Palynofloral investigation of the Tura Formation (Palaeocene) in Nongwal Bibra area, East Garo Hills, Meghalaya*

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A palynofloral assemblage, comprising 30 genera and 48 species, has been recorded from the Tura Formation (Palaeocene) exposed in Nongwal Bibra area in East Garo Hills District, Meghalaya. On the basis of palynofloral analysis, two palynozones have been recognized. The lower palynozone is dominated by angiospermous pollen (79%) with subordinate representation of pteridophytic spores (7.5%) and fungal remains (13.5%) whereas the upper palynozone is dominated by pteridophytic spores (76%) followed by angiospermous pollen (15%) and fungal remains (9%). The palynoflora indicated prevalence of tropical-subtropical climate, luxuriant growth of wet-evergreen forest with mangrove elements in the vicinity of the area and a near-shore, shallow marine environment of deposition. The assemblage shows homotaxiality with those recorded from parts of the Tura Formation (Garo Hills), Cherra Formation (Khasi Hills), Therria Formation (Jaintia Hills), Mikir Formation (North Cachar Hills), subsurface Palaeocene sediments of Bengal Basin and Matanomadh Formation (Kutch) and therefore a Palaeocene age has been assigned to the studied sequence.

Key-words—Palynology, Tura Formation, Palaeocene, Garo Hills, Meghalaya (India).

INTRODUCTION

THE Tura Formation constitutes the oldest lithostratigraphic unit of the Tertiary sequence of Garo Hills. Fox (in Heron, 1937) named this unit as "Tura Sandstone" after Tura (Lat. 25° 31′ 00" N: Long. 90° 13′ 30" E), the headquarters of West Garo Hills District, where fairly good development of this unit can be observed. Bedford (1842, in Medlicott, 1868) was the first to report occurrence of coal in the Tura sandstones. The first reference regarding age of this unit was given by Oldham (1863) who assigned it a Late Cretaceous age. Thereafter, several workers (Medlicott, 1874; LaTouche, 1882, 1887; Pinfold, 1919; Evans, 1932; Fox in Heron, 1937; Ghosh, 1954; Biswas, 1962; Chakraborty, 1972; Chakraborty & Baksi, 1972; Sah, 1974; Sah & Singh, 1974; Rajarao, 1981; Singh, 1982) published valuable information regarding age and stratigraphic position of this formation and its relationship with contemporaneous stratigraphic units of Shillong Plateau.

Palynological studies on the Tura Formation have been done by Biswas (1962), Chatterjee and Ghosh (1962), Banerjee (1964), Ghosh (1969), Salujha *et al.* (1972), Sah and Singh (1974), Singh *et al.* (1976), Singh (1977a,b) and Singh and Singh (1978). Sah and Singh (1977), Singh (1982), Sah and Mehrotra (1988) and Saxena (1988) reviewed the palynostratigraphic information from the Tura Formation and attempted to correlate this unit with other contemporaneous stratigraphic units of Meghalaya and Assam. The present work has been carried out on the Tura Formation of Nongwal Bibra area in East Garo Hills with the objective of studying the palynoflora in order to deduce palaeoclimate and depositional environment and to determine its biostratigraphic potential.

MATERIAL AND METHODS

The samples for the present study were collected from the Tura Formation developed around Nongwal Bibra (Lat. 25° 28′ 00" N: Long. 90° 42′ 00" E) in East Garo

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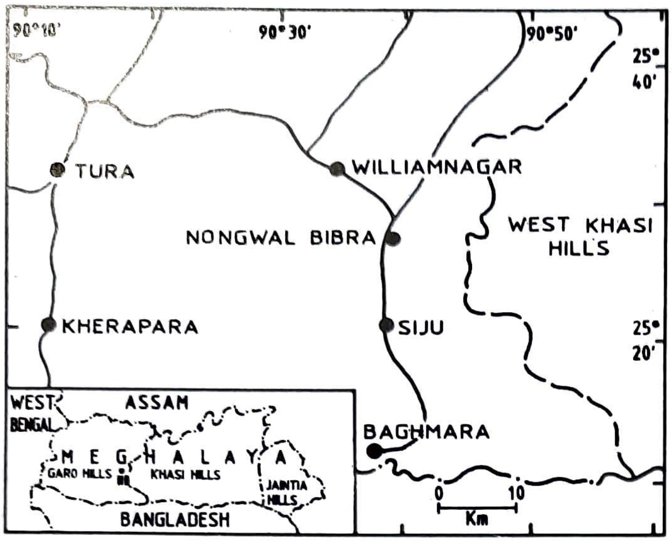


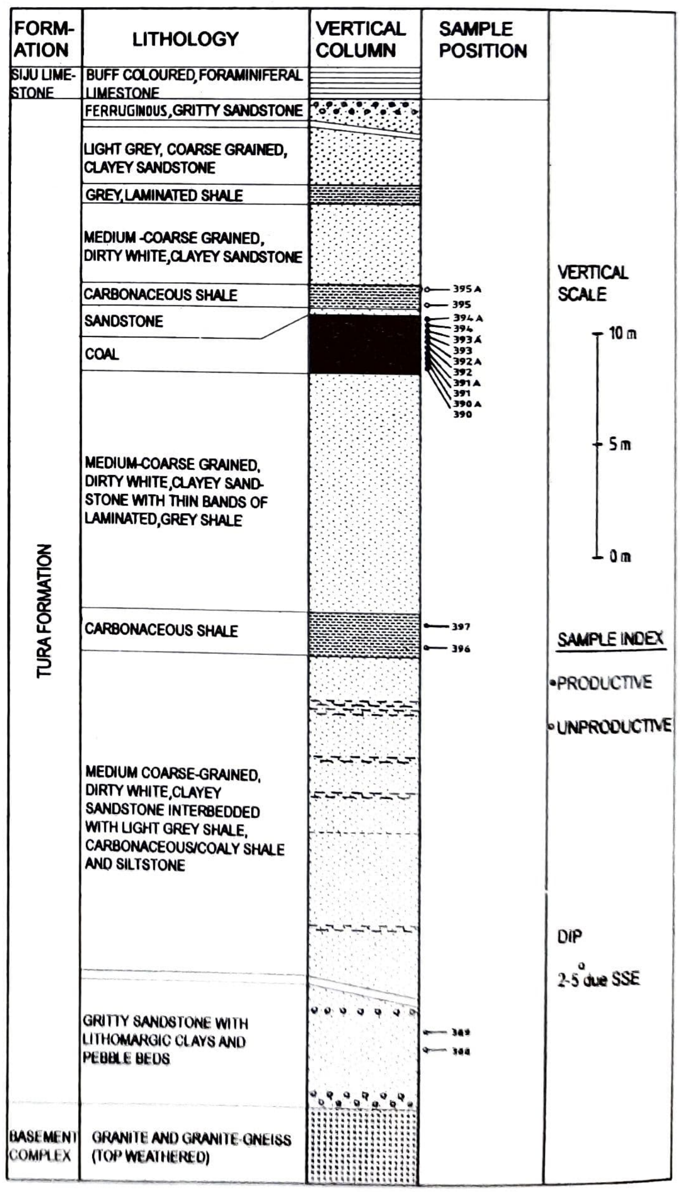
Text-fig. 1. Locality map.

Hills, Meghalaya (Text-fig. 1). Altogether, 16 samples were collected; two samples from near the base of the Tura Formation, two samples from the carbonaceous shale, 10 samples from the coal seam and two samples from the carbonaceous shale overlying the coal seam. Of these, 11 samples are palynologically productive. Samples from the coal seam were collected at a stratigraphic interval of about 0.25 m. During collection of samples, special care was taken to avoid contamination or mixing. The samples were simultaneously sealed after proper labelling and packing in polythene bags. The position of samples is shown in Text-fig. 2.

For recovery of palynofossils, about 25 grams of material was treated with HNO_3 followed by HF and HCl. The digestion period of samples varied from 2 to 4 days. The samples were then washed with water and treated with 3% KOH solution for 5 to 10 minutes. The material was finally washed with water through 400 mesh sieve. The final residue was dried on the coverglass in polyvinyl alcohol and mounted in canada balsam. All the slides and negatives of the figured specimens are stored in the Repository of the Birbal Sahni Institute of Palaeobotany, Lucknow.

GEOLOGICAL SETTING

The oldest geological formation exposed in the area is the Basement Complex of Precambrian age. It occupies a major part of Garo Hills and is made up of granite and granite gneisses. The upper part of this unit, northwest of Nongwal Bibra, is highly weathered and altered into kaolinitic clay. The basement is unconformably overlain by the Tura Formation. Sedimentation of this formation over the uneven surface of the basement gave rise to its patchy development at several places in the marginal part of the basin. The Tura Formation is composed of medium to coarse grained and gritty, clayey, dirty white, yellow and reddish, non-feldspathic, frequently current bedded, quartz-arenite type of sandstones intercalated with thin beds of grey shale, carbonaceous shale, lithomargic clay and siltstone. Three coal seams are generally found within the Tura Formation, of which the middle one (about 2.8 m thick) is workable. The base and top of the Tura Formation are marked by pebble beds indicating both, the lower and the upper, contacts unconformable. The formation is about 200 metres in thickness and dips 2 to 5 degrees SSE. The Tura Formation is overlain by the Siju Formation which is composed of hard, massive, yellow, foraminiferal, occasionally arenaceous limestone with thin marl beds. In the downdip direction, South of Siju, the Siju Formation is succeeded by the Rewak and younger formations. The stratigraphic suc-



Text-fig. 2. Litholog of the studied stratigraphic section showing position of samples.

cession in the Nongwal Bibra area is summarized in table 1.

Table-1

Age	Stratigraphic units	Lithology
Post-Middle Eocene	Post-Siju formations	–
Middle Eocene	Siju Formation	Hard, yellow, foraminiferal limestone and marl.
----------Unconformity----------		
Palaeocene-Early Eocene	Tura Formation	Medium to coarse-grained and gritty, clayey, dirty white, yellow and reddish sandstone intercalated with thin argillaceous beds and coal seams.
----------Unconformity----------		
Precambrian	Basement Complex	Granite and granite gneisses

PALYNOFLORAL ASSEMBLAGE

The palynoflora recorded here is populated by 30 genera and 48 species. Of these, 8 genera and 16 species belong to pteridophytic spores, 18 genera and 28 species to angiospermous pollen and 4 genera and 4 species to fungal remains. Besides, a few specimens of dinoflagellate cysts were also encountered. The assemblage is devoid of gymnospermous elements. The recorded palynotaxa are listed below. Taxa with an asterisk mark (*) have been described. Plate and figure numbers given in parentheses denote illustrations of the present paper.

Algae - Dinoflagellate cysts

Fungi - *Cucurbitariaceites bellus* Kar *et al.* 1972 (P1. 3, fig. 13), *Inapertisporites kedvesii* Elsik 1968 (P1. 3, figs 14, 15), *Multicellaesporites elsikii* Kar & Saxena 1976, *Pluricellaesporites planus* Trivedi & Varma 1973

Bryophyta - *Spore Type 1 (P1. 1, fig. 7, P1. 2, fig.1)

Pteridophyta

Cyatheaceae—*Cyathidites australis* Couper 1953, *C. minor* Couper 1953

Lycopodiaceae—*Lycopodiumsporites parvireticulatus* Sah & Dutta 1966 (P1. 1, figs 9, 13), *L. speciosus* Dutta & Sah 1970 (P1. 1, figs 6, 8), *L. palaeocenicus* Dutta & Sah 1970 (P1. 1, figs 10, 11), *Foveosporites triangulus* Dutta & Sah 1970, * *Foveosporites* sp. (Pl. 1, fig. 12), *Garotriletes assamicus* Singh & Singh 1978 (Pl. 1, figs 4,5)

Matoniaceae—*Dandotiaspora dilata* (Mathur) Sah *et al.* 1971 (P1. 1, fig. 1), *D. plicata* (Sah & Kar) Sah *et al.* 1971 (P1. 1, fig. 2), *D. telonata* Sah *et al.* 1971 (Pl. 1, fig. 3), * Spore Type 2 (P1. 2, fig. 5)

Osmundaceae—*Todisporites major* Couper 1958, *T. kutchensis* Sah & Kar 1969

Schizaeaceae—*Lygodiumsporites lakiensis* Sah & Kar 1969, *L. eocenicus* Dutta & Sah 1970 (Pl. 1, fig. 14), *Intrapunctisporis intrapunctis* Krutzsch 1959 (Pl. 1, fig. 15)

Angiospermae

Arecaceae—*Proxapertites assamicus* (Sah & Dutta) Singh 1975 (Pl. 3, fig. 3), *P. crassimurus* (Sah & Dutta) Singh 1975 (Pl. 2, figs. 10, 12), *P. operculatus* (van der Hamen) van der Hammen 1956, *P. reticulatus* (Kar & Saxena) Kar 1985 (Pl. 2, figs. 11, 13), *Arecipites intrapunctatus* Kar & Saxena 1981, *Palmaepollenites communis* Sah & Dutta 1966, *Palmidites plicatus* Singh in Sah & Singh 1974 (Pl. 2, fig.3), *P. assamicus* Singh 1977, *P. punctatus* Mehrotra 1983 (Pl. 2, fig. 4), **Palmidites* sp. (Pl. 2, fig. 7) *, *Neocouperipollis* sp. (Pl.2 fig. 2), *Longapertites ovalis* Mathur & Jain 1980 (Pl. 3, fig. 8)

Liliaceae—*Liliacidites giganticus* Singh 1977 (Pl.2, fig. 8)

Bombacaceae—*Lakiapollis ovatus* Venkatachala & Kar 1969 (Pl. 3, figs 7, 11), *Tricolporopollis decoris* Dutta & Sah 1970 (Pl. 2, fig. 1), *T. rubra* Dutta & Sah 1970 (Pl. 3, fig. 6), *T. matano madhensis* (Venkatachala & Kar) Tripathi & Singh 1985 (Pl. 3, fig. 2)

Braccicaceae—*Tricolpites minutus* Sah & Kar 1970 (Pl. 3, fig. 17), *Tricolpites gracilis* Salujha *et al.* 1972 (Pl. 3, fig. 9)

Rubiaceae—*Palaeocoprosmadites arcotense* Ramanujam 1966 (Pl. 3, fig. 16), *Granustephanocolpites cooksoniae* (Sah & Dutta) Saxena 1982 (Pl.3, figs. 5,6)

Rhizophoraceae—*Paleosantalaceaepites ellipticus* Sah & Kar 1970 (Pl. 3, fig. 12)

Myricaceae—*Myricipites harrisi-i* (Couper) Dutta & Sah 1970 (Pl. 3, fig. 4)

Oleaceae—*Tricolpites matanomadhensis* Saxena 1979 (Pl. 2, fig. 9)

Urticaceae—*Triporopollenites vimalii* Sah & Dutta 1966 (Pl. 3, fig. 10)

Meliaceae—*Meliapollis ramanujamii* Sah & Kar 1970, *Tetracolporites brevicolpus* Dutta & Sah 1970

Onagraceae—*Triangulorites bellus* (Sah & Kar) Kar 1985

Genus - *Foveosporites* Balme, 1957

***Foveosporites* sp.**
Pl. 1, fig. 12

Description- Spore subspheroidal. Size 65 μm. Trilete, rays distinct, reaching up to more than half of the spore radius. Exine 2 μm thick, foveolate, foveolae closely placed.

Comparison- All species described under the genus *Foveosporites* are triangular to subtriangular in shape. The present form is different from other species of this genus in being subspheroidal.

Spore Type -1
Pl.1, fig.7; Pl.2, fig.1

Description- Spores spheroidal in shape. Size 46-47 μm. Trilete, rays faintly discernible, extending upto half of the spore radius. Exine 1 μm thick, faintly reticulate, muri less than 1 μm thick, lumina about 2 μm across. Exine covered with thin perine which is broken at places.

Remarks- The indistinct trilete mark, the perine and faintly reticulate exine observed in this form indicate its affinity with a bryophytic spore.

Spore Type-2
Pl. 2, fig. 5

Description- Spore spheroidal. Size 90 μm. Trilete, rays distinct, extending up to half of the spore radius. Ray ends associated with globular thickenings. Exine 4 μm thick, provided with sparsely placed coni, coni up to 2 μm long, area between coni psilate.

Remarks- This form resembles *Dandotiaspora dilata* in possessing globular thickening at each ray end but differs from the latter in being larger in size and in possessing exine with sparsely placed coni.

Genus-*Palmidites* Couper, 1953

Palmidites sp.
Pl. 2, fig.7

Description- Pollen grain oval with one end broadly rounded and the other pointed, heteropolar. Size 63 x 50 μm. Monosulcate, sulcus extending from one end to the other, opening at both ends. Exine 1.5 μm thick, scabrate, provided with few coni, coni about 1 μm high and 1-3 μm wide at base.

Comparison- *Palmidites* sp. described here is different from other species of the genus in possessing scabrate exine with few spinules.

Genus-*Neocouperipollis* Kar & Kumar, 1987

Neocouperipollis sp.
Pl. 2, fig. 2

Description- Pollen grain oval. Size 48x30 μm. Monosulcate, sulcus long, extending from one end to the other, widely open. Exine less then 1 μm thick, echinate. Spines about 2 μm apart, 1.5-2 μm long, sharply tapering at ends, interspinal area smooth.

Comparison- The present form compares with *Neocouperipollis achinatus* (Sah & Kar) Kar & Kumar (1987) in size and shape but differs from the latter in having more number of spines.

QUANTITATIVE ANALYSIS

For quantitative analysis of the assemblage, 200 or more specimens per sample were counted and from such counts percentage frequency of each palynotaxon was calculated (Text-fig. 3). The distribution and frequency of palynotaxa show that the studied stratigraphical sequence is divisible into two palynozones. The lower palynozone is dominated by angiospermous pollen (79%) whereas the upper palynozone has dominance of pteridophytic spores (76 %).

Lower Palynozone– This palynozone is encountered in the carbonaceous shale bed and contains 7.5 per cent of pteridophytic spores, 79 per cent of angiospermous pollen and 13.5 per cent of fungal remains. The main taxa of pteridophytic spores are: *Dandotiaspora dilata* (3.6%) and *Todisporites kutchensis* (1.4%). Other pteridophytic spore taxa recorded are: *Lygodiumsporites eocenicus* (1%), *Lycopodiumsporites speciosus* (1%), *Dandotiaspora telonata* and *Foveosporites* sp.

The angiospermous pollen constitute the bulk of the assemblage with *Proxapertites* spp. (17.6%), *Tricol-*

Plate-1

(All photomicrographs are enlarged *ca.* x 700. Coordinates of the specimens in slides refer to the stage of Leitz Laborlux microscope no. 513547).

1. *Dandotiaspora dilata* (Mathur) Sah *et al.*, slide no. 11629/4 (54.5 x 101.1).
2. *Dandotiaspora plicata* (Sah & Kar) Sah *et al.*, slide no. 11631/6 (33.9x110.5).
3. *Dandotiaspora telonata* Sah *et al.*, slide no. 11633/6 (36.4x108.3).
4-5. *Garotriletes assamicus* Singh & Singh, slide nos. 11629/3 (52.3x105.5); 11629/5 (54.1x105.3).
6,8. *Lycopodiumsporites speciosus* Dutta & Sah, slide nos. 11636/12 (42.3x119.7); 11638/11 (51.8x100.9).
7. Spore Type-1, slide no. 11644/12 (60.6x100.5).
9, 13. *Lycopodiumsporites parvireticulatus* Sah & Dutta, slide nos. 11639/9 (55.5x100.5); 11632/13 (47.2x100.4).
10-11. *Lycopodiumsporites palaeocenicus* Dutta & Sah, slide nos. 11631/2 (71.4x115.9); 11629/8 (52.1 x 104.4).
12. *Foveosporites* sp., slide no. 11638/2 (71.1x100.8).
14. *Lygodiumsporites eocenicus* Dutta & Sah, slide no. 11638/4 (48.3x97.4).
15. *Intrapunctisporis intrapunctis* Krutzsch, slide no. 11629/7 (50.1x105.5).

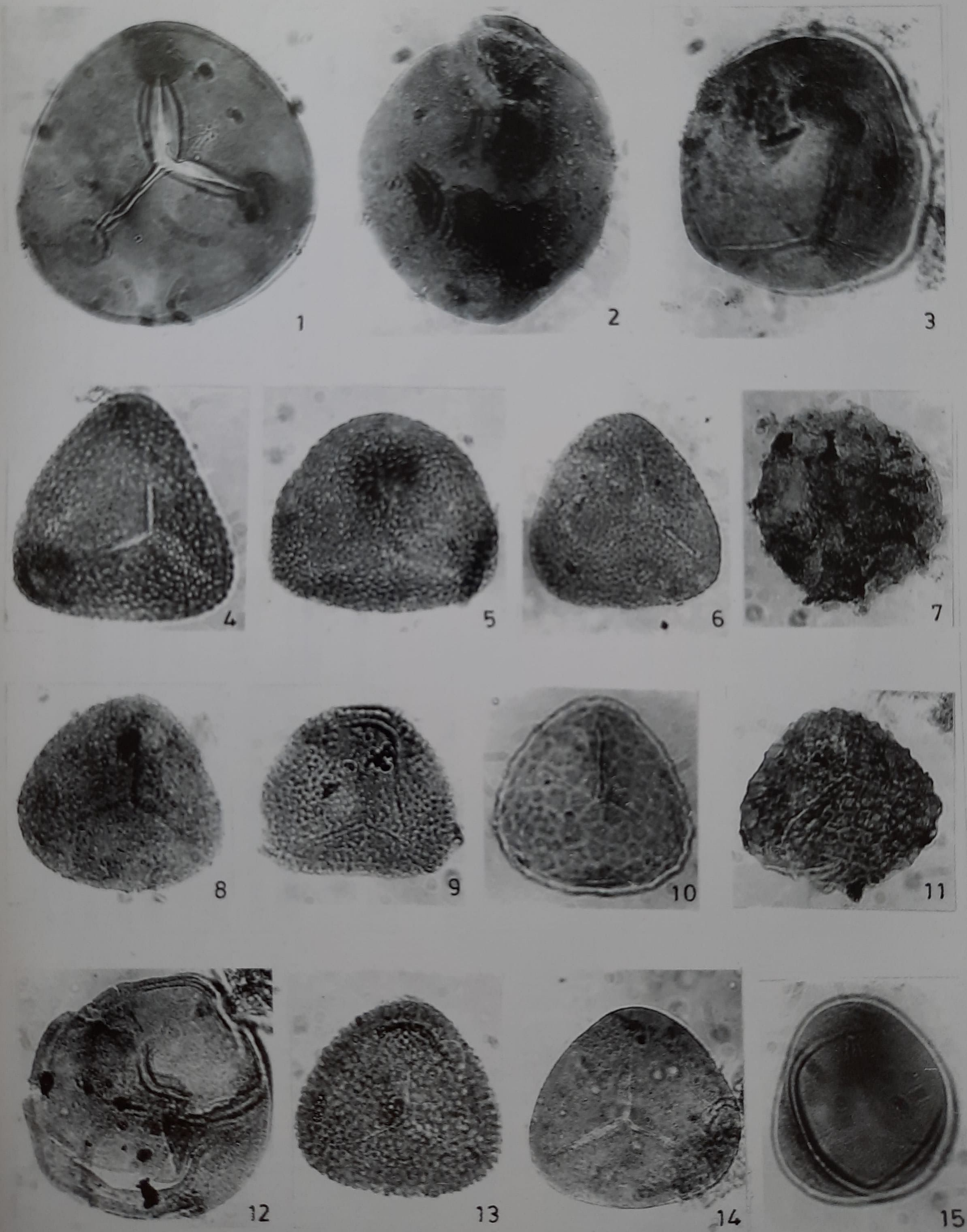
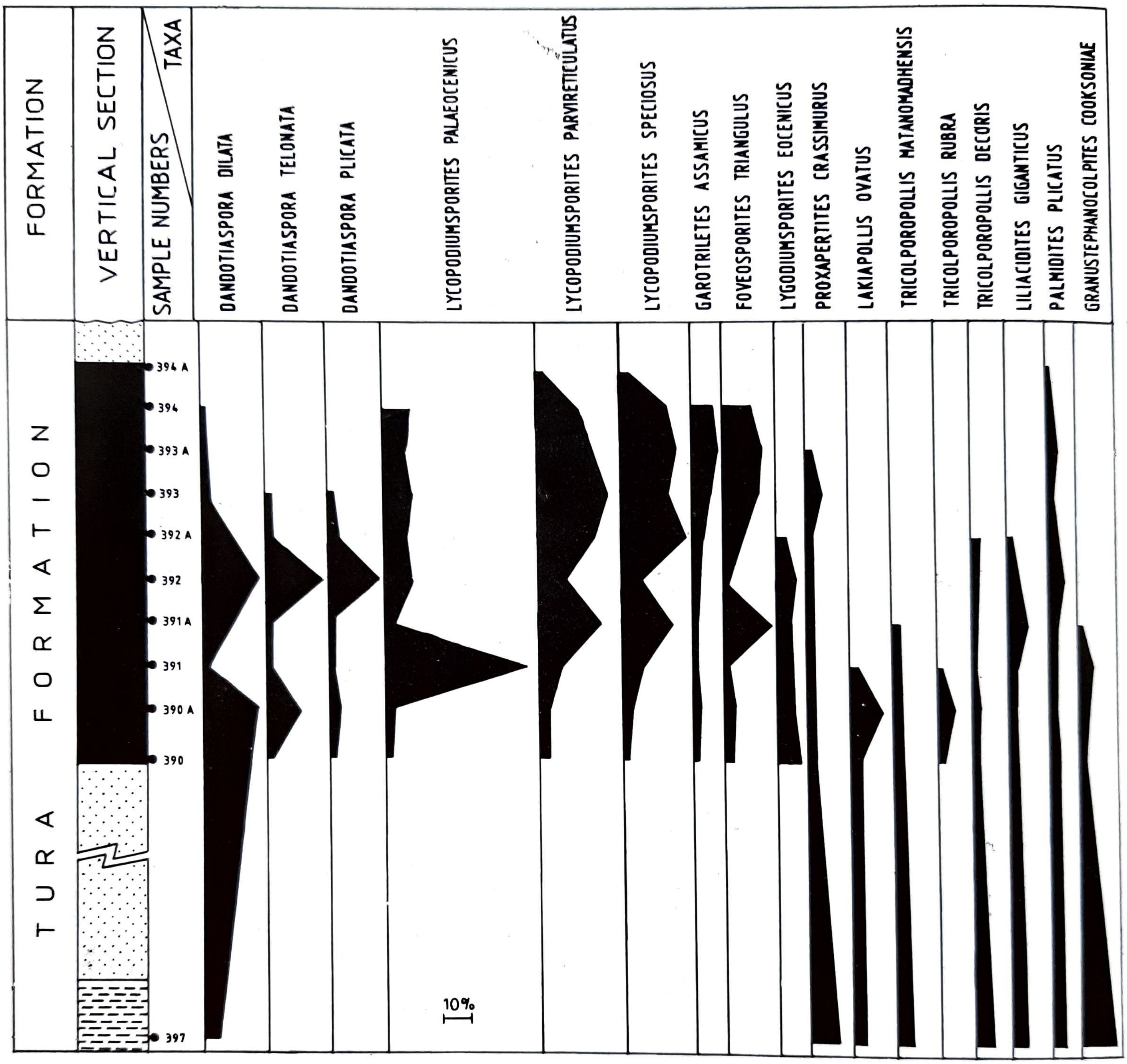


Plate 1



Text-fig. 3. Vertical distribution of the significant palynotaxa.

poropollis spp. (16%), *Granustephanocolpites cooksoniae* (12.7%), *Palmidites* spp. (8.3%) and *Tricolpites matanomadhensis* (5.5%). *Proxapertites* is represented by 4 species, of these, *P. crassimurus* (9.4%) and *P. reticulatus* (7.4%) are abundant whereas *P. operculatus* and *P. assamicus* are rare. The two species of *Tricolporopollis*, viz.,

Plate-2

1. Spore Type-1, slide no. 11644/13 (51.2x99.8).
2. *Neocouperipollis* sp., slide no. 11649/4 (60.5x105.5).
3. *Palmidites plicatus* Singh *in* Sah & Singh, slide no. 11627/6 (63.8x115.5).
4. *Palmidites punctatus* Mehrotra, slide no. 11628/6 (55.3x105.7).
5. Spore Type-2, slide no.11645/16 (57.2x101.1).
6. *Tricolporopollis decoris* Dutta & Sah, slide no. 11629/1 (42.5x96.3).
7. *Palmidites* sp., slide no. 11651/1 (70.8x102.1).
8. *Liliacidites giganticus* Singh, slide no. 11638/12 (50.5x109.5).
9. *Tricolpites matanomadhensis* Saxena, slide no. 11641/1 (11.3x73.1).

10, 12. *Proxapertites crassimurus* (Sah & Dutta) Singh, slide nos. 11642/4 (47.7x115.2); 11648/1 (79.1x115.5).

11, 13. *Proxapertites reticulatus* (Kar & Saxena) Kar, slide nos. 11646/5 (42.3x115.5); 11647/6 (68.2x116.5).

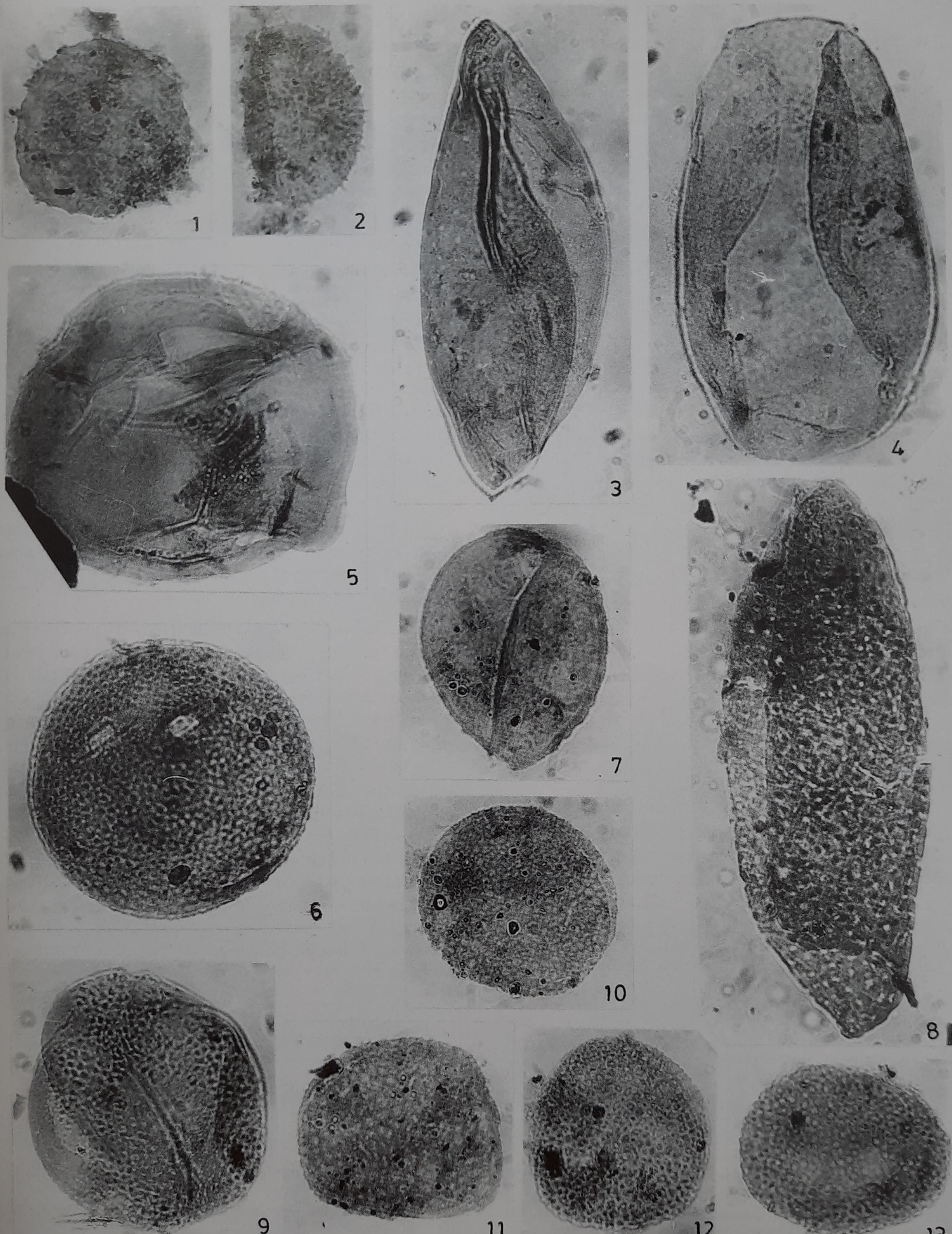


Plate 2

T. matanomadhensis and *T. decoris* constitute 11.6 per cent and 4.4 per cent of the assemblage respectively. Other commonly occurring taxa with frequencies between 2 and 5 per cent (in their relative order of abundance are: *Liliacidites giganticus, Paleosantalaceaepites ellipticus, Longapertites ovalis* and *Lakiapollis ovatus*. The rarely occurring taxa (less than 2%) are: *Myricipites harrisii, Palmaepollenites communis, Arecipites intrapunctatus, Meliapollis ramanujamii* and *Triangulorites bellus*. Amongst the fungal remains, *Inapertisporites kedvesii* (6.3%), *Cucurbitariaceites bellus* (4.3%) and *Pluricellaesporites planus* (2.5%) are represented.

Upper Palynozone- This palynozone is encountered in the middle coal seam of the Tura Formation and is marked by the predominance of pteridophytic spores (76%) and subordinate representation of angiospermous pollen (15%) and fungal remains (9%). The most dominant taxa of pteridophytic spores are: *Lycopodiumsporites* spp. (39.7%) and *Dandotiaspora* spp. (17%) followed by *Foveosporites triangulus* (7%) and *Todisporites* spp. (5%). Other pteridophytic spore taxa present in the assemblage are: *Lygodiumsporites* spp. (4.5%), *Garotriletes assamicus* (4%) and *Intrapunctisporis intrapunctis* (1.8%). *Lycopodiumsporites*, occurring throughout the palynozone, is represented by three species, viz., *L. parvireticulatus, L. speciosus* and *L. palaeocenicus* which constitute 15.5 per cent, 12.7 per cent and 11.5 per cent of the assemblage respectively. The bulk of the spores of *Dandotiaspora* is represented by *D. dilata* (8.5%) whereas *D. telonata* and *D. plicata* constitute 4 per cent and 4.5 per cent respectively.

The angiospermous pollen, constituting 15 per cent of the assemblage, are better represented in the basal part and their frequency decreases significantly in the rest of the palynozone. *Lakiapollis ovatus, Tricolporopollis* spp. and *Granustephanocolpites cooksoniae* are mainly confined to the basal part of this palynozone. Other angiospermous pollen are sporadically represented with average frequency less than 2 per cent and not exceeding 8 per cent in individual sample.

Amongst the fungal remains, *Inapertisporites kedvesii* constitutes the main element (4.7%). Other fungal taxa, viz., *Cucurbitariaceites bellus, Multicellaesporites* sp. and *Pluricellaesporites planus* are represented by less than 2 per cent each.

PALYNOFLORAL COMPARISON AND AGE

Comparison with Early Palaeogene palynofloras of north-eastern India

In north-eastern India, palynostratigraphic studies on the Early Palaeogene sediments have been carried out on the Tura Formation in Garo Hills (Sah & Singh, 1974), Cherra Formation and Lakadong Sandstone in Khasi Hills (Dutta & Sah, 1970, Sah & Dutta 1974, Kar & Kumar, 1986), Therria Formation in Jaintia Hills (Tripathi & Singh, 1984) and Mikir Formation in North Cachar Hills (Mehrotra, 1981). The palynofloras recorded from these formations have been compared with the present assemblage which reveals that a number of palynotaxa of the present assemblage have also been recorded from the various formations of Meghalaya and Assam.

Sah and Singh (1974) identified four palynozones in the Tura Formation of Garo Hills, Meghalaya. Of these, the lower two palynozones, viz., *Assamialetes emendatus* Cenozone and *Dandotiaspora telonata* Cenozone exhibit the presence of many palynotaxa which are also represented in the present assemblage. Forms common between the Lower Palynozone of the present study and *Assamialetes emendatus* Cenozone (Sah & Singh, 1974) are: *Dandotiaspora telonata, D. plicata, Lycopodiumsporites speciosus, Proxapertites assamicus, P. crassimurus, Palmaepollenites communis, Granustephanocolpites cooksoniae* and *Tricolporopollis matanomadhensis*. In both of these assemblages *Proxapertites* spp., *Tricolporopollis matanomadhensis* and *Granustephanocolpites cooksoniae* are recorded in high frequencies. Palynotaxa common

Plate-3

1. *Tricolporopollis rubra* Dutta & Sah, slide no. 11637/8 (57.1x 110.4).
2. *Tricolporopollis matanomadhensis* (Venkatachala & Kar) Tripathi & Singh, slide no. 11629/2 (48.9x101.5).
3. *Proxapertites assamicus* (Sah & Dutta) Singh, slide no. 11646/6 (31.3x115.9).
4. *Myricipites harrisii* (Couper) Dutta & Sah, slide no. 11630/1 (60.7x117.8).
5-6. *Granustephanocolpites cooksoniae* (Sah & Dutta) Saxena, slide nos. 11651/2 (63.3x105.2); 11629/3 (55.9x113.5).
7,11. *Lakiapollis ovatus* Venkatachala & Kar, slide nos. 11627/10 (62.3x116.6); 11627/7 (70.8x109.9).
8. *Longapertites ovalis* Mathur & Jain, slide no. 11650/1 (62.5x104.5).
9. *Tricolpites gracilis* Salujha *et al.*, slide no. 11632/4 (60.2x112.3).
10. *Triporopollenites vimalii* Sah & Dutta, slide no. 11651/3 (67.7x99.2).
12. *Paleosantalaceaepites ellipticus* Sah & Kar, slide no. 11635/8 (69.8x111.6).
13. *Cucurbitariaceites bellus* Kar *et al.*, slide no. 11643/2 (67.4x115.8).
14-15. *Inapertisporites kedvesii* Elsik, slide nos. 11640/6 (71.1x105.4); 11641/15 (56.7x103.1).
16. *Palaeocoprosmadites arcotense* Ramanujam, slide no. 11643/14 (45.8x109.5).
17. *Tricolpites minutus* Sah & Kar, slide no. 11633/6 (62.1x113.6).

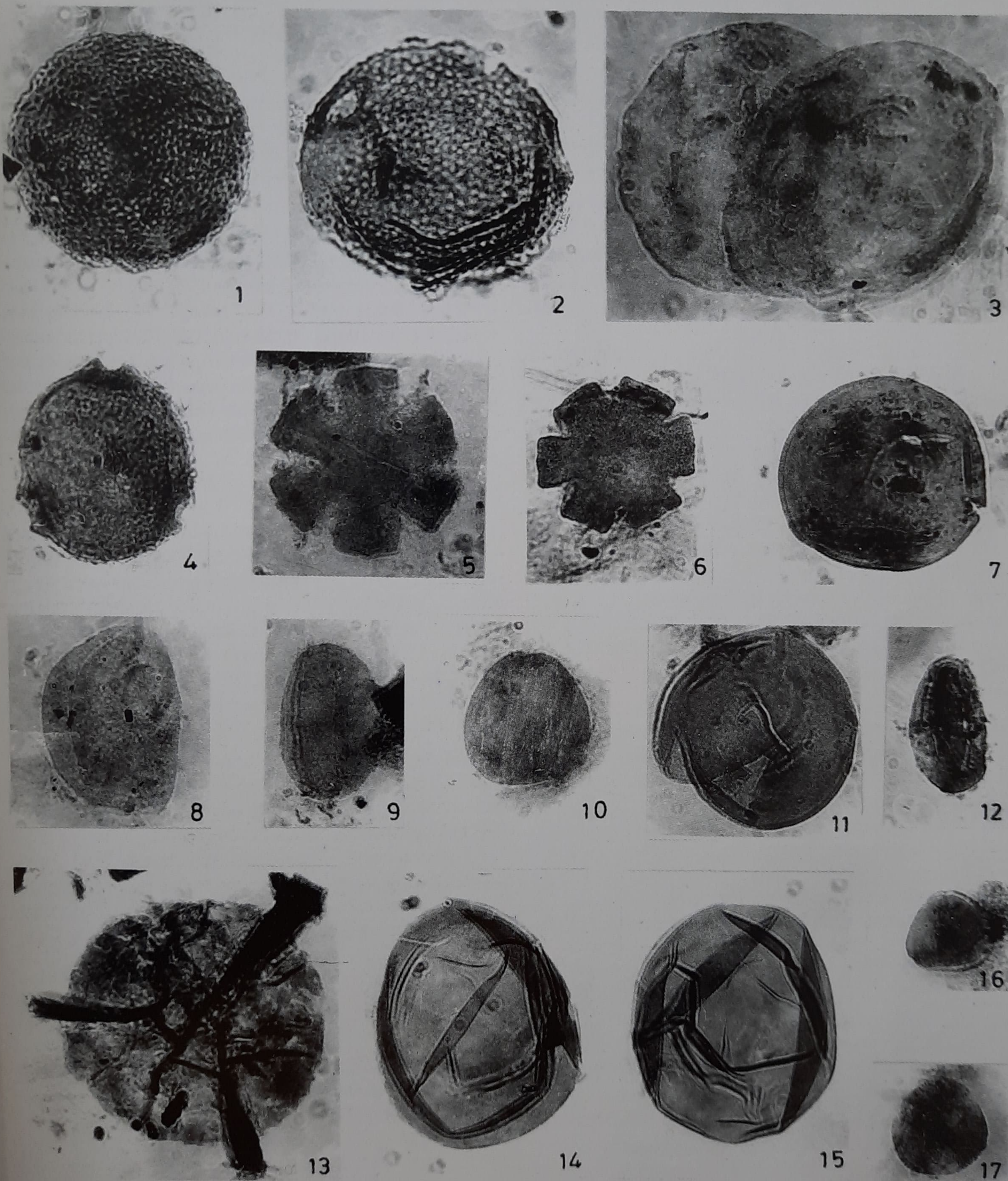


Plate 3

between the *Dandotiaspora telonata* Cenozone (Sah & Singh 1974) and the Upper Palynozone of the present study are : *Dandotiaspora telonata, D. plicata, Lycopodiumsporites palaeocenicus, L. speciosus, Proxapertites assamicus, Palmaepollenites communis, Granustephanocolpites cooksoniae* and *Triporopollenites vimalii*. High frequency of *Dandotiaspora telonata, D. dilata, Lycopodiumsporites palaeocenicus* and *L. speciosus* is noticed in both of these assemblages.

Following palynotaxa recorded from the lowermost palynozone of the Cherra Formation of Khasi Hills, Meghalaya, viz., *Proxapertites crassimurus* Cenozone (Sah & Dutta, 1974) are also present in the Lower Palynozone of the present study: *Lycopodiumsporites palaeocenicus, Palmaepollenites communis, Proxapertites crassimurus, Tricolporopollis matanomadhensis, Granustephanocolpites cooksoniae* and *Dandotiaspora* spp. The dominant elements in these two assemblages are: *Dandotiaspora* spp., *Lycopodiumsporites palaeocenicus, Proxapertites crassimurus* and *Tricolporopollis matanomadhensis*. Taxa common between the Upper Palynozone of the present study and the *Araliaceoipollenites reticulatus* Cenozone (Sah & Dutta, 1974) of the Cherra Formation are: *Lycopodiumsporites palaeocenicus, Dandotiaspora* spp., *Proxapertites crassimurus, Palmaepollenites communis, Tricolporopollis matanomadhensis* and *Granustephanocolpites cooksoniae*. High frequency of *Lycopodiumsporites palaeocenicus* and *Granustephanocolpites cooksoniae* has been noticed in both of these assemblages.

Kar and Kumar (1986) established two cenozones in Lakadong Sandstone of Khasi Hills, Meghalaya. These cenozones are: *Lycopodiumsporites speciosus* Cenozone and *Kielmeyerapollenites syncolporatus* Cenozone. Palynotaxa common between these two palynozones and the present assemblage are: *Dandotiaspora* spp., *Lygodiumsporites lakiensis, Palmidites plicatus* and *Tricolporopollis matanomadhensis*. Besides, Kar and Kumar (*l.c.*) also described many palynotaxa which are not recorded in the present assemblage. In fact, the Lakadong assemblage is younger in age.

Many palynotaxa registering their presence in *Lygodiumsporites psilatus* Cenozone (Tripathi & Singh, 1984) of the Therria Formation in Jaintia Hills, Meghalaya have also been recorded in the present assemblage. These are: *Lygodiumsporites* spp., *Dandotiaspora* spp., *Proxapertites* spp., *Liliacidites giganticus, Tricolporopollis rubra, T. matanomadhensis* and *Palmaepollenites communis*.

Palynotaxa common between the Lower Palynozone of the present study and *Assamialetes macroluminus* Cenozone (Mehrotra, 1981) of the Mikir Formation, Assam are: *Lycopodiumsporites palaeocenicus, Dandotiaspora dilata, D. telonata* and *Proxapertites crassimurus*. The common elements in the present Upper Palynozone and the *Dandotiaspora dilata* Cenozone (Mehrotra, 1981) of the Mikir Formation, Assam are: *Dandotiaspora dilata, D. telonata* and *Proxapertites crassimurus*.

Comparison with other Early Palaeogene assemblages of India

Taxa common between *Dandotiaspora dilata* Cenozone (Saxena, 1981) of the Matanomadh Formation, Kutch and Upper Palynozone of the present study are: *Dandotiaspora* spp., *Todisporites major, Lygodiumsporites eocenicus, L. lakiensis, Proxapertites assamicus, Tricolporopollis matanomadhensis, Lakiapollis ovatus, Triangulorites bellus* and *Paleosantalaceaepites ellipticus*. Both of these palynozones show high frequency of *Dandotiaspora dilata*.

Palynofossils recorded from the *Proxapertites operculatus* Cenozone of the Jalangi Formation of Bengal Basin (Baksi & Deb, 1980) are also noticed in the Lower Palynozone of the present assemblage. These are: *Lycopodiumsporites palaeocenicus, Proxapertites operculatus, P. assamicus* and *Myricipites harrisii*. Palynotaxa common between the Upper Palynozone of the present study and *Proxapertites cursus* Cenozone (Baksi & Deb,

Table-2

Tura Formation, Garo Hills, Meghalaya	Cherra Formation, Khasi Hills, Meghalaya	Therria Formation, Jaintia Hills, Meghalaya	Mikir Formation, North Cachar Hills, Assam	Subsurface Palaeocene sediments, Bengal Basin	Matanomadh Formation, Kutch, Gujarat	Present study
Dandotiaspora telonata Cenozone	*Araliaceoipollenites reticulatus* Cenozone		*Dandotiaspora dilata* Cenozone	*Monocolpopollenites eocenicus* Cenozone	*Dandotiaspora dilata* Cenozone	Upper Palyno zone
----------	----------	*Lygodiumsporites psilatus* Cenozone	----------	----------	----------	----------
Assamialetes emendatus Cenozone	*Proxapertites crassimurus* Cenozone		*Assamialetes macroluminus* Cenozone	*Proxapertites cursus* Cenozone	–	Lower Palynozone

1980) of the Jalangi Formation of Bengal Basin are: *Lycopodiumsporites palaeocenicus*, *Dandotiaspora dilata*, *Proxapertites operculatus* and *Granustephanocolpites cooksoniae*.

It has been observed that the lower and upper palynozones of the present study are palynologically correlatable with the SP. 2 *Proxapertites* Zone and SP. 3 *Dandotiaspora* Zone (Singh & Dogra, 1988) respectively.

From the foregoing discussion it becomes clear that significant number of palynotaxa are common between the present assemblage and those recorded from parts of the Tura, Cherra, Therria and Mikir formations of North eastern India, Matanomadh Formation of Kutch and Jalangi Formation of Bengal Basin. The palynofloral comparison therefore indicates homotaxiality of the Lower Palynozone with *Assamialetes emendatus* Cenozone of the Tura Formation (Garo Hills), *Proxapertites crassimurus* Cenozone of the Cherra Formation (Khasi Hills), lower part of the *Lygodiumsporites psilatus* Cenozone of the Therria Formation (Jaintia Hills), *Assamialetes macroluminus* Cenozone of the Mikir Formation (North Cachar Hills) and *Proxapertites cursus* Cenozone of Bengal Basin and of the Upper Palynozone with *Dandotiaspora telonata* Cenozone of the Tura Formation (Garo Hills), lower part of the *Araliaceoipollenites reticulatus* Cenozone of the Cherra Formation (Khasi Hills), upper part of the *Lygodiumsporites psilatus* Cenozone of the Therria Formation (Jaintia Hills) and the *Dandotiaspora dilata* Cenozone of the Matanomadh Formation (Kutch) and Mikir Formation (North Cachar Hills). Since all these cenozones have been assigned a Palaeocene age (Sah & Dutta, 1974; Sah & Singh 1974; Tripathi & Singh, 1984; Mehrotra, 1981), the stratigraphic sequence under study is also assigned a Palaeocene age (Table-2).

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

Qualitative and quantitative analyses of the palynoflora make it possible to provide information concerning palaeoclimate and environment of deposition which prevailed during the sedimentation of the Tura Formation. It is an accepted fact that the ecological requirements of the past floral elements had been similar to those of their present day counterparts. Their present day distribution is therefore very important in inferring palaeoclimate.

The Tura assemblage is rich and diversified. It contains dinoflagellate cysts, fungal remains, pteridophytic spores and angiospermous pollen. In the Lower Palynozone, the angiospermous pollen are the dominant constituents whereas in the Upper Palynozone pteridophytic spores dominate. The fungal remains occur throughout the sequence.

Majority of the families represented in the present palynoflora have their present day distribution in tropical-subtropical regions. These families are: Cyatheaceae, Matoniaceae, Schizaeaceae, Arecaceae, Bombacaceae, Rubiaceae, Rhizophoraceae and Meliaceae. Oleaceae grows in tropical to warm temperate regions. Other families represented in the assemblage are cosmopolitan in distribution and none is exclusively temperate. The present day distribution of the various families is given in table-3.

Table-3

Tropical-subtropical	Cosmopolitan	Habitat of cosmopolitan families
Cyatheaceae	Osmundaceae	Shady places or swamps
Matoniaceae	Lycopodiaceae	Humid shady habitat
Schizaeaceae	Liliaceae	-
Arecaceae	Braccicaceae	Grows in diverse conditions
Bombacaceae	Myricaceae	-
Rubiaceae	Oleaceae	Chiefly tropical-subtropical
Rhizophoraceae	Urticaceae	-
Meliaceae	Onagraceae	-

The prevalence of tropical-subtropical conditions is evident from the composition of the assemblage and the present day distribution of their nearest extant relatives. Pollen belonging to Oleaceae and Bombacaceae suggest high precipitation. Occurrence of fungal remains and pteridophytic spores in good amount also indicates warm-humid climate. It may therefore be concluded that the studied area enjoyed a tropical (warm-humid) climate with plenty of rainfall throughout the sedimentation period.

The assemblage contains a mixture of land, coastal, mangrove and marine elements. The pteridophytic spores and majority of angiospermous pollen represent land derived elements. Pollen related to Arecaceae (*Proxapertites* spp., *Palmidites* spp., *Arecipites intrapunctatus*, *Palmaepollenites communis*, *Longapertites ovalis* and *Neocouperipollis* sp.) represent coastal elements. Pollen assignable to Rhizophoraceae (*Paleosantalaceaepites ellipticus*) represent shore line vegetation. These elements indicate that the area of deposition was in close proximity to the shore line. The shallow marine conditions are indicated by the occurrence of a few specimens of dinoflagellate cysts. On the basis of the occurrence of such elements it is reasonable to infer a shallow marine environment of deposition. The coastal vegetation was represented by mangroves followed by arecaceous plants. Further landwards, there should have been a zone of luxuriant vegetation of wet evergreen forests and pteridophytes.

CONCLUSIONS

From the foregoing discussion, the following conclusions have been derived.

1. The studied stratigraphic sequence is clearly divisible into two palynozones. The Lower Palynozone is dominated by angiospermous pollen (79%) followed by fungal remains (13.5%) and pteridophytic spores (7.5%) whereas the Upper Palynozone is dominated by pteridophytic spores (76%) followed by angiospermous pollen (15%) and fungal remains (9%).
2. The palynoflora suggests prevalence of tropical-subtropical climate and luxuriant growth of wet evergreen forest with mangrove elements in the vicinity of the area.
3. The palynofloral elements indicate a near-shore, shallow marine environment of deposition.
4. The studied stratigraphic sequence is correlatable with parts of the Tura Formation (Garo Hills), Cherra Formation (Khasi Hills), Therria Formation (Jaintia Hills), Mikir Formation (North Cachar Hills), subsurface Palaeocene sediments of Bengal Basin and Matanomadh Formation (Kutch) and has been assigned a Palaeocene age.

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