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Late Permian palynomorphs from the West Bokaro Coalfield, Damodar Basin, Jharkhand, India

SRIKANTA MURTHY

Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226 007, India.
Corresponding author: srikanta_murthy22@rediffmail.com

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ABSTRACT

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Palynological studies were carried out for samples collected from the Bokaro River section near Danea area from West Bokaro Coalfield, Damodar Basin. The recovered palynomorphs are characterized by the dominance of monosaccate pollen mainly *Densipollenites* (*D. magnicorpus, D. invisus, D. indicus* and *D. densus*) and subdominance of *Faunipollenites* spp.–*Striatopodocarpites* spp. complex. The other stratigraphically significant taxa recorded from this section are *Guttulapollenites hannonicus*, *Crescentipollenites fuscus, Arcuatipollenites (A. pellucidus, A. ovatus* and *A. damudicus), Alisporites asansolensis*, *Verticipollenites gibbosus, Striatites rhombicus*, *Platysaccus densicorpus, Chordasporites* sp., *Parasaccites (P. perfectus* and *P. densicorpus)* and *Horriditriletes* sp. On the basis of the total palynocomposition, the studied section has been dated as late Permian in age. This age correlation also gets support from comparative studies with similar palynoassemblages known from other coalfields of Indian Gondwana basins such as Damodar, Satpura, Son–Mahanadi, Rajmahal and Wardha–Godavari basins. The dominance of Cordaites and subdominance of conifers of Glossopterids suggests that the deposition of the sedimentary sequences took under freshwater environment.

Key–words—Late Permian, Palynofossils, Palaeoenvironment, West Bokaro Coalfield.

भारत में झारखंड की दामोदार द्रोणी के पश्चिमी बोकारो कोयलाक्षेत्र से प्राप्त पर्मियन परागाणुसंरूप

श्रीकांत मूर्ति

सारांश

दामोदार द्रोणी में पश्चिमी बोकारो कोयलाक्षेत्र के दनिया क्षेत्र के नजदीक बोकारो नदी खंड से संगृहीत नमूनों का परागाणविक अध्ययन किया गया। प्राप्त परागाणुसंरूप मुख्यतः *डेन्सीपोलेनाइटिस* (*डी. मैग्नीकार्पस, डी. इनवीसस, डी. इंडिकस* एवं *डी. डेन्सस*) एकलसपुट पराग की प्रभुत्वता तथा *फॉनीपोलेनाइटिस* जातियां – *स्ट्रीएटोपोडोकार्पाइटिस* जातियां सम्मिश्रण से अभिलक्षणित हैं। इस खंड से *गुट्टुलापोलेनाइटिस हेन्नोनिकस, क्रिसेंटीपोलेनाइटिस फस्कस, आर्कुएटीपोलेनाइटिस* (*ए. पेल्लुसिडस, ए. ओवेटस* एवं *ए. डमुडिकस*), *अलीस्पोराइटिस आसनसोलेन्सिस, वर्टिसीपोलेनाइटिस गिब्बोसस, स्ट्रिएटाइटिस रॉम्बीकस, प्लेटीसेक्कस डेन्सीकॉर्पस, कॉर्डास्पोराइटिस* जाति, *पैरासेक्काइटिस* (*पी. पर्फेक्टस* एवं *पी. डेन्सीकॉर्पस*) एवं *हॉरीडिट्रिलीज* जाति अन्य स्तरिकरूप से महत्वपूर्ण वर्गक अभिलिखित की गई हैं। समग्र परागाणुसंघटन के आधार पर अध्ययन किया गया खंड आयु में अंतिम पर्मियन के रूप में आयुनिर्धारण किया गया है। भारतीय गोंडवाना द्रोणियों से ज्ञात सदृश परागाणु समुच्चयों के साथ तुलनात्मक अध्ययनों से भी इस आयु सहसंबंध को संबल मिलता है। *कार्डाइटीज* की प्रभुत्वता तथा ग्लोसोप्टेरिडों के शंकुधारियों की उपप्रभुत्वता संकेत देती है कि अवसादी अनुक्रमों का निक्षेपण अलवणजल पर्यावरण में हुआ है।

सूचक शब्द—अंतिम पर्मियन, परागाणु जीवाश्म, पुरापर्यावरण, पश्चिमी बोकारो कोयलाक्षेत्र।

INTRODUCTION

DAMODAR Basin is the most important storehouse of Indian coal and it spreads in the states of Jharkhand and West Bengal. The important coalfields in this basin are Raniganj, Jharia, East Bokaro, West Bokaro, Ramgarh, South and North Karanpura. The Bokaro Coalfield is located in Jharkhand and it is part of the chain of the Damodar Valley

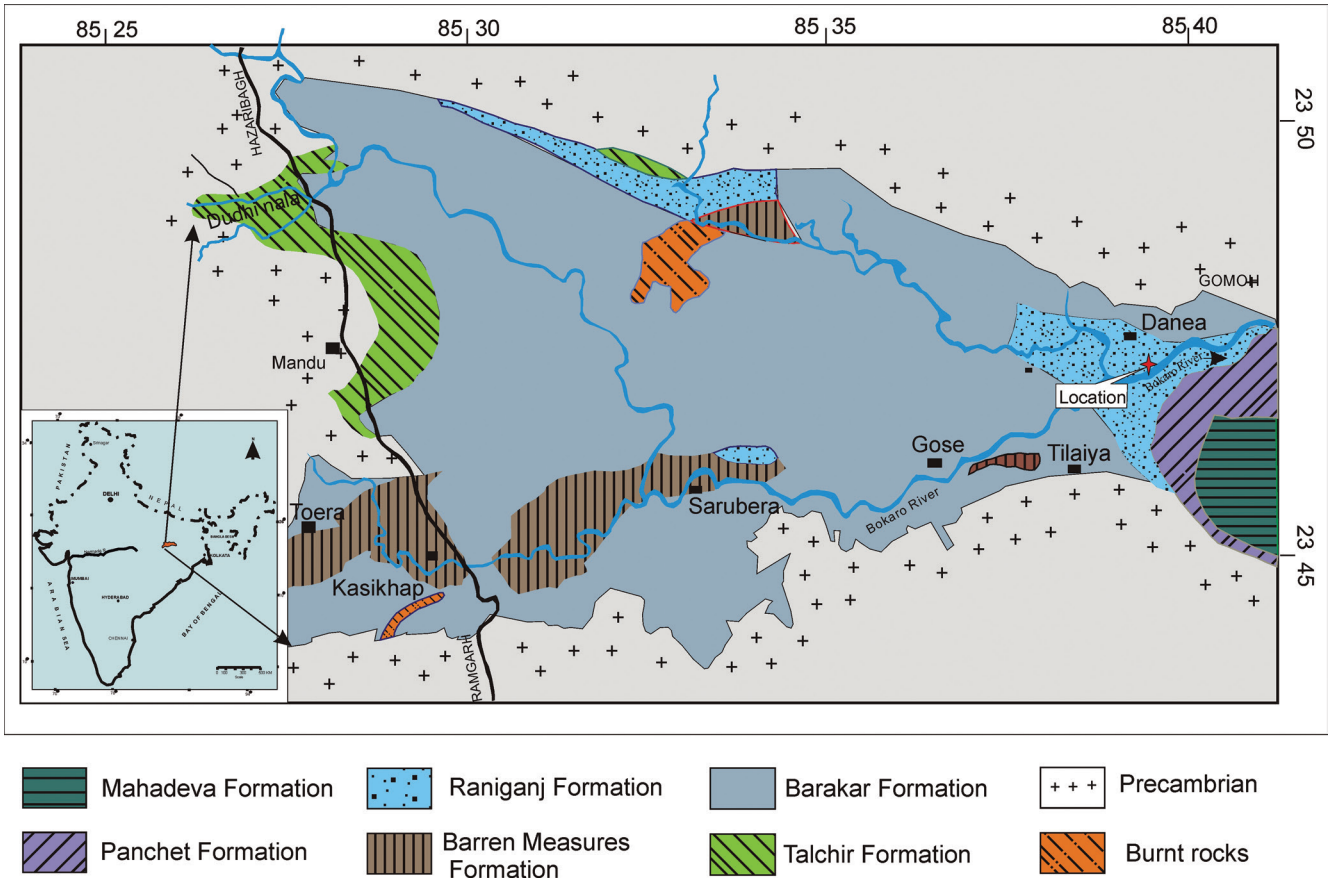

Fig. 1—Geological map of West Bokaro Coalfield showing location of study area near Danea, West Bokaro Coalfield (after Raja Rao 1987).

basins from east to west. The Lugu Hill (978.40 m) is the most important landmark of the area that divides the Bokaro Basin into two parts, East Bokaro and West Bokaro coalfields. The West Bokaro Coalfield is located in Hazaribagh and Ramgarh districts in the state of Jharkhand (23°48' N & 85°45' E), covering an area of 207 km^2.

So far, negligible palynological work has been done in the West Bokaro Coalfield. Surange *et al.,* (1953a, b) have recovered lycopod megaspores, palynofossils, cuticles and wood pieces from the Pindra coal seam of Lower Gondwana sediments. Srivastava (1954) has described four new types of megaspores and one seed from Mangardaha coal seam (Barakar). Ghosh (1962) recorded the dominance of *Callumispora* and *Granulatisporites* from the Barakar Formation (early Permian) palynomorphs. Lele (1975) recorded earliest Permian palynomorphs from the Talchir sediments of Dudhi River section. Anand–Prakash *et al.* (1979) recovered *Callumispora, Microbaculispora* and *Parasaccites* palynoassemblage representing Lower Karharbari and Talchir formations (early Permian) from the Dudi River section of the West Bokaro Coalfield. Banerjee and Das (1991) recovered microcrystal like structure associated with palynomorphs of Gondwana sediments.

The present paper records late Permian palynomorphs from the West Bokaro Coalfield. The present investigation is focused on the palynology of the sediments on one left bank of Bokaro River near Danea Village, Ramgarh District of Jharkhand State (Fig. 1). Palynodating and correlation have been attempted, and palaeoenvironment has also been inferred. Comparisons with other late Permian palynoassemblages of Gondwana basins of Peninsular India have also been done.

GENERAL GEOLOGY

West Bokaro Coalfield unconformably overlies the Precambrian basement represented by granitoids and amphibolites. This coalfield encompasses Talchir, Karharbari, Barakar, Barren Measures, Raniganj, Panchet and Supra Panchet formations ranging from early Permian to upper Triassic age (Raja Rao, 1987).

The beds of Talchir Formation are well exposed in the western part of the coalfield in the Dudhi Nala which comprises tillite, conglomerates, sandstones with drop stones and turbidite sequences comprising siltstones and shales. The Karharbari Formation is recognised only in the western part of the coalfield and that too only in the Dudhi Nala section comprising coarse to very coarse grained sandstones with

mottled appearance, shales carbonaceous shales and thin coal seams. The Barakar Formation covers a major part of the coalfield and is characterised by a thick sequence of conglomeratic sandstones, fine to coarse grained sandstones, carbonaceous and grey shales, fire clays and coal seams. The Barren Measures strata are exposed along the northern boundary and comprise sandstone and shale. The Raniganj Formation occurs as a narrow strip in the northern part of the field near Basantpur and as a small patch in the middle part of the coalfield. The Raniganj Formation is overlain by a thick sequence of fine grained, dirty green micaceous sandstones, intercalated with greenish and chocolate coloured shale beds of the Panchet Formation. The sediments of the Panchet Formation are exposed only in the basal part of the Lugu Hill. The contact of the Panchet beds with the underlying Raniganj beds can be seen in the area south of Chorpaiatoli. The youngest strata in this coalfield, the Supra–Panchet Formation, consists of coarse clastics and rests over the Panchet Formation. The composition of this formation is mostly coarse–grained ferruginous sandstones with lenses of pebbles and interbedded within the sandstones are a few thin beds of red clays (Raja Rao, 1987) (Figs 1 & 2).

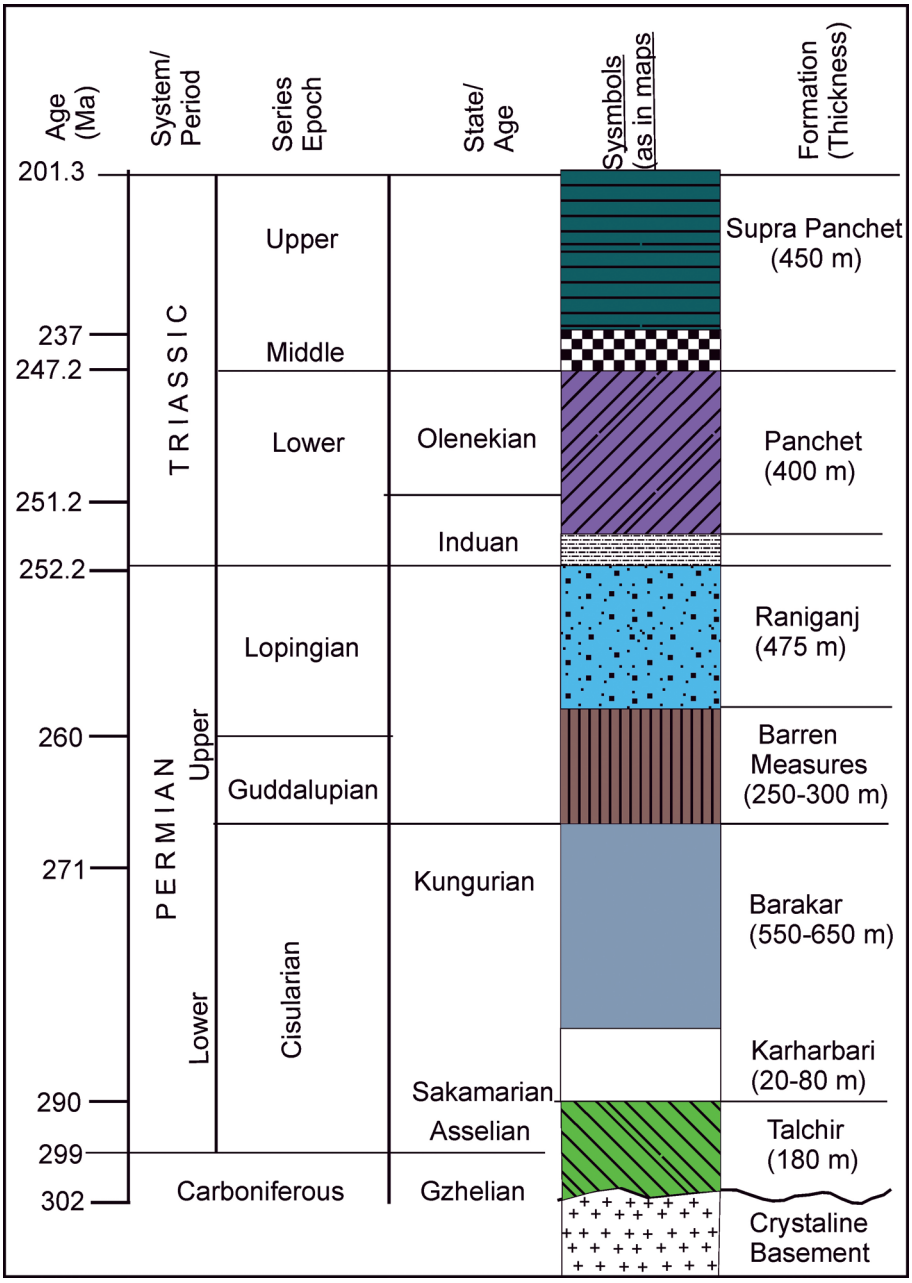

Fig. 2—Generalized stratigraphic succession of West Bokaro (after CMPDIL, 1993; Varma *et al*., 2014).

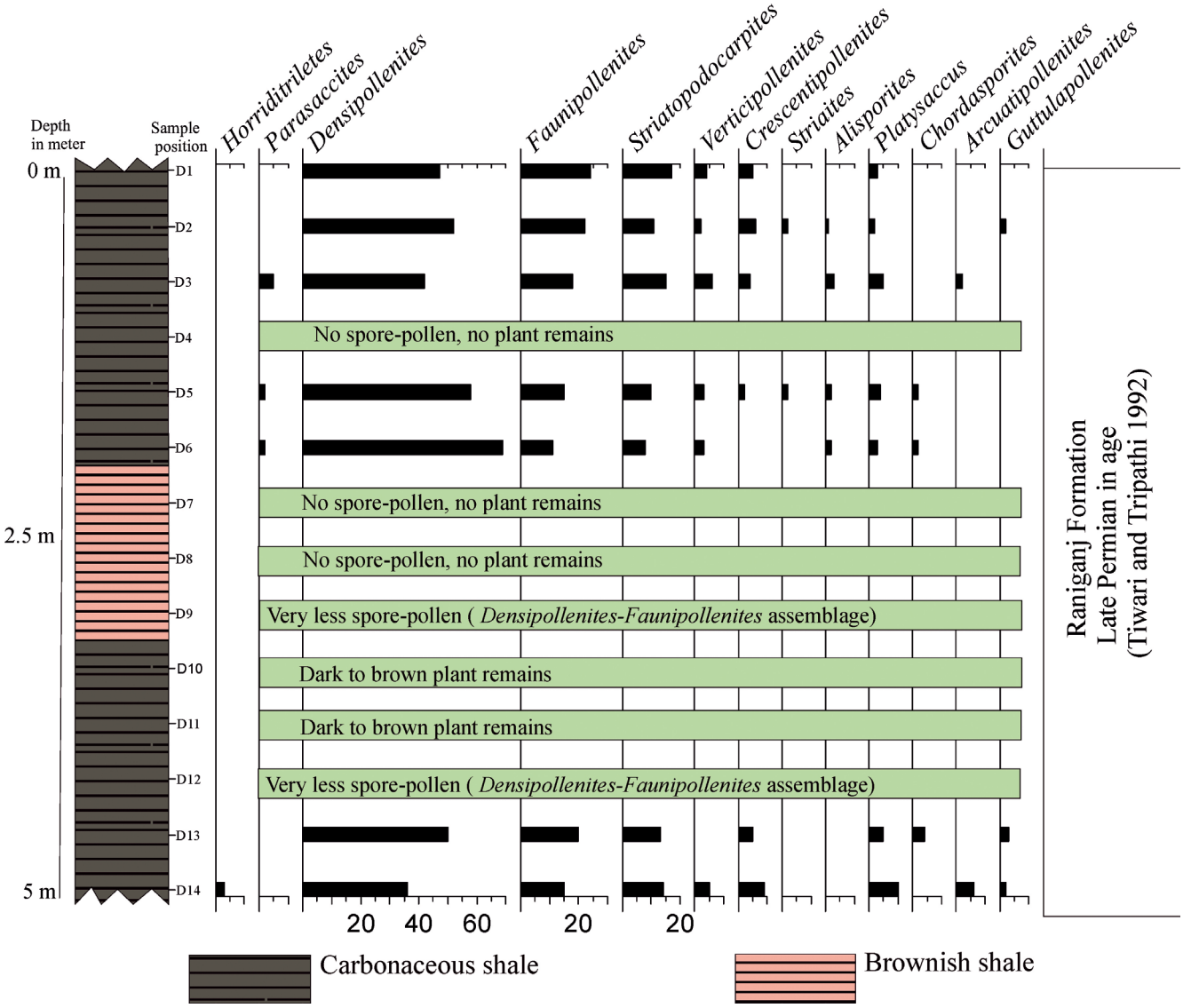

Fig. 3—Litholog and position of samples and distribution of palynotaxa in the Danea area in West Bokaro Coalfield.

MATERIAL AND METHOD

The studied material comprises fourteen samples collected from the left bank of Bokaro River section situated near Danea Village (Fig. 1). The section is approximately 5 m thick and the lithofacies mainly comprises of carbonaceous shales, and brownish shales (Fig. 2). 50 grams of each sample were taken and crushed (2–4 mm) and treated with 40% Hydrofluoric acid for 3–4 days to remove the silica content. Thereafter, the samples were washed thoroughly with distilled water to remove the acid content. The resultant residue was oxidized with concentrated Nitric acid and then treated with 10% Potassium Hydroxide solution. Five slides were prepared from each residue and the palynomorphs were examined under light microscope (Olympus BX61 with DP–25 camera using Cell A software). Of the fourteen samples analysed, seven yielded pollen–spores which have been utilised for palynodating of the sediments.

PALYNOLOGICAL ANALYSIS

The statistical study reveals that the palynomorphs in this assemblage are not much diverse. An overall dominance of enveloping type of monosaccate and bisaccate pollen is observed. The percentage frequency of the palynomorphs is given in Fig. 3 and are indicated as dominant (more than 20%), subdominant (between 20–10%), common (between 9–5%), fair (between 4–2%) and scarce (less than 2%).

Based on quantitative and qualitative analysis, only one palynoassemblage has been established in the studied section (Fig. 3; Pl. 1). The assemblage comprises dominance of monosaccate pollen *Densipollenites* (36–69%) and

subdominance of bisaccate pollen *Faunipollenites* (11–24%), followed by *Striatopodocarpites* (8–17%). The other palynomorphs recovered in this assemblage are very less in number, represented by striate bisaccates–*Crescentipollenites* (2–9%), *Verticipollenites* (2–6%) and *Striatites* (0–2%); non–striate bisaccates–*Alisporites* (1–3%) and *Platysaccus* (2–10%); taeniate bisaccates–*Arcuatipollenites* (0–6%) *Chordasporites* (0–4%) and *Guttulapollenites* (2–3%); radial monosaccate represented by *Parasaccites* (2–5%). Trilete spores are very poor and represented only by *Horriditriletes* (3%).

On the basis of dominance of *Densipollenites* and subdominance of *Faunipollenites,* followed *Striatopodocarpites* in association with other palynomorphs such as *Crescentipollenites*, *Verticipollenites, Striatites*, *Alisporites, Platysaccus, Arcuatipollenites, Chordasporites, Guttulapollenites, Parasaccites* and *Horriditriletes* the present palynoassemblage compares well with the *Densipollenites magnicorpus* assemblage zone of Raniganj Formation of the Damodar Basin, (Zone–IX) which is dated as late Permian in age (Tiwari & Tripathi, 1992).

CORRELATION WITH OTHER GONDWANA BASINS OF INDIA

The Gondwana sequences in peninsular India exhibit different sedimentation patterns in each basin due to variable deposition in linear, fault bounded belts in which recurrent uplift and subsidence at varying rates created different tectonic regimes (Jha *et al.,* 2014). Therefore, there are problems in inter–basinal correlations in the lithological context. However, they display broad similarities of palynoassemblages at the generic levels, thus favouring correlations within the Gondwana basins in peninsular India. The youngest formation in the Permian succession in the Indian peninsula is the Raniganj Formation (Tiwari & Tripathi, 1992). Its equivalent in the other Gondwana basins are the Bijori Formation in the Satpura Basin (Crookshank, 1936), the middle Pali Formation in the Son–Mahanadi Basins (Tiwari & Ram–Awatar, 1986), the Kamthi Formation in the Wardha–Godavari basins (King 1881 & Blanford, 1871) represents the Late Permian age.

DAMODAR BASIN

The late Permian *Densipollenites–Faunipollenites–Striatopodocarpites* assemblage zone recorded from the section at Danea Village of West Bokaro Coalfield closely corresponds with similar assemblages recorded in borecores from Raniganj Coalfield, such as RJS–2 and RT–4 (Srikanta Murthy, 2010, Srikanta Murthy *et al.,* 2010), and borecore RRK–1 (Vijaya, 2011). The palynotaxa most significant and common to both sections (West Bokaro and Raniganj coalfields) of this study include *Densipollenites* and *Striatopodocarpites* along with *Faunipollenites*, *Crescentipollenites*, *Verticipollenites*, *Chordasporites*, *Guttulapollenites*, *Arcuatipollenites*, *Alisporites* and *Platysaccus*.

In the East Bokaro Coalfield of the Damodar Basin, the assemblage from the section at Danea bears a close resemblance with the late Permian palynoassemblage retrieved at a depth interval of 13.00–91.00 m from borehole EBM–1 (Vijaya *et al.,* 2012). Common palynotaxa shared between the two include *Densipollenites* and *Striatopodocarpites* along with *Faunipollenites*, *Crescentipollenites*, *Verticipollenites*, *Chordasporites*, *Guttulapollenites*, *Arcuatipollenites*, *Alisporites* and *Platysaccus*.

The present assemblage closely resembles with the Palynoassemblage II of borecore SKB–1 from South Karanpura Coalfield in having dominance of striate bisaccate chiefly *Striatopodocarpites* and *Faunipollenites,* with increased frequency of *Densipollenites* (Srikanta Murthy *et al.,* 2014). The other taxa similar to both the assemblages comprise *Crescentipollenites*, *Alisporites* and *Lunatisporites*.

SON–MAHANADI BASIN

The present palynoassemblage compares well with the Palynoassemblage B recovered from an outcrop of the Pali Formation near Dargaon and Salaia Village, Madhya Pradesh (Ram–Awatar, 1987); the assemblage from outcrop samples exposed in the Johilla River (Tiwari & Ram–Awatar, 1987); from sediments exposed in Madalia River section near Patrapara Village in western most region of Talcher Coalfield (Tiwari *et al.,* 1991); Assemblage–1 from Iria Nala in the northern part of Tatapani–Ramkola Coalfield (Srivastava *et al.,* 1997); the assemblage from bore–hole TP–8; Assemblage–2 of borehole TNA–7; Assemblage–1 of borehole TCP–39 and Assemblage–1 of borehole TCP–41 (Tripathi & Bhattacharya, 2001) and bore–holes SMJS–3 and SMBS–1 of Singrauli Coalfield (Vijaya *et al.,* 2012) in having an abundance of *Densipollenites* along with striate bisaccate pollen taxa–*Faunipollenites* and *Striatopodocarpites*. The other significant taxa that occur in this palynoassemblage are *Crescentipollenites, Guttulapollenites, Weylandites, Arcuatipollenites* and *Verticipollenites.*

RAJMAHAL BASIN

The palynoassemblage of the present correlates well with Palynoassemblage VIII of borecore DPD–3, Pachami area (Vijaya, 2006) and borecore DPD–6 from Deocha–Pachami area (Vijaya, 2009) of Birbhum Coalfield due to the dominance of *Densipollenites* and subdominance of *Striatopodocarpites* along with *Crescentipollenites* and *Faunipollenites*. Palynological studies carried out from the uppermost part of Raniganj Formation by Tripathi (1986) in borehole RJNE–9 and boreholes RJNE–16 and RJNE–8 from the northern part of Rajmahal Basin (Tripathi, 1989) yielded a rich miofloral assemblage which compares broadly

with the present assemblage considering the abundance of *Striatopodocarpites*, *Faunipollenites*, *Crescentipollenites*, *Alisporites*, *Verticipollenites*, *Striatites* and *Arcuatipollenites,* but differs in the absence of *Densipollenites* in the above borecores. Therefore, they are interpreted to be somewhat older to the assemblage of the present study.

SATPURA BASIN

The present late Permian palynoassemblage broadly corresponds to the palynoflora of Bijori Formation near Sukhtawa Nala, near Akhar Railway Station, Satpura Basin (Bharadwaj *et al.,* 1978). Assemblage A from Tamia Ghat Road, Tamia, Chhindwara District, Madhya Pradesh (Kumar, 1996) and Palynoassemblage IV of Pench Valley Coalfield (Srikanta Murthy *et al.,* 2013). The common palynotaxa favouring correlation of the two studied section include the dominance of *Striatopodocarpites* associated with *Faunipollenites* and other common components such *Densipollenites*, *Guttulapollenites*, *Verticipollenites, Crescentipollenites, Lunatipollenites (= Arcuatipollenites)* and *Alisporites*.

WARDHA–GODAVARI BASINS

The present palynoassemblage can be broadly correlated from studies in the Wardha–Godavari basins (Srivastava & Jha, 1988, 1990, 1992, 1995; Jha, 2008; Jha & Srivastava, 1996 & Jha *et al.,* 2014; Aggarwal *et al.,* 2015) in having common palynoassemblages, such as *Striatopodocarpites* spp. and *Faunipollenites* spp. in association with other stratigraphically significant palynofossils, such as *Callumispora, Densipollenites, Parasaccites, Platysaccus, Striatites, Crescentipollenites*, *Alisporites*, *Arcuatipollenites, Guttulapollenites, Horriditriletes* and *Tiwariasporis*. Even though, these basins show a broad similarity, slight differences are also recorded from the present assemblage of West Bokaro Coalfield in not having some palynofossils like *Corisaccites, Gondisporites, Lundbladispora, Distriatites, Brevitriletes,* etc.

PALAEOENVIRONMENT

The palynological analysis from the Danea area shows that enveloping type of monosaccate forms are dominant in percentage and are also diverse being represented by different species of *Densipollenites* (*D. magnicorpus, D. invisus, D. indicus* and *D. densus*). This reflects the presence of Cordaites in the peat forming flora. Cordaites prefered mesophilous palaeoenvironment and inhabited in well drained and low land substrates (Taylor & Taylor, 1993). Presence of Cordaites suggests the incursion of remnants of a parautochthonous land flora in the depositional environment (Jasper *et al.*, 2006). The striate bisaccates–*Faunipollenites* (= *Protohaploxypinus*)*, Striatopodocarpites, Crescentipollenites, Verticipollenites, Striatites,* and taeniate bisaccates *Arcuatipollenites* and *Chordasporites* indicate the conifers in the peat forming vegetation in the sediments. Conifers are considered to be extra–basinal or hinterland elements, which typically show several adaptations for survival in drier habitats. The nonstriate bisaccate pollen of glossopterids represented by *Alisporites* and *Platysaccus,* are low in count indicating their sporadic presence in the peat forming vegetation. Glossopterids grew in mesophilous to xerophilous palaeoenvironment and flourished in lowland peats. The trilete spores are very low in percentages and represented by Filicopsids (*Horriditriletes)* and are related to herbaceous groups, which flourished in hygrophilous and mesophilous environments (Cazzulo–Klepzig *et al.,* 2005). The conifer pollen in the present assemblage suggests the dominance of arborescent vegetation in the form of a forest swamp, probably in a small distant marginal part of the mire. The overall palynological assemblage suggests that the Danea area palaeomire occupied inland areas of the basin and was deposited under fresh water environment.

Tiwari and Tripathi (1987) have concluded a warm climate with high humidity for the upper most Raniganj palynoflora of late Permian age on the basis of morphological characters like haploxylnoid construction (length of saccus and central body are same), striation diversity in bisaccates and presence of leathery saccus in *Densipollenites*. These morphological characters are also observed in the present palynocomposition. Therefore, prevalence of warm climate

PLATE 1

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1. *Parasaccites perfectus* Bose & Maheshwari 1968
2. *Parasaccites densicorpus* Lele 1975
3. *Densipollenites magnicorpus* Tiwari & Rana 1980
4. *Densipollenites densus* Bharadwaj & Srivastava 1969
5. *Densipollenites indicus* Bharadwaj 1962
6. *Densipollenites invisus* Bharadwaj & Salujha 1964
7. *Guttulapollenites hannonicus* Goubin 1965
8. *Faunipollenites perexiguus* Bharadwaj & Salujha 1965
9. *Faunipollenites varius* Bharadwaj 1962
10. *Striatopodocarpites decorus* Bharadwaj & Salujha 1964
11. *Crescentipollenites* sp.
12. *Crescentipollenites fuscus* Bharadwaj *et al.,* 1974
13. *Striatopodocarpites diffusus* Bharadwaj & Salujha 1964
14. *Platysaccus densicorpus* Anand–Prakash 1972
15. *Verticipollenites gibbosus* Bharadwaj 1962
16. *Arcuatipollenites damudicus* Tiwari & Vijaya 1995
17. *Arcuatipollenites ovatus* Tiwari & Vijaya 1995
18. *Arcuatipollenites pellucidus* (Goubin) Tiwari & Vijaya 1995
19. *Alisporites opii* Daugherty emend Jansonius 1971
20. *Striatites rhombicus* Bharadwaj & Salujha 1964

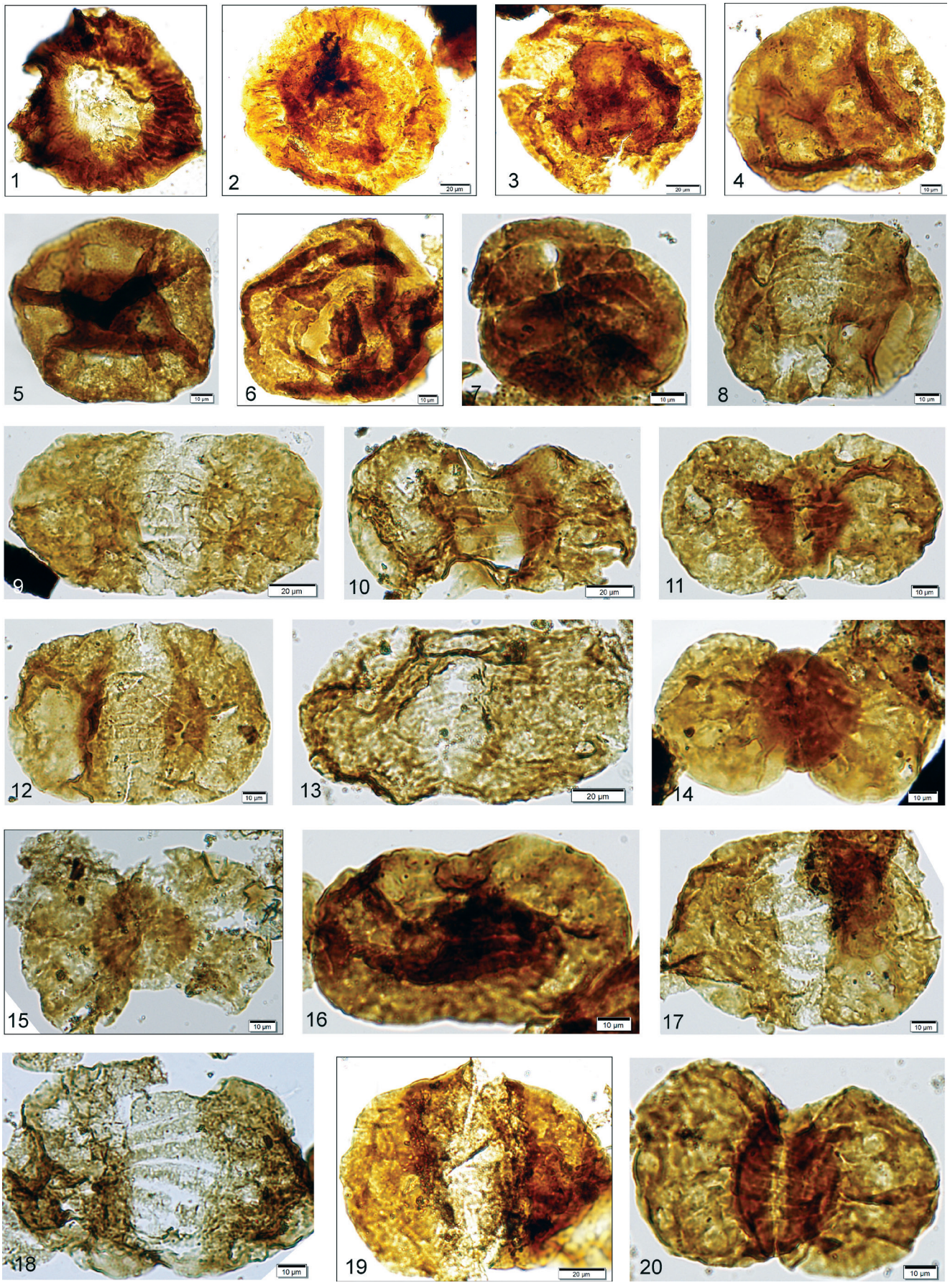

PLATE 1

with high humidity is interpreted during the deposition of sediments of the present study.

DISCUSSION AND CONCLUSION

Out of fourteen samples, seven samples (D1, D2, D3, D5, D6, D13 and D14) have yielded palynomorphs sufficient for qualitative and quantitative analysis. Lithologically these samples are carbonaceous shales and light brown shales. Besides, other two samples (D9 and D12) have also yielded palynomorphs however, preservation and the quantitative representation is poor and hence percentage frequency could not be determined. The remaining samples (D4, D7, D8, D10 and D11) did not yield palynomorphs. Nevertheless, these findings are important because Raniganj palynomorphs have not been reported so far from the West Bokaro Coalfield (Fig. 3).

A more or less similarity in the percentages of *Densipollenites, Faunipollenites* and *Striatopodocarpites* in the yielded samples is observed but the diversity increases in the upper part of the section. Overall, the yielded samples do not differ much from each other and so it has been considered to be a single palynoassemblage (Fig. 3).

Densipollenites contributes more than fifty per cent of the total assemblage. Besides, striate bisaccate pollen *Faunipollenites* and *Striatopodocarpites* sub–dominant and quantitatively well represented. Other palynomorphs in the assemblage are striate bisaccates (*Crescentipollenites, Verticipollenites* and *Striatites*); non striate bisaccates (*Alisporites* and *Platysaccus*); taeniate bisaccates (*Arcuatipollenites* = *Lunatipollenites*, *Chordasporites* and *Guttulapollenites*), which though less in count are significant because of their stratigraphic value.

Srivastava (1992) identified *Densipollenites* palynozone in the Middle member of Kamthi Formation in Godavari Basin representing the uppermost Permian palynoflora in the region. Generally, it is comparable to the younger Raniganj Palynozone of Damodar Basin except some variations in palynoflora. In Satpura Basin (Bharadwaj *et al.,* 1978), the Bijori Formation is equated with the Raniganj Formation of upper Permian age by presence of striate bisaccate palynomorphs along with representation of *Densipollenites, Corrisaccites* and *Guttulapollenites* complex. They have concluded that predominance of bisaccate genera in association with *Densipollenites* indicates the upper most part of Raniganj Formation (upper Permian).

The present palynological studies carried out in the Bokaro River section from the Raniganj Formation in West Bokaro Coalfield indicate late Permian palynoassemblage. The samples were collected for studying in the only late Permian transition; however, the section yielded palynomorphs only Raniganj Formation. The palynological assemblage is dominated by monosaccate pollen *Densipollenites* and sub–dominated by striate bisaccate pollen chiefly *Faunipollenites* and *Striatopodocarpites* and this association is indicative of late Permian *Densipollenites magnicorpus* Assemblage zone of the peninsular Gondwana sequences (Tiwari & Tripathi, 1992).

Late Permian assemblages have been reported from a number of boreholes and outcrop sections from different Indian Gondwana basins however, detailed comparisons and correlations with the late Permian assemblages of West Bokaro Coalfield were earlier not documented and the present work discusses a detailed correlation of the late Permian peninsular deposits of India.

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