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Palynostratigraphy, dating and correlation of coal bearing and associated sediments in Mamakannu area, Godavari Graben, Andhra Pradesh, India

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ABSTRACT

Jha N & Aggarwal N 2010. Palynostratigraphy, dating and correlation of coal bearing and associated sediments in Mamakannu area, Godavari Graben, Andhra Pradesh, India. The Palaeobotanist 59(1-3) : 91-106.

Palynological investigations carried out in Bore core MMK-19 from Mamakannu area, Lingala-Koyagudem coal belt, Godavari sub-basin have revealed presence of five distinct palynoassemblages. The oldest Palynoassemblage-I is demarcated by the dominance of *Callumispora* with monosaccate pollen taxa *Parasaccites*. Palynoassemblage-II is characterised by dominance of monosaccate *Parasaccites* and non-striate disaccate *Scheuringipollenites* along with striate disaccates chiefly, *Striatopodocarpites* and *Faunipollenites*. Palynoassemblage-III shows dominance of non-striate disaccates, *viz. Scheuringipollenites* and *Ibisporites* along with subdominance of striate disaccates, *viz. Striatopodocarpites* and *Faunipollenites*. Early Permian age has been assigned to Palynoassemblage-I, II and III belonging to Lower Karharbari, Upper Karharbari and Barakar respectively. Palynoassemblage IV is exemplified by dominance of *Faunipollenites* and *Striatopodocarpites* along with striate disaccate *Crescentipollenites* and monosaccate taxa *Parasaccites*. Youngest palynoassemblage, i.e. Palynoassemblage-V is demarcated by the dominance of *Crescentipollenites* alongwith sub dominance of *Faunipollenites* and *Striatopodocarpites*. Late Permian (Raniganj Formation) age has been assigned to Palynoassemblage-IV and Palynoassemblage-V. These two palynoassemblages also show the appearance of some younger forms, *viz. Lundbladispora, Falcisporites, Playfordiaspora,* and *Densoisporites*, which are significant taxa of Early Triassic. Presence of *Parasaccites* in high percentage alongwith striate disaccates in Palynoassemblage-IV suggests that the climate towards the end of the Permian time tended to become colder. This evidence supports the contention of a third glacial phase during Late Permian/Early Triassic time. The presence of the Lower Raniganj palynoflora has been demarcated in lithologically designated Barren Measures Formation.

Key-words—Palynostratigraphy, Lower Gondwana, Permian, Karharbari, Barakar, Raniganj, Godavari Graben.

भारत में आंध्र प्रदेश की गोदावरी द्रोणिका के मामाकन्नू क्षेत्र में कोयलाधारी तथा सहयोगी अवसादों का परागाणुस्तरिकी आंकड़े एवं सहसंबंध

नीरजा झा एवं नेहा अग्रवाल

सारांश

गोदावरी उपद्रोणी की लिंग्ला-कोयागुडेम कोयला बेल्ट के मामाकन्नू क्षेत्र से प्राप्त वेध क्रोड़ एम.एम.के. 19 में किए गए परागाणविक अन्वेषणों से पांच परागाणु समुच्चयों की उपस्थिति पाई गई है। सबसे पुराने परागाणु समुच्चय I एकसपुटी पराग वर्गक *पैरासेक्साईटीज* के साथ *कैलुमीस्पोरा* की प्रमुखता सीमांकित होती है। परागाणु समुच्चय II रेखित द्विसपुटी मुख्यतः *स्ट्रायाटोपोडोकार्पाइटीज* एवं *फॉनीपोलेनाइटीज* के साथ-साथ एकसपुटी *पैरासेक्साइटीज* एवं अरेखित द्विसपुटी *श्यूरिंगीपोलेनाइटीज* की प्रमुखता लक्षणित होती है। परागाणु समुच्चय III रेखित द्विसपुटी अर्थात् *स्ट्रायाटोपोडोकार्पाइटीज* एवं *फॉनीपोलेनाइटीज* की उपप्रमुखता के साथ-साथ अरेखित द्विसपुटी *श्यूरिंगीपोलेनाइटीज* एवं *ईबीस्पोराइटीज* की प्रमुखता प्रदर्शित होती है। प्रारंभिक पर्मियन आयु निम्न करहरबारी, उपरि करहरबारी तथा बराकार क्रमशः से संबंधित परागाणु समुच्चय I, II तथा III को निर्धारित की गई है। परागाणु समुच्चय IV रेखित द्विसपुटी *क्रिसेंटीपोलेनाइटीज* एवं एकसपुटी वर्गक *पैरासेक्साईटीज* के साथ-साथ *फॉनीपोलेनाइटीज* एवं *स्ट्रायाटोपोडोकार्पाइटीज* की प्रमुखता प्रमाणित करती है। सबसे नयी परागाणु समुच्चय अर्थात् परागाणु समुच्चय V *क्रिसेंटीपोलेनाइटीज* की प्रमुखता और *फॉनीपोलेनाइटीज* एवं *स्ट्रायाटोपोडोकार्पाइटीज* की उपप्रमुखता को सीमांकित किया जाता है। अंतिम पर्मियन (रानीगंज शैलसमूह) आयु परागाणु समुच्चय IV और परागाणु समुच्चय V को निर्धारित की गई है। इन दो परागाणु समुच्चयों में कुछ रूपों अर्थात् *लुंडब्लेडीस्पोरा, फाल्सीस्पोराइटीज, प्लेफोर्डियास्पोरा* तथा *डेंसोइस्पोराइटीज* का होना भी प्रदर्शित करता है जो कि प्रारंभिक ट्रायसिक आयु के मुख्य वर्गक हैं। परागाणु समुच्चय IV में रेखित द्विसपुटियों के साथ-साथ उच्च प्रतिशतता में *पैरासेक्साईटीज* की उपस्थिति प्रस्तावित करती है कि पर्मियन समय के अंत में जाती हुई जलवायु ठंडी होने की ओर झुकी थी। यह प्रमाण अंतिम पर्मियन/ प्रारंभिक ट्राइसिक काल के दौरान तीसरे हिमनद चरण के तर्क का समर्थन करता है। निम्न रानीगंज परागाणुवनस्पतिजात की उपस्थिति को अश्म विज्ञान संबंधी रूप से नामित अनुत्पादक शैल-संस्तर शैलसमूह में सीमांकित किया गया है।

संकेत-शब्द—परागाणुस्तरिकी, निम्न गोंडवाना, पर्मियन, करहरबारी, बराकार, रानीगंज, गोदावरी द्रोणिका।

INTRODUCTION

IN India, major coal seams have been deposited in Peninsular India during Permian (Lower Gondwana) time. These Permian coal deposits occur in a triangular pattern distributed along four major river valleys, *viz.* Damodar, Son-Mahanadi, Wardha-Godavari and Satpura basins. The Godavari Valley coalfields make the southernmost limits of Permian coal deposits (Raja Rao, 1982). It covers the area of 17,000 sq km and is bound by 16°38' and 19°32' latitude and 79°12' and 81°39' longitude. It holds the unique position because it is the only coal producing area in south and has more or less uninterrupted succession from Permian-Cretaceous Period. Godavari Graben is traversed by a series of strike/oblique faults trending roughly NW-SE to E-W. Hence, dating and correlation of coal bearing horizons is difficult. About 15 coal belts have been identified in Godavari Graben, out of which different areas, *viz.* Gundala, Kachinapalli and Mamakannu of Lingala-Koyagudem coal belt were selected for palynological study in order to date and correlate the sediments and study the lateral extention of coal bearing horizons. Palynological investigation of Bore core MMK-19 from Mamakannu area has been communicated in the present paper.

GEOLOGY

A 50 km long unbroken stretch of Barakar Formation occurring between Lingala in the north west to Koyagudem in the south east on western margin of Godavari Graben is named as Lingala-Koyagudem coal belt. The Mamakannu Block (Fig. 1) is centrally located in Lingala-Koyagudem coal belt and is bounded by latitude 17°48'01" to 17°54'00" N and longitude 80°21'02" to 80°26'06" E. The stratigraphic succession in the block on the basis of sub-surface data has been worked out by Mineral Exploration Corporation Limited (MECL) and is furnished in Fig. 2.

The sedimentary sequence beneath 3 m soil cover from the top (3-43.50 m) in upper part of Bore core MMK-19 consist of coarse to medium grained yellow brown, yellow white sandstone, grey clay and grey claystone. The underlying sequence (43.50-170 m) mainly consists of grey white, greyish green sandstone,

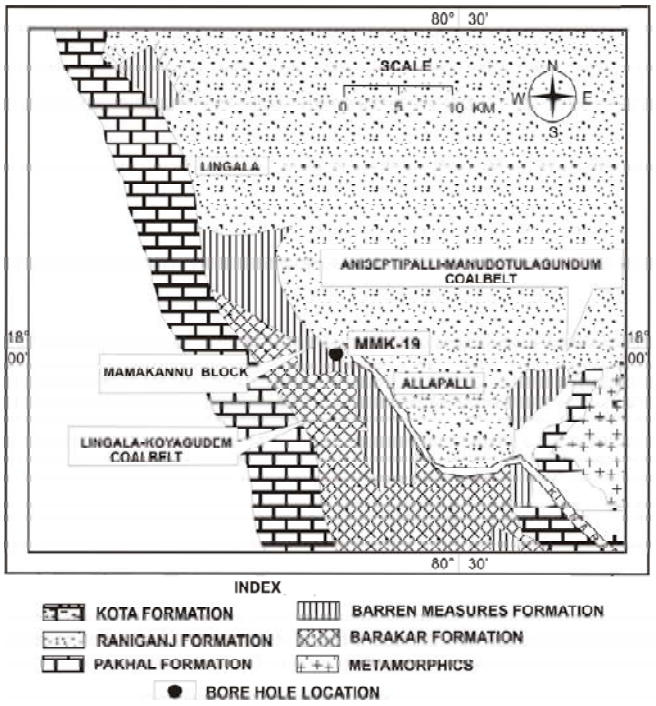

Fig. 1—Geological map of Mamakannu area showing location of Bore core MMK-19 (after MECL).

grey clay/grey claystone and few very thin carbonaceous shale bands. Lithologically, this sequence from 3-170 m has been identified as Barren Measures, while the sequence from 170.00-380.25 m consisting of grey white sandstone, shaly sandstone, grey shale, carbonaceous shale and coal seams has been designated as Barakar Formation. The bore hole was closed at 380.00 m depth (Fig. 3). In this sequence no Kamthi/Raniganj Formation has been defined. List of samples with depth and lithological details have been represented in Fig. 4.

MATERIAL AND METHODS

The exploratory Bore core MMK-19 was drilled by Singareni Collieries Company Limited (SCCL), Khammam, Andhra Pradesh. 47 samples were collected from 380.25 m deep bore core. 38 samples yielded palynomorphs in countable number and remaining 9 samples showed low frequency of pollen and spores, therefore not represented in histogram. Recovery of palynofossils from the sediments was accomplished by usual maceration technique. About 10-20 gm of the material from each sample was taken and crushed into peanut sized pellets in an iron mortar and pestle, initially treated with conc. hydrofluoric acid (HF) for two days to eliminate silica content followed by treatment with commercial nitric acid (HNO_3) for 3-4 days for the digestion of humic matter. Finally, after thorough washing with water, samples were treated with 10% potassium hydroxide (KOH) to get clear palynomorphs. All samples were checked under microscope at each step of maceration before further treatment. Recuperated palynofossils were mounted in canada balsam with the help of polyvinyl chloride (PVC). Eight slides of each sample were prepared and dried in oven. Photographs of palynomorphs were undertaken by DPX25 Camera. Quantitative and qualitative studies of palynomorphs were carried out under Olympus BX61 microscope. The slides have been deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow. The succession of the Bore core MMK-19 as represented by palynoassemblages through Lower Gondwana sediments in Mamakannu

Group	Formation	Lithology
-------- Soil Cover ------		
LOWER GONDWANA	Kamthi	Sandstone with subordinate shales and coal seams.
	Barren Measures	Grey to greenish grey coarse to pebbly felspathic sandstone with shale bands.
	Barakar	Predominantly of medium to coarse grained, grey white sandstone, altered feldspars with subordinate clays/shales and persistent coal seams.
	Talchir	Fine to medium grained pale green, sandstone with occasional olive green shales.

Fig. 2—Stratigraphic succession in Mamakannu area (after MECL, 2002).

area of Godavari Graben, was investigated by their qualitative composition and quantitative abundance of different palynotaxa after the count of 200 specimens in each sample.

PALYNOASSEMBLAGES

Five distinct palynoassemblages have been recognized on the basis of quantitative and qualitative distribution of various palynotaxa. The stratigraphically significant taxa have been shown in Pl. 1, 2 and vertical distribution of various palynotaxa in Bore core MMK-19 have been illustrated in Fig. 5. Details of palynoassemblages are as follows:

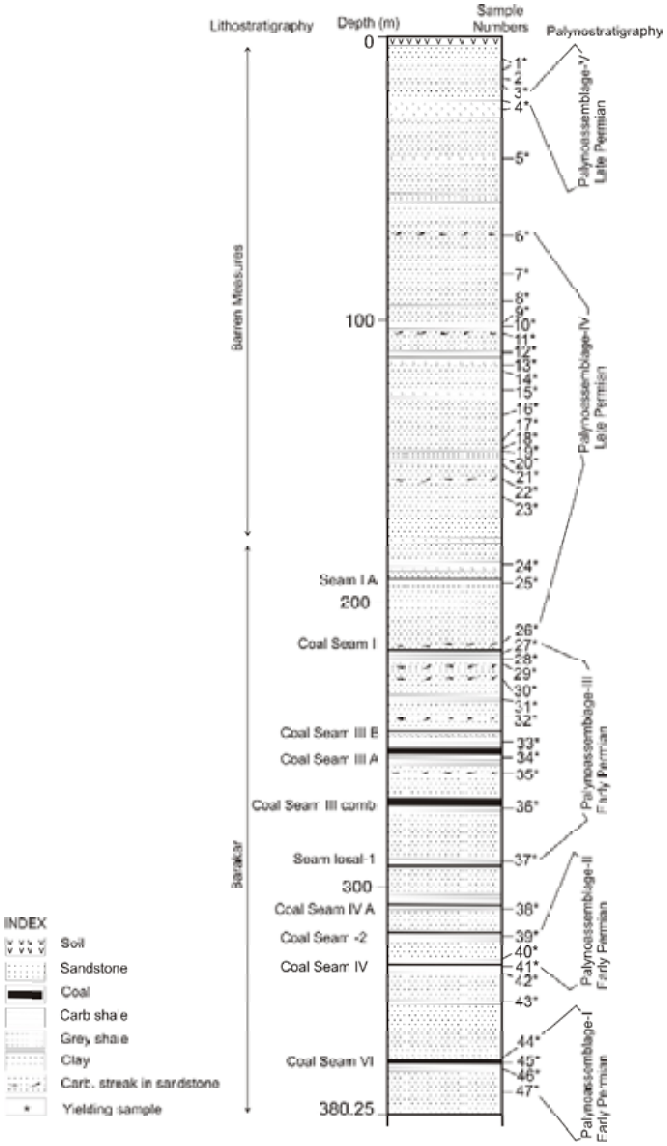

Fig. 3—Litholog of Bore core MMK-19 showing position of samples, lithostratigraphy and palynoassemblages.

PALYNOASSEMBLAGE-I

Palynoassemblage-I in Bore core MMK-19 has been demarcated in carbonaceous shale at the depth of 361.25-373.25 m (sample no. 44-47). This palynoassemblage is dominated by monosaccates chiefly *Parasaccites* (22.5%) and *Caheniasaccites* (20%) along with trilete genus *Callumispora* (9%). Other monosaccates recorded in the palynoassemblage includes *Plicatipollenites* (6%), *Divarisaccus* (5.5%), *Potonieisporites* (2-3%), *Crucisaccites* (1.5%) and *Virkkipollenites* (0.5%). Other associated taxa of this palynoassemblage are triletes *Brevitriletes* (5%), *Microfoveolatispora* (4%), *Indotriradites* (3.5%), *Leiotriletes* (1.5%), *Lophotriletes* (0.5%), *Horriditriletes* (0.5%), monolete *Latosporites* (4.5%). Non-striate disaccates are represented by *Scheuringipollenites* (7.5%), *Sahnites* (2%) and *Ibisporites* (1%). Striate disaccates includes *Faunipollenites* (4%) and *Striatopodocarpites* (0.5%).

PALYNOASSEMBLAGE-II

Palynoassemblage-II has been revealed at the depth of 318-328.25 m (sample no. 39-41) in carbonaceous shales. This palynoassemblage is dominated by monosaccates, *viz. Parasaccites* (16%), *Plicatipollenites* (2%), *Caheniasaccites* (1%) alongwith the presence of non-striate disaccate *Scheuringipollenites* (6.5%). Other taxa recorded in this palynoassemblage are *Brevitriletes* (2%), *Sahnites* (3.5%), *Vestigisporites* (4%), *Striomonosaccites* (0.5%) and *Weylandites* (1%). Striate disaccates includes *Faunipollenites* (13.5%), *Striatopodocarpites* (12.5%) and *Crescentipollenites* (1%). *Tiwariasporis* (35%) has also been recorded.

Sample Nos.	Depth (m)	Lithology
1.	*9-12	Coarse grained sandstone
2.	*15-16	Coarse grained sandstone
3.	*22-25	Grey clay upper sample
4.	*22-25	Grey clay lower sample
5.	*43.50	Grey clay
6.	*70.00	Carbonaceous streaks in sandstone
7.	*84.50	Fine grained grey sandstone
8.	*93.50	Greenish grey fine grained sandstone
9.	*101.00	Carbonaceous shale
10.	*102.00	Grey shale
11.	*103.00	Carbonaceous streaks in medium to fine grained sandstone
12.	*113.50	Carbonaceous shale
13.	*114.75	Greenish sandstone
14.	*115.00	Sandstone
15.	*125.50	Carbonaceous shale in sandstone
16.	*133.00	Sandstone
17.	*144.00	Greenish sandstone
18.	*147.50	Greenish sandstone
19.	*148.50	Carbonaceous shale
20.	*149.00	Carbonaceous shale
21.	*149.50	Carbonaceous shale
22.	*156.50	Coal and carbonaceous shale streaks in between sandstone
23.	*161.00	Carbonaceous streak in sandstone
24.	*187.50	Carbonaceous shale
25.	*193.25	Carbonaceous shale
26.	*216.25	Carbonaceous streak in sandstone
27.	*219.25	Carbonaceous shale
28.	*220.25	Carbonaceous shale
29.	*221.25	Carbonaceous streaks in between sandstone
30.	*225.25	Carbonaceous streaks in between sandstone
31.	*235.25	Carbonaceous shale
32.	*240.25	Carbonaceous streak in sandstone
33.	*249.25	Carbonaceous shale
34.	*253.75	Carbonaceous shale
35.	*260.25	Carbonaceous streak in sandstone
36.	*273.50	Carbonaceous shale
37.	*292.00	Carbonaceous shale
38.	*308.00	Carbonaceous shale
39.	*318.00	Carbonaceous shale
40.	*327.25	Carbonaceous shale
41.	*328.25	Carbonaceous shale
42.	*331.75	Carbonaceous shale
43.	*341.25	Carbonaceous shale
44.	*361.25	Carbonaceous shale
45.	*362.50	Carbonaceous shale
46.	*363.25	Carbonaceous shale
47.	*373.25	Carbonaceous shale

Fig. 4—List of samples of Bore core MMK-19, Mamakannu area, Godavari Graben, Andhra Pradesh (* indicates the yielded samples).

PALYNOASSEMBLAGE-III

The Palynoassemblage-III has been divulged at depth of 219.25-292 m (sample no. 27-37) lithologically represented by carbonaceous shale, carbonaceous streak in sandstone. It shows the dominance of non striate disaccates, *viz. Scheuringipollenites* (28-79%), *Ibisporites* (1-18%) and sub-dominance of striate disaccates, *viz. Striatopodocarpites* (1-28%) and *Faunipollenites* (3-24%). Other associated taxa in the present palynoassemblage are triletes *Callumispora* (2.5%), *Lophotriletes* (1%), *Brevitriletes* (0.5-2.5%); monosaccates *Parasaccites* (2-7.5%), *Potonieisporites* (0.5-4.5%), *Plicatipollenites* (0.5-1.5%), *Caheniasaccites* (1%), *Densipollenites* (1%), *Divarisaccus* (0.5%), *Crucisaccites* (0.5%), and *Striomonosaccites* (0.5%); non-striate disaccates *Platysaccus* (3.5-6.5%), *Vestigisporites* (1%); striate disaccates *Striatites* (1-7%), *Strotersporites* (1-1.5%), *Crescentipollenites* (0.5%), taeniate *Lunatisporites* (0.5-1%). Beside these *Tiwariasporis* (0.5%), *Weylandites* (1-4%) and *Latosporites* (0.5%) have also been recorded.

PALYNOASSEMBLAGE-IV

Palynoassemblage-IV has been discriminated in carbonaceous shale, carbonaceous streak in sandstone, siltstone, sandstone and grey shale samples between depth 216.25-70 m (sample no. 6-26). Palynoassemblage is epitomized by the dominance of striate disaccates, *viz. Striatopodocarpites* (5.5-37.5%), *Faunipollenites* (5-23.5%), *Crescentipollenites* (1.5-13%), *Striatites* (0.5-6%) and *Strotersporites* (1-10%). Monosaccates are represented by *Parasaccites* (1-12%), *Divarisaccus* (1-8.5%), *Caheniasaccites* (0.5-7%), *Plicatipollenites* (1-3.5%), *Densipollenites* (2-3.5%), *Potonieisporites* (0.5-2.5%) and *Crucisaccites* (0.5%). Non-striate disaccates present in the assemblage includes *Primuspollenites* (0.5-3%), *Ibisporites* (3-10.5%), *Platysaccus* (0.5-3%), *Sahnites* (0.5-1%) and *Vestigisporites* (0.5-1%). Taeniate taxa *Corisaccites* is 0.5-1%. Other associated trilete taxa of this palynoassemblage are *Brevitriletes* (0.5-9%), *Callumispora* (0.5-1%), *Lophotriletes* (1%), *Indotriradites* (1%), *Leiotriletes* (0.5%) and *Horriditriletes* (0.5%). Beside these other allied taxa are *Inaperturopollenites* (2.5%), *Quadrisporites* (0.5-2%), *Tiwariasporis* (0.5-1.5%) and *Latosporites* (0.5%). Monosaccates chiefly *Parasaccites* has been recorded in high percentage in this palynoassemblage.

Rare but stratigraphically considerable taxa present in the palynoassemblage are *Falcisporites* (0.5-5%), *Chordasporites* (0.5-4%), *Kamthisaccites* (2%), *Striasulcites* (1%), *Hamiapollenites* (2%), *Lunatisporites* (1-6%), *Weylandites* (0.5-1.5%) and *Guttulapollenites* (0.5-1%). The taxa *Lundbladispora*, *Playfordiaspora* and *Densoisporites* also demonstrate their existence but they are extremely rare less than 1%.

PLATE 1 →

Early Permian palynotaxa recovered in Bore core MMK-19, Mamakannu area, Godavari Graben.

1. *Callumispora*, B.S.I.P. Slide No. 13837, Bottom.
2. *Brevitriletes*, B.S.I.P. Slide No. 13838, J42.
3. *Indotriradites*, B.S.I.P. Slide No. 13839, G34/1.
4. *Platysaccus*, B.S.I.P. Slide No. 13838, O46/3.
5. *Striatopodocarpites*, B.S.I.P. Slide No. 13840, L57.
6. *Parasaccites*, B.S.I.P. Slide No. 13841, S63/4.
7. *Sahnites*, B.S.I.P. Slide No. 13841, D41/3.
8. *Faunipollenites*, B.S.I.P. Slide No. 13838, M45/1.
9. *Crescentipollenites*, B.S.I.P. Slide No. 13842, S32/4.
10. *Ibisporites*, B.S.I.P. Slide No. 13838, H39/3.
11. *Crucisaccites*, B.S.I.P. Slide No. 13843, Q60.
12. *Potonieisporites*, B.S.I.P. Slide No. 13844, V29/1.
13. *Plicatipollenites*, B.S.I.P. Slide No. 13845, E38/2.
14. *Caheniasaccites*, B.S.I.P. Slide No. 13846, S33.
15. *Jayantisporites*, B.S.I.P. Slide No. 13839, K34/3.
16. *Striatites*, B.S.I.P. Slide No. 13847, V39/4.
17. *Crescentipollenites*, B.S.I.P. Slide No. 13848, G52/4.
18. *Potonieisporites*, B.S.I.P. Slide No. 13849, K65/4.
19. *Verrucosisporites*, B.S.I.P. Slide No. 13850, T36/1.
20. *Scheuringipollenites*, B.S.I.P. Slide No. 13838, H38/4.
21. *Tiwariasporis*, B.S.I.P. Slide No. 13841, J66.
22. *Scheuringipollenites*, B.S.I.P. Slide No. 13838, S55/4.

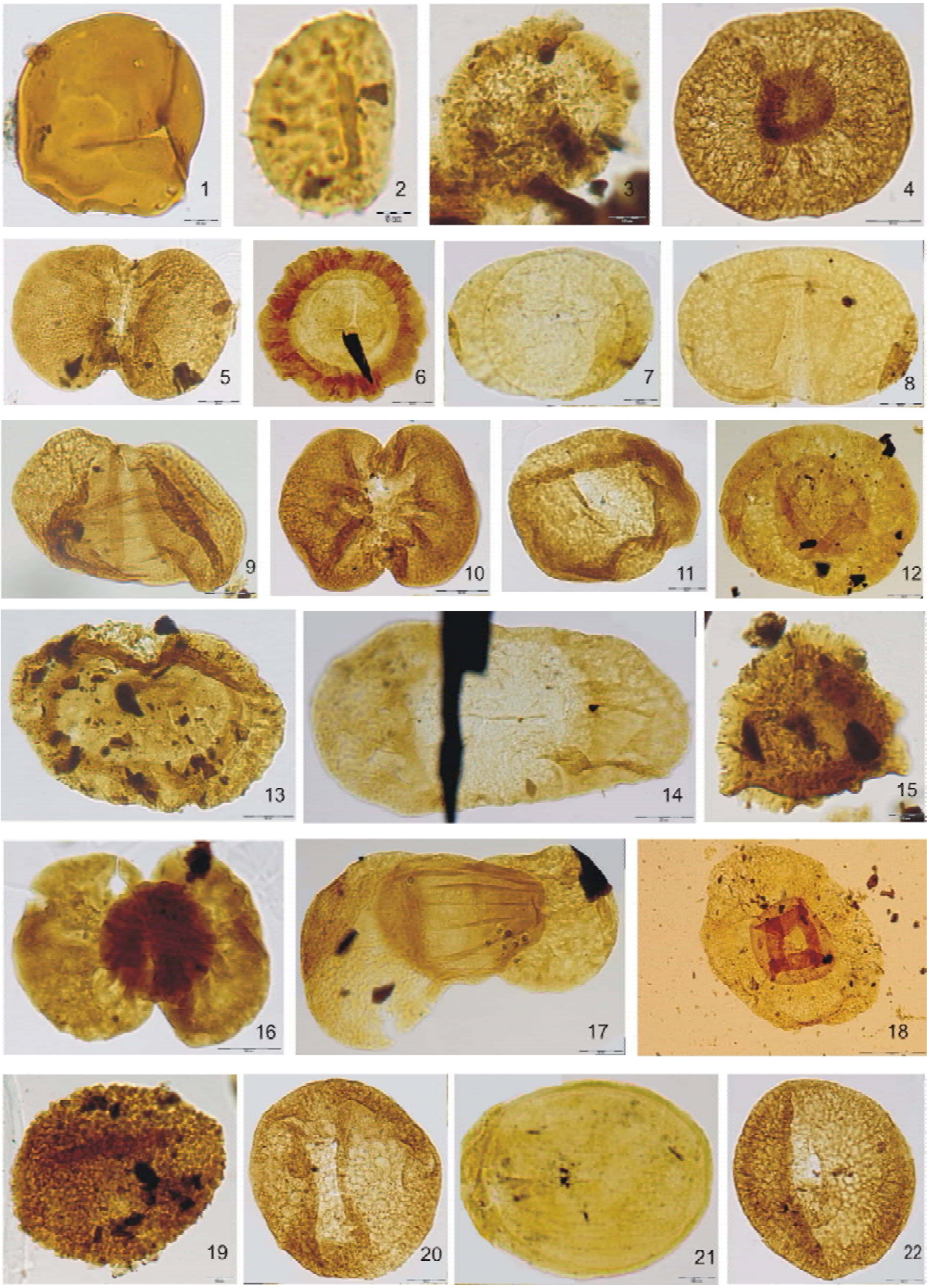

PLATE 1

PALYNOASSEMBLAGE-V

Youngest Palynoassemblage-V has been revealed at the depth of 22-25 m (sample nos. 3-4) in grey clay which is symbolized by the dominance of striate disaccates *viz.*, *Crescentipollenites* (14.5%), *Striatopodocarpites* (12.5%) and *Faunipollenites* (17%). Other associated taxa of this palynoassemblage are trilete *Callumispora* (2%); monosaccates *Plicatipollenites* (3.5%), *Striomonosaccites* (1%); non-striate disaccates *Scheuringipollenites* (11%), *Ibisporites* (0.5%), *Platysaccus* (0.5%); striate disaccate *Striatites* (2%); taeniate *Corisaccites* (1%) and alete *Inaperturopollenites* (1%). Stratigraphically important taxa present in the palynoassemblage are *Klausipollenites* (3%), *Hamiapollenites* (6.5%), *Lunatisporites* (6.5%), *Chordasporites* (3%), *Falcisporites* (3%), *Strotersporites* (2.5%), *Striasulcites* (2.5%) and *Guttulapollenites* (1%). *Playfordiaspora* and *Densoisporites* are also recorded but their percentage frequency is less than 1%.

Palynocomposition of these five distinct palynoassemblages are summarized in Fig. 6.

COMPARISON AND CORRELATION

Palynoassemblage-I shows resemblance with the younger part of Zone 1 of Giridih Coalfield (Srivastava, 1973), Zone 1 of Raniganj Coalfield (Tiwari, 1973), Biozone 1 of Umrer Quarry, Nagpur (Bharadwaj & Anand Prakash, 1974) in having the dominance of *Parasaccites* and *Callumispora*, Palynozone 2 of Ramakrishnanpuram (Srivastava & Jha, 1992b), Lower Karharbari Palynozone of Chintalapudi sub basin (Srivastava & Jha, 1993). It represents Lower Karharbari palynoflora.

Palynoassemblage-II is comparable with the Zone 2 of Raniganj Coalfield (Tiwari, 1973), Zone 2 of Korba Coalfield (Bharadwaj & Srivastava, 1973), Zone 2 of Umaria Coalfield (Srivastava & Anand Prakash, 1984), Zone 2 of Johilla Coalfield (Anand Prakash & Srivastava, 1984), Zone I of Pathakhera Coalfield (Sarate, 1986), Palynozone 3 of Ramakrishnapuram (Srivastava & Jha, 1992b), Palynoassemblage-2 of Manuguru area (Srivastava & Jha, 1992a), Upper Karharbari Palynozone of Chintalapudi sub basin (Srivastava & Jha, 1993), Palynozone 1 of Koyagudem area (Srivastava & Jha, 1996), Assemblage-A of Wardha Coalfield (Bhattacharyya, 1997). This palynoassemblage represents Upper Karharbari palynoflora.

Palynoassemblage-III corresponds well with Barakar palynoassemblage of Giridih Coalfield (Srivastava, 1973), Zone 3 of Johilla Coalfield (Anand Prakash & Srivastava, 1984), Zone 3 of Umaria Coalfield (Srivastava & Anand Prakash, 1984), Assemblage-II of Pathakhera Coalfield (Sarate, 1986), Palynozone 4 of Ramakrishnapuram (Srivastava & Jha, 1992b), palynoassemblage of Manuguru area (Srivastava & Jha, 1992a), Palynozone 5 of Budharam area (Srivastava & Jha, 1995), Palynozone 2 of Koyagudem (Srivastava & Jha, 1996), Assemblage-B

PLATE 2 →

Late Permian palynotaxa recovered in Bore core MMK-19, Mamakannu area, Godavari Graben.

1. *Lundbladispora*, B.S.I.P. Slide No. 13851, G30/2.
2. *Chordasporites*, B.S.I.P. Slide No. 13842, L30/4.
3. *Strotersporites*, B.S.I.P. Slide No. 13852, P30/4.
4. *Weylandites*, B.S.I.P. Slide No. 13842, K49/2.
5. *Striatopodocarpites*, B.S.I.P. Slide No. 13842, Q38/4.
6. *Lunatisporites*, B.S.I.P. Slide No. 13853, H61/3.
7. *Chordasporites*, B.S.I.P. Slide No. 13854, J44/3.
8. *Densoisporites*, B.S.I.P. Slide No. 13855, H34.
9. *Verticipollenites*, B.S.I.P. Slide No. 13838, W42/4.
10. *Hamiapollenites*, B.S.I.P. Slide No. 13852, T33.
11. *Striatites*, B.S.I.P. Slide No. 13856, N47/1.
12. *Weylandites*, B.S.I.P. Slide No. 13857, M36.
13. *Falcisporites*, B.S.I.P. Slide No. 13852, L37/3.
14. *Faunipollenites*, B.S.I.P. Slide No. 13850, C38.
15. *Hamiapollenites*, B.S.I.P. Slide No. 13852, K37.
16. cf. *Corisaccites*, B.S.I.P. Slide No. 13858, L41/1.
17. *Corisaccites*, B.S.I.P. Slide No. 13851, P52/3.
18. *Kamthisaccites*, B.S.I.P. Slide No. 13859, G57/1.
19. *Crescentipollenites*, B.S.I.P. Slide No. 13860, O35/2.
20. *Playfordiaspora*, B.S.I.P. Slide No. 13852, U51/3.
21. *Strotersporites*, B.S.I.P. Slide No. 13851, Q62.
22. *Densipollenites*, B.S.I.P. Slide No. 13857, W34/3.
23. *Lunatisporites*, B.S.I.P. Slide No. 13861, N59/3.
24. *Striatites*, B.S.I.P. Slide No. 13852, L36/2 .

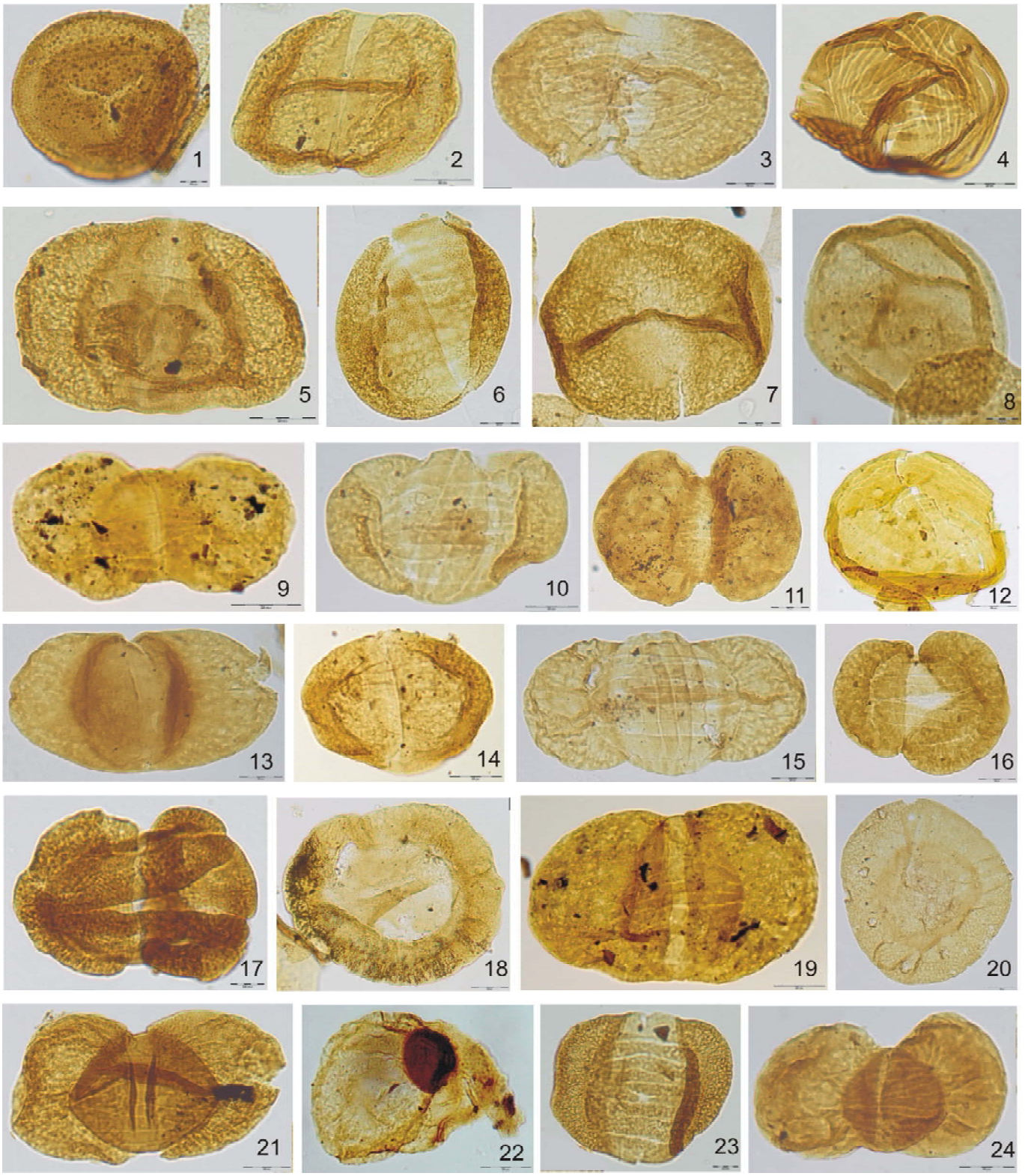

PLATE 2

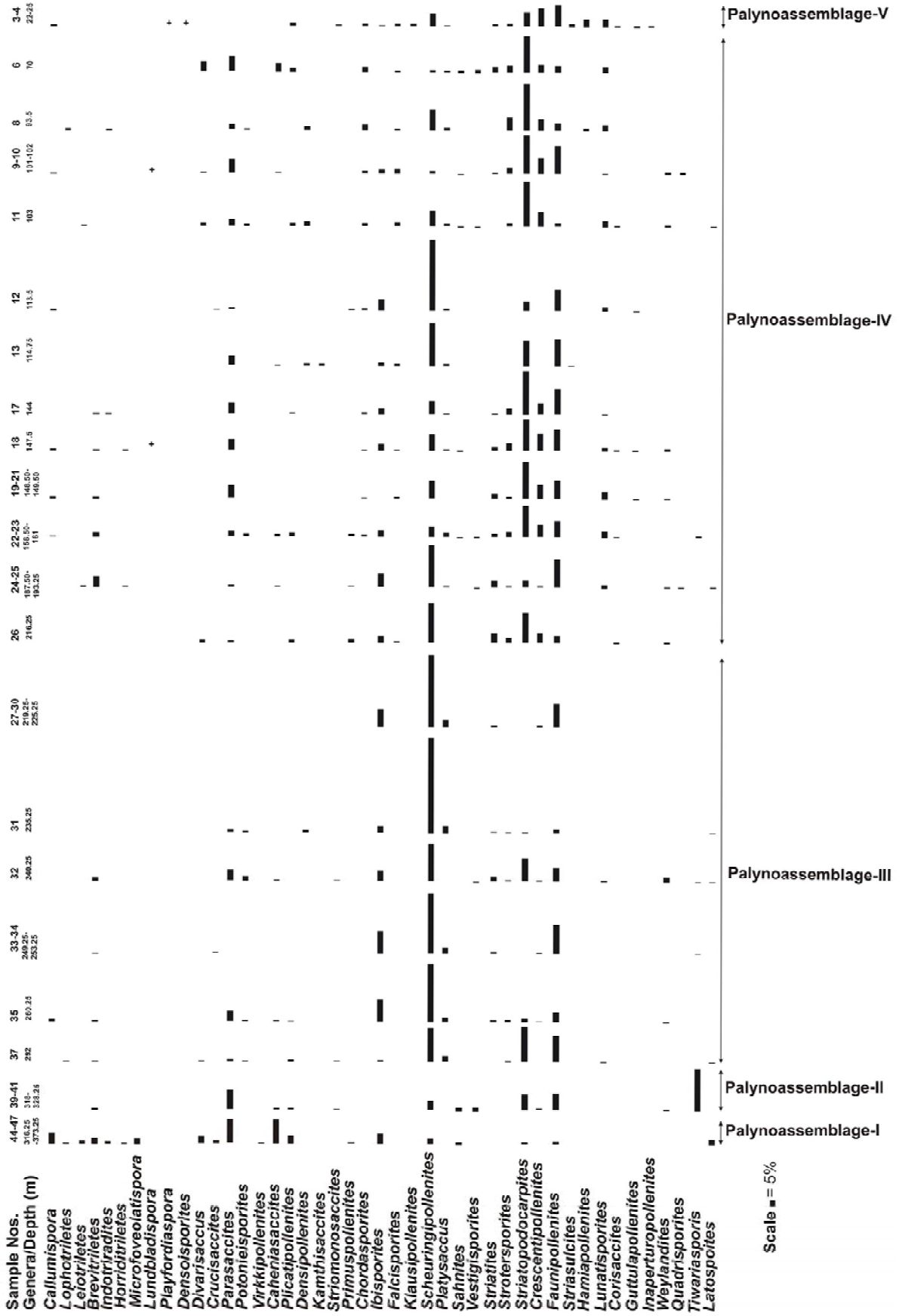

Fig. 5—Histogram showing vertical distribution of palynotaxa in Bore core MMK-19.

PALYNOASSEMBLAGES		Depth (m)	Quantitatively important taxa	Qualitatively important taxa	Other genera	Palyno zone	Age
	V	22-25	*Crescentipollenites* (14.5%), *Faunipollenites* (17%), *Striatopodocarpites* (12.5%),	*Klausipollenites* (3%), *Chordasporites* (3%), *Falcisporites* (3%), *Strotersporites* (2.5%), *Striasulcites* (2.5%), *Lunatisporites* (6.5%), *Hamiapollenites* (6.5%), *Guttulapollenites* (1%), *Corisaccites* (1%), *Striomonosaccites* (1%). Beside these presence of *Playfordiaspora* and *Densoisporites* have also been marked.	*Callumispora* (2%), *Plicatipollenites* (3.5%), *Scheuringipollenites* (11%), *Ibisporites* (0.5%), *Platysaccus* (0.5%), *Striatites* (2%), *Inaperturopollenites* (1%).	RANIGANJ	LATE PERMIAN
	IV	216.25-70.00	*Faunipollenites* (5-23.5%), *Striatopodocarpites* (5.5-37.5%), *Parasaccites* (1-12.5%)	*Densipollenites* (2-3.5%), *Kamthisaccites* (2%), *Falcisporites* (0.5-5%), *Chordasporites* (0.5-4%), *Strotersporites* (1-10%), *Crescentipollenites* (1.5-3%), *Striasulcites* (1%), *Lunatisporites* (1-6%), *Weylandites* (0.5-1.5%), *Hamiapollenites* (2%), *Corisaccites* (0.5-1%), *Guttulapollenites* (0.5-1%). Beside these *Lundbladispora*, *Playfordiaspora* and *Densoisporites* are also present.	*Brevitriletes* (0.5-9%), *Lophotriletes* (1%), *Indotriradites* (1%), *Callumispora* (0.5-1%), *Horriditriletes* (0.5%), *Leiotriletes* (0.5%), *Divarisaccus* (1-8.5%), *Caheniasaccites* (0.5-7%), *Plicatipollenites* (1-3.5%), *Potonieisporites* (0.5-2.5%), *Crucisaccites* (0.5%), *Ibisporites* (3-10.5%), *Platysaccus* (0.5-3%), *Primuspollenites* (0.5-3%), *Sahnites* (0.5-1%), *Vestigisporites* (0.5-1%), *Striatites* (0.5-6%), *Inaperturopollenites* (2.5%), *Quadrisporites* (0.5-2%), *Tiwariasporis* (0.5-1.5%), *Latosporites* (0.5%).		
	III	292-219.25	*Scheuringipollenites* (28-79%)	*Striatopodocarpites* (1-28%), *Faunipollenites* (3-24%), *Ibisporites* (1-18%)	*Parasaccites* (2-7.5%), *Striatites* (1-7%), *Platysaccus* (3.5-6.5%), *Potonieisporites* (0.5-4.5%), *Weylandites* (1-4%), *Brevitriletes* (0.5-2.5%), *Callumispora* (2.5%), *Strotersporites* (1-1.5%), *Plicatipollenites* (0.5-1.5%), *Caheniasaccites* (1%), *Densipollenites* (1%), *Lunatisporites* (0.5-1%), *Vestigisporites* (1%), *Lophotriletes* (1%), *Divarisaccus* (0.5%), *Crucisaccites* (0.5%), *Striomonosaccites* (0.5%), *Crescentipollenites* (0.5%), *Tiwariasporis* (0.5%), *Latosporites* (0.5%).	BARAKAR	EARLY PERMIAN
	II	318-328.25	*Parasaccites* (16%) *Scheuringipollenites* (6.5%)	*Faunipollenites* (13.5%) *Striatopodocarpites* (12.5%)	*Tiwariasporis* (35%), *Vestigisporites* (4%), *Sahnites* (3.5%), *Plicatipollenites* (2%), *Brevitriletes* (2%), *Caheniasaccites* (1%), *Crescentipollenites* (1%), *Weylandites* (1%), *Striomonosaccites* (0.5%).	Upper Karhar-bari	
	I	361.25-373.25	*Parasaccites* (22.5%), *Caheniasaccites* (20%), *Callumispora* (9%)	*Plicatipollenites* (6%), *Divarisaccus* (5.5%), *Potonieisporites* (2-3%), *Crucisaccites* (1.5%), *Scheuringipollenites* (7.5%).	*Brevitriletes* (5%), *Latosporites* (4.5%), *Microfoveolatispora* (4%), *Indotriradites* (3.5%), *Leiotriletes* (1.5%), *Lophotriletes* (0.5%), *Horriditriletes* (0.5%), *Virkkipollenites* (0.5%), *Sahnites* (2%), *Ibisporites* (1%), *Faunipollenites* (4%), *Striatopodocarpites* (0.5%).	Lower Karhar-bari	

Fig. 6—Showing palynocomposition of different palynoassemblages in Bore core MMK-19.

EARLY PERMIAN

Triletes

Brevitriletes communis Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
B. unicus (Tiwari) Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
Callumispora barakarensis (Bharadwaj & Srivastava) Tiwari *et al.*, 1989
C. tenuis Bharadwaj and Srivastava, 1969
Horriditriletes rampurensis Tiwari, 1968
Indotriradites sparsus Tiwari, 1965
Leiotriletes rectus Bharadwaj and Salujha, 1964
Lophotriletes rectus Bharadwaj and Salujha, 1964
Microfoveolatispora foveolata (Tiwari) Tiwari and Singh, 1981

Monosaccates

Caheniasaccites distinctus Lele and Makada, 1972
C. ovatus Bose and Kar, 1966
C. ellipticus Bose and Maheshwari, 1968
C. elongatus Bose and Kar, 1966
Crucisaccites indicus Srivastava, 1970
C. monoletus Maithy, 1965
Densipollenites invisus Bharadwaj and Salujha, 1964
Divarisaccus lelei Venkatachala and Kar, 1966
Parasaccites korbaensis Bharadwaj and Tiwari, 1964
P. obscurus Tiwari, 1965
P. distinctus Tiwari, 1965
Striomonosaccites sp.
Plicatipollenites indicus Lele, 1964
Potonieisporites neglectus Potonié and Lele, 1961
P. barrelis Tiwari, 1965
P. lelei Maheshwari, 1967
P. distinctus Lele and Makada, 1972
Virkkipollenites orientalis, Tiwari, 1965

Non-striate disaccates

Platysaccus sp.
Ibisporites jhingurdahiensis Sinha, 1972
I. diplosaccus Tiwari, 1968
Scheuringipollenites maximus (Hart) Tiwari, 1973
S. barakarensis (Tiwari) Tiwari, 1973
S. tentulus (Tiwari) Tiwari, 1973
Sahnites sp.
Vestigisporites sp.

Striate disaccates

Crescentipollenites sp.
Faunipollenites varius Bharadwaj, 1962
F. bharadwajii Maheshwari, 1967
Striatites communis Bharadwaj and Salujha, 1964
Striatopodocarpites tiwarii Bharadwaj and Dwivedi, 1981
S. diffusus Bharadwaj and Salujha, 1964
S. decorus Bharadwaj and Salujha, 1964
Strotersporites sp.

Others

Latosporites sp.
Lunatisporites pellucidus Goubin, 1965 emend. Maheshwari and Banerjee, 1975
Tiwariasporis gondwanensis (Tiwari) Maheshwari and Kar, 1967
T. simplex (Tiwari) Maheshwari and Kar, 1967
Weylandites circularis Bharadwaj and Srivastava, 1969

LATE PERMIAN

Triletes

Brevitriletes communis Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
B. unicus (Tiwari) Bharadwaj and Srivastava emend. Tiwari and Singh, 1981
Callumispora sp.
Horriditriletes rampurensis Tiwari, 1968
H. ramosus (Balme & Hennelly) Bharadwaj and Salujha, 1964
Indotriradites sp.
Leiotriletes sp.
Lophotriletes rectus Bharadwaj and Salujha, 1964
Lundbladispora raniganjensis Tiwari and Rana, 1981
L. microconata Bharadwaj and Tiwari, 1977
Densoisporites sp.
Playfordiaspora sp.

Monosaccates

Caheniasaccites distinctus Lele & Makada, 1972
Densipollenites indicus Bharadwaj, 1969

D. invisus Bharadwaj, 1962
D. densus Bharadwaj and Srivastava, 1969
Parasaccites korbaensis Bharadwaj and Tiwari, 1964
P. obscurus Tiwari, 1965
P. distinctus Tiwari, 1965
Crucisaccites sp.
Divarisaccus sp.
Plicatipollenites ganjraensis Saxena, 1971
Potonieisporites crassus Lele and Chandra, 1973
Potonieisporites sp.
Kamthisaccites kamthiensis Srivastava and Jha, 1986
Striomonosaccites sp.

Non-striate disaccates
Chordasporites sp.
Falcisporites nuthallensis (Clarke) Balme, 1970
Ibisporites jhingurdahiensis Sinha, 1972
I. diplosaccus Tiwari, 1968
Scheuringipollenites maximus (Hart) Tiwari, 1973
S. barakarensis (Tiwari) Tiwari, 1973
S. tentulus (Tiwari) Tiwari, 1973
Klausipollenites sp.
Platysaccus plicatus Bharadwaj and Dwivedi, 1981
P. papilionis Potonié and Klaus, 1954
Primuspollenites levis Tiwari, 1964
Sahnites sp.
Vestigisporites sp.

Striate disaccates
Crescentipollenites globosus (Maithy) Jha, 1996
C. fuscus (Bharadwaj) Bharadwaj *et al.*, 1974
C. brevis (Bose and Kar) Bharadwaj *et al.*, 1974
C. gondwanensis (Maheshwari) Bharadwaj *et al.*, 1974
Faunipollenites varius Bharadwaj, 1965
F. bharadwajii Maheshwari, 1967
F. parvus Tiwari, 1965
F. goraensis (Potonié and Lele) Maithy, 1965
Striasulcites tectus Venkatachala and Kar, 1968
Striatites communis Bharadwaj and Salujha, 1964
S. solitus Bharadwaj and Salujha, 1964
Striatopodocarpites tiwarii Bharadwaj and Dwivedi, 1981
S. diffusus Bharadwaj and Salujha, 1964
S. multistriatus Jha, 1996
S. labrus Tiwari, 1965
S. globosus (Maheshwari) Bharadwaj and Dwivedi, 1981
Strotersporites communis Wilson, 1962
S. wilsonii Klaus, 1963

Taeniate
Lunatisporites diffusus Bharadwaj and Tiwari, 1977
L. ovatus (Goubin) Maheshwari and Banerji, 1966
Corisaccites alutus Venkatachala and Kar, 1966
Hamiapollenites minimus Jha, 1996
H. insolitus Bharadwaj and Salujha, 1964
Guttulapollenites hannonicus Goubin, 1965
G. gondwanensis Goubin, 1965

Monolete
Latosporites sp.

Others
Inaperturopollenites sp.
Quadrisporites sp.
Tiwariasporis sp.
Weylandites magnus (Bose and Kar) Bharadwaj and Dwivedi, 1981
W. indicus Bharadwaj and Srivastava, 1969
W. minutus Bharadwaj and Srivastava, 1969

Fig. 7—Check list of spore-pollen species recorded in Bore core MMK-19.

of Wardha Coalfield (Bhattacharyya, 1997), Assemblage-II of Talcher Coalfield (Tripathi, 1997). This palynoassemblage represents Barakar palynoflora and is equivalent to *Scheuringipollenites barakarensis* Assemblage Zone (Tiwari & Tripathi, 1992).

Palynoassemblage-IV is correlatable with Palynozone 7 of Ramakrishnapuram area (Srivastava & Jha, 1992b), Assemblage-III of Bhopalpalli area (Srivastava & Jha, 1998), Palynozone B of Mahadoli area of Wardha Coalfield (Bhattacharyya & Sarate, 2002), Assemblage-III of Katol area, Wardha Valley

(Kumar & Jha, 2000). Similar palynoassemblages have also been recorded from Supra Barakar sediments of Son Valley (see Histogram Assemblage-5; Tiwari & Ram Awatar, 1987) and Johilla Coalfield, Son Valley (see Histogram Tiwari & Ram Awatar, 1989).

Palynoassemblage-V is correlatable with Assemblage-RB-I of Damodar Basin (Tiwari & Singh, 1986), Assemblage-IV of Mahanadi Basin (Tiwari *et al.*, 1991), Palynozones 2 of Kamptee Coalfield (Srivastava & Bhattacharyya, 1996), Palynozones 9 of Budharam area (Srivastava & Jha, 1995), Palynoassemblage-III of Bottapagudem area (Jha, 2004), Assemblage-III of Mailaram area (Srivastava & Jha, 1990). But some of the significant taxa recorded only in Assemblage-III of Mailaram area, *viz. Columinisporites, Kendosporites* are lacking in the present Palynoassemblage-V of Mamakannu area.

DISCUSSION AND CONCLUSION

The foregoing account of palynology of Lower Gondwana sequence in Mamakannu area of Godavari Graben suggests that rich and diversified vegetation grew in the region during the deposition of these sediments. *Sporae dispersae* recovered from these sediments has been assigned to 44 genera and 76 species (Fig. 7). The quantitative estimation of various taxa at generic level shows marked changes in palynoflora from Lower Karharbari to Raniganj Formation.

In all, five distinct palynoassemblages have been identified in coal bearing horizons of Lower Gondwana succession in Mamakannu area of Godavari Graben, out of which Palynoassemblage-I, II and III belongs to Lower coal horizons (Karharbari and Barakar formations-Early Permian) and Palynoassemblage-IV and V belongs to Upper coal horizon (Raniganj Formation-Late Permian). Karharbari palynoflora (Palynoassemblage-I and II) has been recorded in lithologically designated Barakar Formation, while, Raniganj palynoflora (Palynoassemblage-IV and V) has been demarcated in lithologically designated Barren Measures Formation (Fig. 3).

Dominance of striate disaccates and fairly well representation of *Parasaccites* (upto 12%) alongwith *Densipollenites* (upto 3.5%) is characteristic association in Palynoassemblage-IV. *Densipollenites* alongwith striate disaccates is also characteristic of Barren Measures Formation. This genus almost disappears in Lower part of Raniganj Formation and reappears in uppermost part of Raniganj Formation. *Densipollenites* assemblage of Raniganj Formation is differentiated by the restricted occurrence of *Densipollenites magnicorpus*. Further, the presence of some younger taxa, *viz. Falcisporites, Chordasporites, Kamthisaccites, Lunatisporites, Lundbladispora, Playfordiaspora* and *Densoisporites* in the present Palynoassemblage-IV distinguishes it from Barren Measures palynoflora. Hence, Palynoassemblage-IV and V represents Raniganj equivalent palynoassemblage in Bore core MMK-19 of Mamakannu area.

High incidence of *Parasaccites* in association with striate disaccates has also been reported in Bore core GRK-25 from Ramakrishnapuram area, in Bore core GJP-1 from Jaipuram area (Srivastava & Jha, 1992b) and in Bore core GJ-6 from Bhopalpalli area (Srivastava & Jha, 1998) of Godavari Graben.

In Wardha Valley Coalfield, high incidence of *Parasaccites* alongwith *Densipollenites* and striate disaccates, *viz. Striatopodocarpites, Faunipollenites* and some younger taxa *viz., Falcisporites* and *Satsangisaccites* have been recorded in Mahadoli area by Bhattacharyya and Sarate (2002). Kumar and Jha (2000) also reported similar palynoassemblage (Palynoassemblage-III) from Katol area where radial monosaccate genus *Parasaccites* is present in high percentage (upto 20%) alongwith dominance of striate disaccates and presence of some younger forms, *viz. Goubinispora, Densoisporites, Lundbladispora, Lunatisporites* and *Chordasporites* in low percentage.

In Son Valley, Assemblage-V of Bore core JHL-24, JHL-25 and Assemblage-I of Bore core UKD-8 also show high incidence of *Parasaccites* (see Tiwari & Ram-Awatar, 1987, 1989). Occurrence of *Parasaccites* in high percentage is known from Talchir Formation and Upper Karharbari sediments which are

associated with the cold climate. In Palynoassemblage-IV its association with striate disaccates and some younger forms is significant, suggesting Late Permian affinity. Hence, it is possible that towards the end of the Raniganj Formation (Late Permian) the climate of the region tended to become colder. However, the other spore taxa, e.g. *Plicatipollenites* (1-3%) and *Callumispora* (1%) which suggests cold climate in association with *Parasaccites* present in low amount, could mean a weak cool oscillation. Nevertheless, this evidence from Mamakannu area tends to extend support to the contention of Bharadwaj (1975) for the third glacial phase during Panchet stage. However, lithological evidence for this glaciation in India is not available till now but it is necessary to search in this direction in Godavari Graben due to its close proximity to South Pole during Permian time. Bhattacharyya and Sarate (2002) have reported conglomerate boulder bed at 103.65-103.85 m depth in Bore core WH-14, which substantiates this observation. Talchir like climate have been suggested during Raniganj and Lower Panchet by Tiwari and Tripathi (1988). Late Permian/ Early Triassic plant microfossils have been reported by Dahanayeke *et al.*, 1989 from varve-like rythmites deposited on Sri Lankan fragment of Gondwanaland. Varve-like rythmites are considered to be of glacial origin.

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