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Palynological investigation of the Kherapara Formation (Oligocene) exposed along Tura-Dalu Road near Kherapara, West Garo Hills District, Meghalaya, India

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ABSTRACT

Rao MR 2000. Palynological investigation of the Kherapara Formation (Oligocene) exposed along Tura-Dalu Road near Kherapara, West Garo Hills District, Meghalaya, India. Palaeobotanist 49(2) : 293-309.

A diversified palynofloral assemblage has been recovered from the Kherapara Formation (Oligocene) exposed along Tura-Dalu Road near Kherapara, West Garo Hills District, Meghalaya, India. The palynoflora is represented by 53 genera and 77 species of algal and fungal remains, pteridophytic spores and gymnospermous and angiospermous pollen. Of these, three species, viz., *Garotriletes kheraparaensis*, *Striatriletes tetradites* and *Echistephanocolpites quadrangularis* have been proposed as new. Reworked Permian and Cretaceous palynofossils (10 genera and 11 species) have also been recorded. The assemblage is dominated by pteridophytic spores followed by angiospermous and gymnospermous pollen. Based on palynofossil distribution, the Kherapara Formation is divisible into two cenozones, viz., *Polyadopollenites sahii* Cenozone and *Striatriletes* spp. Cenozone which can be recognised by their characteristic and restricted palynotaxa. On the basis of affinity with the modern plant families represented in the assemblage and dominance of pteridophytic spores, a tropical-subtropical (warm-humid) climate has been suggested. The assemblage contains a mixture of ecological groups such as lowland, fresh water swamp and water edge, montane, mangrove and back-mangrove and sandy beach elements. The palynoflora indicates a coastal marine depositional environment of deposition having fresh water connections with swamps and ponding conditions nearby.

Key-words—Palynology, palynostratigraphy, palaeoecology, Kherapara Formation, Oligocene, Meghalaya (India).

भारत के मेघालय प्रान्त के पश्चिमी गारो हिल्स जनपद में खेरापाड़ा के निकट तूरा-डालू रोड के आस-पास अनावरित खेरापाड़ा शैलसमूह (ओलिगोसीन युगीन) का परागाणविक अन्वेषण

मुलागलापल्ली रामचन्द्र राव

सारांश

भारत के मेघालय प्रान्त के पश्चिमी गारो हिल्स जनपद में खेरापाड़ा के निकट तूरा-डालू रोड के आस-पास अनावरित खेरापाड़ा शैलसमूह (ओलिगोसीन युगीन) से एक वैविध्यमय परागाणु वनस्पतिजात समुच्चय की खोज की गई है. यह परागाणु वनस्पतिजात शैवाल एवं कवकीय अवशेषों टेरिडोफ़ाइटी बीजाणुओं तथा अनावृतबीजी एवं आवृतबीजी परागकणों के 53 वंशों

तथा 77 प्रजातियों द्वारा निरूपित है. इनमें से *गारोट्राइलिटीज़ खेरापाड़ाएन्सिस, स्ट्रायाट्रायलिटीज़ टेट्राडायटीज़* एवं *एकीस्टीफेनोकोलपाइटीज़ क्वाड्रैंगुलेरिस* नामक तीन प्रजातियाँ नई प्रजातियों के रूप में प्रस्तावित की गई हैं. परमियन एवं क्रिटेशस युगीन परागाणु पादपाश्म (10 वंश एवं 11 प्रजातियाँ) भी अंकित किए गए हैं. समुच्चय में टेरिडोफ़ाइटी बीजाणुओं की प्रमुखता है, जिसके पश्चात क्रमशः आवृतबीजी तथा अनावृतबीजी परागकण आते हैं. परागाणु पादपाश्मों के वितरण के आधार पर खेरापाड़ा शैलसमूह को दो समुच्चय मण्डलों *पालीएडोपोलेनाइटीज़ साहाइ* समुच्चय मण्डल एवं *स्ट्रायाट्रायलिटीज़* प्रजाति समुच्चय मण्डल में विभाजित किया गया है, जिन्हें उनके अभिलाक्षणिक तथा प्रतिबन्धित परागाणु वर्गकों के आधार पर अभिनिर्धारित किया जा सकता है. समुच्चय में निरूपित विद्यमान पादप कवकीय अवशेषों की प्रचुरता के आधार पर एक उष्ण-उपोष्णकटिबन्धीय (ऊष्म-आर्द्र) जलवायु प्रस्तावित की जाती है. समुच्चय निम्नभूमि, ताजे जल अनूप एवं जल तट, पर्वतीय मैंग्रोव एवं पश्च मैंग्रोव तथा बलुई पुलिन तत्व जैसे पारिस्थितिकीय समूहों के सम्मिश्र को निरूपित करता है. परागाणु वनस्पतिजात अनूप के साथ ताजे जलीय संयोजन युक्त निक्षेप के समुद्रतटीय निक्षेपणीय पर्यावरण तथा आस-पास जलावरोधन स्थितियों का संकेत करता है.

संकेत शब्द—परागाणुविज्ञान, परागाणुस्तरिकी एवं सहसम्बन्धन, खेरापाड़ा शैलसमूह, ओलिगोसीन, मेघालय, भारत.

INTRODUCTION

THE Kherapara Formation was instituted by Chakraborty (1972) for a huge thickness of finely bedded, thin alternations of shale and fine grained clayey sands. The type section is exposed at the village Kherapara (25° 20' 40" N : 90° 46' 40" E). This formation conformably overlies the shales of the Rewak Formation and is unconformably overlain by the Boldamgiri Formation (Fig. 1). The Kherapara Formation was further subdivided into two members; the lower one is arenaceous with finely bedded alternations and thick sandstone at the base and is named as Darik Member, named after the village Darik (25° 13' 40" N : 90° 25' 48" E). The upper Inolgiri Member is thinly bedded but more argillaceous, grading to shales at places. This is best exposed in the Rongra River Section near the village Inolgiri (25° 13' 01" N : 90° 47' 40" E) is also thinly bedded but more argillaceous (Fig. 2). The lithostratigraphic succession of the area is summarized below (Fig. 3).

Arenaceous foraminiferas like *Trochammina, Miliammina, Cyclommina* assemblage has been recovered from the shales collected from the road section near the Kherapara is correlatable with that of the Barail Group (Oligocene) of the type area in the Barail Range (Chakraborty & Baksi, 1972).

Detailed palynological and palynostratigraphical studies have been carried out on the Palaeocene-Eocene sediments of North-East India, but only a few papers have been published on the palynological studies of Oligocene sediments (Baksi, 1962, 1965, 1974; Salujha *et al.*, 1972, 1974; Rao, 1986; Saxena *et al.*, 1987; Rao & Singh, 1987, Rao *et al.*, 1985, Misra *et al.*, 1996). The present study is an another attempt to record palynoflora from the Kherapara Formation (Oligocene) exposed along Tura-Dalu Road near Kherapara, West Garo Hills District, Meghalaya. The palynological data generated have been utilized in stratigraphical and palaeoecological interpretations.

MATERIAL AND METHODS

The samples were collected from the Kherapara Formation exposed along Tura-Dalu Road near Kherapara, West Garo Hills District, Meghalaya. Sixty samples were collected from the carbonaceous shales. Of these, 40 samples yielded palynofossils. Samples were treated with HCl, HF and HNO_3 followed by 5% solution KOH. The slides were prepared in polyvenyl alcohol and mounted in Canada balsam. An Olympus BH-2 microscope has been used for the study and photomicrography. The material, slides and negatives have been deposited in the Museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

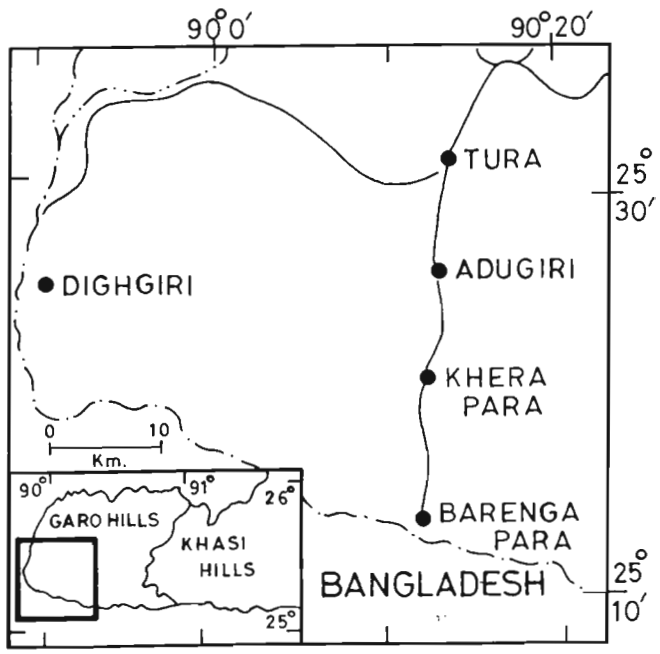

Fig. 1—Locality map showing area of study.

PALYNOFLORAL ASSEMBLAGE

Dinoflagellate cysts
Polysphaeridium subtile Davey & Williams *in* Davey *et al.*, 1966
Achomosphaera sp.
Cribroperidium sp. (Pl. 2, Fig. 12)

Fungal remains
Phragmothyrites eocaenica Edwards emend. Kar & Saxena, 1976
Parmathyrites indicus Jain & Gupta, 1970
P. ramanujamii Singh *et al.*, 1986
Trichothyrites setiferus (Cookson) Saxena & Misra, 1990
Kutchiathyrites eccentricus Kar, 1979
Inapertisporites sp.

Pteridophytic spores
Lygodiumsporites lakiensis Sah & Kar, 1969 (Pl. 2, Fig.2)
L. eocenicus Dutta & Sah, 1970
L. pachyexinus Saxena, 1978
Todisporites major Couper, 1958
T. minor Couper, 1958 (Pl.2, Fig. 4)
Cyathidites australis Couper, 1953
Foveotriletes garoensis Saxena & Rao, 1996
**Foveosporites* sp. (Pl. 1, Fig. 19)
Biretisporites convexus Sah & Kar, 1969
B. oligocenicus Rao & Singh, 1987 (Pl.2, Fig. 1)
B. meghalayaensis Rao & Singh, 1987
Dictyophyllidites granulatus Saxena, 1978
**Dictyophyllidites* sp. A (Pl .1, Fig.1)
**Dictyophyllidites* sp. B (Pl. 2, Fig. 3)
**Garotriletes kheraparaensis* sp.nov. (Pl.1, Figs 17-18).
Striatriletes susannae van der Hammen emend. Kar, 1979 (Pl. 2, Fig. 18)
S. punctatus Saxena & Rao, 1996
S. pachyexinus Rao & Singh, 1987
S. multicostatus Kar, 1979
**S. tetradites* sp. nov. (Pl. 2, Fig. 17)
Crassoretitriletes vanraadshooveni Germeraad *et al.*, 1968
Corrugatisporites formosus Dutta & Sah, 1970
Pteridacidites vermiverrucatus Sah, 1967
**Foveomonoletes* sp. (Pl. 1, Fig. 4)
Cheilanthoidspora monoleta Sah & Kar, 1974 (Pl. 1, Fig. 9)
Polypodiaceaesporites major Saxena, 1978
Polypodiisporites mawkmaensis Dutta & Sah, 1970
P. miocenicus Rao & Ramanujam, 1978
P. formosus Salujha *et al.*, 1972
P. speciosus Sah, 1967
P. tuberculensis (Baksi) Rao & Singh, 1987
**Polypodiisporites* sp. (Pl. 1, Fig. 2)
Pilamonoletes excellensus Kar, 1991 (Pl. 1, Fig. 11)

Gymnospermous pollen
Podocarpidites meghalayaensis Rao, 1986
Pinuspollenites foveolatus Rao, 1986 (Pl. 1, Fig. 12)

Angiospermous pollen
Assamiapollenites ghoshii Singh & Saxena, 1984
Inaperturopollenites punctatus (Saxena) Saxena & Bhattacharyya, 1987
**Inaperturopollenites* sp. (Pl. 2, Fig. 9)
Verrualetes assamicus Singh & Saxena, 1984
**Verrualetes* sp. (Pl. 2, Fig. 8)
Pinjoriapollis lanceolatus Saxena & Singh, 1981
Spinizonocolpites echinatus Muller, 1968 (Pl. 1, Fig. 10)
Tricolpites reticulatus Cookson ex Couper, 1953
T. matanomadhensis Saxena, 1979 (Pl. 1, Fig.15)
T. perforatus van der Hammen & Garcia de Mutis, 1965 (Pl. 2, Fig. 11)

Age	Stratigraphic unit		Lithology
Miocene	Angartoli Formation		Fine grained, nonfeldspathic, micaceous sandstone, bluish siltstone and sandy shales.
	Boldamgiri Formation		Coarse grained, gritty, feldspathic, ferruginous sandstone with carbonaceous shale.
	——— Unconformity ———		
Oligocene	Kherapara Formation	Inolgiri Member	Fine grained alternations of thinly bedded sandstone and shale.
		Darik Member	Thickly bedded sandstone and carbonaceous shale.
Pre-Oligocene	Pre-Kherapara formations		
	——— Unconformity ———		
Precambrian	Basement complex		Granite and granite gneisses

Fig. 2. Stratigraphic section of Kherapara Formation, Garo Hills, Meghalaya.

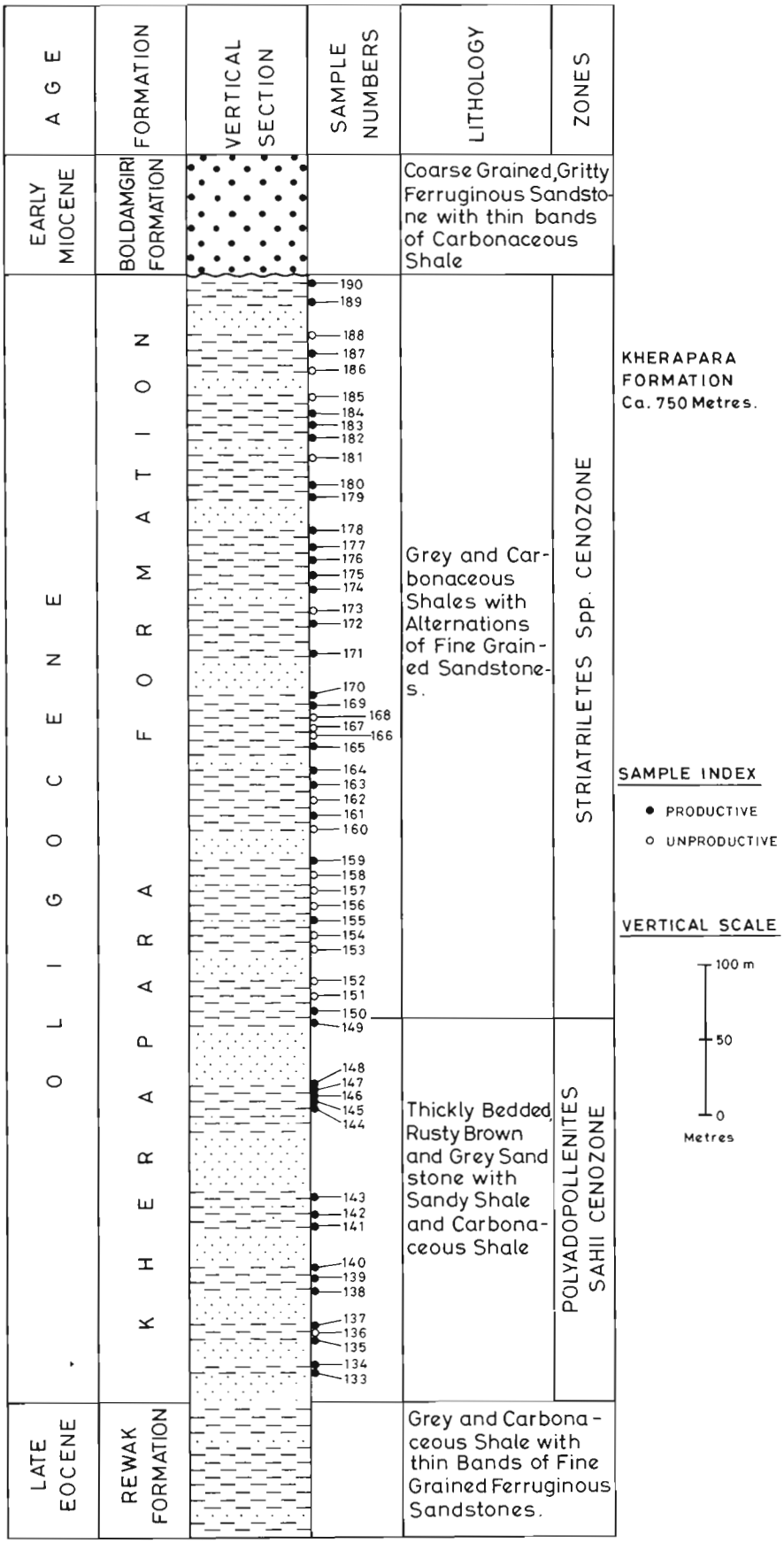

Fig. 3—Lithostratigraphic succession of the Kherapara Formation.

Warkallipollenites erdtmanii Ramanujam & Rao *in* Thanikaimoni *et al.*, 1984
Plumbaginacipites neyvelii Navale & Misra, 1979 (Pl. 2, Fig. 7)
Lakiapollis ovatus Sah & Kar, 1969 (Pl. 2, Fig. 5)
Tricolporopollis matanomadhensis (Venkatachala & Kar) Tripathi & Singh, 1985
Alangiopollis gemmatus Navale & Misra, 1979
Paleocaesalpiniaceaepites eocenica Biswas, 1962 (Pl. 2, Figs 6, 13)
Palaeosantalaceaepites ellipticus Sah & Kar, 1970
Pelliceroipollis langenheimii Sah & Kar, 1970 (Pl. 1, Fig. 16)
Marginipollis kutchensis (Venkatachala & Kar) Kar, 1978
Triangulorites bellus (Sah & Kar) Kar, 1985
Margocolporites dubius Ramanujam, 1966
Meliapollis triangulus Saxena, 1979 (Pl. 1, Fig. 4)
M. raoi Sah & Kar, 1970 (Pl. 1, Fig. 13)
Echistephanocolpites meghalayaensis Rao *et al.*, 1985
E. boldamgiriensis Saxena & Rao, 1996 (Pl. 1, Fig. 7)
**E. quadrangularis* sp. nov. (Pl. 1, Figs 5-6)
Polycolpites tertiarus (Singh *in* Sah & Singh) Saxena, 1982
*Polycolporate pollen type (Pl. 1, Fig. 3)
Ghoshiacolpites globatus (Sah & Kar) Kar, 1978
Polyadopollenites sahii Rao *et al.*, 1985 (Pl. 2, Fig. 10)
Malvacearumpollis bakonyensis Nagy, 1962 (Pl. 2, Fig. 16)
Varispinitriporites ratariaensis (Kar & Saxena) Kar, 1985
Polyporina multiporosa Kar, 1985 (Pl. 2, Fig. 14)
Clavaperiporites jacobii Ramanujam, 1966
* Pollen tetrad type (Pl. 1, Fig. 8)

Reworked spores /pollen
Striatopodocarpites sp. (Pl.2, Fig. 15)
Callialasporites trilobatus (Balme) Dev, 1961
Callialasporites sp.
Parasaccites sp. (Pl. 2, Fig. 18)
Plicatipollenites ovatus Kar, 1968
Rouseisporites sp.
Echitriletes sp.
Araucariacites sp.
Abietineaepollenites sp.
Scheuringipollenites maximus (Hart) Tiwari, 1971

Incertae sedis
Heliospermopsis ankleshvarensis (Srivastava) Saxena & Misra, 1990

Taxa with asterisk (*) mark have been either described or commented in the text. Plate and figure numbers given in the above text in parentheses refer to the illustrations of present paper.

SYSTEMATICS

Genus—DICTYOPHYLLIDITES Couper, 1958

Type species—DICTYOPHYLLIDITES HARRISII Couper, 1958

DICTYOPHYLLIDITES sp . A

Pl. 1·1

Description—Miospore subcircular. Size 79 x 78 µm. Trilete, rays distinct, reaching 2/3 radius. A distinct kyrtome present along the trilete mark. Exine 4 µm thick, laevigate.

Comparison—Dictyophyllidites harrisii Couper (1958) is distinguished from the present species by its smaller size (up to 56 µm) and longer rays extending up to the equator.

DICTYOPHYLLIDITES sp. B

Pl. 2·3

Description—Miospore subtriangular with rounded apices. Size 58 x 55 µm. Trilete, feathery, reaching almost up to apices, ends bifurcated, distinct kyrtome present along the trilete. Exine 4 µm thick, laevigate.

Comparison—Dictyophyllidites sp. B is distinct from the type species in its feathery trilete rays.

Genus—FOVEOSPORITES Balme, 1957

Type species—FOVEOSPORITES CANALIS Balme, 1957

FOVEOSPORITES sp.

Pl. 1·19

Description—Miospore subcircular. Size 104 x 93 µm. Trilete, rays extending half radius. Exine 4 µm thick, foveolate to foveoreticulate.

Comparison—Foveosporites canalis Balme (1957) differs from the present species in its smaller size and in possessing coalescent foveolae.

Genus—GAROTRILETES Singh & Singh, 1978

Type species—GAROTRILETES ASSAMICUS Singh & Singh, 1978

GAROTRILETES KHERAPARAENSIS sp. nov.

Pl. 1·17-18

Holotype—Pl. 1·18, size. 115 x 105 µm. BSIP slide no. 12316.

Type locality, horizon and age—Tura-Dalu Road Section near Kherapara, West Garo Hills District, Meghalaya; Kherapara Formation; Oligocene.

Diagnosis—Miospore triangular-subtriangular, interapical margins straight to concave, apices broadly rounded. Size 115-132 x 90-105 µm. Trilete, rays reaching up to equator, ray ends bifurcated, globular exinal thickening at ray ends. Exine thickness variable, thinner at interapical margins (4-6 µm), thicker at apices (8-10 µm), foveolate to foveoreticulate.

Comparison—The present species is closely comparable to the type species *Garotriletes assamicus* Singh & Singh (1978) in its shape and foveoreticulate exine but latter is distinguished by its smaller size (54 µm) and thinner exine

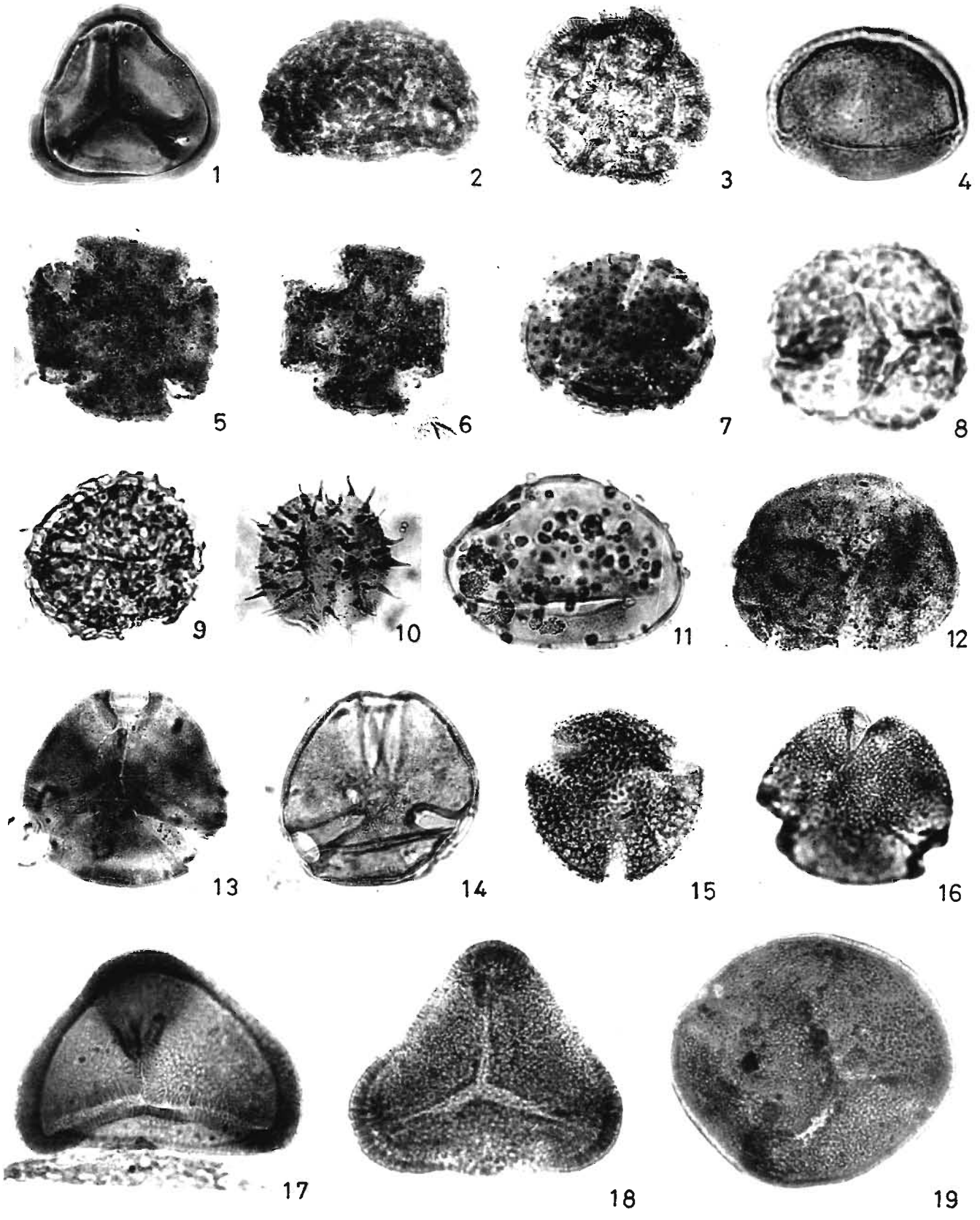

PLATE 1

(2·5 µm). *G. incompositus* Singh & Singh (1978) differs in having characteristic deltoid shape and incipient globular thickening developed at each ray end.

Genus—STRIATRILETES van der Hammen emend. Kar, 1979

Type species—STRIATRILETES SUSANNAE van der Hammen, 1956 emend. Kar, 1979

STRIATRILETES TETRADITES sp. nov.

Pl. 2·17

Holotype—Pl. 2·17, size. 104 x 92 µm, BSIP slide no. 12302.

Type locality, horizon and age—Tura-Dalu Road Section near Kherapara, West Garo Hills District, Meghalaya; Kherapara Formation; Oligocene.

Diagnosis—Miospores are in tetrad condition. Spore tetrad subtriangular with rounded apices. Size range 100-108 x 85-92 µm. Individual spore subtriangular with broadly rounded apices and convex sides. Size range 60-64 x 50-55 µm. Trilete. Exine striate, ridges sparsely placed, ridges and furrows laevigate.

Comparison—The present species is comparable to the type species *S. susannae* in its general characters but the former is differentiated by its tetrad condition of the spore.

Genus—FOVEOMONOLETES van der Hammen, 1954 ex Mathur, 1966

Type species—FOVEOMONOLETES BREVILETES Mathur, 1966

FOVEOMONOLETES sp.

Pl. 1·4

Description—Miospore bean shaped. Size 76 x 60 µm. Monolete. Exine 2 µm thick, foveolate-foveoreticulate.

Comparison—The specimen is different from the type species in its foveoreticulate ornamentation.

Genus—POLYPODIISPORITES (Potonié) Potonié, 1956

Type species—POLYPODIISPORITES FAVUS Potonié 1931 ex Potonié, 1956

POLYPODIISPORITES sp.

Pl. 1·2

Description—Miospore bean shaped. Size 90 x 58 µm. Monolete, ray indistinct due to heavy sculpture. Exine 6 µm thick, verrucate, foveolae present in between verrucae. Surface showing negative reticulum.

Comparison—The type species *Polypdiisporites favus* is distinct in its smaller size and thinner exine (3 µm thick).

Genus—ECHISTEPHANOCOLPITES Wijmstra, 1971

Type species—ECHISTEPHANOCOLPITES ECHINATUS Wijmstra, 1971

ECHISTEPHANOCOLPITES QUADRANGULARIS sp. nov.

Pl. 1·5-6

Holotype—Pl. 1.6, size. 80 x 70 µm, BSIP slide no. 12307.

Type locality, horizon and age—Tura-Dalu Road Section near Kherapara, West Garo Hills District, Meghalaya; Kherapara Formation; Oligocene.

Diagnosis—Pollen grains quadrangular in shape. Size 75-80 x 70-74 µm (including sculpture). Tetracolpate, brevicolpate, colpi 7-15 µm wide at equatorial region. Exine 2·5-4 µm thick, conate, coni sparsely placed, exine between coni pitted-reticulate.

Comparison— *Echistephanocolpites quadrangularis* sp. nov. is closely comparable to *E. echinatus* Wijmstra (1971)

←—

PLATE 1

(All photomicrographs are enlarged ca. x 500. Coordinates of the specimens refer to the stage of BH-2 Olympus microscope no. 217267).

1. *Dictyophyllidites* sp. A. Slide no. BSIP 12302, coordinates 11·6 x 130·5.
2. *Polypodiisporites* sp., Slide no. BSIP 12303, coordinates 15·5 x 133·4.
3. Polycolporate pollen type, Slide no. BSIP 12304, coordinates 7·0 x 156·0
4. *Foveomonoletes* sp., Slide no. BSIP 12305, coordinates 3·4 x 153·5.
5-6. *Echistephanocolpites quadrangularis* sp. nov., Slide nos. BSIP 12306, coordinates 5·5 x 144·5; 12307, coordinates 15·0 x 160·0(Holotype).
7. *Echistephanocolpites boldamgiriensis* Saxena & Rao, Slide no. BSIP 12308, coordinates 17·5 x 157·0.
8. Pollen tetrad type, Slide no. BSIP 12309, coordinates 19·0 x 136·5.
9. *Cheilanthoidspora monoleta* Sah & Kar, Slide no. BSIP 12310, coordinates 4·6 x 142·0.
10. *Spinizonocolpites echinatus* Muller, Slide no. BSIP 12311, coordinates 5·6 x 160·5.
11. *Pilanonoletes excellensus* Kar, Slide no. BSIP 12312, coordinates 9·0 x 148·0.
12. *Pinuspollenites foveolatus* Rao, Slide no. BSIP 12313, coordinates 8·7 x 147·5.
13. *Meliapollis raoi* Sah & Kar, Slide no. BSIP 12307, coordinates 14·6 x 133·0.
14. *Meliapollis triangulus* Saxena, Slide no. BSIP 12304, coordinates 15·4 x 145·0.
15. *Tricolpites matanomadhensis* Saxena , Slide no. BSIP 12312, coordinates 17·0 x 152·0.
16. *Pellicieroipollis langenheimii* Sah & Kar, Slide no. BSIP 12314, coordinates 11·5 x 159·6.
17-18. *Garotriletes kheraparaensis* sp. nov., Slide nos. BSIP 12315, coordinates 5·5x 145·3; 12316, coordinates 21·4 x 132·0 (Holotype).
19. *Foveosporites* sp., Slide no. BSIP 12317, coordinates 11·5 x 167·0.

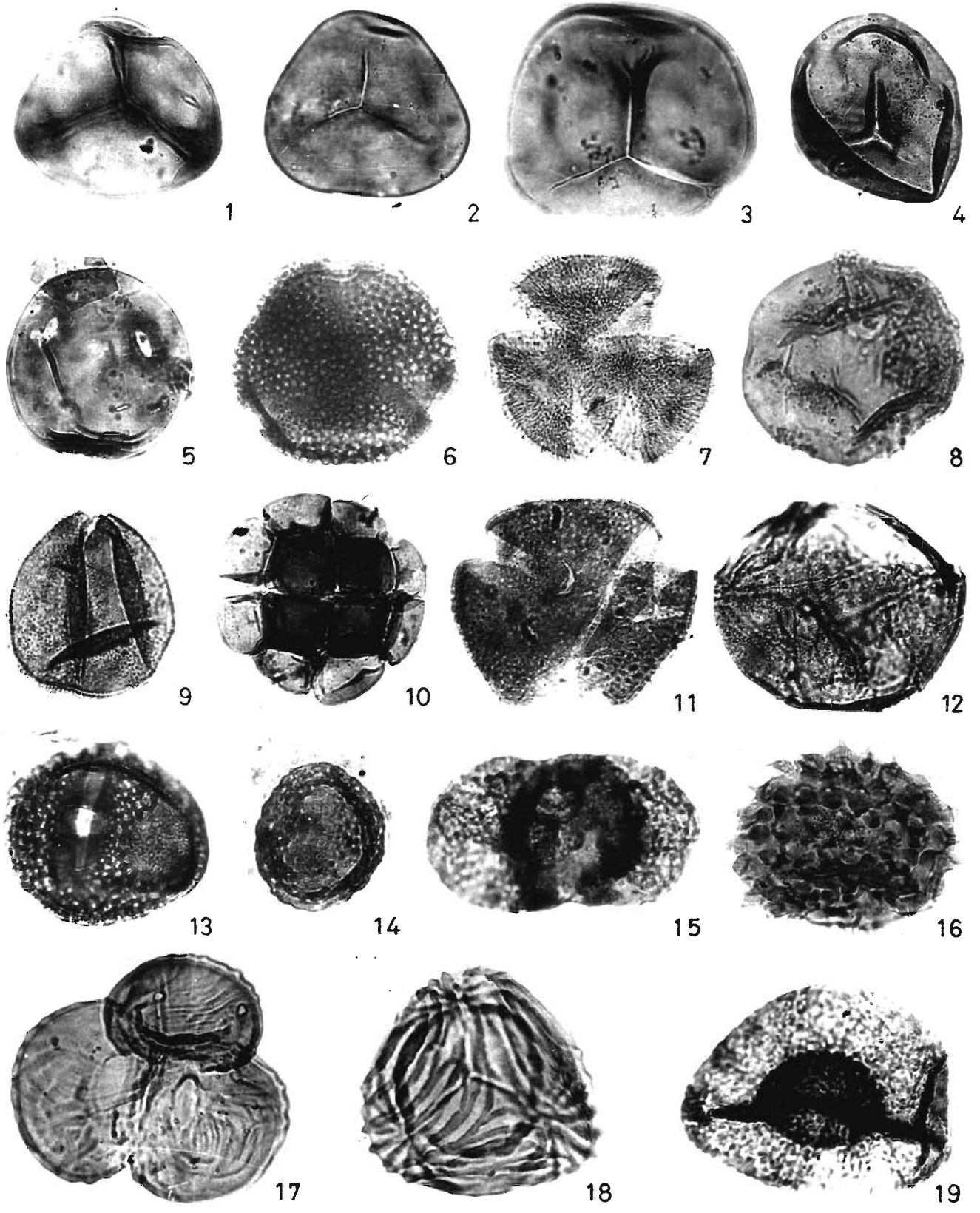

PLATE 2

but the latter can be distinguished by its compactly placed coni. *Echistephanocolpites boldamgiriensis* Saxena & Rao (1996) differs in possessing 5 colpi and being comparatively smaller size (65 µm).

POLLEN TETRAD TYPE

Pl. 1·8

Description—Pollen tetrad subcircular. Size 60 µm. Individual grains oval to elliptical. Size 38 x 27 µm. Monosulcate, showing simple cohesion in a tetrad. Exine 2 µm thick, verrucate.

POLYCOLPORATE POLLEN TYPE

Pl. 1·3

Description—Pollen grain subcircular in polar view, margin wavy. Size 66 x 61 µm. Polycolporate. Exine 4 µm thick, perforated, sexine and nexine not differentiated. Surface showing foveoreticulate ornamentation.

Genus—INAPERTUROPOLLENITES Pflug & Thomson *in*

Thomson & Pflug, 1953

Type species—INAPERTUROPOLLENITES DUBUIS (Potonié & Venitz) ex Thomson & Pflug, 1953

INAPERTUROPOLLENITES sp.

Pl. 2·9

Description—Pollen grain subtriangular. Size 80 x 70 µm. Inaperturate. Exine 2 µm thick, pilate, pila sparsely placed. Surface showing distinct reticulate ornamentation.

Comparison—The present species is distinguished from *I. dubius* by its bigger size and pilate exine.

Genus—VERRUALETES Singh & Saxena, 1984

Type species—VERRUALETES ASSAMICUS Singh & Saxena, 1984

VERRUALETES sp.

Pl. 2·8

Description—Pollen grain subcircular, margin wavy. Size 81 x 79 µm. Inaperturate. Exine 3 µm thick, verrucate, verrucae sparsely placed, interverrucal space laevigate.

Comparison—*Verrualetes assamicus* Singh & Saxena (1984) is comparable in being inaperturate and in having verrucate exine but in the present species verrucae are sparsely placed.

PALYNOFLORAL ANALYSIS

The palynoassemblage recovered from the Kherapara Formation consists of dinoflagellate cysts (3 genera and 3 species), fungal remains (5 genera and 6 species), pteridophytic spores (16 genera and 33 species) and gymnospermous (2 genera and 2 species) and angiospermous pollen (26 genera and 33 species). Besides, reworked Permian and Cretaceous palynofossils (9 genera and 10 species) and salt glands of mangrove plants (*Heliospermopsis ankleshvarensis*) have also been recovered.

The occurrence of recycled palynofossils in the present study indicates that bulk of the material for the Kherapara Formation sedimentation was derived from the pre-existing Permian and Cretaceous sediments. The source area of reworked Permian palynomorphs in the present assemblage may be derived from isolated outcrops at Singrimiri (89° 53' 30" E : 25° 38' 35" N) in Garo Hills, Meghalaya. The Cretaceous sediments on the other hand are exposed in the Khasi and Jaintia Hills, Meghalaya. The recycling of the Permian palynofossils, in Cretaceous sediments has already been reported by Dutta (1979).

PLATE 2

(All photomicrographs are enlarged ca. x 500. Coordinates of the specimens refer to the stage of BH2 Olympus microscope no. 217267).

1. *Biretisporites meghalayaensis* Rao & Singh, Slide no. BSIP 12311, coordinates 19·6 x 136·0.
2. *Lygodiumsporites lakiensis* Sah & Kar, Slide no. BSIP 12318, coordinates 10·4 x 142·0.
3. *Dictyophyllidites* sp. B. Slide no. BSIP 12319, coordinates 13·0 x 126·5.
4. *Todisporites minor* Couper, Slide no. BSIP 12320, coordinates 13·0 x 154·0.
5. *Lakiapollis ovatus* Sah & Kar, Slide no. BSIP 12321, coordinates 3·0 x 126·0.
6. 13. *Paleocaesalpiniaceaepites eocenica* Biswas, Slide nos. BSIP 12318, coordinates 5·0 x 136·0; 12322, 7·0 x 132·5.
7. *Plumbaginacipites neyvelii* Navale & Misra, Slide no. BSIP 12323, coordinates 12·0 x 150·0.
8. *Verrualetes* sp., Slide no. BSIP 12324, coordinates 6·5 x 154·0.
9. *Inaperturopollenites* sp., Slide no. BSIP 12325, coordinates 7·0 x 168·0.
10. *Polyadopollenites sahii* Rao *et al.*, Slide no. BSIP 12320, coordinates 14·3 x 164·5.
11. *Tricolpites perforatus* van der Hammen & Garcia de Muits, Slide no. BSIP 12326, coordinates 19·5 x 151·6.
12. *Cribroperidinium* sp., Slide no. BSIP 12327, coordinates 18·0 x 132·5.
13. *Polyporina multiporosa* Kar, Slide no. BSIP12326, coordinates 8·0 x 143·0.
15. *Striatopodocarpidites* sp., Slide no. BSIP 12328, coordinates 13·5 x 162·0.
16. *Malvacearumpollis bakonyensis* Nagy, Slide no. BSIP 12329, coordinates 5·5 x 147·5.
17. *Striatriletes tetradites* sp. nov., Slide no. BSIP 12302, coordinates 10·5 x 130·6 (Holotype).
18. *Striatriletes susannae* van der Hammen emend. Kar, Slide no. BSIP 12330, coordinates 7·0 x 157·0.
19. *Parasaccites* sp., Slide no. BSIP 12328, coordinates 11·0 x 139·6.

Family	Taxa	Climate
Microthyriaceae	*Phragmothyrites eocaenica*	Warm and humid
	Parmathyrites indicus	Tropical
	P. ramanujamii	climate
	Trichothyrites setiferus	
	Kutchiathyrites eccentricus	
Cyatheaceae	*Cyathidites australis*	Tropical-
	C. minor	subtropical
Osmundaceae	*Todisporites major*	Cosmopolitan
	T. minor	
Dicksoniaceae	*Dictyophyllidites granulatus*	Tropical-
		subtropical
Schizaeaceae	*Lygodiumsporites* spp.	Tropical-
(*Lygodium*)	*Crassoretitriletes*	subtropical
	vanraadshooveni	
Parkeriaceae	*Striatriletes*	Tropical-
(*Ceratopteris*)	*susannae*	subtropical
Polypodiaceae	*Polypodiaceaesporites* spp.	Cosmopolitan
(*Polypodium*)	*Polypodiisporites* spp.	
	Pilamonoletes excellensus	
	Foveomonoletes sp.	
Adiantaceae	*Pteridacidites verniverrucatus*	Cosmopolitan
Podocarpaceae	*Podocarpidites meghalayaensis*	Temperate
Pinaceae (*Pinus*)	*Pinuspollenites foveolatus*	Temperate
Magnoliaceae (*Magnolia*)	*Pinjoriapollis lanceolatus*	Temperate
Bombacaceae (*Durio*)	*Lakiapollis ovatus*	Tropical-
		subtropical
Caesalpiniaceae	*Margocolporites dubius*	Tropical-
	Paleocaesalpiniaceaepites	subtropical
	eocenica	
Meliaceae	*Meliapollis triangulus*	Tropical-
	M. raoi	subtropical
Malvaceae	*Malvacearumpollis bakonyensis*	Tropical-
		temperate
Cheno/Amaranthaceae	*Polyporina multiporosa*	Tropical-
		temperate
Thymeliaceae	*Clavaperiporites jacobii*	Cosmopolitan
Mimosaceae	*Polyadopollenites sahii*	Tropical-
		subtropical
Gunneraceae	*Tricolpites reticulatus*	Cosmopolitan
Rhizophoraceae	*Paleosantalaceaepites*	Tropical-
(*Rhizophora*)	*ellipticus*	subtropical
Plumbaginaceae	*Plumbaginacipites neyvelii*	Tropical-
	Warkallipollenites erdtmanii	temperate
Alangiaceae	*Alangiopollis gemmatus*	Tropical-
		subtropical
Arecaceae (*Nypa*)	*Spinizonocolpites echinatus*	Tropical-
		subtropical
Euphorbiaceae	*Tricolporopollis*	Cosmopolitan
	matanamadhensis	
Hymenophyllaceae	*Biretisporites* spp.	Tropical-
		subtropical

Fig. 4—Possible affinities of palynomorphs recognized in the assemblages and present day distribution

Fig. 5—Palynostratigraphic zonation in the Kherapara Formation, Meghalaya.

★ Rare 1 - 5%
□ Common 6 - 10%
◆ Abundant 11 -20%
● Predominant Above 20%

AGE	ZONES	FORMATION	SAMPLE NUMBERS	*Lygodiumsporites* spp.	*Todisporites* spp.	*Foveotriletes garoensis*	*Biretisporites* spp.	*Garotriletes kheraparaensis*	*Striatriletes* spp.	*Crassoretitriletes vanraadshooveni*	*Cheilanthoidspora monoleta*	*Polypodiaceaesporites major*	*Polypodiisporites* spp.	*Spinizonocolpites echinatus*	*Pinjoriapollis lanceolatus*	*Plumbaginacipites neyvelii*	*Lakiapollis ovatus*	*Paleocaesalpiniaceaepites eocenica*	*Echistephanocolpites* spp.	*Polyadopollenites sahii*	*Malvacearumpollis bakonyensis*	*Varispinitriporites rataiensis*	*Polyporina multiporosa*	*Pinuspollenites foveolatus*	Dinoflagellate cysts	Reworked palynomorphs
OLIGOCENE	*Striatriletes* spp. Cenozone	KHERAPARA	190	★					●		★				★						★			□	★	●
			189	●	★				●		★		★			★	★		★		★			□		◆
			187	★					●		★			★	★	★			★		★			★	★	●
			184	□					●	★		★							★			★	★			★
			183	□					●	★		★	★			★			★					★		★
			182	●			□		◆	★		●	□		★	★								★		★
			180	□			★	★	●		★	★	★		★		★		★					★		●
			176	□					●				★		★				★					★	□	◆
			174	□					●				★		★	★			◆		★			★	□	◆
			171	●			★	★	●		★		★			★			★		★	★		★		◆
			170	□					●			★	★		★	★			★		★			★		●
			168	●				★	●						★	★			★		★			★		□
			159						●																★	
			150	□					◆		□								★				□	★	★	●
	Polyadopollenites sahii Cenozone		149	□	★		★		●		★				★		★		◆	★				★	□	□
			146	□					●		★	★			★				◆	★			★	◆		◆
			144	□	★	★			●		★	★		★	★	★	★		★	★			□	★		□
			143	●	□				●		★	★		★	★	★	★	★	□	★			★	★	□	□
			142	●	□		★		◆		★	★			★	★		◆	◆	★			★	★		◆
			141	●	◆				●		★			★	★	★	★	★	◆	★			★		□	□
			140	◆		★	★		●									★	◆		★			★		◆
			138	●		★	★		●		★				★		★		●		★	★	★		★	◆
			137	◆			★		◆			★		★		★	★	★	◆		★		★	★		◆
			134	□		□	★		□		□					★			◆			★	□	★		◆
			133	◆		□			●		□					□			◆					□		◆

The pteridophytic spores are dominant over angiospermous pollen followed by gymnospermous pollen. *Garotriletes kheraparaensis, Striatriletes tetradites* and *Echistephanocolpites quadrangularis* are proposed as new. The possible affinities of palynomorphs recognised in the assemblage and present day distribution of their families are given in Fig. 4.

PALYNOSTRATIGRAPHIC ZONATION

For the quantitative analysis of the assemblage, 150 specimens per sample were counted. However, in case of samples with the poor yield only 100 specimens were counted. Percentage frequency of all the species were calculated and plotted under four categories, namely, rare (1-5%), common (6-10%), abundant (11-20) and predominant (above 20%) (Fig. 5).

On the basis of qualitative and quantitative analyses of the palynoflora, the Kherapara Formation has been divided into two cenozones. Recognition of these cenozones is based on the first (FAD) and last appearance (LAD) of various palynotaxa and their maximum development, decline, restricted occurrence and absence. The two cenozones, recognised in the Kherapara Formation, are:

2. *Striatriletes* spp. Cenozone
1. *Polyadopollenites sahii* Cenozone

A description of these cenozones, in accordance with the International Stratigraphic Guide (Hedberg, 1976), is given below.

Polyadopollenites sahii Cenozone

Type section—Tura-Dalu Road near Kherapara, between 27.5 to 28 km. from Tura, West Garo Hills, Meghalaya.

Lithology—This cenozone is made up of thickly bedded, rusty brown and grey sandstone with sandy shale and carbonaceous shale.

Restricted palynofossils—Foveotriletes garoensis, Paleocaesalpiniaceaepites eocenica and *Polyadopollenites sahii.*

Characteristic palynofossils—Lygodiumsporites spp., *Todisporites* spp., *Biretisporites* spp., *Spinizonocolpites echinatus, Lakiapollis ovatus, Plumbaginacipites neyvelii, Echistephanocolpites* spp. and *Polyporina multiporosa.*

Remarks—Polyadopollenites sahii is restricted to this cenozone and characteristic genus for the Oligocene sediments and hence the zone is named after it. The frequencies of *Cheilanthoidspora monoleta* (average 4·5%), *Echistephanocolpites* spp. (average 13%) and *Plumbaginacipites neyvelii* (average 3%) are high in the lower part of the cenozone and decreases at the top (1·5%, 6%, 1% respectively) whereas the frequency of *Polypodiaceaesporites major* is rare (average 2%) in the lower part (*Polyadopollenites sahii* Cenozone) and increases (average 10%) at the top of the *Striatriletes* spp. Cenozone. *Lygodiumsporites* spp. and *Echistephanocolpites* spp. are abundant and important in this cenozone.

Striatriletes spp. Cenozone

Type section—Tura-Dalu Road near Kherapara, between 28 to 29 km. from Tura, West Garo Hills, Meghalaya.

Lithology—This cenozone is characterized by grey and carbonaceous shale with alternation of fine grained sandstone.

Restricted palynofossils—Garotriletes kheraparaensis and *Crassoretitriletes vanraadshooveni.*

Characteristic palynofossils—Striatriletes spp. and *Polypodiisporites* spp.

Remarks—Striatriletes spp. are dominant in this cenozone (up to 95% in sample no. 159). The frequency of *Polypodiisporites* spp. is very rare in the lower part of the cenozone (average 1%) and increases at the top (average 3%). *Lygodiumsporites* spp. (average 17%) and *Echistephanocolpites* spp. (average 12%) are abundant in the lower part of the *Polyadopollenites sahii* cenozone and decreases (rare to common; average 11% and 4% respectively) at the top of the section.

Dinoflagellate cysts are present in both the cenozones but they are dominant in the *Striatriletes* spp. Cenozone. Reworked Permian and Cretaceous palynofossils are also present in all the samples but they are predominant (average 23%) in *Striatriletes* spp. cenozone.

PALYNOFLORAL COMPARISON AND AGE

A comparison of the present assemblage with the known Oligocene assemblages from the Tertiary sediments of India and other countries is discussed below:

Baksi (1962) recorded palynofossils from the Tertiary sediments of Simsang River Section, Meghalaya and recognised four palynozones. Of these, Zone III is assigned to Oligocene. The common features of the present assemblage and the Zone III of Simsang River Section are *Lygodiumsporites* (= *Leiotriletes*), frequent occurrence of schizaeaceous/parkeriaceous spores and good number of *Tricolpites* pollen and some conifer pollen. Dinoflagellate cysts and fungal remains are also shared by the two assemblages. The comparative study reveals that the dominant element *Striatriletes* is present in both the assemblages showing close resemblance between them.

Salujha *et al.* (1972) reported palynofossils from the Palaeogene sediments of Garo Hills, Meghalaya. The genera common to both the assemblages are *Cyathidites, Biretisporites, Foveosporites, Corrugatisporites, Striatriletes*(= *Cicatricosisporites*), *Polypodiisporites, Podocarpidites, Inaperturopollenites, Tricolpites* and

Marginipollis. The above comparison reveals that the palynoassemblage recorded by Salujha *et al.* (1972) is comparable to the present assemblage.

Salujha *et al.* (1974) recorded palynofossils from the Palaeogene sediments of Khasi and Jaintia Hills. The common palynotaxa of both the assemblages are *Cyathidites, Striatriletes (= Magnastriatites), Polypodiaceaesporites, Tricolpites* and *Marginipollis*. A critical comparison reveals that the dominant element *Striatriletes* is present in both the assemblages, hence both the assemblages are broadly comparable.

Saxena *et al.* (1987) made a detailed palynostratigraphic study of the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section in Jaintia Hills (Meghalaya) and Cachar (Assam) and divided the sequence into 5 palynological cenozones. Of these, the lower three palynozones, viz., *Polysphaeridium subtile* Cenozone, *Todisporites major* Cenozone and *Lygodiumsporites eocenicus* Cenozone are comparable with the present assemblage. The common genera between the two assemblages are *Cyathidites, Todisporites, Foveosporites, Polypodiaceaesporites, Polypodiisporites, Lygodiumsporites, Striatriletes, Biretisporites, Garotriletes, Corrugatisporites, Tricolpites, Echistephanocolpites, Polyadopollenites* and *Malvacearumpollis*. The above comparison shows that the present assemblage is very much comparable to the same of the Barail Group (Oligocene) of Sonapur-Badarpur Road Section.

Kar (1990) recorded palynofossils from the Barail Group (Oligocene) in the type area exposed along Haflong-Silchar Road, Assam. The following genera have also been recorded in the present assemblage *Cyathidites, Todisporites, Dictyophyllidites, Lygodiumsporites, Striatriletes, Polypodiaceaesporites, Polypodiisporites, Cheilanthoidspora, Pilamonoletes, Podocarpidites, Pinuspollenites, Spinizonocolpites, Polyadopollenites, Pellicieroipollis* and *Tricolpites*. Spores of Parkeriaceae and Polypodiaceae are dominant in both the assemblages. The above comparison reveals that the assemblage recorded by Kar (1990) is closely comparable with the present assemblage.

Misra *et al.* (1996) carried out palynological studies of Post Kopili sediments of Garo Hills, Meghalya and identified 5 distinct biostratigraphic palynozones. Of these, biostratigraphic zone-1 represents Chengpara Formation (Oligocene). The characteristic microflora of this zone are: gemmate-syncolpate pollen, frequent presence of *Polypodiisporites tuberculensis, Schizaeceaesporites, Corrugatisporites* and *Retistephanocolpites*. Acoording to them, biostratigraphic zone- I is closely comaparable to the Simsang Palynological Zone - III of Baksi (1962), the age for this biozone assigned as Oligocene. The present assemblage is also closely comparable to the Simsang Palynological Zone-III.

Mandaokar (1993) reported palynotaxa from the Tikak Parbat Formation (Oligocene) of Dangri Kumari Colliery, Dibrugarh district, Assam, India. The genera common to both the assemblages are *Biretisporites, Cheilanthoidspora, Lygodiumsporites, Dictyophyllidites, Cyathidites, Todisporites, Striatriletes, Polypodiaceaesporites, Polypodiisporites, Pilamonoletes, Spinizonocolpites, Tricolpites, Pellicieroipollis* and *Polyadopollenites*. The above comparison shows both the assemblages are closely comparable.

Baksi (1972) made a detailed palynostratigraphic study of the Upper Mesozoic and Tertiary succession of Bengal Basin, subdividing it into 7 palynological zones. Of these, Zone IV is of Oligocene age. The common palynomorphs between the two assemblages are *Cyathidites, Polypodiisporites, Striatriletes (= Schizaeaceaesporites)* and some dinoflagellate cysts. The association of some important elements like *Meyeripollis*, abundance occurrence of *Bauhinia burdwanensis* and *Barringtonia* in the Zone IV of Bengal Basin has not been detected in the Oligocene sediments of the present study. But the dominant element *Striatriletes* is present in both the assemblages, hence, both are broadly comparable.

Mandal (1996) reported palynofossils from the Tertiary (Barail) sediments of Nagaland. The genera common between the present assemblage and that from the Barail Group (Oligocene) of Nagaland are *Cyathidites, Lygodiumsporites, Striatriletes, Polypodiaceaesporites, Polypodiisporites, Pilamonoletes, Foveomonoletes, Todisporites, Lakiapollis, Pellicieroipollis, Spinizonocolpites, Marginipollis* and *Polyadopollenites*. The assemblage recorded by Mandal (1996) is broadly comparable to the present one.

Kar (1979) recorded a rich palynofloral assemblage from the Oligocene sediments (Maniyara Fort Formation) of Kutch, western India. The following taxa of this assemblage have also been recorded from the present assemblage are *Lygodiumsporites, Todisporites, Biretisporites, Striatriletes, Polypodiaceaesporites, Polypodiisporites, Cheilanthoidspora, Podocarpidites, Tricolpites, Paleosantalaceaepites* and *Malvacearumpollis*. Detailed comparative study indicates that the dominant genera like *Lygodiumsporites, Striatriletes* and *Polypodiisporites* are present in both the assemblages, hence, the two assemblages are closely comparable.

Venkatachala and Rawat (1973) recorded palynofossils from the subsurface Oligocene and Miocene sediments of Cauvery Basin. The genera common between the two assemblages are: *Crassoretitriletes, Striatriletes (= Magnastriatites), Lygodiumsporites, Biretisporites, Polypodiaceaesporites, Polypodiisporites, Tricolpites, Margocolporites, Marginipollis* and *Polyporina*. A critical study of the two palynoassemblages reveal that the assemblage recorded by Venkatachala and Rawat (1973) is broadly comparable to the present one.

Germeraad *et al.* (1968) made a intensive study of spore-pollen content of Tertiary sediments in some parts of South America, Africa and Asia by companies of the Royal Dutch/ Shell Group. They made different palynological zones to Eocene to Pliocene sediments . Of these, *Magnastriatites howardi* Cenozone (Pantropical area), *Cicatricosisporites dorogenesis* Cenozone (Atlantic area) and *Florschuetzia trilobata* Cenozone (Borneo area) are represents the Oligocene sediments. The common genera between the two assemblages are *Crassoretitriletes, Striatriletes = (Magnastriatites), Margocolporites* and *Spinizonocolpites*. A critical comparison reveals that the predominant element *Striatriletes* is present in all the assemblages, hence, they are broadly comparable.

PALAEOCLIMATE

The Kherapara palynoassemblage contains dinoflagellate cysts, fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen. The assemblage has been critically studied and compared with the modern families and found they are comparable to 24 families. Of these, 12 families are restricted to tropical-subtropical, 3 families to tropical-temperate, 3 families to temperate and 6 families are cosmopolitan in distribution. The pteridophytic spores generally favour moist and shady habitat. *Ceratopteris*, a dominant genus represented by *Striatriletes*, is a water fern growing in tropical region. The presence of fungal fruiting bodies and spores are indicative of warm and humid condition. The overall vegetational pattern indicates a tropical-subtropical, humid climate during the sedimentation of the Kherapara Formation. The temperate flora belong to Magnoliaceae (*Magnolia*) and Pinaceae (*Pinus*) appear to be transported from the upland areas in the north.

ENVIRONMENT OF DEPOSITION

The assemblage contains a mixture of palynotaxa assignable to plants of various ecological groups such as lowland, freshwater swamp and water edge, montane, back-mangrove and mangrove and sandy beach elements (Fig. 6).

An analysis of ecological groups of the Kherapara Formation reveals that the fresh water swamps and water edge elements are predominant over the lowland elements. The lowland elements are dominant in the lower part of the formation but decreases in the middle and again increase at the top. The fresh water elements are dominant throughout the assemblage. Mangrove and backmangrove elements and dinoflagellate cysts are dominant in the lower part and decreases at the top whereas the frequency of montane elements is less in the lower part and increases at the top (Fig. 7).

Ecological Groups	Palynotaxa
Low-land elements	*Lakiapollis ovatus, Tricolpites* spp., *Triangulorites bellus, Margocolporites dubius, Meliapollis* spp., *Polycolpites tertiarus, Polyadopollenites sahii, Echistephanocolpites* spp.
Fresh water swamp and water edge elements	*Lygodiumsporites* spp., *Todisporites* spp., *Biretisporites* spp., *Dictyophyllidites* spp., *Garotriletes kheraparaensis, Striatriletes* spp., *Crassoretitriletes vanraadshooveni, Pteridacidites vermiverrucatus, Polypodiaceaesporites* spp., *Polypodiisporites* spp., *Pilamonoletes excellensus, Polyporina multiporosa*
Montane elements	*Pinjoriapollis lanceolatus Podocarpidites meghalayaensis Pinuspollenites foveolatus*
Sandy-beach elements	*Spinizonocolpites echinatus*
Mangrove and back-mangrove elements	*Paleosantalaceaepites ellipticus, Paleocaesalpiniaceaepites eocenica, Alangiopollis gemmatus, Warkalliipollenites erdtmanii, Malvacearumpollis bakonyensis, Varispinitriporites ratariaensis*

Fig. 6—Representation of different ecological groups in the Kherapara Formation.

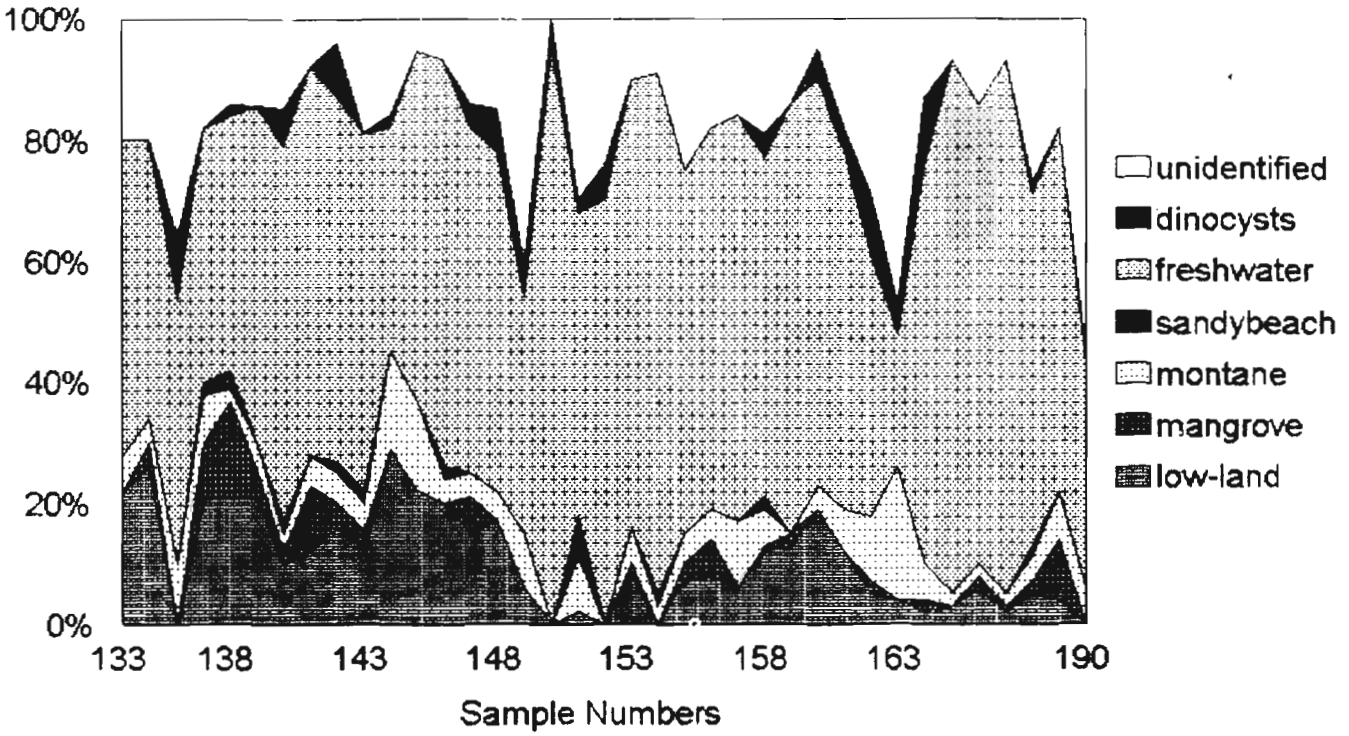

Fig. 7—Vertical distribution of palynotaxa in the Kherapara Formation, Garo Hills, Meghalaya.

The high percentage of *Lygodiumsporites* and *Striatriletes* in the assemblage indicates fresh water swamps and ponding conditions near the site of deposition. Pollen belonging to Chenopodiaceae/Amaranthaceae (*Polyporina*) are salt loving and occur near sea coast. The dinoflagellate cysts and mangrove and back-mangrove elements are well represented in the lower part of the sequence and decline upwards, which may possibly be related to gradual regression of the sea. The coastal elements are represented by arecaceous pollen (*Spinizonocolpites*). The gymnospermous pollen may be derived from the high mountains near by in the north. So it may be inferred that the Kherapara Formation was deposited in a coastal marine environment having fresh water connections with swamps and ponding conditions nearby and the coast was bordered by mangroves and other coastal elements.

SUMMARY AND CONCLUSIONS

1. The palynoassemblage recovered from the Kherapara Formation (Oligocene), is well diversified and contains algal and fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen.

2. *Garotriletes kheraparaensis, Striatriletes tetradites* and *Echistephanocolpites quadrangularis* have been proposed as new.

3. Qualitative and quantitative analyses reveal that the pteridophytic spores are dominant over angiospermous followed by gymnospermous pollen.

4. Based on the palynofossil distribution, the Kherapara Formation is divisible into two cenozones, viz., *Polyadopollenites sahii* Cenozone and *Striatriletes* spp. Cenozone.

5. On the basis of affinity with modern families, a tropical-subtropical, humid climate has been interpreted during the sedimentation of the Kherapara Formation.

6. The assemblage represents a mixture of ecological groups such as low-land, freshwater swamps and water edge, montane, mangrove and back-mangrove and sandy beach elements.

7. The Kherapara Formation was deposited in a coastal marine environment having fresh water connections with swamps and ponding conditions nearby and coast was bordered by mangroves and other coastal elements.

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