Palynostratigraphy and age correlation of subsurface strata within the sub-basins in Singrauli Gondwana Basin, India

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In the study area, changes in the facies of sediments and spores-pollen content appear to be all causally linked with the depositional set-up. Here, the qualitative and quantitative changes observed in the spores-pollen assemblages have led to recognize 10 Assemblage-zones representing from that earliest Permian in the Talchir Formation to that latest Late Triassic in the Parsora Formation. These spores-pollen assemblages are obtained from the wider parts in the Singrauli Gondwana Basin that includes (i) Moher sub-basin (boreholes SSM-1 and 2), and (ii) Singrauli main sub-basin (boreholes SMJS-2, 3 and SMBS-1). The progressively changing spores-pollen content infer the hiatuses of varied magnitude in the sedimentary sequences during the extended time interval of Permian and Triassic.

1. Introduction

The sedimentary sequences comprising the Permian and Triassic deposits in the Singrauli Gondwana Basin are intersected in number of borecores, and these deposits are widely scattered (figures 1, 2). Previous spores-pollen studies carried out in the subsurface deposits in this basin (Bharadwaj and Sinha 1969a,b; Sinha 1972; Tiwari and Srivastava 1984; Tripathi *et al.* 2005) have documented the existence of Upper Permian and Upper Triassic strata punctuated within many hiatus levels.

Present study includes dating of subsurface strata in boreholes SMJS-2, 3, and SMBS-1, in the Singrauli main sub-basin. Beside this, the spores-pollen data from the Moher sub-basin (boreholes SSM-1 and 2 in Tripathi *et al.* 2005) has also been included herein to built-up the palynostratigraphy in the Singrauli Gondwana Basin. The spores-pollen studies done in these five borecores are interpreted for age correlation of the sedimentary sequences from that earliest Permian through Late Triassic.

2. Geology

The Singrauli Gondwana Basin (figures 1, 2) is the northernmost part of the Son-Mahanadi master Gondwana Basin, and is situated in the drainage area of Son and Rihand rivers. In the heart of peninsular India, it occupies the north-western zone between NW–SE trending rift zone of Son/Mahanadi Valley Basin and east–west trending Tatapani–Koel–Damodar Basin. As the Gondwana sediments in Singrauli Gondwana Basin were deposited through fluvial network, it contains a predominance of sandstone dominated cycle. This character is typical of the Son Valley Basin belt (Mukhopadhyay and Mukhopadhyay 1999).

Keywords. Spores-pollen; Permian; Triassic; Singrauli Gondwana Basin; India.

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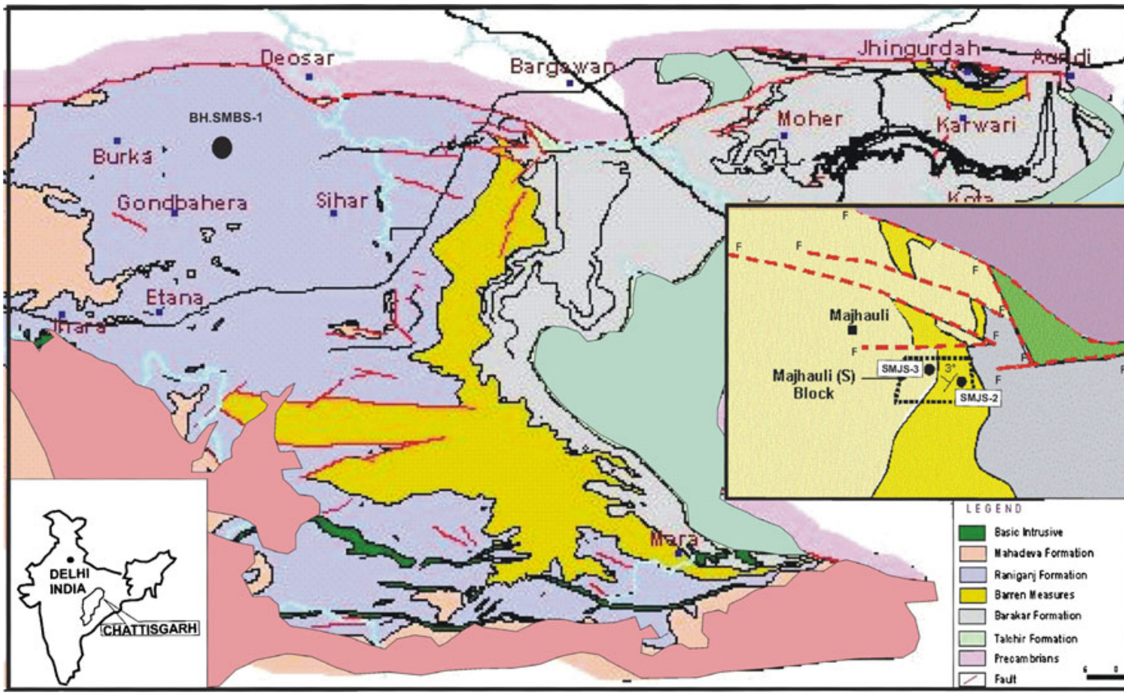

Figure 1. Map of Singrauli Gondwana Basin to show the Majhauli block, and the location of three borehols – SMJS-2, 3, and SMBS-1.

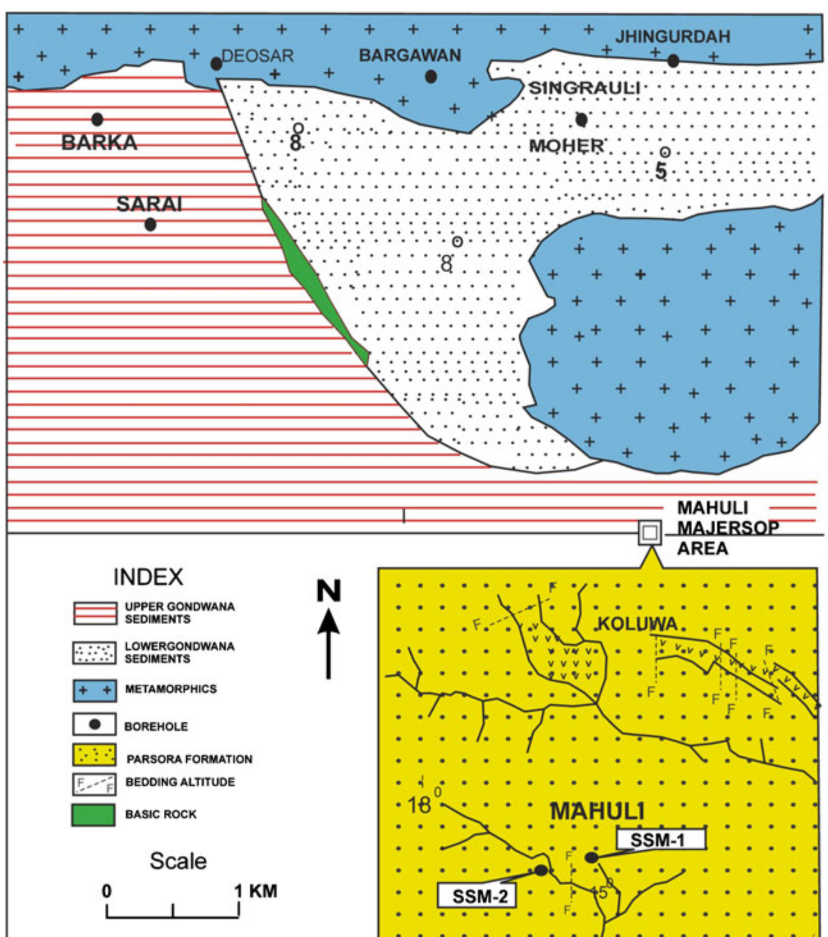

Figure 2. Part of Singrauli Gondwana Basin to show the Mahuli–Mahersop block, and the location of two boreholes SSM-1 and SSM-2.

Table 1. *General stratigraphic succession of Singrauli Coalfield (after GSI unpublished report).*

Age	Formation/group	Thickness	General lithology
Recent			Alluvium
Cretaceous	Basic intrusive		Dolerite dykes and sills
Late Triassic	Parasora	500 m+	Medium-to-coarse grained ferruginous quartzose sandstone
Early Triassic	Pali	700 m+	Greenish yellow to reddish yellow, medium-to-coarse grained sandstone with variegated siltstone and clay
Late Permian	Raniganj	215–400 m	Fine-to-medium grained dirty to buff coloured subarkose to feldspathic wacke with alternation of thin lamination of grey and carbonaceous shale along with impersistent coal seams
Middle Permian	Barren Measures	110–300 m	Dark brown to brownish yellow to greenish grey, medium-to-coarse grained flaggy sandstone with thin grey clay bands in between
Early Permian	Barakar	325–550 m	Dirty white fine-to-coarse grained sub-arkosic to arkosic sandstone along with siltstone, shale, carbonaceous shale and coal seams
Early Permian	Talchir	75–230 m	Dark greenish grey to grey shale, fine grained sandstone diamictite, siltstone pebbly sandstone and boulder bed
- - - - - - - -	- - - - - - - -	- - - -	*Unconformity* - - - - - - - - - - - - - - - -
Precambrian	Mahakoshal		Granite, gneiss, quartzite, phyllite, schist and pegmatite

The Singrauli Gondwana Basin has been considered to be comprised of two tectono-sedimentary sub-basins: (i) the Moher sub-basin in the north-eastern flank and (ii) the Singrauli main sub-basin to the west (figures 1, 2). Demarcation between these two sub-basins is not possible in the field, as all the formations in the Lower Gondwana are continuously exposed (without any structural break) within these two so called sub-basins. Only major difference between the two is in the coal resource potentiality and its developmental pattern. The Moher sub-basin contains more coal resources as compared to the main sub-basin.

In general, the Singrauli main sub-basin of about 1900 km^2, is dissected into flat-topped plateau of Upper Gondwana rocks. Lower Gondwana rocks are exposed particularly in the east and central parts of the main sub-basin, whereas the outcrops of Upper Gondwana occurred predominantly towards the western and southern portions. The Gondwana rocks are juxtaposed against the metamorphics of Mahakoshal Group in the north along mostly an east–west trending shear zone.

Majhauli (S) block, under present study, forms the eastern part of the Singrauli main sub-basin (figure 1). During sub-surface exploration, a sedimentary sequence from Talchir to Raniganj formations has been encountered. Strata belonging to Barren Measures and Raniganj formations also occur as outcrops here, whereas of Barakar and Talchir formations are encountered as subsurface strata.

In Mahuli-Mahersop block of the Moher sub-basin (figure 2), the Parsora Formation is intersected in two boreholes – SSM-1 and SSM-2, and that is mainly represented by medium-to-coarse grained sandstone facies. The most significant finding within the Parsora Formation is the occurrence of palaeosol bed in borehole SSM-2 at 509.00 m (figure 4).

Based on the surface and sub-surface data acquired so far, the generalized stratigraphic sequences developed in the Singrauli Gondwana Basin are given in table 1.

3. Materials

The materials for present spores-pollen study includes the subsurface sediments explored in the two sub-basins of that Singrauli Gondwana Basin (figures 1, 2). Details about the facies in each borehole are given in figures 3, 4.

(i) Boreholes SSM-1 and SSM-2, Moher sub-basin (in Tripathi *et al.* 2005).
(ii) Boreholes SMJS-2, SMJS-3, and SMBS-1, Singrauli main sub-basin (present study).

The rock samples are processed with the standard method using the chemicals – HF and HCL, for the recovery of spores-pollen. The slides prepared for microscopic observations are stored in the repository of the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

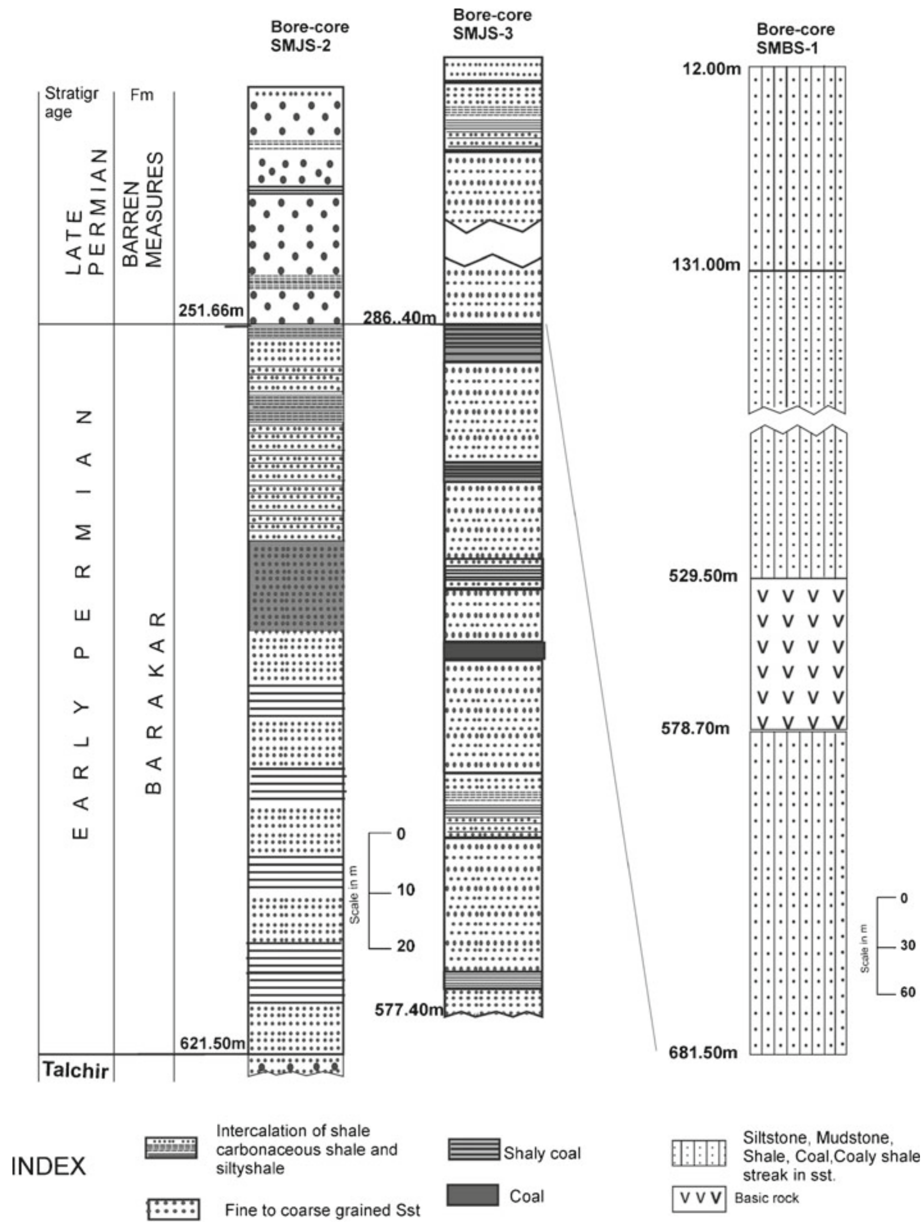

Figure 3. Sedimentary sequences in boreholes – SMJS-2, 3 and SMBS-1 (Majhauli block), Singrauli Gondwana Basin, U.P. and Chattisgarh.

4. Palynological observations

The sedimentary successions encounterd in the three boreholes SMJS-2 (depth 5.70–631.50 m), SMJS-3 (depth 15.50–319.50 m) and SMBS-1 (depth 12.00–681.50 m; figures 3, 4) are analysed for their spore-pollen contents. In general, well preserved, unaltered organic matter, including the spores-pollen are recovered (figures 5, 6), but at different depth intervals, the strata have yielded mainly the amorphous plant matter.

Based on the quantitative occurrences, and diversity of spores and pollen species (figures 7, 8), the assemblages identified within each borecore are described below. Besides, the data published earlier (Tripathi *et al.* 2005) has also been included here, to built-up the palynostratigraphy in the two blocks of Singrauli Gondwana Basin (figure 9). Furthermore, these assemblages are compared with the Palynozones already established for the Permian and Triassic sequences on Indian peninsula (see in Tripathi *et al.* 2005); and Australia (Helby *et al.* 1987; Backhouse 1993).

(i) Borehole SMJS-2: depth 5.70–631.50 m; five assemblages
(ii) Borehole SMJS-3: depth 15.50–319.10 m; three assemblages
(iii) Borehole SMBS-1: depth 12.00–681.50 m; three assemblages

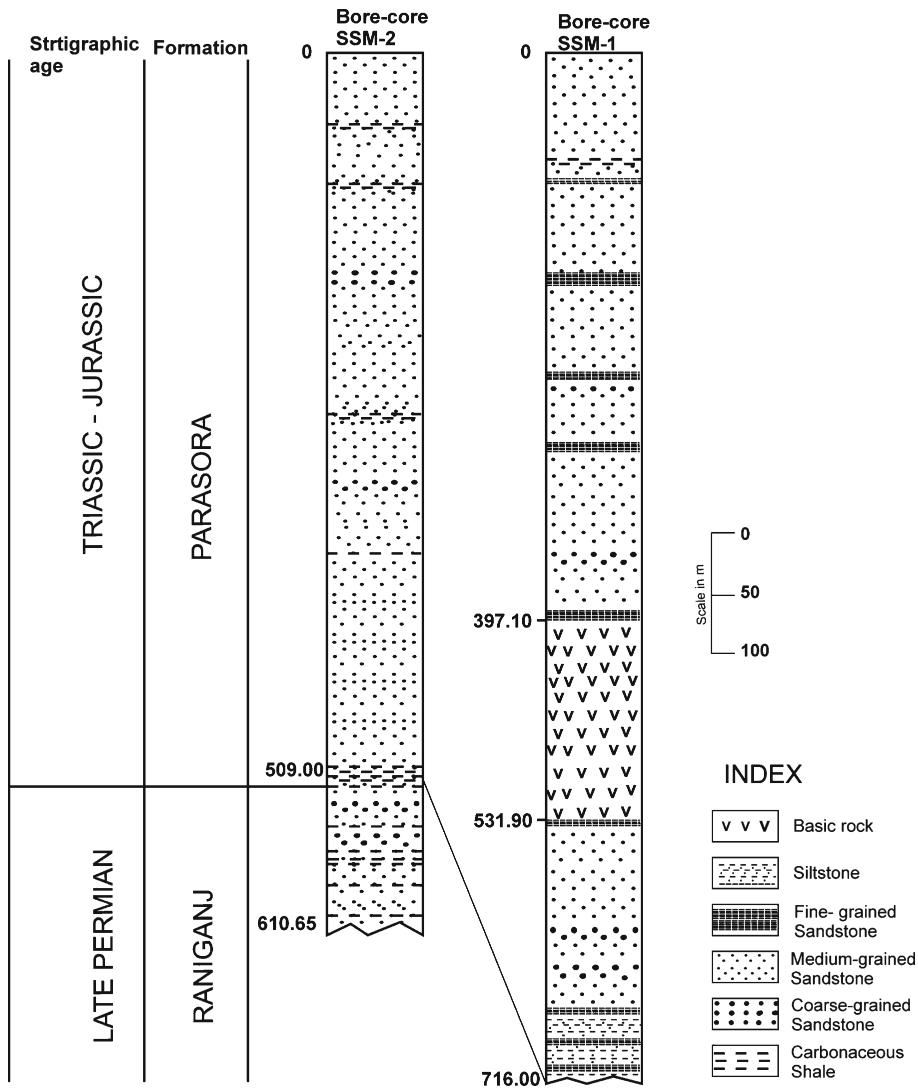

Figure 4. Sedimentary sequences in boreholes – SSM-1 and SSM-2 (Mahuli–Mahersop block), Singrauli Gondwana Basin, U.P. and Chattisgarh.

(iv) Borehole SSM-1: depth 00.7–18.00 m; two assemblages

(v) Borehole SSM-2: depth 00.6–10.65 m; four assemblages

4.1 *Talchir Formation*

Borehole SMJS-2, depth 621.60–631.50 m, figure 3

Assemblage I: Depth 625.50, 627.65, 631.50 m; figures 7, 8; fine grained greenish sandstones with specks of carbonaceous matter

Monosaccate pollen taxa (*Parasaccites-Plicatipollenites*) abundance associated with these spores *Callumispora* and *Jayantisporites* characterize this assemblage. The diversity among spores-pollen contents is shown by the occurrences of *Potoieisporites magnus, Tuberisaccites tuberculatus*, *Crucisaccites* sp., *Microbaculispora tentula, Lacinitriletes minutus, Brevitriletes unicus, Circumstriatites* spp., *Faunipollenites* sp., *Striatopodocarpites* sp.,*Crescentipollenites fuscus, Tiwariasporis* sp., *Platysaccus* sp., and the alete forms *Tetraporina, Maculatasporites.*

This assemblage is comparable with the *Parasaccites korbaensis* Palynozone in Tiwari and Tripathi (1992), which is dated earliest Permian in age (figure 7).

4.2 *Barakar Formation*

Boreholes SMJS-2, depth 251.66–621.60 m; SMJS-3, depth 286.40–319.10 m; and SMBS-1, depth 351.75–547.50 m; figure 3

Assemblage II: Borehole SMJS-2, depth 512.80, 532.60, 583.50 m; figures 7, 8; fine-to-medium

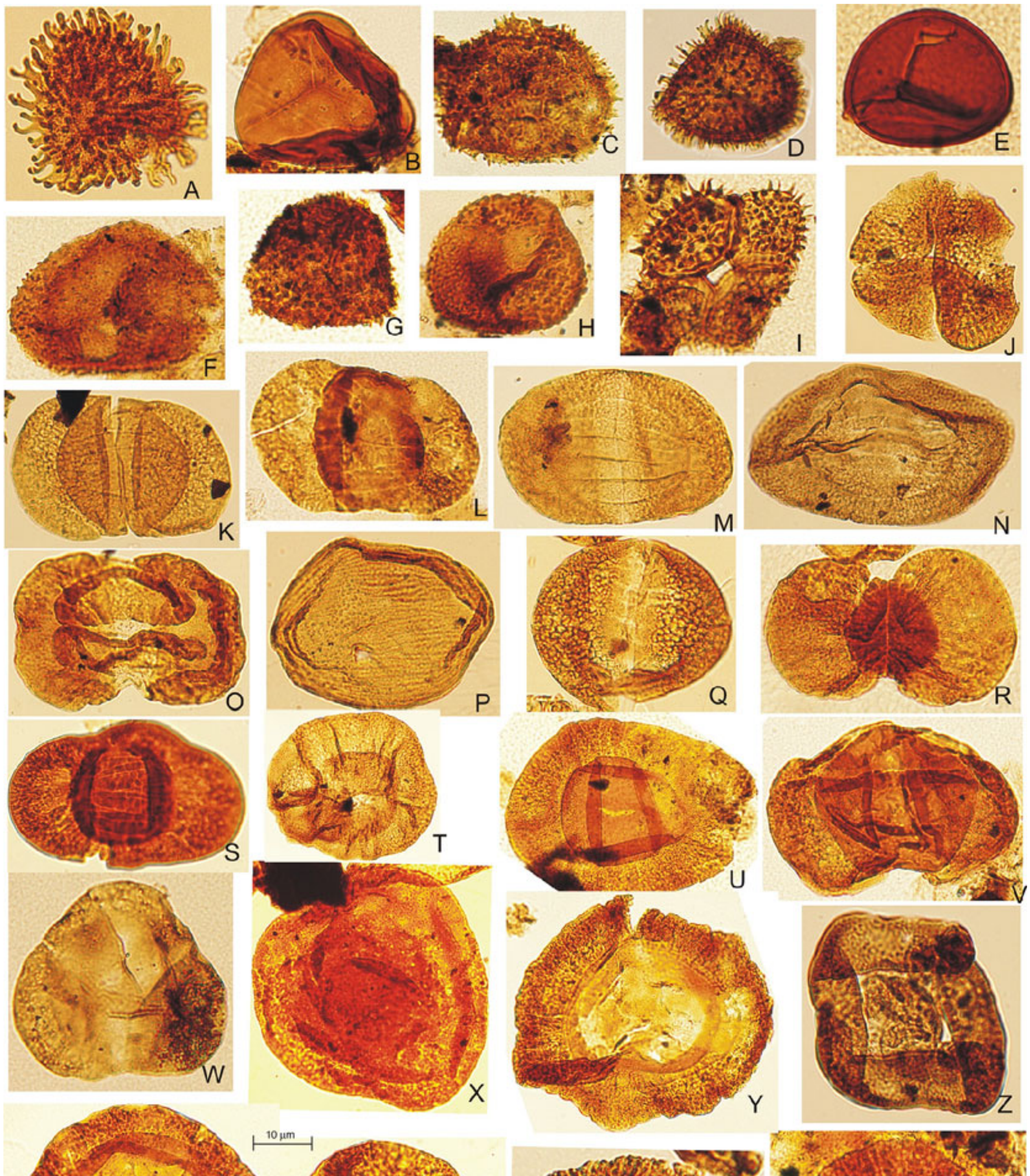

Figure 5. Characteristic spores-pollen species identified in the Permian succession intersected in these boreholes – SMJS-2, SMJS-3 and SMBS-1 from study area. A. *Jayantisporites pseudozonatus* Lele and Makada (1972), B. *Lacinitriletes badamensis* Venkatachala and Kar emend. Tiwari and Singh (1981), C. *Jayantisporites conatus* Lele and Makada (1972), D. *Jayantisporites indicus* Lele and Makada (1972), E. *Callumispora barakarensis* Bharadwaj and Srivastava (1969), F. *Horriditriletes novus* Tiwari (1965), G. *Dentatispora gondwanensis* Tiwari (1965), H. *Cyclogranisporites gondwanensis* Bharadwaj and Salujha (1964), I. *Quadrisporites horridus* Potonie and Lele (1961), J. *Crucisaccites latisulcatus* Lele and Maithy (1964), K. *Crescentipollenites fuscus* (Bharadwaj) Bharadwaj, Tiwari and Kar (1974), L. *Circumstriatites talchirensis* Lele and Makada (1972), M. *Striatopodocarpites magnificus* Bharadwaj and Salujha (1964), N. *Striomonosaccites ovatus* Bharadwaj (1962), O. *Dicapipollenites nykaendensis* (Hart) Tiwari and Vijaya (1995), P. *Bharadwajiapollis striatus* Kar (1969), Q. *Faunipollenites perexiguus* Bharadwaj and Salujha (1964), R. *Verticipollenites gibbosus* Bharadwaj (1962), S. *Arcuatipollenites ovatus* (Goubin) Tiwari and Vijaya (1995), T. *Densipollenites invisus* Bharadwaj and Salujha (1964), U. *Potoniesporites* sp., V. *Sahnites jayantiensis* (Lele and Makada) Tiwari and Singh (1984), W. *Stellapollenite talchirensis* Lele (1965), X. *Densipollenites magnicorpus* Tiwari and Rana (1981), Y. *Plicatipollenites indicus* Lele (1964), Z. *Crucisaccites monoletus* Srivastava (1970), AA. *Plicatipollenites gondwanensis* (Balme and Hennelly) Lele (1964), AB. *Densipollenites indicus* Bharadwaj (1962), AC. *Goubinispora indica* Tiwari and Rana (1981), AD. *Parasaccites densicorpus* Lele (1975).

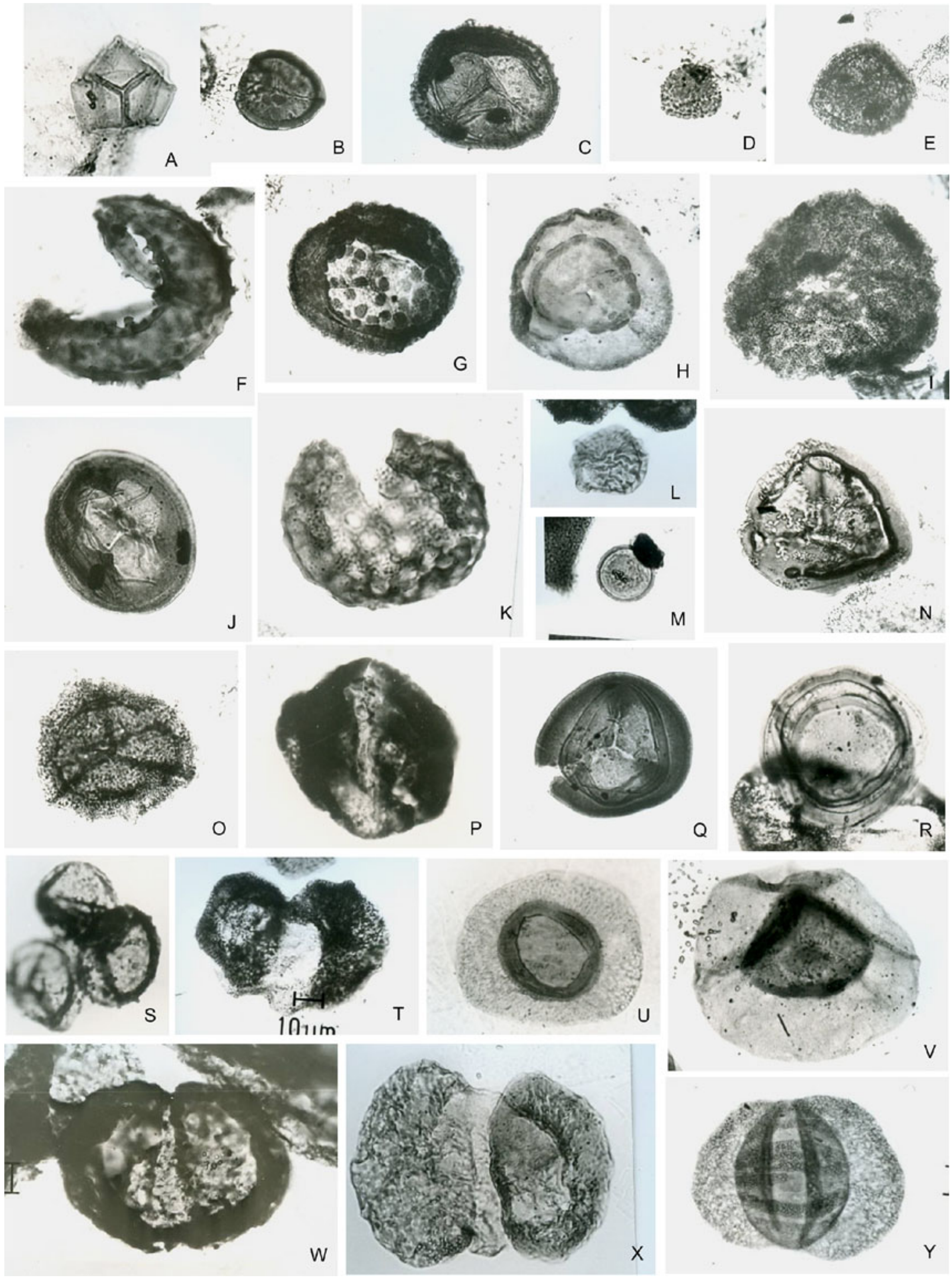

Figure 6. Characteristic spores-pollen species identified in the Parsora Formation intersected in these boreholes – SSM-1, and SSM-2 from the study area. A. *Carnisporites mesozoicus* (Klaus) Mädler (1964), B. *Camerozonosporites rudis* (Leschik) Klaus (1960), C. *Anapiculatisporites telephorus* Pautsch (1958), D. *Uvaesporites verrucosus* Helby in de Jersey (1971), E. *Dictyotosporites filosus* Dettmann (1963), F. *Clavatisporites hammenii* (Herbst) de Jersey (1971), G. *Lundbladispora warti* Tiwari and Rana (1981), H. *Polycingulatisporites crenulatus* Playford and Dettmann (1965), I. *Lundbladispora baculata* Bharadwaj and Tiwari (1977), J. *Carnisporites raniganjensis* Tiwari and Rana (1980), K. *Klukisporites variegates* Couper (1958), L. *Tigrisporites hallienis* Klaus (1960), M. *Circulisporites parvus* de Jersey (1962), N. *Tikisporites balmei* Kumaran in Kumaran and Maheshwari (1980), O. *Tethysispora playfordii* Vijaya and Tiwari in Vijaya *et al.* (1988), P. *Minutosaccus crenulatus* Dolby and Balme (1976), Q. *Cingutriletes* sp cf. *C. clavus* (Balme) Dettmann (1963), R. *Grebespora concentrica* Jansonius (1962), S. *Cadargasporites baculatus* de Jersey and Paten (1964), T. *Striatopodocarpites dubrajpurensis* Tripathi *et al.* (1990), U. *Kamthisaccites ringus* Vijaya and Tripathi (2008), V. *Playfordiaspora cancellosa* (Maheshwari and Banerji) Vijaya (1995), W. *Plicatisaccus badius* Partsch (1971), X. *Arcuatipollenites tethysensis* (Vijaya and Tiwari) Tiwari and Vijaya (1995), Y. *Arcuatipollenites ovatus* (Goubin) Tiwari and Vijaya (1995).

Age	Fm.	Depth in m SMJS-2	Depth in m SMJS 3	Depth in m SMBS 1	Assemblages identified	Palynozones (after Tiwari & Tripathi 1992)	Strata identified	Age assessed
UPPER PERMIAN	Raniganj		15.50 20.20 32.00 35.00 36.27	25.65 40.50 45.00 69.80 132.60	Assemblage VI	*Densipollenites magnicorpus*	Raniganj Formation	Latest Permian
UPPER PERMIAN	Barren Measures	00.00 140.00 144.20 170.40 187.20 251.66	147.15 221.50 227.90 262.00 277.00 286.40	144.00 216.60 223.40 258.70 266.00 351.75	Assemblage V	UNPRODUCTIVE STRATA *Densipollenites indicus* UNPRODUCTIVE	Barren Measures	early Late Permian
LOWER PERMIAN	BARAKAR	256.80 260.80 345.70 353.85	287.50 302.10 309.50	270.00 351.75 407.50 (studied upto this depth)	Assemblage IV	UNPRODUCTIVE STRATA *Faunipollenites varius*	Upper Barakar	late Early Permian
		428.00 436.25 452.50 470.40			Assemblage III	UNPRODUCTIVE STRATA *Scheuringipollenites barakarensis* Mixed Population	Lower Barakar Barakar/ Karharbari Transition	
		512.80 532.60 583.50 621.60	577.40	547.50	Assemblage II	UNPRODUCTIVE STRATA *Crucisaccites monoletes* UNPRODUCTIVE STRATA	Karharbari Formation	Early Permian
	Talchir	625.50 627.65 631.50			Assemblage I	*Parasaccites korbaensis*	Talchir Formation	Earliest Permian

Figure 7. Palynostratigraphy of the Permain succession in boreholes SMJS-2, 3, and SMBS-1 Majhauli block, Singrauli Gondwana Basin, Chattisgarh.

grained sandstones with alternate laminations of carbonaceous shales.

A much diversified spores-pollen assemblage is obtained in approximately 71.00 m thick strata. Here, an abundance of *Parasaccites* and *Callumispora* is associated with good frequency of *Plicatipollenites, Circumstriatites.* Further, these pollen taxa *Striatopodocarpites, Faunipollenites, Diverisaccus* and *Crucisaccites* are added along with a group of species. Rare occurrences *Jayantisporites* spp., *Brevitriletes unicus, Imparitriletes korbaensis, Verrucosisporites donarii, Sahnites thomasi, Cuneatisporites* sp., *Potonieisporites* spp., *Tuberisaccites* spp., and *Cycadopites* sp. are also observed. And, the vegetal matter do occur fairly along with hyaline mineral particles.

This assemblage is correlatable with the *Crucisaccites monoletes* Palynozone in Tiwari and Tripathi (1992), which suggests the presence of Karharbari Formation, a formational unit in the Lower Permian (figure 7).

Assemblage III: Borehole SMJS-2, depths 428.00, 436.25, 452.50, 470.40 m; figures 7, 8; fine-to-coarse grained sandstones with specks of carbonaceous shales and coal intermittently.

At 470.40 and 452.50 m depth, the assemblage contains an admixture of these pollen taxa *Scheuringipollenites, Faunipollenites, Striatopodocarpites* and *Parasaccites* followed by a spore genus *Callumispora.* The relative occurrences

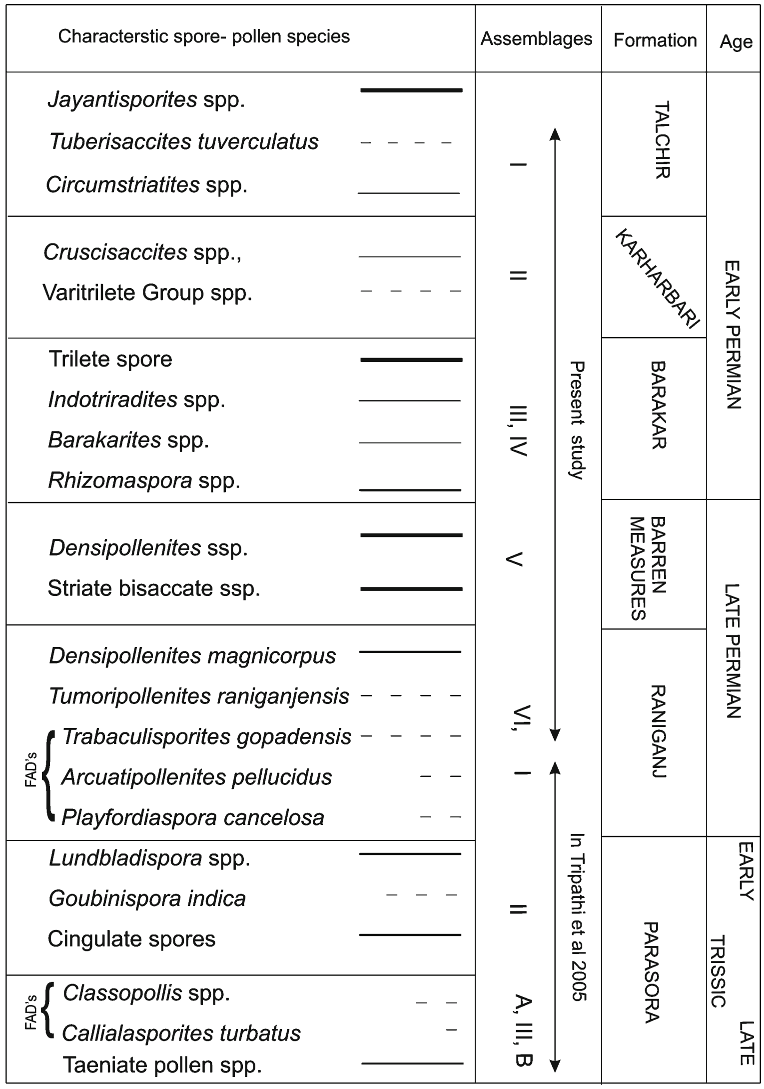

Figure 8. Relative occurrences of characteristic species in each assemblage identified in the Permian and Triassic sequences in the five boreholes from two blocks of Singrauli Gondwana Basin, U.P. and Chattisgarh.

of the four taxa along with these species – *Indotriradites korbaensis, Microbaculispora indica, Microfoveolatispora foveolata, Sahnites thomasi, Cyclogranisporites gondwanensis, Verrucosisporites distinctus, Jayantisporites pseudozonatus, Horriditriletes* spp., *Rhizomaspora* spp., *Platysacus densus, Crescentipollenites* spp., *Densipollenites indicus, D. invisus,* and *Distriamonocolpites ovalis,* have shown the gradual changes in the spores-pollen contents from that Karharbari Formation into the basalmost Barakar Formation. This composition is similar with that of *Scheuringipollenites barakarensis* Palynozone in Tiwari and Tripathi (1992), and that is dated Early Permian in age (figure 7).

Assemblage IV: Boreholes SMJS-2 and 309.50; and SMBS-1, depth 270.00, 351.75 and 407.50m; figures 7, 8; intercalated fine-to-coarse grained sandstones and carbonaceous shales

The assemblage recovered at these depths, has an abundance of striate bisaccate pollen taxa (*Striatopodocarpites, Faunipollenites*) along with *Scheuringipollenites.* At 260.80 m depth are present *Densipollenites indicus, D. invisus* and *Crescentipollenites* spp. in fair numbers. Other commonly found elements are *Microbaculispora* spp., *Microfoveolatispora foveolata, Potonieitriradites barakarensis, Circumstriatites* spp., *Parasaccites* spp., *Platysaccus* spp., *Sahnites* spp., *Rhizomaspora* spp. In very low counts are present *Microfoveolatispora bokaroensis, Cyclobaculisporites minutus, Indotriradites sparsus, Lacinitriletes badamensis, Insignisporites barakarensis, Thymospora* sp., *Crucisaccites* spp., *Distriamonocolpites ovalis, Platysaccus ovatus,* and *Cuneatisporites* spp.

At these depths 251.66, 256.80 and 260.80 m in borehole SMJ-2 and 287.50 m in borehole SMJS-3, admixture of striate bisaccate along with a monosaccate (*Densipollenites indicus, D. densus)* pollen taxa is noted. This shows a gradational change in the composition of assemblage, which suggests the transition from the proximity of the Barakar Formation into the Barren Measures Formation.

Other notable feature observed is the increased frequency of *Parasaccites* at 428.00 and 436.25 m depths in the studied strata from borehole SMJS-2, that might be in continuity from that with the older assemblage. Otherwise, this assemblage compares with *Faunipollenites varius* Palynozone in Tiwari and Tripathi (1992), that is dated younger part of the Early Permian (figures 7, 8).

4.3 *Barren Measures Formation*

Boreholes SMJS-2, depth 5.70–251.66 m; SMJS-3, depth 36.27–286.40 m; and SMBS-1, 132.60–351.75 m; figure 3

The sediments mainly comprise medium-to-coarse grained sandstone facies, which have low presentation of the spores-pollen. In borehole SMBS-1, the sediments are mainly black and hard silty shales. Hyaline to blackish amorphous granular mass of organic matter is present in high quantity. Yellowish-brown to grey, broken pieces of plant matter are commonly observed.

Assemblage V: Boreholes SMJS-2, depth 144.20, 170.40, 187.20 m; SMJS-3, depth 147.15, 221.50, 227.90, 262.00, 277.00 m; and SMBS-1, depth 144.00, 216.60, 223.40, 258.70, 266.00 m; figures 7, 8; fine grained sandstones with shale, siltstones and greenish grey carbonaceous shales

The spores-pollen are recovered at the interval depths in the studied strata. Dominance of striate bisaccate pollen taxa along with fair occurrence of *Densipollenites* (*D. indicus, D. invisus,* and *D. densus*) is observed here. Other common elements are *Crescentipollenites fuscus, C. bengalensis, Rhizomaspora singula, R. monosulcata, R. indica, Korbapollenites* sp., *Cuneatisporites* spp., and *Parasaccites korbaensis, P. diffusus.* Besides, a group of species *Insignisporites barakarensis, Verrucosisporites distinctus, Cyclobaculisporites* sp., *Horriditriletes novus, Microbaculisporites barakarensis, M. indica, Didecitriletes horridus, Barakarites* spp., *Dicapipollenites crassus, Guttulapollenites hannonicus, Distriatites bilaterais, Striomonosaccites* sp., *Crucisaccites latisulcatus, Tiwariasporis flavatus, Vittatina* sp., *Maculatasporites gondwananensis,* and *Cycadopites follicularis* although counts very low, but their occurrences add much diversity to this assemblage.

The assemblage at 256.80 to 187.20 m depth in borehole SMJS-2, is suggestive of the transition from that Barakar Formation into the basalmost Barren Measures. This assemblage is correlatable with the *Densipollenites indicus* Palynozone in Tiwari and Tripathi (1992), and that is dated to be of early Late Permian in age (figure 7).

Here, the bisaccate pollen dominates the scenario. The unproductive strata in between 144.20–187.20 m in borehole SMJS-2; 147.15–277.00 m in borehole SMJS-3 and 144.00–266.00 m in borehole SMBS-1, is rich in elongated wood shreds and plant tissues in the Barren Measures Formation, which mainly comprises of medium-to-coarse grained sandstone facies (figure 3).

4.4 *Raniganj Formation*

Borehole SMJS-3, depth 00.00–36.27 m; and SMBS-1, depth 00.00–132.60, figure 3

Assemblage VI: Boreholes SMJS-3, depth 15.50, 17.00, 20.20, 32.00, 35.50 m; SMBS-1, depth 25.65, 40.50, 45.00, 69.80 m; figures 7, 8; carbonaceous silty shales intercalated with medium-to-coarse grained sandstones

In between the above given depths, recovery of spores-pollen do occur at varied depths. Abundance of *Densipollenites* along with striate bisaccate pollen taxa – *Striatopodocarpites* and *Faunipollenites* is observed within the studied strata.

Relatively fair in quantitative occurrences are *Rhizomaspora* spp., *Barakarites* spp., *Crescentipollenites* spp., *Distriatites* spp., *Weylandites* spp. Rare occurrences of these elements – *Horriditriletes curvibaculosus, H. novus, Cyclobaculisporites* sp., *Potonieitriradites barakarensis, Guttulapollenites hannonicus*, *Tiwariasporis flavatus*, *Striapollenites* spp., *Striomonosaccites* spp., *Gondisporites raniganjensis, Distriomonocolpites ovatus, Dicapipollenites crassus, Marsupipollenites* spp., are observed herein. Presence of *Trabeculosporites gopadensis, Arcuatipollenites pellucidus, Kamthisaccites kamthiensis* and *Goubinispora* sp., along with fair number of *Densipollenites magnicorpus* suggests the comparision of this assemblage with *Densipollenites magnicorpus* Palynozone (Tiwari and Tripathi 1992), and that is dated latest Late Permian in age (figure 7).

4.5 *Parsora Formation*

Boreholes SSM-1, depth 00–718.00 m; SSM-2, depth 00–509.00 m; figure 4

Age	Formation	Palynoassemblages identified	Details of studied bore holes with depths in m	Placement in palynozonation scheme (Tiwari & Tripathi 1992, and in Tripathi et al. 2005)	Age assessed	Reference details
TRIASSIC / JURASSIC	P A R S O R A	Mahuli- Mahersop block: Assemblage B	BH SSM-1, 152.56m	*Arcuatipollenites tethysensis*	↑ Late Triassic ↓	↑ In Tripathi et al. 2005 ↓
		Assemblage IIIb Assemblage IIIa	BH SSM-2, 508.50-487.50, 261.75m	*Tikisporites balmei*		
		Assemblage A	BH SSM-1, 716.15-688.70m	*Rimaesporites potoniei*		
		Assemblage II	BH SSM-2, 537.00, 514.00m	*Krempipollenites indicus*	Early Triassic	
U P P E R P E R M I A N	RANIGANJ	Assemblage I	BH SSM-2, 542.00,543.00,547.00 m BH SMBS-1, 25.65-69.80m BH SMJS-3, 15.50-35.50m	*Densipollenites magnicorpus*	Latest Permian	↑ Present study ↓
		Majhauli block: Assemblage VI				
	BARREN MEASURES	Assemblage V	BH SMJS-2, 144.20-170.40 m BH SMJS-3, 147.15- 277.00m BH SMBS-1, 144.00-266.00m	*Densipollenites indicus*	early Late Permian	
L O W E R P E R M I A N	BARAKAR	Assemblage IV	BH SMJS-2, 256.80-353.85m BH SMJS-3, 287.50-309.50m BH SMBS-1, 270.00-407.50m	Transitional phase *Faunipollenites varius*	late Early Permian	
			BH SMJS-2, 428.00-470.40m	*Scheuringipollenites maximus*	↑ Early Permian ↓	
		Assemblage III	BH SMJS-2, 512.80-583.50m	Transitional phase *Crucisaccites monoletus*		
	TALCHIR	Assemblage II	BH SMJS-2, 625.50-631.50m	*Parasaccites korbaensis*	Earliest Permian	
		Assemblage I				

Figure 9. A summary of the assemblages identified in the two blocks – (1) Majhauli, boreholes SMJS-1 and 2 (present study), and (**2**) Mahuli–Mahershop, boreholes SSM-1 and 2 (Tripathi *et al.* 2005) in Singrauli Gondwana Basin, U.P. and Chattisgarh.

In the studied sedimentary sequences of Parsora Formation, four assemblages (SSM-1/Assemblages A and B; SSM-2/Assemblages II, IIIa and IIIB in Tripathi *et al.* 2005) are identified.

Borehole SSM-2, depth 514.00–537.00 m; figures 4, 9; dark grey fine grained shaly sandstones with carbonaceous pieces

Assemblage II in borehole SSM-2, the oldest one, contain the dominance of *Striatopodocarpites* and *Satsangisaccites.* Other significant species in this assemblage are *Arcuatipollenites* spp., *Ringosporites fossulatus, Verrucosisporites triassicus* and *Indotriradites mammilatus.* This composition is correlatable with the *Krempipollenites indicus* Palynozone in Tiwari and Tripathi (1992), that equates this part of the Parsora Formation with the Lower Triassic Panchet Formation in Damodar Basin (Vijaya and Tiwari 1987).

Borehole SSM-1, depth 716.00–696.90 m; Borehole SSM-2, depth 508.50–261.75 m; figures 4, 9; fine grained sandstones, intercalated with mudstones, shaly sandstone and carbonaceous shales.

In this part of the Parasora Formation, these two pollen taxa – *Striatopodocarpites* and *Arcuatipollenites* are in abundance with their changing relative counts. Besides, a diverse group of species *Striatopodocarpites dubrajpurensis, Arcuatipollenites tethysensis, Infernopollenites claustratus,*

EPOCH	SERIES	AGE	ASSEMBLAGES IDENTIFIED (present study)	PALYNOZONES ESTABLISHED IN LATE PERMIAN AND TRIASSIC SEQUENCE	
				INDIA	AUSTRALIA
TRIASSIC	LATE	RHAETIC	ASSEMBLAGE B	*Arcuatipollenites tethysensis*	*Polycingulatisporites crenulatus*
		NORIAN	ASSEMBLAGE III b ASSEMBLAGE III a	*Tikisporites balmei*	
		CARNIAN	ASSEMBLAGE A	*Rimaesporites potoniei*	*Craterisporites rotundus*
	MIDDLE	LADINIAN			*Aratrisporites parvispinosus*
		ANISIAN		*Goubinispora indica*	
	EARLY	SCYTHIAN		*Playfordiaspora cancellosa*	*Aratrisporites tenuispinosus* *Protohaploxipinus samoilovichi*
			ASSEMBLAGE II	*Krempipollenites indicus*	*Lunatisporites pellucidus*
PERMIAN	Late	TATARIAN	ASSEMBLAGE I	*Densipollenites magnicorpus*	*Protohaploxipinus microcorpus*
		UFIMIAN	ASSEMBLAGE V	*Densipollenites indicus*	*Dulhuntyispora granulata*
		KUNGURIAN	ASSEMBLAGE IV	*Faunipollenites varius*	*Microbaculispora villosa*
	Early	ARTINSKIAN	ASSEMBLAGE III	*Scheuringipollenites barakarensis*	*Praceolpatites sinuosus*
		SAKMARIAN	ASSEMBLAGE II	*Crucisaccites monoletus*	*Microbaculispora trisina* *Pseudoreticulatispora pseudoreticulata*
		ASSELIAN	ASSEMBLAGE I	*Parasaccites korbaensis*	*Pseudoreticulatispora confluens*

Figure 10. Suggested age correlation of the assemblages identified in the two blocks of Singrauli Gondwana Basin with the Palynozones established in India (Tiwari and Tripathi 1992) and Australia (Helby *et al.* 1987; Backhouse 1993).

Table 2. *List of samples from borehole SMJS-2, Majhauli block, Singrauli main sub-basin, U.P. and Chattisgarh.*

	Thickness (m)		
Sl. no.	From	To	Lithology
1.	0.00	5.60	Sludge with sand
2.	5.60	18.01	Medium-to-very coarse grained sandstone
3.	18.01	18.28	Shale
4.	18.28	25.41	Medium-to-very coarse grained sandstone
5.	25.41	27.54	Brownish to creamy shale
6.	27.54	210.81	Medium-to-very coarse/pebbly sandstone with fine grained sandstone at places
7.	210.81	212.45	Siltstone with carbonaceous shale
8.	212.45	251.66	Medium-to-very coarse grained sandstone
9.			Barren Measures/Barakar Formational contact at 251.66 m
10.	251.66	254.13	Greenish grey to carbonaceous shale
11.	254.13	263.95	Medium-to-very coarse grained sandstone
12.	263.95	264.45	Coal
13.	264.45	265.68	Carbonaceous shale with shaly coal band
14.	265.68	266.80	Coal
15.	266.80	267.56	Carbonaceous shale
16.	267.56	291.32	Fine-to-very coarse grained sandstone
17.	291.32	292.30	Coal
18.	292.30	293.30	Carbonaceous shale
19.	293.30	294.40	Intercalation of fine grained sandstone and carbonaceous shale
20.	294.40	296.11	Fine-to-very coarse grained/pebbly sandstone
21.	296.11	297.42	Intercalation of fine grained sandstone and carbonaceous shale
22.	297.42	298.68	Medium-to-very coarse grained sandstone
23.	298.68	308.03	Coal
24.	308.03	308.64	Carbonaceous shale
25.	308.64	312.00	Coal
26.	312.00	312.33	Carbonaceous shale
27.	312.33	317.80	Intercalation of fine-to-medium grained sandstone and micaceous shale
28.	317.80	343.06	Medium-to-coarse grained sandstone
29.	343.06	345.81	Intercalation of sandstone and carbonaceous shale
30.	345.81	349.20	Alternate sequence of fine grained sandstone and carbonaceous shale
31.	349.20	351.45	Fine-to-coarse grained sandstone
32.	351.45	353.82	Coal
33.	353.82	372.65	Fine-to-coarse grained sandstone
34.	372.65	376.60	Coal
35.	376.60	433.50	Fine-to-coarse and very coarse grained sandstone
36.	433.50	436.25	Coal
37.	436.25	450.95	Medium-to-coarse grained sandstone
38.	450.35	451.30	Coal
39.	451.30	467.23	Fine-to-coarse grained sandstone
40.	467.23	467.58	Coal
41.	467.58	468.41	Alternate laminae of fine grained sandstone and carbonaceous shale
42.	468.41	506.97	Fine-to-coarse grained sandstone
43.	506.97	507.61	Carbonaceous shale
44.	507.61	509.14	Alternate band of fine grained sandstone and carbonaceous shale
45.	509.14	509.80	Carbonaceous silty shale with coaly shale at top
46.	509.80	521.85	Fine-to-medium grained sandstone
47.	521.85	522.19	Coal
48.	522.19	522.89	Carbonaceous shale
49.	522.89	532.60	Fine grained sandstone
50.	532.60	534.32	Carbonaceous shale with band of shaly coal at middi
51.	534.32	537.06	Fine grained sandstone
52.	537.06	538.10	Alternate lamination of fine grained sandstone and carbonaceous shale with band of shaly coal at top

Table 2. *(Continued)*

Sl. no.	Thickness (m) From	To	Lithology
53.	538.10	539.50	Carbonaceous shale
54.	539.50	583.02	Fine-to-medium grained sandstone (at places coarse)
55.	583.02	584.00	Carbonaceous shale
56.	584.00	621.60	Very fine-to-coarse grained sandstone
57.			Barakar/Talchir Formational contact at 621.60 m
58.	621.60	631.50	Very fine-to-fine grained sandstone

Table 3. *List of samples from borehole SMJS-3, Majhauli block, Singrauli main sub-basin, U.P. and Chattisgarh.*

1	0.00	5.50	Sandy sludge
2	5.50	13.56	Medium-to-coarse grained sandstone
3	13.56	15.84	Carbonaceous to silty shale with interlamination of shale and sandstone
4	15.84	32.75	Very coarse-to-fine grained sandstone
5	32.75	36.27	Silty shale-to-coaly shale with interlamination of shale and very fine grained sandstone at bottom
6	36.27	39.94	Very fine-to-fine grained sandstone with band of medium grained sandstone and carbonaceous silt\bottom
7	39.94	286.40	Very coarse-to-fine grained sandstone
8			Barren Measures/Barakar Formational contact at 286.40 m
9	286.40	288.44	Shaly coal-to-coaly shale and silty shale
10	288.44	299.40	Very coarse-to-fine grained sandstone
11	299.40	302.30	Coal with band of carbonaceous shale
12	302.30	341.75	Very coarse-to-fine grained sandstone

Staurosacites spp., *Plicatisaccus badius, Enzonalasporites vigens, Tethysipora playfordii, Camerosporites verrucosus, Cadargasporites* spp., *Verrucosisporites morulae, Lycopodiacites rugulatus, Grandispora spinosa, Grebespora concentrica* do occur, and this correlates the assemblage with the known Upper Triassic palynoflora in India (see in Tripathi *et al.* 2005).

In the younger part of Parsora Formation (borehole SSM-1 at 152.56 m; and borehole SSM-2 at 261.75 m), first occurrences of *Callialasporites turbatus* and *Classopollis* spp., are suggestive of the *Rhaetic age* (Helby *et al.* 1987; Tripathi 2000). From the above given data, it is for certain that the studied part of the Parsora Formation represents the Lower and Upper Triassic strata with a hiatus of Middle Triassic (figures 8, 9).

5. Discussion

The spores-pollen studies done in two blocks of the Singrauli Gondwana Basin (figures 1, 2), include five boreholes – SMJS-2/5.30–631.50 m and SMJS-3/5.50–319.10 m in Majhauli block; borehole SMBS-1/12.00–681.50 m near to this block, and boreholes SSM-1/00–718.00 m, SSM-2/00–610.65 m in Mahuli–Moher block (figures 3, 4). This sedimentary sequence includes the deposits from that earliest Permian (Talchir Formation through Barakar Formation) into Late Triassic (Parasora Formation) in the study area. And thus obtained data have been assessed here to built-up the palynostratigraphy of these two formational units – Barakar and Parsora in particular (figures 9, 10).

The rock samples in boreholes SMJS-2, SMJS-3 and SMBS-1 (tables 2–4) have yielded in varied frequency and diversity of plant matter. And, the spores-pollen that could be well preserved specimens or hyaline, distorted to amorphous mass. Relative occurrences of key taxa and species are the main features of each assemblage discussed herein (figure 9).

Part of the Talchir Formation (borehole SMJS-2/621.60–631.50 m, figure 3) consists mainly of fine grained sandstone/siltstone facies with few specks

Table 4. *List of samples from borehole SMBS-1, Majhauli block, Singrauli main sub-basin, U.P. and Chhattisgarh.*

Sl. no.	Depth	Lithology
1	12.00	Coarse grained sandstone
2	14.20	Grey shales
3	16.75	Grey shales intercalated with mudstone
4	17.55	Grey shales intercalated with mudstone
5	19.60	Mudstone in coarse grained sst.
6	25.35	Micaceous sandstone
7	25.65	Mudstone in coarse grained sandstone
8	35.00	Coaly shale
9	38.25	Mudstone
10	39.25	Grey shales
11	40.50	Grey shales
12	41.55	Fine grained sandstone + grey shales
13	43.05	Grey shales
14	45.00	Grey shales in sandstone
15	50.70	Grey shales
16	68.20	Grey streaks in coarse sandstone
17	69.80	Grey shales streak
18	78.00	Coal in sandstone
19	78.50	Coaly shales
20	81.00	Carbonaceous grey shales in sandstone
21	84.00	Laminated shales in sandstone
22	87.00	Mud compact sandstone
23	96.70	Mudstone in sandstone
24	97.90	Khaki-green mudstone
25	100.00	
26	101.15	Coarse grained sandstone run
27	102.80	
28	103.30	Fine grained sandstone
29	131.45	Coal streak in coarse grained sandstone
30	134.60	Gritty sandstone containing mudstone
31	140.05	Coarse grained sandstone
32	143.22	Mudstone in sandstone
33	144.00	Fine grained sandstone
34	154.00	Sandstone
35	164.00	Coal streak in sandstone
36	175.40	Sandstone
37	179.20	Mudstone in sandstone
38	185.00	Fine grained sandstone
39	196.60	Mudstone in sandstone
40	201.10	Fined grained sandstone
41	214.80	Compact grey shale
42	216.60	Grey siltstone
43	219.50	Grey shales
44	223.40	Grey shales in sandstone
45	231.60	Grey shale in sandstone
46	242.50	Gritty sandstone
47	248.10	Baked khaki-green mudstone in sandstone
48	250.00	Grey shale band
49	250.50	Laminated carbonaceous sandy shale
50	257.60	Shaley matter
51	258.70	Fine grained sandstone
52	259.70	Mudstone in sandstone

Table 4. *(Continued)*

Sl. no.	Depth	Lithology
53	266.00	Siltstone patch in sandstone
54	269.00	
55	270.00	Silt stone
56	278.00	Grey shales in sandstone
57	294.60	Carbonaceous matter in sandstone
58	298.75	
59	329.00	Sandstone with carbonaceous matter
60	351.75	Siltstone
61	359.00	Baked muddy siltstone
62	360.00	Grey siltstone
63	362.00	Grey- greenish siltstone
64	364.00	Grey siltstone
65	366.00	
66	367.80	Siltstone in sandstone
67	372.25	Fine grained sandstone
68	373.25	Grey shale with black streak
69	390.00	Siltstone
70	394.00	Baked silt/mudstone
71	395.50	
72	396.50	Siltstone with sandstone
73	407.50	Greenish-grey silt
74	410.00	Grey sliltstone
75	414.85	Grey siltstone
76	433.55	
77	459.30	Hard compact greenish sandstone
78	467.40	Sandstone
79	468.80	Grey sandstone
80	481.50	
81	482.50	Baked mudstone
82	483.50	Grey shales
83	487.50	Grey shales
84	508.75	Grey siltstone
85	522.00	Grey shales
86	524.00	Grey shales
87	526.10	Fine grained sandstone
88	528.50	White siltstone
89	529.50	
90	547.50	
91		
92	553.00	
93	554.50	50 mts thick baked chilled vesicular basalt
94	565.70	
95	569.00	
96	571.75	
97	573.00	
98	578.70	
99	580.50	
100	581.10	
101	582.75	Grey siltstone
102	583.50	
103	584.35	
104	586.00	Coarse grained black sandstone
105	587.00	Off-white sandstone

Table 4. *(Continued)*

Sl. no.	Depth	Lithology
106	588.20	Black sst.
107	591.25	Black matter in sandstone
108	591.50	
109	596.30	Black sandstone
110	598.00	
111	601.60	Carbonaceous matter in sandstone
112	625.00	
113	642.95	Coal band
114	644.50	Coal band
115	662.25	Carbonaceous matter in sandstone
116	678.25	
117	681.50	

of greenish shales. These sediments are considered to be distal and periglacial origin (GSI, unpublished report). Present study infers an earlist Permian age for these strata (Tiwari and Tripathi 1992), which is in accordance with the stratigraphic delimitation (figure 11).

Above the Talchir Formation (621.60 m in borehole SMJS-2), an alternate bands of medium-to-coarse grained sandstones with silty shales, carbonaceous shales and very thin bands of coal comprise the Barakar Formation in the Permian sequence. Inbetween 583.50–512.80 m depth in borehole SMJS-2, the assemblage identified in the basalmost part in the Barakar Formation suggests the existence of strata that is equitable with the Karharbari Formation (figure 11). This formational unit is not delimited in the studied sedimentary sequence (figure 3).

Within 631.50–512.80 m depths in borehole SMJS-2, the occurrences of these three taxa *Parasaccites, Plicatipollenites* and *Callumispora* in the sandstones dominated facies with carbonaceous streaks at places, is suggestive of gymnospermous community that had survived in approximately 119.00 m thick strata.

In borehole SMBS-1, intrusion of basic rock in between 578.70–547.50 m depths is the notable feature. This encounters the hiatus level within the coal horizon and non-availability of the coal bands (figure 3). Herein, the impact of heat on the then vegetation had resulted in the poor recovery of spores-pollen.

The major part of the strata in the Barakar Formation is represented by coarser sandstone facies and comprises irregular alternations of fine-grained sandstones, siltstones, grey to carbonaceous shales (figure 3). This nature of sediments had resulted into no recovery of spores-pollen within the Barakar Formation, and also discontinuity from the older into younger assemblages (621.60–251.66 m in SMJS-2; 286.40–319.00 m in SMJS-3; 407.50–351.75 m in SMBS-1; figures 11, 12).

At certain depths in this sedimentary succession of the Barakar Formation, the assemblages obtained are quite rich and diversified in their spores-pollen composition. An assemblage having mixed population of *Parasaccites, Callumispora, Scheuringipollenites* and *Faunipollenites* at 470.40–452.50 m depths in borehole SMJS-2, allows a transition from that Karharbari Formation into the basalmost Barakar Formation within 18.00 m thick strata (figure 11). These biostratigraphic precisions are not recognisable in the sedimentary sequence (figure 3). An abundance of *Faunipollenites, Scheuringipollenites* and *Striatopodocarpites* within 436.25–428.00 and 353.85–345.70 m depths in borehole SMJS-2, corroborates with the Barakar Formation.

The Barakar Formation, including about 370.00 m thick strata in borehole SMJS-2, 33.00 m in SMJS-3, and 116.00 m in SMBS-1 has many levels of the palyniferous and non-palyniferous matter. Although, the sedimentary facies in this strata include the coal bands of varied thickness at intervals and fine-to-medium grained sandstones intercalated with silty carbonaceous shales (figure 3). The most significant finding is the identification of the Karharbari Formation, in basalmost part of the Barakar Formation (583.50–512.80 m, borehole SMJS-2), while the overlying strata (470.40–260.80 m) conforms with that Barakar Formation. The other two features observed within the Barakar Formation by the mixed population of spores-pollen at 470.40 and 260.80 m depths in borehole SMJS-2, favour the Karharbari–Barakar and Barakar–Barren Measures formational transition respectively (figure 11).

At the very base of the Barren Measures Formation (251.66–144.20 m, borehole SMJS-2; 277.00–147.15 m, borehole SMJS-3, and 266.00–144.00 m, borehole SMBS-1), an increased frequency of *Densipollenites* in association of striate bisaccate pollen is observed in the medium-to-fine grained sandstone facies, carbonaceous silty shales intercalated with very thin layers of coal. This part in the Barren Measures corresponds to earliest Late Permian in age (figure 4). At 144.20 m depth, genus *Densipollenites* attains an abundance, with an unproductive strata of 144.00 m in thick medium-to-coarse sandstone facies intermittently in borehole SMJS-2 (figure 11).

Regarding the Raniganj Formation, not much spores-pollen study is available in the explored strata (figure 3). Moreover, the assemblages recovered in boreholes SMJS-3 (15.00–35.00 m),

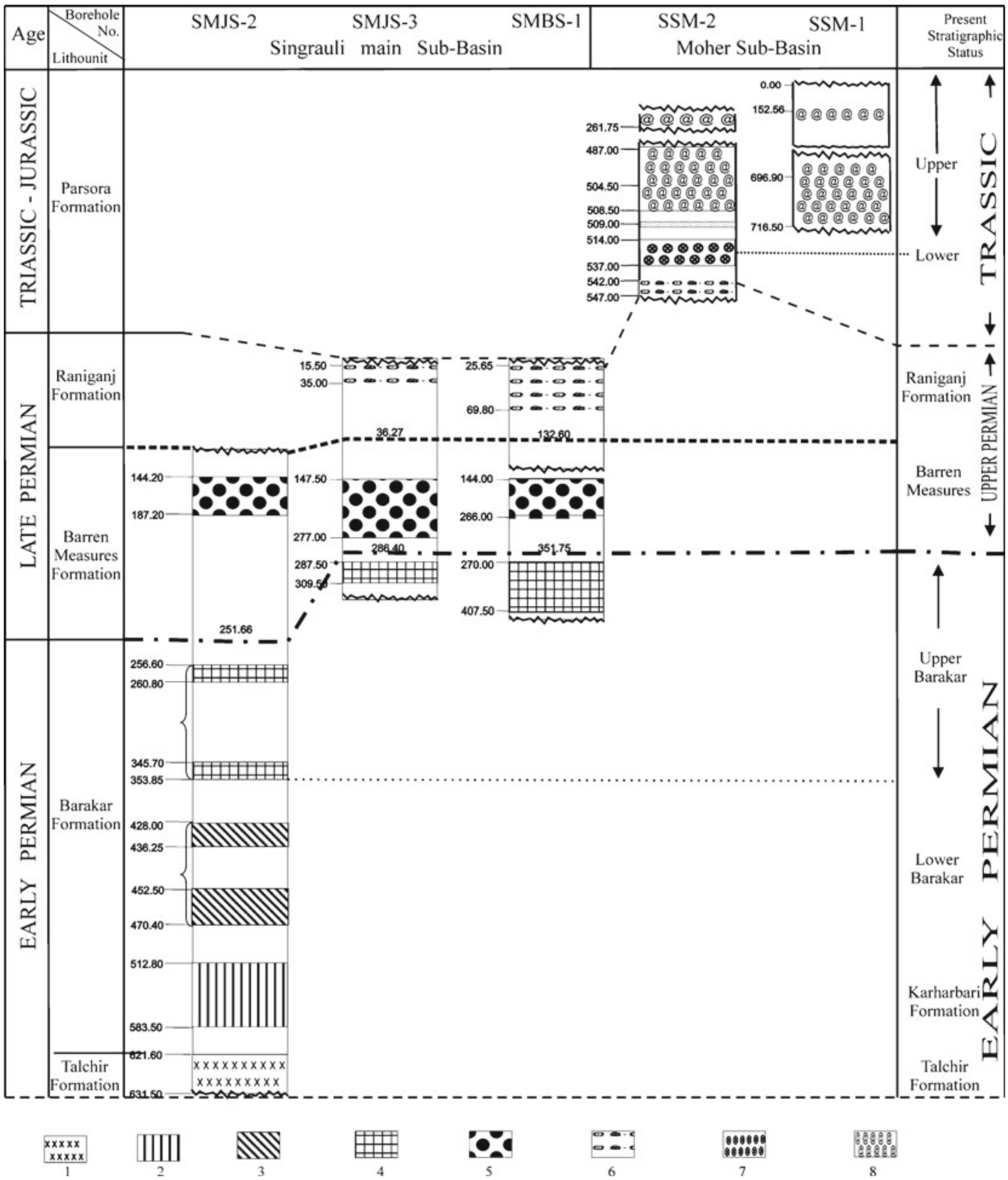

Figure 11. Showing the stratigraphic status of the horizons identified in the Permian and Triassic sequences (boreholes SMJS-2, 3 and SMBS-1, Singrauli main sub-basin; and boreholes SSM-1 and 2 Moher sub-basin) in Singrauli Gondwana Basin, U.P. and Chattisgarh.

SMBS-1(25.65–69.80 m) and SSM-2 (542.00–547.00 m) are suggestive of the deposits of that latest Late Permian (figure 11).

In the total run of studied Permian succession (approximately 650.00 m thick) in boreholes SMJS-2, SMJS-3 and 679.00 m SMBS-1 (figures 3, 4), the unproductive strata encountered is of varied thickness (figure 12). From drastically low to high productivity of spores-pollen, it is derived that depositional set-up might not be favourable to the preservation of the plant matter. And, the levels of unproductive strata possibly had resulted into the condensed sedimentary sequence from that earliest Permian (Talchir Formation) to Latest Permian (Raniganj Formation) in Majhauli(s) block of Singrauli Gondwana Basin.

In and around the Mahuli–Mahersop block, the sedimentary facies encountered as the Parasora Formation in boreholes SSM-1 and SSM-2, lies between these depths in boreholes – SSM-1/00.00–718.00 m; SSM-2/00.00–509.00 m. This is represented mainly by medium-to-coarser sandstone facies, rich in micaceous and ferruginous components (figure 3). The assemblages identified in the

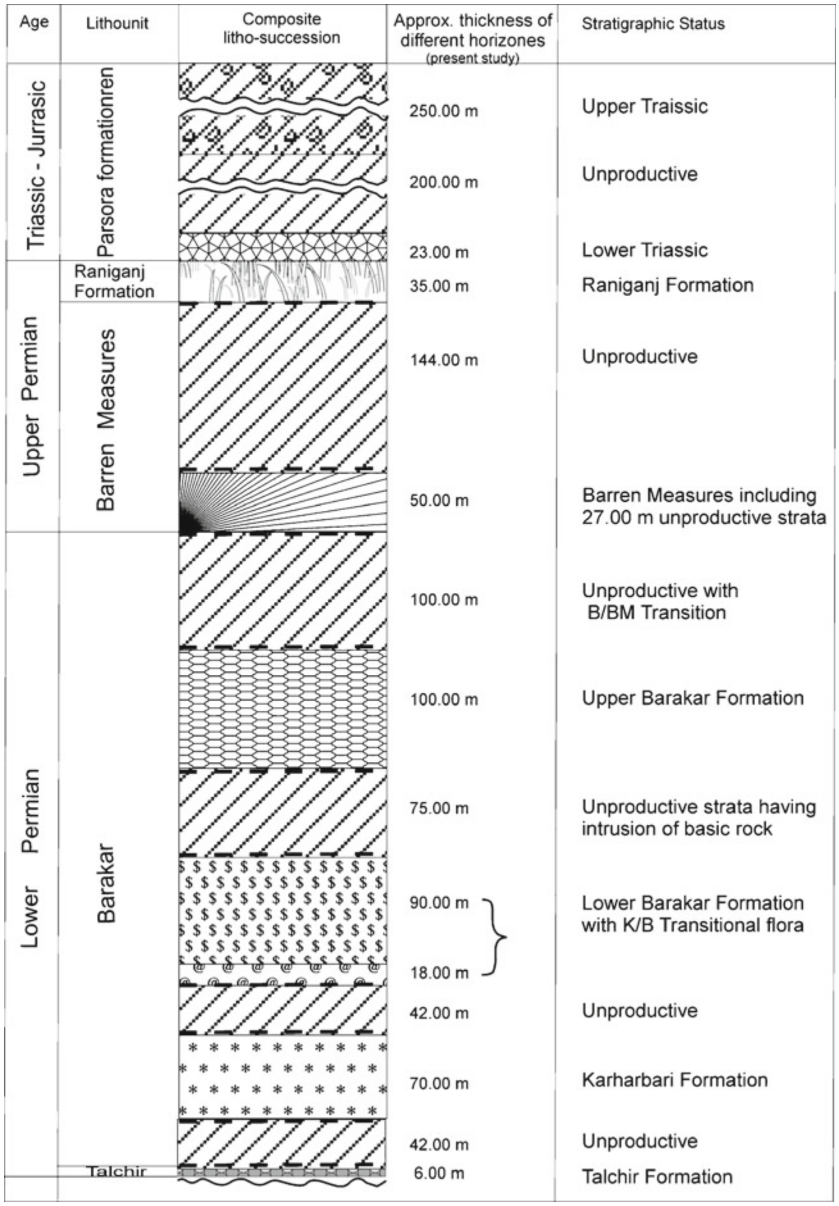

Figure 12. The varied levels of hiatuses identified in the five formational units (approx. 1400.00 m thick) intersected in the Permian (approx. 650.00 m thick, Majhauli block) and Triassic (approx. 720.00 m thick, Mahuli–Mahersop block) sequences in two blocks from Singrauli Master Basin (not to scale).

studied part of the Parasora Formation (figure 9) suggest the deposits of earliest Triassic and Late Triassic age, and display a sharp turnover through the Parasora Formation (figure 11).

The carbonaceous grey facies intercalated with medium-to-coarse grained sandstones of the Raniganj Formation trangresses into the ferugenous facies of the Parsora Formation with a record of palaesol beds (in borehole SSM-2 at 509.00 m depth). This evidences the major regional unconformity in sequence (figure 3).

This study has shown a consistent microfloral change through these sedimentary sequences (figures 11, 12). Several geo-physical and bio-factors have likely contributed to this change within the period of deposition from that glacial to fully arid facies in approximately 1400.00 m thick strata. The coal deposition has its existence from the minimum 00.34 m to the maximum thickness of 9.35 m in the studied sequence (boreholes SMJS-2; SMJS-3; and SSM-2; figure 3).The varied magnitude of hiatuses (figure 12) from that Talchir Formation (earliest Permian) into Parsora Formation (Late Triassic), might be either due to the low presentation of the vegetation or by the silty to sandy alternating layers within a predominantly sandstone facies.

The occurrences of basic rocks that had introduced in the distant areas of these two sub-basins (figures 1, 2) are noteworthy. In Singrauli

Table 5. *List of spore-pollen species identified in the Permian Succession from boreholes SMJS-2,3 and SMBS-1 Singrauli Master Basin, U.P. and Chattisgarh.*

Spores	
Brevitriletes unicus	Bharadwan and Srivastava emend. Tiwari and Singh (1981)
Callumispora barakarensis	Bharadwaj and Srivastava emend. Tiwari *et al.* (1989)
Callumispora fungosa	(Balme) Bharadwaj and Srivastava emend. Tiwari (1977)
Callumispora gretensis	(Balme and Hennely) Bharadwaj and Srivastava (1969)
Cyclobaculisporites minutus	Bharadwaj and Salujha (1964)
Cyclogranisporites gondwanensis	Bharadwaj and Salujha (1964)
Dentatispora gondwanensis	Tiwari (1965)
Didecitriletes horridus	Venkatachala and Kar emend. Tiwari and Singh (1981)
Gondisporites raniganjensis	Bharadwaj (1962)
Horriditriletes bulbosus	Tiwari (1965)
Horriditriletes curvibaculosus	Bharadwaj and Salujha (1964)
Horriditriletes novus	Tiwari (1965)
Indospora sp.	Bharadwaj (1962)
Indotriradites korbaensis	Tiwari (1964)
Indotriradites sparsus	Tiwari (1965)
Insignisporites barakarensis	Bharadwaj and Dwivedi (1977)
Jayantisporites conatus	Lale and Makada (1972)
Jayantisporites indicus	Lale and Makada (1972)
Jayantisporites pseudozonatus	Lale and Makada (1972)
Lacinitriletes badamensis	Venkatachala and Kar emend. Tiwari and Singh (1981)
Lophotriletes frequensus	Tiwari (1965)
Lophotriletes rectus	Bharadwaj and Salujha (1964)
Microbaculispora barakarensis	Tiwari emend. Tiwari and Singh (1981)
Microbaculispora indica	Tiwari emend. Tiwari and Singh (1981)
Microbaculispora tentula	Tiwari emend. Tiwari and Singh (1981)
Microfoveolatispora bokaroensis	Tiwari (1965)
Microfoveolatispora foveolata	Tiwari emend. Tiwari and Singh (1981)
Navalesporites spinosus	Sarate and Ram-Awatar (1984)
Plicatisporites distinctus	Lele and Makada (1972)
Potonieitriradites barakarites	Bharadwaj and Singh (1972)
Striatosporites brazilensis	Bharadwaj, Kar and Navale (1976)
Verrucosisporites donarii	Potonie and Kremp (1955)
Verrucosisporites distinctus	Tiwari (1965)
Verrucosisporites varius	Maheshwari (1967)
Pollen	
Monosaccate	
Barakarites crassus	Tiwari (1965)
Barakarites implicatus	Tiwari (1965)
Barakarites triquetrus	Tiwari (1965)
Crucisaccites latisulcatus	Lele and Maithy (1964)
Crucisaccites monoletus	Maithy (1964)
Densipollenites densus	Bharadwaj and Srivastava (1969)
Densipollenites indicus	Bharadwaj and Salujha (1964)
Densipollenites invisus	Bharadwaj (1962)
Densipollenites magnicorpus	Tiwari and Rana (1980)
Divarisaccus lelei	Venkatachal and Kar (1966)
Divarisaccus scorteus	Lele and Makada (1972)
Imparitriletes korbaensis	Tiwari and Singh (1981)
Kamthisaccites kamthiensis	Srivastava and Jha (1986)
Lacinitriletes minutus	Venkatachala and Kar emend. Tiwari and Singh (1981)
Parasaccites bilateralis	Tiwari (1965)
Parasaccites densicorpus	Lele (1975)
Parasaccites korbaensis	Bharadwaj and Tiwari (1964)
Parasaccites ovatus	Kar (1968)

Table 5. *(Continued)*

Playfordiaspora cancellosa	(Playford and Dettmann) Maheshwari emend. Vijaya (1995)
Plicatipollenites concinnus	Tiwari (1965)
Plicatipollenites gondwanensis	(Balme and Hennelly) Lele (1964)
Plicatipollenites indicus	Lele (1964)
Plicatipollenites triangulatus	Tiwari (1965)
Potonieisporites densus	Maheshwari (1967)
Potonieisporites lelei	Maheshwari (1967)
Potonieisporites magnus	Lele and Karim (1971)
Potonieisporites neglectus	Potonie and Lele (1961)
Stellapollenites talcirensis	Lele (1975)
Striomonosaccites circularis	Bharadwaj and Salujha (1964)
Striomonosaccites ovatus	Bharadwaj (1962)
Tuberisaccites tuberculatus	(Maheshwari) Lele and Makada (1972)
Tuberisaccites varius	Lele and Makada (1972)
Striate Bisaccate	
Circumstriatites obscurus	Lele and Makada (1972)
Crescentipollenites amplus	(Balme and Hennelly) Tiwari and Rana (1980)
Crescentipollenites bengalensis	(Maheshwari and Banerji) Tiwari and Rana (1981)
Crescentipollenites fuscus	(Bharadwaj) Bharadwaj, Tiwari and Kar (1974)
Distriamonocolpites ovalis	Sinha (1969)
Distriatites bilateris	Bharadwaj (1962)
Faunipollenites bharadwaji	Maheshwari (1967)
Faunipollenites perexiguus	Bharadwaj and Salujha (1965)
Faunipollenites singrauliensis	Sinha emend. Tiwari *et al.* (1989)
Faunipollenites varius	Bharadwaj emend. Tiwari *et al.* (1989)
Rhizomaspora indica	Tiwari (1965)
Rhizomaspora monosulcata	Tiwari (1968)
Rhizomaspora singula	Tiwari (1965)
Striapollenites obliqus	Bharadwaj and Salujha (1964)
Striapollenites saccatus	Bharadwaj (1962)
Striasulcites ovatus	Venkatachala and Kar (1968)
Striasulcites tectus	Venkatachala and Kar (1968)
Striatopodocarpites diffusus	Bharadwaj and Salujha (1964)
Striatopodocarpites magnificus	Bharadwaj and Salugha (1964)
Striatopodocarpites ovatus	(Maheshwari) Tiwari and Rana (1980)
Verticipollenites gibbosus	Bharadwaj (1962)
Verticipollenites secretus	Bharadwaj (1962)
Non-Striate Bisaccate	
Cuneatisporites indicus	Maithy (1966)
Krempipollenites indicus	Tiwari and Vijaya (1995)
Nidipollenites monoletus	Bharadwaj and Srivastava (1969)
Platysaccus densicorpus	Anand-Prakash (1972)
Platysaccus ovatus	Maithy (1965)
Protoeusaccites sp.	Tiwari *et al.* (1995)
Sahnites gondwanensis	(Mehta) Pant emend. Tiwari and Singh (1984)
Sahnites jayantiensis	(Lele and Karim) Tiwari and Singh (1984)
Sahnites thomasi	Pant emend. Tiwari and Singh (1984)
Satsangisaccites nidpurensis	Bharadwaj and Srivastava (1969)
Scheuringipollenites barakarensis	(Tiwari) Tiwari (1973)
Scheuringipollenites maximus	(Hart) Tiwari (1973)
Scheuringipollenites tentulus	(Tiwari) Tiwari (1973)
Vesicaspora crassa	Lele and Makada (1972)
Vesicaspora distincta	Tiwari (1965)
Vestigisporites nigratus	Lele and Karim (1971)
Vestigisporites notus	(Lele and Karim) Tiwari and Singh (1984)

Table 5. *(Continued)*

Taeniate	
Arcuatipollenites pellucidus	(Goubin) Tiwari and Vijaya (1995)
Dicapipollenites crassus	(Sinha) Tiwari and Vijaya (1995)
Guttulapollenites hannonicus	Goubin (1965)
Trabeculosporites gopadensis	Trivedi and Misra emend. Tiwari and Ram-Awatar (1992)
Aletes	
Maculatasporites gondwanensis	Tiwari (1965)
Maculatasporites irregularis	Tiwari (1965)
Pilasporites bharadwajii	Balme (1970)
Nonsaccate Sulcate	
Cycadopites follicularis	Wilson and Webster (1946)
Ginkgocycadophytus cymbatus	(Balme and Hennelly) Potonie and Lele (1961)
Ginkgocycadophytus korbaensis	Tiwari (1965)
Marsupipollenites striatus	Balme and Hennely (1956)
Praecolpatites sinuosus	(Balme and Hennelly) Bharadwaj and Srivastava (1969)
Tiwariasporis flavatus	Maheshwari and Kar (1967)
Tiwariasporis gondwanensis	Maheshwari and Kar (1967)
Weylandites bilateralis	Bharadwaj and Srivastava (1969)
Weylandites circularis	Bharadwaj and Srivastava (1969)
Vittatina sp.	

master sub-basin, the outburst of the basic rock seems to have happened during the deposition of Barakar Formation as noted in borehole SMBS-1 (578.70–529.50 m depth). Apart from this, in the northeastern part of the Singrauli Gondwana Basin (Moher sub-basin), the basic rock intrusion is noted in the younger part of the Upper Triassic (Parsora Formation, 398.00–531.90 m in borehole SSM-1). High degree of heating impact can be seen in the sediments that comprise hard, brittle and dark grey to blackish siltstones intercalated with silty shales and medium-to-fine grained sandstone facies. That is also visible from the exinal surface pattern and the colour of spores-pollen specimens along with vegetal matter, which had become translucent and darkened (table 5).

The assemblages recognized here in the two blocks in Singrauli Gondwana Basin (figure 9) have been correlated with the Palynozones established in the Permian and Triassic sequences in Australia for their possible age correlation (figure 10).

6. Conclusions

Present study suggests the below given palynostratigraphy and age correlation among the formational units intersected in subsurface strata within the two sub-basins in Singrauli Gondwana Basin (figures 9, 10, 11):

- Fluvial sediments of Talchir Formation in borehole SMJS-2 (631.50–621.50 m) contain spores-pollen that infers earliest Permian age.
- Strata in between 583.50–512.80 m, a part of the Barakar Formation in borehole SMJS-2, is equitable with that Karharbari Formation of Early Permian in age (figure 11).
- The Barakar Formation intersected in boreholes – SMJS-2 (251.66–470.40 m), SMJS-3 (286.40–309.50 m) and SMBS-1 (351.75–407.50 m) contains the assemblages which conform the early Permian age of the strata.
- The Barren Measures Formation delimited in boreholes SMJS-2 (5.70–251.66 m), SMJS-3 (36.27–286.40 m) and SMBS-1 (132.60–351.75 m) conforms to the age derived from its spores-pollen content.
- The Raniganj Formation within borehole SMJS-3 (approx. 37.00 m), SMBS-1 (100.00 m), and SSM-2 (102.00 m) in both the sub-basins (figures 3, 4), represents the latest Permian level. FAD's of *Arcuatipollenites pellucidus*, *Kamthisaccites kamthiensis* and *Goubinispora* sp. certainly evidence the Permian and Triassic transition in the upper part (figures 11, 12).
- Occurrence of palaeosol horizon at 509.50 m in borehole SSM-2 is significant as one of the sedimentary feature to demarcate the P/Tr level (figure 11).
- The Parasora Formation intersected in the Mahuli–Mahersop block (boreholes SSM-1, 2) represents the Lower and Upper Triassic level with a hiatus of Middle Triassic deposits, as derived from spores-pollen study (figure 11).
- Strata devoid spores-pollen are identified at many intervals in the sedimentary sequences in the study area (figure 12).

- Occurrences of the basic rock intrusions in the Barakar Formation (SMBS-1, figure 3), and Parsora Formation (SSM-1, figure 4) might be inferred the out-brusting of heat flow through the sedimentary rocks irrespective of the geological time.

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