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Record of Gondwana plant mega- and microfossils in Nimugudem area, Telangana, India: palynodating and palaeoenvironmental interpretation

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The present study is a record of Permian (Lower Gondwana) and late Jurassic–early Cretaceous (Upper Gondwana) palynomorphs in megafossil-bearing beds in Nimugudem area, Godavari sub-basin, Telangana, India. Detailed palynological studies were carried out on outcrop samples from the exposure in a nala of Nimugudem area where leaf impressions of plant megafossils were also observed. Leaf impressions of *Ptilophyllum* and *Pterophyllum* recorded in this section indicate Upper Gondwana affinity for these sediments. Presence of different species of palynomorphs of Upper Gondwana affinity in sandstone beds indicates late Jurassic–early Cretaceous (Tithonian–Berriasian) age for these sediments. It is equivalent to Kota/Gangapur Formation of Godavari Graben. Reworked Permian palynomorphs were recorded in these sediments. The coal exposure yielding late Permian palynomorphs belongs to Raniganj Formation.

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Keywords: Leaf impressions, mega- and microfossils, palynomorphs, sandstone beds.

PRANHITA–Godavari Graben, Telangana, India is a linear, NNW–SSE trending intracratonic rift coal-belt resting on Precambrian/Vindhyan rock platform, extending from the north of Boregaon, Maharashtra in north to Eluru in the east coast of Andhra Pradesh in the south. The Pranhita–Godavari basin consists of marine, terrestrial and paralic signatures in deposits comprising Permian, Triassic, Jurassic, including early Cretaceous periods displaying the complete span of the Gondwana period in the South Indian Peninsula (Figure 1). In this linear belt the Lower Gondwana sediments are exposed along both the eastern and western margins of the basin, while the Upper Gondwana sediments cover the central/axial portion[1]. The Lower Gondwana succession consists of Talchir, Barakar, Barren Measures and Raniganj Formation, whereas the Upper Gondwana Formations are Kamthi, Maleri, Kota and Gangapur Sandstone[2]. Gondwana deposits in India show cyclicity in lithology, which makes it difficult to differentiate the formations on the basis of lithology. Nimugudem area lies in Chintaguda block in the northwest part of Dorli. The rocks in the area of Chintaguda block have been designated as Kota/Gangapur by the Geological Survey of India (GSI). Sandstone is exposed at many places in the nala in this block. While in search of coal, geologists from Singareni Collieries Company Limited (SCCL), Bellampalli observed two coal exposures in Chintaguda block (Figure 1), one near Nimugudem and the other near Chintaguda (Figure 1), which raised a controversy about the age of the rocks – whether they belong to Kamthi Formation, as most of the coal deposits in Godavari are of Permian age. In the nala exposure near Nimugudem megafossil leaf impressions belonging to *Ptilophyllum* and *Pterophyllum* were also observed. Figure 2 shows the exposure sites indicating position of plant fossil-bearing bed as well as recovered megafossils. The samples were collected from the area with GPS coordinates 19°19.855″N, 079°08.589″E. Palynomorphs were recovered from these megafossil-bearing beds and coal sample by usual maceration technique. The samples were first treated with 40% hydrofluoric acid to remove silicates, followed by commercial HNO_3 for oxidizing the organic matter and finally washed in 2–5% KOH solution. The macerates were passed through 150 and 400-mesh sieves to get the final residues. These were mixed with polyvinyl alcohol solution, spread on slides and mounted in Canada balsam. The samples and slides are deposited at the repository of the Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow.

Sandstone/siltstone and coal samples were macerated, which yielded well-preserved, rich and diversified palynoflora. Both qualitative and quantitative studies were undertaken in order to understand the age of the sediments as well as to decipher the palaeoenvironment during the deposition of sediments. A variety of palynomorphs was observed and quantitative analysis was based on dominance of palynotaxa in 200 counts in a sample at random fashion.

The palynoassemblage in coal sample (sample no. 1) is dominated by the striate bisaccate (32%), viz. *Striatopodocarpites* (12%), *Faunipollenites* (13%), *Crescentipollenites* (5%), *Strotersporites* (2%) and sub-dominated by enveloping monosaccate pollen grain, *Densipollenites* (25%). Rare but stratigraphically significant taxa present in the assemblage include *Falcisporites*, *Lundbladispora*, *Densipollenites magnicorpus*, *Marsupipollenites* sp., *Klausipollenites*, *Lunatisporites* and *Hamiapollenites* (Figures 3 and 4 *a*). The other palynotaxa found associated with these are *Parasaccites* (9%), *Plicatipollenites* (2%), *Caheniasaccites* (1%), *Scheuringipollenites* (8%), *Alisporites* (4%) and *Vesicaspora* (3%). Trilete spores are rare in occurrence and variability, represented by just two palynotaxa, *Callumispora* (1%) and *Brevitriletes* (2%).

Quantitatively, the palynoassemblage in sandstone/siltstone (sample no. 2) is dominated by Gymnospermous pollen grains, viz. *Araucariacites* spp. (47.30%) and *Callialasporites* spp. (37.30%). Pteridophytic spores are less abundant. Bryophytic and algal spores are poor in occurrence. The taxa recorded in the present samples belong to *Araucariacites australis*, *A. fissus* and various species of *Callialasporites*, viz. *C. indicus*, *C. barragaonensis*, *C. dampieri*, *C. discoidalis*, *C. microvelatus*, *C. monoalasporus*, *C. segmentatus*, *C. triletus*, *C. trilobatus*, *C. turbatus*, *Callialasporites* sp. and *Alsophyllidites kerguelensis*, *Biretisporites eneabbaensis*, *Cicatricosisporites ludbrooki*, *Classopollis classoides*, *Cycadopites follicularis*, *Foveosporites* cf. *canalis*, *Laricoidites magnus, Inaperturopollenites* sp., *Latosporites* sp., *Podocarpidites ellipticus*, *Podocarpidites rarus*, *Podocarpidites typicus*, *Stereisporites antiquasporites* and *Botryococcus* sp. (Figures 4 *a* and 5).

In the Lower Gondwana (Permian) palynological succession, radial monosaccates constitute the dominant component of palynoflora in the early Permian, whereas the striate disaccates attain overall dominance during the late Permian. Striate bisaccates chiefly diploxylonoid forms, viz. *Striatopodocarpites* and *Faunipollenites* tend to occur ubiquitous and abundantly in the Upper Permian of all the 'Gondwanaland' countries[3–8]. In the present study, the coal sample is dominated by striate bisaccates and girdling monosaccate palynotaxa, *Densipollenites* along with some significant forms like *Klausipollenites* and *Lunatisporites*, which indicate younger aspect during the late Permian. *Densipollenites* tends to occur in abundance in Raniganj Formation of all the five major Gondwana basins of India[9–11]. Presence of these taxa denotes late Permian (Raniganj) age for the coal exposure in the Nimugudem area.

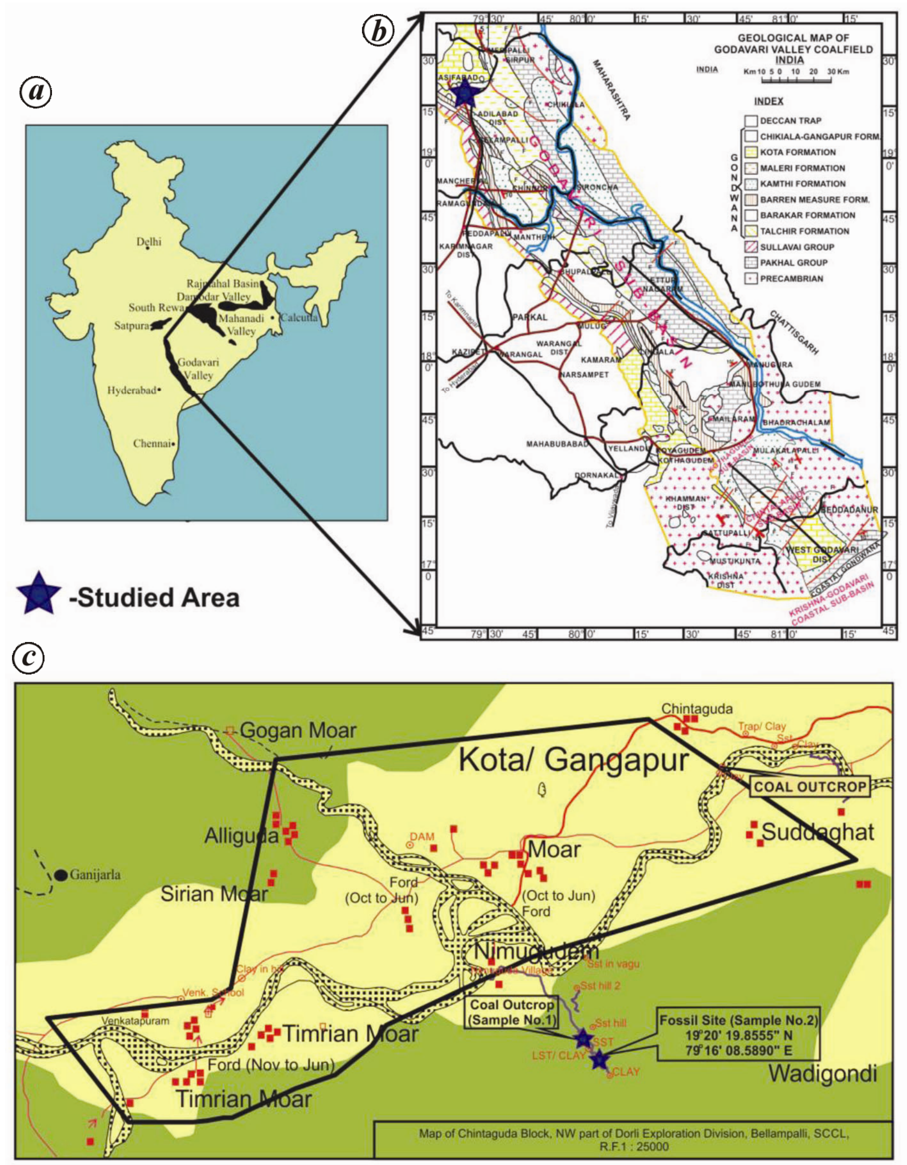

Figure 1. ***a***, Map of India showing location of Godavari Graben. ***b***, Map of Godavari Graben (after GSI) showing location of the study area. ***c***, Map of Nimugudem area showing sample sites.

In Mesozoic Gondwana, striate disaccates which dominated the palynoflora during late Permian declined in percentage and were replaced by taeniate, cingulated cavate trilete spores in the early Triassic. Thus, there has been a major evolutionary change in functional morphology of spore-pollen as well as composition of palynoassemblages from Permian to Triassic. Jurassic palynoflora is basically identified by dominance as well as qualitative diversification of genera *Callialasporites* and *Podocarpidites* along with long-ranging Triassic taxa (*Araucariacites*, *Densoisporites*, *Cyathidites*) and several new forms, viz. *Ceratosporites*, *Klukisporites*, *Ischyosporites*, *Classopollis*, *Foveotriletes*, *Leptolepidites*, *Murospora* and *Contignisporites* which continue to occur in the early Cretaceous. Presence of *Cicatricosisporites*, *Aequitriradites*, *Boseisporites* and *Lametatriletes* indicates stratigraphical vicinity to the Jurassic–Cretaceous boundary[10]. The overall composition of the global Jurassic–Cretaceous palynoflora is represented by the dominance of coniferous gymnosperm pollen grains, viz. Araucareaceae and podocarpidaceous pollen grains[10,12–17]. Thus, in the present palynoassemblage recovered from sample no. 2, the presence of a variety species of *Callialasporites*[18–21] along with other species[14,22,23] as mentioned earlier indicates late Jurassic–early Cretaceous age. Stratigraphic ranges of the different Mesozoic taxa have been suggested by the various Mesozoic palynologist from various parts of the globe[12,24–29]. Figure 6 shows known stratigraphic range of significant species recorded in the present study. Upper Gondwana is equated with Triassic, Jurassic and early

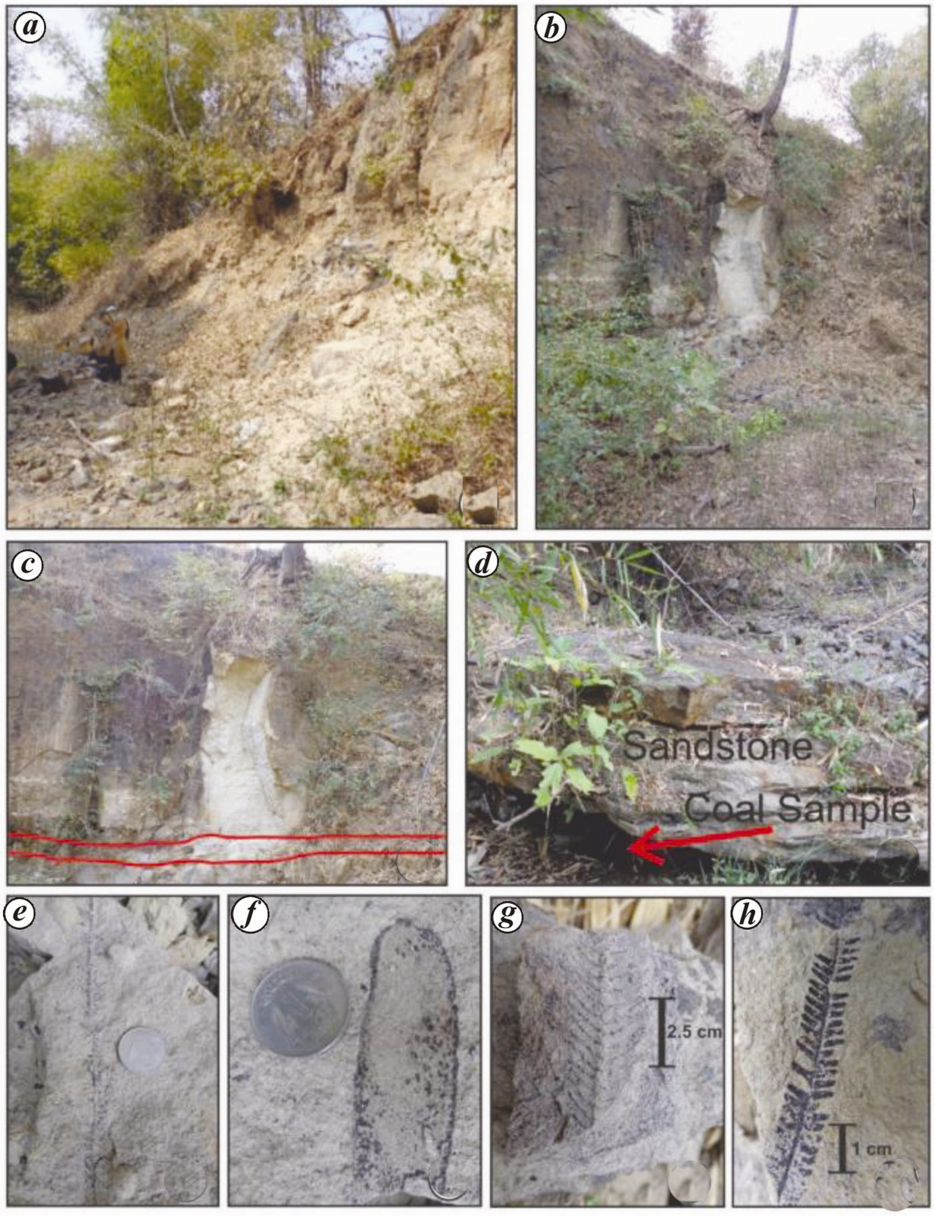

Figure 2. Field photographs showing position of plant fossil-bearing beds, coal exposure and megafossils recorded in Nimugudem area, Godavari sub-basin, Telangana, India. ***a***, ***b***, Megafossil collection sites. ***c***, Enlarged view of fossil site showing position of plant fossil-bearing sandstone/siltstone bed. ***d***, Enlarged view of fossil site showing position of coal sample bed. ***e***, *Ptilophyllum* sp. ***f***, Unidentified. ***g***, *Ptilophyllum* sp. ***h***, *Pterophyllum* sp.

Cretaceous periods. Megafloristically, Permian Triassic boundary has witnessed a decline of *Glossopteris* flora and advent of *Dicroidium* flora, followed by the *Ptilophyllum* flora in the Jurassic–Cretaceous[30–34]. The coal beds ceased to exist after the Permian and profiles of varied mudstone, siltstone, clay, sandstone, and limestone occur all through the sequence up to the early Cretaceous in all the basins. Palynologically, the coal bed in Nemugudem area belongs to the late Permian, while the sandstone/siltstone unit is late Jurassic–early Cretaceous in age, both megafloristically as well as microfloristically.

Palynofacies studies were carried out for interpreting the palaeoenvironmental conditions during deposition of sediments using dispersed organic matter studies. Organic matter has been classified as structured terrestrial, opaque phytoclast, palynomorphs and amorphous organic matter. Sample no. 1 (coal sample, Figure 4 *b*) shows clear abundance of opaque phytoclasts (43%), followed by structured organic matter (13.5%), palynomorph (18%) and amorphous organic matter (25.5%). Palynological study has revealed the presence of thick sub-arborescent to arborescent forest cover in the mire, mainly consisting of gymnospermous pollen (mainly conifers) followed by

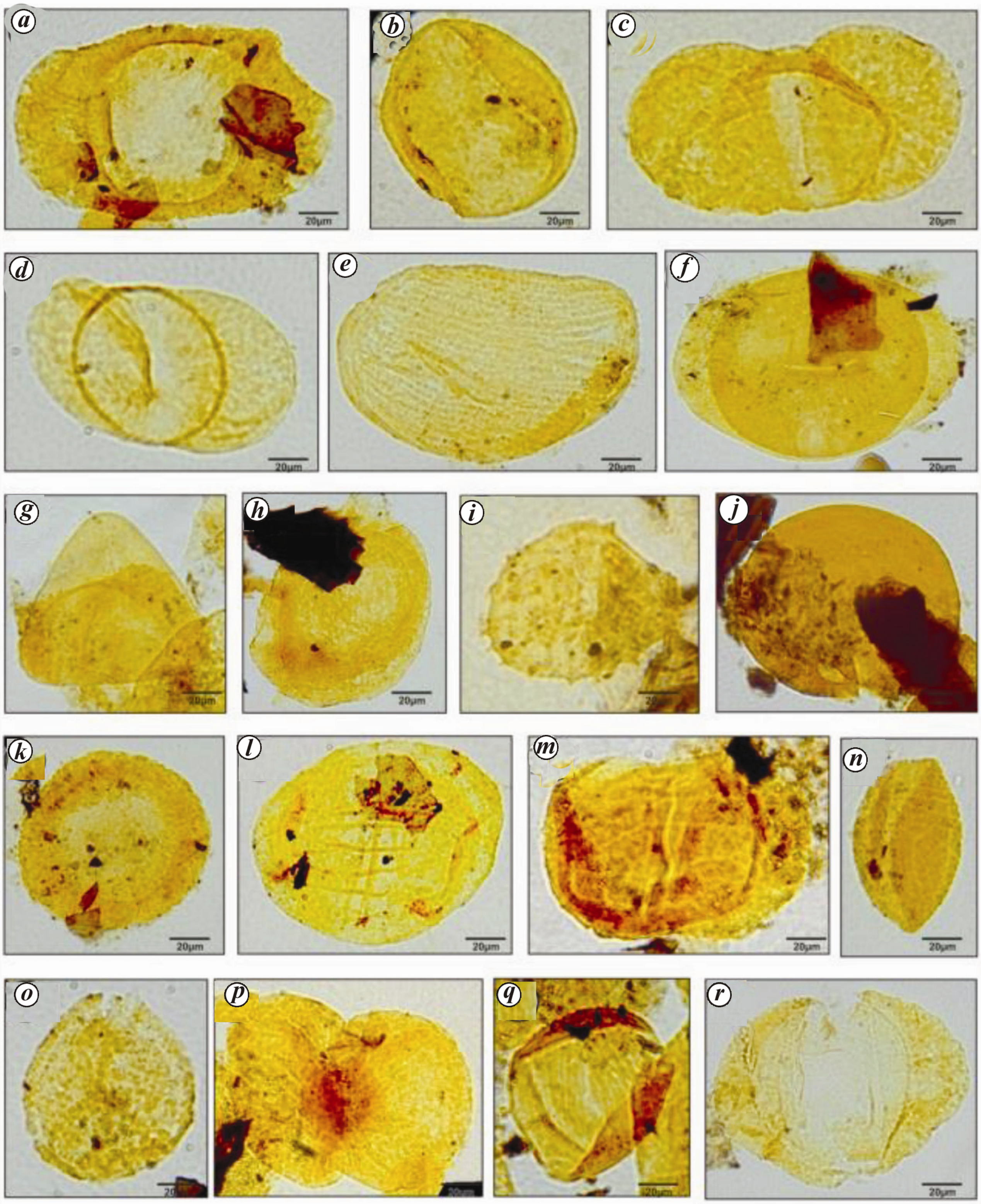

Figure 3. Permian Palynomorphs in coal bed. ***a***, *Caheniasaccites* sp., BSIP slide no. 15416, H52/3. ***b***, *Marsupipollenites* sp., BSIP slide no. 15415, L58/4. ***c***, *Striatopododcarpites* sp., BSIP slide no. 15415, L59/3. ***d***, *Platysaccus* sp., BSIP slide no. 15416, V49/1. ***e***, *Tiwariasporis* sp., BSIP slide no. 15416, O70/4. ***f***, *Limitisporites* sp., BSIP slide no. 15417, N53/2. ***g***, *Microfoveolatisporites* sp., BSIP slide no. 15418, N45/1. ***h***, *Densipollenites magnicorpus*, BSIP slide no. 15417, M52/3. ***i***, *Brevitriletes* sp., BSIP slide no. 15415, R53/2. ***j***, *Callumispora gretensis*, BSIP slide no. 15415, F38/3. ***k***, *Parasaccites* sp., BSIP slide no. 15416, K51/1. ***l***, *Faunipollenites varius*, BSIP slide no. 15415, T59/1. ***m***, *Striatopodocarpites* sp., BSIP slide no. 15415, T64/1. ***n***, *Striasulcites* sp., BSIP slide no. 15416, Q60/2. ***o***, *Lundbladispora* sp., BSIP slide no. 15416, 038/4. ***p***, *Primuspollenites* sp., BSIP slide no. 15415, T58/3. ***q***, *Marsupipollenites* sp., BSIP slide no. 15416, J52/1. ***r***, *Klausipollenites* sp., BSIP slide no. 15415, M36/3.

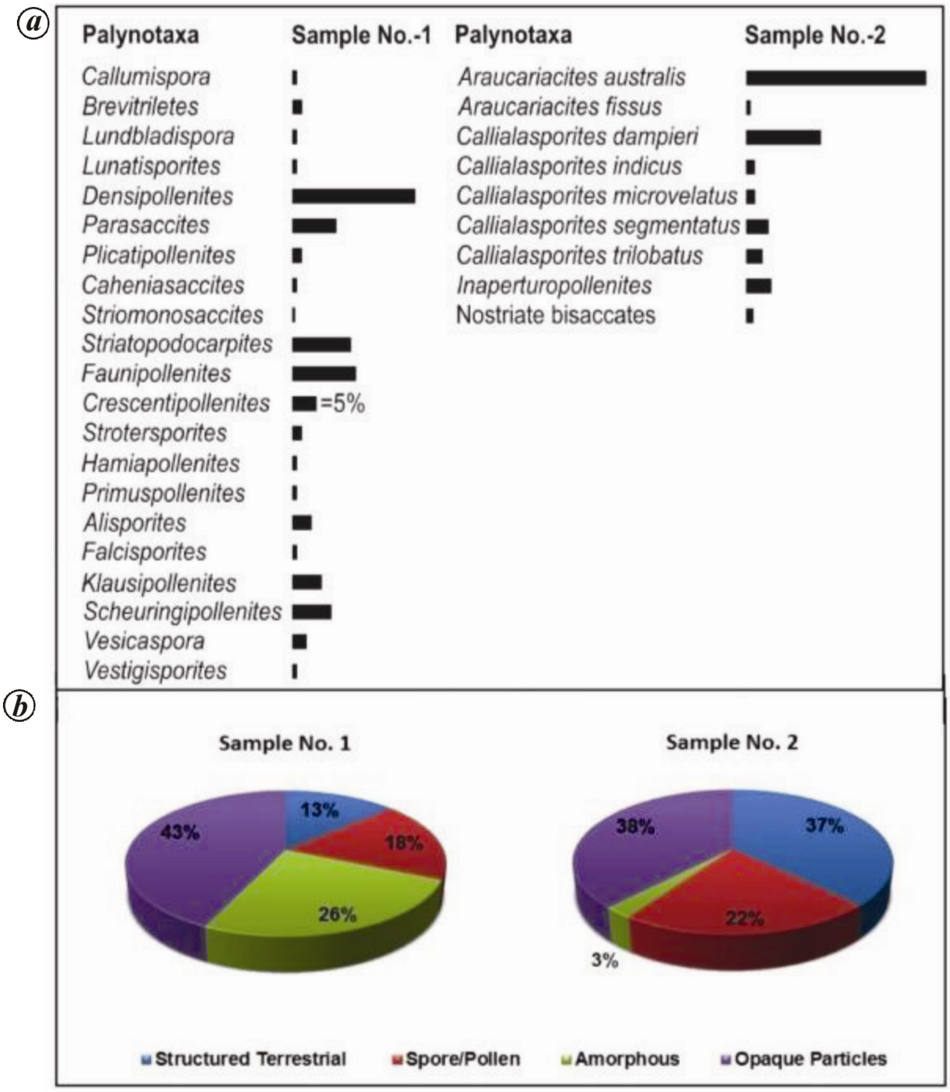

Figure 4. Graphical representation of percentage frequency of various palynotaxa and dispersed organic matter in Nimugudem area. ***a***, Histogram showing frequency distribution of various palynotaxa. ***b***, Pie chart showing distribution of dispersed organic matter.

the pteridophytic spores. Abundance of opaque phytoclast suggests periodic oxidizing conditions during deposition of sediment. The high incidence of amorphous organic matter shows the high microbial activity under anoxic conditions[35]. Anoxic and waterlogged, warm and humid conditions favouring the formation of peat are inferred for these sediments.

Sample no. 2 shows the dominance of opaque phytoclast (43%) and structured organic matter (37.5%) along with the presence of spore and pollen (44%), suggest the presence of thick forest cover in the mire (Figure 4 *b*). Opaque phytoclast (75%) is also present in fair amounts in the samples, suggesting the periodic oxidizing environment which may be the consequence of retarded subsidence[36]. In general, high frequency of conifer pollen like *Araucariacites* and *Callialasporites* represents a warm climate and coastal vegetation. Although some non-striate bisaccate pollen taxa (*Podocarpidites*, *Alisporites*) represented in lesser percentage may have inhabited relatively dry areas of upland floras[37]. Oxidizing, reducing, warm and humid conditions which led to the high incidence of opaque phytoclast have been inferred for these sediments[38].

Some reworked Permian palynomorphs were also recorded in the assemblage recovered in sandstone/siltstone sample. These are *Faunipollenites*, *Crescentipollenites*, *Striatites*, *Striatopodocarpites*, *Scheuringipollenites*, *Densipollenites magnicorpus*, *D. invisus*, *Alisporites*, *Chordasporites*, *Ibisporites*, *Platysaccus*, *Primuspollenites*, *Tiwariasporis*, *Scheuringipollenites*, *Parasaccites*, *Plicatipollenites*, *Barakarites*, *Falcisporites*, *Klausipollenites*, *Hamiapollenites* and *Strotersporites.*

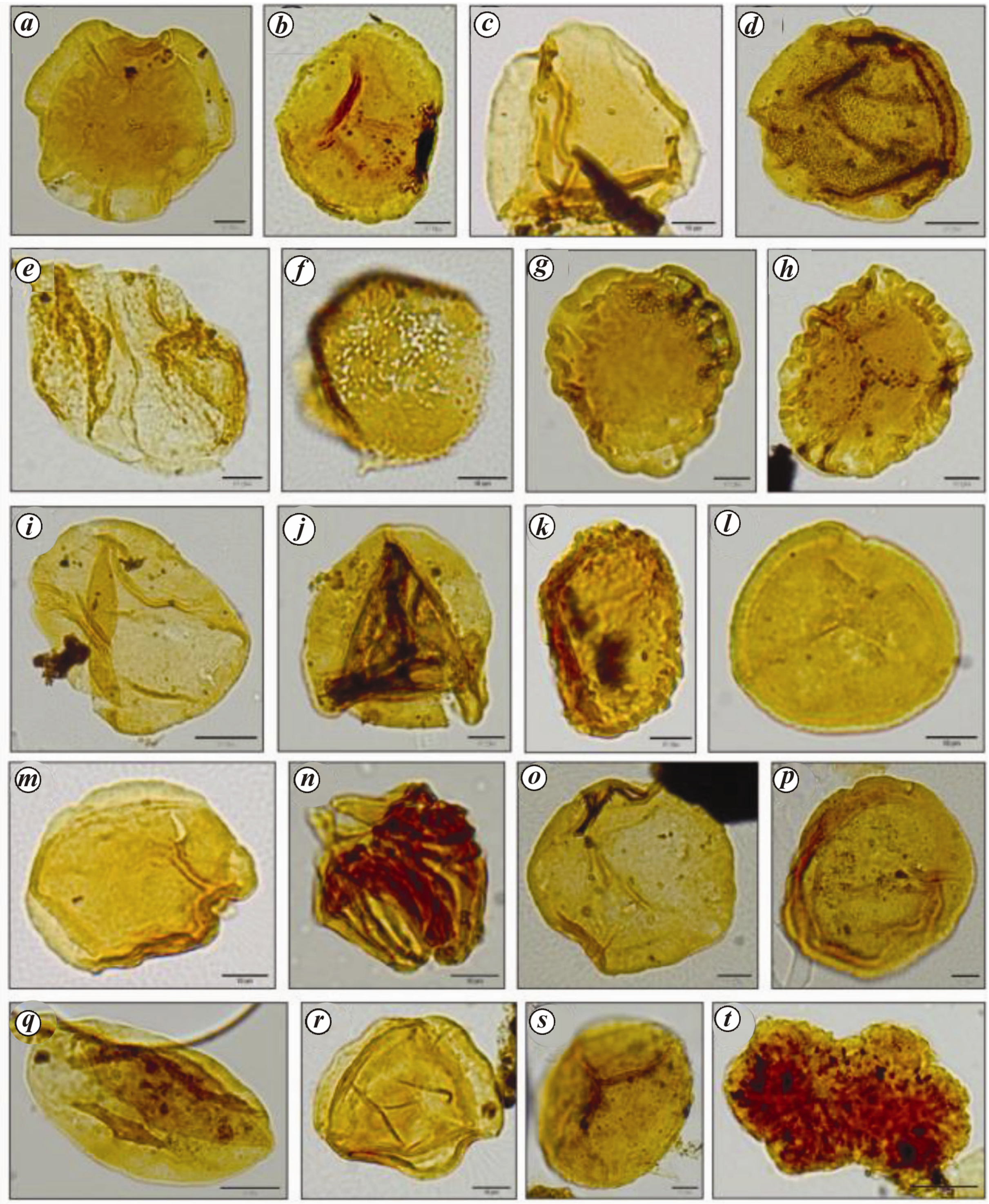

Figure 5. Jurassic–Early Cretaceous palynomorphs in megafossil-bearing sandstone/siltstone bed. ***a***, *Callialasporites trilobatus*, BSIP slide no. 15411, E41/2. ***b***, *Callialasporites microvelatus*, BSIP slide no. 15411, H49/3. ***c***, *Callialasporites barragaonensis*, BSIP slide no. 15411, J62/3. ***d***, *Callialasporites turbatus*, BSIP slide no. 15411, L55/2. ***e***, *Podocarpidites typicus*, BSIP slide no. 15413, L43/1. ***f***, *Foveosporites canalis*, BSIP slide no. 15411, H57/3. ***g***, *Callialasporites dampieri*, BSIP slide no. 15411, K58/4. ***h***, *Callialasporites triletus*, BSIP slide no. 15411, L54/4. ***i***, *Inaperturopollenites* sp. BSIP slide no. 15411, K62/4. ***j***, *Callialasporites turbatus*, BSIP slide no. 15411, M58/2. ***k***, *Callialasporites segmentatus*, BSIP slide no. 15411, U36/4. ***l***, *Stereisporites antiquasporites*, BSIP slide no. 15411, P54/4. ***m***, *Callialasporites discoidalis*, BSIP slide no. 15411, U59/3. ***n***, *Cicatricosisporites ludbrooki*, BSIP slide no. 15411, E40/1. ***o***, *Araucariacites australis*, BSIP slide no. 15413, U38/2. ***p***, *Callialasporites monoalasporus*, BSIP slide no. 15413, G38/2. ***q***, *Cycadopites follicularis*, BSIP slide no. 15414, H60/3. ***r***, *Callialasporites* sp., BSIP slide no. 15413, T52/3. ***s***, *Biretisporites eneabbaensis*, BSIP slide no. 15414, R64/1. ***t***, *Botryococcus* sp., BSIP slide no. 15412, J47/1.

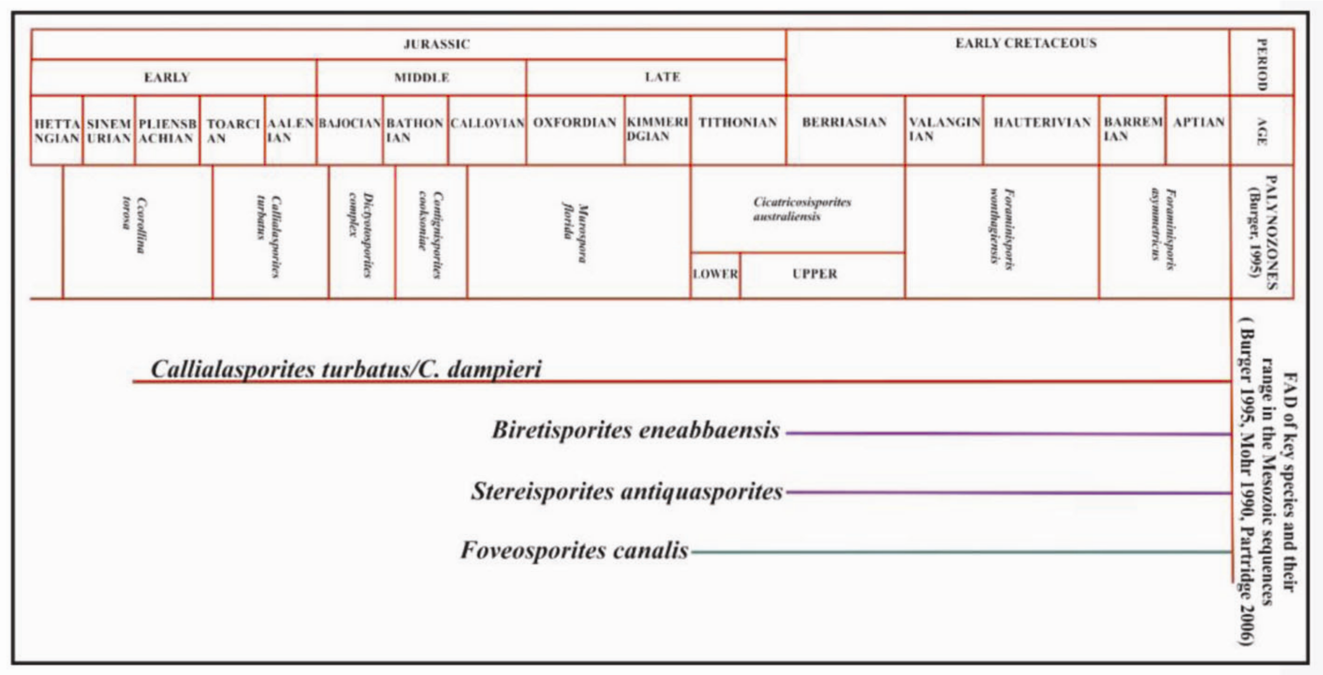

Figure 6. Known stratigraphic range of significant species recorded in the present study.

This indicates presence of older rocks in or around the studied areas. Recycling of various palynotaxa is a common phenomenon in a majority of the depositional systems of younger age[39–41]. These reworked palynomorphs might have been derived by the erosion of older rock existing at the time of deposition of these sediments. The exact locality of such older deposits is difficult to pinpoint as Permian rocks occur in large amount in the Godavari sub-basin. Permian palynomorphs have been recorded in nearby areas, viz. Belampalli, Ramagundam, Ramkrishnapuram (Figure 1). Presence of Permian sediments in these areas of Godavari sub-basin may be the source for the reworked palynomorphs. Permian rocks are well-developed in the Godavari sub-basin, which could have been eroded and redeposited in the Nimugudem area.

Thus, the palynogical data acquired in the present study support the view of GSI that the sandstone in Nimugudem area belongs to Kota/Gangapur Formation, although the coal exposure is Permian in age and is equivalent to Raniganj Formation.

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