Permian Triassic palynofloral transition in Chintalapudi area, Godavari Graben, Andhra Pradesh, India

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The entire 606 m-thick sedimentary sequence in borecore MCP-7 from Chintalapudi area, Chintalapudi sub-basin has been lithologically designated as Kamthi Formation. However, the palynological investigation revealed five distinct palynoassemblages, which essentially fall under two groups, one group (Palynoassemblage-I, II and III) having dominance of striate disaccates along with presence of some stratigraphically significant taxa, belongs to Late Permian (Raniganj) palynoflora, while the other group (Palynoassemblages IV and V) shows sharp decline in percentage of characteristic taxa of first group, i.e., striate disaccates, and consequent rise or dominance of taeniate and cingulate cavate spores, belongs to Early Triassic (Panchet) palynoflora. Palynoassemblage-I, II and III (Group I) are characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* spp. and *Faunipollenites* spp. along with presence of rare but stratigraphically significant taxa, viz., *Gondisporites raniganjensis*, *Falcisporites nuthalien-sis*, *Klausipollenites schaubegeri*, *Chordasporites* sp., *Striomonosaccites*, *ovatus*, *Crescentipollenites multistriatus*, *Verticypollenites debiles*, *Strotersporites crassiletus*, *Guttulapollenites hannonicus*, *G. gondwanensis*, *Hamiapollenites insolitus*, *Corisaccites alutus*, *Lunatisporites ovatus*, *Weylandites* spp. and *Vitreisporites pallidus*. Palynoassemblage-I is distinguished by significant presence of *Densipollenites* spp. while Palynoassemblage-II shows significant presence of *Crescentipollenites* spp. and Palynoassemblage-III differs from the above two assemblages in having significant presence of *Guttulapollenites hannonicus*. Palynoassemblage-IV (Group II) is characterized by high percentage of taeniate disaccates chiefly *Lunatisporites* spp., while Palynoassemblage-V (Group II) is characterized by cingulate-cavate trilete spores chiefly, *Lundbladisporea* spp. and *Densoisporites* spp. Striate disaccates show a sharp decline in these two assemblages.

In Chintalapudi area Late Permian and Early Triassic palynoflora has been recorded for the first time indicating existence of Raniganj and Panchet sediments as well. The study further supports the earlier studies of Jha and Srivastava (1996) that Kamthi Formation represents Early Triassic (=Panchet Formation) overlying Raniganj equivalent sediments with a gradational contact.

1. Introduction

Godavari Graben, one of the biggest sedimentary basins in India, has been structurally subdivided

into four sub-basins: Godavari, Kothagudem, Chintalapudi and Coastal Gondwana tract of Krishna-Godavari sub-basin. Chintalapudi sub-basin represents southeasterly continuation of Kothagudem

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sub-basin. To its further south lies coastal Gondwana tract of Krishna–Godavari sub-basin. Chintalapudi area lies on the southwestern margin of the Chintalapudi sub-basin (figure 1).

Various borecores have been studied from different parts of the sub-basin, *viz.*, Ayyanapalli-Gompana (Srivastava and Jha 1993) and Sattupalli (Srivastava and Jha 1994; Jha 2008) areas from northwestern margin of the sub-basin, Bottapagudem (Jha 2004), Amavaram (Srivastava and Jha 1992) from northeastern margin of the sub-basin and Gattugudem (Jha 2002) area from central part of the sub-basin. In the present communication, palynological studies have been carried out in borecore MCP-7 from southwestern margin of the sub-basin in order to date and correlate the coal-bearing and associated sediments, to understand the stratigraphy of the sub-basin and palynofloral transition in Godavari Graben.

2. Geology and geological setting

The Gondwana rocks of Chintalapudi sub-basin were earlier referred to as Kamthi Sandstone (Blanford 1872), Kamthi Formation (Raja Rao 1982), Chintalapudi Formation (Raiverman *et al.* 1986) and it was said that the sub-basin is of younger generation developed mostly during the Kamthis as evidenced by the general absence of Barakar and Barren Measures formations over a large part of the sub-basin. Lakshminarayana and Murthy (1990) observed the existence of Upper Gondwana sequence and also the Talchir and Barakar formations. Based on the surface and subsurface data, they revised the stratigraphy of the Chintalapudi sub-basin in which Barakars are overlain by the Kamthi Formation. Thus, a considerable gap in stratigraphic sequence is evident. Their findings reinitiated the coal exploration drillings in the area.

The stratigraphy of this sub-basin is not well understood due to the presence of many small faults and gross reduction in thickness of intervening strata (Barren Measures) between the two coal-bearing horizons – Barakar and Raniganj formations from north to south in Godavari Graben. Barren Measures is almost non-existent in Chintalapudi sub-basin and the coal-bearing horizons are distributed throughout the sequence. Hence, the dating and correlation of coal-bearing and associated horizons becomes difficult.

Chintalapudi area falls in Sattupalli–Chintalapudi coal belt, which forms the southern part of Chintalapudi sub-basin. Archaean gneisses, granite and schists form the basement for the Gondwana sequence in the area. The stratigraphic succession in the Chintalapudi sub-basin based on surface and sub-surface data is shown in table 1.

The bore hole MCP-7 was drilled in Chintalapudi area by Mineral Exploration Corporation Limited, Kothagudem. The location of bore hole MCP-7 has been shown in the map (figure 1).

The sedimentary sequence beneath 3 m soil cover from top (3–250.50 m) in upper part of the borecore MCP-7 consists of fine-to-medium grained pinkish, yellowish sandstone, while underlying sequence from 250.50 to 320.60 m consists of fine-grained greenish grey sandstone, micaceous at places. The lower part of the sequence from 320.60 to 596.40 m consists of fine-to-coarse grained grey sandstone, carbonaceous shale, grey shale and shaly coal. The sequence between 596.40 and 606 m consists of greyish white sandstone and clayey sandstone with bands of coal/carbonaceous streaks. The bore hole was closed at the depth of 606.00 m in Kamthi Formation. Lithology along with position of samples has been shown in figure 2.

3. Material and methods

The palynomorphs were recovered by usual palynological maceration technique. The samples were firstly treated with conc. hydrofluoric acid followed by conc. nitric acid and 5% potassium hydroxide. Finally the slides were prepared in canada balsam and studied qualitatively by identifying the palynotaxa on the basis of morphographical characters and quantitatively by counting the percentage frequency of different taxa. Approximately 200 specimens per sample were counted. Palynomorphs are sometimes broken/distorted/folded during preservation. Broken spores are sometimes identifiable if the characters are clear and they have been counted as one. Folded or distorted grains can be identified by LO analysis, so they have been counted. Palynological slides have been deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow. These samples were collected by the courtesy of Singareni Collieries Company Ltd. (SCCL).

4. Palynological data

Out of 45 rock samples only 21 samples were productive, out of these 21 samples eight were poor in spore-pollen while 13 were rich in spore-pollen. On the basis of quantitative and qualitative distribution of various palynotaxa, five distinct palynoassemblages have been identified in 606 m-thick sedimentary sequence of borecore MCP-7 from Chintalapudi area (table 2). Quantitatively significant taxa which contribute to the age assignment and identification of distinct assemblages either individually or by forming the characteristic association with other

Figure 1. (a) Map of Chintalapudi sub-basin showing location of Chintalapudi area. (b) Map of Chintalapudi block showing location of borecore MCP-7 (after SCCL).

Table 1. *Stratigraphic succession in Chintalapudi sub-basin (after Lakshminarayana 1996).*

UPPER GONDWANA			
-----Unconformity-----			
L O W E R G O N D W A N A	Late Permian to Early Triassic	Kamthi	Conglomerate, conglomeratic sandstone, siltstone and grey shale
	-----Unconformity-----		
	Permian	Barakar	Upper: White feldspathic sandstone, siltstone shale carbonaceous shale and coal seams Lower: Very coarse grained, pebbly feldspathic sandstone
		Talchir	Diamictite, rhythmites, light green sandstone
-----Unconformity-----			
Archaean Gneisses			

microspores taxa in the assemblage includes: *Faunipollenites* spp., *Striatopodocarpites* spp., *Crescentipollenites* spp., *Striasulcites* spp., *Scheuringipollenites* spp., *Densipollenites* spp., *Parasaccites* spp., *Guttulapollenites hannonicus*, *Lunatisporites* spp., *Lundbladisporea* spp., and *Densoisporites* spp., whereas the qualitatively significant taxa are *Falcisporites nuthaliensis*, *Striomonosaccites ovatus*, *Kamthisaccites kamthiensis*, *Chordasporites* sp., *Klausipollenites schaubergeri*, *Playfordiaspora cancellosa*, *Strotersporites crassiletus*, *Brachysaccus ovalis*, *Strausaccites marginalis*, *Crescentipollenites multistriatus*, *Gondisporites raniganjensis*, *Ringosporites ringus*, *Vitreisporites pallidus*, *Densipollenites magnicarpus*, *D. marginalis*, and *D. annulatus*. The vertical distribution and percentage frequency of various palynotaxa has been shown in histogram (figure 3). Stratigraphically significant palynomorphs have been shown in plate-1 and 2 (figures 4 and 5) and a complete check list of recovered spore-pollen species have been given in table 3.

4.1 Palynoassemblage-I

Palynoassemblage-I demarcated at the depth of 469.5–597.5 m, is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* spp. (14–33%) and *Faunipollenites* spp. (8–20%), significant presence of *Densipollenites* spp. (3–45%) along with presence of rare but stratigraphically significant taxa, viz., *Falcisporites nuthaliensis* (2%), *Chordasporites* sp. (1–2%), *Striomonosaccites ovatus* (1%), *Crescentipollenites* spp. (2–7%), *Strotersporites* spp. (2–6%), *Verticipollenites* spp. (2–4%), *Guttulapollenites hannonicus* (1–2%), *Hamiapollenites insolitus* (1%), *Lunatisporites ovatus* (1–4%), *Vitreisporites pallidus* (1%).

4.2 Palynoassemblage-II

Palynoassemblage-II demarcated at the depth of 426.95–461.69 m, is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* spp. (17–36%) and *Faunipollenites* spp. (5–13%), significant presence of *Crescentipollenites* spp. (4–14%) along with presence of rare but stratigraphically significant taxa, viz., *Gondisporites raniganjensis* (1%), *Chordasporites* sp. (1–2%), *Falcisporites nuthaliensis* (3%), *Klausipollenites schaubergeri* (1%), *Strotersporites* spp. (2–4%), *Verticipollenites* spp. (2–7%), *Lunatisporites ovatus* (1–3%), *Weylandites* spp. (2%), *Vitreisporites pallidus* (1%).

4.3 Palynoassemblage-III

Palynoassemblage-III recognized at the depth of 390.47 m, also shows dominance of striate disaccates chiefly, *Striatopodocarpites* spp. (26%) and *Faunipollenites* spp. (19%), significant presence of *Guttulapollenites* spp. (8%) chiefly *G. hannonicus* along with presence of rare but stratigraphically significant taxa, viz., *Klausipollenites schaubergeri* (2%), *Falcisporites nuthaliensis* (1%), *Strotersporites* spp. (3%), *Crescentipollenites* spp. (3%), *Lunatisporites ovatus* (3%), *Corisaccites alutus* (2%), *Weylandites obscurus* (1%) distinguishes this assemblage.

4.4 Palynoassemblage-IV

Palynoassemblage-IV recognized at the depth of 367.5 m is characterized by high percentage of taeinate disaccates chiefly *Lunatisporites* spp. (24%) including *Lunatisporites pellucidus*, *L. noviaulensis*, *L. panchetensis*, *L. ovatus* along with *Guttulapollenites hannonicus* and *G. gondwanensis* (total

Figure 2. Litholog of borecore MCP-7 showing position of samples.

8%). Other significant taxa present in the assemblage are *Densipollenites* spp. (10%) including *D. magnicarpus*, *Falcisporites nuthaliensis* (2%),

Klausipollenites schaubergeri (1%), *Chordasporites* sp. (2%). The striate disaccate pollen show sharp decline in percentage at this level.

Table 2. *Palynocomposition of palynoussemblages identified in borecore MCP-7, Chintalapudi area, Chintalapudi sub-basin.*

Assemblage	Lithology	Depth (m)	Palynocomposition	Age
V <i>Lundbladispora</i> , <i>Densipollenites</i> Assemblage	Grey shale	322.50–353.96	Abundance of <i>Lundbladispora</i> spp. <i>Densipollenites</i> spp. Significant presence of <i>Falcisporites nuthaliensis</i> , <i>Playfordiaspora cancellosa</i> . Presence of <i>Chordasporites</i> sp., <i>Klausipollenites schaubergeri</i> , <i>Araucariacites</i> sp., <i>Kamthisacites kamthiensis</i> , <i>Ringosporites fossulatus</i> . Striate disaccates, viz., <i>Striatopodocarpites</i> spp., <i>Faunipollenites</i> spp. present but in very low frequency.	Definitely Triassic
IV <i>Lunatisporites</i> Assemblage	Grey shale	367.50–378.50	Abundance of <i>Lunatisporites</i> spp. including <i>Lunatisporites pellucidus</i> , <i>L. noviaulensis</i> , <i>L. panchetensis</i> , <i>L. ovatus</i> . Presence of <i>Falcisporites nuthaliensis</i> , <i>Klausipollenites schaubergeri</i> , <i>Chordasporites</i> sp. Striate disaccates decline. Presence of <i>Densipollenites</i> spp. including <i>D. magnicarpus</i> , <i>Guttulapollenites hannonicus</i> and <i>G. gondwanensis</i> . Algal filaments and <i>Inaperturopollenites</i> present.	Triassic
III <i>Guttulapollenites</i> Assemblage	Grey shale	390.47	Dominance of striate disaccates chiefly, <i>Striatopodocarpites</i> spp., <i>Faunipollenites</i> spp. and high percentage of <i>Densipollenites</i> spp. and <i>Guttulapollenites hannonicus</i> along with rare presence of some stratigraphically significant taxa, viz., <i>Klausipollenites schaubergeri</i> , <i>Falcisporites nuthaliensis</i> , <i>Lunatisporites ovatus</i> .	Late Permian (Raniganj)
II <i>Crescentipollenites</i> Assemblage	Dark grey shale	426.95–461.69	Dominance of striate disaccates chiefly, <i>Striatopodocarpites</i> spp., <i>Faunipollenites</i> spp. and <i>Crescentipollenites</i> spp. Other striate disaccate taxa includes <i>Strotersporites</i> spp., <i>Striatites</i> spp., <i>Verticipollenites</i> spp. Rare presence of some stratigraphically significant taxa, viz., <i>Falcisporites nuthaliensis</i> , <i>Klausipollenites schaubergeri</i> , <i>Chordasporites</i> sp., <i>Gondisporites raniganjensis</i> , <i>Aurangapollenites minimus</i> , <i>Lunatisporites ovatus</i> and <i>Vitreisporites pallidus</i> .	Late Permian (Raniganj)
I <i>Densipollenites</i> Assemblage	Grey shale, carb shale, shaly coal, coal and sandstone	469.50	Dominance of striate disaccates chiefly, <i>Striatopodocarpites</i> spp. <i>Faunipollenites</i> spp. and <i>Crescentipollenites</i> spp. <i>Densipollenites</i> spp. present in significant amount. Rare but stratigraphically significant taxa includes <i>Chordasporites</i> sp., <i>Klausipollenites schaubergeri</i> , <i>Lunatisporites ovatus</i> , <i>Weylandites</i> spp., <i>Osmundacidites</i> sp.	Late Permian (Raniganj)
		540.52	Dominance of <i>Densipollenites</i> , subdominance of striate disaccates. Rare but stratigraphically significant taxa includes <i>Chordasporites</i> sp., <i>Klausipollenites schaubergeri</i> , <i>Lunatisporites ovatus</i> , <i>Weylandites</i> spp., <i>Falcisporites nuthaliensis</i> .	Late Permian (Raniganj)
		597.50	Dominance of striate disaccates chiefly, <i>Striatopodocarpites</i> spp., <i>Faunipollenites</i> spp. and <i>Crescentipollenites</i> spp. <i>Densipollenites</i> spp. present in significant amount. Rare but stratigraphically significant taxa includes <i>Chordasporites</i> sp., <i>Klausipollenites schaubergeri</i> , <i>Lunatisporites ovatus</i> , <i>Weylandites</i> spp., <i>Guttulapollenites hannonicus</i> , <i>Falcisporites nuthaliensis</i> , <i>Hamiapollenites insolitus</i> .	Late Permian (Raniganj)

Figure 3. Histogram showing vertical distribution and percentage frequencies of various palynotaxa in borecore MCP-7, Chintalapudi area, Chintalapudi sub-basin.

Figure 4. Stratigraphically significant taxa of Late Permian and Early Triassic palynofossils. 1: *Strotersporites communis*, B.S.I.P. Slide No. 14132, J55/3, 2: *Inaperturopollenites nebulosus*, B.S.I.P. Slide No. 14132, P50/4, 3: *Guttulapollenites hammonicus*, B.S.I.P. Slide No. 14134, P42/3, 4: *Staurosaccites marginalis*, B.S.I.P. Slide No. 14134, X63, 5: *Crescentipollenites multistriatus*, B.S.I.P. Slide No. 14138, N50/3, 6: *Lundbladispore willmotti*, B.S.I.P. Slide No. 14133, S32/2, 7: Unidentified, B.S.I.P. Slide No. 14133, S31, 8: *Chordasporites* sp., B.S.I.P. Slide No. 14132, L50/3, 9: *Lundbladispore microconata*, B.S.I.P. Slide No. 14133, N31/4, 10: *Lundbladispore brevicula*, B.S.I.P. Slide No. 14133, N31/4, 11: *Faunipollenites goraiensis*, B.S.I.P. Slide No. 14133, M31/2, 12: *Lunatisporites pellucidus*, B.S.I.P. Slide No. 14133, L31/2, 13: *Falcisporites nuthaliensis*, B.S.I.P. Slide No. 14134, K53/1, 14: *Striatopodocarpites multistriatus*, B.S.I.P. Slide No. 14133, K31/4, 15: *Striatopodocarpites multistriatus*, B.S.I.P. Slide No. 14133, F31/4, 16: *Lundbladispore brevicula*, B.S.I.P. Slide No. 14133, K32/3, 17: Alete, B.S.I.P. Slide No. 14133, F32/2, 18: *Densipollenites densus*, B.S.I.P. Slide No. 14136, J51/1, 19: *Lundbladispore willmotti*, B.S.I.P. Slide No. 14133, H36/3.

Figure 5. Stratigraphically significant taxa of Late Permian and Early Triassic palynoassemblages. 1: Unidentified, B.S.I.P. Slide No. 14134, Q41/2, 2: Unidentified, B.S.I.P. Slide No. 14133, M36/4, 3: *Densoisporites* sp., B.S.I.P. Slide No. 14133, Q46/2, 4: *Guttatisporites* sp., B.S.I.P. Slide No. 14137, T65/2, 5: *Striomonosaccites ovatus*, B.S.I.P. Slide No. 14134, O33/3, 6: *Densipollenites marginalis*, B.S.I.P. Slide No. 14134, V63, 7: *Densipollenites invisus*, B.S.I.P. Slide No. 14134, S63/4, 8: *Brachysaccus ovalis*, B.S.I.P. Slide No. 14134, V49, 9: *Faunipollenites varius*, B.S.I.P. Slide No. 14133, N31/2, 10: *Striatopodocarpites decorus*, B.S.I.P. Slide No. 14136, P51, 11: *Strotersporites communis*, B.S.I.P. Slide No. 14134, F59, 12: *Falcisporites nuthaliensis*, B.S.I.P. Slide No. 14135, Q50/4.

4.5 Palynoassemblage-V

Palynoassemblage-V demarcated at the depth of 353.96–322.5 m is characterised by cingulate-cavate trilete spores chiefly, *Lundbladispora* spp. (20–25%) and *Densoisporites* spp. (1–4%). Striate disaccates show further decline in percentage in this assemblage. The other taxa present in the assemblage are *Falcisporites nuthaliensis* (3–6%), *Chordasporites* sp. (1–3%), *Klausipollenites schaubergeri* (1–2%), *Araucariacites* sp. (1%), *Kamthisaccites kamthiensis* (1%), *Playfordiaspora cancellosa* (1%) and *Ringosporites fossulatus* (1%). High percentage of *Inaperturopollenites* (23%) is recorded at 322.50 m.

5. Comparison and discussion

Palynological investigations in sub-surface sediments of borecore MCP-7 from Chintalapudi area, Chintalapudi sub-basin were carried out.

The dominance of striate disaccate pollen grains along with rare occurrence of stratigraphically significant taxa, viz., *Falcisporites nuthaliensis*, *Chordasporites* sp., *Klausipollenites schaubergeri*, *Verticypollenites* spp., *Crescentipollenites* spp., *Strotersporites* spp., *Lunatisporites* spp., *Corisaccites alutus*, *Guttulapollenites hannonicus*, *G. gondwanensis*, and *Hamiapollenites insolitus* is characteristic association in Palynoassemblage-I, II, and III between 597.50 and 390.47 m. In Lower Gondwana, palynological succession striate disaccates show fairly good representation (subdominant component of the palynoflora) from Lower Barakar (Early Permian), attains dominance in Upper Barakar and continue to remain dominant component of palynoflora up to Late Permian Raniganj Formation (Bharadwaj 1975). Thus, the associated taxa become more important while identifying the assemblages in younger sequences. Presence of above-mentioned stratigraphically important taxa in Palynoassemblage I, II and III shows younger aspect of the palynoflora during Permian, i.e., these palynoassemblages are

Table 3. List of spore-pollen species identified in Permian and Early Triassic palynofossil assemblage is borecore MCP-7 from Chintalapudi area, Chintalapudi sub-basin, Andhra Pradesh.

Late Permian (Raniganj Formation)

- Leiotriletes rectus* Bharadwaj and Salujha (1964)
Callumispora barakarensis (Bharadwaj and Srivastava) Tiwari, Srivastava, Tripathi and Vijaya (1989)
C. tenuis Bharadwaj and Srivastava (1969)
Verrucosisporites gondwanensis Srivastava (1970)
Lobatiporites gondwanensis Tiwari and Moiz (1971)
Brevitriletes communis Bharadwaj and Srivastava emend. Tiwari and Singh (1981)
B. unicus (Tiwari) Bharadwaj and Srivastava emend. Tiwari and Singh (1981)
Lophotriletes rectus Bharadwaj and Salujha (1964)
Calamospora exila Bharadwaj and Salujha (1964)
Horriditriletes ramosus (Balme and Hennely) Bharadwaj and Salujha (1968)
H. rampurensis Tiwari (1968)
Microbaculispora tentula Tiwari (1965)
M. gondwanensis Bharadwaj (1962)
Gondisporites raniganjensis Bharadwaj (1962)
Parasaccites korbaensis Bharadwaj and Tiwari (1964)
Densipollenites invisus Bharadwaj and Salujha (1964)
D. indicus Bharadwaj (1969)
D. densus Bharadwaj and Srivastava (1969)
D. magnicarpus Tiwari and Rana (1981)
D. marginalis Jha (1996)
D. annulatus Jha (1996)
Scheuringipollenites maximus (Hart) Tiwari (1973)
S. tentulus (Tiwari) Tiwari (1973)
S. barakarensis (Tiwari) Tiwari (1973)
Ibisporites jhingurdahiensis Sinha (1972)
I. diplosaccus Tiwari (1968)
Platysaccus densicarpus Anand Prakash (1972)
Chordasporites sp.
Klausipollenites schaubergeri (Potonie and Klaus) Klaus (1953)
Strotersporites communis Wilson (1962)
S. wilsonii Klaus (1963)
Strotersporites crassiletus Jha (1995)
Striapollenites saccates Bharadwaj (1962)
Falcisporites nuthaliensis (Clark) Balme (1970)
Lueckisporites virkii Potonie and Klaus (1954)
Striomonosaccites ovatus Bharadwaj (1962)
Verticipollenites debiles Venkatachala and Kar (1968)
V. finitimus Bharadwaj and Salujha (1964)
Crescentipollenites gondwanensis (Maheshwari) Bharadwaj, Tiwari and Kar (1974)
C. fuscus (Bharadwaj) Bharadwaj, Tiwari and Kar (1974)
C. globosus (Maithy) Jha (1996)
C. barakarensis (Sinha) Jha (1996)
C. multistriatus (Banerji and Maheshwari) Jha (1996)
Faunipollenites varius Bharadwaj (1962)
F. bharadwajii Maheshwari (1967)
F. parvus Tiwari (1965)
F. goraiensis (Potonie and Lele) Maithy (1965)
Striatopodocarpites decorus Bharadwaj and Salujha (1964)
S. tiwarii Bharadwaj and Dwivedi (1981)
S. diffusus Bharadwaj and Salujha (1964)
S. brevis Sinha (1972)
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Table 3. (Continued)

<i>S. multistriatus</i> Jha (1996)
<i>S. subcircularis</i> Sinha (1972)
<i>Striatites communis</i> Bharadwaj and Salujha (1964)
<i>S. parvus</i> Tiwari (1965)
<i>S. solitus</i> Bharadwaj and Salujha (1964)
<i>S. tentulus</i> Tiwari (1965)
<i>Ditsriatites insolitus</i> Bharadwaj and Salujha (1964)
<i>Aurangapollenites minimus</i> Jha (1995)
<i>Corisaccites alutas</i> Venkatachala and Kar (1966)
<i>Hamiapollenites insolatus</i> Bharadwaj and Salujha (1964)
<i>Guttulapollenites hannonicus</i> Goubin (1965)
<i>G. gondwanensis</i> Goubin (1965)
<i>Lunatisporites ovatus</i> (Goubin) Maheshwari and Banerji (1975)
<i>Weylandites circularis</i> Bharadwaj and Srivastava (1969)
<i>W. obscurus</i> (Tiwari) Bharadwaj and Dwivedi (1981)
<i>W. minutus</i> Bharadwaj and Srivastava (1969)
<i>Inaperturopollenites nebulosus</i> Balme (1970)
<i>Schizosporis</i> sp.
<i>Maculatasporites gondwanensis</i> Tiwari (1965)
<i>Osmudacidites</i> sp.
<i>Laevigatosporites colliensis</i> (Balme and Hennely) Venkatachala and Kar (1968)
<i>Alisporites landianus</i> Balme (1970)
<i>A. indarrensensis</i> , Segroves (1969)
<i>Vitreisporites pallidus</i> (Ressinger) Balme (1970)
Early Triassic (Kamthi/Panchet Formation)
<i>Verrucosporites surangei</i> Maheshwari and Banerjee (1975)
<i>Lophotriletes rectus</i> Bharadwaj and Salujha (1964)
<i>Callumispora tenuis</i> Bharadwaj and Srivastava (1969)
<i>Playfordiaspora cancellosus</i> (Playford and Dettman) Maheshwari and Banerjee (1975)
<i>Densoisporites playfordii</i> Balme (1963)
<i>D. nejburgii</i> (Schulz) Balme (1970)
<i>Densoisporites</i> sp.
<i>Lundbladispora willmotti</i> Balme (1963)
<i>Lundbladispora microconata</i> Bharadwaj and Tiwari (1977)
<i>L. breicula</i> Balme (1963)
<i>L. obsoleta</i> Balme (1970)
<i>Ringosporites fossulatus</i> Tiwari and Rana (1980)
<i>Densipollenites invisus</i> Bharadwaj (1962)
<i>D. magnicarpus</i> Tiwari and Rana (1981)
<i>Striomonosaccites ovatus</i> Bharadwaj (1962)
<i>Klausipollenites schaubegeri</i> (Potonie and Klaus) Klaus (1953)
<i>Chordasporites</i> sp.
<i>Falcisporites nuthaliensis</i> (Clark) Balme (1970)
<i>Crescentipollenites multistriatus</i> (Banerji and Maheshwari) Jha (1996)
<i>Strotersporites crassiletus</i> Jha (1995)
<i>Verticipollenites</i> sp.
<i>Guttulapollenites hannonicus</i> Goubin (1965)
<i>Kamthisaccites kamthiensis</i> Srivastava and Jha (1986)
<i>Lunatisporites ovatus</i> (Goubin) Maheshwari and Banerji (1975)
<i>L. pellucidus</i> (Goubin) Maheshwari and Banerji (1975)
<i>L. noviaulensis</i> (Leschik) Scheuring, Tiwari and Rana (1980)
<i>L. panchetensis</i> Tiwari and Rana (1981)

Table 3. (Continued)

<i>Staurosaccites marginalis</i> Kumaran and Maheshwari (1980)
<i>Brachysaccus ovalis</i> Maedler (1964)
<i>Laevigatosporites colliensis</i> (Balme and Hennely) Venkatachala and Kar (1968)
<i>Inaperturopollenites nebulosus</i> Balme (1970)
<i>Osmundacidites senectus</i> Balme (1970)
<i>Araucariacites</i> sp.
<i>Alisporites</i> sp.

Late Permian in age. Hence, Palynoassemblage I, II, III represent Raniganj equivalent (Late Permian) palynoflora. It compares well with the Lower Raniganj palynofloras of Ramagundam, Ramakrishnapuram and Bhopalpalli areas (Srivastava and Jha 1988; Jha and Srivastava 1996), Mailaram area (Srivastava and Jha 1990), Chelpur area (Srivastava and Jha 1987), Manuguru area (Srivastava and Jha 1992), Budharam area (Srivastava and Jha 1995) Sattupalli area (Srivastava and Jha 1994; Jha 2008), and Amavaram area (Srivastava and Jha 1991) in Godavari Graben (table 4).

Palynoassemblage-I is equivalent to *Striatopodocarpites-Densipollenites* Assemblage Zone (zone V-C) or *Densipollenites magnicarpus* Assemblage Zone described by Tiwari and Tripathi (1992) in having dominance of striate disaccates *Striatopodocarpites* and *Faunipollenites* spp. and acme of *Densipollenites*. *Densipollenites* Assemblage during Late Permian is well known from Damodar Basin (Bharadwaj et al. 1979; Tiwari and Singh 1983), Rajmahal Basin (Tiwari and Tripathi 1984), Son Valley (Tiwari and Ram-Awatar 1989), Mahanadi Basin (Tiwari et al. 1991; Tripathi 1997), Satpura Basin (Bharadwaj

et al. 1978), Kamptee Coalfield (Srivastava and Bhattacharyya 1996) (table 5).

Palynoassemblage-II is equivalent to *Striatopodocarpites-Crescentipollenites* Zone (zone V-D) of Tiwari and Tripathi (1992). This assemblage can be accommodated well in the *Densipollenites magnicarpus* Assemblage Zone described by Tiwari and Tripathi (1992). Similar palynoassemblages have been recognized in Damodar Basin (Bharadwaj et al. 1979; Tiwari and Singh 1983), Son Valley (Tiwari and Ram-Awatar 1989), Talcheer Coalfield, Mahanadi Basin (Tiwari et al. 1991; Tripathi 1997), Kamptee Coalfield (Srivastava and Bhattacharyya 1996), Satpura Basin (Bharadwaj et al. 1978).

Palynoassemblage-III has never been recorded in Damodar Basin. In India high incidence of *Guttulapollenites hannonicus* has been recorded in Godavari Graben (Srivastava and Jha 1989, 1990), Satpura (Bharadwaj et al. 1978) and Wardha basin (Bhattacharyya 2003). Outside India, Palynoassemblage-III bears a close resemblance with the Late Permian assemblage recorded from Chhidru Formation in Salt Range (Balme 1970), and upper part of Sakamena Group in

Table 4. Correlation of Late Permian and Early Triassic palynoflora in different areas of Godavari Graben and Damodar Basin.

Age	Formation	Assemblage	Godavari					Damodar
			1	2	3	4	5	
Early Triassic	Panchet	<i>Lundbladispota</i> + <i>Densosporites</i>	+	+		+	+	P-IV
		<i>Lunatisporites</i> + <i>Verrucosisorites</i>		+	+	+	+	P-III
		<i>Verrucosisorites</i> + <i>Callumispota</i>						P-II
		<i>Striatopodocarpites</i> + <i>Klausipollenites</i>						P-I
Late Permian	Raniganj	<i>Striatopodocarpites</i> + <i>Corisaccites</i> + <i>Guttulapollenites</i>		+	+		+	
		<i>Striatopodocarpites</i> + <i>Crescentipollenites</i>	+		+		+	R-IA
		Striate disaccates+ <i>Densipollenites</i>	+	+	+	+	+	R-IB
		Striate disaccates+ <i>Parasaccites</i>		+				
		<i>Faunipollenites</i> + <i>Striasulcites</i>		+		+		R-IIB*
		<i>Faunipollenites</i> + <i>Striatopodocarpites</i>	+	+	+	+		R-IA

1. Budharam Area (Srivastava and Jha 1998); 2. Manuguru Area (Srivastava and Jha 1992; Jha et al. 2011); 3. Mailaram Area (Srivastava and Jha 1990); 4. Sattupalli Area (Srivastava and Jha 1994; Jha 2008); 5. Chintalapudi area (Present paper); Damodar Basin (Tiwari and Singh 1986).

Table 5. Palynological correlation chart for Late Permian and Early Triassic units in Gondwana basins of India.

Age	Formation	Assemblage	G	W	S	SR	M	D	R
Early Triassic	Anisian	<i>Lundbladispora</i> + <i>Densoisporites</i>	*					*	
		<i>Lunatisporites</i> + <i>Verrucosisporites</i>	*		*	*	*	*	
		<i>Verrucosisporites</i> + <i>Callumispora</i>		*	*			*	
	Scythian	<i>Striatopodocarpites</i> + <i>Klausipollenites</i>						*	
Late Permian	Lopingian	<i>Striatopodocarpites</i> + <i>Corisaccites</i> + <i>Guttulapollenites</i>	*	*	*				
		<i>Striatopodocarpites</i> + <i>Crescentipollenites</i>	*	*	*		*	*	■
		Striate disaccates+ <i>Densipollenites</i>	*	*	*	*	*	*	
		Striate disaccates+ <i>Parasaccites</i>	*	*		*			
	Guadalupian	<i>Faunipollenites</i> + <i>Striasulcites</i>	*			*	*	♣	
		<i>Faunipollenites</i> + <i>Striatopodocarpites</i>	*	*	*	*	*	*	*

■ indicates *Striatopodocarpites*–*Alisporites* Assemblage; ♣ indicates *Striatopodocarpites*–*Gondisporites* Assemblage; * indicates present; G: Godavari Graben, W: Wardha Valley, S: Satpura Basin, SR: South Rewa Basin, M: Mahanadi Basin, D: Damodar Basin, R: Rajmahal Basin.

Malagasy (De Jekhowsky and Goubin 1964; Goubin 1965; Wright and Askin 1987). The palynoflora recovered from the Sumbadzi Member in the Luwega Basin is also characterized by abundance of *Guttulapollenites* (Hankel 1987). A similar palynoflora has been recorded by Weiss from the Pangani Member of the Selous Basin (in Wopfner and Kaaya 1991), Karoo sediments of Rukwa Basin by Wescott *et al.* (1991), and from Steigler Gorge in Tanzania by Msaky and Srivastava (1997) from Lower and Upper Madumabisa Mudstone Member in north Luangwa Valley, Zambia (Utting 1979) and Zambesi Basin (Falcon 1975). Oesterian and Millsted (1994) have recorded *Guttulapollenites hannonicus* in Mkanga Formation from Cobra Basin Lower Zambesi Basin, Zimbabwe. These assemblages compare well with the *Guttulapollenites* assemblage of Godavari Graben, India.

From Australian Permian Triassic palynozones (Helby *et al.* 1987) *Protohaploxylinus microcorpus* zone corresponds Assemblage III of the present study in having dominance of striate disaccates but differs in absence of *Guttulapollenites hannonicus* as significant component. *Dulhuntyispora* a significant Late Permian taxa of Australia has never been recorded from Gondwana basins of India. Palynofloral similarity and occurrence of *Guttulapollenites hannonicus* in Late Permian of Amery Basin, Antarctica and Godavari Graben (Jha and Srivastava 1996) supports the Indo-Antarctic fit proposed by Mitra *et al.* (1979) where Godavari Graben is in juxtaposition with the Amery basin of Antarctica. Recently, Holdgate *et al.* (2005) state ‘comparison of Indian and Antarctic Permian succession indicates that maceral components of the Bainmedart coal most closely

matches those of similar rank with Godavari basin rather than more commonly correlated Mahanadi basin. Based on identification of shared megaspore taxa *Singhisporites* and *Banksisporites*, Slater *et al.* (2011) supported the palaeogeographic reconstruction that place the Indian Mahanadi Basin adjacent to the Lambert Graben of Antarctica during Middle Permian. However, both of these genera are also reported from sediments of Godavari Graben, India (Jha and Tewari 2003; Tewari and Jha 2007). Existence of *Guttulapollenites* palaeophytogeographic province in central part of Gondwanaland during Late Permian time has been recognized within *Glossopteris* dominated Gondwana megafloral province, extending from Salt Range (Pakistan) in the north to Amery Basin (Antarctica) in south, Satpura–Wardha–Godavari Basin (India) in east to Mid Zambesi–Luangwa Valley (Africa) in the west (Jha 2006).

In Indian Lower Gondwana palynological succession (Permian), the striate disaccates chiefly *Striatopodocarpites* spp. and *Faunipollenites* spp. show fairly good representation (sub-dominant component of the palynoflora) from Lower Barakar (Early Permian), attain dominance in the Upper Barakar and continue to remain dominant up to the Raniganj Formation (Late Permian). During Late Permian, these two taxa of striate disaccates being long ranging lose the stratigraphic significance and the associated taxa, *viz.*, *Striasulcites*, *Parasaccites*, *Densipollenites*, *Crescentipollenites*, *Guttulapollenites* becomes more important while identifying the assemblages. Thus, the latest Permian assemblage is dominated by striate disaccates, *viz.*, *Striatopodocarpites* spp. and *Faunipollenites* spp. with prominent *Guttulapollenites hannonicus* in Satpura, Wardha–Godavari basins

and *Crescentipollenites* spp. in Damodar and Mahanadi basins. Early Triassic palynoassemblage is marked by increased frequency or predominance of taeniate pollen, viz., *Lunatisporites* spp. and cingulate-cavate spores, viz., *Lundbladispota* spp., *Densoisporites* spp. The transformation of palynoflora at Permian Triassic boundary is without a sharp abrupt break but the change is definite in quality and quantity of palynoflora. Some of the genera, viz., *Klausipollenites*, *Falcisporites*, *Chordasporites*, *Playfordiaspora*, *Lundbladispota*, *Densoisporites* make their earliest appearance in the Raniganj, where they are meager and sporadic, becomes prominent or dominant in Early Triassic palynoassemblages; whereas the taxa, viz., *Striatopodocarpites*, *Faunipollenites*, *Crescentipollenites*, *Guttulapollenites*, etc. which are dominant in Raniganj (Late Permian) reduces and gradually almost disappear in Early Triassic palynoassemblages. In the present borecore MCP-7, some of the dominant striate disaccate taxa of Palynoassemblage-I, II, and III, viz., *Striatopodocarpites* spp. and *Faunipollenites* spp. continue to occur in Palynoassemblage-IV and V but their overall percentage decreases. On the other hand, the taeniate (chiefly *Lunatisporites* spp.), cingulate, cavate taxa, viz., *Lundbladispota* and *Densoisporites* spp. show increase in percentage frequencies in Assemblage IV and V. Taeniate pollen *Lunatisporites* spp. increases in percentage in Assemblage IV and cingulated trilete spore, viz., *Lundbladispota* spp. and cavate trilete spore *Densoisporites* spp. increase in percentage in Palynoassemblage-V, which distinguish the Palynoassemblage-IV and V from underlying Raniganj equivalent assemblages, i.e., Palynoassemblage-I, II and III. These genera make their earliest appearance in Raniganj, where they are meager and sporadic. Thus, Palynoassemblage-IV and V record conclusive evidence of the presence of Lower Triassic sediments in Chintalapudi area. Palynoassemblage-IV and V are equivalent to *Lunatisporites*–*Verrucosisporites* Zone (zone VI-C) and *Lundbladispota*–*Densoisporites* Zone (zone VI-D) described by Tiwari and Tripathi (1992) in Damodar Basin.

Thus, the positive evidence of change in palyno-composition is revealed at 378.50 m by sharp decline in percentage of striate disaccates chiefly, *Striatopodocarpites* spp. and *Faunipollenites* spp. and rise in percentage of *Lunatisporites* spp. (16%) and *Falcisporites nuthaliensis* (8%) and occurrence of taxa, viz., *Guttulapollenites hannonicus* (3%), *Hamiapollenites insolitus* (2%), *Kamthisaccites kamthiensis* (1%), *Klausipollenites schaubergeri* (4%) and *Chordasporites* sp. (4%). Palynoassemblage-V is strikingly different in having dominance of cingulate cavate spores, i.e.,

Lundbladispota spp. (15%) and *Densoisporites* spp. (3%) and further lowering in percentage of striate disaccates. Thus, five palynoassemblages demarcated in borecore MCP-7 from Chintalapudi area essentially fall under two groups:

1. Palynoassemblage-I, II, III are of Late Permian age by virtue of dominance of striate disaccate pollen and appearance of some younger Early Triassic forms.
2. Palynoassemblage-IV and V are strikingly different from group-I showing gradual disappearance of striate disaccates and consequent dominance of taeniate pollen and cingulate cavate trilete spores. This is Early Triassic in age.

Palynoassemblage-IV and V of the present area compare well with the Lower Triassic Palynoassemblages II and III of Sattupalli area (Jha 2008) and *Lunatisporites* Assemblage of Mailaram area (Srivastava and Jha 1990) which are located in the north of the Chintalapudi area. *Lundbladispota*–*Densoisporites* Assemblage has also been recorded in Manuguru area (Jha et al. 2011) located in the northwestern side of this area. Dominance of *Lundbladispota* has also been recorded from Panchet Formation of Raniganj coalfield of Damodar Basin (Bharadwaj and Tiwari 1977; Tiwari and Singh 1983), Talcher coalfield (Tripathi 1996). When compared with Damodar Basin of India P-I (*Striatopodocarpites*–*Klausipollenites* Assemblage) and P-II (*Verrucosisporites*–*Callumispota* Assemblage) assemblages have not been recorded in Godavari Graben. Outside India, present Palynoassemblage-IV is comparable to *Lunatisporites pellucidus* zone (*Falcisporites* superzone) of Australia (Rigby et al. 1987) and Assemblage of Mianwali Formation, Salt Range (Balme 1970).

Palynoassemblage-V corresponds to Assemblage P-IV in Damodar Basin synthesized by Tiwari and Singh (1986) but differs in having subdominance of *Falcisporites*. Dominance of *Lundbladispota* spp. and *Densoisporites* spp. has been recorded in Budharam, Sattupalli and Manuguru areas of Godavari Graben. Outside India, Palynoassemblage-V corresponds *Lunatisporites pellucidus* zone of Australia (Helby et al. 1987) which is widely reported from central and eastern Australia and less common in western Australia. Palynological pattern of Permian Triassic transition in Godavari Graben is similar to Salt Range.

Existence of Talchir, Barakar and Raniganj equivalent sediments has already been proved in Ayyanapalli Gompana area (Srivastava and Jha 1993), Chintalapudi and Sattupalli areas (Srivastava and Jha 1994) of Chintalapudi sub-basin. Present communication records Early Triassic

palynoflora in Chintalapudi area of Chintalapudi sub-basin. Presence of *Inaperturopollenites* in high percentage in Palynoassemblage-II to V is significant as this indicates shallow marine influence during the deposition of these sediment in Early Triassic (Balme 1970).

Lithologically, the sequence from 597.50 to 320.60 m show grey clay, coarse grained grey sandstone, carbonaceous shale, grey shale and thin shaly coal, grey sandstone with carbonaceous streaks. The Late Permian palynoflora has been demarcated in this sequence from 597.50 to 390.47 m. Definite Triassic palynoflora has been recorded in grey shale at 367.50–378.50 m. This indicates that Permian/Triassic boundary passes somewhere between 378.50 and 390.47 m, i.e., within a gap of 12 m. Lithologically, the changeover is observed above 320.60 m having light green sandstone and pinkish yellow sandstone. However, palynologically the change from Permian to Triassic has been recorded between 378.50 and 390.47 m. The upper part of the sequence having light green sandstone and pinkish yellow sandstone between 320.60 and 3 m lithologically represents Kamthi Formation (Early Triassic). *Densoisporites*, *Lundbladispora* Assemblage is much younger than *Lunatisporites* Assemblage and represents Late Early Triassic.

The present investigation leads to the conclusion that the carbonaceous shale, grey clay, grey sandstone horizon between 597.50 and 390.47 m in borecore MCP-7 is equivalent to the sediments above Sondila seam bearing coal horizon of Godavari sub-basin and actual coal bearing horizons may be beneath the depth of 606 m which holds a greater promise of economically viable coal reserves in this area.

Early Triassic palynoflora equivalent to Panchet has been recorded for the first time in Chintalapudi area. The earlier view of the absence of this member (equivalent to Panchet Formation) in Chintalapudi area is ruled out palynologically. Thus, Kamthi sediments (Jha and Srivastava 1996) equivalent to the Panchet Formation are also present in Chintalapudi area. The transition from Late Permian to Early Triassic is gradational similar to Sattupalli (Jha 2008) and Budharam (Srivastava and Jha 1995) areas while a sudden change in palynoflora at this level is recorded in Mailaram area (Srivastava and Jha 1990).

The present data again confirms the findings of Jha and Srivastava (1996) that Kamthi Formation represents Triassic sequence equivalent to Panchet Formation overlying the Raniganj equivalent sediments with a gradational contact. A perusal of the foregoing account reveals the existence of Panchet Formation in Chintalapudi area of Chintalapudi sub-basin.

Early Triassic assemblage from Salt Range, Pakistan (Balme 1970) has a predominance of the genus *Lunatisporites* (= *Taeniaesporites*) in association with *Densoisporites* and *Lundbladispora*. But the frequencies of these genera decline at the level of Late Early Triassic.

The Australian Early Triassic mioflora (De Jersey 1968, 1970; Dolby and Balme 1976) like the present assemblages is also characterized by taeniate and cingulate forms. However, the genus *Aratrisporites* which occurs frequently in the Australian Assemblage is absent in the present borecore from Chintalapudi sub-basin.

6. Conclusions

- Palynological studies have opened the possibility of presence of younger coal horizon (Late Permian–Raniganj) in Chintalapudi sub-basin also.
- Early Triassic palynoflora equivalent to that of Lower Panchet of Damodar Basin has been recorded for the first time in Chintalapudi area of Chintalapudi sub-basin.
- The transition from Late Permian to Early Triassic in Chintalapudi is gradational similar to Sattupalli and Budharam areas of Godavari Graben and is similar to that recorded at Salt Range in Pakistan.
- Shallow marine influence during the deposition of Early Triassic sediments has been observed in Chintalapudi area as in Sattupalli area too.
- The present data again confirms the findings of Jha and Srivastava (1996) that Kamthi Formation represents Triassic sequence equivalent to Panchet Formation overlying the Raniganj equivalent sediments with a gradational contact.
- Palynofloral similarity of Late Permian of Amery Basin, Antarctica and Godavari Graben supports the Indo-Antarctic fit proposed by Mitra *et al.* (1979) where Godavari Graben is in juxtaposition with the Amery Basin of Antarctica.

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References

- Balme B E 1970 Palynology of Permian and Triassic strata in the Salt Range and Surghar Range, western Pakistan; In: *Stratigraphic boundary problems: Permian and Triassic of west Pakistan* (eds) Kummel B and Teichert C, Geology Department, Univ. Kansas, **4** 305–455.
- Bharadwaj D C 1975 Palynology in biostratigraphy and palaeoecology in Indian Lower Gondwana Formations; *Palaeobotanist* **22** 150–157.
- Bharadwaj D C and Tiwari R S 1977 Permian–Triassic miofloras from Raniganj Coalfield, India; *Palaeobotanist* **24** 26–49.
- Bharadwaj D C, Tiwari R S and Anand-Prakash 1978 A Talchir mioflora from northern Satpura Basin, India; *Palaeobotanist* **25** 62–69.
- Bharadwaj D C, Tiwari R S and Anand-Prakash 1979 Permo-Triassic palynostratigraphy and lithostratigraphical characteristic in Damodar Basin, India; *Biol. Mem.* **4** 49–82.
- Bhattacharyya A P 2003 Late Permian microflora from Pirli–Pavna area, Wardha Valley Coalfield and Katol sub-basin, Kamptee Coalfield, Maharashtra; *Geophytology* **32** 91–96.
- Blanford W T 1872 Description of the sandstone in the neighbourhood of the first barrier on the Godavari and in the country between the Godavari and Ellore; *Rec. Geol. Surv. India* **6** 23–29.
- De Jekhowsky B and Goubin N 1964 Subsurface palynology in Madagascar: A stratigraphic sketch of the Permian, Triassic and Jurassic of the Morondava Basin; In: *Palynology in oil exploration* (ed.) Cross A T, *Soc. Econ. Paleontol. Mineral. Spec. Publ.* **11** 116–130.
- De Jersey N J 1968 Triassic spores and pollen grains from clematis sandstone; Publication Geological Survey of Queensland 338; *Palaeontology Papers* **14** 1–44.
- De Jersey N J 1970 Early Triassic miospores from Rewan Formation Publication Geological Survey of Queensland 345; *Palaeontology Papers* **19** 1–29.
- Dolby J and Balme B E 1976 Triassic palynology of Caranvon basin western Australia; *Rev. Palaeobot. Palynol.* **22** 105–168.
- Falcon R M S 1975 Palynostratigraphy of the Karroo sequence in the central Sebungwe District, Mid Zambesi Basin, Rhodesia; *Palaeontogr. Afri.* **18** 1–29.
- Goubin N 1965 Description et repartition des principaux pollenites permien, triasiques et jurassiques des sondages du sassin de Morondava (Madagascar); *Rev. Inst. Fr. Pet.* **20** 1415–1461.
- Hankel O 1987 Lithostratigraphic subdivision of the Karroo rocks of the Luwegu Basin (Tanzania) and their biostratigraphic classification based on microfloras, macrofloras, fossil woods and vertebrates; *Geol. Rundsch.* **76** 539–565.
- Helby R, Morghan R and Partridge A D 1987 A palynological zonation of Australian Mesozoic; In: *Studies in Australian Mesozoic palynology*, pp. 1–94.
- Holdgate G R, McLoughlin S, Drinnam A N, Finkelman R B, Willett J C and Chiehowsky L A 2005 Inorganic chemistry, petrography and palaeobotany of Permian coals in the Prince Charles Mountains, East Antarctica; *Int. J. Coal Geol.* **63** 156–177.
- Jha Neerja 2002 Palynological dating of sediments from Gattugudem area, Chintalapudi sub-basin, Andhra Pradesh; *Geophytology* **30** 85–89.
- Jha Neerja 2004 Palynological dating of coal bearing sediments from the Bottapagudem area, Chintalapudi sub-basin, Andhra Pradesh, India; *Palaeobotanist* **53** 61–67.
- Jha Neerja 2006 Permian Palynology from India and Africa – A Phytogeographic Paradigm; *J. Palaeontol. Soc. India* **51** 43–55.
- Jha Neerja 2008 Permian Triassic palynofloral transition in the Sattupalli area, Chintalapudi sub-basin, Godavari Graben, Andhra Pradesh, India; *J. Palaeontol. Soc. India* **53** 159–168.
- Jha Neerja and Srivastava Suresh C 1996 Kamthi Formation palynofloral diversity; In: *Gondwana Nine* (eds) Guha P K S, Sengupta S, Ayyasami K and Ghosh R N (Calcutta: Oxford & IBH Publishing Co.) **1** 355–368.
- Jha Neerja, Pauline Sabina K and Mehrotra N C 2011 Early Triassic palynomorphs from Manuguru area of Godavari Graben, Andhra Pradesh, India; *J. Geol. Soc. India* **78** 167–174.
- Jha Neerja and Tewari Rajni 2003 Megaspores from Raniganj Formation of Mailaram area, Godavari Graben, Andhra Pradesh, India; *Phytomorphology* **53** 141–156.
- Lakshminarayana G 1996 Stratigraphy and structural framework of the Gondwana sediments in the Pranhita–Godavari Valley, Andhra Pradesh; In: *Ninth International Gondwana Symposium, Hyderabad* (eds) Guha P K S, Sengupta S, Ayyasami K and Ghosh R N, *Geological Survey of India*, Oxford and IBH Publishing Co., New Delhi–Calcutta, pp. 311–330.
- Lakshminarayana G and Murthy K S 1990 Stratigraphy of the Gondwana Formations in the Chintalapudi sub-basin, Godavari Valley, Andhra Pradesh; *J. Geol. Soc. India* **36** 13–35.
- Mitra N D, Bandyopadhyaya S K and Basu U K 1979 Sedimentary framework of Gondwana sequence of eastern India and its bearing on Indo-Antarctic fit; *Proceedings IVth International Gondwana Symposium*, Calcutta, pp. 37–41.
- Msaky E and Srivastava Veena 1997 Lower Karoo (K5–K6) palynological assemblage from Tanzania; Abstract *3rd Symposium of African palynology*, Johannesburg, South Africa, 14–19 Sept., 1997, p. 31.
- Oosterian P M and Millstead B D 1994 Lithostratigraphy, palaeontology and sedimentary environment of the western Cabora Bassa Basin, Lower Zambesi Valley, Zimbabwe; *South African J. Geol.* **97** 205–224.
- Raiverman V, Rao M R and Pal D 1986 Stratigraphy and structure of the Pranhita–Godavari Graben; *Petroleum Asia Journal* **8** 174–189.
- Raja Rao C S 1982 Coalfields of India. 2. Coal resources of Tamil Nadu, Andhra Pradesh, Orissa and Maharashtra; *Bull. Geol. Surv. India, Ser. A* **45** 9–40.
- Rigby J K, Newman K R, Smit J, Der Kaars Van S and Sloan R E 1987 Dinosaurs from the Paleocene part of the Hell Creek Formation, McCone County, Montana; *Palaio* **2** 296–302.
- Slater B J, Mc Loughlin S and Hilton J 2011 Guadalupian (Middle Permian) megaspores from a permineralised peat in the Bainmedart Coal Measures, Prince Charles Mountains, Antarctica; *Rev. Palaeobot. Palynol.* **167**(1–2) 140–155.
- Srivastava S C and Bhattacharyya A P 1996 Permian–Triassic palynofloral succession in subsurface from Bazargaon, Nagpur District, Maharashtra; *Palaeobotanist* **43** 10–15.
- Srivastava Suresh C and Jha Neerja 1987 Palynology of Kamthi Formation from Chelpur area, Godavari Graben, Andhra Pradesh, India; *Palaeobotanist* **35** 342–346.

- Srivastava Suresh C and Jha Neerja 1988 Palynology of Kamthi Formation in Godavari Graben; In: *Concepts, limits and extension of Indian Gondwana* (eds) Venkatachala B S and Maheshwari H K, *Palaeobotanist* **36** 123–132.
- Srivastava Suresh C and Jha Neerja 1989 A Lower Triassic palynoassemblage from Budharam area, Godavari Graben, Andhra Pradesh, India; *Geophytology* **18** 124–125.
- Srivastava Suresh C and Jha Neerja 1990 Permian–Triassic palynofloral transition in Godavari Graben, Andhra Pradesh; In: *Proceedings of Symposium–Vistas n Indian Palaeobotany, Lucknow* (eds) Jain K P and Tiwari R S, *Palaeobotanist* **38** 92–97.
- Srivastava Suresh C and Jha Neerja 1991 Palynological dating of coal seams in Amavaram Area, Khammam District, A.P., India; *Geophytology* **20** 161.
- Srivastava Suresh C and Jha Neerja 1992 Palynostratigraphy of Permian sediments in Manuguru area, Godavari Graben, Andhra Pradesh; *Geophytology* **22** 102–110.
- Srivastava Suresh C and Jha Neerja 1993 Palynostratigraphy of Lower Gondwana sediments in Chintalapudi sub-basin, Godavari Graben, Andhra Pradesh; *Geophytology* **23** 93–98.
- Srivastava Suresh C and Jha Neerja 1994 Palynological dating of Lower Gondwana sediments in Sattupalli area, Chintalapudi sub-basin, Andhra Pradesh, India; *Palaeobotanist* **42** 169–173.
- Srivastava Suresh C and Jha Neerja 1995 Palynostratigraphy and correlation of Permian–Triassic sediment in Budharam area, Godavari Graben, India; *J. Geol. Soc. India* **46** 647–653.
- Srivastava S C and Jha Neerja 1998 Palynology of Lower Gondwana sediments in the Bhopalpalli area, Godavari Graben; *J. Palaeontol. Soc. India* **43** 41–48.
- Tewari Rajni and Jha Neerja 2007 Permian megaspores from Godavari Graben, India: Present status; *Palaeobotanist* **56** 133–138.
- 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 Singh Vijya 1983 Miofloral transition at Raniganj–Panchet boundary in east Raniganj coalfield and its implication on Permo–Triassic time boundary; *Geophytology* **13** 227–234.
- Tiwari R S and Singh Vijya 1986 Palynological evidences for Permo–Triassic boundary in Raniganj Coalfield, Damodar Basin, India; *Bull. Geol. Min. Metall. Soc. India* **54** 25–264.
- Tiwari R S and Tripathi A 1984 A report of Raniganj mioflora from sediments of Dubrajpur Formation in Brahmani Coalfield, Rajmahal Basin; *Geophytology* **14** 244–245.
- Tiwari R S and Tripathi A 1992 Marker assemblage zones of spore and pollen species through Gondwana 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; *Curr. Sci.* **61** 407–420.
- Tripathi A 1996 Early and Late Triassic palynoassemblages from subsurface Supra-Barakar sequence in Talcher Coalfield, Orissa, India; *Geophytology* **26** 109–118.
- Tripathi A 1997 Palynostratigraphy and palynofacies analysis of subsurface Permian sediments in Talcher Coalfield, Orissa; *Palaeobotanist* **46** 79–88.
- Utting J 1979 Lower Karoo pollen and spore assemblages from the coal measures and underlying sediments of the Siankondobo Coalfield, Mid-Zambesi Valley, Zambia; *Palynology* **2** 53–68.
- Wescott W A, Krebs W N, Engelhardt D W and Cunningham S W 1991 New biostratigraphic age dates from the Lake Rukwa Rift Basin in western Tanzania; *Amer. Assoc. Petrol. Geol. Bull.* **75** 1255–1263.
- Wopfner H and Kaaya C Z 1991 Stratigraphy and morpho-tectonics of Karoo deposit of the northern Selous Basin, Tanzania; *Geol. Mag.* **128** 319–334.
- Wright R P and Askin R A 1987 The Permian–Triassic boundary in the southern Morondava basin as defined by plant microfossils; In: *Gondwana Six. Stratigraphy, Sedimentology and Paleontology* (ed.) McKenzie G D, *Geophys. Monogr., Washington* **41** 157–166.