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Sporae-dispersae and correlation of Gondwana sediments in Johilla Coalfield, Son Valley Graben, Madhya Pradesh

R. S. Tiwari & Ram-Awatar

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The dispersed spores and pollen grains preserved in the sediments exposed along Johilla River Section, Ganjra Nala Section and in three bore-cores, viz., JHL-23, JHL-24, JHL-25, in Johilla Coalfield have been described. The rich miofloral assemblage consists of 58 genera and 126 species, out of which seven species are new on the basis of their morphological characters. These are—*Callumispora paliensis, C. saksenae, Osmundacidites baculatus, Dentatispora mammoida, D. reticulata, Gondisporites reticulatus* and *Lunatisporites paliensis.*

On the basis of composition of spores and pollen grains, it has been concluded that the South Rewa Gondwana Basin shows broader relationship with equivalent strata in other basins of India. In general, the monosaccate pollen have a better representation in the Talchir as well as Barakar sediments which is suggestive of relatively cooler conditions than those in Damodar Valley. Six palynological zones have been identified on the basis of quantitative analysis.

Key-words—Palynostratigraphy, Correlation, Gondwana, Son Valley Graben (India).

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साराँश

मध्य प्रदेश में सोन घाटी द्रोणिका के जोहिल्ला कोयला-क्षेत्र में गोंडवाना अवसादों से विकीरित बीजाणु-परागकण तथा इनके सहसम्बन्ध

राम शंकर तिवारी एव राम अवतार

जोहिल्ला नदी खंड, गजरा नाला खड के मंग-संग विगोपित अवसादों तथा जोहिल्ला कोयला-क्षेत्र के जे-एँच-एँल० 23, जे-एँच-एँल० 24 एवं जे-एँच-एँल० 25 नामक तीन वेध-क्रोड़ों में सुपरिरक्षित बीजाणुओं एवं परागकणों का वर्णन किया गया है। उपलब्ध भरपूर समुच्चय में 58 प्रजातियाँ एवं 126 जातियाँ विद्यमान है जिनमें से आकारिकीय लक्षणो के आधार पर सात जातियाँ नई हैं। ये **केलूमिस्पोरा पालीयेन्सिस, के० सक्सेनी, ओस्मुन्डेसीडाइटिस बेक्युलेटस, डेन्टाटिस्पोरा मेमोइडा, डे० रेटिकुलाटा, गोन्डिस्पोराइटिस रेटिकुलेटस** एवं **ल्यूनाटिस्पोराइटिस पालीयेन्सिस** नामक वर्गक हैं।

बीजाणुओं एवं परागकणों की संरचना के आधार पर यह निष्कर्ष निकाला गया है कि दक्षिण रीवा गोंडवाना का भारत की अन्य द्रोणियों में स्थित समतुल्य स्तरों से विस्तृत सम्बन्ध है। सामान्यतया तलचीर एवं बराकार अवसादों में एक-कोष्ठीय परागकणों का अपेक्षाकृत अच्छा निरूपण है जिससे यहां दामोदर घाटी की अपेक्षा ठंडी परिस्थितियों का होना इंगित होता है। परिमाणात्मक विश्लेषण के आधार पर छः परागाणविक मडल अभिनिर्धारित किये गये हैं।

JOHILLA Coalfield is situated (23°16′ : 23°23′ latitude and 80°57′ : 81°05′ longitude) at about 33 km south-east of Umaria Railway station on Katni-Bilaspur line of the Central Railway in district Shahdol, Madhya Pradesh. In this area, the age of Pali and Parsora formations and the strata of Middle Gondwana have been controversial since long.

During the last two decades, considerable palynological work has been carried out on the sediments of Son Valley Graben (South Rewa Gondwana Basin). Mehta (1944), for the first time, reported the presence of spores and pollen grains from this area and identified them as—*Pityosporites gondwanensis, Hymenozonotriletes,* etc. Saksena

(1947, 1949) reported a number of megaspores and seed-like bodies from Ganjra Nala bed from this region. Later on, Tripathi (1952) recorded the presence of megaspores from coal horizons of Umaria Coalfield and Saksena and Krishnamurti (1960) also reported a miofloral assemblage from Rangta Coal mine in South Rewa Gondwana Basin. Potonié and Lele (1961) were the first to report the *Sporae dispersae* from the Talchir Formation exposed at Goraia in Johilla Coalfield and recorded 13 genera of palynofossils from this bed; in this assemblage two species, i.e., *Lunatisporites goraiaensis* and *Potonieisporites neglectus* were proposed to be new. Maithy (1968) also recorded some miospores from Umaria and Johilla coalfields. Lele and Chandra (1969, 1972) reported Talchir assemblages including acritarch-like microfossils from this area. In 1971, Saksena described the dispersed palynofossils from the Ganjra Nala Section, while Lele and Chandra (1973) gave detailed account of palynological assemblages from this area. Thereafter, Chandra and Lele (1979) recovered palynofloras from Talchir Formation of Birsinghpur Pali, Anuppur, Chirimiri, Manendragarh and Umaria areas and established two major palynological zones—*Plicatipollenites-Parasaccites* miofloral Zone and *Parasaccites-Plicatipollenites* Zone within the Talchir. Jhingran (1979) also recorded palynofossils from Johilla Coalfield and commented upon the age of Parsora Formation. Srivastava and Anand-Prakash (1984) and Anand-Prakash and Srivastava (1984) have given an account of palynozones in Umaria and Johilla coalfields, respectively. Recently, Tiwari and Ram-Awatar, (1986, 1987) and Ram-Awatar (1988) recorded two palynological assemblages from Pali Formation and dated them Permian and Permian/Triassic in age, respectively.

Recently, Chandra and Srivastava (1986) have reported palynological assemblages from four areas, viz., Umaria, Birsinghpur Pali, Anuppur and Chirimiri with their biostratigraphical significance and assigned Karharbari age to these beds.

Presently, the results of palynological investigations have been given for the material representing Talchir to Pali formations (i.e. Early Permian to Early Triassic) from Birsinghpur Pali (Johilla Coalfield) in Son Valley, Madhya Pradesh. Palynological assemblages have been determined after quantitative analysis; sequential successions have also been built up. New taxa have been described in detail and compared morphographically. The six recognized palynozones have been dated, correlated and compared for general relationship. These results have thrown light on the variability of palynoassemblages in Lower Gondwana of this basin in comparison to Damodar Basin.

GEOLOGY

The area was surveyed by Medlicott in 1860; later, Hughes in the year 1881, systematically mapped the area. In 1928, Gee proved the presence of workable coalseams in Umaria Coalfield. Fox (1934) gave a brief geological account of the Johilla Coalfield describing the presence of Talchir, Karharbari, Barakar and Supra-Barakar formations in the area; he also suggested the presence of Karharbari horizon at about 0.92 km South of Mangthar Village. The oldest rocks found in the Johilla Coalfield are metamorphic which are exposed mainly in the southern region of Birsinghpur Pali. The Archean rocks are unconformably overlain by Gondwana sediments the base of which is Talchir, overlain by Barakar and Supra-Barakar sediments; still younger sequences consist of Lameta and trap covered by soil. According to Jhingran (1979), the lithostratigraphic sequence is as given below (Map 1):

Traps
Lametas
..................................Unconformity..............................
Supra-Barakar
Barakar
Talchir
..................................Unconformity..............................
Metamorphic

The characteristic sedimentological features and other details of the lithological succession are as follows.

Metamorphic—These rocks cover an area of about 20.72 sq km lying in the southern part of the coalfield; towards their north, the basement rocks are covered by Talchir and partly by alluvium. The south-west portion is bordered by Lametas.

Talchir—Talchir Formation overlies the metamorphics; they are characterised by boulder bed, needle shales, siltstone and green sandstone. In Johilla Coalfield, Talchir exposures occupy an area about 10.84 km long and 0.9 km wide between the villages Kudri and Kumurdu; it is also exposed as a small band to the north of Mangthar. A good section of Talchir exposures can be seen near Barachada (23°21′ : 81°1′) where laminated greenish sandstone and needle shales are exposed at the base. Talchir boulder bed is exposed near Ponri

Village, where contact of Archean and Talchir can be traced.

Barakar—In Johilla Coalfield, Barakar sediments are exposed in south and south-west of Birsinghpur Pali township. Good sections of Barakar are exposed at about 3.6 km north-east of Mangthar Village, in a nala which is a tributary of Johilla River (Chandra & Lele, 1979) and at the junction of Ganjra Nala with Johilla River, 4.5 km south-west of Pali The Barakar sediments consist of yellowish to greyish feldspathic, silicious sandstone, shale, carbonaceous shale and coal.

The important seam in the northern area is Johilla seam which is exposed in Ganjra Nala in the east and Marjada Nala on the west splitting into three distinct bands.

Supra-Barakar—The Supra-Barakar encompasses all the Gondwana beds that are younger to the typical coal-bearing Barakars and differ in its lithology. Supra-Barakar sediments include Pali and Parsora formations which are homotaxial with Raniganj, Panchet and Supra-Panchet formations, in sequential position.

The Supra-Barakar are highly ferruginous in composition characterized by varuiys tints of red, yellow and whitish colour. The texture is graded and sandstones are with low iron content. The rocks near Parsora Village are fine-grained, dark red, ferruginous and reddish-brown sandstone, with thin bands (1-2 cm) of various shades of clay.

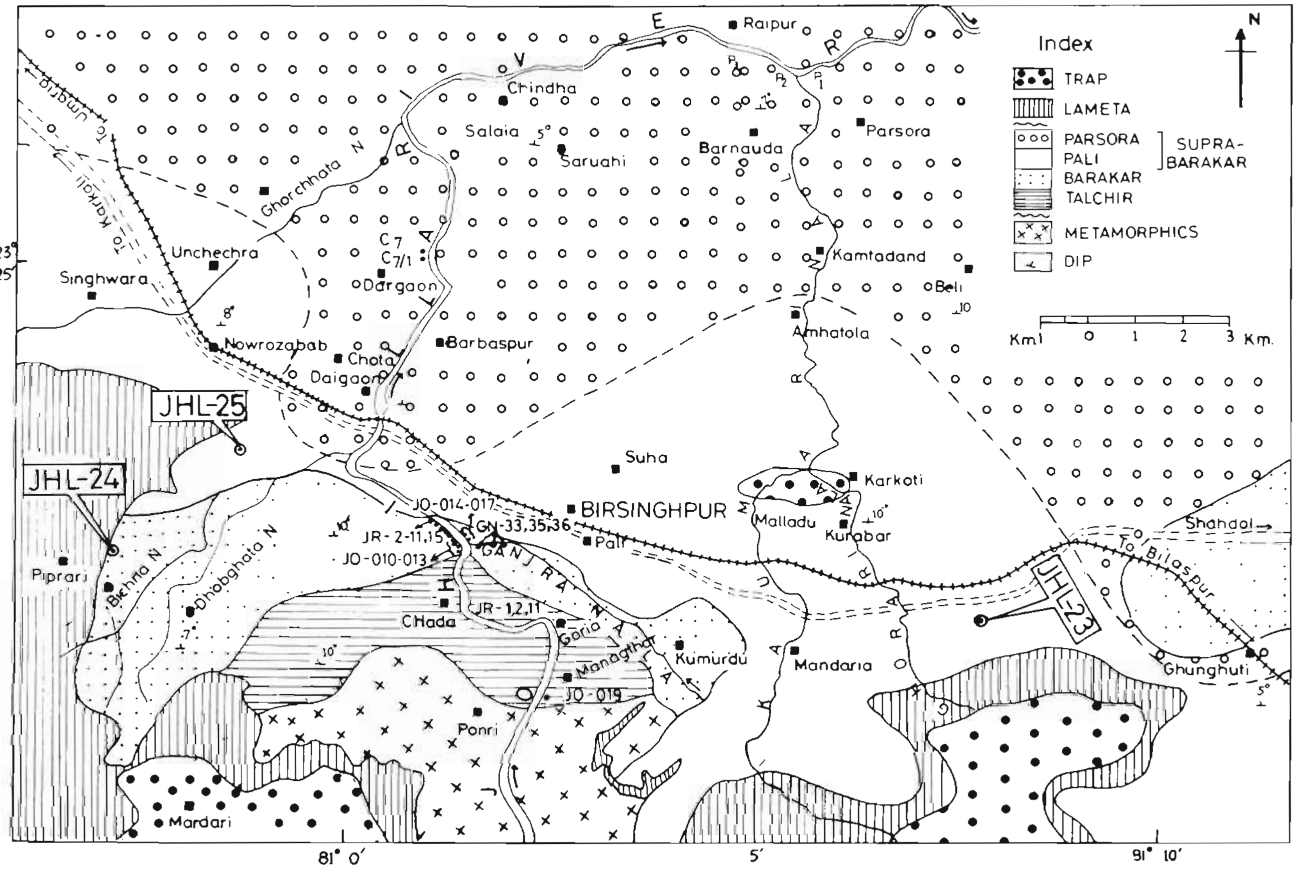
Lameta—The Lameta unconformably overlies Supra-Barakar which are exposed at the fringes, at about 1.8 km south of Maliagura and 3.7 km east of Ponri Village; there is an outlier of Lameta rock overlying the metamorphics. The rock type of Lametas are limestone, mostly gritty, but sometimes crysalline also.

Trap—The trap-flows exposed in the area are probably the continuation of Deccan trap (Hughes, 1884).

Soil—It covers different formations in different parts of the area. The blackish colour of the soil suggests that it is derived from trap rocks.

MATERIAL AND METHODS

For the present investigation 374 samples were collected, out of which 118 samples were found to



Map 1—Geological map of the part of Johilla Valley showing location of bore-holes and outcrop samples studied.

be productive. The samples were procured from three bore-holes (JHL-23, JHL-24 and JHL-25) and three river/nala sections, viz., Johilla River, Ganjra Nala and Kamari Nala (locally known as Ghorari Nala). A list of productive samples alongwith their locations are given in the following Tables (1-5). In maceration the usual method of acid and alkali treatment was followed and all the slides and negatives have been deposited at the Birbal Sahni Institute of Palaeobotany Museum.

Table 1—Eastern part of Johilla Coalfield—bore-hole no. JHL-23

Sample nos.	*Lithology*	*Depth in meters*
JHL-23/59	Coarse grained greenish sandstone	154.00-150.00
JHL-23/58	Sandy shale in sandstone	157.00-156.20
JHL-23/57	Carbonaceous streak in sandstone	173.50
JHL-23/56	Shale and coal in sandstone	175.30
JHL-23/55	Sandy shale	182.80-180.00
JHL-23/54	Sandy shale	183.00-182.80
JHL-23/53	Shale and sandy shale	185.00-183.00
JHL-23/52	Black shale	185.00
JHL-23/51	Fine laminated shale	186.52-185.50
JHL-23/50	Siltstone with thin shale streaks	187.50-186.50
JHL-23/49	Coaly shale	188.20-187.50
JHL-23/47	Shale	189.50 (30 cm)
JHL-23/46	Shale	203.00-202.50
JHL-23/45	Carbonaceous shale	204.00-203.00
JHL-23/44	Shaly coal	205.00-204.00
JHL-23/43	Shale	206.00-205.00
JHL-23/42	Shale	206.00-
JHL-23/41	Coal streaks in sandstone	206.80
JHL-23/40	Shale in sandstone	207.00-206.40
JHL-23/38	Shale	213.70-212.70
JHL-23/37	Carbonaceous shale	218.00-217.00
JHL-23/36	Carbonaceous shale	219.00-218.00
JHL-23/35	Coal with shale	220.80-219.00
JHL-23/34	Grey shale	222.80-220.80
JHL-23/33	Coaly shale	240.00-239.70
JHL-23/27	Shale	242.70-242.00
JHL-23/26	Micaceous greenish sandstone	269.70-
JHL-23/21	Shale in sandstone	277.00
JHL-23/20	Shale	280.80-280.00
JHL-23/19	Shale	283.00
JHL-23/17	Carbonaceous shale in sandstone	285.50-286.00
JHL-23/16	Coarse grained sandstone	299.00-286.00
JHL-23/15	Shaly streak in sandstone	306.00-304.00
JHL-23/13	Coaly shale	327.00
JHL-23/12	Grey shale	329.25-327.00
JHL-23/11	Grey shale	331.10-330.00
JHL-23/9	Shale	334.00-333.50
JHL-23/8	Shale	335.00
JHL-23/7	Shale	336.30-335.35
JHL-23/6	Shale	338.20-337.20
JHL-23/5	Grey shale	339.00
JHL-23/4	Shale	340.00
JHL-23/3	Shale	341.00
JHL-23/2	Shale	347.80
JHL-23/1	Shale	348.00

Table 2—Western part of Johilla Coalfield—bore-hole no. JHL-24

Sample nos.	*Lithology*	*Depth in meters*
JHL-24/8	Carbonaceous shale	72.30-72.80
JHL-24/10	Shale	73.30-74.00
JHL-24/11	Shale	80.90
JHL-24/13	Coarse grained sandstone	81.90-82.50
JHL-24/14	Shale	82.50-82.80
JHL-24/15	Shale with fossils	82.80-83.00
JHL-24/16	Carbonaceous streak in sandstone	83.00-85.00
JHL-24/17	Carbonaceous shale	85.00-85.30
JHL-24/18	Coal	85.30-85.60
JHL-24/19	Shale and coal	85.60-86.00
JHL-24/20	Sandstone and shale	87.00-88.00
JHL-24/21	Shale and sandstone	88.00-88.60
JHL-24/23	Shale and sandstone	90.00-91.00
JHL-24/24	Carbonaceous shale	91.00-91.20
JHL-24/25	Sandstone with shale streak	91.60-92.10
JHL-24/27	Sandstone with shale streak	93.00-94.00
JHL-24/29	Shale	96.80-97.20
JHL-24/30	Shale	112.00-113.00
JHL-24/32	Shale	150.00-150.20
JHL-24/34	Sandstone with compact shale	153.25-155.00
JHL-24/35	Sandstone with coal streak	161.00
JHL-24/36	Shale	174.00-175.00
JHL-24/37	Shale	186.00-185.00
JHL-24/39	Compact shale	181.00-187.00
JHL-24/40	Grey shale	192.00-193.00
JHL-24/41	Black shale	193.00-194.00
JHL-24/42	Sandstone	194.00-206.00
JHL-24/43	Shale with fossils	206.00-206.70
JHL-24/44	Sandstone with shale	209.00-210.00
JHL-24/45	Sandstone with shale	211.00-210.00
JHL-24/45A	Sandstone with shale	210.00-211.00
JHL-24/46	Sandstone with shale	212.00 212.50
JHL-24/47	Sandstone with shale	212.50-213.00
JHL-24/48	Sandstone with shale	213.00-213.50
JHL-24/49	Sandstone with shale	213.50-215.00
JHL-24/50	Sandstone with coal	215.00-215.50
JHL-24/51	Sandstone with shale	231.00-234.00

Table 3—Western part of Johilla Coalfield—Bore-hole no. JHL-25

Sample nos.	*Lithology*	*Depth in meters*
JHL-25/13	Shale	39.00-37.00
JHL-25/12	Carbonaceous shale and coal	40.00-39.00
JHL-25/11	Carbonaceous shale	46.00
JHL-25/10	Shale	65.00
JHL-25/8	Coal	108.00-106.00
JHL-25/7	Shale	125.15
JHL-25/5	Coaly shale	135.75
JHL-25/1	Shale	180.00
JHL-25/01	Shale	190.00

Table 4—Johilla River Section from Ponri to Dargaon villages

Sample nos.	*Lithology*	*Remarks*
C-7	Black micaceous shale	
C-7/1	Black micaceous shale	Pali

Jo-13	Coal	Barakar
Jo-14	Shale	
Jo-015	Coal	
Jr-10	Coal	Karharbari
Jr-15	Coal	
Jr + 3	Carbonaceous shale	
Jr + 4	Fine grained sandstone	
Jr + 5	Coal	
Jr + 6	Carbonaceous shale	
Jr + 7	Carbonaceous shale	
Jr + 8	Coarse grained sandstone	
Jr + 9	Carbonaceous shale	
Jr + 11	Carbonaceous shale	
Jr - 2	Mudstone	Talchir
Jo - 09	Khaki shale	

Table 5—Ganjra Nala Section

Sample nos.	*Lithology*	*Remarks*
GN-33	Carbonaceous shale	Karharbari/Barakar
GN-35	Carbonaceous shale	
GN-36	Carbonaceous shale	

SYSTEMATIC PALYNOLOGY

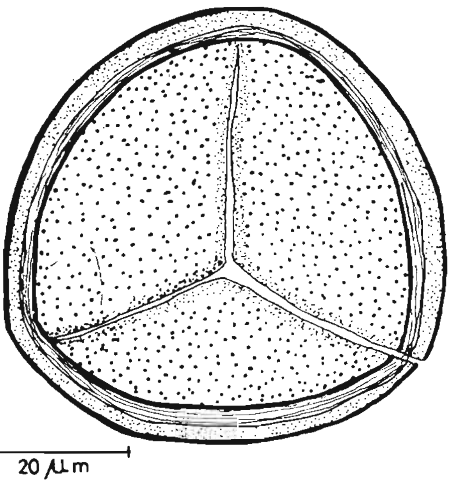
Genus—*Callumispora* Bharadwaj & Srivastava 1969

Type species—*Callumispora barakarensis* Bharadwaj & Srivastava 1969

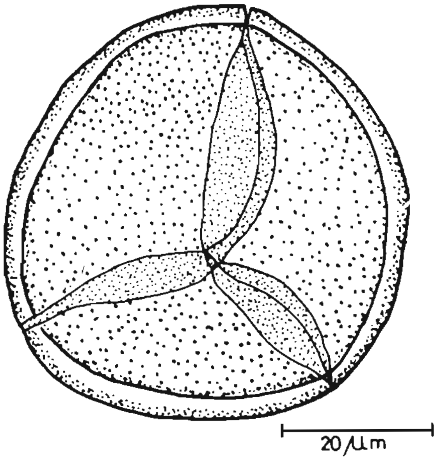
Callumispora paliensis sp. nov.
Pl. 1, figs 5-8; Text-fig. 1

Holotype—Pl. 1, fig. 5, size 58 μm; slide no. BSIP 9308.

Locus typicus—Bore-hole no. JHL-25, depth 180-190 m, about 8 km west from Birsinghpur-Pali, Johilla Coalfield, Lower Karharbari Formation, Early Permian.



Text-figure 1—*Callumispora paliensis* sp. nov. showing the nature of trilete mark, rays extending up to the equatorial margin; distribution of intrapunctate structure throughout the surface, and the thickened exine.



Text-figure 2—*Callumispora saksenae* sp. nov. showing the nature of folded trilete rays extending up to the equatorial margin.

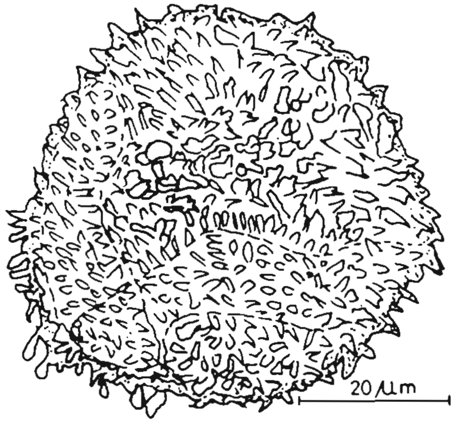
Diagnosis—Triangular to subtriangular with prominent trilete mark, rays reaching up to equatorial margin. Exine finely inframicropunctate in structure, with uniformly distributed pits all over body surface, exine 3-4 μm thick, a sharp line of thickness demarcation being distinct in optical section. *Extrema lineamenta* smooth.

Description—Miospores triangular to subtriangular with convex sides and rounded corners. Size range 58-70 μm. Trilete rays distinctive in being extended up to the equator and in having uniformly thick lips. Exine thickness sharply defined in optical section, puncta not restricted to the contact area, on the contrary uniformly distributed all over the body surface.

Comparison—*Callumispora paliensis* sp. nov. *differs from all the known species of the genus—C. barakarensis, C. tenuis* (Bharadwaj & Srivastava 1969) and *C. fungosa* (Balme) Bharadwaj & Srivastava emend. Bharadwaj & Tiwari 1977, in having well-defined trilete mark whose rays reach up to the equator and also in the nature of uniformly structured exine.

The scanning electron micrograph (Pl. 1, fig. 8) of a slightly opened specimen reveals the presence of structure within the surface on inner side (top left region) and also the nature of surface where few sparse low elevations are seen (top right region), suggesting thereby that the exine is not 'polished' smooth but has some specks or pimple-like low elevations which could be revealed only in SEM.

Derivation of name—The name has been derived after Pali Village, the type area.



Text-figure 3—*Osmundacidites baculatus* sp. nov. exhibiting the nature of ornamentation including bacula and coni on the equator as well as on surface.

Callumispora saksenae sp. nov.
Pl. 1, figs 3, 4; Text-fig. 2

Holotype—Pl. 1, fig. 3, size 66 μm; slide no. BSIP 9309.

Locus typicus—Bore-hole no. JHL-25, depth 182-190 m; about 8 km west from Birsinghpur-Pali, Johilla Coalfield, Lower Karharbari Formation, Early Permian.

Diagnosis—Subcircular to circulotriangular. Trilete mark distinct, rays reaching up to equator, accompanied with prominent folds. Exine 2-3 μm thick, distinctly and uniformly inframicropunctate; *extrema lineamenta* smooth.

Description—Size range 52-82 μm. Trilete mark prominent, rays associated with flapy folds which are broader at their centres (10-20 μm) and narrower at their tips. Exine coarsely infrapunctate, puncta distributed all over the body surface.

Comparison—Among the known species, only *Callumispora fungosa* (Balme) Bharadwaj & Srivastava 1969 emend. Bharadwaj & Tiwari 1977 compares due to its uniformly punctate nature of exine structure, but *C. saksenae* sp. nov. differs in having distinct folds which accompany the trilete rays.

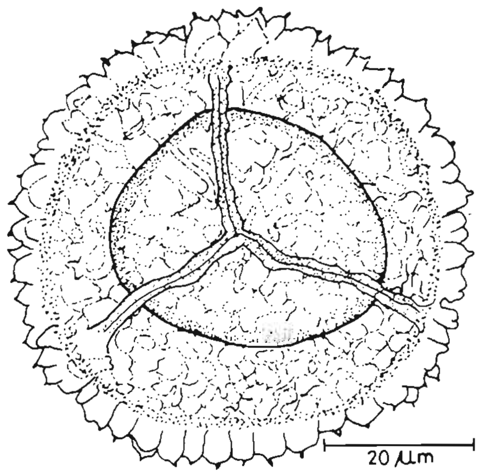
Derivation of name—The name has been derived after Prof. S. D. Saksena.

Genus—*Osmundacidites* Couper 1953

Type species—*Osmundacidites wellmanii* Couper 1953

Osmundacidites baculatus sp. nov.
Pl. 1, figs 12-13; Text-fig. 3

Holotype—Pl. 1, fig. 12; size-53 μm; Slide no.



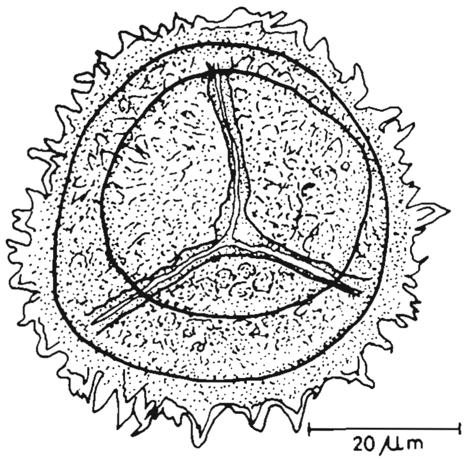
Text-figure 4—*Dentatispora mammoida* sp. nov. showing the nipple-like sculptural elements and folded, thick-lipped trilete mark beside the cingulum, inner body and general pattern of sculpture.

BSIP 9052.

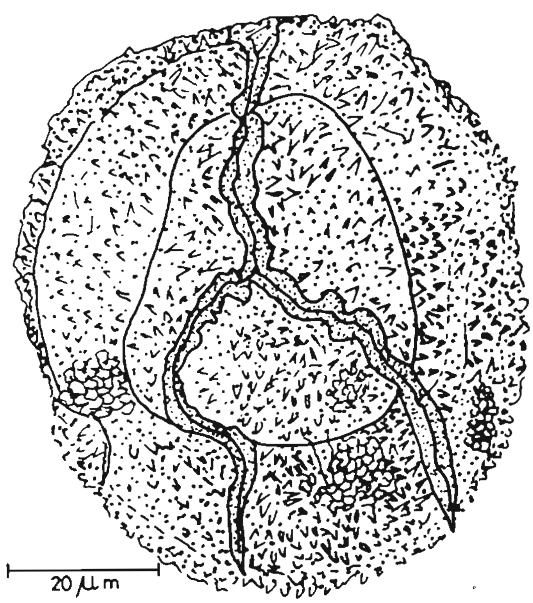
Locus typicus—Near Dargaon Village; Johilla River Section, Johilla Coalfield, Pali Formation, Late Permian/Early Triassic.

Diagnosis—Circular to subcircular; trilete mark distinct, rays reaching ± ¾ of spore radius; exine ± 1 μm thick, sculpture consisting of densely placed, 3-5 μm long and 1-1.5 μm broad, round-headed as well as finger-shaped bacula of varying shapes and sizes, intermixed with rare short coni and spines.

Description—Normally circular to subcircular, 50-60 μm, may be subtriangular due to folding and orientation of compressions. Trilete mark distinct, rays straight, simple with thin lips and low vertex. Ornamentation predominantly consisting of broad



Text-figure 5—*Dentatispora reticulata* sp. nov. showing reticulate exine, characteristic cingulum and the trilete mark.



Text-figure 6—*Gondisporites reticulatus* sp. nov. specimen showing the reticulate nature of exine at places.

cylindrical, round-headed, bacula or finger-shaped processes; short coni or spines are rarely found; sculptural elements found all over the surface of spore.

Comparison—*O. wellmanii* Couper 1953, *O. senectus* Balme 1963 and *O. pilatus* Tiwari & Rana 1981 are different from this species because of the nature of sculptural elements. The genus *Osmundacidites* is based on the type species which possesses small coni intermixed with a few spines. The present species possesses bacula, thus basically it is different, but now the circumscription of the genus being enlarged by inclusion of other types of ornamentation in this group, the present species has also been assigned to this genus. The mixed type of elements, however, remains the basic character of this genus.

Genus—*Dentatispora* Tiwari 1964

Type species—*Dentatispora indica* Tiwari 1964

Dentatispora mammoida sp. nov.
Pl. 1, figs 9-11; Text-fig. 4

Holotype—Pl. 1, fig. 9; size 60 × 62 μm; Slide no. BSIP 9307.

Locus typicus—Bore-hole no. JHL-24, depth 212.0-213.50 m; 10 km west from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Subcircular to roundly triangular. Trilete mark distinct, rays thick-lipped extending up to inner margin of cingulum. Proximally exine intramicropunctate, on distal face ornamented with mostly nipple-like, rarely coni-type sculptural elements measuring 4-5 μm high and 3-4 μm broad at their bases. Cingulum distinct, 5-10 μm wide, bearing 4-8 μm high mammoidal sculpture. Inner body distinct.

Description—Roundly triangular in general shape, 60-72 μm, Y-mark distinct, rays thick-lipped, folded, reaching up to the cingulum; sculptural elements nipple-like, rarely coni, sometimes two or more than two elements being fused with each other; sparsely to densely distributed all over the distal surface as well as on the cingulum. A triangular, thin inner body generally seen.

Comparison—*D. mammoida* sp. nov. differs from all the other known species of this genus in having nipple-like sculptural elements.

Dentatispora reticulata sp. nov.
Pl. 1, figs 1-2; Text-fig. 5

Holotype—Pl. 1. fig. 1; size 70 μm; Slide no. BSIP 9304.

Locus typicus—Bore-hole no. JHL-24, depth 213.0-213.50 m; 10 km east from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Subtriangular with dentate cingulum. Trilete mark distinct, rays thick-lipped, reaching up to cingulum. Body exine prominently intramicroreticulate, distally ornamented with 5-7 μm long, pointed or round-tipped coni which sometimes fused with each other. Inner body distinct.

Description—Trilete, rays thick-lipped and occasionally folded, reaching up to the cingulum, 65-70 μm. Body exine distinctly structured as intramicroreticulate (Pl. 1, fig. 1) distally ornamented with 5-7 μm high and 4-5 μm broad at base, conical sculptural elements which being closely placed and sometimes fused with each other at their bases. Cingulum 5-10 μm, unevenly broad, bearing longer processes. A subtriangular, thin inner body present.

Comparison—The specimens studied here are comparable to *D. gondwanensis* Tiwari 1965 in the nature of ornamentation but differs in having reticulate structure of exine.

Genus—*Gondisporites* Bharadwaj 1962

Type species—*Gondisporites raniganjensis* Bharadwaj 1962

Gondisporites reticulatus sp. nov.
Pl. 1, figs 16, 17; Text-fig. 6

Holotype—Pl. 1, fig. 16, size 90 × 95 μm; Slide no. BSIP 9055.

Locus typicus—Near Dargaon Village, Johilla River Section, Johilla Coalfield, Pali Formation, Late Permian/Early Triassic.

Diagnosis—Subcircular to roundly subtriangular. Exine thin, uniformly inframicroreticulate; trilete mark distinct, rays reaching beyond the equatorial ridge and entering into zona. Body surface showing coarse reticulate sculpture at places with fine muri and wide meshes, also sparsely spinulate to baculate ornaments present. Inner body distinct.

Description—Generally subcircular but sometimes aquiring subtriangular shape 90-95 μm in size; a well-defined inner body present. Y-mark prominent, rays extending up to the outer margin of zona; thick-lipped, slightly folded. Exine coarsely intrareticulate sculptured, at places, muri ± 1 μm thick, meshes 2-4 μm in diameter. Zona thin, transparent, consisting of irregular denticulate edge, densely covered with spinules, rarely less than 1 μm coni. Inner body distinct in being darker in appearance than the central body.

Comparison—Amongst the known species of *Gondisporites*, the present species compares with *G. raniganjensis* Bharadwaj 1962 in having densely covered spinules all over the surface as well as the zona. However, the specimens studied here are entirely different due to the presence of coarse reticulate sculpture at places on the exine.

Genus—*Lunatisporites* Leschik 1955 emend. Scheuring 1970

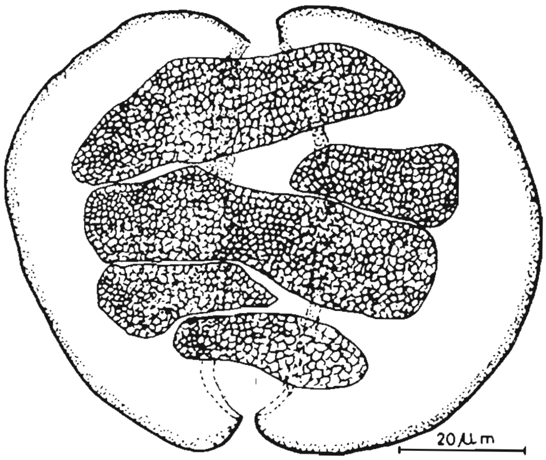
Type species—*Lunatisporites acutus* Leschik 1955

Lunatisporites paliensis sp. nov.
Pl. 1, figs 14, 15; Text-fig. 7

Holotype—Pl. 1, fig. 14; size 110-40 μm; Slide no. BSIP 9305.

Locus typicus—Bore-hole no. JHL-23, depth 203.0-204.0 m; about 9 km east from Birsinghpur-Pali, Johilla Coalfield, Barakar Formation, Permian.

Diagnosis—Central body indistinct, apparently subcircular to horizontally oval, indicated by taeniae-ends, bearing 3-5 big and massive taeniae having intramicroreticulate structure; rest of exine unstructured. Sacci proximally equatorially attached, distally inclined leaving a 10-20 μm broad free area, no typical lunar folds present, only narrow sometimes indistinct folding of saccus seen at the distal attachment zones. Sacci less than hemispherical, intramicroreticulate, meshes fine to medium-sized, muri thin.



Text-figure 7—*Lunatisporites paliensis* sp. nov. showing complete to incomplete, broad, thick, band-like massive taeniae and coarse reticulation on them.

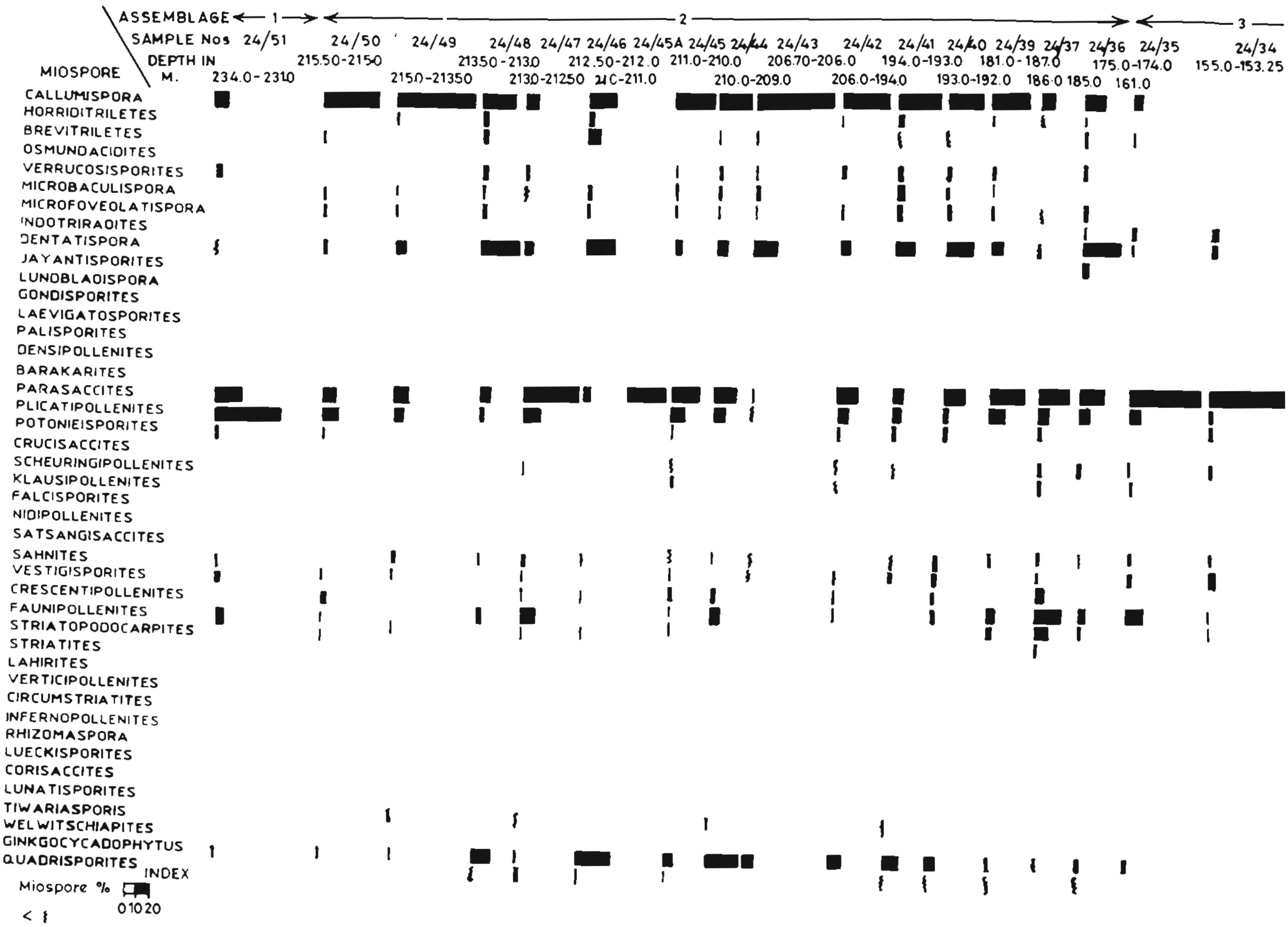
Description—Sacci hemispherical or less than hemispherical imparting a subcircular to oval outline to the grains. Taeniae massive, thick, strip-like and incomplete to complete with relation to the body width. Intrareticulation of sacci and that of the taeniae giving more or less similar pattern of structure indicating the comparable development as sexinal layers. Body outline very thin or ill-defined. Sacci structure exhibiting fine intrareticulate structure.

Comparison—Among the known species of this genus, *L. diffusus* and *L. rhombicus* (Bharadwaj & Tiwari 1977) have diffused and rhomboidal central body, respectively; *L. asansoliensis* Tiwari & Rana 1981 differs from the present species in having ± vertically elongated body with a thick equatorial rim around it. *L. asulcus* described by Bose and Kar (1966) possesses a distinct central body with prominent lunar folds along the distal attachment of saccus in the body. The present species differs from all the known species in having almost indistinct central body, thick, massive, complete to incomplete taeniae and the absence of typical lunar folds along the zones of saccus attachment.

Derivation of name—After Pali Village, the type area from where the present species has been described.

PALYNOSTRATIGRAPHY

In all, three bore-cores have been quantitatively studied for their palynological succession. The details are given below:



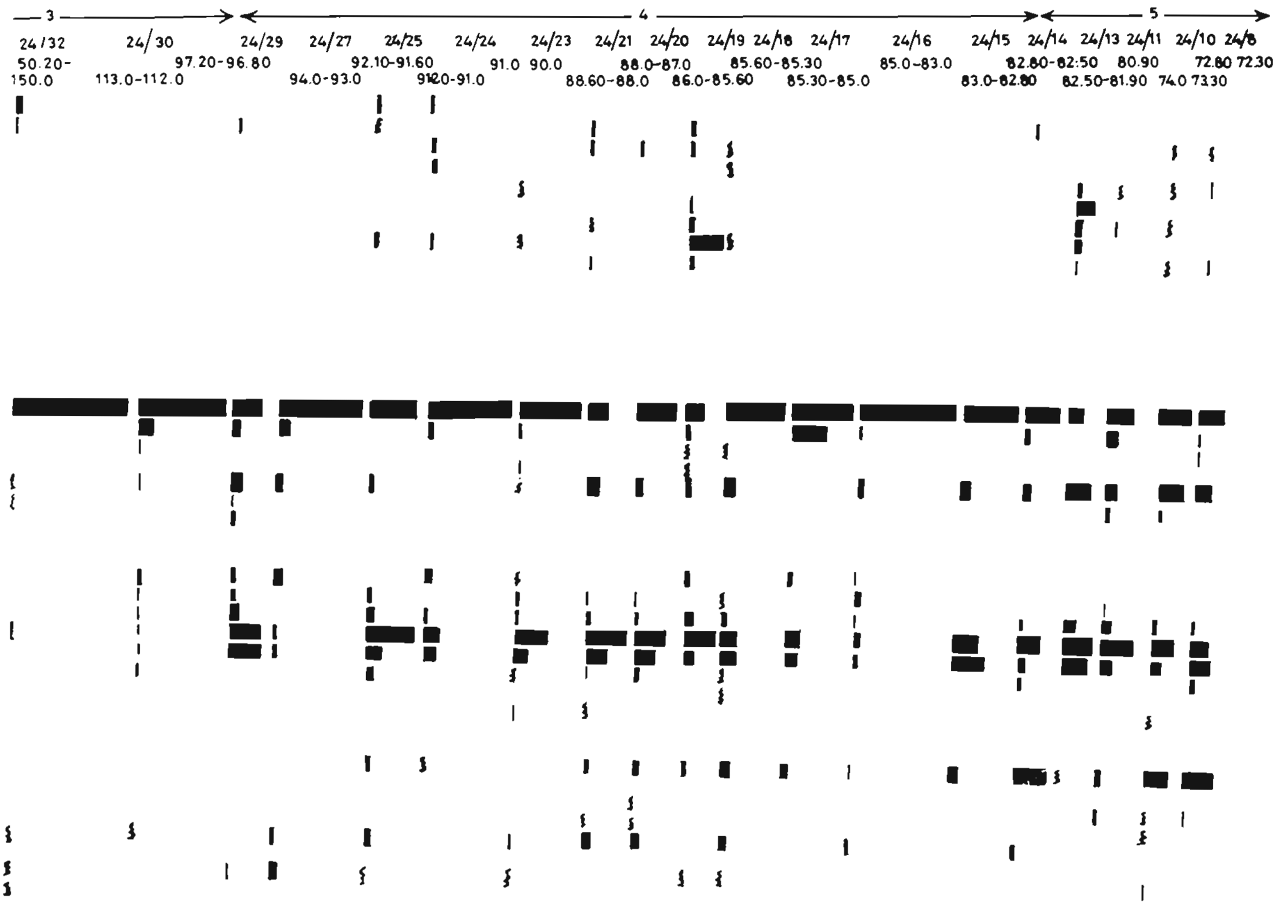
Histogram 1—Percentage frequency of important miospore genera through bore-hole JHL-24.

Bore-hole JHL-23—From this bore-hole, 79 samples were macerated (depth from surface 150.00-348.00 m), out of which 45 samples were found to be productive. On the basis of qualitatively as well as quantitatively significant genera five palynological assemblages have been identified (Histogram 2). In the following tables, palynological assemblages have been delimited and details, like depth of the samples, quantitatively dominating as well as important genera and rare but qualitatively significant genera, are given:

Assemblage nos.	*Depth in meter*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
5	183.0-150.0	*Parasaccites, Faunipollenites, Striatopodocarpites*	*Crescentipollenites, Verrucosisporites, Klausipollenites*	Raniganj
4	220.80-183.0	*Faunipollenites, Striatopodocarpites, Parasaccites*	*Scheuringipollenites, Crescentipollenites, Striatites, Indotriradites*	Barakar
3	283.0-220.80	*Callumispora, Plicatipollenites*	*Verrucosisporites, Microbaculispora, Crescentipollenites, Ginkgocycadophytus*	Upper Karharbari
2	247.80-286.00	*Parasaccites, Plicatipollenites, Callumispora*	*Potonieisporites, Scheuringipollenites, Microbaculispora*	Lower Karharbari
1	0-348.00	*Dentatispora, Parasaccites*	*Brevitriletes, Verrucosisporites, Striatopodocarpites, Potonieisporites*	Talchir

Bore-hole JHL-24—In this bore-hole, out of 51 samples 37 samples yielded pollen and spores (depth 72.30-234.0 m from the surface, Histogram 1). The palynological assemblages have been grouped into five zones as under:

Assemblage nos.	*Depth in meter*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
5	82.80-72.30	*Striatopodocarpites, Faunipollenites, Rhizomaspora*	*Scheuringipollenites.*	Raniganj
4	97.20-83.0	*Parasaccites, Faunipollenites,*	*Indotriradites, Scheuringipollenites*	Barakar



Histogram 1—*Contd*

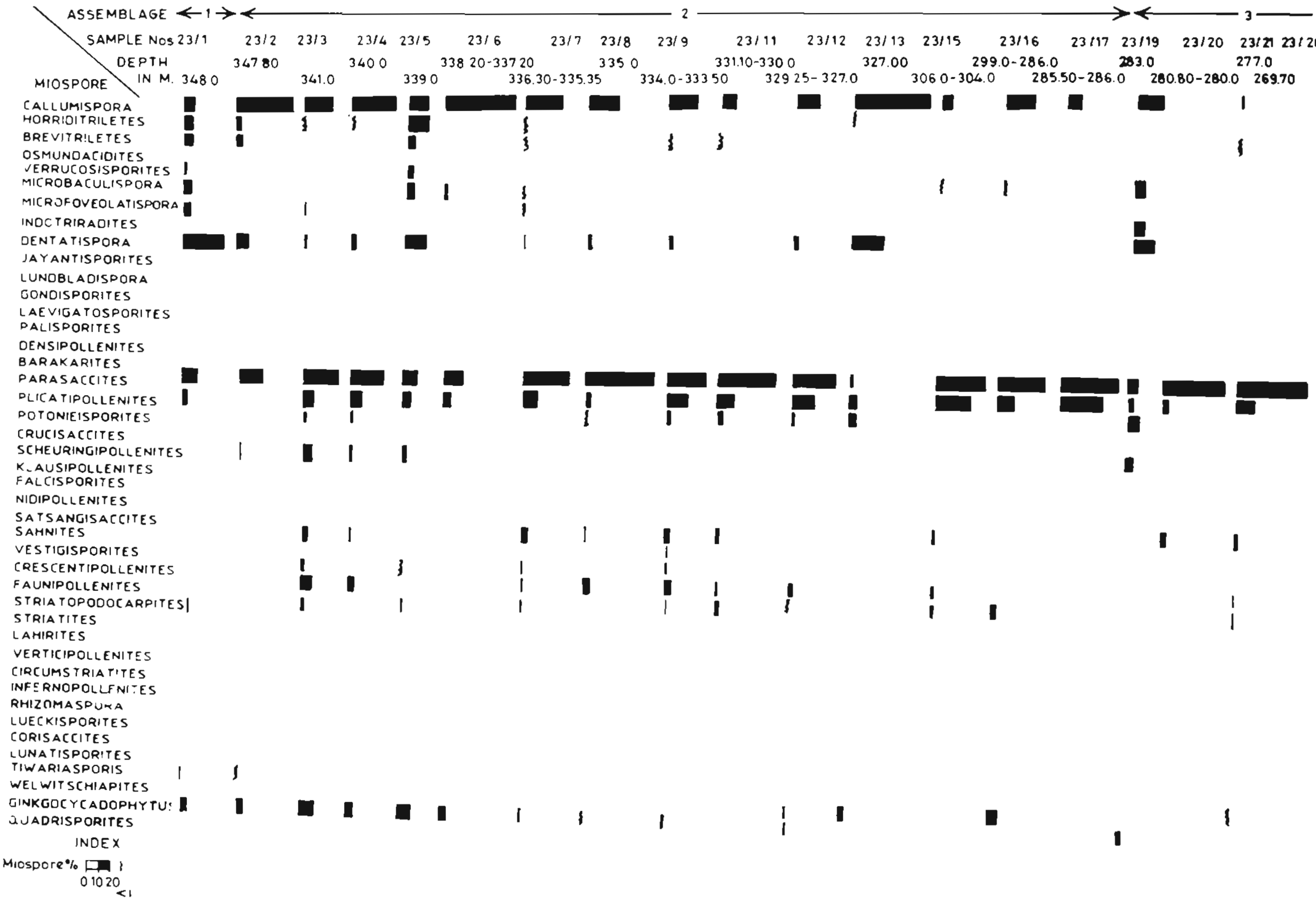
		Striatopodocarpites		
3	213.0-161.0	*Parasaccites, Callumispora*	*Callumispora, Microfoveolatispora, Faunipollenites, Horriditriletes, Brevitriletes, Striatopodocarpites, Faunipollenites*	Upper Karharbari
2	215.50-213.0	*Callumispora, Plicatipollenites, Parasaccites*	*Microbaculispora, Scheuringipollenites, Brevitriletes*	Lower Karharbari
1	234.0-231.0	*Plicatipollenites, Parasaccites*	*Callumispora, Verrucosisporites, Ginkgocycadophytus*	Talchir

Bore-hole JHL-25—From this bore-hole, 15 samples have been macerated out of which nine samples yielded (depth from surface 190.0-37.0 m). After a critical study of palynological contents they have been grouped into three aseemblages, as given below (Histogram 3).

Assem-blage nos.	*Depth in meter*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
3	65.0-37.0	*Parasaccites, Faunipollenites, Crescentipollenites*	*Callumispora, Verrucosisporites, Dentatispora*	Barakar
2	135.75-65.0	*Parasaccites, Plicatipollenites*	*Verrucosisporites, Indotriradites, Scheuringipollenites, Faunipollenites*	Upper Karharbari
1	190.0-180.0	*Callumispora*	*Dentatispora, Parasaccites, Plicatipollenites*	Lower Karharbari

Beside the above bore-cores, about 175 outcrop samples were also macerated from Johilla River Section, Ganjra Nala Section and Kamari Nala (locally known as Ghorari Nala) Section. The palynological details of each section and their palynozonations are given below

Johilla River Section—Sixty samples have been macerated out of which only 17 samples yielded the miospores. On the basis of this analysis following six palynological assemblages have been delimited (Histogram 5).



Histogram 2—Percentage frequency of important miospore genera through bore-hole JHL-23.

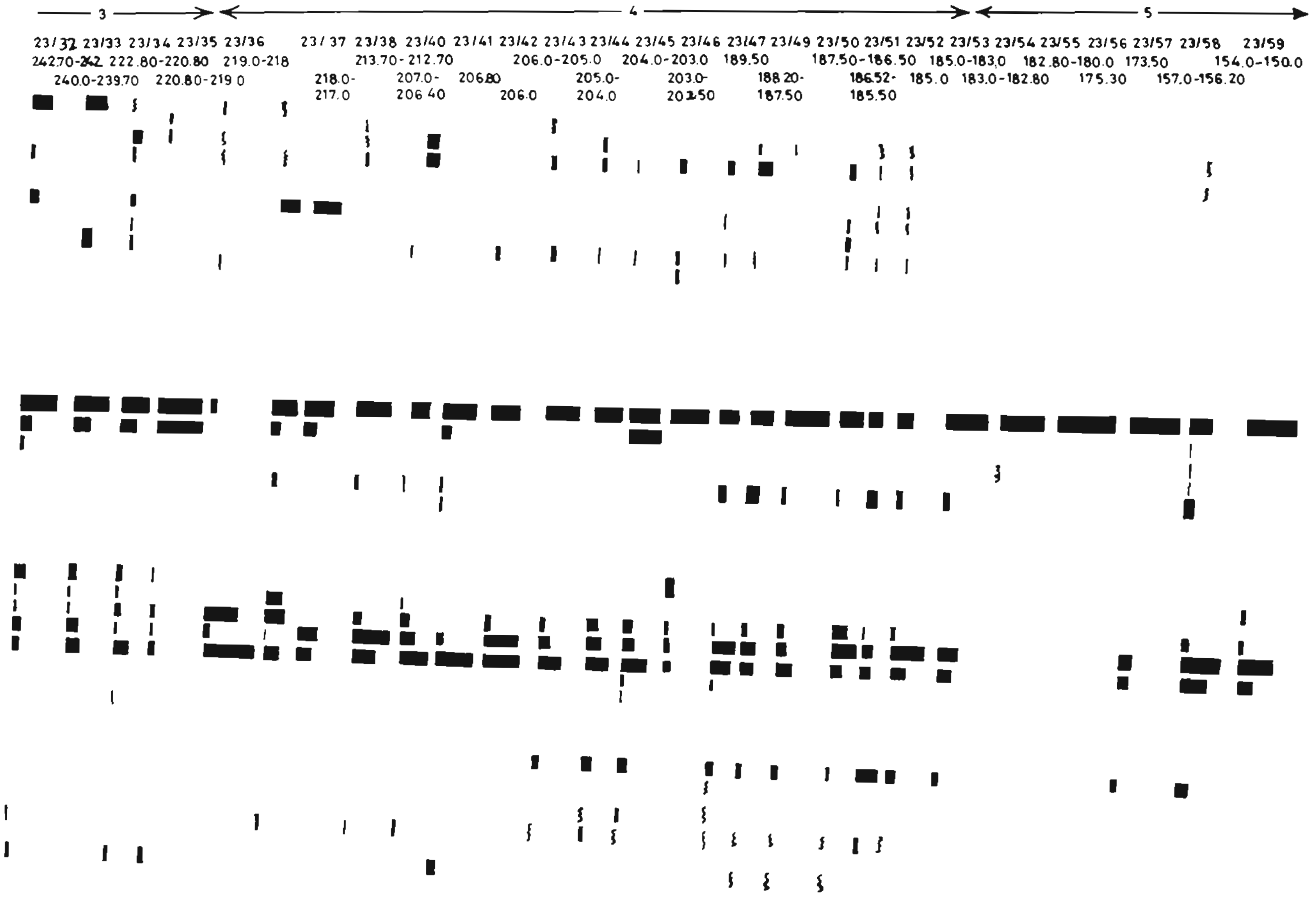
Assemblage nos.	*Sample nos.*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
J-VI	C7, C7/1	*Faunipollenites, Striatopodocarpites*	*Lundbladispora, Gondisporites, Scheuringipollenites, Lueckisporites*	Permian/ Triassic
J-V	Jo-15, Jo-14, Jo-13	*Parasaccites, Faunipollenites*	*Verrucosisporites, Dentatispora*	Upper Barakar
J-IV	JR-10, JR-15	*Callumispora, Dentatispora, Plicatipollenites*	*Brevitriletes, Horriditriletes, Crescentipollenites, Faunipollenites*	Upper Karharbari
J-III	JR 2, 3, 4 5, 6, 7, 8 9, 11	*Parasaccites, Plicatipollenites, Faunipollenites, Striatopodocarpites*	*Callumispora, Scheuringipollenites, Horriditriletes, Crescentipollenites*	Talchir
J-II	JR-2	*Parasaccites*	*Plicatipollenites, Crescentipollenites, Faunipollenites, Striatopodocarpites*	Talchir
J-I	Jo-019	*Parasaccites, Plicatipollenites*	*Sahnites, Striatopodocarpites*	Talchir

Ganjra Nala Section—Forty samples were macerated out of which only 3 samples yielded spores and pollen. The single palynological assemblage identified here is dominated by the genus *Parasaccites* and *Striatopodocarpites.*

Assemblage nos.	*Sample nos.*	*Quantitatively important genera*	*Rare but qualitatively significant genera*	*Horizon*
1	GN-33, 35, 36	*Parasaccites, Striatopodocarpites, Faunipollenites*	*Plicatipollenites, Scheuringipollenites, Klausipollenites, Crescentipollenites*	Upper Barakar

CORRELATION

After delimiting various assemblages in the three bore-holes and two out-crop sections as well as Bore-hole JHL-27A and UKD-8 (Tiwari & Ram-Awatar, 1986, 1987b) a relationship amongst these assemblages have been established which is mainly based on the dominance and subdominance of various taxa. Six successive palynological zones (A to F) have been recognised.



Histogram 2—*Contd.*

Palynological Zone-A

It includes Assemblage-1 of Bore-hole no. JHL-24 and Assemblages J-I, J-II, J-III of Johilla River Section. Quantitatively important taxa are: *Parasaccites* and *Faunipollenites*, while qualitatively *Callumispora* is an important taxon.

Diagnostic features—This assemblage is poor in overall diversification. The monosaccates are in dominance; triletes and striate-disaccates are rare. The genus *Callumispora* is present but not so effective in its incidence.

Palynological Zone-B

It incorporates the following assemblages:

(i) Assemblage-1, 2 of Bore-hole no. JHL-23
(ii) Assemblage-2, 3 of Bore-hole no. JHL-24
(iii) Assemblage-1 of Bore-hole no. JHL-23
(iv) Assemblage-J-IV of Johilla River Section (Pars.)

The quantitatively important taxa are: *Dentatispora, Parasaccites, Ginkgocycadophytus, Callumispora, Plicatipollenites,* while qualitatively important taxa are: *Microbaculispora, Faunipollenites, Quadrisporites, Dentatispora* and *Ginkgocycadophytus.*

Diagnostic features—This assemblage is characterized by the dominance of smooth and zonate triletes and subdominance of girdling monosaccates. A few striate-disaccate and non-striate disaccate are also common.

Palynological Zone-C

Two assemblages, as given below, are included in this zone:

(i) Assemblage-3 of Bore-hole no. JHL-23
(ii) Assemblage-2 of Bore-hole no. JHL-25

Quantitatively, the taxa *Callumispora, Brevitriletes, Verrucosisporites, Faunipollenites, Sahnites and Vestigisporites* are important for this level.

Diagnostic features—In this palynological zone, the girdling monosaccates are in dominance, while

Callumispora is relatively less represented; non-striate-disaccates with monolete mark are also significant.

Palynological Zone-D

This zone includes the following assemblages:
(i) Assemblage-4 of Bore-hole no. JHL-23
(ii) Assemblage-4 of Bore-hole no. JHL-24
(iii) Assemblage-3 of Bore-hole no. JHL-25
(iv) Assemblage-J-V of Johilla River Section
(v) Assemblage-1 of Ganjra Nala Section

Quantitatively the important identified taxa in this zone are: *Faunipollenites, Striatopodocarpites, Crescentipollenites, Parasaccites, Plicatipollenites,* while qualitatively important taxa are *Scheuringipollenites* and *Faunipollenites.*

Diagnostic features—In this palynological zone, the striate-disaccates are in dominance and taeniate-disaccates are in common occurrence. The monosaccates are rare but varied.

Palynological Zone-E

This zone includes the following assemblages:
(i) Assemblage-5 of Bore-hole no. JHL-23
(ii) Assemblage-5 of Bore-hole no. JHL-24
(iii) Assemblage-1 of Bore-hole no. UKD-8 (Tiwari & Ram-Awatar, 1987b)
(iv) Assemblage-1 of Bore-hole no. JHL-27A (Tiwari & Ram-Awatar, 1986)

Here the quantitatively important taxa are represented by *Faunipollenites, Striatopodocarpites, Barakarites, Scheuringipollenites* and *Parasaccites* while qualitatively important taxa are *Ibisporites, Rhizomaspora, Infernopollenites, Densipollenites, Gondisporites* and *Microfoveolatispora.*

Diagnostic features—This zone is dominated by striate-disaccates, while monosaccates are less significant, in general, the trilete spores exhibit a declined percentage.

Palynological Zone-F

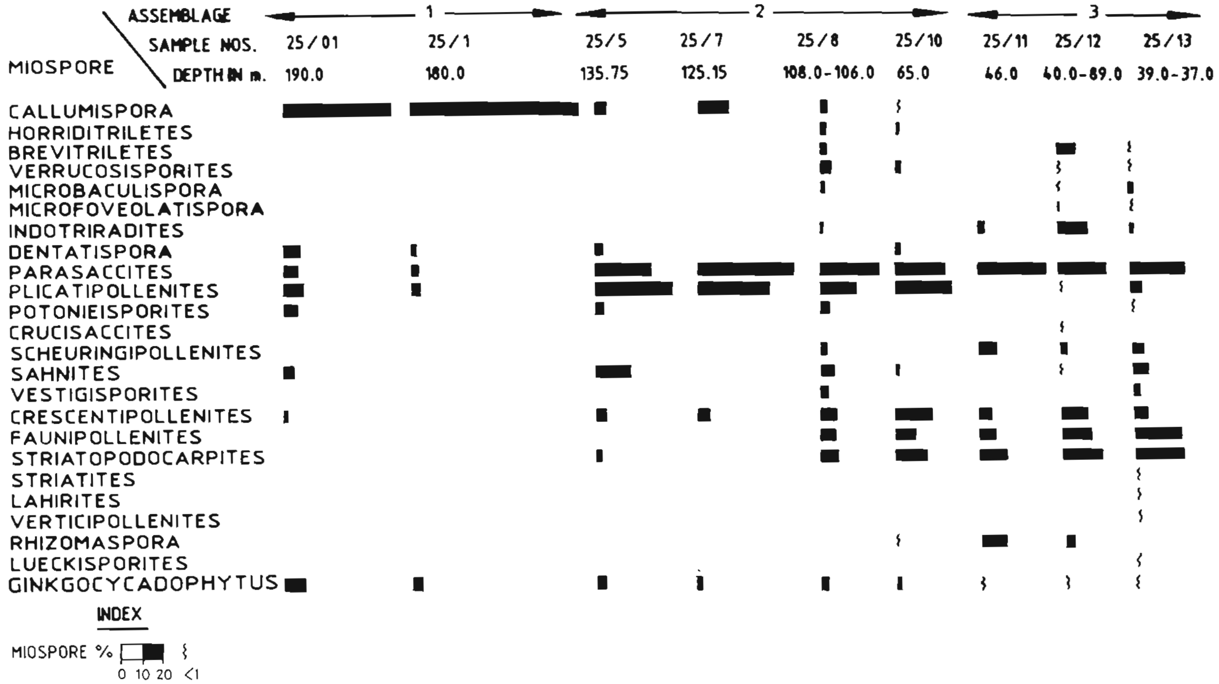
This zone is composed of two assemblages:
(i) Assemblage J-VI of Johilla River Section
(ii) Assemblage-2 of Bore-hole no. UKD-8 (Tiwari & Ram-Awatar, 1987b)

The taxa such as *Faunipollenites, Crescentipollenites, Striatopodocarpites, Parasaccites, Callumispora, Densipollenites, Satsangisaccites* are quantitatively prominent while *Klausipollenites* is significant.

Diagnostic features—In this zone striate-disaccates are in dominance. The apiculate, zonate triletes are also present but the monosaccates are poor in frequency.

DISCUSSION

The identification of 58 genera and 126 species of pollen and spores in the palynological



Histogram 3—Percentage frequency of important miospore genera through bore-hole JHL-25.

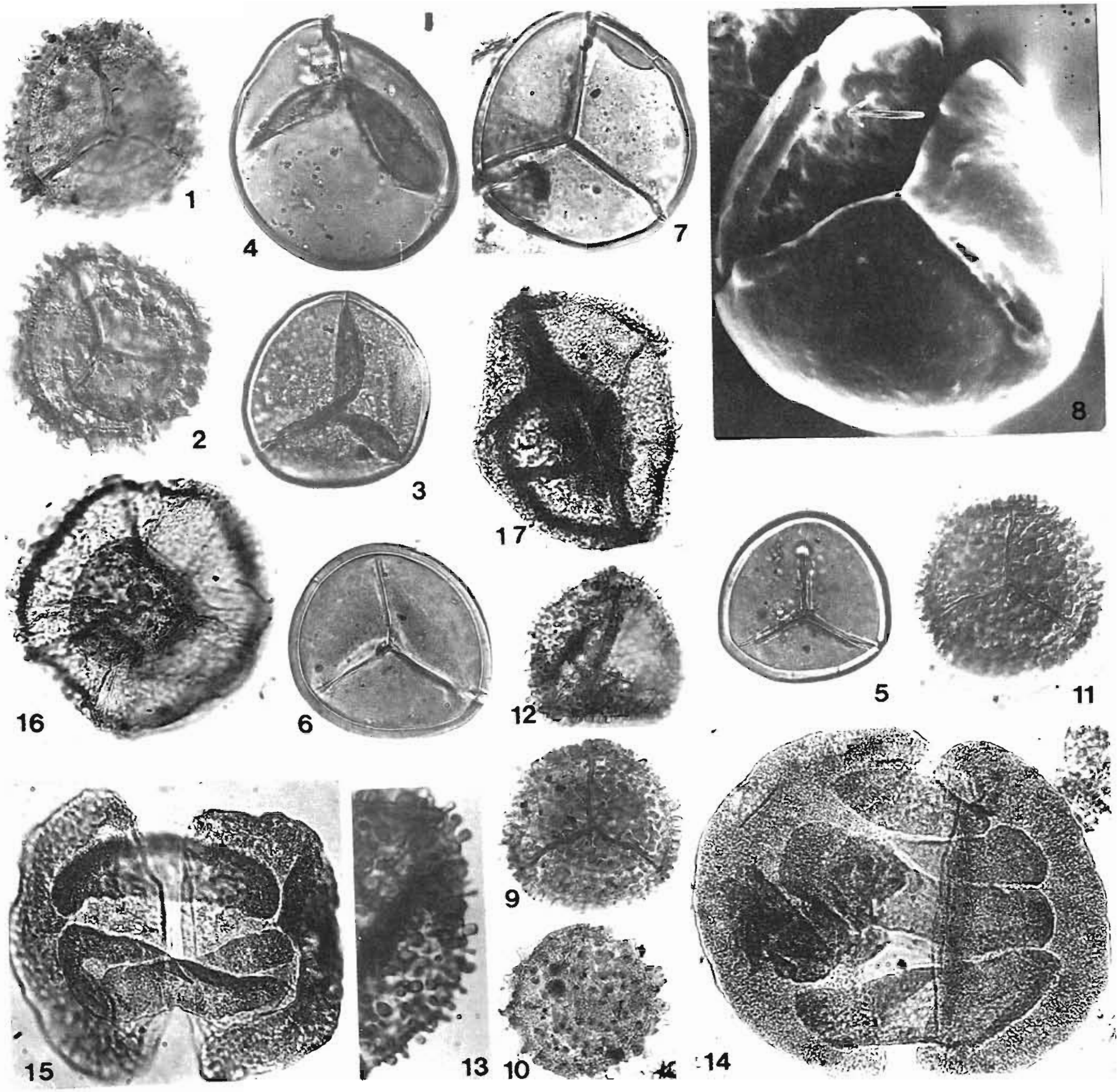


PLATE 1

(All photomicrographs are enlarged ca × 500)

1, 2. *Dentatispora reticulata* sp. nov.—1. Holotype, slide no. BSIP 9304; 2. Same specimen under differential interference phase contrast showing the distinct intrareticulate structure on the surface.

3, 4. *Callumispora saksenae* sp. nov.—3. Holotype, slide no. BSIP 9309; 4. Specimen under normal light, slide no. BSIP 9311.

5-8. *Callumispora paliensis* sp. nov.—5. Holotype, slide no. BSIP 9308; 6, 7. Specimens under normal light, slide no. BSIP 9309; 8. Scanning electron micrograph of a specimen showing the nature of puncta and smooth nature of exine with few specks; also a partly open portion (arrow) shows the internal structure of the exine within the spore cavity × 1500; slide no. BSIP 9309.

9-11. *Dentatispora mammoida* sp. nov.—9. Holotype, slide no. BSIP 9307; 11. Same specimen under differential interference phase contrast showing the nipple-like scluptural elements; 10. Specimen under normal light, slide no. BSIP 9310.

12, 13. *Osmundacidites baculatus* sp. nov.—12. Holotype, slide no. BSIP 9052; 13. An enlarged portion of fig. 12, showing the finger-shaped bacula. × 750; slide no. BSIP 9052.

14, 15. *Lunatisporites paliensis* sp. nov.—14. Holotype, slide no. BSIP 9305; 15. A specimen under normal light, slide no. BSIP 9305.

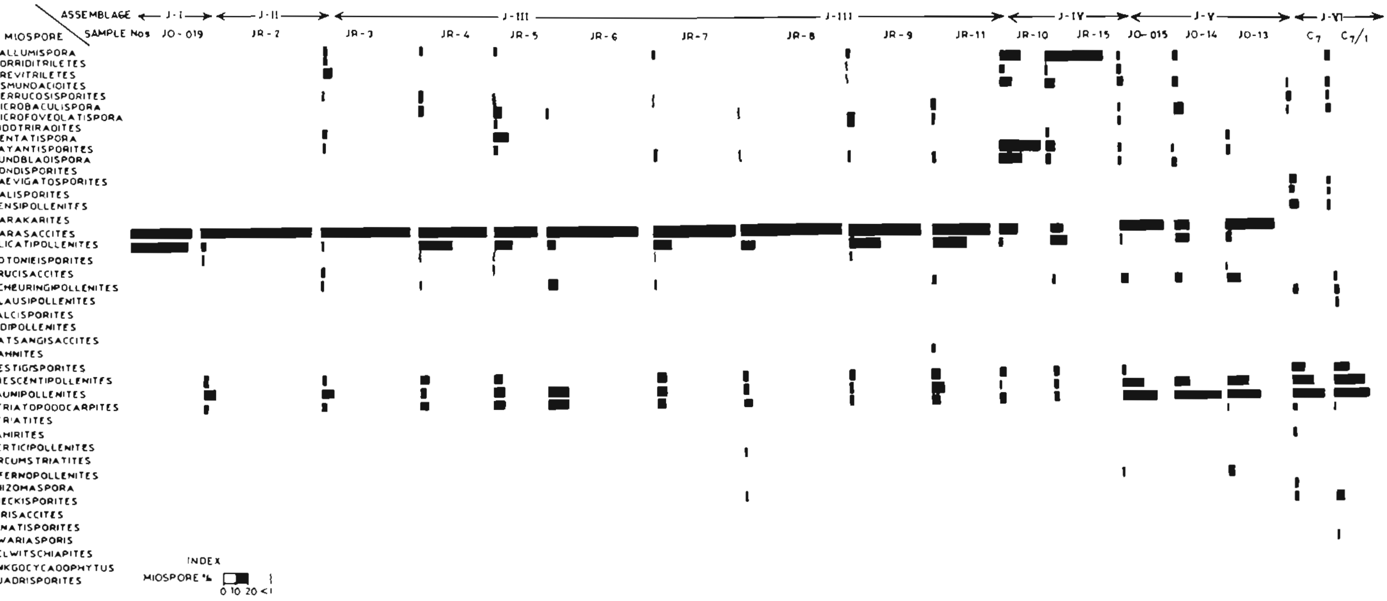
16, 17. *Gondisporites reticulatus* sp. nov.—16. Holotype, slide no. BSIP 9055; 17. Specimen showing the reticulate pattern on the surface, slide no. BSIP 9053.

Table 6—Distribution chart of different species in palynological zones A-F

PALYNOTAXA	**Zone A** TALCHIR (Early Permian)	**Zone B** LOWER KARHARBARI (Early Permian)	**Zone C** UPPER KARHARBARI (Early Permian)	**Zone D** UPPER BARAKAR (Late Permian)	**Zone E** MIDDLE PALI (Late Permian)
Plicatipollenites triagonalis	+				
Plicatipollenites distinctus	+				
Virkkipollenites densus	+				
Potonieisporites triangulatus	+				
Crucisaccites monoletus	+				
Crucisaccites indicus	+				
Vestigisporites diffusus	+				
Horriditriletes curvibaculosus	+				
Rhizomaspora monosulcata	+	+			
Callumispora barakarensis	+	+			
Callumispora tenuis	+	+			
Dentatispora indica	+	+			
Jayantisporites pseudozonatus	+	+			
Parasaccites diffusus	+	+			
Parasaccites bilateralis	+	+			
Circumstriatites talchirensis	+	+			
Faunipollenites goraiensis	+	+			
Brevitriletes unicus	+	+			
Sahnites gondwanensis	+	+			
Callumispora tenuis var. *minor*	+	+			
Callumispora gretensis	+	+	+		
Callumispora fungosa	+	+	+		
Callumispora paliensis	+	+	+		
Callumispora saksenae	-	+	+		
Primuspollenites levis		+	+		
Primuspollenites lintrus		+	+		
Verrucosisporites narmianus		+	+		
Horriditriletes novus		+	+		
Horriditriletes bulbosus		+	+		
Horriditriletes ramosus		+	+		
Horriditriletes concavus	+	+	+		
Godavarisporites indicus		+	+		
Insignisporites barakarensis		-	+		
Microbaculispora tentula			+		
Didecitriletes horridus			+		
Microfoveolatispora trissina			+		
Microfoveolatispora media			+		
Microfoveolatispora foveolata			+		
Lacinitriletes badamensis			+		
Imparitriletes korbaensis			+	+	
Brevitriletes communis			+	+	
Pseudoreticulatispora barakarensis			+	+	
Dentatispora mammoida			+	+	
Dentatispora superba			+	+	
Dentatispora gondwanensis		+		+	
Dentatispora reticulata			+	+	
Indotriradites korbaensis			+	+	
Parasaccites korbaensis			+	+	
Parasaccites distinctus			+	+	
Parasaccites densicorpus			+	+	
Plicatipollenites indicus			+	+	
Plicatipollenites densus			+	+	
Plicatipollenites gondwanensis			+	+	
Potonieisporites congoensis			+	+	
Potonieisporites crassus			+	+	
Caheniasaccites indicus			+	+	
Sahnites mathoris				+	
Sahnites elilaensis				+	
Vestigisporites densus				+	
Scheuringipollenites barakarensis				+	
Scheuringipollenites maximus				+	
Scheuringipollenites tentula				+	
Ibisporites jhingurdahiensis				+	+

Table 6—Contd.

			Zone F MIDDLE PALI UPPER PART (Permian/Triassic)
Ginkgocycadophytus cymbatus	+	+	
Ginkgocycadophytus deterius	+	+	
Ginkgocycadophytus korbaensis	+	+	
Ginkgocycadophytus novus	+	+	
Quadrisporites horridus	+	+	
Primuspollenites singrauliensis	+	+	
Striatopodocarpites ovatus	+	+	
Horriditriletes brevis	+	+	
Horriditriletes rampurensis	+	+	
Microbaculispora indica	+	+	
Microbaculispora barakarensis	+	+	
Indotriradites sparsus	+	+	
Sahnites barrelis	+	+	
Ibisporites diplosaccus	+	+	
Rhizomaspora indica	+	+	
Rhizomaspora costa	+	+	+
Faunipollenites bharadwajii	+	+	+
Striatopodocarpites diffusus	+	+	+
Striatopodocarpites decorus	+	+	+
Verticipollenites gibbosus	+	+	+
Labirites parvus	+	+	+
Crescentipollenites fuscus	+	+	+
Crescentipollenites notabilis	+	+	+
Crescentipollenites magnicorpus	+	+	+
Lunatisporites pellucidus	+	+	+
Lunatisporites paliensis	+	+	+
Tiwariasporis indicus	+	+	+
Tiwariasporis flavatus		+	+
Gondisporites raniganjensis		+	+
Laevigatosporites colliensis		+	+
Densipollenites densus		+	+
Densipollenites magnicorpus		+	+
Playfordiaspora cancellosa		+	+
Striamonosaccites ovatus		+	+
Rhizomaspora fimbriata		+	+
Faunipollenites various		+	+
Faunipollenites perexiguus		+	+
Striatopodocarpites tiwarii		+	+
Distriatites insolitus		+	+
Distriatites bilateralis		+	+
Guttulapollenites hannonicus		+	+
Corisaccites alutas		+	+
Labirites karanpuraensis		+	+
Verrucosisporites verrucosus		+	+
Cyclogranisporites gondwanensis		+	+
Barakarites triquetrus		+	+
Striomonosaccites invisus		+	+
Satsangisaccites nidpurensis		+	+
Infernopollenites janarensis		+	+
Welwitschiapites tenuis			+
Gondisporites indicus			+
Densipollenites invisus			+
Osmundacidites pilatus			+
Osmundacidites senectus			+
Densipollenites indicus			+
Gondisporites reticulatus			+
Falcisporites stabilis			+
Klausipollenites vestitus			+
Klausipollenites sulcatus			+
Lundbladispora brevicula			+
Lundbladispora microconata			+
Lundbladispora raniganjensis			+
Weylandites indicus			+
Striatites subtilis			+



Histogram 4—Percentage frequency of important miospore genera in Johilla River Section.

assemblages described above indicates their diversified nature. The presence of several new taxa indicates the characteristic feature of vegetational components in Johilla Valley.

The palynological dating of Pali beds in the Supra-Barakar Formation has been a significant outcome of this study. The palynological assemblage found in the coal beds of Pali (in subsurface samples) has been dated to be Late Permian, while beds exposed in between Dargaon and Salaia villages contain a Permian/Triassic transitional palynoflora (Tiwari & Ram-Awatar, 1986, 1987a; Ram-Awatar, 1988). The assemblages described here (Assemblage A to F) represent Talchir, Lower and Upper Karharbari, Upper Barakar, middle Middle Pali Member and uppermost Middle Pali Member respectively.

Relationship between Umaria, Korar and Johilla coalfields—A comparison of palynoassemblages from Johilla, Umaria and Korar coalfields of Son Valley shows a close correlation in composition. In Lower Permian the monosaccate pollen are dominating, while few striate-disaccates are also present. In view of this data, the presently designated Palynological Zone-A is dated to be of Early Permian age because this assemblage is dominated by monosaccate genera, viz., *Parasaccites, Plicatipollenites* and the trilete genus *Callumispora*. The Assemblage-A described in this paper, thus, corresponds the mioflora described by Potonié and Lele (1961) from the locality of Goraia, and Assemblage Zone-A of Chandra and Lele (1979) in the Johilla Coalfield; so also the assemblage reported by Lele and Chandra (1969, 1972) from Umaria Coalfield had a closer affinity.

Palynological Zone-B, equated to the Lower Karharbari mioflora, contains *Callumispora* as a dominating taxon followed by *Parasaccites* and *Plicatipollenites*, zonate, non-striate and striate-disaccate forms. The Zone-B, thus, resembles the mioflora described by Lele and Maithy (1969) and Saksena (1971) from Ganjra Nala Section and Anand-Prakash and Srivastava (1984) from Pali coalmine; palynoflora described by Chandra and Srivastava (1986) from this area also compares closely. It also resembles the flora described by Maithy (1966), and Zone-1 of Srivastava and Anand-Prakash (1984) in Umrar River near Jawalamukhi Temple, except that *Dentatispora* is replaced by *Jayantisporites*.

Palynological Zone-C, as designated here, is equated with Upper Karharbari which resembles the palynoflora described by Lele and Maithy (1969), Saksena (1971), and Zone-2 proposed by Anand-Prakash and Srivastava (1984) from this region.

Palynological Zone-D, consisting of *Striatopodocarpites, Faunipollenites, Scheuringipollenites*, etc., has been dated as Upper Barakar and compared with miofloral assemblage of Jhingran, (1979). So also, palynological Zone-4 of Anand-Prakash and Srivastava (1984) from Johilla Coalfield has a correspondence with Zone-D of present paper.

The palynoflora yielded from Pali Formation (Late Raniganj) contains mainly striate forms (more than 80%) with rare occurrence of zonate and triletes grains; this zone closely resembles Assemblage-1 of Tiwari and Ram-Awatar (1986) from Bore-hole no.

JHL-27A, Johilla Coalfield (Palynological Zone-E). It is also comparable with Assemblage-1 of Tiwari and Ram-Awatar (1987b) from Korar Coalfield (Bore-hole no. UKD-8).

Palynological Zone-F, dominated by *Faunipollenites, Striatopodocarpites* and some younger elements like—*Nidipollenites* and *Klausipollenites*, has been dated to be Permian/Triassic. It shows resemblance with Assemblage J-VI of Tiwari and Ram-Awatar (1987a). To some extent, the Assemblage-2 of Tiwari and Ram-Awatar (1987b) from Bore-hole no. UKD-8, Korar Coalfield, also shows similarity with Zone-F.

Comparison with other basins

As such, this area of Son Valley has similar palynological history in its older horizons (i.e., Talchir and Karharbari) when compared with Damodar Basin, while in the upper horizons, i.e., Barakar and Supra-Barakar (Pali), the constituents of the assemblage show considerable differences. The Talchir mioflora is dominated by monosaccates, as in the case of Damodar Valley, Satpura Gondwana and Mahanadi basins (Lele, 1975; Lele & Karim, 1971; Lele & Makada, 1972; Bharadwaj & Srivastava, 1973; Srivastava, 1973; Bharadwaj & Anand-Prakash, 1972).

In case of Talchir palynoflora, in the Johilla Coalfield (Assemblage J-I, J-II, J-III in Histogram-IV and Assemblage-1 of Bore-hole no. JHL-24) it is evident that the genus *Parasaccites* is outstanding in percentage. It is also interesting to note that the disaccates, on the whole, are meagre in this assemblage.

As in other basins, the general trends of the monosaccate decline in the Lower Karharbari (where *Callumispora* increases), and their rise in the Upper Karharbari have been recorded in Johilla Coalfield also (cf. Bharadwaj & Srivastava, 1973; Tiwari, 1973; Srivastava, 1973; Srivastava, 1980). However, certain trends of variation have been observed here, viz., unlike other basins, the genus *Ginkgocycadophytus* (and to a certain extent *Quadrisporites*) shows a well-marked presence in Lower Karharbari. The genus *Dentatispora* has a very good representation in these beds, while it is not so in other basins where this group of spores occurs in the younger horizon. In the Upper Karharbari (Assemblage-4 of Bore-hole no. JHL-24) of the presently studied succession, the assemblage is totally dominated by *Parasaccites* while most of the triletes and striate-disaccate grains have declined. This is a major difference when compared to the other areas where normally the complexity of pollen contents increases in the Upper Karharbari.

The Barakar palynoflora is diversified, both quantitatively as well as qualitatively, in all the basins of India, and broadly speaking the assemblages of Johilla Coalfield at this level also have a closer resemblance with them (Tiwari, 1973; Srivastava, 1973; Kar, 1973, Bharadwaj & Tripathi, 1978; Bharadwaj, Navale & Anand-Prakash, 1974; Srivastava & Anand-Prakash, 1984). However, there are certain changes in the behaviour of some palynofossils which qualify the present assemblage. The presence of taeniate forms like—*Lunatisporites paliensis* sp. nov., shows a peculiar condition for Johilla River Section, because in other basins taeniate forms are found only in the Late Permian and Triassic horizons. Similarly, the zonate cingulate trilete spores are relatively less represented in the presently studied Barakar samples. The monosaccate genus *Parasaccites* continues to be quite significant even in Barakar Formation of Johilla Coalfield, while it is not the case in other basins. This indicates a lingering on of the cooler effect of the older condition even into the Barakar Formation in this basin.

The palynoflora from Pali, designated here to be of Raniganj equivalent, resembles those of Upper Permian from other basins (Bharadwaj 1962; Bharadwaj & Tiwari, 1977; Kumaran & Maheshwari, 1980; Tiwari & Rana, 1980) in the prominence of striate-disaccate pollen grains. However, the genus *Infernopollenites* makes the Pali Assemblage a peculiar palynoflora, as no where else such a combination has been found so far. The absence of *Indospora, Thymospora* and *Gondisporites* and the presence of *Brachysaccus, Densipollenites, Lunatisporites*, etc. further make the present assemblage different from other comparable assemblages.

The assemblage from upper part of Pali Formation contains a variety of miospores. The dominating elements are mainly striate-disaccate in which it resembles Late Raniganj assemblage (Bharadwaj, 1962; Bharadwaj & Salujha, 1964; Bharadwaj, Tiwari & Anand-Prakash, 1979). Besides, some younger elements like—*Lundbladispora, Guttulapollenites, Nidipollenites, Satsangisaccites* are also present in this assemblage which are definite indicators of younger aspect. Therefore, the Palynological Zone-F is correlatable with the Permian-Triassic transitionary phase (see Bharadwaj & Tiwari, 1977; Maheshwari & Banerji, 1975; Rana & Tiwari, 1980; Tiwari & Singh, 1983).

The distribution of various species in Palynological Zones-A to F has been plotted (Table 6). The picture thus obtained clearly depicts a systematic and synchronised mode of qualitative occurrence. This corroborates with the quantitative results obtained in the present analysis. Identity of each zone, characteristic for each level of formation, is thus established through specific distributional determination.

PALAEOGEOGRAPHY AND PALAEOCLIMATE

During Permian and Triassic times, India was still a part of Gondwanaland, including Africa, Antarctica, South Africa and Australia (Dietz & Holden, 1970). The initial rifting of continents probably occurred in Jurassic and Lower Cretaceous time (Smith & Hallam, 1970).

As we are concerned mainly with the Permian and Early Triassic times, it is significant to note that the peninsular India laid between 50° and 70° south latitude during the Permo-Carboniferous times; in Late Permian times most of it remained in this belt except for its north-western portion which extended up to 40° south of equator. It is also envisaged that during the Triassic time, the present eastern part of India was situated between 60°-55° latitude and rest between 52°-30° south. The shifting has apparently taken place due to rotation of continents as well as the polar wandering (McElhinny, 1973; Bharadwaj, 1976). It is presumed from this situation that most of the peninsular India must have had a cold climate during the Permian time, but a little less cold or even warm during the Triassic time. The South Rewa Gondwana Basin occupies a position at an angle formed by the chain of Damodar Valley coalfields as one arm and the Son-Mahanadi Valley coalfields as the other arm. These two valleys were separated by a highland, named as "Fox-ridge". On the northern as well as southern side of these valleys also two highlands existed (Ahmad, 1961). Such physical barriers and the latitudinal difference were responsible for the variance in the palynoflora of Damodar and Son Valley basins. The South Rewa Basin lays in the lowland along with other basins and these low lying areas were partly connected with sea, as it has been evidenced in the Umaria, Manendragarh, Daltonganj and other places of the Peninsular India.

The sedimentation in Johilla Coalfield also started with the deposition of Tillite of the Talchir Formation. As in other coal-basins, here also the miospore assemblage from the Talchir is dominated by monosaccates suggesting a resemblance of climate with other similar areas having mainly glacial and fluvio-glacial environmental conditions (Lele & Chandra, 1972; Srivastava, 1973; Kar, 1976).

The dominance of the genus *Callumispora* in the assemblage comparable to Lower Karharbari suggests that influence of cold climate was decreasing. However, in the Upper Karharbari the *Parasaccites* again came into prominence suggesting a cooler climate once again (Bharadwaj, 1975). These cycles have also been supported by the present study. The coal-bearing Barakar Formation records the upsurge of trilete forms but the monosaccates continue to be relatively abundant; moreover, the diversity in kinds has also increased tremendously in this phase of deposition. This observation is in accordance with rest of the records known from Damodar Basin and other areas (Tiwari, 1973). Thus, in Barakar the intensive cold climate was replaced by the relatively warmer climate. The massive coal deposits point out that the climate must have been humid and palynological study indicates a diversity and richness of vegetation.

In the Supra-Barakar (Pali-Parsora), normally the coal is absent and the rocks consist of clay, red, white, yellow, grey shales and ferruginous sandstone. On the basis of this type of lithology it is generally interpreted that the climate must have been dry, warm or even semi-arid during these phases. However, the present palynological findings do not support this contention. The Supra-Barakar includes equivalents of Barren Measures, Raniganj, Panchet and younger horizons of Supra-Panchet. In Johilla Coalfield Barren Measures appear to be subdued; the palynological assemblages of Pali Formation are highly diversified having striate and non-striate disaccates, laevigate as well as ornamented triletes, cavates, monosaccates and alete miospore genera. This naturally reflects that the vegetation was quite luxuriant which gave rise to qualitatively complex spore and pollen assemblages, consequently the climate must have been humid to have produced such a plant population. The presence of coal beds in Middle Pali supports this view. However, the absence of coal in rest of the Pali, inspite of rich vegetation, may be due to the tectonic behaviour of the basin and absence of suitable conditions in the area leading to the peat deposition. The continuous energy flow and supply of oxygen in shallow swamps did not create the aseptic conditions, hence no coals.

CONCLUSION

The present analysis of the Gondwana sediments in Johilla Coalfield evidences that new groups of spores and pollen grains existed in this region, when compared to the miofloras of other basins of India. Besides, it has also come to light that the radial monosaccate pollen genera continue to occur for quite some extent in the Lower Gondwana succession, including the Barakar Formation. The significant continuity of this group in the Upper Permian does not coincide with the situation in other basins. Generally, the monosaccate pollen are indicators of cooler climate, and hence cold and humid type of climate is envisaged for the Barakar in this region. This conclusion is also supported by the fact that during Permian times the position of South Rewa Gondwana Basin was relatively nearer to the South Pole than that of the Damodar Basin.

On the basis of the complexity of spores and pollen in kind and number from Pali Formation it has been concluded that the vegetation was very rich, and not poor as generally considered, although there is no major coal horizon in these formations; the reason for the later situation is attributed to the local tectonic conditions and energy distribution. The basin has its own individuality in the components of vegetation, palaeoecology and climatic condition. The climate during the deposition of Pali Formation was not arid because it sustained a luxuriant vegetation. On the basis of palynomorphs, Talchir, Lower Karharbari, Upper Karharbari and Barakar assemblages have been identified. It has been concluded that Pali Formation is of Upper Permian age in its middle part; it transgresses into Triassic in the upper part. The Parsora Formation represents still younger sequence.

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