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Palynology of the Jaintia Group (Palaeocene-Eocene) exposed along Jowai-Sonapur Road, Meghalaya, India (Part II). Data analysis and interpretations

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The palynoflora recovered from the Jaintia Group (Palaeocene-Eocene) exposed along the road between Jowai and Sonapur, Jaintia Hills has been dated and compared with various Lower Tertiary palynological assemblages. The present studies support tropical to subtropical vegetation during the Palaeocene-Eocene times. It has also been inferred that the Jaintia Group sediments were deposited under shallow marine conditions.

Key-words—Palynology, Stratigraphy, Jaintia Group, Palaeocene-Eocene (India).

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साराँश

मेघालय (भारत) में जोवई-सोनपुर मार्ग के संग-संग विगोपित जयन्तिया समूह (पुरानूतन-आदिनूतन) का परागाणविक अध्ययन. भाग 2–आँकड़ों का विश्लेषण एवं व्याख्या

हरिपाल सिंह एवं सूर्यकान्त मणि त्रिपाठी

जयन्तिया पहाड़ियों में जोवई और सोनपुर के बीच में सड़क के संग-संग विगोपित जयन्तिया समूह (पुरानूतन-आदिनूतन) से उपलब्ध परागाणु-वनम्पतिजात का कालनिर्धारण किया गया है तथा विभिन्न अधरि तृतीयक युगीन परागाणविक समुच्चयो से इसकी तुलना की गई है। प्रस्तुत अध्ययन पुरानूतन-आदिनूतन काल में उष्णकटिबन्धीय से उपोष्णकटिबन्धीय वनस्पति की उपस्थिति प्रमाणित करता है। यह भी निष्कर्ष निकाला गया है कि जयन्तिया समूह के अवसाद छिछली समुद्री परिस्थितियों में निक्षेपित हुए थे।

THE sediments of Jaintia Group are exposed along National Highway 44, connecting Shillong (Meghalaya) and Badarpur (Assam). These sediments belong to the shelf facies and are exposed between Jowai and Sonapur, southeast of Shillong. The Jaintia Group is divided into three formations, which in the ascending order are: Therria Formation, Sylhet Limestone and Kopili Formation. At Jowai, the Shillong Group (Precambrian) is unconformably overlain by the Therria Formation. Further south-ward, the Therria Formation is overlain by the Sylhet Limestone which in turn is succeeded by the Kopili Formation (Map 1). Detailed geological information and a geological map of the area have been published by Saxena and Tripathi (1982).

Therria Formation (about 100 m thick) is constituted by monotonous white-brown and pale-red, medium to very coarse-grained, often gritty, cross-bedded, ferruginous sandstone, alternating with subordinate shale and fine-grained carbonaceous sandstone. The shale is mostly bentonitic and without megafossils. The carbonaceous sandstones are generally associated with thin coal seams.

The Sylhet Limestone (about 500 m thick) is made up mainly of limestone with thin alternations of sandstone and consists of five members. Kopili Formation, the youngest stratigraphic unit of the Jaintia Group, is made up of grey, fine to very fine grained, massive to laminated, compact sandstone, alternating with shales. The shales represent ellipsoidal structures showing laminae like successive layers of onion. Kopili Formation is about 500 m thick.

Sein and Sah (1974) on the basis of palynological study, mostly at generic level, demarcated the Eocene and Oligocene sediments exposed along the road between Lumshnong and Sonapur. Later, Dutta and Jain (1980) described acritarch and dinoflagellate assemblages from the Sylhet Limestone and Kopili Formation in the Lumshnong area and pointed out their biostratigraphic potential. However, palynostratigraphical information available so far from this area is meagre and the results are based on study of limited number of samples.

The present analysis of palynological data is based on 318 rock samples which were collected from stratigraphically measured sections. Of these, 160 samples proved to be productive, yielding a rich palynofloral assemblage constituted by algal, fungal, pteridophytic and angiospermic remains. Systematic palynology alongwith critical observations has already been dealt with by Singh and Tripathi (1983), Tripathi and Singh (1984a), Tripathi and Singh (1985), Singh and Tripathi (1986) and Tripathi (in Press).

A paper on palynostratigraphical zonation and correlation of the Jaintia Group sediments, exposed along Jowai-Sonapur Road, Meghalaya has also been published by Tripathi and Singh (1984b). In the present paper a comparative account of the assemblages known from the stratigraphically equivalent horizons is given and palynological data has been analysed qualitatively and quantitatively to reflect upon palaeogeography, palaeoclimate, palaeoecology and age of the sediments.

PALYNOFLORAL COMPOSITION AND ITS QUALITATIVE ANALYSIS

The Jaintia Group (Palaeocene-Eocene) sediments exposed along the road between Jowai and Sonapur, Meghalaya have yielded 59 genera and 92 species. Out of these, 15 genera and 25 species represent the pteridophytes, 20 genera and 29 species represent the angiosperms, 13 genera and 26 species represent the algae and 11 genera and 12 species represent the fungi.

Qualitatively angiospermous pollen grains exhibit their dominance over other plant groups but quantitatively pteridophytic spores constitute the major part of the assemblage (30%). The dinoflagellate cysts (algae) constitute 29% of the total palynofloral assemblage, while the angiosperms share 20% of it. The fungal remains are represented by 2% only. Gymnospermous pollen grains are conspicuously absent in the present palynofloral assemblage. The presence of various palynotaxa in the three formations is as follows:

	FORMATION		
	THERRIA	SYLHET	KOPILI
Cyathidites australis	+		
Intrapunctisporis densipunctis	+		
Dandotiaspora dilata	+		+
D. telonata	+	+	+
Dandotiaspora sp.	+		
Biretisporites sp.	+		
Lygodiumsporites eocenicus	+		+
L. meghalayaensis	+		
L. khliehriatensis	+		
L. marginiplicatus	+		
L. psilatus	+		
Todisporites major	+		+
Osmundacidites sp.			+
Corrugatisporites sp.			+
Foveotriletes pachyexinous	+		
Foveotriletes sp.	+		
Striatriletes susannae			+
S. paucicostatus			+
S. attenuatus			+
Cingutriletes sp.	+		
Monolites mawkmaensis	+		
M. discordatus	+		
Polypodiisporites mawkmaensis	+		
Verrucatosporites sp.			+
Schizaeoisporites sp.	+		
Sciadopityspollenites sp.	+		+
Trifossapollenites constatus	+		
Couperipollis brevispinosus	+	+	
C. meghalayaensis	+		
C. wodehousei	+		
C. robustus	+		
C. rarispinosus	+		
Couperipollis sp.			+
Liliacidites microreticulatus	+		
L. giganticus	+	+	
L. major	+		
Collospermumpollis laevigatus	+		
Palmidites plicatus	+		+
P. obtusus	+	+	+
P. maximus	+		
Palmaepollenites communis	+		
Pinjoriapollis magnus			+
Proxapertites assamicus	+		
Assamialetes emendatus	+		
Ladakhipollenites elongatus	+		
Tricolpites alveolatus	+	+	
Trisynocolporites angularis	+		
Retitrescolpites sp.			+
Tricolporopollis rubra	+	+	+
Densiverrupollenites eocenicus			+
Lakiapollis assamicus			+
Myricipites vulgaris	+		
Graminidites maximus	+		
Polyporina sp.		+	
Gonyaulacysta sp.			+
Apteodinium sp.	+		+
Turbiosphaera filosa			+
T proximata			+
Apectodinium homomorphum	+		
A. parvum	+		
Apectodinium sp. cf. *A. hyperacanthum*	+		

Homotryblium tenuispinosum	+		
H. oceanicum	+		
H. plectilum			+
Cordosphaeridium exilimurum	+		+
C. multispinosum	+		+
C. valiantum	+		
Cordosphaeridium sp.		+	
Prolixosphaeridium conulum	+		
Impletosphaeridium sp.	+		
Polysphaeridium subtile	+		+
P. giganteum			+
P. ornamentum			+
Operculodinium centrocarpum	+		+
O. israelianum	+		
O. major	+		+
Adnatosphaeridium vittatum	+	+	
A. robustum	+		
Codoniella langparensis	+		
Eocladopyxis sp.	+		
Callimothallus pertusus			+
Phragmothyrites eocenica	+		+
Phragmothyrites sp.			+
Paramicrothallites sp.	+		+
Microthallites sp.			+
Cucurbitariacites bellus	+		
Pluricellaesporites psilatus	+		
Dicellaesporites popovii	+		
Dicellaesporites minutus	+		
Diporisporites sp.	+		+
Diporicellaesporites sp.	+		
Inapertisporites sp.	+		

Botanical affinity of studied fossil spores and pollen grains has been inferred by comparing their morphographic features with those of the living ones. Mostly the published information on the morphology of spores and pollen grains has been used for this purpose. In most of the cases the affinity could be traced only up to family level, however, in some cases it has been possible to compare them up to the generic level as well. The pteridophytes are represented by the following families:

Lycopodiaceae

Foveotriletes pachyexinous and *Foveotriletes* sp. are comparable to the spores found in some members of the family Lycopodiaceae. This family is presently found in tropical to temperate regions and favours moist and shady places.

Polypodiaceae

The family Polypodiaceae is represented by *Monolites mawkmaensis, M. discordatus, Polypodiisporites mawkmaensis* and *Verrucatosporites* sp. The present day distribution of this family is cosmopolitan.

Matoniaceae

Biretisporites and *Dandotiaspora* are doubtfully related to the fern family Matoniaceae.

Schizaeaceae

Schizaeoisporites sp. appears to be related to this family due to the comparable spore morphology. This family is chiefly distributed in the tropical and subtropical regions of the world. *Lygodiumsporites* and *Intrapunctisporis* also show affinity with this family.

Cyatheaceae

Cyathidites australis resembles the spores of the family Cyatheaceae. Presently plants of this family are found mainly in the tropical and subtropical areas of the world.

Osmundaceae

Todisporites major and *Osmundacidites* sp. resemble the spores of the family Osmundaceae.

Parkeriaceae

The genus *Striatriletes* is quite similar to the spores found in *Ceratopteris* (Parkeriaceae). This is a water fern and is distributed in the tropical and subtropical regions of the world.

The angiosperms are represented by the following families:

Palmae

Palmidites, Palmaepollenites and *Couperipollis* resemble the pollen grains of the family Palmae. The present day distribution of this family is restricted to tropical and subtropical regions of the world.

Liliaceae

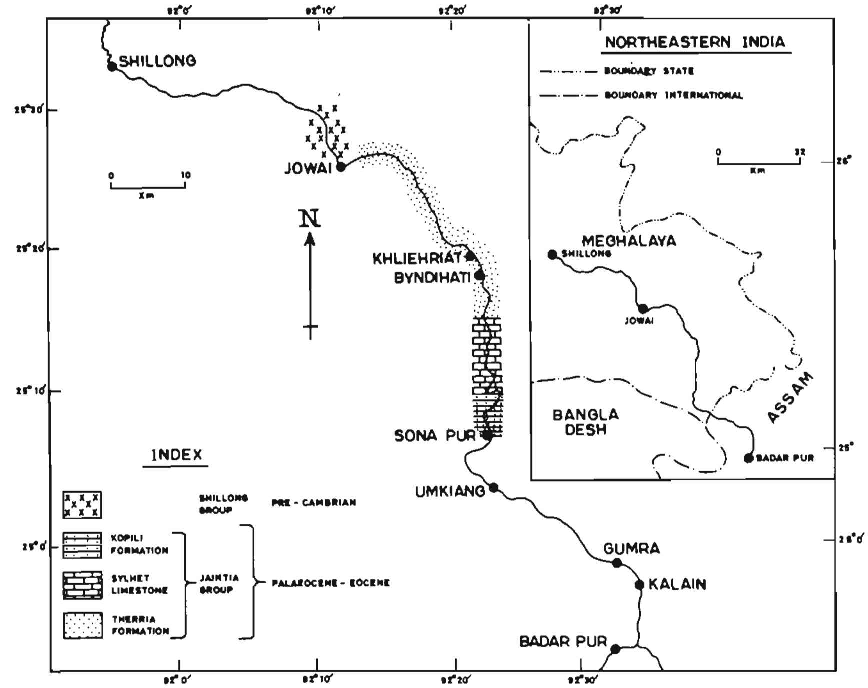
Liliacidites and *Collospermumpollis* are closely comparable to the pollen grains of the family Liliaceae. This family is cosmopolitan in the present day distribution.

Graminae

Graminidites maximus resembles the pollen grains of the family Graminae. This family is cosmopolitan in the present day distribution.

Nymphaeaceae

This family appears to be represented by the pollen grains of *Proxapertites assamicus.* The present day distribution of this family is mainly restricted to the tropical regions. It is an aquatic family.



Map 1—Showing the area of investigation.

Nelumboniaceae

Pollen grains assignable to *Assamialetes emendatus* resemble the pollen grains of this family. This family is also aquatic and is restricted to the tropical regions of the world.

Cruciferae

Ladakhipollenites elongatus resembles the pollen grains of the family Cruciferae. This family is cosmopolitan in the present day distribution and it grows in diverse conditions. However, pollen grains of similar morphology are also found in the family Polygonaceae.

Oleaceae

The family appears to be represented by the pollen grains assignable to *Retitrescolpites* sp. The present day geographical distribution of this family is restricted to tropical and warm temperate regions of the world.

Labiatae

Trifossapollenites constatus doubtfully represents this family. The family is cosmopolitan in the present day distribution.

Chenopodiaceae

The family is represented by *Polyporina* sp. However, similar pollen grains are also found in the family Amarantaceae.

Euphorbiaceae

Tricolporopollis rubra and *Lakiapollis assamicus* are comparable to the pollen grains of the family Euphorbiaceae. The present day distribution of this family is cosmopolitan. Pollen grains of similar morphology are also found in the family Araliaceae.

Myricaceae

Myricipites vulgaris shows affinity with the family Myricaceae. The present day distribution of this family is restricted to subtropical to temperate regions of the world. *Myricipites vulgaris* is abundantly found in the Indian Tertiary sediments but during the present study its frequency was found to be extremely low.

Magnoliaceae

This primitive family is probably represented in the assemblage by *Pinjoriapollis magnus*. The present day distribution of this family is in the temperate regions of the world.

?Aristolochiaceae

The genus *Sciadopityspollenites* may doubtfully be related to the family Aristolochiaceae. The affinities of *Tricolpites alveolatus* and *Densiverrupollenites eocenicus* are uncertain.

Palynofloral assemblage recovered from the Palaeocene-Eocene sediments of Jowai-Sonapur Road section, Meghalaya reflects a tropical to subtropical type of vegetation; however, a few temperate elements were also encountered.

PALYNOFLORAL COMPARISON

Punjab Basin

Palynological studies on the Subathu Formation have been carried out by Mathur (1963, 1966); Salujha, Srivastava and Rawat (1969) and Singh and Khanna (1980). The Subathu palynological assemblage described by Salujha, Srivastava and Rawat (1969) comprises 28 genera and 45 species. Of these, 10 genera belong to pteridophytes, 1 to gymnosperms, 12 to angiosperms and 5 to microplanktons. The palynofossils are poorly preserved precluding a close comparison. However, *Todisporites (Scabratriletes), Dandotiaspora (Psilatriletes lobatus), Osmundacidites (Scabratriletes* sp. A), *Couperipollis (Echinomonoletes)* and *Palmaepollenites (Retimonocolpites)* appear to be common to both the assemblages. Forms restricted to the Subathu Formation are : *Lycopodiacidites, Polypodiaceaesporites, Granodiporites, Anacolcidites, Triorites, Nyssapollenites, Polycolpites, Microhystridium, Canno-sphaeropsis*, etc. The palynofossils restricted to the Therria Formation but not reported from the Subathu Formation are: *Intrapunctisporis densipunctis, Foveotriletes, Monolites, Liliacidites, Assamialetes*, etc.

Recently Singh, Khanna and Sah (1978) and Singh and Khanna (1980) carried out a detailed palynostratigraphic study of the Subathu Formation and recovered a rich palynofloral assemblage. The assemblage recorded by Singh and Khanna (1980) consists of 15 dinoflagellate genera, 4 pteridophytic genera, 2 gymnospermic genera and 5 angiospermic genera. The palynotaxa common to the Subathu and Therria formations are: *Cordosphaeridium, Homotryblium, Gonyaulacysta, Polysphaeridium, Lygodiumsporites, Todisporites, Cyathidites, Proxapertites, Couperipollis, Tricolpites* and *Palmidites*. Palynotaxa restricted to the Subathu Formation are: *Hystrichosphaeridium, Oligosphaeridium, Spiniferites, Cleistosphaeridium, Cyclonephelium, Thalassiphora, Subathua, Araneosphaera, Achilleoidinium, Tenua, Hexagonifera, Verrutricolpites* and *Podocarpidites*. The palynotaxa represented in the Therria Formation but absent in the Subathu Formation are *Turbiosphaera, Apectodinium, Operculodinium, Adnatosphaeridium* and *Codoniella*. Besides, many angiospermous pollen grains, pteridophytic spores and fungal remains have been recovered from the Therria Formation, which are not present in the Subathu Formation.

A comparative study of the palynological assemblages from the Therria and Subathu Formation reveals that the former is dominated by the pteridophytic spores and angiospermic pollen grains, while the latter is characterized by the abundant occurrence of dinoflagellate cysts. A few dinoflagellate cyst genera are common between the two formations, but most of the elements are not comparable. Singh, Khanna and Sah (1978) assigned an Upper Palaeocene-Upper Eocene age to the Subathu Formation.

Rajasthan

Bose (1952), Singh and Natrajan (1950) and Jain, Kar and Sah (1973) investigated the Barmer Sandstone of Rajasthan palynologically. The palynoflora described by Jain, Kar and Sah (1973) comprises 36 genera and 43 species, of which *Proxapertites, Tricolpites, Palmaepollenites*, etc. are common between the two assemblages. The following Barmer Sandstone forms are absent in the present assemblage: *Araliaceoipollenites, Proteacidites, Extratriporopollenites* and *Triorites*. Many palynofossils present in the Therria Formation are absent in the Barmer Sandstone. The Barmer Sandstone has been assigned a Palaeocene age (Jain *et al.*, 1973).

Rao and Vimal (1950, 1952) and Sah and Kar (1974) made palynological studies on the Palana beds, Rajasthan. The palynological assemblage described by Sah and Kar (1974) is richly diversified and consists of 32 genera and 47 species. The palynotaxa common between the Palana beds, Rajasthan and Therria Formation, Meghalaya are: *Todisporites, Osmundacidites, Dandotiaspora dilata, Schizaeoisporites, Palmaepollenites, Liliacidites, Couperipollis, Tricolpites*, and *Callimothallus*. The forms present in the Palana beds but absent in the Therria Formation are: *Dictyophyllidites, Laevigatosporites, Cheilanthoidspora, Retipilonapites, Cupuliferoipollenites, Rhoipites, Caprifoliipites, Hippocrateacidites, Margocolporites, Verrutricolpites, Verrucolporites, Platoniapollenites, Calophyllumpollenites, Kielmeyerapollenites, Polybrevicolporites, Pseudonothofagidites*, etc.

The following palynotaxa of the Therria Formation are not present in the Palana Bed, Rajasthan: *Intrapunctisporis, Lygodiumsporites*, *Foveotriletes, Monolites, Polypodiisporites, Palmidites, Proxapertites, Assamialetes, Tricolporopollis, Densiverrupollenites*, etc. In addition to this the Therria assemblage possesses many dinoflagellate cysts. The palynofloral assemblages of Palana beds and Therria Formation have very few elements in common. Sah and Kar (1974) assigned a Lower Eocene age to the Palana beds.

Kutch

Palynological studies on the Lower Tertiary sediments of Kutch have been carried out by Mathur (1963, 1966), Venkatachala and Kar (1968, 1969a, 1969b), Sah and Kar (1969, 1970), Kar and Saxena (1976), and Saxena (1978, 1979).

Saxena (1978, 1979) reported a rich palynological assemblage from the Matanomadh Formation, Kutch (Palaeocene), comprising 45 genera assignable to 86 species. Of these, 14 genera and 27 species belong to pteridophytes, 3 genera and 3 species belong to gymnosperms and 28 genera and 56 species belong to angiosperms. Palynofossils common between the Matanomadh and Therria formations are: *Cyathidites australis, Lygodiumsporites eocenicus, Todisporites major, Dandotiaspora dilata, D. telonata, Intrapunctisporis, Osmundacidites, Polypodiisporites mawkmaensis, Couperipollis wodehousei, C. brevispinosus, C. robustus, Liliacidites, Palmidites maximus, Palmaepollenites, Proxapertites* and *Tricolpites*.

The palynotaxa present in the Matanomadh Formation but absent in the Therria Formation are: *Dictyophyllidites, Leptolepidites, Foveosporites, Lycopodiumsporites, Cicatricosisporites, Polypodiaceaesporites, Dracaenoipollis, Verrutricolpites, Psilastephanocolpites, Striatricolporites, Meliapollis, Triorites, Triporopollenites, Sonneratioipollenites* and *Pseudonothofagidites*. The palynofossils which are present in the Therria Formation but absent in the Matanomadh Formation are: *Assamialetes emendatus, Tricolporopollis, Foveotriletes, Monolites*, etc. In addition to this many dinoflagellate cyst genera occurring in the Therria Formation are also not represented in the Matanomadh assembalge. A comparative study reveals that the palynofloral assemblages from Therria and Matanomadh Formation are closely comparable.

The palynological assemblage from the Naredi and Harudi formations, Kutch (Lower-Middle Eocene), described by Kar (1978), is also not closely comparable to the present assemblage. Very few elements, viz., *Cyathidites, Polypodiisporites, Palmaeopollenites, Couperipollis, Proxapertites* and *Dandotiaspora* are common among the Naredi, Harudi and Therria assemblages.

Jain and Tandon (1981) described a palynological assemblage from the Middle Eocene sediments of Kutch establishing five informal zones within it. This assemblage is not closely comparable to the present one as only a few elements, viz., *Operculodinium centrocarpum, Homotryblium plectilum, Adnatosphaeridium vittatum, Polysphaeridium subtile* and *Cordosphaeridium* are common to both the assemblages.

Cambay Basin

The palynological reports from the Cambay Basin have been published by Varma and Dangwal (1964), Venkatachala and Chowdhary (1977), Rawat, Mukherjee and Venkatachala (1977), Mathur and Chowdhary (1977) and Mathur, Juyal and Chopra (1977). The palynofloral assemblage from the Kadi Formation, Cambay Basin (Venkatachala & Chowdhary, 1977) is not closely comparable to the present assemblage. However, the following elements are common to both the assemblages: *Lygodiumsporites, Biretisporites, Verrucatosporites, Schizaeoisporites, Palmaepollenites, Liliacidites, Proxapertites* and *Tricolpites*. The palynotaxa present in the Kadi Formation but absent in the present assemblage are: *Polypodiaceaesporites, Arecipites, Mauriidites, Spinizonocolpites, Psilodiporites, Retitricolpites, Margocolporites, Rhoipites, Cupuliferoipollenites* and *Marginipollis*. The palynofossils present in the Therria and Kopili assemblages but not recorded from the Kadi Formation are: *Cyathidites, Intrapunctisporis, Couperipollis, Assamialetes, Tricolporopollis, Todisporites, Palmidites* and *Lakiapollis*. Besides, many dinoflagellate cyst genera recorded in the present assemblage are also absent in the Kadi Formation. Venkatachala and Chowdhary (1977) assigned a Lower Eocene age to the Kadi Formation.

The palynological assemblage from the Kalol Formation, Cambay Basin (Mathur & Chowdhary, 1977) is also not much comparable to the present assemblage. The following palynotaxa are common to both the assemblages: *Lygodiumsporites, Polypodii-sporites, Schizaeoisporites, Osmundacidites, Striatriletes (Magnastriatites), Palmaepollenites, Retitrescolpites, Proxapertites* and *Liliacidites*. The palynotaxa present in the Kalol Formation but not represented in the present assemblage are: *Gleicheniidites, Alsophilidites, Lycopodiumsporites, Baculatisporites, Mauritidites, Psilatricolpites, Anacolcidites, Cupuliferoipollenites, Bombacacidites, Rhoipites, Acanthacidites, Araliaceoipollenites, Margocolporites*, etc. Forms recorded in the present assemblage but absent in the Kalol assemblage are: *Intrapunctisporis, Todisporites, Assamialetes, Tricolporopollis, Couperipollis, Palmidites, Tricolpites*, etc.

Cauvery Basin

The palynological studies on the Palaeocene-Eocene sediments of the Cauvery Basin have been carried out by Venkatachala and Rawat (1972). The following palynotaxa are common to both the assemblages: *Lygodiumsporites, Schizaeoisporites, Proxapertites, Couperipollis, Palmaepollenites, Liliacidites, Tricolpites* and *Myricipites*. The palynotaxa present in the Cauvery basin but absent in the present assemblage are: *Laevigatosporites, Spinainaperturites, Psilodiporites, Marginipollis, Palaeocaesalpiniaceaepites, Margocolporites, Rhoipites, Caprifoliipites*, etc.

The palynotaxa occurring in the present assemblage but absent in the Cauvery Basin assemblage are: *Cyathidites, Intrapunctisporis, Dandotiaspora, Todisporites, Osmundacidites, Assamialetes, Palmidites, Tricolporopollis, Lakiapollis*, etc.

Bengal Basin

Baksi (1972) carried out a detailed palynostratigraphic work on the Upper Mesozoic and Tertiary succession of the Bengal Basin dividing it into seven palynological zones.

The sediments in the Bengal Basin range from Middle Cretaceous to Plio-Pleistocene in age. The Zone II and Zone III are of Palaeocene to Early Eocene and Middle to Late Eocene ages respectively. The Zone II and Zone III have some palynofossils which also occur in the present assemblage. These are: *Assamialetes emendatus, Palmaepollenites* and *Couperipollis*. A comparative study reveals that the Bengal Basin palynoassemblage is not comparable to the present assembalge except for the common occurrence of a few elements.

Assam Basin

The palynological studies in the Lower Tertiary sediments of Assam and Meghalaya have been carried out by Biswas (1962), Baksi (1962), Sah and Dutta (1966, 1968, 1974), Dutta and Sah (1970), Sah, Kar and Singh (1970), Salujha, Kindra and Rehman (1972, 1974), Salujha, Rehman and Kindra (1973), Sah and Singh (1974), Sein and Sah (1974), Singh (1977a, 1977b), Singh and Tiwari (1979), Dutta and Jain (1980) and Mehrotra (1981). Dutta and Sah (1970) described a rich palynological assemblage from the Cherra Formation, Meghalaya. It comprises 49 genera assignable to 103 species. Out of this 18 genera and 34 species belong to pteridophytes, one genus and one species to gymnosperm and 27 genera and 68 species belong to angiosperms. The following palynotaxa are common between the Cherra and Therria assemblages: *Cyathidites, Lygodiumsporites eocenicus, Foveotriletes pachyexinous, Dandotiaspora dilata, Polypodiisporites, Monolites mawkmaensis, Schizaeoisporites, Assamialetes emendatus, Couperipollis brevispinosus, C. wodehousei, Liliacidites microreticulatus, Palmaepollenites communis, Proxapertites assamicus, Tricolpites, Sciadopityspollenites, Tricolporopollis rubra*, etc.

The palynotaxa recorded in the Cherra Formation but absent in the present assemblage are: *Stereisporites, Lycopodiumsporites, Sestrosporites, Retipilonapites, Polycolpites, Nyssapollenites, Triporopollenites, Meliapollis, Foveosporites, Microreticulatisporites, Foraminisporis*, etc. The palynomorphs present in the Therria Formation but not represented in the Cherra Formation are: *Intrapunctisporis, Dandotiaspora telonata, Todisporites, Palmidites plicatus*, etc. Besides these many dinoflagellate cyst genera recovered from the Therria Formation are also absent in the Cherra Formation. It is observed that the Therria and Cherra assemblages are closely comparable. The Cherra Formation is of Palaeocene age (Dutta & Sah, 1970).

The palynological assemblage from the Tura Formation, Meghalaya described by Singh (1977a) comprises 53 spore-pollen genera referable to 89 species. Out of these, 19 genera and 29 species belong to pteridophytes and 34 genera and 69 species belong to angiosperms. The palynotaxa common to the Tura and Therria assemblages are: *Cyathidites, Lygodiumsporites eocenicus, Foveotriletes pachyexinous, Dandotiaspora dilata, D. telonata, Monolites discordatus, Monolites mawkmaensis, Assamialetes emendatus, Couperipollis brevispinosus, C. wodehousei, Liliacidites microreticulatus, Palmaepollenites communis, Proxapertites assamicus, Liliacidites major, L. giganticus, Palmidites maximus*, etc. The palynotaxa occurring in the Tura Formation but absent in the Therria Formation are: *Stereisporites, Lycopodiumsporites, Retipilonapites, Polycolpites, Nyssapollenites, Triporopollenites, Triorites, Meliapollis, Droseridites, Pseudonothofagidites*, etc. The palynomorphs present in the Therria Formation but absent in the Tura Formation are: *Intrapunctisporis, Sciadopityspollenites, Tricolpites alveolatus, Retisyncolporites, Tricolporopollis rubra*, etc. It is apparent from the above mentioned comparative study that the Tura and Therria assemblages are closely comparable. Sah and Singh (1974) assigned a Palaeocene age to the lower part of the Tura Formation.

Dutta and Jain (1980) recorded a rich dinoflagellate cyst assemblage from the Upper Palaeocene-Upper Eocene sediments of the Jaintia Hills, Meghalaya. The forms common to both the assemblages are as follows: *Turbiosphaera, Cordosphaeri-*

dium exilimurum, C. multispinosum, Operculodinium centrocarpum, O. major, Homotryblium plectilum, Apectodinium homomorphum and *A. parvum.* The dinoflagellate cysts occurring in the assemblage described by Dutta and Jain (1980) but absent in the present assemblage are : *Thalassiphora Distatodinium, Samlandia, Araneosphaera, Hystrichokolpoma, Spiniferites* and *Glaphyrocysta.* The dinoflagellate cysts occurring in the present assemblage but absent in the assemblage described by Dutta and Jain (1980) are: *Gonyaulacysta, Apteodinium, Prolixosphaeridium, Polysphaeridium, Adnatosphaeridium* and *Codoniella.* A comparative study shows that the two assemblages are closely comparable.

Dandot (Pakistan)

Vimal (1952) described a palynological assemblage from Dandot Lignite, Pakistan comprising 29 spore/pollen types assignable to 10 genera. The forms appearing to be common between the two assemblages are: *Dandotiaspora dilata* (=*Trilites* spm. 6), *Dandotiaspora telonata* (=*Trilites* spm. 6) and *Lygodiumsporites eocenicus* (=*Trilites* spm. 4). The common occurrence of these forms favours the dating of Dandot Formation as Palaeocene.

Australia and New Zealand

The Lower Tertiary palynological assemblage of New Zealand (Couper, 1953, 1958) and Australia (Cookson, 1946, 1947; Cookson & Pike, 1954) are dominated by the pollen grains of *Nothofagus, Cupenidites, Podocarpus,* etc. These forms are absent in the present assemblage. However, some pollen grains, viz., *Palmidites maximus, Cyathidites australis, Tricolpites alveolatus, Couperipollis* and *Liliacidites* are common between the New Zealand and Therria assemblages. Wilson (1967) described *Apectodinium (Wetzeliella)* from the Palaeocene-Eocene strata of New Zealand. This form has also been recorded in the Therria assemblage. The Australian Palaeocene-Eocene dinoflagellate cyst assemblages are dominated by *Apectodinium (Wetzeliella)* and *Deflandrea.* The genus *Deflandrea* is not present in the present assemblage.

A world wide palynofloral comparison of the Palaeocene-Eocene assembalges reveals that the present assemblage is partially comparable to the palynoflora of south-east Asian countries, Austrialia, New Zealand and western European countries. The dinoflagellate cyst assemblage is strikingly similar to the one described from the London Clay (Eocene) of Britain.

QUANTITATIVE ANALYSIS OF THE PALYNOFLORA

The percentage frequency of various palynotaxa has been determined by counting 200 palynofossils per sample but in some cases where the yield was poor 150 palynofossils were counted. Out of 59 genera and 92 species, 26 genera assignable to 48 species were found to be stratigraphically significant.

The quantitative analysis of the palynofloral assemblage reveals that the lower part of the Therria Formation is dominated by the pteridophytic spores, particularly the genus *Lygodiumsporites.* The middle part of the Therria Formation is characterized by the predominance of angiospermic pollen grains, whereas its upper part is richly dominated by the dinoflagellate cysts. The Sylhet Limestone has yielded very few palynofossils, hence, it has not been possible to observe any palynofloral change within this formation.

In the Kopili Formation the lower part is dominated by the dinoflagellate cysts while the upper part is characterized by the high frequency of pteridophytic spores. The genus *Striatriletes* is characteristically associated with this Formation.

On the basis of qualitative and quantitative analyses of the palynoflora recovered from the Palaeocene-Eocene sediments exposed along the road between Jowai and Sonapur, Meghalaya, Tripathi and Singh (1984b) established five palynozones which are given below in ascending order of stratigraphy (Text-fig. 1).

KOPILI FORMATION:

5. *Densiverrupollenites eocenicus* Cenozone Tripathi & Singh (1984b)
4. *Turbiosphaera proximata* Cenozone Tripathi & Singh (1984b)

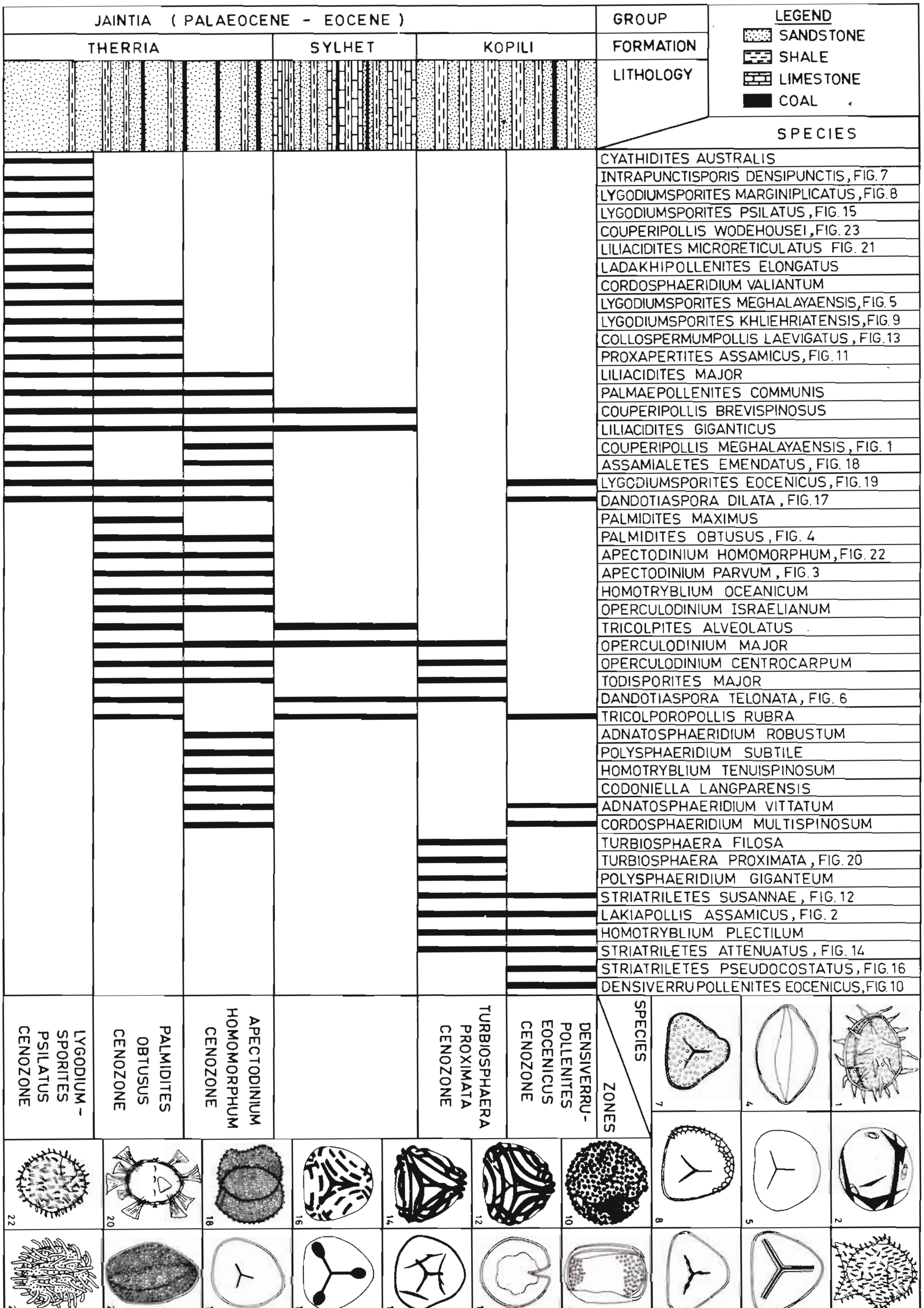
THERRIA FORMATION:

3. *Apectodinium homomorphum* Cenozone Tripathi & Singh (1984b)
2. *Palmidites obtusus* Cenozone Tripathi & Singh (1984b)

Lygodiumsporites psilatus Cenozone Tripathi & Singh (1984b)

PALAEOECOLOGY, PALAEOGEOGRAPHY AND ENVIRONMENT OF DEPOSITION

The palynological assemblage recovered from the Palaeocene-Eocene sediments, exposed along the road between Jowai and Sonapur, Meghalaya is represented by many pteridophytic and angiospermic families which are presently restricted to the tropical to subtropical regions of the world.



Text-figure 1—Palynological zonation of the Palaeocene-Eocene strata (Jawai-Sonapur), Meghalaya (Litholog not to the scale).

These families are: Lycopodiaceae, Polypodiaceae, Schizaeaceae, Cyatheaceae, Parkeriaceae, Palmae, Liliaceae, Nymphaeaceae, Nelumboniaceae, Oleaceae and Myricaceae. Besides, other families represented in the assemblage are cosmopolitan in the present day distribution.

Lakhanpal (1970), on the basis of the palaeobotanical evidences, envisaged that the Palaeogene flora in the Indian Subcontinent was predominantly tropical. The fact that tropical to subtropical vegetation was existing in the nearby areas of Assam and Meghalaya has been confirmed by the palynological studies (Dutta & Sah, 1970; Sah & Singh, 1974; Singh, 1977a, b). The present palynological evidences also indicate that the area in the vicinity of Meghalaya was supported by a tropical to subtropical flora.

The climate during the deposition of the investigated Palaeocene-Eocene sediments of Meghalaya was warm and humid. This view is supported by the presence of many fungal remains in the palynological assemblage recovered from this area. Amongst fungal remains the fruiting bodies like *Callimothallus, Phragmothyrites* and *Paramicrothallites*, belonging to the epiphyllous fungi, are very common. The frequent occurrence of these fruiting bodies suggests that a warm and humid climate prevailing during that period supported a vegetation favourable for the growth of the epiphyllous fungi. A similar palaeoclimate has been deduced for the Cherra (Dutta & Sah, 1970) and Tura formations (Sah & Singh, 1974).

As mentioned earlier the Tertiary sediments in the area of investigation rest unconformably over the Precambrian Shillong Group. This indicates that the area remained a high ground during the Palaeozoic and Mesozoic times but finally got submerged into the water by the close of the Mesozoic Era paving a way for the deposition of Tertiary sediments.

Singh (1977b) mentioned that the Garo, Khasi, Jaintia and Mikir Hills, comprising the Assam autochthon, were initially a north-easterly extension of the Peninsular India and they got detached from the mainland sometimes during the Cretaceous Period. The break up of the Gondwanaland during that time upset the isostatic balance of the region causing various earth movements. The Dauki Tear Fault, which crosses the Jowai-Badarpur Road near Sonapur, appears to be attributed to one of these movements. These earth movements also seem to be responsible for the subsidence of the southern slopes of the Garo, Khasi and Jaintia Hills (Singh, 1977b).

It appears that the gradual sinking of the southern slope of the Jaintia Hills, Meghalaya was probably associated with the rise of the Shillong Plateau. This caused the invasion of the sea in the southern part of the Jaintia Hills. Simultaneously the area started withdrawing from the Shillong Plateau (Singh, 1977b). The continued subsidence of the southern slope of the Shillong Plateau is indicated by the huge thickness of the strata exhibited by the Sylhet Limestone and Kopili formations. The transgression of the sea in this area is evidenced by the presence of dinoflagellate cysts in these sediments. The Palaeocene-Eocene sediments exposed along the road between Jowai and Sonapur, Meghalaya appear to have been deposited under the brackish water to shallow marine environments.

The oldest sediments of the Therria Formation, represented by the *Lygodiumsporites psilatus* Cenozone, is characterized by the dominance of the pteridophytic spores (47%) and angiospermic pollen grains (38%). The dinoflagellate cysts are represented by 7 per cent of the total assemblage of the cenozone. The *Palmidites obtusus* Cenozone of the Therria Formation is dominated by the angiospermic pollen grains (47%) and pteridophytic spores (24%). The dinoflagellate cysts are represented by 25 per cent of the total cenozone assemblage. The youngest palynological zone of the Therria Formation, viz., *Apectodinium homomorphum* Cenozone is dominated by the dinoflagellate cysts (78%). Here the angiospermic pollen grains and the pteridophytic spores are represented by 17 per cent and 4 per cent respectively.

Therefore, it is clear that the older sediments of the Therria Formation exhibit comparatively low percentage frequency of the dinoflagellate cysts while, its younger sediments are characterized by a very rich representation of the dinoflagellate cysts. This perceptible change in the palynological spectrum of the Therria Formation indicates that the sediments representing the *Lygodiumsporites psilatus* and *Palmidites obtusus* cenozones were deposited under the brackish water estuarine conditions, whereas the sediments representing the *Apectodinium homomorphum* Cenozone were deposited under shallow marine conditions.

In the Kopili Formation the older *Turbiosphaera proximata* Cenozone is characterized by the dominance of the dinoflagellate cyst assemblage (44%). The pteridophytic spores and angiospermic pollen grains are collectively represented by 16 per cent of the total assemblage. The youngest palynozones of the Kopili Formation, viz., *Densiverrupollenites eocenicus* Cenozone exhibits the dominance of the pteridophytic spores (40%) and angiospermic pollen grains (7%) over the dinoflagellate cysts (10%).

The palynological spectrum of the Kopili Formation indicates that the sediments representing the *Turbiosphaera proximata* Cenozone were deposited under shallow marine conditions, while the sediments representing the *Densiverrupollenites eocenicus* Cenozone were deposited under brackish water estuarine conditions. The Kopili Formation sediments appear to have been deposited under the shallow sea which was subjected to frequent oscillations. This view is supported by the alternate deposition of the shales and sandstones in this formation (Dutta & Jain, 1980).

Coastal conditions prevailing during the time of deposition of the investigated Palaeocene-Eocene sediments is proved by the rich representation of the pollen grains resembling those of the family Palmae. These pollen grains are: *Palmidites maximus, P. obtusus, P. plicatus, Palmaepollenites communis, Couperipollis brevispinosus, C. meghalayaensis, C. wodehousei* and *C. rarispinosus*. The fresh water elements represented in the palynoassemblage, viz., *Proxapertites assamicus* and *Assamialetes emendatus* appear to have been transported to the near-shore areas through the fresh water channels which might have had connections with the sea then. The coastal vegetation seems to have been followed by the swamp vegetation. The presence of swamp vegetation is supported by the pollen grains of the family Chenopodiaceae, viz., *Polyporina* sp.

AGE OF THE THERRIA FORMATION

The earlier workers like Oldham (1863), Medlicott (1869), La Touche (1887), Medlicott and Blanford (1893), and Pinfold (1919) assigned a Cretaceous age to the Tura Formation (=Therria and Cherra formations). Evans (1932), while dealing with lithostratigraphy of Tertiary sediments in Assam assigned a Lutetian (Middle-Eocene) age to most of the Jaintia Group sediments. The basal sediments of this group are represented by Therria Formation. Fox (1936) also expressed the view that the Tura Formation (=Therria Formation) may belong to the Lower Tertiary age. The Tertiary age for these sediments was later confirmed by Jacob (1949) and Pascoe (1963), Sah and Dutta (1966, 1968) and Dutta and Sah (1970).

Langpar Formation, which represents lowermost Tertiary sediments in Assam Basin, is overlain by a coal measure sequence. This sequence has been named as Therria Formation along the Umshoryngkew River, Cherra Formation in Cherrapunji Plateau, Tura Formation in Garo Hills and Mikir Formation in Mikir Hills. Dutta and Sah (1970) and Sah and Dutta (1974) recovered a rich palynological assemblage from Cherra Formation and proposed Palaeocene age for it. The Palaeocene age for this formation was indicated by these authors on the basis of the following evidences.

1. Cherra Formation is disconformably underlain by Langpar Formation which is supposed to be Danian in age. It shows the presence of foraminifera like *Globigerina pseudobulloides* and *Globigerina triloculinoides*, etc. These forms are characteristic of the Danian age.
2. Cherra Formation is conformably overlain by the Lakadong Limestone Member of the Sylhet Limestone. This member has yielded typical Ranikot (Lower Eocene) fossils like *Nummulites thalicus, N. sindensis, Lockhartia hamei, Miscellania miscella, M. meandrina, Operculina* cf. *canalifera, Alveolina* sp., *Orbitospiphon tibetica* and *Discocyclina ranikotensis*.

Therefore, the Cherra Formation between the underlying Langpar Formation (Danian) and overlying Lakadong Limestone Member (Lower Eocene) was dated by Dutta and Sah (1970) as Palaeocene. The palynofossils common to the Therria Formation and Cherra Formation are: *Cyathidites australis, Lygodiumsporites eocenicus, Corrugatisporites, Foveotriletes pachyexinous, Monolites mawkmaensis, Polypodiisporites mawkmaensis, Schizaeoisporites, Sciadopityspollenites, Assamialetes emendatus, Trifossapollenites constatus, Couperipollis (Monosulcites) brevispinosus, C. (monosulcites) rarispinosus, Liliacidites microreticulatus, Proxapertites (Schizosporis) assamicus, Retitrescolpites, Myricipites* and Formation, *Polyporina*.

It is apparent from comparisons of the palynofloras of Therria and Cherra formations that many spore and pollen genera are common between the two. Hence, it is logical to assume that both these formations are time equivalents. Therefore, on the basis of the palynological similarities between the Cherra and Therria formations, Palaeocene age has been assigned to the Therria Formation.

Palaeocene dating of Therria Formation is further supported by the fact that, its youngest palynozone, viz., *Apectodinium homomorphum* Cenozone is characterized by the presence of *Apectodinium homomorphum* and *A. parvum*. These forms are considered to be characteristic of Upper Palaeocene age (Harland, 1979). The presence of these palynofossils in various Upper Palaeocene sediments has been reported by Cookson (1967), Wilson (1967) and Chateauneuf and Gruas-Cavagnetto (1978).

Sah and Singh (1974) correlated three lower palynozones of Tura Formation, viz., *Assamialetes emendatus* Cenozone, *Dandotiaspora telonata* Cenozone and *Palmidites plicatus* Cenozone with the three palynozones of Cherra Formation, viz., *Proxapertites crassimurus* Cenozone, *Araliaceoipollenites reticulatus* Cenozone and *Tricolpites reticulatus* Cenozone respectively and assigned a Palaeocene age to these Tura sediments.

AGE OF KOPILI FORMATION

As mentioned earlier no detailed palynostratigraphical work has been carried out on the Kopili Formation, Meghalaya, on the basis of which any precise date could be given to this formation. Samanta (1968) on the basis of presence of small foraminifera like *Pellatispira* and absence of characteristic Middle Eocene forms like *Assilina, Alveolina, Dictyoconoides* and *Lockhartia* confirmed an Upper Eocene age for this formation. Sein and Sah (1974) and Dutta and Jain (1980) did not assign any age to Kopili Formation. Their palynological assemblages lack any Upper Eocene stratigraphical marker. The present Kopili assemblage also lacks any Upper Eocene marker form. Archangelsky (1969) described *Turbiosphaera* from the Rio-Turbio (Lower Eocene-Upper Eocene) of Santa Cruz Province, Argentina. This form has also been recovered from Lower palynological zone of Kopili Formation, viz., *Turbiosphaera proximata* Cenozone Therefore, occurrence of *Turbiosphaera* in Kopili Formation may prove helpful in its dating at a later date by carrying out detailed study of this genus up to the specific level. However, Kopili Formation is dated as Eocene on palaeontological evidences.

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