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Palynological investigation of the Tura Formation (Early Eocene) exposed along the Tura-Dalu Road, West Garo Hills, Meghalaya, India

S.K.M. TRIPATHI, R.K. SAXENA AND VANDANA PRASAD

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.

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ABSTRACT

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The present paper deals with the palynological study of the Tura Formation exposed along the Tura-Dalu Road in West Garo Hills, Meghalaya. The recovered palynoflora is represented by dinoflagellate cysts, fungal remains, pteridophytic spores and angiosperm pollen. The assemblage is dominated by angiosperm pollen assignable to the families Arecaceae, Liliaceae, Oleaceae, Bombacaceae, Caesalpiniaceae, Mimosaceae, Urticaceae and Alangiaceae. Three new species of angiosperm pollen viz., *Retitricolpites singhii, Lanagiopollis meghalayaensis* and *Lanagiopollis subglobosus* have been proposed. Pteridophytic spores, which constitute the subdominant element of the assemblage, are assignable to the families Osmundaceae, Matoniaceae, Polypodiaceae, Schizaeaceae and Parkeriaceae. Based on the quantitative analysis of the palynoflora, the studied sequence has been divided into three formal palynological assemblage zones. In ascending order, these are: (1) *Lanagiopollis* spp. Assemblage-zone (2) *Palmidites* spp. Assemblage-zone and (3) *Tricolporopilites* spp. Assemblage-zone. A comparison of the present assemblage with other Palaeogene assemblages of India indicates that it correlates well with those known from the upper part of the Mikir Formation, North Cachar Hills, Assam; the Prang Formation, Jaintia Hills, Meghalaya; the Naredi Formation, Kutch; and the Rajpardi Lignite, Gujarat. Since these formations are of Early Eocene age, the studied sequence is also dated as Early Eocene. Most families represented in the assemblage are presently distributed in tropical to subtropical regions, indicating a similar climate during the deposition of Tura sediments. The presence of coastal elements and dinoflagellate cysts in the assemblage is indicative of a littoral depositional environment.

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

भारत के मेघालय प्रान्त की पश्चिमी गारो पर्वतश्रेणियों में तूरा-डालू मार्ग के आस-पास अनावरित टूरा शैलसमूह (प्रारंभिक इओसीन) का परागाणविक विश्लेषण

सूर्यकांतमणि त्रिपाठी, रमेश कुमार सक्सेना एवं वन्दना प्रसाद

सारांश

प्रस्तुत शोध पत्र में मेघालय की पश्चिमी गारो पर्वतश्रेणियों में टूरा-डालू मार्ग के आस-पास अनावरित प्रारंभिक इओसीन युगीन टूरा शैलसमूह का परागाणविक विश्लेषण किया गया है. परागाणुवनस्पतिजात घूर्णीकशाभ पुटियों, कवकीय अवशेषों, टेरिडोफ़ाइटी बीजाणुओं तथा आवृतबीजी परागकणों द्वारा निर्मित है. समुच्चय में अर्टीकेसी, लिलिएसी, ओलिएसी,

बॉम्बेकेसी, सीजेलपिनेसी, मिमोसेसी, अर्टीकेसी तथा एलैंजिएसी के कुलों से सम्बन्धित आवृतबीजी परागकणों की प्रमुखता है. आवृतबीजी परागकणों की *रेटिट्राइकोलपाइटीज़ सिंहाइ, लैनेजियोपोलिस मेघालयेन्सिस* एवं *लैनेजियोपोलिस मेघालयेन्सिस* एवं *लैनेजियोपोलिस सबग्लोबॉसस* नामक तीन नई प्रजातियाँ प्रस्तावित की गई हैं. टेरिडोफ़ाइटी बीजाणु, जो समुच्चय के दूसरे प्रमुख तत्व हैं, में ऑसमण्डेसी, मैटोनिएसी, पॉलीपोडिएसी, शीजिएसी तथा पार्केरिएसी के कुलों की प्रचुरता है. परागाणुवनस्पतिजात के गुणात्मक विश्लेषण के आधार पर अध्ययन के अनुक्रम को तीन प्रमुख भागों में विभक्त किया गया है. आरोही क्रम में इनके नाम क्रमशः *लैनेजियोपोलिस* प्रजाति *पॉमीडाइटीज़* समुच्चय मण्डल एवं *ट्राइकोलपोरोपाइलाइटीज़* प्रजातियों के समुच्चय मण्डल हैं. वर्तमान समुच्चय की अन्य पेलियोजीन समुच्चयों के साथ तुलना करने पर संकेतित होता है कि यह असम की उत्तरी कछार पहाड़ियों के अन्तर्गत मिकिर शैलसमूह के ऊपरी भाग, मेघालय की जयन्तिया पहाड़ियों में स्थित प्रांग शैलसमूह, नरेदी शैलसमूह तथा गुजरात के कच्छ एवं राजपरदी लगुडांगार से प्राप्त समुच्चयों के साथ सहसम्बन्धित है. चूंकि ये शैलसमूह प्रारंभिक इओसीन आयु के हैं, अतः अध्ययन किए गये अनुक्रम को प्रारंभिक इओसीन आयु का माना गया है. समुच्चय में निरूपित अधिकांश कुल वर्तमान में उष्णकटिबन्धीय से उपोष्णकटिबन्धीय क्षेत्रों के बीच वितरित है. टूरा अवसादों से इन अवसादों के निक्षेपण के दौरान समरूप जलवायु के होने का संकेत मिलता है। समुच्चय में समुद्रतटीय तत्वों तथा घूर्णीकशाभ पुटियों की उपस्थिति से ताजे समुद्री प्रभाव युक्त समुद्र तटीय निक्षेपणीय पर्यावरण संकेतित होता है.

संकेत शब्द—परागाणुविज्ञान, टूरा शैलसमूह, प्रारंभिक इओसीन, गारो पर्वतश्रेणियाँ, मेघालय (भारत).

INTRODUCTION

A thick sedimentary sequence, unconformably overlying the Precambrian Basement Complex and ranging in age from Palaeocene to Recent, occupies the southern portion of the Garo Hills, Meghalaya. The basal lithostratigraphic unit of this sequence is represented by the Tura Formation (Palaeocene-Early Eocene). Fox (in Heron, 1937) named these sediments as 'Tura Sandstone' after Tura (Lat. 25° 31' 00" N: Long. 90° 13' 30" E), the headquarters of the West Garo Hills District, Meghalaya, south of which this unit is fairly well developed. Bedford (1842, in Medlicott, 1868), for the first time, reported the occurrence of coal in the Tura sandstones.

The age and relative stratigraphic position of the Tura Formation have remained disputed as divergent views have been expressed by various workers. The earliest reference to the geology of Meghalaya was by Oldham (1863), who assigned a Late Cretaceous age to the Tura Formation. Medlicott (1868, 1874) and Raja Rao (1981) published information regarding the geology of the Garo Hills and the coal deposits found in the Tura Formation. LaTouche (1882, 1887) studied the geology of Darranggiri Coalfield and other areas in the Garo Hills. Evans (1932) included the Tura Sandstone into the Therria Stage in his classification of the Tertiary sediments in northeastern India. Publications by the Director General, Geological Survey of India (1974) and Murthy *et al.* (1976) did not recognize the Tura Formation as a separate unit, instead considered it to be the basal part of the sandstone/limestone alternation of the Shella Formation. Chakraborty (1972) and Chakraborty and Baksi (1972), proposed a lithostratigraphic classification of the Cretaceous-Tertiary sequence of the Garo Hills and western part of Khasi Hills and included the entire sandstone sequence, underlying the Siju Formation, into the Tura Formation. Other significant contributions on the age and the stratigraphic position of the Tura Formation, and its relationship with the contemporaneous units of northeastern India, have been published by Pinfold (1919), Ghosh (1954), Biswas (1962), Sah (1974), Sah and Singh (1974) and Singh (1982).

Palynological studies on the Tura Formation were initiated by Biswas (1962) and were continued by Chatterjee and Ghosh (1962), Banerjee (1964), Ghosh (1969), Salujha *et al.* (1972), Kar *et al.* (1972), Sah and Singh (1974), Singh *et al.* (1976), Singh (1977a, b), Singh and Singh (1978) and Saxena *et al.* (1996). The palynostratigraphic work on the Tura Formation has been reviewed by Sah and Singh (1977), Singh (1982), Sah and Mehrotra (1988) and Saxena (1988). These authors also attempted to correlate the Tura Formation with other contemporaneous stratigraphic units of Meghalaya and Assam. The present work is yet another contribution on the palynology of the Tura Formation with the objectives to study the palynoflora, to interpret the depositional environment and to determine the biostratigraphic potential of the palynofossils.

STRATIGRAPHICAL SETTING

The oldest stratigraphic unit exposed in the area is the Precambrian Basement Complex, which is made up of granite and granite gneisses. It is unconformably overlain by the Tura Formation. The Tura Formation is composed of medium to coarse grained and gritty, dirty white, yellow and reddish, clayey, non-feldspathic, frequently current-bedded sandstone intercalated with grey shale, carbonaceous shale, lithomargic clay, siltstone and coal seams. This formation is extensively developed in the north and south of Tura Range. The fact that sedimentation of this formation took place over the uneven surface of the basement is evident by its patchy development in the marginal part of the basin. The base of the Tura

Age	Stratigraphic unit	Lithology	Remarks
Post-Middle Eocene	Post-Siju formations	—	—
Middle Eocene	Siju Formation	Hard, yellowish, arenaceous, fossiliferous limestone with thin beds of calcareous shale	Exposed in a stream cutting at 10 km from Tura on Tura-Dalu Road
Palaeocene - Early Eocene	Tura Formation	Medium to coarse grained and gritty, clayey, dirty white, yellow and reddish, non-feldspathic, current bedded sandstone with intercalations of grey shale, carbonaceous shale, siltstone, lithomargic clay and coal	Exposed between Tura and 10 km from Tura on Tura- Dalu Road
		Unconformity	
Precambrian	Basement Complex	Granite and granite gneisses	

Fig. 1—Stratigraphic succession along Tura-Dalu Road, West Garo Hills, Meghalaya (after Chakraborty & Baksi, 1972).

Formation is marked by a pebble bed, indicating an unconformable lower contact. In contrast, the upper contact with the Siju Formation is conformable in the Tura-Dalu Road Section. In this section the Tura Formation is about 100 m thick and dips up to 5° SSE. However, in the eastern part of the Garo Hills, in the Nongwalbibra area, the thickness of this formation is over 200 m.

The overlying Siju Formation, well exposed in a stream cutting at about 10 km from Tura on Tura-Dalu Road, is made up of hard, yellow, arenaceous and fossiliferous limestone, with thin beds of calcareous shales. Further down dip, the Siju Formation is succeeded by the predominantly argillaceous Rewak and younger formations. The stratigraphic succession along the Tura-Dalu Road in West Garo Hills, Meghalaya is shown in Fig. 1.

MATERIAL AND METHODS

The material for the present palynological investigation was collected from the Tura Formation exposed between Tura and 10 km from Tura, along the Tura-Dalu Road in the West Garo Hills District, Meghalaya (Fig. 2). Altogether, 34 samples were collected from carbonaceous shale and siltstone bands within the sandstones. Of these, 16 samples yielded palynofossils. The stratigraphic position of the samples is shown in Fig. 3.

For recovery of palynofossils, samples were treated with HCl followed by HF and HNO_3. After acid treatment, the samples were thoroughly washed with water and then treated with 3% KOH solution for 5-10 minutes, followed by repeated washing with water through 400 mesh sieve to remove all traces of alkali. The residue was then mixed with polyvinyl alcohol, spread uniformly over coverglasses and dried in oven. The coverglasses were mounted upon slides, using Canada balsam. All the slides and negatives of figured specimens are stored in the Museum of the Birbal Sahni Institute of Palaeobotany, Lucknow.

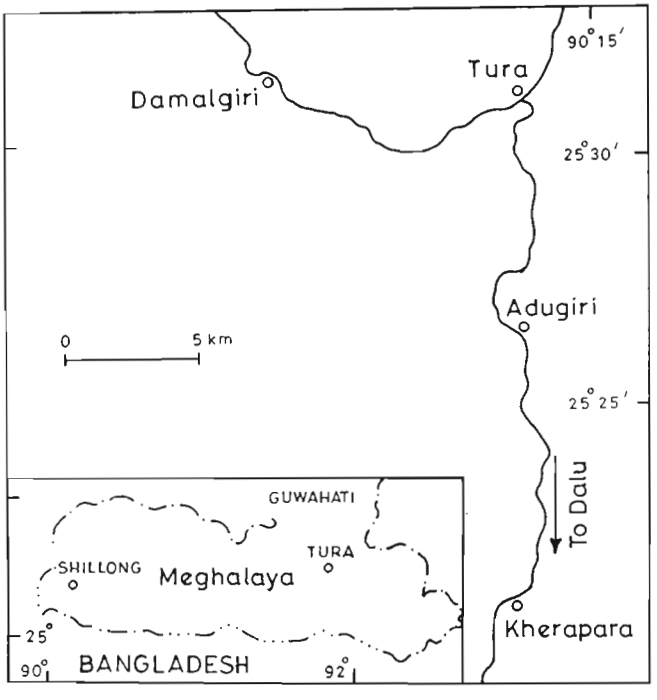

Fig 2 —Location map of the area.

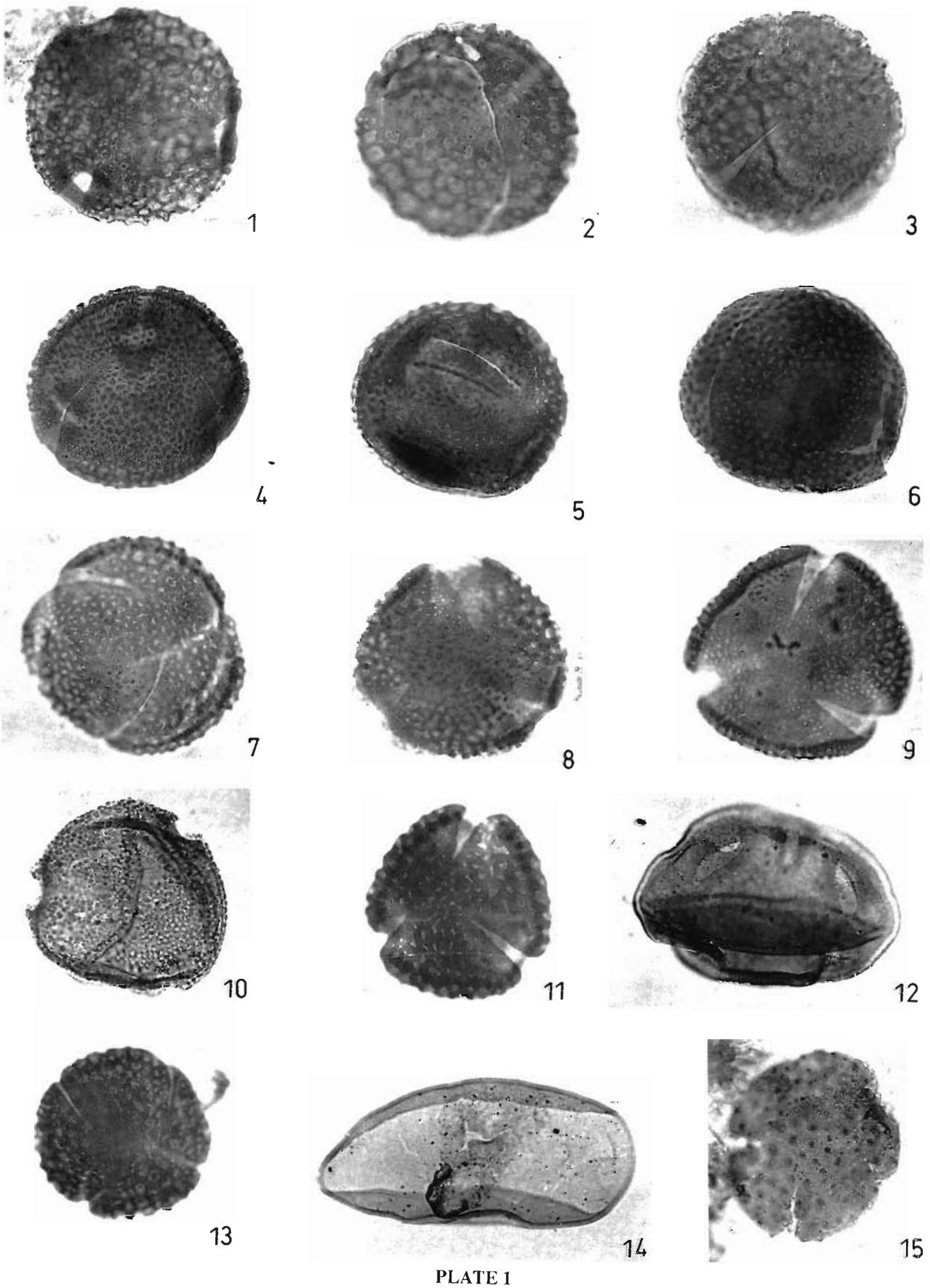

PLATE 1

PALYNOLOGICAL ASSEMBLAGE

The recovered palynological assemblage from the Tura Formation is represented by dinoflagellate cysts, fungal remains, pteridophytic spores and angiosperm pollen. Qualitatively and quantitatively, the assemblage is dominated by angiosperm pollen. Pteridophytic spores are the subdominant elements. An attempt has been made to assign the recorded palynotaxa to extant genera or families. Pollen grains showing affinity with the family Alangiaceae and Caesalpiniaceae are abundant in the assemblage. The pollen of Alangiaceae are tricolporate (generally brevicolpate), with a variety of exine ornamentation - reticulate, rugulate, gemmate and verrucate. Pollen grains assigned to the family Caesalpiniaceae are also tricolporate but possess long colpi and a broad-meshed reticulum. A variety of fungal remains represented by fruiting bodies, spores and mycelia are present in the assemblage; indeed, in one of the samples (sample no. 27) fungal hyphae and spores are especially profuse.

Palynotaxa present in the assemblage are listed below under the attributable families. Only new species and forms which could not be assigned to any known species have been described.

Algae

This group is represented by dinoflagellate cysts. Taxonomy of this group has not been dealt with in this communication. However, dinocysts have been used to interpret the environment of deposition.

Fungal remains

A variety of spores and fruiting bodies are recorded. These are: *Multicellaesporites elsikii* Kar & Saxena, 1976; *M. ellipticus* Sheffy & Dilcher, 1971; *Dicellaesporites elongatus* Kumar, 1990; *Fusiformisporites foedus* Salujha *et al.*, 1974; *Callimothallus pertusus* Dilcher, 1965; *Phragmo-thyrites eocenica* Edwards, 1922 emend. Kar & Saxena, 1976; *Trichothyrites setiferus* (Cookson, 1947) Saxena & Misra, 1990.

Pteridophytic spores

Matoniaceae

Dandotiaspora dilata (Mathur, 1966) Sah *et al.*, 1971; *D. telonata* Sah *et al.*, 1971; *D. plicata* (Sah & Kar, 1969) Sah *et al.*, 1971.

Osmundaceae

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

Schizaeaceae

Lygodiumsporites eocenicus Dutta & Sah, 1970; *L. lakiensis* Sah & Kar, 1969; *L. pachyexinus* Saxena, 1978; *Intrapunctisporis intrapunctis* Krutzsch, 1959; *Corrugatisporites formosus* Dutta & Sah, 1970.

Parkeriaceae

Striatriletes susannae van der Hammen, 1956 emend. Kar, 1979.

Polypodiaceae

Polypodiisporites tuberculensis (Baksi, 1962) Rao & Singh, 1987; *P. ornatus* Sah, 1967; *P. repandus* Takahashi, 1964; *Laevigatosporites lakiensis* Sah & Kar, 1969; *Monolites mawkmaensis* Sah & Dutta, 1966; *Polypodiaceaesporites strictus* Kar & Saxena, 1981.

Others

Biswasiaspora pseudoreticulata Kar & Saxena, 1981; *Cheilanthoidspora monoleta* Sah & Kar, 1974; *Dictyophyllidites cherrapunjiensis* Kar & Kumar, 1986; *Deltoidospora plicata* Singh, 1977a.

Angiosperm pollen

Arecaceae

Palmidites granulatus Mehrotra, 1983; *P. plicatus* Singh in Sah & Singh, 1974; *P. punctatus* Mehrotra, 1983; *P. naviculus* Kar & Saxena, 1981; *P. assamicus* Singh, 1977a; *Arecipites matanomadhensis* (Saxena, 1979) Kar, 1985.

Liliaceae

Liliacidites giganticus Singh, 1977a.

←

PLATE 1

(All photographs are enlarged x 750)

1. *Lanagiopollis emarginatus* Morley; Slide no. BSIP 12332; Coordinates : 51·6 x 103·4.
2. 3. *Lanagiopollis meghalayaensis* sp. nov.; Slide no. BSIP 12333; Coordinates : 54·7 x 108·2.
4. 5. *Lanagiopollis subglobosus* sp. nov.; Slide nos. BSIP 12334 and 12335; Coordinates : 43·6 x 97·3 and 65·6 x 103·4 respectively.
6. 7. *Retitricolpites singhii* sp. nov.; Slide nos. BSIP 12336 and 12337; Coordinates : 53·1 x 102·7 and 58·3 x 109·7 respectively.
8. *Lanagiopollis nanggulaensis* Morley; Slide no. BSIP 12332; Coordinates : 53·4 x 98·6.
9. *Retitrescolpites crassimurus* Sah; Slide no. BSIP 12338; Coordinates : 52·3 x 105·7.
10. *Favitricolporites magnus* Sah; Slide no. BSIP 12339; Coordinates : 49·6 x 97·2.
11. *Paleocaesalpiniaceaepites eocenica* Biswas; Slide no. BSIP 12340; Coordinates : 54·3 x 103·6.
12. Pollen Type - 1: Slide no. BSIP 12340; Coordinates : 51·3 x 102·5.
13. *Retistephanocolpites* sp.; Slide no. BSIP 12333; Coordinates : 49·3 x 104·7.
14. *Palmidites assamicus* Singh; Slide no. BSIP 12342; Coordinates : 53·6 x 105·3.
15. *Echistephanocolpites* sp.; Slide no. BSIP 12332; Coordinates : 51·3 x 104·2.

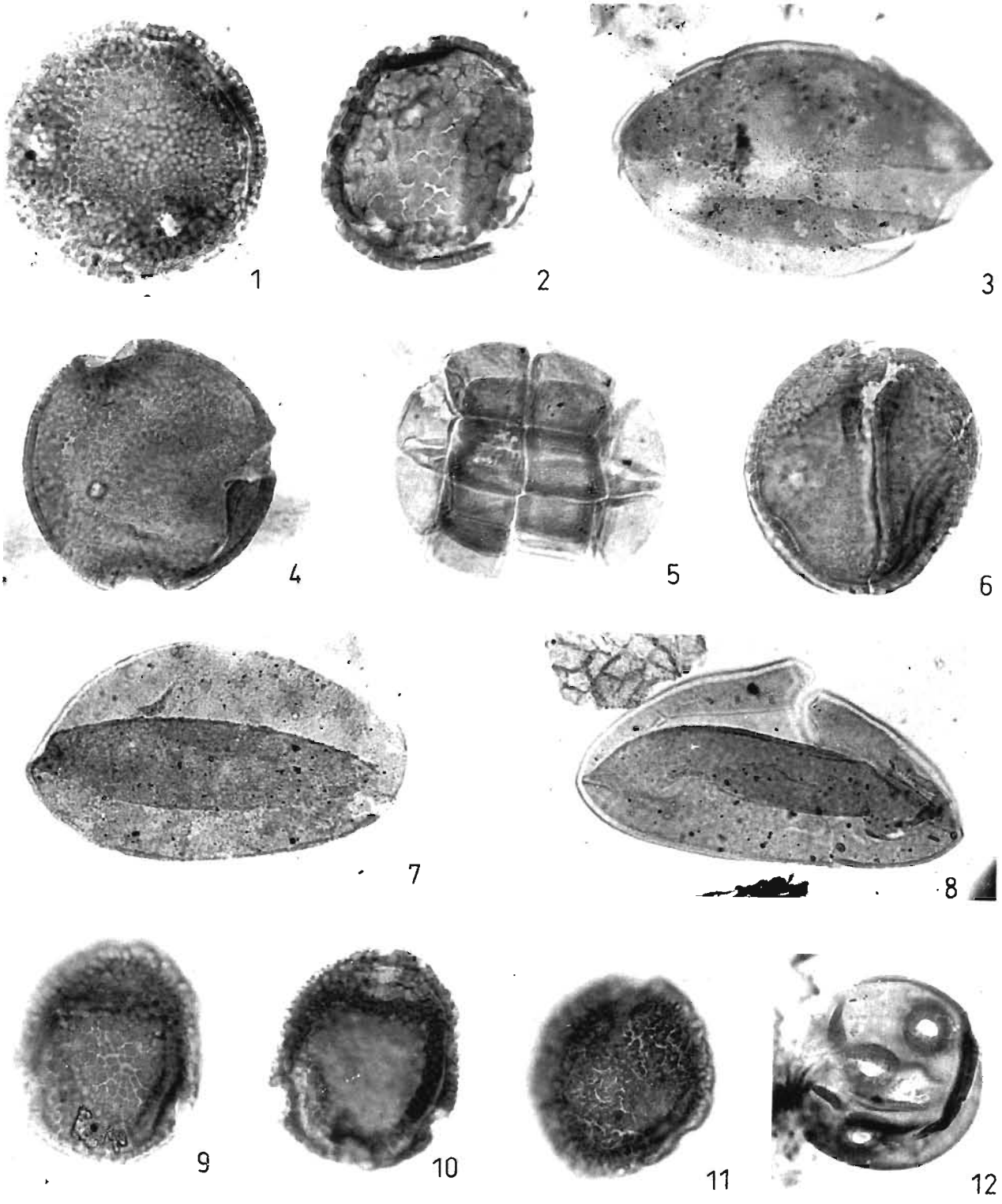

PLATE 2

Alangiaceae

Lanagiopollis meghalayaensis sp. nov.; *Lanagiopollis subglobosus* sp. nov.; *L. emarginatus* Morley, 1982; *L. nanggulaensis* Morley, 1982; *L. retismae* Phadtare & Thakur, 1990; *L. ruguloreticulatus* Phadtare & Thakur, 1990; *Tricolporopilites robustus* (Kar & Saxena, 1981) Kar, 1985; *T. tectatus* Singh & Misra, 1991; *T. uniformis* Singh & Misra, 1991; *Favitricolporites magnus* Sah, 1967.

Bombacaceae

Lakiapollis ovatus Venkatachala & Kar, 1969.

Caesalpiniaceae

Paleocaesalpiniaceaepites eocenica Biswas, 1962; *Margocolporites tsukadae* Ramanujam, 1966.

Mimosaceae

Polyadopollenites siwalikus Saxena & Singh, 1982.

Oleaceae

Tricolpites matanomadhensis Saxena, 1979; *T. crassireticulatus* Dutta & Sah, 1970.

Urticaceae

Triporopollenites vimalii Sah & Dutta, 1966.

Others

Echistephanocolpites sp.; *Inaperturopollenites punctatus* (Saxena, 1979) Saxena & Bhattacharyya, 1987; *Spinainaperturites conatus* Venkatachala & Rawat, 1972; *Retipilonapites arcotense* Ramanujam, 1966; *Favitricolporites grandis* Venkatachala & Rawat, 1972; *Retitrescolpites crassimurus* Sah, 1967; *Retitricolpites singhii* sp. nov.; *Retistephanocolpites* sp.; Pollen Type - 1.

SYSTEMATICS

Genus—RETITRICOLPITES (van der Hammen) Pierce, 1961

RETITRICOLPITES SINGHII sp. nov.

Pl. 1·6-7

Holotype—Pl. 1·7; Slide no. BSIP 12337.

Type locality and horizon—Tura-Dalu Road Section, West Garo Hills, Meghalaya; Tura Formation.

Diagnosis—Pollen grains spheroidal-subspheroidal. Tricolpate, colpi long, narrow, reaching up to the poles. Exine moderately thick, foveoreticulate, muri 1 µm thick, lumina 1-2·5 µm across, meshes smaller near colpi and broad in apocolpial region.

Dimensions—Size range: 65-67 µm; exine thickness: 2-3 µm.

Number of specimens studied—Nine.

Comparison—Retitricolpites singhii sp. nov. differs from *R. delicatus* Kar (1979) in being larger in size and in possessing broad meshes of the reticulum which are variable in size in each single specimen. *Retitricolpites robustus* Sah & Kar (1970), though possesses broad-meshed reticulum, is duplicolumellate.

Genus—LANAGIOPOLLIS Morley, 1982

LANAGIOPOLLIS MEGHALAYAENSIS sp. nov.

Pl. 1·2-3

Holotype—Pl. 1·2-3; Slide no. BSIP 12333.

Type locality and horizon—Tura-Dalu Road Section, West Garo Hills, Meghalaya; Tura Formation.

Diagnosis—Pollen grains spheroidal to subspheroidal. Tricolporate, colpi (ectoaperture) distinct, reaching almost up to the poles, ora (endoaperture) indistinct, lalongate. Exine irregularly reticulate, muri composed of distinct capita, each supported by group of columellae, pluricolumellate, lumina 1·5-3 µm across, meshes smaller near colpi, free bacular heads seen in the lumina. Exine fairly thick, sexine thicker than nexine.

Dimensions—Size range: 62-68 µm; exine thickness: 4-5 µm.

Number of specimens studied—Twenty four.

Comparison—Lanagiopollis rugularis Morley (1982) differs from the present species in having a semi-angular shape, shorter colpi, thickened pore margin and smaller mesh size. *Lanagiopollis nanggulaensis* Morley (1982) exhibits smaller mesh size, a thicker nexine and thickening around the ora. *Lanagiopollis emarginatus* Morley (1982) and *L. retismae* Phadtare & Thakur (1990) are semi-angular in shape and possess irregular warty elements on the exinal surface.

←

PLATE 2

(All photographs are enlarged x 750)

1, 2. *Tricolporopilites robustus* (Kar & Saxena) Kar; Slide nos. BSIP 12343 and 12344; Coordinates : 48·2 x 96·3 and 55·3 x 104·6 respectively.

3. *Palmidites plicatus* Singh in Sah & Singh; Slide no. BSIP 12345; Coordinates : 58·3 x 106·4.

4. *Favitricolporites grandis* Venkatachala & Rawat; Slide no. BSIP 12346; Coordinates . 51·4 x 97·3.

5. *Polyadopollenites siwalikus* Saxena & Singh; Slide no. BSIP 12347; Coordinates : 59·2 x 104·7.

6. *Tricolporopilites tectatus* Singh & Misra; Slide no. BSIP 12348; Coordinates : 56·2 x 103·6

7 *Palmidites granulatus* Mehrotra; Slide no. BSIP 12344; Coordinates · 51·1 x 106·3.

8. *Palmidites punctatus* Mehrotra; Slide no. BSIP 12343; Coordinates . 49·6 x 97·4.

9-11. *Tricolporopilites uniformis* Singh & Misra; Slide nos. BSIP 12337 and 12349; Coordinates : 58·7 x 104·6 and 49·4 x 106·8 respectively.

12. *Lakiapollis ovatus* Venkatachala & Kar; Slide no. BSIP 12331; Coordinates . 58·3 x 104·3.

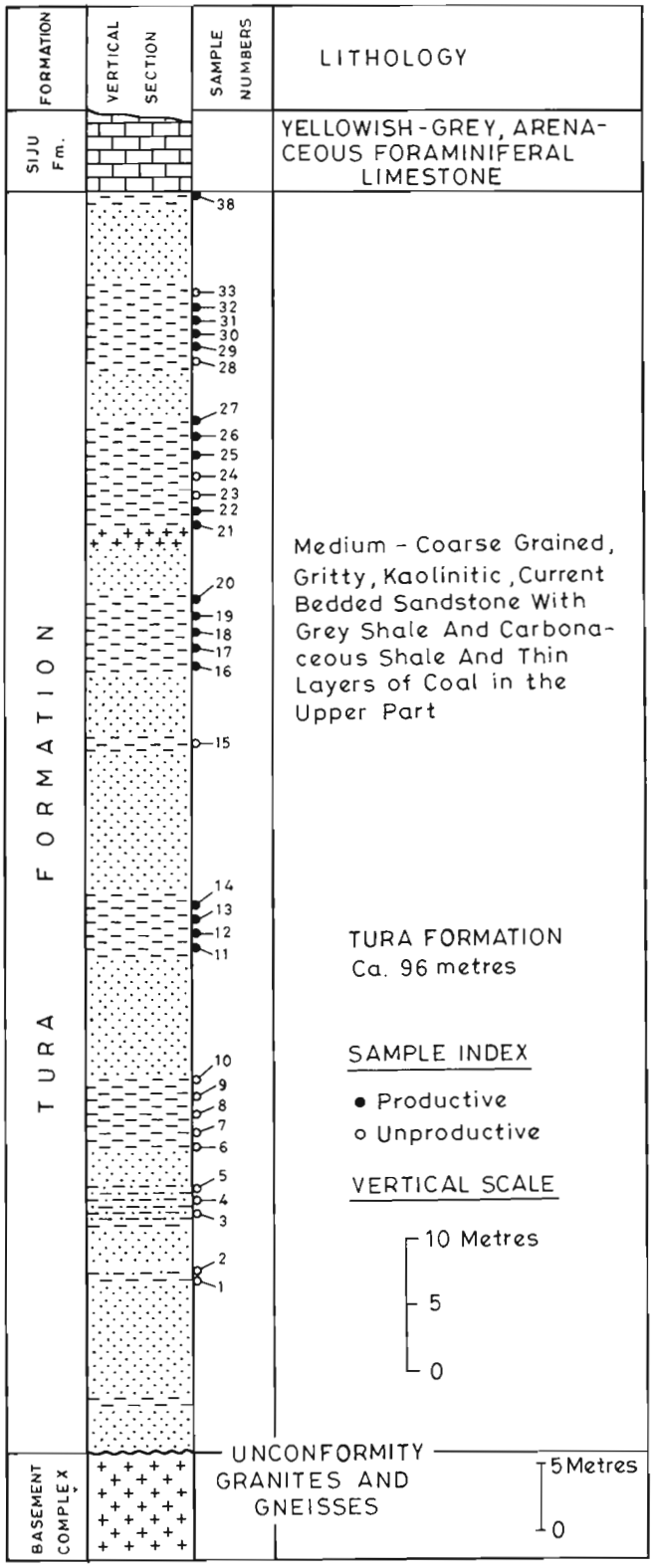

Fig. 3—Lithosuccession of Tura Formation, Tura-Dalu Road, West Garo Hills, Meghalaya.

Fig. 4—Palynotaxa/plant group frequency in productive samples. →

LANAGIOPOLLIS SUBGLOBOSUS sp. nov.

Pl. 1·4-5

Holotype—Pl. 1·5; Slide no. BSIP 12335.

Type locality and horizon—Tura-Dalu Road Section, West Garo Hills, Meghalaya; Tura Formation.

Diagnosis—Pollen grains oval-spheroidal. Tricolporate, colpi distinct, long, reaching almost up to the poles, ora distinct, subequatorial, lalongate, 8-10 µm across (transversely), ora margin thickened. Exine moderately thick, finely reticulate, muri formed by fusion of columellae, simplicolumellate, nexine slightly thicker than sexine.

Dimensions—Size range: 63-69 µm; exine thickness: 3 µm.

Number of specimens studied—Thirteen.

Comparison—Lanagiopollis rugularis Morley (1982) differs from the present species in having semi-angular shape and rugulate exine. *Lanagiopollis nanggulaensis* Morley (1982) has thicker exine. *Lanagiopollis retismae* Phadtare & Thakur (1990) is semi-angular in shape and possesses irregularly arranged warts on exinal surface. *Lanagiopollis subglobosus* sp. nov. is different from *L. meghalayaensis* sp. nov. in having subglobose shape, subequatorial apertures and distinct reticulate pattern.

Genus—RETISTEPHANOCOLPITES Leidelmeyer, 1966

RETISTEPHANOCOLPITES sp.

Pl. 1·13

Description—Pollen grains spheroidal. Size 53 µm. Tetracolpate, colpi narrow, long. Exine 2 µm thick, reticulate, muri 1 µm thick, lumina 1·5-2 µm across.

Number of specimens studied—Two.

Remarks—The present specimens resemble *Tetracolpopites* sp. described by Biswas (1962) from the Tura Formation of Tura-Dalu Road Section, Garo Hills, Meghalaya.

Genus—ECHISTEPHANOCOLPITES Wijmstra, 1971

ECHISTEPHANOCOLPITES sp.

Pl. 1·15

Description—Pollen grains spheroidal to subspheroidal. Size 60-68 µm. Pentacolpate, colpi narrow, moderately long. Exine 1 µm thick, provided with small coni (about 2 µm long). spaces between coni granulate.

Number of specimens studied—Two.

TAXA / SAMPLE NUMBER	11	12	14	16	17	18	19	20	21	22	26	27	29	30	31	38
Dandotiaspora telonata		O	O			O										
D. plicata			O	+	O	O							+		+	
Todisporites kutchensis				+	+		+							+		
Lygodiumsporites eocenicus		+		O	+		+					+	+	+	+	
L. lakiensis				O	+	+										+
Striatriletes susannae	O	+			+	O	O	+	O	+						
Polypodiisporites tuberculensis				O								+	+		+	
P. repandus				O	+									+		+
Laevigatosporites lakiensis				+							+		+	+	O	+
Palmidites granulatus					+	+										
P. plicatus						+			+		+					
P. punctatus						+			+							
P. naviculus					+	+	+									
Lanagiopollis emarginatus	X	O		O	+			+				O	O	O	O	
L. nanggulaensis	O			X								O	O	O	+	
L. retismae	O			O								O	O			
L.ruguloreticulatus		+		O									+			
L. meghalayaensis				O									+	+		
L. subglobosus												+	+	+		
Tricolporopilites robustus	+										O		+		+	
T. tectatus	+										O					O
T. uniformis				+							O		+	+	O	O
Paleocesalpiniaceaepites eocenicus	+			O		+			+		O	+		O		
Margocolporites tsukadae								+	+							
Dinoflagellate cysts					*	*	#	X	X	O	#		+			+
Fungal remains			O	+	+	+	O			+	+	O	+			

+ Up to 2%; O 3-10 %; X 11-20 %; # 21-30 %; * 31-40 %

POLLEN TYPE—1

Pl. 1·12

Description—Pollen grain spheroidal (looking ovoidal because of fold). Size 80 µm. Hexacolporate, colpi distinct, 8-10 µm long, ora distinct, lalongate, 5-7 µm in diameter. Exine 1 µm thick, intrapunctate.

Number of specimen studied—One.

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

Most of the families represented in the assemblage are presently distributed in tropical to subtropical regions. These are: Matoniaceae, Schizaeaceae, Arecaceae, Bombacaceae and Alangiaceae. Other families are cosmopolitan and none is exclusively temperate. The present-day distribution of the nearest extant relatives of the recorded palynotaxa indicates a tropical to subtropical climate during the deposition. The presence of fungal remains and pteridophytic spores in fairly good number indicates that the climate was warm and humid.

The assemblage from the lower part of the studied section is rich in pollen having affinity with the family Alangiaceae, which are plants of a lowland, humid deciduous forest. Pollen showing affinity with *Caesalpinia*, a coastal forest element, also profusely occur in the assemblage, indicating deposition in a coastal environment. The assemblage from the middle part shows the presence of pollen having affinity with the family Palmae and the dinoflagellate cysts indicating that deposition of these sediments took place under shallow marine conditions. The absence of dinocysts and palm pollen in the upper part of the section is suggestive of the diminishing marine influence during this phase of deposition. Overall palynofloral spectrum from the studied sediments of Tura Formation thus indicates that these sediments were deposited in the littoral zone.

PALYNOSTRATIGRAPHIC ZONATION

The percentage of each palynotaxon was calculated by counting 200 specimens per sample. The distribution and frequency of stratigraphically significant palynotaxa are given in Fig. 4. On the basis of quantitative analysis of the palynoflora, the studied sequence is divisible into three distinct assemblage zones. The lower zone is dominated by pollen having affinity with the families Alangiaceae and Caesalpiniaceae. The middle zone is marked by the presence of palm pollen indicating the onset of coastal deposition. This zone is rich in dinoflagellate cysts also. The upper zone is characterized by dominance of angiospermic pollen having affinity with *Alangium*. In the ascending order, the formal palynozones are: 1. *Lanagiopollis* spp. Assemblage-zone; 2. *Palmidites* spp. Assemblage-zone; and 3. *Tricolporopilites* spp. Assemblage-zone. In accordance with the requirements laid down in the International Stratigraphic Guide (Hedberg, 1976), a formal description of the three proposed assemblage zones is given below.

Lanagiopollis spp. Assemblage-zone

Diagnostic palynofossils—Lanagiopollis emarginatus, L. nanggulaensis, L. retismae, Dandotiaspora telonata, Paleocaesalpiniaceaepites eocenica.

Palynofossils restricted to the zone—Lanagiopollis retismae.

Stratotype—The stratotype is exposed along Tura-Dalu Road (between Tura and 10 km from Tura), West Garo Hills, Meghalaya.

Associated lithology—Medium to coarse grained, gritty kaolinitic sandstone with frequent grey shale and occasional carbonaceous shale bands.

Thickness—The zone is represented by 60 m thick sequence.

Boundaries and relation to the adjacent biozones—The lower part of the type section is composed of coarse-grained current bedded sandstone whereas, the upper part is made up of grey shale band.

Geological age—Early Eocene.

Remarks—The zone is characterized by the high frequency of species assignable to *Alangium*. The upper part of this Cenozone is characterized by the sudden increase of arecaceous pollen.

Palmidites spp. Assemblage-zone

Diagnostic palynofossils—Palmidites plicatus, P. naviculus, P. granulatus, P. punctatus.

Palynofossils restricted to the Cenozone—Palmidites plicatus, P. naviculus, P. granulatus, P. punctatus and dinoflagellate cysts.

Stratotype—The stratotype is exposed along Tura-Dalu Road (between Tura and 10 km from Tura), West Garo Hills, Meghalaya.

Associated lithology—Medium to coarse grained, gritty kaolinitic sandstone with frequent grey shale and occasional carbonaceous shale bands.

Thickness—The zone is represented by 18 m thick sequence.

Boundaries and relation to the adjacent biozones—This part is made up of grey shale bands and is in contact with coarse-grained sandstone of overlying *Tricolporopilites* spp. Assemblage-zone.

Geological age—Early Eocene.

Remarks—Occurrence of different species of *Palmidites* and the dinoflagellate cysts is the characteristic feature of this zone.

Tricolporopilites spp. Assemblage-zone

Diagnostic palynofossils—*Tricolporopilites uniformis, T. tectatus, T. robustus.*

Palynofossils restricted to the Cenozone—*Tricolporopilites uniformis, T. robustus.*

Stratotype—The stratotype is exposed along Tura-Dalu Road (between Tura and 10 km from Tura), West Garo Hills, Meghalaya.

Associated lithology—Coarse-grained sandstone with grey shale and carbonaceous shale bands.

Thickness—The zone is represented by 18 m thick sequence.

Boundaries and relation to the adjacent biozones—Base of this zone is represented by sandstone which is in contact with grey shale of the underlying zone whereas, the top of it is in contact with the limestone of the Siju Formation.

Geological age—Early Eocene.

Remarks—This zone is characterized by the high frequency of different species of *Tricolporopilites* related to the family Alangiaceae.

PALYNOFLORAL COMPARISON AND AGE

Palynostratigraphical work on the Early Palaeogene sediments of Meghalaya and Assam has been extensively carried out by a number of workers. These studies are mainly on the Tura Formation, Garo Hills (Sah & Singh, 1974), the Cherra Formation and Lakadong Sandstone in the Khasi Hills (Dutta & Sah, 1970; Kar & Kumar, 1986), the Therria Formation in the Jaintia Hills (Tripathi & Singh, 1984) and the Mikir Formation in the North Cachar Hills (Mehrotra, 1981). The palynological assemblages from the Cherra Formation (Dutta & Sah, 1970; Sah & Dutta, 1974), the Lakadong Sandstone (Kar & Kumar, 1986) of the Khasi Hills and the Therria Formation of the Jaintia Hills (Tripathi & Singh, 1984), Meghalaya are not comparable to the present assemblage, as only a few palynotaxa are held in common. However, the palynological assemblages from the Tura Formation (Biswas, 1962; Sah & Singh, 1974) of Garo Hills are broadly comparable.

The palynoflora from the two topmost assemblage zones, viz., *Foveotriletes palaeocenicus* Cenozone and *Palmaepollenites eocenicus* Cenozone of the Mikir Formation, North Cachar Hills, Assam (Mehrotra, 1981) is comparable to the present assemblage. Palynotaxa common between the assemblages from these two cenozones and that recorded in the present assemblage are: *Dandotiaspora dilata, D. telonata, Corrugatisporites formosus* and *Polypodiisporites*. In addition to this, the upper palynozone of the Mikir Formation is characterized by a high frequency of dinoflagellate cysts. In the studied sequence also, the middle zone is characterized by the dominance of dinoflagellate cysts.

The palynological assemblage from Prang Formation, exposed near 132 km post on Jowai-Badarpur Road, Jaintia Hills, Meghalaya (Kar 1992), is comparable to the present assemblage. The common forms are: *Todisporites kutchensis, Lygodiumsporites lakiensis, Striatriletes susannae* and *Lakiapollis ovatus*. The palynological assemblage from the upper palynozone of Naredi Formation, viz., *Lygodiumsporites lakiensis* Cenozone Kar (1985), registers the presence of many palynotaxa which appear in the present assemblage also. These are: *Lygodiumsporites lakiensis, Dandotiaspora plicata, Lakiapollis ovatus* and *Intrapunctisporis intrapunctis.*

Palynological assemblages from the Rajpardi Lignite, Gujarat (Phadtare & Thakur, 1990; Kar & Bhattacharya, 1992; Kumar, 1996) are comparable to the present assemblage since pollen assignable to *Alangium* are common.

The comparison of present palynofloral assemblage with those from other Palaeogene sediments of India indicates that it contains many palynotaxa which are also reported from the top part of the Mikir Formation, North Cachar Hills, Assam, the Prang Formation, Jaintia Hills, Meghalaya, the Naredi Formation, Gujarat and the Rajpardi Lignite, Gujarat. On the basis of palynological studies these stratigraphical units have been assigned an Early Eocene age. It is therefore concluded that the Tura Formation, exposed along the Tura-Dalu Road, West Garo Hills, Meghalaya, is of Early Eocene age.

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