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PALYNOLOGY AND PALYNOFACIES OF THE PERMIAN STRATA IN THE KOTHAGUDEM SUB BASIN, ANDHRA PRADESH, SOUTHERN INDIA

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ABSTRACT:

Quantitative and qualitative palynological investigations of 448 m deep borecore A/333, 5B Incline from Kothagudem sub-basin have revealed two distinct palynological assemblages. Palynoassemblage-I (425.50 to 448 m) is characterized by the dominance of non-striate bisaccates mainly, *Scheuringipollenites* spp. (43-57%; *S. barakarensis*, *S. maximus*, *S. tentulus*) and *Ibisporites* spp. (7-15%; *I. diplosaccus, I. jhingurdahiensis*). Striate bisaccates *viz*., *Striatopodocarpites* spp. (10-18%; *S. brevis, S.decorus*, *S. diffuses*) and *Faunipollenites* spp. (5-25%; *F. bharadwajii*, *F. goraiensis*, *F. varius*) are sub-dominant. Palynoassemblage-II (202 - 240 m) is characterized by the dominance of striate bisaccates mainly, *Striatopodocarpites* spp. (7-38%; *S. decorus*, *S. diffuses*, *S. brevis, S. ovalis*), *Faunipollenites* spp. (14-38%; *F. varius*, *F. bharadwajii*, *F.goraiensis*) alongwith good percentage of *Striasulcites* spp. (15-33%; *S. tectus*, *S. ovatus*). Stratigraphically significant taxa indicating Late Permian (Raniganj) affinity recorded in the assemblage in rare percentage includes *Chordasporites australiensis*, *Densoisporites* sp., *Guttulapollenits, hannonicus*, *Hamiapollenites insolatus*, *Klausipollenites schaubergeri*, *Lunatisporites* spp. (*L. paliensis*, *L. pellucidus*), *Osmundacidites* sp., *Striomonosaccites ovatus*, *Strotersporites communis* and *Weylandites obscures*. By palynocomposition Artinskian and Guadalupian age has been assigned to Palynoassemblage-I and Palynoassemblage-II respectively. By the stratigraphic division of the palynofacies associations, three intervals were documented in fluviatile sequence. Interval 1 (I1) is distinguished by the dominance of palynomorphs with a moderate water level, low energy and depleted oxygen conditions; interval 2 (I2) is characterized by high water level alongwith the pre-eminence of amorphous and degraded terrestrial and interval 3 (I3) predominated by charcoal is illustrated by the lowest water level in the paleomire with highly oxidizing conditions.

Keywords: Permian, Palynofacies, Kothagudem sub-basin, Lower Barakar, Raniganj, Godavari Graben, Palaeoenvironment.

INTRODUCTION

Enormous coal deposits in India occur in Lower Gondwana basins of Permian age. The complete Lower Gondwana succession comprises different formations viz., Talchir, Karharbari, Barakar, Barren Measures and Raniganj. Karharbari and Barakar formations are of Early Permian age, and Raniganj Formation is of Late Permian age. Palynologically, these formations are characterized by the presence of specific palynomorphs or their groups. Pollen and spores present in various coal-bearing horizons are quite different in their morphological as well as their numerical characters. Evolutionary changes reflect rather the adaptation to environmental conditions which are also represented by the pollen and spores being deposited contemporary with the sediments. In consequence the occurrence of a specific group of pollen and spores characterizes that particular ecozone. By the quantitative and qualitative study of these spores and pollen coal seams and their formations can be recognized. Thus, the study of spore and pollen aims in the dating of coal and associated sediments and understanding the palynostratigraphy of an area. Stratigraphical position of coal seams in the Godavari Graben is difficult to define due to complicated tectonics, the coal seams cannot be fitted interested in a universal pattern of basin evolution. Consequently, the palynological dating and correlation of coal measures are the prime taste for prospecting of coal in newer areas of this Graben. The present study has been taken up for the first time in Kothagudem sub-basin to build up the depositional history of the Permian sequences of Barakar, Barren Measures and Raniganj formations of Kothagudem sub-basin of Godavari Graben.

GEOLOGY

The Pranhita-Godavari Graben is a major linear NNW-SSE trending coal belt on Precambrian platform, extending over 470 km from the north of Boregaon, Maharashtra in the north to Eluru on the east coast of Andhra Pradesh. Godavari Graben contains a 4000-5000 m thick sedimentary succession comprised of fluviatile sediments ranging from late Carboniferous/ Early Permian to early Cretaceous age. The Godavari is one of the biggest Gondwana basins in India and is the only coal producing area in South India. Most of the coalfields are located along the western margin at Sirpur, Bellampalli, Mandamari, Ramagundam, Chelpur, Pasra, Lingala, Kothagudem, Yellandu and Sattupalli, whereas Cherla and Manuguru are located in the east. Based on geological as well as geophysical data, it has been structurally subdivided in to four sub-basins from north to south as Godavari, Kothagudem, Chintalapudi and Coastal Gondwana tract of Krishna-Godavari sub-basin (Ramanamurty and Parthasarathy, 1988). Kothagudem sub-basin represents south eastern continuation of Godavari sub-basin. The Gondwana rocks in Kothgudem sub-basin lie unconformably over the Dharwan schists and gneisses of Precambrian age. The Lower Gondwana succession in this sub-basin is represented by Talchir, Barakar, Barren Measures and Kamthi formations. The lithological succession in the area has been shown in the table-1 (after Singrani Collieries Company Limited). Location of the drill borecore A/333 has been shown in the map (fig.1).

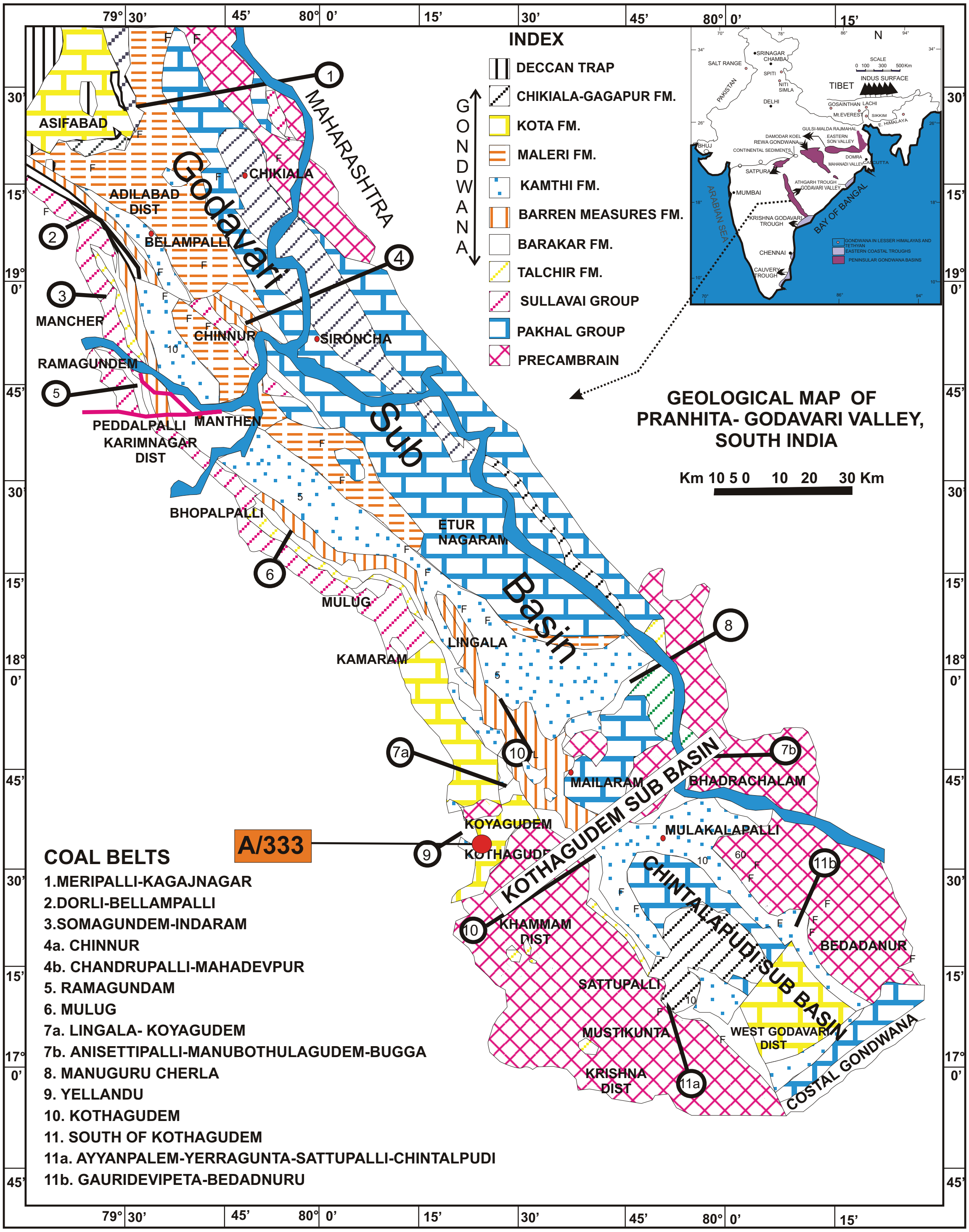
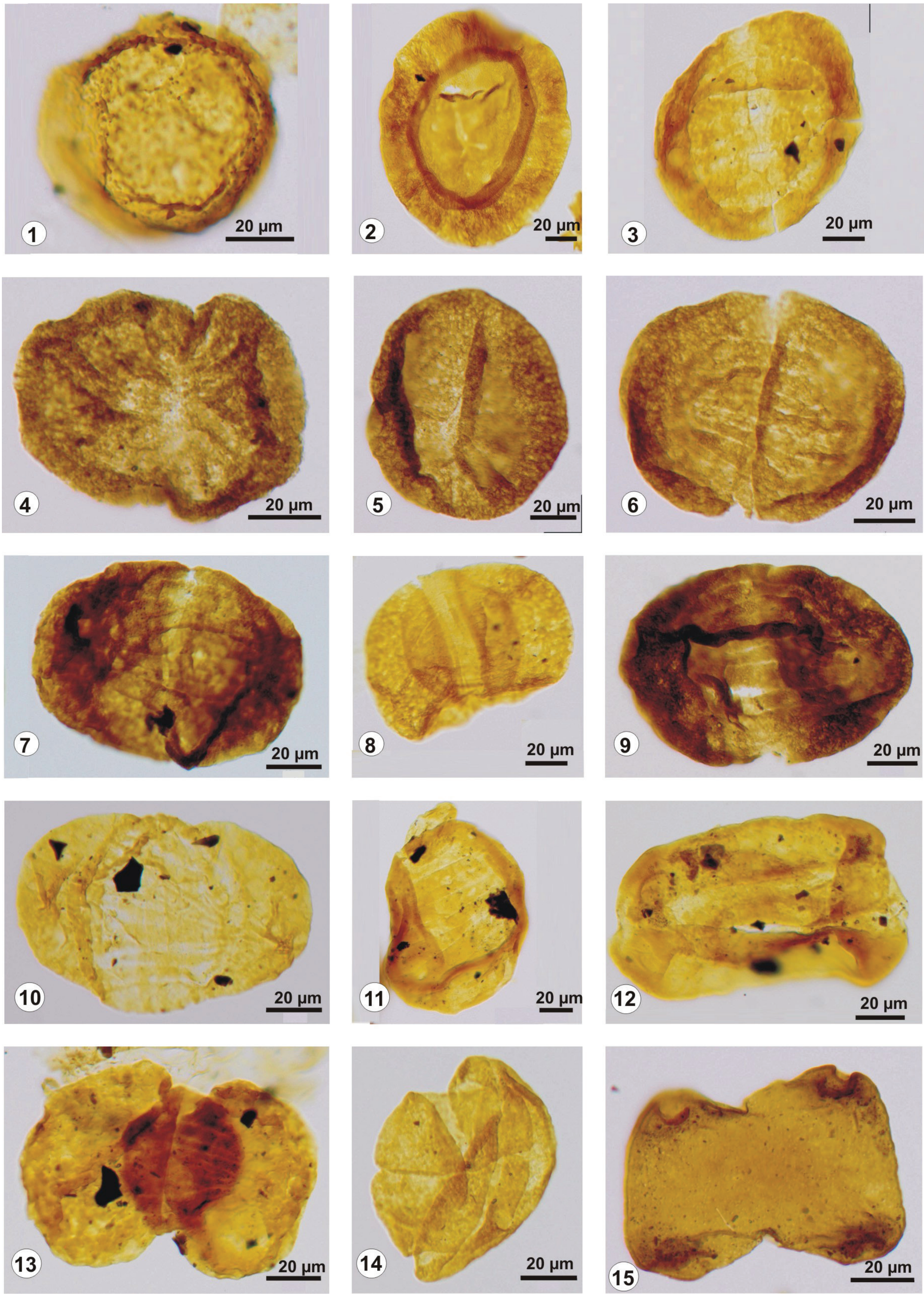


Fig. 1. Location of borecore A/333 in Godavari Graben.

EXPLANATION OF PLATE I

Stratigraphically significant palynomorphs recovered from borecore A/333; 1. ***Lundbladispora microconata,*** B.S.I.P. Slide no. 15674, U60; 2. ***Plicatipollenites gondwanensis,*** B.S.I.P. Slide no. 15675, Q53-3; 3. ***Lunatisporites*** sp., B.S.I.P. Slide no. 15680, K36-3; 4. ***Ibisporites diplosaccus,*** B.S.I.P. Slide no. 15677, M43-3; 5. ***Scheuringipollenites maximus***, B.S.I.P. Slide no. 15677, R42-1; 6. ***Striatopodocarpites tiwarii,*** B.S.I.P. Slide no. 15677, V48-4; 7. ***Striatopodocarpites*** sp., B.S.I.P. Slide no. 15678, L31-1; 8. ***Crescentipollenites fuscus***, B.S.I.P. Slide no. 15679, Q54-1; 9. ***Strotersporites indicus***, B.S.I.P. Slide no. 15678, O42; 10. ***Hamiapollenites insolitus***, B.S.I.P. Slide no. 15680, O35-2; 11. ***Striasulcites ovatus***, B.S.I.P. Slide no. 15675, O50-2; 12. ***Lunatisporites pellucidus***, B.S.I.P. Slide no. 15681, G51-1; 13. ***Striatites parvus***, B.S.I.P. Slide no. 15680, J45-3; 14. ***Guttulapollenites hannonicus***, B.S.I.P. Slide no. 15681, J43-4; 15. ***Tetraporina*** sp., B.S.I.P. Slide no. 15677, J46-3

Plate I


1
20 µm
2
20 µm
3
20 µm
4
20 µm
5
20 µm
6
20 µm
7
20 µm
8
20 µm
9
20 µm
10
20 µm
11
20 µm
12
20 µm
13
20 µm
14
20 µm
15
20 µm

MATERIAL AND METHODS

The bore-core material A/333 for the present studies was collected from 5B Incline area of Kothagudem sub-basin, Godavari Graben, South India.

Palynomorphs were recovered from the sediments using standard palynological processing technique, which involves treatment of rock material with acids and alkali. About 10-20 gm of the material from each sample were taken and crushed into small size pieces (not powder) with the help of pestle and mortar, then first treated with conc. hydrofluoric acid (HF) for two days to remove silica content. After complete washing with water, the material was then treated with commercial nitric acid (conc. HNO_3) for 3-5 days with proper stirring and addition of fresh nitric acid, for oxidation and removal of humic matter, followed by treatment with 10% potassium hydroxide (KOH) after complete washing with water. Finally, the macerates were mounted in Canada balsam with the help of polyvinyl chloride. Qualitative and quantitative analysis was carried out by the study of morphographical characters of palynomorphs, their identification and counting the distinct palynotaxa from each sample at the generic level for identifying the palynoassemblages. For quantitative analysis, about 200 specimens per sample were counted and identified. Lithological details and quantitative analysis of the samples have been shown in fig. 2. Palynological slides have also been used for the palynofacies studies. For detailed palaeoenvironmental studies based on palynofacies, 300 particles were counted and converted into a percentage. Stratigraphically significant palynomorphs and recovered palynofacies have been shown in plate-1 and plate-2 respectively.

The dispersed organic matter was classified into four major categories (palynomorphs, biodegraded matter, structured terrestrial, charcoal) including further minor categories (Table 2) using terminology tailored by different authors (Van Bergen *et al*. 1990; Batten, 1996, Oboh-Ikuenobe and Yepes, 1997, Oboh - Ikuenobe and de Villiers, 2003).

Table 1. Lithological succession in 5B Incline area of Kothagudem sub-basin, Godavari Graben, South India.

GROUP	AGE	FORMATION	LITHOLOGY
LOWER GONDWANA	Upper Permian	Raniganj	Conglomerate, sandstone, siltstone, grey shale
	Upper Permian	Barren Measures/ Kulti	Sandstone, siltstone and carbonaceous clays
	Upper part of Lower Permian	Barakar	Upper: White feldspathic sandstone, siltstone, shale, carb shale and coal seam
			Lower: very coarse grained pebbly sandstone, feldspathic
	Lower Permian	Talchir	Diamitite, rhythmite and light green sandstone
----------Unconformity----------			
Archeans			

RESULTS

The age has been assigned by recovered palynomorph association at the different depth levels in borecore A/333, 5B Incline, Kothagudem area. Quantitative and qualitative palynological analysis of sediments has revealed two palynoassemblages. The vertical distribution of various palynotaxa in the borecore has been shown in the histogram (fig. 2). Palynocomposition of the borecore A/333 at the different depth levels has been shown in Table -3 and a list of recovered spore-pollen species from the studied borecore has been summarized in Table-4.

4.1 Palynoassemblage-I recorded from the depth of 425.50 to 448 m is characterized by the dominance of non-striate bisaccate chiefly *Scheuringipollenites* spp. (Plate-1, fig. 5; 43-57%; *S.barakarensis*, *S. maximus*, *S. tentulus*) and *Ibisporites* spp. (Plate-1, fig. 4; 7-15%; *I. diplosaccus, I. jhingurdahiensis*). Striate bisaccates *viz*., *Striatopodocarpites* spp. (Plate-1, fig. 6 and 7; 10-18%; *S. brevis, S. decorus*, *S. diffuses*) and *Faunipollenites* spp. (5-25%; *F. bharadwajii*, *F. goraiensis*, *F. varius*) are sub-dominant. Other recorded taxa present in the palynoassemblage are *Lophotriletes rectus* (1%), *Caheniasaccites* spp. (1-5%; *C. distinctus*, *C. ellipticus*, *C. elongates*), *Parasaccites* spp. (1-7%; *P. distinctus*, *P. korbaensis*, *P. longus, P. obscurus*), *Plicatipollenites* spp. (Plate-1, fig. 2; 1%; *P.ganjraensis, P. indicus*), *Primuspollenites* sp. (1-2%), *Platysaccus* spp. (4-10%; *P. leschikii*, *P. plicatus*), *Illinites* sp. (4%) and *Striatites communis* (1%). *Tetraporina* sp. (Plate-1, fig. 15; 0.5%) has also been recorded.

4.1.1 Age: By recovered palynocomposition, Early Permian (Artinskian) age (Jha 2006) has been assigned to Palynoassemblage-I.

4.1.2 Botanical Affinity: Palaeovegetation of Palynoassemblage-I is represented by the dominance of gymnospermous pollen grains (glossopterids (Balme, 1995, Jasper *et al*., 2006): *Striatopodocarpites* spp., *Faunipollenites* spp., *Striatites communis; Scheuringipollenites* spp., *Ibisporites* spp.; conifers (Balme, 1995, Jasper *et al*., 2006): *Caheniasaccites* spp., *Parasaccites* spp., *Platysaccus* spp., *Primuspollenites* sp., *Plicatipollenites* spp.) On the other hand filicopsids (Balme, 1995; *Lophotriletes rectus*) are faintly present.

4.1.3 Comparison:

4.1.3.1 Intrabasinal: Similar type of palynocomposition has also been identified in Barakar palynoassembalge from Ramakrishnapuram, Manuguru and Budharam (Srivastava and Jha 1992a, Srivastava and Jha 1992b, Srivastava and Jha 1995) areas of Godavari Graben. Palynoassemblage-I compared well with Assemblage-2 of Ramakrishnapuram (Srivastava and Jha 1989); Assemblage-C of Ramagundam (Srivastava and Jha 1989); Palynozone-2 of Koyagudem (Srivastava and Jha 1996) and Palynozone-3 of Mailaram area (Jha and Aggarwal 2012).

EXPLANATION OF PLATE II

Palynofacies recovered from borecore A/333; 1. An overview of the different type of Dispersed Organic Matter (DOM), B.S.I.P. Slide no. 15675, O51-2; 2. Structured terrestrial organic matter in association with degraded terrestrial, B.S.I.P. Slide no. 15675, O46; 3. Structured terrestrial organic matter (cuticle), B.S.I.P. Slide no. 15675, M48-3; 4. Degraded terrestrial organic matter, B.S.I.P. Slide no. 15675, O48-1; 5. Structured terrestrial organic matter (wood), B.S.I.P. Slide no. 15675, R34-1; 6. Degraded terrestrial organic matter, B.S.I.P. Slide no. 15675, V33-2; 7. Charcoal, B.S.I.P. Slide no. 15679, O54-2; 8. Amorphous Organic matter, B.S.I.P. Slide no. 15682, N40-1; 9. Amorphous Organic matter with pollen grains and cuticles, B.S.I.P. Slide no. 15682, O42-4; 10. Pollen grains, B.S.I.P. Slide no. 15675, P36; 11. Structured terrestrial organic matter (cuticles), B.S.I.P. Slide no. 15679, R63-1

Plate II

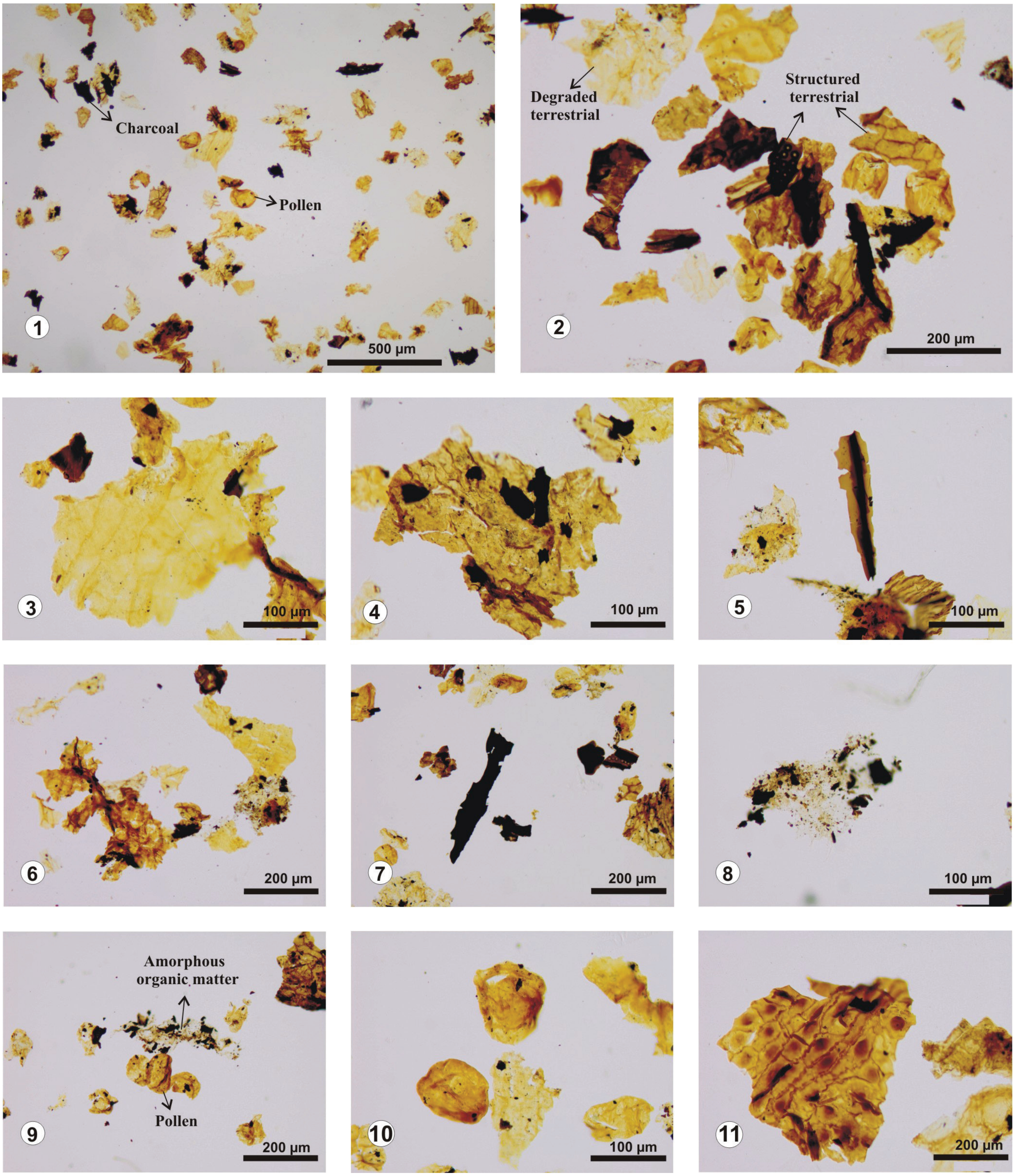

Charcoal
Pollen
1
500 µm
Degraded
terrestrial
Structured
terrestrial
2
200 µm
3
100 µm
4
100 µm
5
100 µm
6
200 µm
7
200 µm
8
100 µm
Amorphous
organic matter
Pollen
9
200 µm
10
100 µm
11
200 µm

Table 2. Classification of Dispersed Organic matter (Van Bergen et al., 1990; Batten, 1996; Oboh-Ikuenobe *et al*., 1997; Oboh-Ikuenobe and Villers, 2003).

Palynomorphs	Spore/pollen (SP)	Pollen and spores are simply documented by their specific character and morphology. Different type of spores and pollens has been identified includes triletes, monosaccates, non-striate bisaccates, striate bisaccates and taeniates. Because of the presence of sporopollenin (most chemically inert biological polymer) in the exine of spore/pollen these have been considered the most resistant plant parts. Presence of different type of spore/pollen reveals different type of habitat.
	Fungal remains (FU)	Fungi are the degrading agents found in ancient as well as in the recent sediments. In the present study, septate and nonseptate types of fungi have been observed. But the frequency is very less.
Biodegraded matter	Degraded terrestrial (DT)	Degraded structured terrestrial organic matter is formed as an effect of fungal and bacterial activities. Fungi act as the most visible degrading agents which transforms vegetal parts into various organic types with the help of biochemical mechanisms. Various states of preservation partial to completely degraded has been observed in this category.
	Amorphous organic matter (AOM)	Fungi and bacteria acting further on partially biodegraded organic matter convert them into totally structureless amorphous mass. Such amorphous matter looks to be porous and spongy. Various stage of amorphous organic matter ranging from partial to complete degradation has been observed under this category.
Structured terrestrial	Tubles/filaments (T/F)	Variable size of structured, unstructured, filamentous, unbranched/branched tubes, either of algal or vascular origin has been considered under this category.
	Wood (W)	Organic matter with a lath-shaped/blocky outline, changeable from pale yellow to brown/dark brown in color, with cellular structure, partially/clearly visible has been considered under this category.
	Poorly preserved wood (PW)	These are bright brown-orange, elongated structureless remains.
	Cuticle (CT)	Protective epidermal cells of higher plants' leaves, shoots aerial plant organs, often pale yellow to pale brown/dark brown in color, thin, rounded or polygonally-shaped cells has been included under this category.
	Plant tissues (PT)	Category includes cellular structures excluding cuticles and wood mainly attributed to parenchyma and herbaceous plants.
Charcaol	Structured charcoal (SC)	opaque and black particles with noticeable structure are incorporated (mainly trachedial structures)
	Non- Structured charcoal (NSC)	Opaque and black particles without noticeable structure are incorporated.

4.1.3.2 Interbasinal: Palynoassemblage-I show its equivalence with *Scheuringipollenites barakarensis* Assemblage zone (zone III A) of Tiwari and Tripathi (1992) in having the dominance of non-striate bisaccates, *viz*., *Scheuringipollenites barakarensis*, *S. maximus*, *Primuspollenites* sp. Beside this, Palynoassemblage-I also have its resemblance with Zone 3, 4 and 5 of Raniganj Coalfield (Tiwari, 1973); Zone-3 of Johilla Coalfield (Anand-Prakash and Srivastava, 1984); Assemblage-B of Korba Coalfield (Srivastava 1984); Assemblage-II of Shobhapur and Pathakhera Coal mine from Pathakhera Coalfield (Sarate 1986); Zone-2 of Shobhapur block, Pathakhera Coalfield (Srivastava *et al*., 1989); Assemblage-B of Wardha Coalfield (Bhattacharyya, 1997); Assemblage-II of Talcher Coalfield (Tripathi, 1997).

4.1.3.3 Comparisons with other Gondwana continents: Barakar palynoflora is tentatively akin to *Vesicaspora* zone of Ktewaka Coalfield in Tanzania (Manum and Tien, 1973) in having the dominance of bisaccates; *Scheuringipollenites*-dominant palynoassemblage of Namwele-Mkomolo and Moze coalfields in Tanzania (Semkiwa *et al*., 1998); upper part of Rio Bonito Formation (Lower part of *Lueckisporites virkkiae* Interval zone), Paraná Basin, Brazil (Souza and Toigo, 2005) in having the few monosaccate and spores; Lower part of *Lueckisporites–Weylandites* (LW) Assemblage Biozone of Argentina in having the abundant bisaccates (Césari and Gutiérrez, 2001); Queen Maud Formation and also with Middle and Upper Weller Coal Measures in having the abundance of *Scheuringipollenites* and *Faunipollenites* with few monosaccate and triletes (Tiwari, 1999).

4.2 Palynoassemblage-II recorded from the depth of 202 to 240 m is characterized by dominance of striate bisaccates chiefly *Striatopodocarpites* spp. (7-38%; *S. decorus*, *S. diffuses*, *S. brevis, S. ovalis*), *Faunipollenites* spp. (14-38%; *F. varius*, *F. bharadwajii*, *F. goraiensis*) alongwith good percentage of *Striasulcites* spp. (Plate-1, fig. 11; 15-33%; *S. tectus*, *S. ovatus*). Stratigraphically significant taxa indicating Late Permian (Raniganj) affinity recorded in the assemblage in rare percentage includes *Chordasporites australiensis* (1-2%), *Densoisporites* sp. (1%), *Guttulapollenites hannonicus* (Plate-1, fig. 14; 1%), *Hamiapollenites insolatus* (Plate-1, fig. 10; 1%), *Klausipollenites schaubergeri* (1%), *Lunatisporites* spp. (Plate-1, fig. 3 and 12; 1-5%; *L. paliensis*, *L. pellucidus*), *Osmundacidites* sp. (1%), *Striomonosaccites ovatus* (1%), *Strotersporites* communis (Plate-1, fig. 9; 1-7%), *Crescentipollenites fuscus* (Plate-1, fig. 8; 1%), *Weylandites obscurus* (1%). Other recorded taxa of the palynoassembalge are *Brevitriletes communis* (1%), *Lacinitriletes conatus* (0.5%), *Microbaculispora barakarensis* (1%), *Caheniasaccites* spp. (1-2%; *C. distinctus*, *C. ellipticus*, *C. elongates*), *Densipollenites* spp. (3-12%; *D. densus*, *D. indicus*, *D. invisus*), *Parasaccites* spp. (1-7%; *P. distinctus*, *P. korbaensis, P. obscures*, *P. longus*), *Plicatipollenites* spp. (2-3%; *P. indicus, P. ganjraensis*), *Potonieisporites distinctus* (1%), *Scheuringipollenites* spp. (2-15%; *S. maximus*, *S. barakarensis*), *Ibisporites* spp. (1-3%; *I. jhingurdahiensis*, *I. diplosaccus*), *Ginkgocycadophytus* sp. (1%) *Tiwariasporis simplex* (1%), *Inaperturopollenites* sp. (3%), *Striatites* spp. (Plate-1, fig. 13; 1-5%; *S. communis*, *S. obliquus*) and *Vesicaspora* sp. (3%).

Fig. 2. Lithological details and quantitative distribution of miospore genera.

4.2.1 Age: By recovered palynocomposition, Late Permian (Guadalupian) age (Jha 2006) has been assigned to Palynoassemblage-II.

4.2.2 Botanical Affinity: Palaeovegetation of Palynoassemblage-II is represented by the dominance (> 50%) of gymnospermous pollen grains (conifers (Balme, 1995, Jasper *et al*. 2006): *Striasulcites* spp., *Lunatisporites* spp., *Hamiapollenites insolatus, Strotersporites communis, Guttulapollenites hannonicus, Chordasporites australiensis, Klausipollenites schaubergeri, Densipollenites* spp., *Parasaccites* spp., *Plicatipollenites* spp., *Potonieisporites distinctus*; glossopterids (Balme, 1995; Jasper *et al*., 2006): *Striatopodocarpites* spp., *Faunipollenites* spp., *Scheuringipollenites* spp. *Ibisporites* spp.; cordiates (Jasper *et al*., 2006): *Striomonosaccites ovatus, Caheniasaccites* spp.) and very least spores (lycopsids (Balme, 1995): *Densoisporites* sp.; filicopsids (Blame, 1995): *Osmundacidites* sp. *Brevitriletes communis*, *Lacinitriletes conatus, Microbaculispora barakarensis*) are present.

4.2.3 Comparison:

4.2.3.1 Intrabasinal: This palynoassemblage correlates with Assemblage-II of Mantheni area (Bharadwaj, 1987); Palynoassemblage-II from Ramagundam, Khammampalli and Manuguru areas (Srivastava and Jha, 1988); Palynozone-5 of Mailaram area (Jha and Aggarwal, 2012) of Godavari Graben.

4.2.3.2 Interbasinal: Palynoassemblage-II compares well with Palynozone-F of Johilla Coalfield of Son Valley (Tiwari and Ram-Awatar, 1989) in having the presence of *Striatopodocarpites, Crescentipollenites*, *Faunipollenites, Klausipollenites;* Assemblage-IV of Talcher Coalfield, Orissa (Tiwari *et al*., 1991); Palynozone-2 of Bazargaon, Nagpur (Srivastava and Bhattacharyya, 1996).

4.2.3.3 Comparisons with other Gondwana continents: In the Godavari, palynoassemblages have been distinguished on the basis of dominance and sub-dominance of the datum while, the workers of other Gondwana continents identified the palynocomposition assuming the concurrent range zone (South Africa; MacRae, 1988), by the first occurrence of index taxa (Australia; Kemp *et al*. (1977), etc. In such cases, where direct correlation is not possible only interim correlation is possible in place of accurate relationship. Late Permian palynofloras are tentatively correlatable with Amery Group of East Antarctica, Buckley Formation from Mount Archernar and FossilryggenVestfjella Dronning Maund Land, Antartcica (Balme and Playford, 1967; Lindström, 1995; Lindström, 1996; Playford, 1990; Truswell, 1980); Karoo Zone 4 and 5 of South Africa and palynomorph zone of Madumabasin Mudstone Formation from Mid-Zambia Basin (Nyambe and Utting, 1997), Upper part of *Lueckisporites*–*Weylandites* (LW) and *Striatites* Assemblage Biozone of Argentina (Archangelsky and Vergel, 1996; Beri *et al*., 2011, Césari and Gutiérrez, 2001).

PALYNOFACIES ANALYSIS

Recovered palynofacies has been categorized into four major categories of kerogen. 1. palynomorphs includes spore/pollen (SP; Plate-2, fig. 1 and 10), and fungal remains (FU)

Table 3. Palynocomposition of the bore core A/333 at the different depth levels

Depth (m)	Palynocomposition	Remarks
202	Poor in organic matter, few wood fragments and tracheids present.	Palyno-assemblage-II Raniganj (Late Permian)
203	Dominance of striate bisaccates chiefly, *Faunipollenites* (30%), *Striatopodocarpites* (7%) and *Striasulcites* (25%). Significant percentage of *Densipollenites* (5%). Presence of *Lunatisporites* (5%), *Chordasporites* (1%), *Klausipollenites* (1%), *Scheuringipollenites* (14%), *Striomonosaccites* (1%), *Osmundacidites* (1%) in rare amounts.	
207	Poor in spore pollen.	
216	Dominance of striate bisaccates chiefly, *Faunipollenites* (38%), *Striatopodocarpites* (10%), *Striasulcites* (26%). Presence of *Densipollenites* (3%), *Lunatisporites* (3%), *Chordasporites* (2%) in rare percentage.	
218	Dominance of striate bisaccates chiefly, *Faunipollenites* (18%), *Striatopodocarpites* (25%), *Striasulcites* (27%). Presence of *Densoisporites, Striomonosaccites, Strotersporites, Hamiapollenites, Lunatisporites, Guttulapollenites, Weylandites* are in rare percentage.	
219	Poor in spore pollen, tracheids present, *Striasulcites* present.	
220	Poor in spore pollen, tracheids and wood fragments present. *Faunipollenites* present.	
221	Poor in spore pollen but presence of striate bisaccates chiefly, *Faunipollenites, Striatopodocarpites, Striasulcites* has been marked while *Guttulapollenites*, *Stromonosaccites, Osmundacidites* are in rare percentage.	
222	Dominance of striate bisaccates chiefly, *Faunipollenites* (14%), *Striatopodocarpites* (28.5%), *Striasulcites* (32%). Rare percentage of *Strotersporites* and *Lunatisporites* has been observed.	
223	Poor in spore pollen, presence of *Faunipollenites, Scheuringipollenites* and *Striatopodocarpites* has been marked.	
226	Dominance of striate bisaccates chiefly, *Faunipollenites* (15%), *Striatopodocarpites* (38%), *Striasulcites* (19%). Rare percentage of *Chordasporites, Klausipollenites, Strotersporites, Lunatisporites, Weylandites* has been observed.	
228	Dominance of striate bisaccates chiefly, *Faunipollenites* (23%), *Striatopodocarpites* (25%), *Striasulcites* (33%). *Lunatisporites, Strotersporites* are in rare percentage while *Densipollenites* is 12%.	
231	Dominance of striate bisaccates chiefly *Striatopodocarpites, Faunipollenites*. Presence of *Lunatisporites, Chordasporites, Falcisporites* in rare percentage.	
240	Dominance of striate bisaccates chiefly, *Faunipollenites* (23%), *Striatopodocarpites* (32%), *Striasulcites* (15%). Presence of rare but stratigraphically significant taxa *viz*. *Klausipollenites* (1%), *Lunatisporites* (2%), *Crescentipollenites* (2%).	
422	Poor in spore pollen.	Palyno-assemblage-I Lower Barakar (Early Permian)
423	Poor in spore pollen.	
428	*Dominance of Scheuringipollenites* (50%), subdominance of striate bisaccates- *Striatopodocarpites* (16%), *Faunipollenites* (12%). Presence of *Parasaccites* (7%), *Platysaccus* (4%), *Primuspollenites* (1%).	
430	Dominance of non-striate bisaccates chiefly, *Scheuringipollenites* (43%), *Ibisporites* (7%). Sub dominance of striate bisaccates *Striatopodocarpites* (18%), *Faunipollenites* (25%). Presence of *Parasaccites* (3%), *Barakarites* (1%), *Primuspollenites* (2%).	
438.50	Dominance of non striate bisaccates chiefly *Scheuringipollenites* (57%), *Ibisporites* (15%). Few striate bisaccates *viz*. *Striatopodocarpites* (10%) *Faunipollenites* (5%) are present. Megaspores are also present here.	
448	Abundance of cuticles and trachied, spore low- presence of one/two grains of *Scheurengipollenites*, *Caheniasaccites, Ibisporites, Parasaccites, Striatopodocarpites, Faunipollenites*.	

2. biodegraded matter includes degraded terrestrial (DT; Plate-2, fig. 2, 4 and 6) and amorphous organic matter (AOM; Plate-2, fig. 8 and 9) 3. structured terrestrial includes tubes/filaments (T/F), wood (W; Plate-2, fig. 5), poorly preserved wood (PW), cuticle (CT; Plate-2, fig. 3 and 11) and plant tissues (PT) 4. Charcoal includes structured charcoal (SC) and non- structured charcoal (NSC; Plate-2, fig. 7). Classifications of different types of recovered organic matter have been summarized in table-2. Four palynofacies associations were determined based upon the origin of particulate organic matter: palynomorphs, structured terrestrial, charcoal amorphous organic matter and degraded terrestrial.

The studied section is strongly dominated by amorphous particles (average 31.6%) with a predominance of degraded terrestrial material. This material, also named as pseudo amorphous (Carvalho *et al*., 2013; Tyson 1995), reflect a process of degradation that may be related to oxic conditions during transport. The second group in abundance is the palynomorphs (spores and pollen grains) with 27.9% in average. By the stratigraphical distribution of the palynofacies associations, three intervals were recognized (Fig. 3).

5.1 Interval 1 (425.5—448 m)

The sediment interval shows high content of carbonaceous shale and grey shale with minor alternating layers of sandstone. The sediments are laminated and stacked in horizontal arrangement with very low dips/ arranged parallel. The sediment association indicates stagnant water setting but due to elevated evapotranspiration; the water level must have been reduced to a great extent which led to differential deposit of palynofacies components (bisaccate pollen grains). The I1 is coincident with the interval Palynoassemblage-I which is dominated by bisaccate types. These palynomorphs are known for their buoyancy and hence demonstrates the pollen rain during the depositional time span. The palynomorph records 79% of the total organic matter at 430 m. The palynomorphs show low proportion of spores that in general tend to be abundant only near shore's settings (Tyson, 1995). This reinforces the idea of a paleomire located in more inland area with a moderate water level, low energy and depleted oxygen conditions (Fig. 3). The conjunction of sediment and palynofacies components has led us to infer the moderate water level during the depositional time.

5.2 Interval 2 (240—221 m)

This interval comprises of sandstone and frequent intercalations of carbonaceous shales. The composition may be the result of elevated impounding water levels in the environment with lofty stagnant conditions. In this unit alternating cycles of coarse to fine grained sediment variation can be easily identified. This may be due to the high sluggish water content allocating settling of the coarser and finer sediment respectively. Consequently, a fining upward sequence can be easily encountered.

The interval 2 (I2, Fig. 3) is characterized by high content of amorphous material (true amorphous and degraded terrestrial). In general, both particles, particularly amorphous, require quite water into the system to preserve them. At a depth of 223 m is recorded the percentage of 66.3% of amorphous organic matter, which reflects the significant flooding of the paleomire in the section. However, the whole section is marked by a large amount of amorphous + degraded material, indicating that although the terrigenous material input on the paleoenvironment was continuous, the conditions of low oxygenation were enabled to preserve the particulate organic material.

5.3 Interval 3 (221—202 m)

The interval comprises of high sandstone content with minor intercalations of the carbonaceous shales. This may be due to the affluent supply of terrigenous clastic sediments alongwith short stretch of high precipitation. This inference has been derived due to the recovered variable palynofacies components of environmental variability. The Interval 3 (I3) shows high abundance of charcoal (opaque) particles. At 202 m, these particles reach 70.1%. The high amount of opaque material can be explained by oxidation after sub-aerial exposure of non-opaque particles. The decrease in abundance of amorphous material can be the response to the oxidizing conditions. The distribution of particulate organic matter indicates that in the I3 (Fig. 3) occurred the lowest water level or even the drying in the paleomire with highly oxidizing conditions.

Table 4. List of spore pollen species recovered from bore core A/333.

Recovered genera	Early Permian	Late Permian	Botanical Affinity (Balme, 1995; Beri *et al*., 2011; Quadros *et al*., 1996; Diéguez and Barrón, 2005; Jasper *et al*., 2006)
Lophotriletes rectus Bharadwaj and Salujha, 1964	+		Filicopsids
Illinites sp.	+		Coniferopsids
Platysaccus plicatus Bharadwaj and Dwivedi, 1981	+		
Platysaccus leschikii Kar, 1960	+		
Scheuringipollenites tentulus (Tiwari) Tiwari, 1973	+		glossopterid
Primuspollenites sp.	+		Coniferopsids
Parasaccites distinctus Tiwari, 1965	+	+	Coniferopsids
Parasaccites korbaensis Bharadwaj and Tiwari, 1964	+	+	
Parasaccites obscurus Tiwari, 1965	+	+	
Parasaccites longus Kar and Bose, 1967	+	+	
Plicatipollenites indicus Lele, 1964	+	+	Coniferophyta
Plicatipollenites ganjraensis Saxena, 1971	+	+	
Caheniasaccites distinctus Lele and Makada, 1972	+	+	Cordiates
Caheniasaccites ellipticus Bose and Maheshwari, 1968	+	+	
Caheniasaccites elongates Bose and Kar, 1966	+	+	
Ibisporites jhingurdahiensis Sinha, 1972	+	+	Gymnospermophyta
Ibisporites diplosaccus Tiwari, 1968	+	+	
Scheuringipollenites maximus (Hart) Tiwari, 1973	+	+	
Scheuringipollenites barakarensis (Tiwari) Tiwari, 1973	+	+	
Striatopodocarpites decorus Bharadwaj and Salujha, 1964	+	+	Ginkgoopsida (? Glossopteridales)
Striatopodocarpites diffusus Bharadwaj and Salujha, 1964	+	+	
Striatopodocarpites brevis Sinha, 1972	+	+	
Faunipollenites varius Bharadwaj, 1962	+	+	
Faunipollenites bharadwajii Maheswari, 1967	+	+	
Faunipollenites goraiensis (Potonié and Lele) Maithy, 1965	+	+	
Striatites communis Bharadwaj and Salujha, 1964	+	+	Glossopteridales
Lacinitriletes conatus Srivastava, 1977		+	Filicopsid
Microbaculispora barakarensis Tiwari (1965) Tiwari and Singh, 1981		+	
Densoisporites sp.		+	Lycopsids

Striomonosaccites ovatus Bharadwaj, 1964		+	Cordiates
Densipollenites densus Bharadwaj and Srivastava, 1969		+	Coniferopsida
Densipollenites indicus Bharadwaj, 1962		+	
Densipollenites invisus Bharadwaj and Salujha, 1964		+	
Potonieisporites distinctus Lele and Makada, 1972		+	
Chordasporites australiensis de Jersey, 1962		+	
Falcisporites nuthallensis Clarke, Balme, 1970		+	Ginkgoopsida (Peltaspermales)
Falcisporites stabilis Balme, 1970		+	
Klausipollenites schaubergeri (Potonié and Kremp) Klaus, 1963		+	Coniferopsids (Pinopsida)
Vesicaspora sp.		+	Ginkgoopsida (? Glossopteridales)
Striatopodocarpites ovalis Sinha, 1972		+	
Striasulcites tectus Venkatachala and Kar, 1968c		+	Coniferopsids
Striasulcites ovatus Venkatachala and Kar, 1968c		+	
Strotersporites communis Wilson, 1962		+	
Striatites obliquus Srivastava, 1979		+	Glossopteridales
Crescentipollenites fuscus (Bharadwaj) Bharadwaj, Tiwari and Kar, 1974		+	Coniferopsids
Crescentipollenites globosus (Maithy) Jha, 1996		+	
Hamiapollenites insolatus Bharadwaj and Salujha, 1964		+	
Brevitriletes communis Bharadwaj and Srivastava emend. Tiwari and Singh, 1981		+	Filicopsids
Lunatisporites paliensis Tiwari and Ram-Awatar, 1988		+	Coniferopsids
Lunatisporites pellucidus (Goubin, 1965) Maheshwari and Bnaerji, 1975		+	
Guttulapollenites hannonicus Goubin, 1965		+	Coniferopsids
Osmundacidites sp.		+	Filicopsids
Inaperturopollenites sp.		+	others
Ginkgocycadophytus sp.		+	
Tiwariasporis simplex (Tiwari) Maheshwari and Kar, 1967		+	
Weylandites obscurus (Tiwari) Bharadwaj and Dwivedi, 1981		+	Ginkgoopsida (? Glossopteridales)

CONCLUSIONS

Palynological and palynofacies analysis of borecore A/333, 5B incline from Kothagudem sub-basin has been done in the present study from which the following inferences have been drawn:

1. Palynologically the borecore A/333 yielded 56 spore-pollen species. Identified palynoassemblages are dominated by non-striate bisaccates (Palynoasemblage-I) and striate bisaccates (Palynoasemblage-II).
2. Palynoassemblage-I (428-448 m) is distinguished by the dominance of chiefly *Scheuringipollenites* and sub-dominance of striate bisaccates indicate Early Permian Lower Barakar affinity (Artinskian), while the Palynoassemblage-II (202-240 m) is differentiated by the dominance of striate bisaccates alongwith some stratigraphically significant taxa *viz. Lunatisporites* spp., *Chordasporites australiensis, Klausipollenites schaubergeri, Guttulapollenites hannonicus, Falcisporites* spp. etc. which indicates Late Permian, Raniganj affinity (Guadalupian).
3. By the stratigraphical division of the palynofacies associations, three intervals were documented. The Interval 1 (I1, 425.5—448 m) shows lofty content of carbonaceous shale and grey shale with small intercalations of sandstone, which is distinguished by a moderate water level, low energy and depleted oxygen conditions. Interval 2 (I2, 240—221 m) is characterized by fining upward sequence and elevated water level alongwith the dominance of amorphous and degraded terrestrial palynofacies components. Interval 3 (I3, 221—202 m) comprises of high sandy content with minor carbonaceous shales and lowest water level in the paleo mire. The decrease in abundance of amorphous material can be the response to the oxidizing conditions in I3. The absence of marine elements in the presently studied section suggests the lacustrine condition of the deposition.

The palynodata presented here provides important information for palaeoenvironment reconstruction, international comparison of palaeofloral diversity pattern and climate change within the Permian sediments of Kothagudem sub-basin. Ongoing studies will also address basin-wide palynofacies analysis of the Kothagudem sub-basin and a high-resolution palynostratigraphic construction of the Permian sediments.

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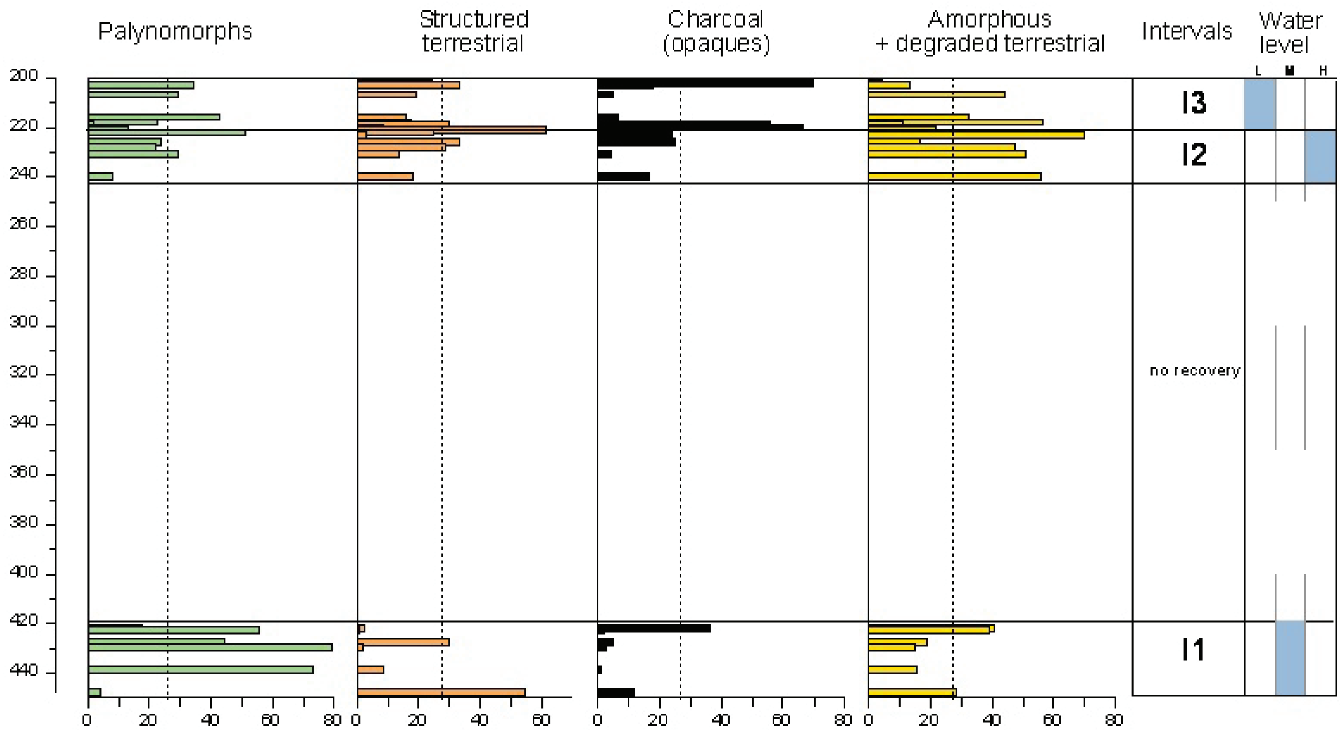

Fig. 3. Stratigraphic distribution of palynofacies associations and the inferred water level. Dashed line = average values. L= low, M=moderate and H= high.

REFERENCES

Anand-Prakash and Srivastava, S. C. 1984. Miofloral studies of the Lower Gondwana sediments in Johilla Coalfield, Madhya Pradesh, India. *Palaeobotanist*, **32**: 243-252.

Archangelsky, S. and Vergel, M. D. M. 1996. Capítulo 2. Cuenca Chacoparanense. Paleontología, bioestratigrafía y paleoecología Academia Nacional de Ciencias, Córdoba, Argentina.

Balme, B. E. and Playford, G. 1967. Late Permian plant microfossils from the Prince Charles Mountains, Antarctica. *Review of Micropalaeontology,* **10**: 179–192.

Balme, B. E. 1995. Fossil in situ spores and pollen grains: an annotated catalogue. *Review of Palaeobotany and Palynology,* **87**: 81-323.

Batten, D. J., 1996. Palynofacies and paleoenvironmental interpretation: American Association of Stratigraphic Palynologists Foundation.

Batten, D.J. 1996. Palynofacies and plaeoenvironmental interpretation, p. 1011-1064. In: Palynology: *Principles and applications*, (Eds. Jansonius, J. and McGregor, D.C.), American Association of Stratigraphic Palynologists Foundation, **3**.

Beri, Á., Gutiérrez, P. and Balarino, L. 2011. Palynostratigraphy of the late Palaeozoic of Uruguay, Paraná Basin. *Review of Palaeobotany and Palynology*, **167**: 16-29.

Bharadwaj, D. C, Srivastava, S.C., Ramanamurty, B. V. and Jha, N. 1987. Palynology of Kamthi Formation from Ramagundam-Mantheni area, Godavari Graben, India. *Palaeobotanist*, **35**: 318-330.

Bhattacharyya, A. P. 1997. Palynological recognition of the Karharbari-Barakar formations in the sub-surface sediments of Wardha Coalfield, Maharashtra, India. *Palaeobotanist*, **46**: 217-219.

Carvalho, M. D. A., Ramos, R. R. C., Crud, M. B., Witovisk, L., Kellner, A. W., Silva, H. D. P., Grillo, O. N., Riff, D. and Romano, P. S. 2013. Palynofacies as indicators of paleoenvironmental changes in a Cretaceous succession from the Larsen Basin, James Ross Island, Antarctica. *Sedimentary Geology*, **295**: 53-66.

Césari, S. N. and Gutiérrez, P. R. 2001. Palynostratigraphy of Upper Paleozoic sequences in Central–Western Argentina. *Palynology,* **24**: 113–146.

Diéguez, C. and Barrón, E. 2005. Upper Permian floral vegetation changes near the PIT boundary in the Landete section of the Alcotas Formation (SE Iberian Ranges, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **229**: 54-68.

Jasper, A., Menegat, R., Guerra-Sommer, M., Cazzuloklepzig, M. and Souza, P. A. 2006. Depositional cyclicity and paleoecological variability in an outcrop of Rio Bonito formation, Early Permian, Paraná Basin, Rio Grande do Sul, Brazil. *Journal of South American Earth Sciences*, **21**: 276–293.

Jha, N. 2006. Permian palynology from India and Africa: A phytogeographical paradigm. *Journal of the Palaeontological Society of India*, **51**: 43-55.

Jha, N. and Aggarwal, N. 2012. Permian–Triassic palynostratigraphy in Mailaram area, Godavari Graben, Andhra Pradesh, India. *Journal of Earth System Science*, **121**: 1257–1285.

Kemp, E. M., Balme, B. E., Helby, R. J., Kyle, R. A., Playford, G. and Price, P. L. 1977. Carboniferous and Permian palynostratigraphy in Australia and Antarctica: a review. *Bureau of Mineral Resources journal of Australian geology and geophysics,* **2**: 177-208.

Lindström, S. 1995. Early Permian palynostratigraphy of the northern Heimefrontfjella Mountain-range, Dronning Maud Land, Antarctica. *Review of Palaeobotany and Palynology*, **89**: 359–415.

Lindström, S. 1996. Late Permian palynology of Fossilryggen, Vestfjella, Dronning Maund Land, Antarctica. *Palynology,* **20**: 15-48.

MacRae, C. S. 1988. Palynostratigraphic correlation between the Lower Karoo sequence of the Waterberg and Pafuri coal bearing basins and the Hammanskraal palnt microfossil locality, Republic of South Africa. Department Mineral Energy Affairs, *Geological Survey, Memoir* **75**: 217.

Manum, S. B. and Tien, N. D. 1973. Palynostratigraphy of the Letewaka Coalfield (Lower Permian). *Review of Palaeobotany and Palynology*, **16**: 213-227.

Nyambe, I. and Utting, J. 1997. Stratigraphay and palynostratigraphy Karoo super group (Permian and Triassic) Mid Zambesi Velly southern Zambia. *Journal of African Earth Sciences,* **24**: 563-583.

Oboh – Ikuenobe, F. E. and de Villiers, S. E. 2003. Dispersed organic matter in samples from the western continental shelf of South Africa: palynofacies assemblages and depositional environments of Late Cretaceous and younger sediments. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **201**: 67-88.

Oboh-Ikuenobe, F. E., Yepes, O. and Leg, O. D. P. 159 Scientific Party. 1997. Palynofacies analysis of sediments from the Côte d'Ivoire-Ghana Transform Margin: Preliminary correlation with some regional events in the eastern Equatorial Atlantic. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **129**: 291-314.

Playford, G. 1990. Antarctic Paleobiology: Its Role in the Reconstruction of Gondwanaland. In: Taylor, T.N. and Taylor, E.L. (Eds.): Proterozoic and Paleozoic palynology of Antarctica; a review. Springer-Verlag, New York, 51-70 pp.

Quadros, L.P., Marques-Toigo, M. and Cazzulo Klepzig, M. 1996. Catálogo de esporas e pólen fósseis do Paleozoico. *Boletim de Geociências da Petrobrás*, **9:** 1-151.

Ramanamurty, B. V. and Parthasarathy, E. V. R. 1988. On the evolution of the Godavari Gondwana graben based on LANDSAT imagery interpretation. *Journal of the Geological Society of India,* **32**: 417-425.

Sarate, O. S. 1986. Palynological correlation of the coal seams of Pathakhera Coalfield, Madhya Paradesh, India. *Geophytology,* **16**: 239–248.

Semkiwa, P., Kalkeuth, W., Utting, J., Mayagilo, F., Mpanju, F. and Hagemann, H. 1998. The geology, petrology, palynology and geochemistry of Permian coal basin in Tanzania. NamweleMkomolo, MuzeGalula Coalfields. *International Journal of Coal Geology*, **36**: 63–110.

Souza, P. A. and Toigo, M. M. 2005. Progress on the palynostratigraphy of the Permian strata in Rio Grande do Sul State, Paraná Basin, Brazil. *Anais da Academia Brasileira de Ciências*, **77**: 353-365.

Srivastava S. C., Jha N. 1988. A Lower Triassic palynoassemblages from Budharam area, Godavari Graben, Andhra Pradesh, India. *Geophytology*, **18**: 124-125.

Srivastava, S. C. and Bhattacharyya, A. P. 1996. Permian-Triassic palynofloral succession in subsurface from Bazargaon. Nagpur District, Maharashtra. *Palaeobotanist,* **43**: 10-15.

Srivastava, S. C. and Jha, N. 1989. Palynology of Lower Gondwana sediments in the Godavari Graben, Andhra Pradesh, India. Palaeobotanist, **37**: 199-209.

Srivastava, S. C. and Jha, N. 1992b. Permian palynostratigraphy in Ramakrishnanpuram area, Godavari Graben, Andhra Pradesh, India. *Geophytology*, **20**: 83-95.

Srivastava, S. C. and Jha, N. 1995. Palynostratigraphy and correlations of Permian-Triassic sediments in Budharam Area, Godavari Graben, India. *Journal of the Geological Society of India,* **46**: 647-653.

Srivastava, S. C. and Jha, N. 1996. Palynology of sub-surface Permian sediments in Koyagudem area, Godavari Graben, Andhra Pradesh. *Geophytology*, **25**: 131-136.

Srivastava, S. C., 1984. Palynological correlation of coal seams in Kusmunda block, Korba Coalfield, Madhya Paradesh, India. *Palaeobotanist*, **32**: 230-235.

Srivastava, S. C., Anand-Parkesh and Sarate, O. S., 1989. Palynology of the Talchir Formation from Betul Coalfield, Satpura Basin, India. *Palaeobotanist*, **37**: 81-84.

Srivastava, S.C. and Jha, N. 1992a. Palynostartigraphy of Permian sediments in Manuguru area, Godavari Graben, Andhra Pradesh. *In:* Vankatachala, V.S., Jain K.P. and Awasti, N. (eds.) – *Proceedings of Birbal Sanhi Birth Centenary Palaeobotanical Conference*, *Geophytology,* **22**: 103-110.

Tiwari, R. S. and Ram-Awatar, 1989. Sporae dispersae and correlation of Gondwana sediments in Johilla Coalfield, Son Valley Graben, Madhya Pradesh. *Palaeobotanist*, **37**: 94-114.

Tiwari, R. S. and Tripathi, A. 1992. Marker Assemblage Zones of spore and pollen species through Gondwana Palaeozoic-Mesozoic sequence in India. *Palaeobotanist*, **40**: 194-236.

Tiwari, R. S. Tripathi, A. and Jana, B. N. 1991. Palynological evidence for Upper Permian Raniganj Coals in western part of Talcher Coalfield, Orissa, India. *Current Science*, **61**: 407-420.

Tiwari, R. S. 1973. Palynological succession in the Barakar type area. *Geophytology*, **3**: 166-183.

Tiwari, R. S. 1999. The palynological succession and spatial relationship of the Indian Gondwana sequence. *PINSA*, **65A**: 329-375.

Tripathi, A. 1997. Palynostratigraphy and palynofacies analysis of subsurface Permian sediments in Talcher Coalfield, Orissa. *Palaeobotanist*, **46**: 79-88.

Truswell, E. M. 1980. Permo-Carboniferous palynology of Gondwanaland: progress and problem in the decade to 1980. *BMR Journal of Australian Geology and Geophysics*, **5**: 95-111.

Tyson, R. V. 1995. Sedimentary Organic Matter Chapman and Hall, Londons.

Van Bergen, P., Janssen, N., Alferink, J. and Kerp, J. 1990. Recognition of organic matter types in standard palynological slides. *Mededelingen Rijks Geological Dienst,* **45**: 1-23.

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