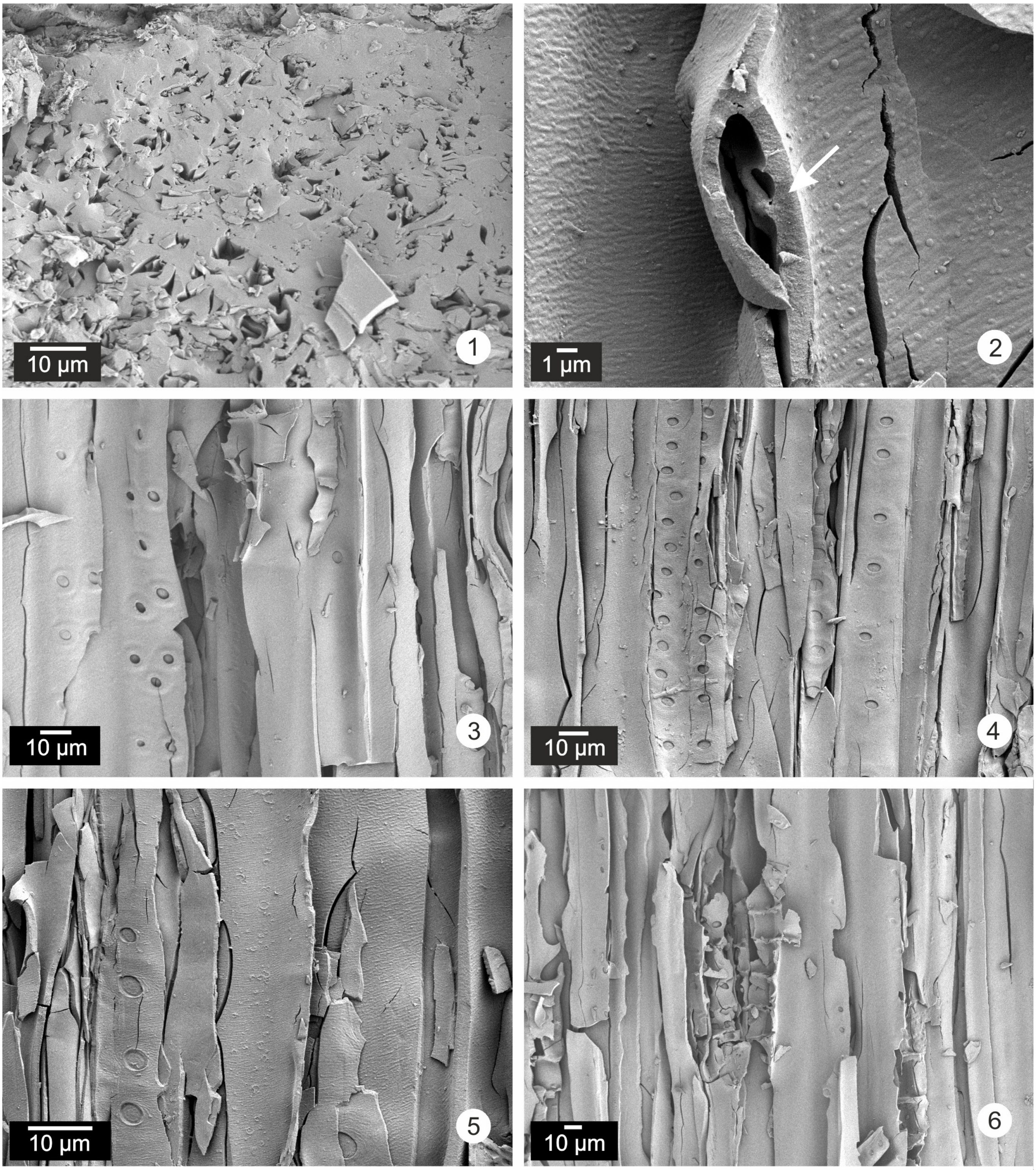

PLATE 2

Striatopodocarpites sp., *Sahnites barrelis*, *Primuspollenites levis*, *Crescentipollenites fuscus*, *Verticipollenites gibbosus*, *Densipollenites densus*, *Potonieisporites novicus*, *Parasaccites bilateralis*. Thus, this palynoassemblage is well comparable with the *Scheuringipollenites barakarensis* assemblage zone of Tiwari and Tripathi (1992) that is known from the lower part of the Barakar Formation in the Damodar Basin and dated as early Permian (Artinskian) in age (Murthy *et al.*, 2021).

The taxonomic analysis of the studied sequence reveals that only pollen grains are present in the assemblage. The qualitative analysis of palynotaxa shows the overall dominance of elements attributable to Glossopteridales in this palynoassemblage, representing two species of *Faunipollenites* and three species of *Scheuringipollenites*, one species each of *Striatopodocarpites*, *Verticipollenites, Crescentipollenites* and *Primuspollenites*. The rest of the palynoassemblage belongs to Cordaitales representing three species of *Parasaccites* and one species of *Plicatipollenites*. Conifers are represented by one species of *Potonieisporites*, *Rhizomaspora, Sahnites* and *Tiwariasporis*. The genera *Densipollenites* is of unknown affinity (cf. Table 2). Trilete spores are completely absent in the assemblage.

The early Permian palynoassemblages have been recorded in various Gondwana basins of India such as the Rajmahal, Damodar, Son–Mahanadi, Wardha–Godavari and Satpura. An intra–basinal correlation within the Rajmahal Basin shows that the palynoassemblage from the present study is similar to assemblage–1 of Tripathi (2001) recorded from the Chuperbhita Coalfield, Rajmahal Basin by showing the dominance of *Scheuringipollenites–Faunipollenites* and other palynotaxa including *Primuspollenites levis*, *Crescentipollenites fuscus*, *Rhizomaspora indica* and *Densipollenites indicus*. Recently, Murthy *et al.* (2021) also reported an Artinskian palynoassemblage from Rajmahal Basin that is also well correlated with the present assemblage in presence of palynotaxa, namely *Scheuringipollenites* (*S. barakarensis*, *S. maximus*, *S. tentulus*), *Faunipollenites* (*F. varius*, *F. singrauliensis*), *Rhizomaspora indica*, *Primuspollenites levis*, *Striatopodocarpites* sp., *Densipollenites indicus* and *Potonieisporites novicus*

The regional correlation with other Gondwana basins of India shows that the palynoassemblage from this study compares well with assemblage–II in the borehole RT–4 from the Raniganj Coalfield (Murthy *et al.*, 2010) and palynoassemblage–III in the borehole MBKW–3 from the Mand–Raigarh Coalfield (Murthy *et al.*, 2014) in the Damodar Basin by having the similar dominance of *Scheuringipollenites–Faunipollenites* along with *Rhizomaspora indica, Crescentipollenites fuscus, Densipollenites indicus* and other palynotaxa, namely *Striatopodocarpites* sp., *Verticipollenites* and *Tiwariasporis*.

The palynoassemblage of the present study can be well correlated with the lower Barakar palynoflora of several areas of the Godavari Basin, like Mamakannu area (Palynoassemblage–III: Jha & Aggarwal, 2010), Gundala area (Palynoassemblage–D: Jha & Aggarwal, 2011) and Mailaram area (Palynozone–3: Jha & Aggarwal, 2012) in having the predominance of *Scheuringipollenites* and sub–dominance of striate bisaccate pollen. It also correlates well with the Barakar palynoflora from other coalfields, viz. Umaria Coalfield (Zone–3: Srivastava & Anand–Prakash, 1984), Johilla Coalfield (Zone–3: Anand–Prakash & Srivastava, 1984), Pathakhera Coalfield (Assemblage–B: Sarate, 1986; Zone–2: Srivastava & Sarate, 1989), Wardha Coalfield (Assemblage–B: Bhattacharyya, 1997), Talcher Coalfield (Assemblage–II: Tripathi, 1997), Ib River Coalfield (Palynozone–2: Meena, 2000) and Pali Formation of Sohagpur Coalfield (Palynoassemblage–I: Ram–Awatar *et al.*, 2003) due to the dominance of pollen, mainly *Scheuringipollenites* and sub–dominance of *Faunipollenites.*

Based on the observed anatomical details, i.e. uni– to bi–seriate bordered pitting, the charcoal most likely originates from gymnosperms, but a more specific taxonomic assignment is not possible, due to the lack of data. Charcoal of gymnospermous affinity dominates so far all charcoal assemblages described from the Permian of India (e.g. Jasper *et al.,* 2012, 2016, 2017; Mahesh *et al.*, 2015, 2017; Murthy *et al.,* 2020a, 2021, 2022; Mishra *et al.*, 2021, 2022), but also other parts of Gondwana (S–America: Jasper *et al.*, 2008, 2011a, b, c, 2013; Degani–Schmidt *et al.*, 2015; Manfroi *et al.*, 2015; Kauffmann *et al.*, 2016; Benício *et al.*, 2019; Kubik *et al.*, 2020; Jordan: Uhl *et al.*, 2007; Antarctica: Holdgate *et al.*, 2005; Slater *et al.*, 2015; Africa: Glasspool, 2003; Jasper *et al.*, 2013; Australia: Mays & McLoughlin 2022), as well as Euramerica (e.g. Uhl & Kerp, 2003; Uhl *et al.*, 2004). The dominance of gymnospermous charcoal within all so far studied Permian coals from Gondwana (Jasper *et al.*, 2021; Murthy *et al.,* 2021) supports the assumption that the source vegetation which fuelled these fires had a considerable gymnosperm (i.e. glossopterids) components (Jasper *et al.*, 2017).

Based on the pollen taxa recovered from our sample, the gymnosperms were not only important components of humid habitats (swamps and floodplains) in which probably the peats formed, but also of (seasonally) drier upland habitats in the larger surrounding of the area of deposition (Table 2). Although it is likely that a part or most of the charcoal has not been transported over a long distance, as indicated by the non–abraded edges of many fragments (e.g. Nichols *et al.*, 2000), we cannot exclude that at least some of the charcoal has been transported over some distance. Thus it is possible that the charcoal assemblage represents a mix of swamp and flood plain taxa (glossopterids and Cordaitales) together with upland taxa (conifers).

Together with previous records of macro–charcoal, as well as the high inertinite contents of many Permian coals from India (cf. Diessel, 2010), our results support the observation that palaeo–wildfires were widespread and certainly frequent

Table 2—Identified pollen taxa, their assumed botanical affinity and possible habitat based on the compilation in Mishra *et al.* (2017), Murthy *et al.* (2021).

Taxon	**Botanical affinity**	**Habitat**
Scheuringipollenites barakarensis	Glossopterids	broad swamps and floodplains
Scheuringipollenites tentulus	Glossopterids	broad swamps and floodplains
Scheuringipollenites maximus	Glossopterids	broad swamps and floodplains
Faunipollenites varius	Glossopterids	broad swamps and floodplains
Faunipollenites singrauliensis	Glossopterids	broad swamps and floodplains
Crescentipollenites fuscus	Glossopterids	broad swamps and floodplains
Striatopodocarpites sp.	Glossopterids	broad swamps and floodplains
Verticipollenites oblongus	Glossopterids	broad swamps and floodplains
Primuspollenites levis	Glossopterids	broad swamps and floodplains
Potonieisporites novicus	Conifer	upland drier areas
Rhizomaspora indica	Conifer	upland drier areas
Sahnites barrelis	Conifer	upland drier areas
Tiwariasporis novus	Conifer	upland drier areas
Plicatipollenites indicus	Cordaitales	broad flood plain to larger swamp and lake areas
Parasaccites korbaensis	Cordaitales	broad flood plain to larger swamp and lake areas
Parasaccites obscurus	Cordaitales	broad flood plain to larger swamp and lake areas
Parasaccites bilateralis	Cordaitales	broad flood plain to larger swamp and lake areas
Densipollenites indicus	unknown affinity	?

sources of disturbance in different continental ecosystems in this part of Gondwana during the Permian (e.g., Jasper *et al.*, 2013, 2021).

CONCLUSIONS

- *Scheuringipollenites barakarensis* palynoassemblage has been identified in the sample collected from the Simlong coalmine section, Chuberbhita Coalfield in the Rajmahal Basin and assigned an early Permian (Artinskian) age.
- The anatomical details such as uni to biseriate bordered pits pattern and rays on the tracheid walls of charcoal fragments point to the gymnosperm affinity.

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