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Permian–Triassic palynofloral transition in Sohagpur Coalfield, South Rewa Gondwana Basin, Madhya Pradesh, India

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ABSTRACT

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A 1300 m thick sedimentary sequence in borehole SNB–1 around Jaisinghnagar area in the western part of the South Rewa Basin has been lithologically designated as the Pali Formation. However, palynological investigation reveals presence of three distinct palynoassemblage zones belonging to late Permian, early and late Triassic ages in ascending order. Palynoassemblage I (*Striatopodocarpites magnificus–Crescentipollenites fuscus*) recorded between a depth of 1213.40–1164.10 m showing dominance of striate bisaccate pollen taxa chiefly—*Striatopodocarpites ovatus, Faunipollenites varius* and *Crescentipollenites fuscus* in association with *Alisporites ovalis, Lunatisporites pellucidus, Densipollenites indicus* and *Lahirites rarus* is late Permian (Raniganj) in age. Palynoassemblage II (*Lundbladispora densispinosa–Densoisporites playfordii*) recorded between a depth of 1054.30–956.00 m and showing dominance of cavate/cingulate spores, like *Lundbladispora microconata, Densoisporites complicatus* along with *Kraeuselisporites rallus, Lapposisporites lapposus, Playfordiaspora crenulata, Goubinispora indica, Klausipollenites schaubergeri, Limatulasporites fossulatus* and *Reduviasporonites chalastus* indicates an early Triassic age. Palynoassemblage III (*Aulisporites astigmosus–Falcisporites nuthallensis*) recorded between a depth of 404.40–53.60 m and characterized by the dominance of *Aulisporites astigmosus* along with *Falcisporites nuthallensis, Tikisporites balmei, Dubrajisporites unicus*, *Enzonalasporites densus, Leschikisporites aduncus, Lunatisporites rhaeticus, Lueckisporites virkkiae, Playfordiaspora vellata, Polycingulatisporites crenulatus, Cingulizonates indicus, Neoraistrickia taylori* and *Aratrisporites fischeri* is equated with late Triassic (Supra–Panchet) age.

The Permian–Triassic boundary is delineated at the contact of coal/shale bearing upper part of the Middle Member and lower part of the Upper Member of the Pali Formation (between 1164.10–1075.15 m depth). At the P/T boundary, the abrupt change of the palynoflora is marked by the disappearance of the striate bisaccate pollen grains and appearance of non–striate bisaccate grains in association with cingulate–cavate/zonate trilete spores. The Permian/Triassic palynofloras recorded in South Rewa Basin show close similarities with those of the uppermost Bainmedart Coal Measures (McKinnon Member) and Flagstone Bench Formation of east Antarctica.

Key–words—Palynology, Permian/Triassic, Pali Formation, Sohagpur Coalfield, South Rewa Basin.

सोहागपुर कोयलाक्षेत्र, दक्षिण रीवा गोंडवाना द्रोणी, मध्य प्रदेश, भारत में पर्मियन ट्राइएसिक परागाणुपुष्पी संक्रमण

सौरभ गौतम, राम अवतार, रजनी तिवारी एवं श्रीरूप गोस्वामी

सारांश

दक्षिण रीवा द्रोणी के पश्चिमी भाग में जयसिंहनगर क्षेत्र के चहुंओर वेध–छिद्र एस एन बी–1 में एक 1300 मीटर स्थूल अवसादी अनुक्रम पाली शैलसमूह के रूप में आश्मिक रूप से नामित की गई है। फिर भी, परागाणविक अन्वेषण आरोही क्रम में, विलंबित पर्मियन, प्रारंभिक एवं विलंबित ट्राइएसिक काल के तीन भिन्न परागाणुसमुच्चय अंचलों की मौजूदगी बयाँ करता है। 1213.40–1164.10 मीटर गहराई के बीच अभिलिखित प्रथम परागाणुसमुच्चय (*स्ट्रिएटोपोकार्पाइटिस मैग्नीफिकस– क्रेसेंटीपॉल्लेनाइटिस फस्कस*), *ऐलीस्पोराइटिस आवलिस, लुनाटीस्पोराइटिस पेल्लुसिडस, डेन्सीपॉल्लेनाइटिस इंडिकस* एवं *लाहिराइटिस रेरस* के साहचर्य में मुख्यतः – *स्ट्रिएटोपोडोकार्पाइटिस ओवेटस, फॉनीपॉल्लेनाइटिस वेरियस* और *क्रेसेंटीपॉल्लेनाइटिस फस्कस* रेखित द्विसपुट पराग टैक्सा की प्रमुखता दर्शाते हुए विलंबित पर्मियन (रानीगंज) काल का है। 1054.30–956.00 मीटर की गहराई के बीच अभिलिखित द्वितीय परागाणुसमुच्चय (*लुंडब्लाडिस्पोरा डेन्सिसपिनोसा –डेन्सिोइस्पोराइटिस प्लेफॉर्डियाई*) तथा *क्रेउसेलिस्पोराइटिस रेल्लस, लेप्पोसीस्पोराइटिस लेप्पोसस, प्लेफॉर्डियास्पोरा क्रनुलेटा, गौबिनीस्पोरा इंडिका, क्लॉसीपॉल्लेनाइटिस साउबर्जेरी, लिमेटुलास्पोराइटिस फॉस्सुलेटस* एवं *रेडुविआस्पोरोनाइटिस चलास्टस* के साथ *लुंडब्लाडिस्पोरा माइक्रोकोनेटा, डेन्सोइस्पोराइटिस कॉम्पलीकेटस* जैसे गुहावत/ सिंगुलेट बीजाणुओं की प्रधानता दर्शाते हुए प्रारंभिक ट्राइएसिक काल इंगित करता है। 404.40–53.60 मीटर गहराई के मध्य अभिलिखित तृतीय परागाणुसमुच्चय (*ऐलीस्पोराइटिस अष्टिगमोसस – फाल्सीस्पोराइटिस नथेल्लेन्सिस*) तथा *फाल्सीस्पोराइटिस नयेल्लेन्सिस, टिकीस्पोराइटिस बल्मी, दुबराजीस्पोराइटिस यूनीकस, एन्ज़ोनालास्पोराइटिस डेन्सस, लेस्चिकीस्पोराइटिस एडन्कस, लुनाटीस्पोराइटिस रेह्‌ओटिकस, लुएकीस्पोराइटिस विर्कीए, प्लेफॉर्डिआस्पोरा वेल्लेटा पॉलीसिंगुलेटीस्पोराइटिस क्रेनुलेटस, सिंगुलीज़ोनेटस इंडिकस, न्योरैस्ट्रिकीआ टेलोरी* एवं *अट्रीस्पोराइटिस फिस्चेरी* सहित *ऐलीस्पोराइटिस अष्टिगमोसस* की प्रमुखता से अभिलक्षणित, विलंबित ट्राइएसिक (सुप्र–पंचेट) काल के बराबर है।

पर्मियन– ट्राइएसिक सीमा कोयला/शेल दिकमान पाली शैलसमूह के मध्य घटक के ऊपरी भाग तथा ऊपरी घटक के अधो भाग (1164.10–1075.15 मीटर गहराई के मध्य) के संपर्क पर विचित्रित है। पी/टी सीमा, रेखित द्विसपुट पराग कणों की विलुप्तता से तथा सिंगुलेट–गुहावत/ क्षेत्रीय वर्गीकरण त्रिअरीय बीजाणुओं के सहयोग से गैर–रेखित द्विसपुट कणों के आभास द्वारा परागाणु वनस्पतिजात के यकायक परिवर्तन से चिह्नित है। दक्षिण रीवा द्रोणी में अभिलिखित पर्मियन/ ट्राइएसिक परागाणु वनस्पति समूह पूर्व दक्षिणध्रुव अंटार्टिका के शीर्षतम बैनमेडार्ट कोयला संस्तर (मैककिन्नॉन घटक) एवं फ्लैगस्टोन बेंच शैलसमूह से निकट सदृशता दर्शाता है।

सूचक शब्द—परागाणुविज्ञान, पर्मियन/ ट्राइएसिक, पाली शैलसमूह, सोहागपुर कोयलाक्षेत्र, दक्षिण रीवा द्रोणी।

INTRODUCTION

THE Sohagpur Coalfield occupies an east–trending rectangular area in the west central part of the South Rewa Basin, Madhya Pradesh. It is one of the largest coal bearing areas and lies between latitude 23°05': 23°30' N and 81°13': 81°12' E longitude (Fig. 1A, B). The Sohagpur Coalfield (~ 3100 sq km) is bounded by Ghunghuti in the west, Hasia Nala in the east and junctions of Kewai and Tipan rivers with Son River in the south. Northern boundary is not precisely defined. The palynological studies of the Permian and Triassic sediments of the Sohagpur Coalfield have been carried out by various researchers (Navale & Tiwari, 1967; Bharadwaj & Srivastava, 1971; Ram–Awatar, 1993, 1996a, 2003; Ram–Awatar *et al.*, 2004; Ram–Awatar & Dutta, 2005; Ram–Awatar & Gautam, 2013; Gautam *et at.*, 2014) in the past. Mitra (1993) and Ram–Awatar (1996b, 1997) have discussed the Permo–Triassic boundary problem in South Rewa Basin.

The name "Pali Bed" was given by Hughes (1881) for the sediments exposed in Johilla River, about 3 km west of Pali (23º24' N lat.: 81º04' E long.). On the basis of the facies organization, the Pali Formation has been divided into Lower, Middle and Upper members (Chakraborti, 1982; Mitra, 1993; Kundu *et al.,* 1993). Bandhopadhyay (1999) divided it into Lower and Upper members, respectively. Rao and Shukla (1954), Dutta *et al.*, (1977), Raja Rao (1983), Dutta and Ghosh (1993), Rajaiya and Agasty (1990), Dutta (2002), Mukhopadhyay *et al.*, (2010) and Mukherjee *et al.*, (2012) clubbed the Pali and Tiki beds of Fox (1931) into a single litho–unit on the basis of the lithological similarities and designated it as Pali–Tiki Formation ranging from late Permian–lower Norian in age. The palynological study by earlier workers reveals that the Pali Formation is divisible in three members, Lower Member is equivalent to the Barren Measures, Middle Member is equivalent to the late Permian Raniganj Formation and while the lower part of the Upper Member correlates with the early Triassic (Panchet) the upper part straddles across the late Triassic (Carnian–Norian). Dutta (2002) classified the entire Gondwana deposits (late Permian to early Jurassic) into four sedimentary facies in ascending order; a glaciogenic facies (Facies A), a coal bearing facies (Facies B), a red shale–sandstone facies (Facies C) and a hill–forming coarse grained conglomerate facies (Facies D). According to him, all the red bed facies (Facies C) from four basins, viz. Panchet Formation of Damodar Basin, Maleri Formation of Pranhita–Godavari Basin, Pali–Tiki Formation of South Rewa Basin and Panchmarhi–Denwa Formation of Satpura Basin are coeval unit ranging in age from early to late Triassic (Dutta, 2002; Fig. 6). Mukhopadhyay *et al.* (2010) and Mukherjee *et al.* (2012) suggested that the Upper Pali Member and Tiki Formation are coeval lithounit.

The Geological Survey of India has drilled a scout borehole (SNB–1) in search of coal reserves around Jaisinghnagar area in the western part of the Sohagpur Coalfield (Fig. 1C). The palynoflora encountered in the subsurface sedimentary sequence of the Pali Formation from this borehole is reported herein, and its chronological significance is discussed.

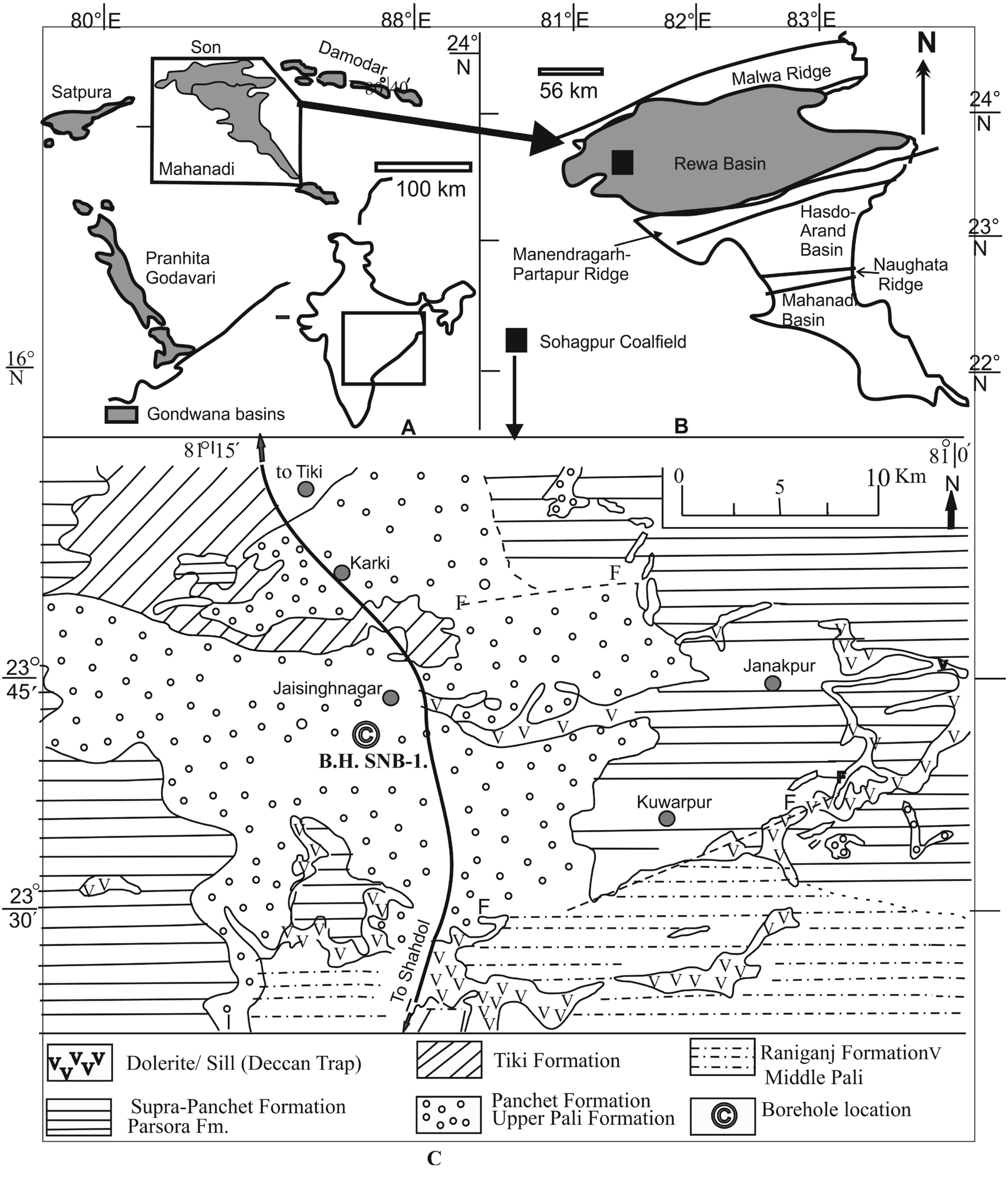

Fig. 1—A. Geological map showing major Gondwana basins of peninsular India; B. Son–Mahanadi Basin comprising the three sub–basins and the geographical position of the study area (after Mukherjee *et al.* 2012); C. Geological map of the area showing location of borehole SNB–1 (after Trafdar *et al*., 1993).

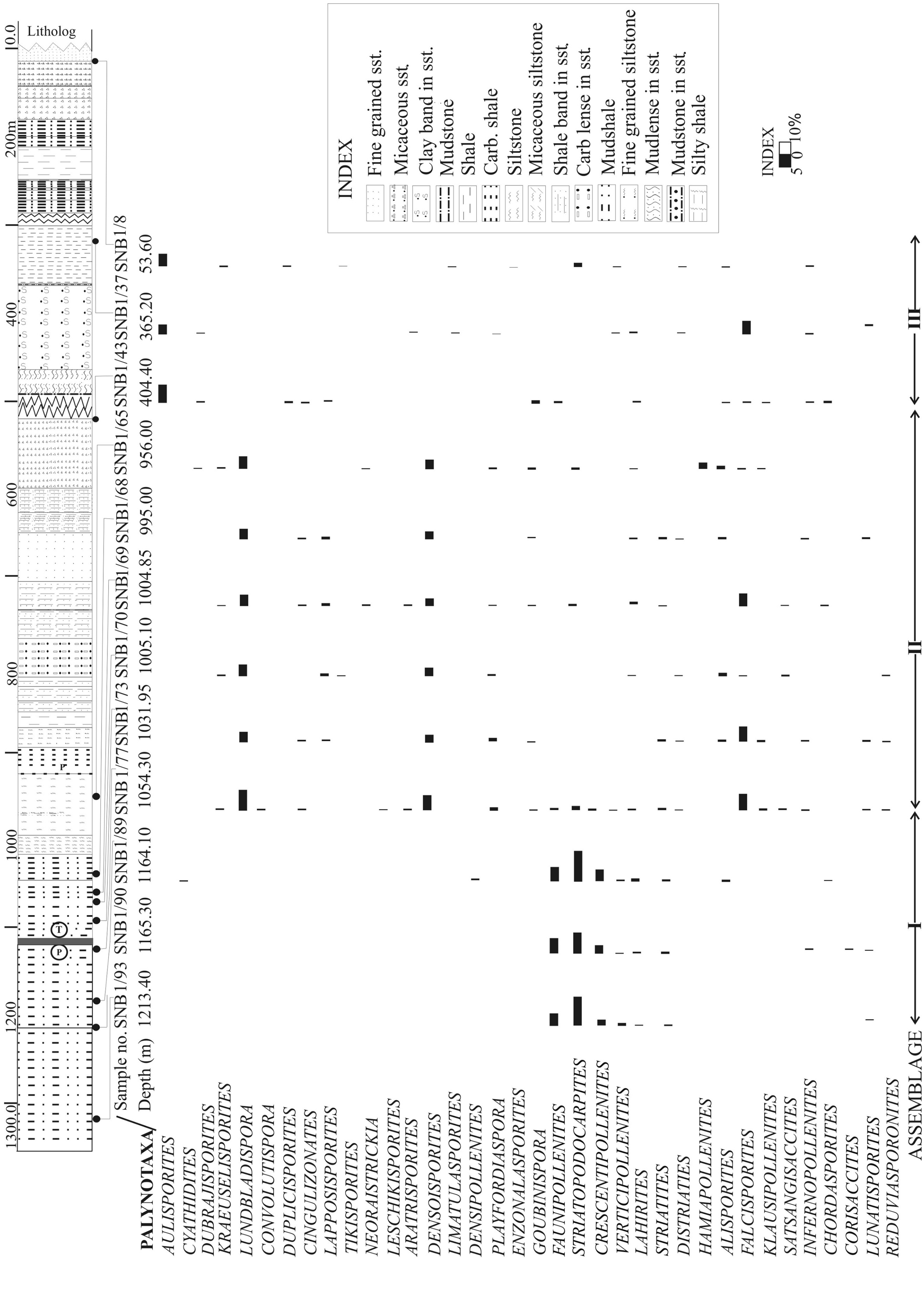

Fig. 2—Histogram showing P/T boundary and percentage frequency of important palynotaxa of borehole SNB–1.

<table>
<tr><th colspan="2">Formation</th><th>Thickness</th><th>Lithology</th><th>Age</th></tr>
<tr><td colspan="2">Deccan Trap</td><td></td><td>Basalt flow and dolerite Dykes.</td><td>Up. Cretaceous to Eocene</td></tr>
<tr><td colspan="2">Lameta Bed</td><td></td><td>White impure marlstone, pinkish to white sandstone.</td><td>Up. Cretaceous</td></tr>
<tr><td colspan="2">Chandia Bed</td><td>30–70 m</td><td>White clay and sandstone.</td><td>Lr. Cretaceous</td></tr>
<tr><td colspan="2">Hartala Hill</td><td>300 m</td><td>White coloured medium– to coarse–grained sandstone with low clay clast having siliceous matrix; often with ferruginous cement with medium–grained white coloured cross–bedded sandstone.</td><td>Early Jurassic</td></tr>
<tr><td colspan="2">Parsora</td><td>200 m</td><td>Mostly massive with very large scale cross stratification, coarse to pebbly arenite; at places red clay stone.</td><td>Jurassic to Carnian</td></tr>
<tr><td colspan="2">Tiki</td><td>200 m</td><td>Red clay, buff coloured fine– to medium–grained sandstone with calcareous sandstone with partly or fully ferruginous clay clast.</td><td>Upper Triassic</td></tr>
<tr><td colspan="2">Karki</td><td>~150 m</td><td>Thick multistoried, pebbly coarse–grained, red coloured sandstones.</td><td>Middle Triassic</td></tr>
<tr><td rowspan="3">P
A
L
I</td><td>Upper</td><td rowspan="3">300 m</td><td>Coarse grained arkosic sandstone. The granules and pebbles of quartz and fresh feldspars occur as a clast with siliceous matrix.</td><td>Early to Middle Triassic</td></tr>
<tr><td>Middle</td><td>White to grey coloured, medium– to coarse–grained arkosic sandstone, grey shale, carbonaceous shale and coal seams.</td><td>Late Permian</td></tr>
<tr><td>Lower</td><td>Alternate band of red and green clay with medium– to coarse–grained arkosic sandstone.</td><td>Middle Permian</td></tr>
<tr><td colspan="2">Barakar</td><td>+280 m</td><td>Coarse–grained, calcareous, sandstone, thin shale and silt-stone bands, seven regionally distributed coal beds (Seams I to V; L_1, and L_2); fine–grained calcareous sandstone, inter-laminated and rippled sandstone and shale, and thin, discon-tinuous coal beds.</td><td>Late Early Perm-ian</td></tr>
<tr><td colspan="2">Talchir</td><td>+275 m</td><td>Matrix supported conglomerate, medium– to coarse–grained cross bedded sandstones containing rounded quartz pebbles and rock fragments, green to buff coloured very fine to fine grained sandstones, silt and mudstones, rhythmites and lime stones.</td><td>Early Permian</td></tr>
<tr><td colspan="2">Precambrian</td><td></td><td>Granite, gneisses and quartzite</td><td>Early Proterozoic</td></tr>
</table>

Table 1—Generalized stratigraphical column of the South Rewa Basin (after Mitra 1993; Bandhopadhyay 1999; Dutta 2002 and Mukherjee *et al.*, 2012).

GEOLOGY OF THE AREA

In the Sohagpur Coalfield, the Gondwana sediments unconformably overly the granites of the Precambrian basement rocks comprising coarse porphyritic, reddish orange (pink) feldspathic phenocysts. The generalized lithological succession of the coalfield comprises—Talchir, Barakar and Supra–Barakar formations (Raja Rao, 1983) in ascending order. The Supra–Barakar rocks encompass Pali, Tiki, Parsora and Bandhogarh formations. Adhikari and Hore (1989) first recognised a thick variegated clay beds within the Barren Measures strata in Mithauri–Kelmania area intersecting many boreholes as palaeosol. Later, Mukhopadhyay and Mukhopadhyay (1999) identified a 25–40 m thick palaeosol bed indicating hiatus which separates the Raniganj Formation from the overlying Pali beds. In the southern and southwestern parts, the late Cretaceous Lameta beds unconformably overly strata of the Talchir–Parsora formations as one moves from east to west. The sediments are intruded by low angle dykes and sills, and covered by flow of basic rocks of Deccan Trap age (Mukhopadhyay *et al.*, 2001). The general lithological succession of the Sohagpur Coalfield is given in Table 1 (after Mitra, 1993; Bandhopadhyay, 1999; Dutta, 2002; Mukherjee *et al.*, 2012).

MATERIAL AND METHODS

The present study is based on the subsurface core sample (SNB–1) collected from 3 km south of Jaisinghnagar, Shahdol District, Madhya Pradesh (Figures–1A–C). Out of one hundred, only 15 samples have yielded spores/pollen grains. Majority of the samples were mudstones of different colours like grey, chocolate, buff and brown. For the recovery of spores and pollen grains, samples were crushed into small pieces (2–3 mm in size) and treated with hydrofluoric acid (40% concentration) to dissolve the siliceous component, followed by nitric acid to digest the organic matter and finally with 5–10% alkali to remove the humus. The samples were thoroughly washed with distilled water and the residue was mixed with polyvinyl alcohol and smeared over cover glass and kept for drying at room temperature. After complete drying, the cover glasses were mounted in canada balsam. The microphotographs were taken with the help of Olympus Microscope (B.H. 2 Model, No. 216294). All the slides have been deposited in the Repository of the Birbal Sahni Institute of Palaeobotany, Lucknow vide Statement No. 1436.

PALYNOLOGICAL COMPOSITION AND AGE OF THE ASSEMBLAGE

Out of one hundred samples, only 15 have yielded rich and diversified palynofosils. On the basis of quantitative and qualitative distribution of various spore–pollen taxa, three palynoasemblage zones have been identified in borehole SNB–1, in the sedimentary sequence of 1300 m thick strata of the Pali Formation (Table 3). A classified check list of identified palynotaxa is given in Table 4. The vertical distribution and percentage frequency of various palynotaxa has been shown in Histogram (Fig. 2). Some of the stratigraphically significant palynotaxa have been illustrated in plates (Pl. 1–3).

Palynoassemblage I—(*Striatopodocarpites magnificus–Crescentipollenites fuscus* zone; depth 1213.40–1164.10; Table 3). The assemblage is characterized by dominance of striate bisaccate pollen grains mainly *Striatopodocarpites* spp. (20.3%), *Crescentipollenites* spp. (18.4%) and *Faunipollenites* spp. (11.6%) in association with *Verticipollenites* spp. (6%), *Striatites* spp. (6%), *Lahirites* spp. (5.6%), *Hamiapollenites* spp. (5%), *Lunatisporites* spp. (5%), *Distriatites* spp. (4.3%), *Densipollenites* spp. (4%), *Rhizomaspora* (2%), *Alisporites* spp. (4%), *Chordasporites* spp. (5%), *Cuneatisporites* sp. (1%) and *Lundbladispora* spp. (1.3%).

Suggested age: Raniganj (Permian Lopingian/ Changhsinghian; Cohen *et al*., 2013)

Palynoassemblage II—(*Lundbladispora densispinosa–Densoisporites playfordii* zone; depth 1054.30–956.00 m; Table 3). This assemblage is characterized by dominance of cavate–cingulate spores mainly *Lundbladispora* spp. (22%) and *Densoisporites* spp. (10%), along with *Playfordiaspora* spp. (5.3%), *Goubinispora* spp. (5%), *Kraeuselisporites* spp. (4.2%), *Lunatisporites* spp. (4%), *Striatopodocarpites* spp. (5%), *Crescentipollenites* (3%), *Faunipollenites* spp. (3%), *Cadargasporites* spp. (2%), *Alisporites* (2%) *Limatulasporites* spp. (1.5%), *Reduviasporonites* (1.5%) and *Osmundacidites* spp. (0.5%).

Suggested age: Panchet (Scythian, Changhsinghian; Cohen *et al*., 2013)

Palynoassemblage III—(*Aulisporites astigmosus–Falcisporites nuthallensis* zone; depths 404.40–53.60 m; Table 3). This zone is characterized by dominance of *Aulisporites* spp. (22%), *Falcisporites* spp. (20%), *Klausipollenites* spp. (7%), *Lapposisporites* (5%), *Cingulizonates* (5%) along with *Playfordiaspora* spp. (3%), *Dubrajisporites* spp. (2%), *Goubinispora* spp. (2%), *Minutosaccus* spp. (2%), *Lueckisporites* spp. (2%), *Infernopollenites* spp. (2%), *Leschikisporites* sp. (1%), *Polycingulatisporites* sp. (1%), *Neoraistrickia* sp. (1%), *Brachysaccus* sp. (1%), *Tikisporites* sp. (1%), *Grebespora* sp. (1%), *Enzonalasporites* sp. (1%), *Aratrisporites* sp. (1%) and *Foviosporites* sp. (1%).

Suggested age: Late Triassic (Carnian–Norian, Changhsinghian; Cohen *et al*., 2013)

PLATE 1

⟶

1. *Aulisporites astigmosus* BSIP Slide No.15656; coordinates 10 x 120.
2. *Foviosporites triassicus* BSIP Slide No.15668; coordinates 09 x 110.
3. *Divaripunctites globosus* BSIP Slide No. 15664; coordinates 11x 140.
4. *Duplicisporites granulates* BSIP Slide No. 15667; coordinates 16 x 128.
5. *Neoraistrickia taylorii* BSIP Slide No. 15655; coordinates 16 x 128.
6. *Cyclotriletes triassicus* BSIP Slide No. 15656; coordinates 15 x 120.
7. *Convolutispora perfecta* BSIP Slide No. 15655; coordinates 11 x 115.
8. *Lycopodiumsporites* sp. BSIP Slide No. 15655; coordinates 11 x 126.
9. *Kraeuselisporites rallus* BSIP Slide No.15664; coordinates 12 x 117.
10. *Kraeuselisporites wargalensis* BSIP Slide No.15664; coordinates 18 x 122.
11. *Lundbladispora warti* BSIP Slide No. 15667; coordinates 22 x 109.
12. *Lundbladispora densispinosa* BSIP Slide No. 15664; coordinates 10 x 130.
13. *Lundbladispora microconata* BSIP Slide No.15666; coordinates 16 x 135.
14. *Densoisporites complicatus* BSIP Slide No15666; coordinates 18 x 134.
15. *Densoisporites playfordii* BSIP Slide No.15664; coordinates 10 x 138.
16. *Cingulizonates indicus* BSIP Slide No.15664; coordinates 19 x 126.
17. *Enzonalasporites densus* BSIP Slide No. 15657; coordinates 20 x 120.
18. *Lapposisporites lapposus* BSIP Slide No. 15663; coordinates 06 x 122.
19. *Dubrajisporites bulbosus* BSIP Slide No. 15660; coordinates 05 x 134.
20. *Dubrajisporites unicus* BSIP Slide No. 15654; coordinates 13 x 124.

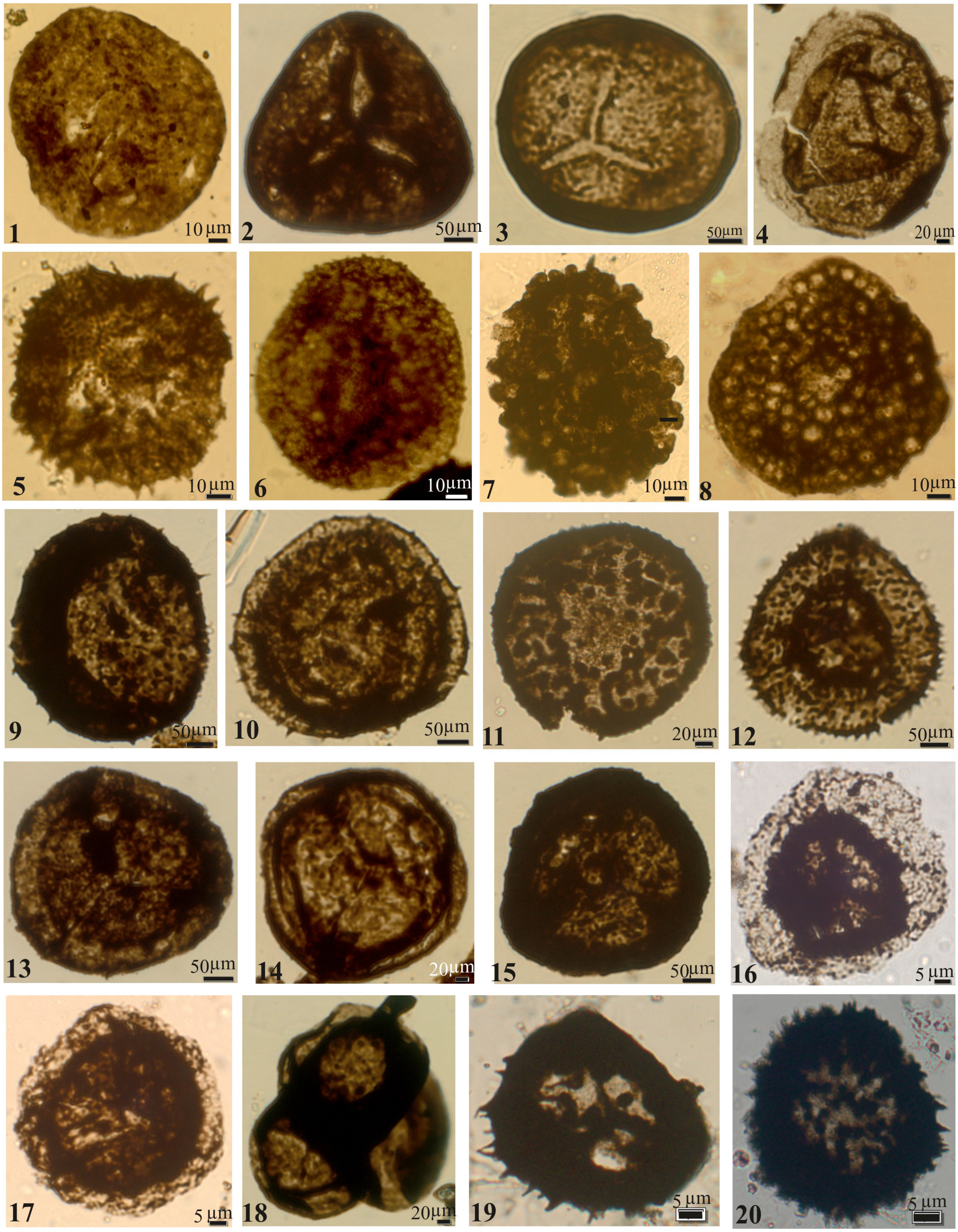
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PLATE 1

CORRELATION AND DISCUSSION

Palynoassemblage I—The assemblage recorded from the borehole SNB–1 between 1213.40–1164.10 m depth is characterized by the dominance of striate bisaccate pollen grains mainly *Striatopodocarpites, Faunipollenites* along with *Lunatisporites* and *Densipollenites* species Late Permian palynoassemblages with similar palynofloral composition have been described from different coalfields of Damodar Basin, namely Raniganj (Bharadwaj *et al.,* 1979; Tiwari & Singh, 1983;Vijaya & Tiwari, 1987; Vijaya, 2011; Murthy, 2010; Murthy *et al*., 2015); East Bokaro (Vijaya *et al*., 2012a) and South Karanpura (Murthy *et al*., 2014b). However, *Densipollenites* species, are sporadic in the present assemblage. The palynoassemblage also compares well with those recorded from different coalfields of Son–Mahanadi Basin, e.g. Korar (Tiwari & Ram–Awatar, 1987a); Johilla (Tiwari & Ram–Awatar, 1986, 1987b,1989); Sohagpur (Ram–Awatar *et al*., 2004, Ram–Awatar & Gautam, 2013); Singrauli (Vijaya *et al*., 2012b); Mand–Raigarh (Jana *et al*., 2002; Chakraborti & Ram–Awatar, 2006; Murthy *et al*., 2014a) and Talcher (Tiwari *et al*., 1991; Tripathi, 1997; Tripathi & Bhattacharya, 2001). Similar palynoassemblages have also been recorded from the Satpura Basin (Bharadwaj *et al.,* 1978); e.g. Assemblage A of the Tamia Ghat Section, (Kumar, 1996) and Pench Valley Coalfield (Murthy *et al*., 2013). The present assemblage can also be correlated with the latest Permian palynoassemblages known from the different areas/coalfields of Wardha–Godavari Basin such as Kamptee (Srivastava & Bhattacharyya, 1996); Manuguru (Srivastava & Jha, 1992); Sattupalli (Srivastava & Jha, 1994); Budharam (Srivastava & Jha, 1995); Bottapagudem (Jha, 2004); Gundala (Jha & Aggarwal, 2010); Mailaram (Jha & Aggarwal, 2012); Lingala–Koyagudem (Aggarwal & Jha, 2013) and Chintalapudi sub–basin (Jha *et al.,* 2014) showing dominance of striate bisaccate pollen grains along with *Densipollenites* sp. However, *Guttullapollenites* has not been recorded in the present assemblage.

When compared with other Gondwanic continents, Assemblage I can be correlated with the *Protohaploxypinus* zone (Kyle, 1977) and the *Densipollenites magnicorpus* zone recorded from the middle and upper parts of the Weller Coal Measures, Allan Hills, South Victoria Land, Antarctica (Ram–Awatar *et al*., 2014), in showing dominance of striate bisaccate taxa, namely *Striatopodocarpites, Faunipollenites* (*Protohaploxipinus*) and sporadic occurrence of *Lunatisporites* (*=Arcuatipollenites*)*, Densipollenites, Klausipollenites, Osmundacidites, Goubinispora* and *Lundbladispora.* The assemblage also compares favourably with late Permian palynoassemblages described from the Upper Mount Glossopteris Formation of the Ohio Range and from the Queen Maud Formation of the Nilsen Plateau (Kyle & Schopf, 1982), Prince Charles Mountains (Blame & Playford, 1967; Kemp, 1973; Dibner, 1976, 1978), Bainmedart Coal Measures (McKinnon Member) of the Amery Group (McLoughlin *et al.,* 1997), Buckley Formation, Central Transantarctic Mountains (Farabee *et al*., 1991) and the palynofloras described from the Fossilryggen and north west Nunatak Section of Dronning Maud Land (Lindström, 1996), Antarctica. However, *Marsupipollenites, Daltodiaspora* spp. and *Camptotriletes* spp. are absent in the present assemblage.

It is difficult to compare the late Permian palynoflora with the palynofloral schemes proposed from different stages/zones of Australia due to the absence of *Dulhuntyispora*. However, Assemblage 1 identified herein, is tentatively correlated with 'Stage 5' (Evans, 1969), 'Unit VII' of the Canning Basin (Kemp *et al.*, 1977), *Protohaploxypinus microcorpus* Zone of Helby (1974), *Playfordiaspora crenulata* Zone (Foster, 1982), Bowen Basin and the 'APP6 Subzone' of Price (1997) in the presence of taeniate and non–taeniate bisaccate pollen grains such as *Protohaploxypinus* (*Faunipollenites*), *Striatopodocarpites, Alisporites* in association with *Lunatisporites*, *Klausipollenites* and *Densipollenites*. However, *Tigrisporites playfordii, Dulhuntyispora* sp., *Triplexisporites* sp., *Granulatisporites trisinus* and *Vitreisporites* sp. are not recorded in the present assemblage.

PLATE 2

⟶

1. *Limatulasporites fossulatus* BSIP Slide No.15666; coordinates 12 x 1147.
2. *Playfordiaspora vellata* BSIP Slide No. 15661; coordinates 09 x 112.
3, 4. *Playfordiaspora crenulata* BSIP Slide No. 15664, 1973; coordinates 15 x107, 12 x 134.
5. *Playfordiaspora cancellosa* BSIP Slide No. 15664; coordinates 14 x 104.
6. *Satsangisaccites nidpurensis* BSIP Slide No.15659; coordinates 13 x 127.
7. *Falcisporites nuthallensis* BSIP Slide No.15662; coordinates 14 x 125.
8. *Klausipollenites schaubergeri* BSIP Slide No. 15670; coordinates 12 x 138.
9. *Brachysaccus* sp. cf. *B. triassicus* BSIP Slide No.15670; coordinates 12 x 138.
10. *Klausipollenites staplinii* BSIP Slide No. 15657; coordinates 19 x 1042.
11. *Minutosaccus crenulatus* BSIP Slide No. 15657; coordinates 18 x 144.
12. *Alisporites opii* BSIP Slide No. 15657; coordinates 15 x 108.
13. *Plicatisaccus badius* BSIP Slide No. 15657; coordinates 16 x 125.
14. *Brachysaccus indicus* BSIP Slide No. 15663; coordinates 19 x 104.
15. *Aratrisporites parvispinosus* BSIP Slide No. 15664; coordinates 16 x 114.
16. *Chordasporites australiensis* BSIP Slide No. 15657; coordinates 05 x 127.
17. *Dacrycarpites australis* BSIP Slide No. 15661; coordinates 16 x 123.
18. *Grebespora concentrica* BSIP Slide No. 15664; coordinates 05 x 122.

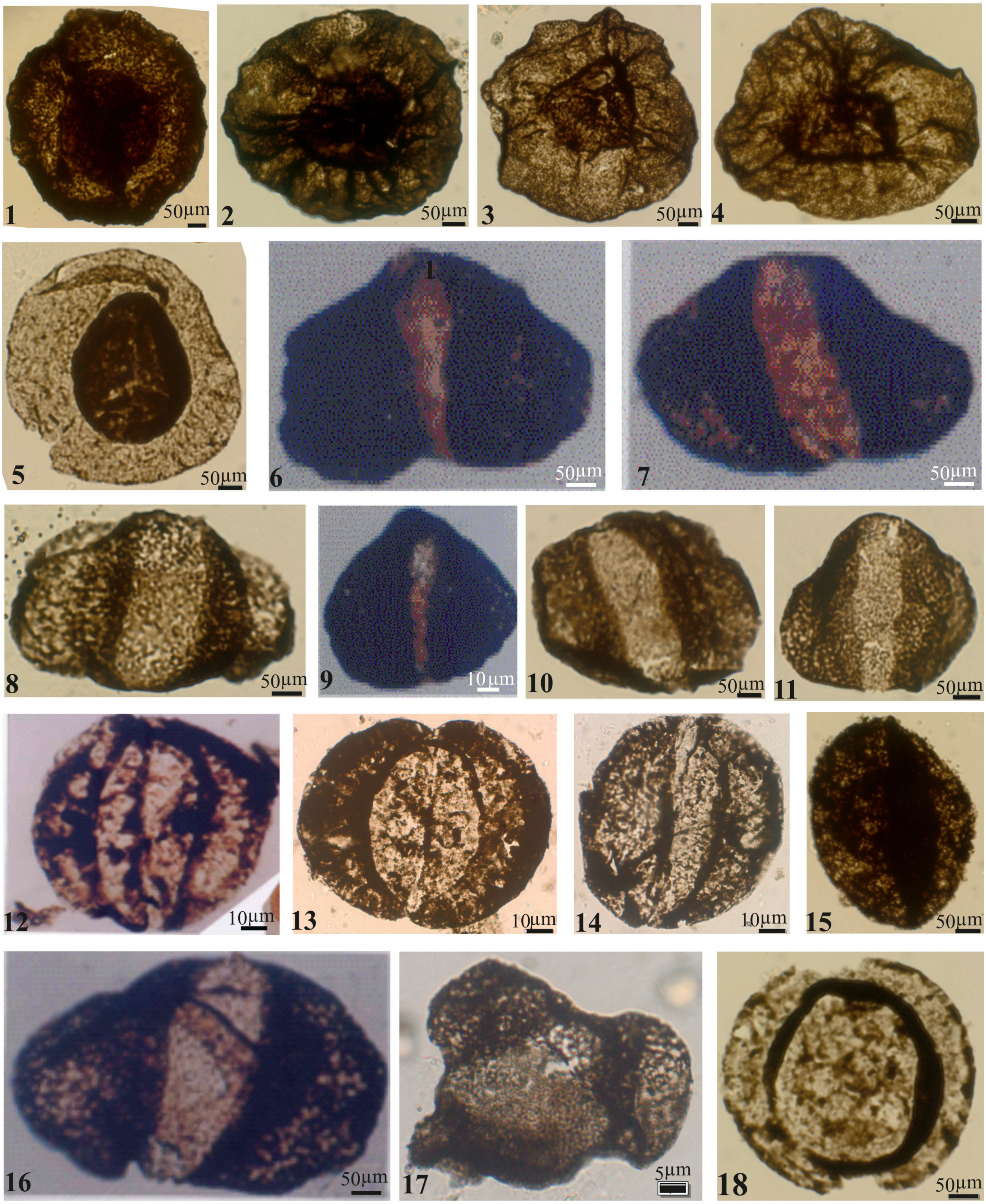
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PLATE 2

Helby *et al*. (1987) considered that the *Protohaploxypinus microcorpus* Oppel Zone is the oldest zone of the *Falcisporites* Superzone (late Permian to early Jurassic). They suggested that *Falcisporites australis* and *Protohaploxypinus microcorpus* in association with *Playfordiaspora velata, Triplexisporites playfordii* and other forms like *Lunatisporites pellucidus* and *Protohaploxypinus samoilovichii* represent late Permian to early Triassic transitional palynofloras in Australia. Besides, the assemblages described from the lower part of the Sabina Sandstone (Southern Perth) and the Wagina Sandstone, northern Perth Basin of Australia (Backhouse, 1993) is tentatively correlated with the present assemblage due to presence of *Faunipollenites* (*Protohaploxypinus* spp.) and *Densoisporites indicus*, however, taxa like *Camptotriletes warchianus* and member of *Dulhuntyispora* complex have not been recorded here.

Palynoassemblage–I can further be correlated with the Normandien Formation, KwaZulu–Natal (Prevec *et al*., 2009), the Wapadsberg Pass of Eastern Cape Province (Prevec *et al*., 2010) and the Witbank / Highveld Coal seams (Number 5) of the Vryheid Formation of Ecca Group, South Africa (Aitken, 1994). Besides, the assemblage also correlates with the Assemblage subzone H of Falcon (1975), Assemblage III of the Angwa Sandstone Formation (D'Engelbronner, 1996) of the Mid–Zambezi Basin, Zimbabwe in presence of *Protohaploxypinus varius* (=*Faunipollenites varius*), *Striatopodocarpites* spp., *Alisporites* spp., *Densipollenites indicus* and *Lunatisporites pellucidus*. Late Permian palynotaxa (*Protohaploxypinus microcorpus* Zone) recorded from the basal part of the Maji Ya Chumvi Formation of Mombasa Basin, Kenya (Hankel, 1992) and the palynoflora of the Lower Sakamena Group of Malagasy (Southern Morondava Basin) can broadly be compared with the present assemblage in the dominance of striate bisacctae pollen grains in association with sporadic occurrence of *Alisporites* sp., *Lueckisporites virkkiae, Playfordiaspora* sp., *Falcisporites* sp. and *Lunatisporites pellucidus*.

The late Permian palynoassemblages recorded by Balme (1970) and the basal most assemblage Chhidru 1 (*Protohaploxypinus* spp.–*Weylandites* spp.) from the Chhidru Formation, Salt Range, Pakistan recorded by Hermann *et al*. (2012) can be correlated with Assemblage–1 of the present study on the basis of dominance of *Faunipollenites* (=*Protohaploxypinus*), and sporadic occurrence of *Playfordiaspora* spp. and *Lunatisporites pellucidus*. However, *Klausipollenites schaubergeri*, *Protohaploxypinus* spp., *P. limpidus*, *Weylandites lucifer* and *Alisporites* spp., reported in dominance in the Upper Permian strata of Chhidru Formation, are scarcely represented in the present assemblage.

The present assemblage can also be correlated with South American palynozones, e.g. the *Tornopollenites toreutos* Zone (middle–late Permian) described from the Tapajos Group, Amazonas Basin by Playford and Dino (2000), *Lueckisporites virkkiae* (Lv) Interval Zone Souza and Marques–Toigo (2005) and the *Striatoabieites anaverrucosus–Staurosaccites cordubensis* (AC) assemblage zone of Beri *et al*. (2011) from the Parana Basin, Brazil and the *Tornopollenites toreutos–Reduviasporonites chalastus* (TC) assemblage zone recorded from the Claromecó Basin, Argentina. These zones show common occurrence of several species like *Lunatisporites, Lueckisporites, Protohaploxypinus, Striatopodocarpites fusus* and *Hamiapollenites*.

Palynoassemblage II—The assemblage identified herein from borehole SNB–1, between depths of 1054.30–956.00 m is characterized by the dominance of cavate/cingulate spores mainly *Lundbladispora* and *Densoisporites* spp. along with non striate bisaccate and taeniate pollen grains (Fig. 2). Palynoassemblage II can be correlated with the early Triassic palynofloral composition known from the different coalfields of Damodar Basin. The assemblage shows a broad resemblance with *Klausipollenites schaubergeri* assemblage zone of Panchet Formation (Tiwari & Tripathi, 1992) in having *Lundbladispora brevicula, Densoisporites playjordii, Playjordiaspora cancellosa, Lunatisporites pellucidus, Alisporites asansoliensis*. However, *Callumispora fungosa*

PLATE 3

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1. *Crescentipollenites fuscus* BSIP Slide No. 15664; coordinates 07 x 112.
2. *Lunatisporites ovatus* BSIP Slide No. 15664; coordinates 07 x 122.
3. *Lunatisporites pellucidus*. BSIP Slide No. 15664; coordinates 22 x 109.
4. *Lueckisporites virkkiae* BSIP Slide No. 15657; coordinates 15 x 108.
5. *Infernopollenites parvus* BSIP Slide No. 15670; coordinates 20 x 144.
6. *Lueckisporites junior* BSIP Slide No. 15661; coordinates 11 x 121.
7. *Lunatisporites rhaeticus* BSIP Slide No. 15656; coordinates 18 x 127.

8, 9. *Distriatites insculptus* BSIP Slide Nos.15671,15672; coordinates 08 x 141, 11 x 120.

10. *Triadispora vilis* BSIP Slide No. 15666; coordinates 12 x 136.
11. *Goubinispora morondavensis* BSIP Slide No. 15659; coordinates 14 x 130.
12. *Goubinispora indica* BSIP Slide No. 15658; coordinates 16 x 124.
13. *Kamthisaccites ringus* BSIP Slide No. 15666; coordinates 10 x 138.
14. *Cadargasporites baculatus* BSIP Slide No. 15667; coordinates 05 x 122.
15. *Leschikisporites aduncus* BSIP Slide No. 15663; coordinates 16 x 121.
16. *Reduviasporonites chalastus* BSIP Slide No. 15668; coordinates 19 x 121.

17, 18. *Reduviasporonites indicus* BSIP Slide No. 15663, 15667; coordinates 07 x 118; 13 x 117.

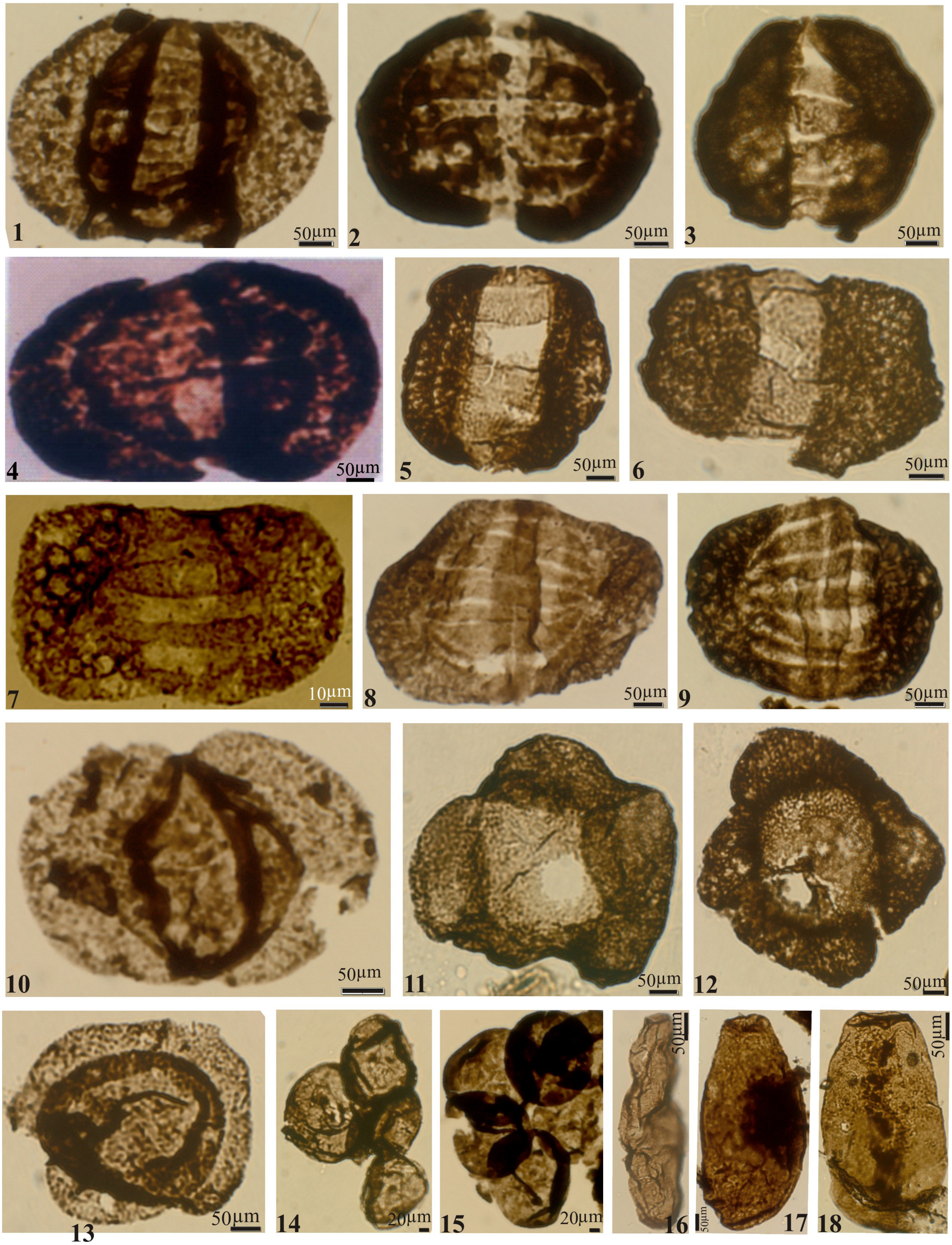
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PLATE 3

Table 2— List of samples. Productive samples are marked with Asterisk (*).

Sl. no.	Sample no. no.	Depth (m)	Lithology
1.	SNB–1/1	12.00	Fine–grained sst.
2.	SNB–1/2	20.65	Micaceous sst.
3.	SNB–1/3	20.95	Micaceous sst.
4.	SNB–1/4	25.10	Clay band in sst.
5.	SNB–1/5	32.50	Clay band in sst.
6.	SNB–1/6	38.50	Mudstone (buff colour)
7.	SNB–1/7	42.20	Mudstone (buff colour)
8.	SNB–1/8*	53.60	Shale
9.	SNB–1/9	54.10	Shale
10.	SNB–1/10	56.55	Mudstone (chocolate colour)
11.	SNB–1/11	57.30	Mudstone (chocolate colour)
12.	SNB–1/12	60.75	Mudstone (grey)
13.	SNB–1/13	61.80	Mudstone (chocolate colour)
14.	SNB–1/14	72.30	Mudstone
15.	SNB–1/15	74.00	Mudstone
16.	SNB–1/16	75.10	Mudstone (chocolate colour)
17.	SNB–1/17	99.75	Lavender colour mudstone
18.	SNB–1/18	102.40	Mudstone
19.	SNB–1/19	105.40	Mudstone
20.	SNB–1/20	109.90	Mudstone
21.	SNB–1/21	125.85	Carb.shale
22.	SNB–1/22	130.75	Carb.shale
23.	SNB–1/23	139.05	Carb.shale
24.	SNB–1/24	150.15	Shale
25.	SNB–1/25	165.00	Grey shale
26.	SNB–1/26	195.20	Shale
27.	SNB–1/27	202.40	Siltstone
28.	SNB–1/28	207.10	Micaceous siltstone
29.	SNB–1/29	228.35	Shale (buff colour)
30.	SNB–1/30	252.45	Variegated colour shale
31.	SNB–1/31	259.40	Shale band in sst.
32.	SNB–1/32	266.75	Clay band in sst.
33.	SNB–1/33	291.85	Micaceous sst.
34.	SNB–1/34	292.50	Shale
35.	SNB–1/35	322.10	Shale
36.	SNB–1/36	322.85	Mudstone
37.	SNB–1/37*	365.20	Clay band in sst.
38.	SNB–1/38	368.35	Micaceous sst.
39.	SNB–1/39	378.50	Carb. lenses in sst.
40.	SNB–1/40	378.95	Mudshale
41.	SNB–1/41	380.05	Shale (chocolate colour)
42.	SNB–1/42	397.20	Fine grained siltstone
43.	SNB–1/43*	404.40	Carb.shale
44.	SNB–1/44	432.90	Mud lenses in sst.
45.	SNB–1/45	455.95	Mudstone in sst.
46.	SNB–1/46	456.10	Mudstone in sst.
47.	SNB–1/47	506.10	Clay band in sst. (2cm)
48.	SNB–1/48	524.30	Mudstone in sst. (5cm)
49.	SNB–1/49	535.70	Mud lense in sst.
50.	SNB–1/50	543.80	Varigated colour mudstone
51.	SNB–1/51	544.35	Mudstone (brown)
52.	SNB–1/52	597.60	Mudstone (grey)
53.	SNB–1/53	599.50	Mudstone (grey)
54.	SNB–1/54	612.20	Siltstone
55.	SNB–1/55	627.20	Shale (brown)
56.	SNB–1/56	631.35	Mudstone
57.	SNB–1/57	692.90	Siltstone
58.	SNB–1/58	703.85	Siltstone
59.	SNB–1/59	712.15	Micaceous siltstone
60.	SNB–1/60	763.10	Clay band in sst.
61.	SNB–1/61	787.50	Shale
62.	SNB–1/62	825.60	Siltstone fine grained
63.	SNB–1/63	888.75	Mudstone (grey)
64.	SNB–1/64	907.15	Mudstone
65.	SNB–1/65*	956.00	Shale in sst.
66.	SNB–1/66	970.75	Shale band (4cm) in sst.
67.	SNB–1/67	977.85	Fine grained sst.
68.	SNB–1/68*	995.00	Shale (15cm) in sst.
69.	SNB–1/69*	1004.85	Shale in sst. (4cm)
70.	SNB–1/70*	1005.10	Shale band in sst. (8cm)
71.	SNB–1/71	1015.05	Clay lens in sst.
72.	SNB–1/72	1028.65	Shale in sst. (10cm)
73.	SNB–1/73*	1031.95	Shale band in sst.
74.	SNB–1/74	1037.00	Shale in sst. (10cm)
75.	SNB–1/75	1040.85	Shale
76.	SNB–1/76	1050.15	Shale in sst.
77.	SNB–1/77*	1054.30	Shale in sst.
78.	SNB–1/78	1075.15	Clay band in sst.
79.	SNB–1/79	1075.80	Shale in sst.
80.	SNB–1/80	1081.15	Silty shale (brown)
81.	SNB–1/81	1084.90	Shale (chocolate colour)
82.	SNB–1/82	1090.30	Shale (chocolate colour)
83.	SNB–1/83	1093.15	Grey+Brown siltstone
84.	SNB–1/84	1102.50	Shale (chocolate colour)
85.	SNB–1/85	1117.75	Mudshale (grey)
86.	SNB–1/86	1126.95	Mudshale (grey)
87.	SNB–1/87	1136.85	Shale (buff)
88.	SNB–1/88	1144.85	Carb. shale
89.	SNB–1/89*	1164.10	Shale
90.	SNB–1/90*	1165.30	Shale
91.	SNB–1/91	1176.05	Micaceous siltstone
92.	SNB–1/92	1198.25	Micaceous siltstone
93.	SNB–1/93*	1213.40	Carb.shale
94.	SNB–1/94	1215.45	Shale Carb.
95.	SNB–1/95	1218.40	Fine grained siltstone
96.	SNB–1/96	1227.70	Carb. shale in sst.
97.	SNB–1/97	1272.70	Siltstone
98.	SNB–1/98	1279.40	Siltstone
99.	SNB–1/99	1288.55	Mudshale
100.	SNB–1/100	1300.00	Compact mudshale

Abbreviation: sst. =sandstone; carb. =carbonaceous

Table 3—A summary of the assemblages identified in borehole SNB–1 of the exploration block of Nigwani–Bakeli area, western part of Sohagpur Coalfield, Madhya Pradesh.

Fm.	Mem.	Depth (m)	Assem. identified	Dominating taxa	Other characteristic taxa	Age
PALI	UPPER	53.60–404.40	**III**	*Aulisporites astigmosus–Falcisporites nuthallensis*	*Cadargasporites baculatus, Densoisporites playfordii, Enzonalasporites densus, Cingulizonates indicus, Dubrajisporites unicus, Duplicisporites granulates, Lapposisporites lapposus, Leschikisporites aduncus, Limatulasporites fossulatus, Neoraistrickia taylorii, Polycingulatisporites crenulatus, Minutosaccus crenulatus, Plicatisaccus badius, Triadispora vilis, Foviosporites triassicus, Klausipollenites staplinii, Tikisporites balmei, Goubinispora morondavensis, Kraeuselisporites rallus* and *Lunatisporites rhaeticus*	NORIAN/CARNIAN
		956.00–1054.30	**II**	*Lundbladispora densispinosa–Densoisporites playfordii*	*Alisporites grobus, Klausipollenites schaubergeri, K. rallus, Limatulasporites fossulatus, Osmundacidites senects, Kamthisaccites ringus, Lundbladispora warti, L. microconata, Goubinispora indica, Satsangisaccites nidpurensis, Aratrisporites fischeri, Lueckisporites virkkiae, Reduviasporonites chalastus, Brachysaccus triassicus, Striatopodocarpites nidpurensis* and *Chordasporites australiensis*	SCYTHIAN
	MIDDL*E*	1164.10–1213.40	**I**	*Striatopodocarpites magnificus–Crescentipollenites fuscus*	*Striatopodocarpites magnificus, Distriatites insculptus, Lahirites raniganjensis, Verticipollenites gibbosus, Faunipollenites varius, F. perexiguus, Striatites sewardii, Lunatisporites pellucidus, Densipollenites indicus, D. magnicorpus,* and *Lueckisporites junior*	CHANGHSINGIAN

is not recorded in the present assemblage. The assemblage is further comparable with the early Triassic palynofossils described by Bharadwaj and Tiwari (1977) and other Panchet equivalent palynofloras of different cores samples (RAD–2, Singh & Tiwari, 1982; RNM–4, Tiwari & Rana, 1984; RAD–11, Singh 1984; and Assemblage P–IVA, Tiwari & Singh, 1986) (early Triassic) of Raniganj Coalfield in view of the presence of *Lundbladispora brevicula, Densoisporites playjordii, Lunatisporites pellucidus, Playfordiaspora cancellosa, Alisporites asansoliensis, Goubinispora morondavensis, G. indica* and *Chordasporites* spp.

The assemblage shows a fair degree of resemblance with early Triassic palynoflora (Asssemblage II) of Chundi River Section (Ram–Awatar, 1997) and the Assemblage1 described from the Pali Formation (Ram–Awatar, 2003) in the presence of *Alisporites* sp., *Lundbladispora* sp., *Densoisporites playfordii, Falcisporites* sp., *Playfordiaspora cancellosa, Brachysaccus* sp., *Satsangisaccites nidpurensis,*

Table 4—A classified check list of identified palynotaxa.

Trilete spores	*Aulisporites astigmosus* (Leschik) Klaus, 1960 *Cadargasporites baculatus* de Jersey and Paten emend. Reiser & Williams, 1969 *Cingulizonates indicus* Kumaran & Maheshwari, 1980 *Convolutispora perfecta* Kumaran & Maheshwari, 1980 *Cyclotriletes* sp. cf. *C. triassicus* Mädler, 1964 *Densoisporites complicates* Balme, 1970 *D. playfordii* Balme, 1970 *D.bulbosus* Tiwari & Tripathi, 1987 *Dubrajisporites unicus* Tripathi *et al.*, 1990 *Duplicisporites granulates* Leschik emend. Scheuring, 1970 *Enzonalasporites densus* (Leschik) Dolby & Balme, 1976 *Foviosporites triassicus* Kumaran & Maheshwari, 1980 *Kraeuselisporites rallus* Balme, 1970 *K. wargalensis* Balme, 1970 *Lapposisporites lapposus* Visscher, 1966 *L. villosus* Visscher, 1966 *Leschikisporites aduncus* Potonié emend Bharadwaj & Singh, 1964 *Limatulasporites fossulatus* (Balme) Helby & Foster in Foster, 1979 *Lundbladispora warti* Tiwari & Rana, 1981 *L. densispinosa* Bharadwaj & Tiwari, 1977 *L. microconata* Tiwari & Rana, 1981 *Lycopodiumsporites* sp. in Kumaran & Maheshwari, 1980 *Neoraistrickia taylorii* Playford & Dettmann, 1965 *Osmundacidites senectus* Balme, 1963 *Polycingulatisporites crenulatus* Playford & Dettmann, 1965 *Punctatisporites fungosus* Balme, 1970 *Tikisporites balmei* Kumaran in Kumaran & Maheshwari, 1980 *Uveaesporites verrucosus* Helby in de Jersey, 1971
Monosaccate pollen grains	*Densipollenites indicus* Bharadwaj, 1962 *D. magnicorpus* Tiwari & Rana, 1981 *Goubinispora indica* Tiwari & Rana, 1981 *G. morondavensis* Tiwari & Rana, 1981 *Kamthisaccites ringus* Tripathi & Vijaya, 2008 *Playfordiaspora cancellosa* Maheshwari & Banerjee emend. Vijaya, 1995 *P. crenulatus* Wilson) Vijaya, 1995 *P. vellata* (Leschik) Vijaya, 1995
Straite–bisaccate pollen grains	*Crescentipollenites fuscus* (Bharadwaj) Bharadwaj *et al.*, 1974 *Distriatites insculptus* (Playford & Dettmann) Bharadwaj & Srivastava, 1969 *Faunipollenites varius* Bharadwaj 1962 emend. Tiwari *et al.*, 1989 *F. perexiguus* Bharadwaj & Salujha 1965 emend. Tiwari *et al.*, 1989 *Hamiapollenites insolatus* Bharadwaj & Salujha, 1964) *Lahirites raniganjensis* Bharadwaj, 1962 *Rhizomaspora indica* Tiwari, 1965 *Striatopodocarpites magnificus* Bharadwaj & Salujha, 1964 *S. nidpurensis* Bharadwaj & Srivastava, 1969 *Striatites sewardii* Pant emend. Lakhanpal *et al.,* 1959 *Verticipollenites gibbosus* Bharadwaj, 1962
Non striate bisaccate pollen grains	*Alisporites asansolensis* Maheshwari and Banerji, 1975 *A. grobus* Bharadwaj & Tiwari, 1977 *Brachysaccus triassicus* Tripathi *et al.*, 1990 *B. indicus* Kumaran & Maheshwari, 1980

	Cuneatisporites sp. *Falcisporites nuthallensis* (Clarke) Balme, 1970 *Klausipollenites schaubergeri* Potonié & Klaus emend. Jansonius, 1962 *K. staplinii* Jansonius, 1962 *Minutosaccus crenulatus* Dolby in Dolby & Balme, 1976 *Plicatisaccus badius* Pautsch, 1971 *Satsangisaccites nidpurensis* Bharadwaj & Srivastava, 1969 *Triadispora vilis* Scheuring, 1970
Taeniate pollen grains	*Chordasporites australiensis* de Jersey, 1962 *C. klausii* Kumaran & Maheshwari, 1980 *Infernopollenites parvus* Scheuring, 1970 *Lueckisporites junior* Klaus, 1960 *L. virkkiae* Potonié & Klaus, 1954 *Lunatisporites pellucidus* (Goubin) Maheshwari & Banerji, 1975 *L. rhaeticus* (Schultz) Warrington, 1974, *L. acutus* Leschik emend. Scheuring, 1970
Monolete spores	*Aratrisporites fischeri* (Klaus) Playford & Dettmann, 1965
Others	*Grebespora concentric* Jainsonius, 1962 *Reduviasporonites chalastus* (Foster) Elsik, 1999 *R. indicus* Ram–Awatar *et al*., 2013 *Schizosporis* sp.

Chordasporites australiensis and *Lunatisporites pellucidus.* However, *Staurosaccites marginalis* is absent in the latter assemblage. Similarly, it is also comparable with Nidpur palynoflora (Tiwari & Ram–Awatar, 1990) in having non–striate bisaccate pollen taxa *Satsangisaccites nidpurensis*, *Falcisporites* sp. and *Klausipollenites* sp. along with *Goubinispora morondavensis, Playfordiaspora cancellosa, Lundbladispora* sp. and *Lunatisporites pellucidus.* The present assemblage shows a close affinity with early Triassic palynoflora (Assemblage–A) recorded by Tripathi *et al*. (2005) from borehole SSM–II of Singrauli Coalfield; Assemblage III of Iria Nala Section (Srivastava *et al.*, 1997) and Assemblage VI recorded in borehole TROD–1 of Ramkola–Tatapani Coalfield (Tripathi *et al*., 2012) due to common occurrence of *Klausipollenites schaubergeri, Striatopodocarpites* sp., *Playfordiaspora cancellosa, Satsangisaccites nidpurensis, Plicatisaccus, Brachysaccus, Minutosaccus, Lundbladispora, Densoisporites*, *Lunatisporites pellucidus, Goubinispora morondavensis* and *Chordasporites australiensis.* The assemblage shows a close affiliation with the Assemblage IIIB of borehole TP–8, Talcher Coalfield, Orissa (Tripathi, 1996) in dominance of *Lundbladispora* and nonstriate bisaccate pollen– *Klausipollenites schaubergeri, Satsangisaccites nidpurensis* along with rare occurrence of trilete *Playfordiaspora cancellosa,* monosaccate *Goubinispora morondavensis* and taeniate *Lunatisporites pellucidus.*

The *Lundbladispora–Densoisporites* dominant Palynozone–10 of Budharam area (Srivastava & Jha, 1995) closely resembles with present palynozone in dominance of *Lundbladispora* but the former differs in having *Densoisporites* as the subdominant taxa. Additionally, it also resembles with Assemblage V of Mailaram area (Srivastava & Jha,1990), Assemblage III of Sattupali area (Jha, 2008) and palynoassemblages recovered from the borehole 1008 of the Manuguru area (Jha *et al*., 2011) in dominance of *Lundbladispora* and subdominance of *Densoisporites* in association with *Satsangisaccites nidpurensis*, *Falcisporites* sp. *Klausipollenites* sp., *Goubinispora morondavensis, Lundbladispora* sp. *Playfordiaspora cancellosa* and *Lunatisporites*. The present assemblage is also correlated with the Palynoassemblage III of Bazargaon (Srivastava & Bhattacharyya, 1996) and the early Triassic palynoassemblage described from the Wardha Basin, Maharashtra (Murthy & Sarate, 2015) in the presence of *Klausipollenites schaubergeri, Goubinispora morondavensis, Densoisporites playfordii, Playfordiaspora cancellosa, Lunatisporites pellucidus, Brachysaccus* sp., *Alisporites* sp. *Lueckisporites virkkiae* and *Chordasporites* sp. The palynoflora recorded from the Chota Mahadeva of Tamia Scrap (Kumar, 1995) and Pachmarhi Formation of Tamia River Section (Kumar, 1996), Satpura Basin is also comparable to the present assemblage in having significant common forms like *Falcisporites*, *Klausipollenites*, *Goubinispora, Satsangisaccites, Alisporites,* and *Chordasporites.*

Assemblage II from borehole (SNB–1) can be tentatively correlated with the palynoassemblages of other Gondwananic continents, e.g. it is comparable with the *Alisporites* zone (subzone A) of the Falla Formation (Kyle & Fasola, 1978; Kyle & Schopf, 1982; Barrett *et al*., 1986; Frabee *et al*., 1990), Central Transantarctic Mountains, palynofloras identified by Kyle (1977) from The *Alisporites* zone (subzone–A of the Upper Fleming Member, subzone–B of the Lower

Member of the Lashly Formation) and the palynofloras recorded from sample no. TTU–ATP–289 (Ram–Awatar *et al.,* 2014) from the Lashly Formation of the Allan Hills, South Victoria Land, Antarctica. The most characteristic taxa pertinent to this correlation include: *Alisporites* spp., *Falcisporites* spp., *Densoisporites* spp., *Playfordiaspora cancellosa* (=*Guthoerlisporites cancellosa*), *Lundbladispora brevicula*, *L. willmotti*, *Kraeuselisporites* spp. However, the difference lies in presence of *Tigrisporites playfordi.* A comparison of the palynoflora recorded in Palynozone–II, with that of Ritchie Member (McLoughlin *et al.,* 1997) from the Lower Flagstone Bench Formation of Antarctica indicates dominance of non striate bisaccate and striate bisaccate pollen taxa —*Falcisporites australis, Chordasporites australiensis*, *Klausipollenites schaubergeri* like *Lunatisporites pellucidus*, *Protohaploxypinus* sp. (=*Faunipollenites*) in association with *Goubinispora morondavensis, Limatulasporites* spp. and cavate/ zonate forms like *Densoisporites playfordii* and *Lundbladispora* spp.

The *Lunatisporites pellucidus* zone, identified by Foster (1982) from the Bowen Basin, Queensland, Australia, is marked by the dominance of cavate/zonate trilete spores and first appearance of *L. pellucidus, Kraeuselisporites septatus, K. cuspidus,* and *Lundbladispora obsoleta* and rare occurrence of *Aratrisporites* sp. The presence of similar forms (Table 3) recorded in the present assemblage (Assemblage II) shows a broad correlation with the early Triassic palynofloral zone *Lunatisporites pellucidus* (Foster, 1982), entire *Protohaploxypinus samoilovichii* Zone (Helby *et al.,* 1987) from eastern Australia and the *Kraeuselisporites septatus* Zone of western Australia (Dolby & Balme, 1976). According to Helby *et al.* (1987), *Protohaploxypinus microcorpus* zone is not recorded in the western and northern parts of Australia, since the endemic macrofloristic succession was affected by environmental changes during separation of Gondwana continents. The present assemblage is also comparable with the Palynozone–3 (*Kraeuselisporites–Lunatisporites* Zone) of the Katberg Formation of Carlton Heights, South Africa (Steiner *et al.,* 2003), the Middle Sakamena microflora (Wright & Askin, 1987) and palynotaxa described from Unit II of the Morondava Basin, southwest Madagascar (Goubin, 1965) in the presence of *Falcisporites* spp., *Klausipollenites* spp. and *Lunatisporites pellucidus,* (*Taeniaesporites noviaulensis*). The early to middle Triassic palynoassemblages of northern Gondwana have been recorded from different sections (Nammal Zone, Chhidru, Chitta–Landu and Narmia) of Mianwali and Tredian formations of Salt Range, Pakistan (Balme, 1970; Hermann *et al.,* 2012). The forms of present study which are common to those of the Salt Range, Pakistan (Assemblage Zones PTr1–PTr3 and Assemblage II of this study) are *Lundbladispora obsoleta, L. brevicula* and *D. playfordii* (cavate/cingulated forms) which occur in dominance in association with *Falcisporites* sp., *Kraeuselisporites septatus, Klausipollenites schaubergeri* and *Lunatisporites pellucidus.* According to Hermann *et al.* (2012), the palynofloras described from the Upper Chhidru Formation (Balme, 1970) and the palynozones Chiddru–2 to PTr2 (Hermann *et al*., 2012) are coeval.

Palynoassemblage III—The youngest assemblage identified here between a depth 404.40–53.60 m is characterized by the dominance of *Aulisporites astigmosus, Falcisporites nuthallensis* along with *Enzonalasporites densus, Neoraistrickia taylorii, Polycingulatisporites crenulatus, Lapposisporites lapposus* and *Dubrajisporites unicus* (Table 3). The assemblage can be correlated with the upper Triassic (Carnian–Noranian) palynofloras described from the Bijouri–Harai area (Sundram *et al*., 1979), Tharipathar and Ghiar sections of the Son River, (Maheshwari & Kumaran, 1979) and Janar Nala Section (Kumaran & Maheshwari, 1980), Tiki Formation, South Rewa Basin, but differs in the absence of *Staurosaccites, Guttatisporites* and *Camerosporites*. Palynoassemblage–III further shows a close resemblance with the late Triassic palynoflora recorded in boreholes SSM–1 (Assemblage–A) and SSM–2 (Assemblages IIIa and IIIb) of Mahuli–Mahersop area of Singrauli Coalfield (Tripathi *et al*., 2005) in presence of *Cadargasporites baculatus, Chordasporites australiensis, Cingulizonates indicus, Convolutispora perfecta, Densoisporites playfordii*, *Enzonalasporites densus, Foviosporites triassicus, Grebespora concentric, Kraeuselisporites* sp., *Lapposisporites lapposus, Lunatisporites rhaeticus, Minutosaccus crenulatus, Playfordiaspora crenulata, Plicatisaccus badius, Polycingulatisporites crenulatus* but differs in the absence of *Staurosaccites, Guttatisporites, Rimaesporites* and *Camerosporites.* The assemblage is broadly compared with *Enzonalasporites ignacii–Minutosaccus crenulatus* assemblage zone of Maleri Formation of Krishna–Godavari Basin (Prasad, 1997) in presence of *Falcisporites nuthallensis, Klausipollenites schaubergeri, K. staplinii, Minutosaccus crenulatus, Chordasporites australiensis, Lunatisporites rhaeticus, Playfordiaspora crenulata, Plicatisaccus badius, Polycingulatisporites crenulatus, Goubinispora morondavensis, Densoisporites playfordii*, *Enzonalasporites* sp. and *Dubrajisporites unicus* but lacks *Staurosaccites, Guttatisporites, Rimaesporites* and *Camerosporites*. The present assemblage is also comparable to Denwa Palynoassemblage–I, II (Nandi, 1996) and the palynoflora recorded by Vijaya and Murthy (2012) from the Satpura Basin in the presence of *Brachysaccus, Nidipollenites, Krempipollenites* (*Klausipollenites*), *Chordasporites australiensis, Satsangisaccites nidpurensis, Falcipollenites strabilis* and *Minutosaccus* sp. The late Triassic (Carnian–Norian) palynofloras described by Tiwari *et al.* (1984) from the Dubrajpur Formation, Rajmahal Basin contains high percentage of non–striate disaccate pollen grains, namely *Satsangisaccites, Nidipollenites* and *Alisporites* in association with *Rajmahalispora* and *Tigrisporites*. Assemblage III of borehole SNB–1 shows a fair degree of resemblance with that of Dubrajpur Formation, except that taxa *Rajmahalispora* and *Tigrisporites* are absent in this assemblage.

When compared with other Gondwanic continents, the presently recorded Assemblage III can be correlated with the well established late Triassic palynofloras known from different localities of Antarctica (Kyle, 1977; Taylor *et al*., 1988; Farabee *et al*., 1989, 1990; Foster *et al*., 1994). It is also comparable with the *Alisporites* zone (subzones C & D) of Kyle (1977) recovered from the Feather Conglomerate and the Lashly Formation of South Victoria Land in having dominance of *Alisporites* spp. along with *Neoraistrickia taylorii, Duplexisporites* sp*., Polycingulatisporites crenulatus* and *Osmundacidites senectus.* The palynofloras recovered from the Falla Formation of the Beardmore Glacier region (Taylor *el al*., 1988), Central Transantarctic Mountains (Farabee *et al*., 1989, 1990) and McKelvey Member of the Flagstone Bench Formation (Foster *et al.,* 1994; McLoughlin *et al*.,1997) can be correlated with the present assemblage in dominance of *Falcisporites* spp. found in association with *Neoraistrickia taylorii, Cadargasporites baculatus, Minutosaccus crenulatus, Polycingulatisporites crenulatus, Enzonalasporites densus, Limatulasporites fossulatus, Osmundacidites senectus, Playfordiaspora cancellosa*. However, *Rimaesporites aquilonalis, Stereisporites antiquasporites* and *Ashmoripollis reducta* are absent in the present assemblage.

The palynotaxa recorded in Assemblage III can be correlated with those recorded from the upper part of Onslow, of western Australia (Dolby & Balme, 1976). The forms which are common between the Onslow and SNB–1 palynofloras are *Aulisporites astigmosus, Convolutispora perfecta, Chordasporites australiensis, Densoisporites playfordii, Distriatites insculptus, Falcisporites* sp., *Lunatisporites pellucidus, Minutosaccus crenulatus, Osmundacidites senectus* and *Uveaesporites verrucosus*. However, *Rimaesporites, Ashmoripollis reducta, Dictyophillidites mortonii, Clavatisporites hammenii, Samaropollenites speciosus* and *Staurosaccites* sp., are not recorded in borehole SNB–1 palynoflora (Assemblage III) of the present study. The late Triassic continental Ipswich microfloral assemblage *Craterisporites rotundus* Oppel zone (Carnian to lowermost Norian) of southeastern Queensland identified by de Jersey (1975) and modified by Helby *et al.* (1987) can be tentatively correlated with that of the present assemblage in dominance of *Falcisporites australis* found in association with other accessory forms like *Duplicisporites, Cadargasporites, Playfordiaspora crenulata, Polycingulatisporites crenulatus*. On the other hand, certain important genera like *Enzonalasporites densus, Foviosporites triassicus, Goubinispora morondavensis* and *Aulisporites astigmosus* recovered presently in the Palynoassemblage III are not reported from the Australian Assemblage.

The present assemblage can be correlated with the late Triassic palynoassemblage recorded from the Paso Flores Formation, Limay area, Patagonia (Zavattieri & Mego, 2008), Argentina in common occurrence of *Cadargasporites, Uveaesporites verrucosus* and *Alisporites* spp.

Permian–Triassic Boundary (PTB)—Tiwari (1999) synthesized the Permian/Triassic boundary on the basis of Dominance Datum (DOD), First Appearance Datum (FAD) and the Last Appearance Datum (LAD) of the important palynotaxa recorded from the non–marine and marine strata of the peninsular and extra peninsular regions of India with slight variations. According to him, in most Indian peninsular basins, the palynological data revealed the DOD in following combinations: *Striatopodocarpites* in association with *Faunipollenites/Gondisporites/* (or *Verticipollenites*)/*Densipollenites/ Crescentipollenites* (or *Guttulapollenites*). The latest Permian is succeeded by *Klausipollenites*/ (*Falcisporites*) /*Arcuatipollenites* (=*Lunatisporites*) /*Verrucosisporites–Callumispora / Lundbladispora / Densoisporites* in the early Triassic strata. When we compared our palynological data with the PTB data provided by Tiwari (1999), a distinct Permian/Triassic boundary is observed in borehole SNB–1 of the study area.

The palynological study reveal that the late Permian palynoflora is marked by the dominance of striate bisaccate pollen taxa between 1213.40–1164.10 m depth, while the early Triassic palynoflora is characterized by the dominance of cavate/cingulate spores, non striate bisaccate pollen and taeniate pollen grains in between 1054.30–956.00 m depth. Thus, positive evidence of abrupt change in the palynocomposition is observed by sudden decline in percentage of *Striatopodocarpites* and *Crescentipollenites* and rise in percentage of *Lundbladispora, Densoisporites, Kraeuselisporites* and *Lunatisporites* spp. Accordingly, in the studied borehole, the P/T boundary is present somewhere in between 1164.10–1054.30 m depth, apparently at a depth of 109.80 m (Fig. 2). Similar trend of the palynological composition indicating the P/T boundary (Ram–Awatar, 1997) has also been recorded in the Chundi River Section (~300 m), south of the presently studied borehole (SNB–1). Most of the palynomorphs are common in both the PTB assemblages, except that *Staurosaccites, Kamthisaccites* and *Todisporites* are present in the Chundi palynoassemblage.

Besides, a large numbers of *Reduviasporonites* (fungal spores) have also been recorded in Palynoassemblage II (1054.30 m depth) along with *Lundbladispora, Densoisporites, Kraeuselisporites* and *Lunatisporites* spp. which demarcate a definite P/T boundary in the studied area. Steiner *et al*. (2003) delineated the P/T boundary on the basis of fungal spikes (*Reduviasporonites* or its junior synonyms *Chordecystia* or *Tympanicysta*) in the Carlton Heights Section, southern Karoo Basin, South Africa which was earlier mapped as Upper Permian (Balfor Formation) by Keyser (1977).

It is well established that about 90% gymnospermous plant species died during the end Permian mass extinction (Retallack, 1995; Visscher *et al*., 1996; Looy *et al*., 1999). The plant extinction is evidenced by disappearance of gymnospermous pollen grains (mainly striate bisaccate) below the fungal horizon and appearance of early Triassic palynofloras dominated by lycopsid spores (*Lundbladispora, Densoisporites, Kraeuselisporites*) in association with taeniate pollen (Visscher *et al.,* 1996) above it. In the present case, Palynoassemblage–I is characterized by the dominance of striate bisaccate pollen grains while in the Palynoassemblage–II, cavate/ cingulate spores are dominant along with the occurrence of *Reduviasporonites* suggesting a positive signature of PTB. Occurrence of *Reduviasporonites* close to the P/T boundary has been well established in other countries like Russia, Australia, Austria, Greenland, South Africa, U.K. and India (Ram–Awatar *et al*., 2013). Recently, *Reduviasporonites* has been recorded from the PTB at Guryul Ravine Section, Kashmir, India (Tewari *et al*., 2015) and the PTB transitional section between the Upper Permian Xuanwei and the early Triassic Kayitou formations in South China (Bercovici *et al*., 2015). Earlier workers considered *Reduviasporonites* an algal spore (Afonin *et al*., 2001; Foster *et al*. 2002). However, on the basis of organic geochemical analysis, Visscher *et al*. (2011) suggested that *Reduviasporonites* is a fungal spore which is found close to the end of Permian. In the present study, occurrence of *Reduviasporonites* suggests that the P/T boundary lies somewhere in between the upper part of the Middle Member and the lower part of the Upper Member of the Pali Formation.

CONCLUSIONS

On the basis of palynological study, the following conclusions are drawn.

- This is the first report of palynoassemblages from the Upper Permian and Lower and Upper Triassic strata of Nigwani–Bakeli area of the western part of Sohagpur Coalfield, Shahdol District, Madhya Pradesh.
- Three palynoassemblages have been identified from the Pali Formation in the studied sequence of borehole SNB–I (Table 3). Assemblage–1, oldest in the sequence, in SNB–1 (1213.40–1164.10 m depth) is equated with the *Densipollenites magnicorpus* Assemblage zone of Tiwari and Tripathi (1992) and dated latest Permian in age. Assemblage II (1054.30–956.00 m depth) related with the *Krempipollenites indicus* Assemblage zone (Tiwari & Tripathi, 1992) suggests Lower Triassic strata in the area. Assemblage III (404.40–53.60 m depth) correlates with the Upper Triassic/Supra–Panchet (Carnian–Norian) palynozones (Tiwari & Tripathi, 1992) due to presence of *Aulisporites astigmosus, Aratrisporites parvispinosus, Brachysaccus indicus, Enzonalasporites densus, Duplicisporites granulates, Dubrajisporites unicus, Lapposisporites lapposus, Minutosaccus crenulatus* and *Uveaesporites verrucosus.*
- On the basis of occurrence of significant spore and pollen taxa, it is suggested that the P/T boundary exists somewhere in between 1213.40–1164.10 m depth between the top of the late Permian strata and base of the early Triassic, which is also supported by the presence of *Reduviasporonites* at a depth of 1054.30 m.
- On the basis of lithological similarities, the Pali and Tiki formations were clubbed together as Pali–Tiki Formation (Dutta, 2002; Mukhopadhyay *et al.*, 2010; Mukherjee *et al.*, 2012). The present palynological study also supports the view that the Pali and Tiki formations are coeval lithounit.

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