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Research Article

PALYNOBIOSTRATIGRAPHY AND FLORAL BIODIVERSITY OF LATE PERMIAN SEDIMENTS FROM GODAVARI GRABEN, ANDHRA PRADESH

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ABSTRACT
Palynological investigation in 370m deep sedimentary sequence has been done in bore core MCP-8 from Chintalapudi area, Chintalapudi sub-basin. The sedimentary sequence mainly consists of sandstone, shale or intercalation of these two, inferring fluvially derived deposits. Qualitative as well as quantitative analysis has been done for the palynological analysis. Two palynoassemblages have been identified which are majorly dominated by striate bisaccates, representing Late Permian (=Raniganj palynoflora). Palynoassemblage –I is characterized by the dominance of striate bisaccates *viz*., *Striatopodocarpites*, *Faunipollenites*, *Crescentipollenites* along with a characteristic enveloping monosaccate pollen *viz*., *Densipollenites.* The Palynoassemblage-II defers from later in having a significant presence taenite bisaccates chiefly, *Guttulapollenites* and *Corisaccites.* On the basis of palynocomposition of the assemblage and comparison of the palynoflora with other Gondwana continents late Permian (Guadalupian-Lopingian) age has been assigned to the studied sequence. Paleovegetation studies have revealed the presence of thick arborescent forests during Late Permian times in Godavari Graben. The canopy of the forest is mainly dominated by the glossopterids, cordaitales and conifers while peltasperms were less abundant. The understorey flora formed by the pterophyta, Equisetopsids and algal forms. A change in palynoflora has been observed from Late Permian to latest Permian. Many of the dominant early Triassic forms starts appearing (lycopsids and conifers) in the Lopingian age while dominant Permian forms like glossopterids start declining.

Keywords: *Palynology, Permian, Palaeovegetation, Chintalapudi Area, Guadalupian, Lopingian*

INTRODUCTION
The Gondwana successions of peninsular India were deposited in fault-bounded basins that developed along Precambrian lineaments during deposition. There deposition is affected by intrabasinal faults indicating fault-controlled synsedimentary subsidence (Chakraborty *et al.,* 2003). The presence of these faults makes the stratigraphy and correlation of the strata difficult. However, on the basis of lithic characters various stratigraphic schemes in a sequence have been identified and correlated through floral and faunal assemblages.
Although boundary of biozones doesn't coincide with the lithozones. The presence of sporopollenin, abundant production, robustness and small size make spores and pollen ubiquitous in distribution. Thus, palynology serves as the best tool for the dating and correlation of terrestrial sediments. To overcome this problem palynological succession of Lower Gondwana sequence has been studied in different basins of India by several authors (Bharadwaj, 1975; Lele and Karim, 1971; Lele and Srivastava, 1980; Tiwari and Ram-Awatar, 1989; Tiwari *et al.,* 1991, Tiwari and Tripathi, 1992; Srivastava and Jha, 1989, 1990, 1992a and 1992b; Jha and Srivastava, 1996; Jha *et al.,* 2014). The present study has been done in the bore core MCP-8 at Chintalapudi area of Chintalapudi sub-basin, Godavari Graben. Qualitative as well as the quantitative study of spores and pollen has been done for the biostratigraphy of coal seams and their associated sediments.
Paleovegetation studies were done on the basis of compilation of work on pollen and spore affinity by different workers *viz*., Balme (1970, 1995); Grauvogel-Stamm (1978, 1999); Retallack (1975, 1997); Hochuli *et al.,* (2010); Lindstorm *et al.,* (1997); Looy *et al.,* (1999); Krassilov and Karasev, (2009); Kustatscher *et al.,* (2010); Gastaldo *et al.,* (2005); Lindstorm and McLoughlin, (2007). The palynomorph

mainly belongs to nine groups, viz., algal, pterophyta, equisetopsids, lycopsids, cordaitales, glossopterids, peltasperms, conifers and gnetopsida.

Geological Setup

The present investigation is dealt with the Gondwana deposits (Permian) in Pranhita-Godavari Valley, situated at Andhra Pradesh and Telangana. The peninsular shield of Andhra Pradesh and Telangana exposes lithounits of Archaean to Quaternary. The states have the rich sediment record of the great tectonic history of the earth in about 3000m thick sediments deposited in a time span of 200 Ma from Late Carboniferous/ Early Permian to Cretaceous. Pranhita – Godavari (P-G) Basin, the NW – SE trending intra-cratonic basin covering an area of about 17000 sq km., bounded by latitudes 16˚38' to 19˚32' in north and longitudes 79˚12' to 81˚39'in east. The basin is unique as it preserves about 6000 m thick sediments, deposited in a time span of 200 Ma from Late Carboniferous/ Early Permian to Cretaceous. Not only this, the basin is worth working for its huge coal deposits, and it stands first in having the most abundant coal reserves in Southern India. Basin is divisible into four structural sub-basins (Godavari, Kothagudem, Chintalapudi and coastal Krishna Godavari) (Raja, 1982).

The Chintalapudi sub-basin is an NW-SE trending basin occurring at the south-eastern part of the Godavari valley, covering an area of 2500 Km^2. The Gondwana deposits in the sub-basin attain a thickness of about 3200m (Bhaskararao *et al.,* 1971). The geology of the Chintalapudi sub-basin has been primarily worked out by Blandford (1871). According to him and King (1881), the sub-basin has the deposits of Kamthi Formation and a small patch of Barakar Formation near Beddadanur. Further Raja (1982), Raiverman *et al.,* (1985) also opined the same. Later the studies done by Lakshminarayana and Murti (1990), Lakshminarayana (1996) revealed the presence of Talchir and Barakar and Kamthi Formations of the Lower Gondwana Group, and Kota and Gangapur Formations of the Upper Gondwana Group. The Chintalapudi area lies in Sattupalli-Chintalapudi coal belt, forming the southern part of Chintalapudi sub-basin. The complete lower Gondwana succession in Chintalapudi sub-basin is given in table 1 and location map and lithology of the bore core is given in figure 1 and 4 respectively.

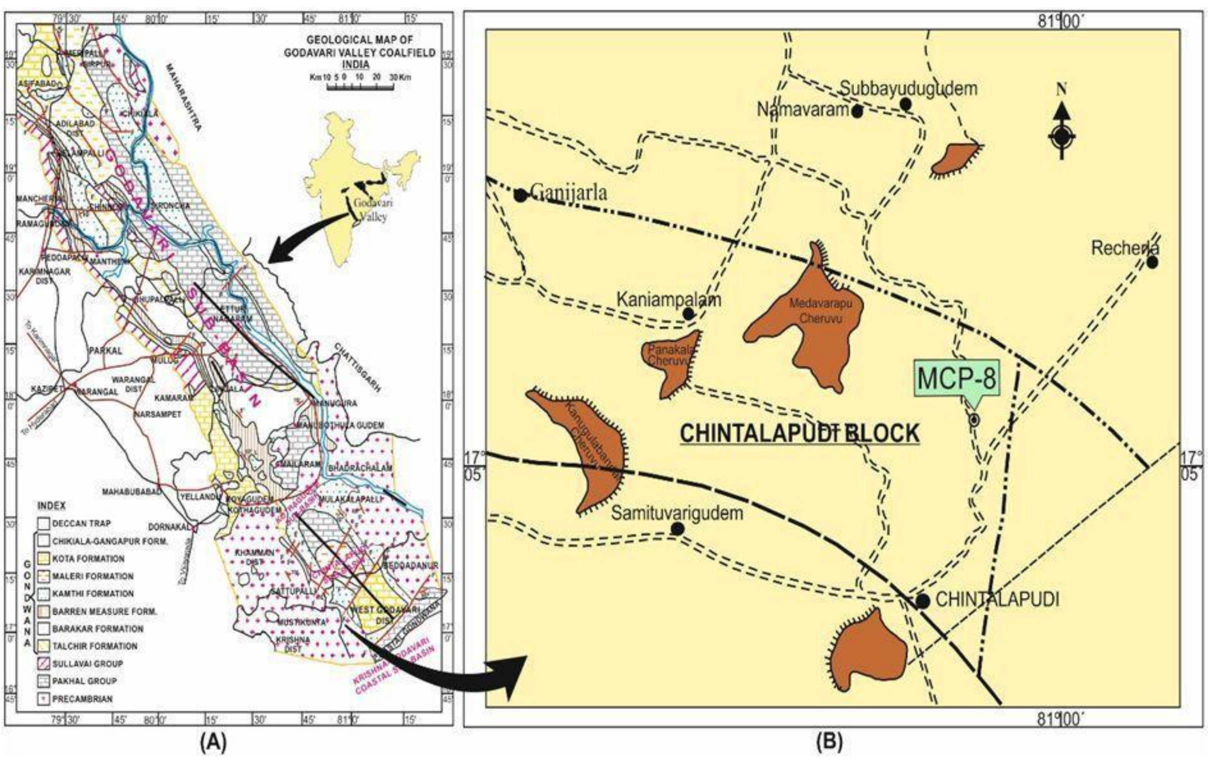

Figure 1: (A) Map of Godavari Graben showing the detailed geology of the area. (B) Map showing detailed location of boe core MCP-8, Chintalapudi area

Table 1: Stratigraphic succession of Lower Gondwana in Chintalapudi sub-basin (after Lakshminarayana, 1996)

Age	Group	Formation	Lithology
L.PERMIAN - E.TRIASSIC	LOWER G O N D W A N A	Kamthi	Conglomerate, conglomeratic sandstone, siltstone and grey shales
Early P E R M I A N		Unconformity	
		Barakar	**UPPER:** White felspathic sandstone, siltstone, shale, carbonaceous shale and coal seams **LOWER:** Very coarse grained, pebbly, feldspathic sandstone
		Talchir	Diamictite, rhythmite, fine-grained light green sandstone and siltstone
Unconformity			
Proterozoic Archaean			

MATERIALS AND METHODS

Total twenty-five samples have been collected in the bore core MCP-8 (270.0m deep), out of which only nineteen yielded a significant amount of palynomorphs that can be used for palynostratigraphy and paleovegetation studies. Samples have varied lithologies viz., shale, sandstone, coal, carbonaceous shale, shaly coal and intercalation of these. Extraction of palynomorphs has been done using standard acid maceration technique. 5-20 gm of each sample, based on lithology has been used for palynomorph extraction. Samples were first crushed using mortar and pestle and then followed by 2-4 days HF treatment in plastic jars. After washing through water, samples were treated with HNO_3 for 3-4 days followed by treatment with 10% KOH treatment. Samples were thoroughly washed using water after each acid and base treatment through an acid resistant sieve having 150 to 400 mesh size. Permanent slides were made using polyvinyl alcohol and Canada balsam. The scanning of palynomorphs and photography of pollen and spores were done using BX62microscope and DP25 Olympus digital camera. Significant slides have been deposited in the museum of Birbal Sahni Institute of Palaeobotany, Lucknow, India. 200 palynomorphs have been counted in each sample for making palynoassemblages. Botanical affinities of cryptogrammic spores and flowering plant's pollen have been done using the compilation of work by the various author. The complete list of palynomorphs along with their relevant affinity has been given in table 2.

RESULTS AND DISCUSSION

Results

Total of forty palynotaxa have been recorded on the basis of morphological studies. Among them three were of algal affinity, ten to pteridophytic spore group and rest twenty-seven to gymnosperms. The spore-pollen taxa along with their corresponding affinities have been listed in table 2. The percentage frequency chart of palynomorphs and photomicrographs of significant palynotaxa has been given in figure 2 and 3. Two palynoassemblages have been made on the basis of qualitative and quantitative studies. The palynocomposition of the palynoassemblages is given below:

Palynoassemblage-I: This palynoassemblage is demarcated from the depth of 365.50m to 330.16m. It is characterised by the dominance of striate bisaccate pollen taxa viz., *Striatopodocarpites* spp.(17%), *Faunipollenites* spp. (21%), *Crescentipollenites* spp. (1%), *Striatites* spp. (4.5%) and *Strotersporites* spp. (2.5%). The other stratigraphically significant and abundant palynotaxa is *Densipollenites* spp. (10.5%). While other like *Chordasporites* spp. (2.5%), *Parasaccites* spp. (2%), *Verrucosisporites* sp. (2.5%), *Lophotriletes* sp. (1.5%) are stratigraphically significant but rare taxa. Non-striate bisaccates viz., *Scheuringisporites* spp. (13%), *Primuspollenites* sp. (1.5%) along with inaperturate spores (*Leiosphaeridia*, *Inaperturopollenites*) were also recorded.

Botanical affinity: The palynological content of this palynoassemblage is found to be dominated by bisaccates chiefly striate bisaccates viz., *Striatopodocarpites*, *Faunipollenites*, *Crescentipollenites*, *Striatites* and *Strotersporites* having a glossopterid affinity (shown in figure 4).

Glossopterids (45.5%) were the main arborescent plant groups which were adapted to temperate, cool and moist environments (McLoughlin, 1993; McManus *et al.*, 2002). The other arborescent taxa include peltasperms (5%), conifers (19%) which formed the thick upper storey of the paleovegetation. Understorey fauna mainly consists of herbs and small shrubs, whose growth is dependent on the availability of water.

Understorey fauna of this palynoassemblage includes equisetopsids (4%), Pterophyta (7.5%) and algal forms (4%). The abundance of pteridophytes and algal spores is representative of hot and humid conditions near the site of sediment deposition.

Age: Guadalupian (Jha, 2006)

Comparison: This palynoassemblage id distributed in all the major five Gondwana basins of India. It is comparable to Assemblage -6 of Ramakrishnapuram and Ramagundam area (Srivastava and Jha, 1988), Assemblage –III of Mantheni (Bharadwaj *et al.*, 1987) and *Densipollenites* rich phase of Kamthi Formation (Srivastava and Jha, 1987), Assemblage -5 of Sattupalli area (Srivastava and Jha, 1994), Palynozone-8 of Budharam Area (Srivastava and Jha, 1995) of Godavari Graben. Palynoassemblage –II of Bottapagudem area (Jha, 2004), Palynoassemblage-III of Mailaram area in Bore Core GAM-3 and GAM-7 (Jha and Aggarwal, 2012) and Palynoassemblage –I of MGP-4 of Gauridevipet area (Jha *et al.*, 2014) compares well with the present palynoassemblage –II of MCP-8.

Hence, palynoassemblage- II is comparable to Striate Bisaccate + *Densipollenites* assemblage of Godavari Graben (Jha, 2006) and belongs to Late Permian (Lopingian) Raniganj Formation. Densipollenites assemblage is well known from other Gondwana Basins of India viz., Damodar Basin (Bharadwaj *et al.*, 1979; Tiwari and Singh, 1983; Tiwari and Tripathi, 1992), Rajmahal Basin (Tiwari *et al.*, 1991; Tripathi, 1997), Son Valley (Tiwari and Ram-Awatar, 1989), Mahanadi Basin (Tiwari *et al.*, 1991; Tripathi, 1997); Satpura Basin (Bharadwaj *et al.*, 1978a, 1978b) and Kamptee Coalfield (Srivastava and Bhattacharya, 1996).

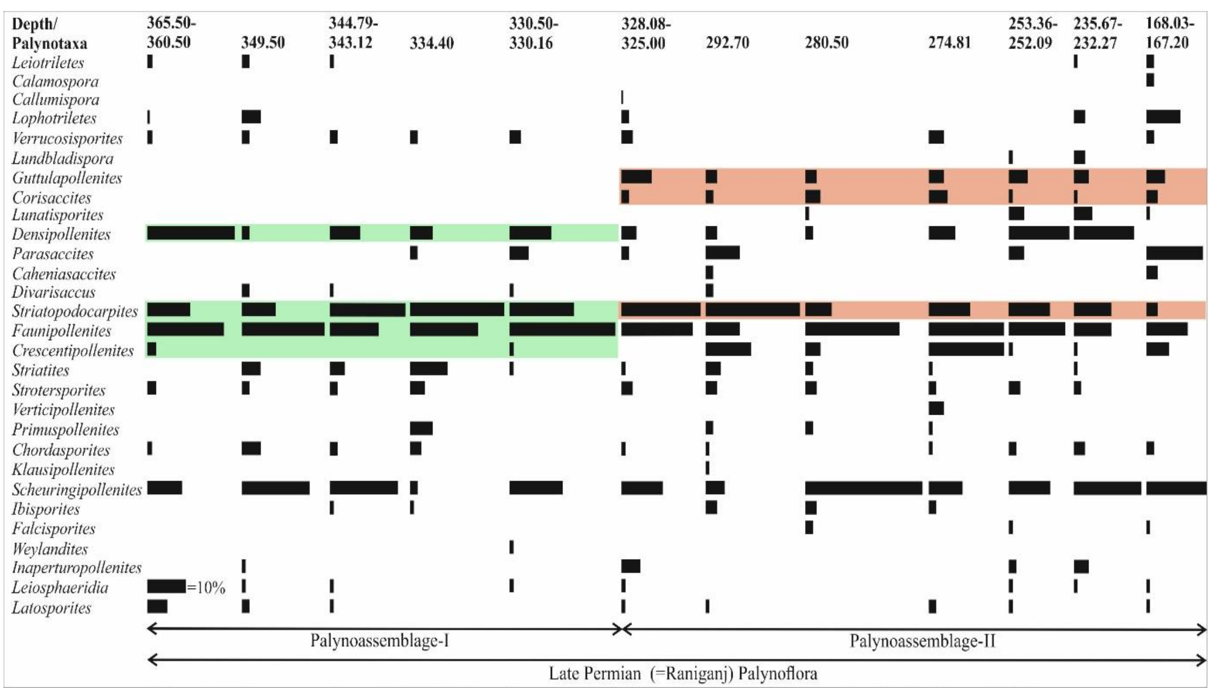

Figure 2: Histogram showing vertical distribution of palynomorphs in Chinatalpudi area, Chintalapudi sub-basin, Godavari Graben

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Table 2: Spore and Pollen taxa with their allied affinity based on the compilation of works by several authors

Spore/ Pollen	Phylum/Class	Order	Pollen Taxa
Spores	Algal		*Leiosphaeridia* Eisenack (1958) *emend*. Downie & Sarjeant (1963) *emend*. Turner (1984)
			Inaperturopollenites (Thomson and Pflug) Nilsson, 1958
			Maculatasporites Tiwari, 1964
	Pteridophyta	Filicopsida	*Callumispora* Bharadwaj and Srivastava, 1969c
			Cyclogranisporites Potonié and Kremp, 1954
			Cyclobaculisporites Bharadwaj, 1955
			Leiotriletes (Naumova) Potonié and Kremp, 1954
			Lophotriletes (Naumova) Potonié and Kremp, 1954
			Brevitriletes Bharadwaj and Srivastava, emend. Tiwari and Singh, 1981
		Equisetopsida	*Calamospora* Schopf, Wilson and Bentall, 1944
			Latosporites Potonié and Kremp, 1954 emend. Potonié, 1966
			Verrucosisporites Ibrahim emend. Smith, 1971
		Lycopsida	*Lundbladispora* Balme emend. Playford, 1965
Gymnosperm Pollen	Monosaccate pollen	Cordaitales	*Parasaccites* Bharadwaj and Tiwari, 1964a
			Plicatipollenites Lele, 1964
			Densipollenites Bharadwaj, 1962
		Coniferales	*Potonieisporites* Bharadwaj, 1954 emend. Bharadwaj, 1964
			Divarisaccus Venkatchala and Kar, 1966a
			Caheniasaccites Bose and Kar, 1966
	Taeniate Bisaccate	Coniferales	*Lunatisporites* Leschik emend. Bharadwaj, 1974
			Corisaccites Venkatchala and Kar, 1966b
			Guttulapollenites Goubin emend. Venkatchala, Goubin and Kar, 1967
	Striate Bisaccate	Glossopterids	*Striatopodocarpites* Sorittch and Sedova emend. Bharadwaj, 1962
			Faunipollenites Bharadwaj, 1962
			Crescentipollenites Bharadwaj, Tiwari and Kar, 1974
			Strotersporites Wilson, 1962
			Verticipollenites Bharadwaj, 1962
			Striasulcites Venkatchala and Kar, 1968c
			Striatites Pant emend. Bharadwaj, 1962
			Weylandites Bharadwaj and Srivastava, 1969
	Non-Striate Bisaccate	Peltaspermales	*Alisporites* Daugherty emend. Jansonius, 1971
			Falcisporites Leschik emend. Klaus, 1963.
			Platysaccus (Naumova) emend. Potonié and Klaus, 1954
			Primuspollenites Tiwari, 1964
			Klausipollenites Jansonius, 1962
		Coniferales	*Scheuringipollenites* Tiwari, 1973b
			Ibisporites Tiwari, 1968b
			Sahnites Pant emend. Tiwari and Singh, 1984
			Chordasporites Klaus, 1960
		Gnetopsida	*Welwitschiapites*

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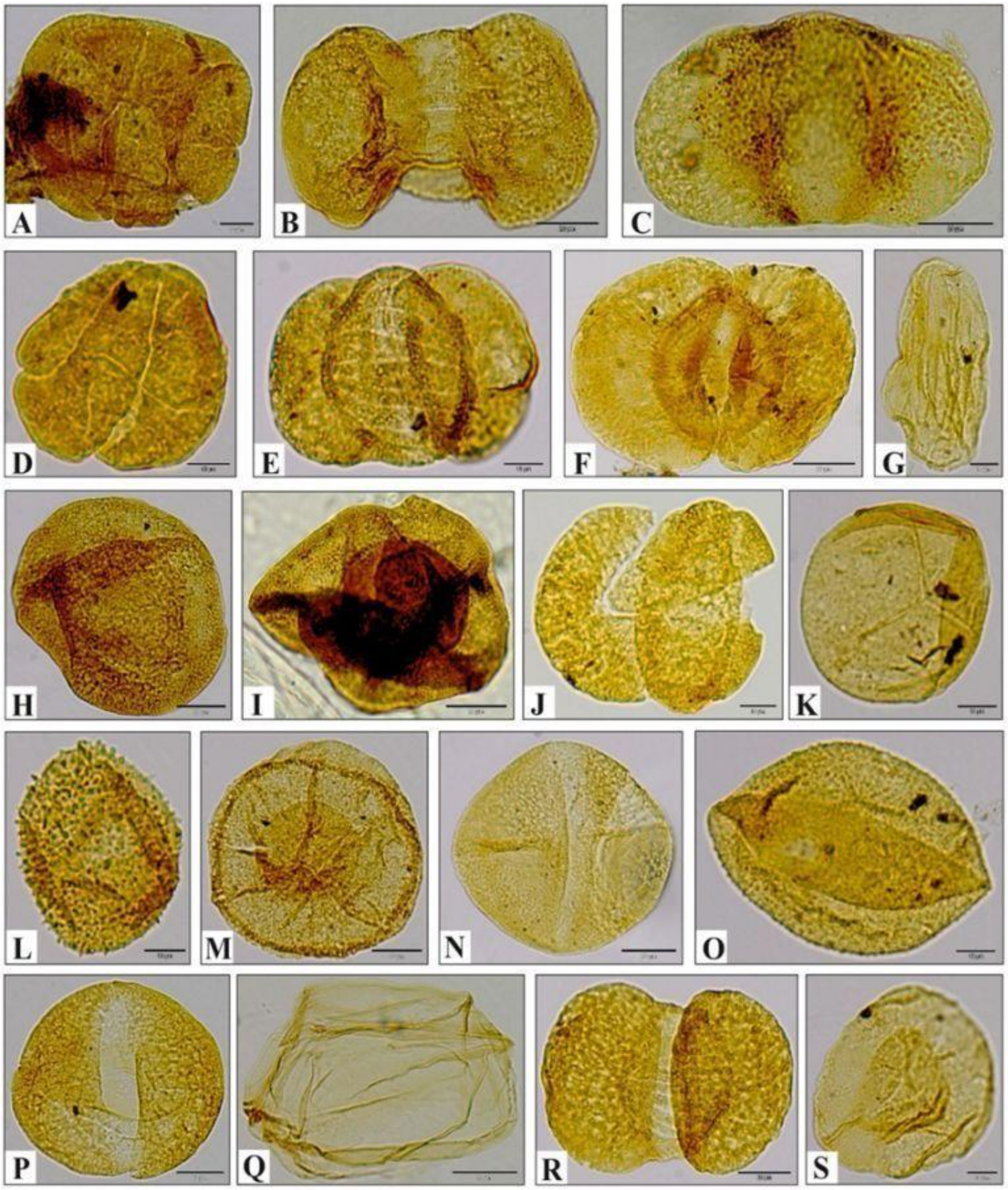

Figure 3: A- *Guttullapollenites hannonicus*, B.S.I.P. Slide No. 15521, P22, B- *Verticipollenites secretus*, B.S.I.P. Slide No. 15517, K15-4, C- *Falcisporites* sp., B.S.I.P. Slide No. 15512, G39-2, D- *Guttulapollenites hannonicus*, B.S.I.P. Slide No. 15515, P24-4, E- *Lunatisporites pellucidus*, B.S.I.P. Slide No. 15505, O32, F-*Primuspollenites* sp., B.S.I.P. Slide No. 15506, N26-4, G-*Welwetschiapites* sp., B.S.I.P. Slide No. 15515 V29-4, H- *Densipollenites invisus*, B.S.I.P. Slide No. 15513, F16-3, I- *Densipollenites magnicorpus*, B.S.I.P. Slide No. 15511, W27-4, J- *Corisaccites distinctus*, B.S.I.P. Slide No. 15515, P41-4, K- *Cyclogranisporites distinctus*, B.S.I.P. Slide No. 15510, O27, L- *Verrucosisporites* sp., B.S.I.P. Slide No. 15515, L37, M- *Lundbladispora willmotti*, B.S.I.P. Slide No. 15515 N28-1, N- *Scheuringipollenites maximus*, B.S.I.P. Slide No. 15505, T42, O- *Cyclogranisporites* sp., B.S.I.P. Slide No. 15515, M23-2, P- *Faunipollenites* B.S.I.P. Slide No. 15514, E25-3, Q- *Inaperturopollenites* sp., B.S.I.P. Slide No. 15514, W32-2, R- *Striatopodocarpites multistriatatus*, B.S.I.P. Slide No. 15505, R20-4, S- *Lundbladispora* sp., B.S.I.P. Slide No. 15516, V31-3

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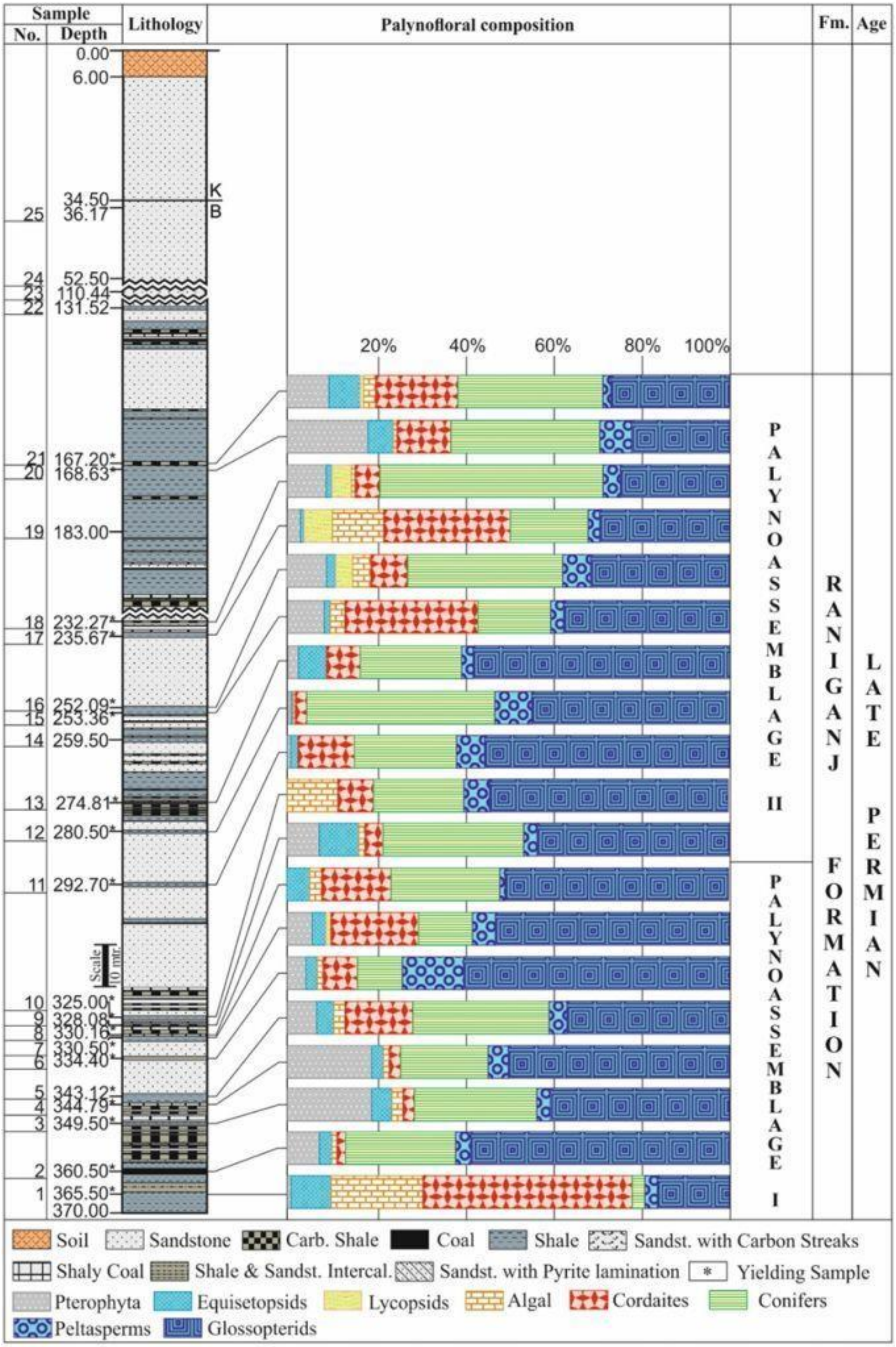

Figure 4: Lithological details and sample position of Bore core MCP- 8 along with palynofloral distribution

Palynoassemblage-II: It is demarcated from the depth of 328.08m to 167.20m and is marked by the dominance of striate bisaccates chiefly, *Striatopodocarpites* spp. (13%), *Faunipollenites* spp. (16%), *Crescentipollenites* spp. (6.5%) and significant presence of *Corisaccites* sp. (3%) and *Guttulapollenites* sp. (5%) along with presence of some stratigraphically significant taxa, *viz*., *Densipollenites* spp. (7%), *Chordasporites* spp. (2%), *Lunatisporites* spp. (2%) and *Falcisporites* spp. (1%), *Weylandites* spp. (1%) and *Parasaccites* spp. (4.5%). Spores were represented by *Lophotriletes* sp. (2.5%), *Verrucosisporites* sp. (1.5%), *Inaperturopollenites* sp. (1.5%), *Leiosphaeridia* sp. (1%) and *Latosporites* sp. (1%).
Botanical Affinity: This palynoassemblage is youngest Permian palynoassemblage of Godavari Graben (Jha, 2006), and is overlain by the Early Triassic palynoassemblage. This phase is marked by the dominance of striate and non-striate bisaccates having glossopterid, peltasperms and conifer affinity. However, the distribution frequency of glossopterids (34%) and cordaitales (12%) declines in this phase while peltasperms abundance remains same (5%) and conifer abundance increases (30%). Many early Triassic forms start emerging in this phase viz., lycopsids (*Lundbladispora*; 1.5%) along with taeniate bisaccate *Lunatisporites.* The occurrence of these forms infers younger age for this palynoassemblage. Along with these forms equisetopsids (3%), pterophyta (6%) and algal spores (3%) remains the occasionally growing understorey flora of the paleovegetation (shown in fig. 4).
Age: Lopingian (Jha, 2006)
Comparison: It is an endemic palynoassemblage, occurring only in Godavari and Satpura Basins of India. While, it has never been reported from the Damodar Basin (Tiwari and Tripathi, 1992). The assemblage is recovered from the Godavari graben (Srivastava and Jha, 1989, 1990). It also compares well with the Assemblage-4 of Ramakrishnapuram, Ramagundam and Mantheni area (Srivastava and Jha, 1987) and Palynoassemblage –V of Mailaram area in Bore core GAM-7 (Jha and Aggarwal, 2012) of Godavari Graben. It has also been recovered from some of the parts of Satpura Basin (Bharadwaj *et al.,* 1978a, 1978b).

Discussion

Age of the Sediments: Plants are immobile they can't escape the harsh conditions through movement. Thus, nature has provided them with large genome size, which provides them greater adaptability. This feature is favourable for the survival of the plants but unsuitable for precise dating of the deposits as they become long ranging in fossil records. However, dating and correlation of strata using palynology is done through the identification of a dominant and sub-dominant component of palynoflora along with some stratigraphically significant palynotaxa. In the present study complete sequence is found to be dominated by striate bisaccates and non-striate bisaccates remains a sub-dominant component of the palynoflora. In general, the Late Lower Permian and Upper Permian microflora are mainly typified by the high proportions of diverse diploxylonoid Striatiti forms (Evans 1964). However, the presence of stratigraphically significant palynotaxa like, *Densipollenites magnicorpus* in palynoassemblage-I and *Guttulapollenites* and *Corisaccites* in palynoassemblage-II refers the deposits to late Permian in age.
Well established palynostratigraphy in the Gondwana basins of India is mainly done by Tiwari and Tripathi (1992) and Jha (2006). Tiwari and Tripathi have given the spore-pollen assemblage zones in Damodar basin on the basis of FAD and LAD of significant taxa. They divided Permian palynoassemblages into nine assemblage zones, in which *Gondisporites raniganjensis* and *Densipollenites magnicorpus* belongs to late Permian in age, precisely Raniganj Formation. However, Jha (2006) constituted the palynoassemblages on the basis of dominant and sub-dominant palynotaxa along with some stratigraphically significant palynotaxa. She divided Permian palynoflora into fourteen assemblages, in which five belong to Raniganj Formation (Late Permian). Comparing these two palynostratigraphic schemes palynoassemblage-I having the characteristic presence of *Densipollenites* along with striate bisaccates the age of the deposits can be inferred as Guadalupian. While, the sequence of palynoassemblage-II having dominance of *Guttulapollenites + Corisaccites + Striatopodocarpites* is equitable to Lopingian in age. *Floral Diversity and Palaeoecology:* The present investigation in bore core MCP-8 in Chinatalapudi area reveals a presence of late Permian flora on the basis of palynological studies. Spores are majorly produced by cryptograms, which are mostly low lying plants like, herbs and

shrubs and constitute understorey flora of forest vegetation. They are majorly fluvially transported and their dominance represents autochthonous fossil assemblage. While pollens are produced by flowering plants.

They can be herbs, shrubs or even trees of varied height. The height of the plant and altitude of the plant habitat controls the dispersal of pollen grains. Higher the height and altitude of the habitat more distant dispersal. Dispersal of palynomorphs is also dependent on the structure of the plant viz., saccus size, pollen size, ornamentation. The palynoassemblage reveals that the major constituent of the Chintalapudi flora corresponds to gymnosperms, chiefly glossopterids, conifers, cordaits and peltasperms. Therefore, the present palynoassemblage is mainly allochthonous in origin as it contains more of pollens having wide dispersal. While, spores having algal and pteridophytic affinity are uneven is distribution, the difference may occur due to the availability of water (as most of the spore producing plants are hygrophytic) and the agent of sediment transport. Glossopterids were the main component of the palynoassemblage, which grow in mesophyllous to xerophilous environments, and are the major peat-producing plants (Knoll and Nickas, 1987). While, conifers mainly grow in high altitude area and drier habitats. They can be transported to the length of various kilometres so considered to be extrabasinal components. Cordaitales remains the third dominant palynocomponent of the floral vegetation which represents mesophilic palaeoenvironment near the mire (Taylor & Taylor, 1993). Algal spores and pteridophytic spores belonging to Pterophyta, equisetopsids and lycopsids are less common and their distribution is dependent on water availability as they are mostly flourishing in hygrophilous to mesophyllous in nature.

Conclusion

The palynological investigation has revealed the presence of two palynoassemblages, in which palynoassemblage-I (*Densipollenites* + striate bisaccate) is Guadalupian in age. While, palynoassemblage-II having the characteristic presence of *Guttulapollenites* + *Corisaccites* + *Striatopodocarpites* is the youngest Permian palynoassemblage and belongs to Lopingian in age. The palynoassemblage-II also represents the emergence of Triassic forms and decline in dominant Permian forms, which represents the gradual floral transition from Permian to Triassic paleovegetation. The paleovegetation studies depict the dominance of arborescent vegetation along with the low percentage of algal and pteridophytic spores. The paleovegetation supports the occurrence of hot, humid tropical forests. However, the occasional bloom in algal and pteridophytic spores represents the flooding environment.

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