Palaeobotanist 49 (2000) : 253-267
0031-0174/2000/253-267 $2.00

Palynological investigation of the Siju Formation (Middle Eocene) in the type area, South Garo Hills, Meghalaya, India

R.K. SAXENA AND SAMIR SARKAR

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

(Received 28 January 2000; revised version accepted 5 June 2000)

ABSTRACT

Saxena RK & Sarkar S 2000. Palynological investigation of the Siju Formation (Middle Eocene) in the type area, South Garo Hills, Meghalaya, India. Palaeobotanist 49(2) : 253-267.

A palynofloral assemblage, consisting of 37 genera and 53 species, has been recorded from the Siju Formation (Middle Eocene) exposed along Simsang River near Siju, South Garo Hills, Meghalaya. The assemblage is dominated by dinoflagellate cysts and acritarchs (73%) followed by fungal remains (26%) whereas spores-pollen (1%) are rare. Predominant palynotaxa of the assemblage are *Achomosphaera ramulifera, Cleistosphaeridium brevispinosum, C. sijuensis, Collumosphaera fruticosa, Homotryblium floripes, H. pallidum, H. tenuispinosum, Lingulodinium machaerophorum, Operculodinium centrocarpum, O. major,* etc. Three species, viz., *Cleistosphaeridium sijuensis, Collumosphaera garoensis* and *Thalassiphora indica,* are proposed as new. On the basis of frequency and distribution of palynotaxa, two cenozones, viz., *Homotryblium pallidum* Cenozone and *Cleistosphaeridium sijuensis* Cenozone, have been proposed in the Siju Formation. These cenozones can be recognized by their characteristic and restricted palynotaxa. The palynoflora indicates prevalence of tropical (warm-humid) climate and presence of mangrove elements along the shore and also wet evergreen forest further inland. The environment of deposition has been interpreted as marginal marine. The palynoflora has been compared with the Eocene assemblages recorded from various sedimentary basins of India and has been assigned a Middle Eocene age.

Key-words—Palynology, biostratigraphy, dinoflagellate cysts, Siju Formation, Middle Eocene, Garo Hills, Meghalaya (India).

भारत के मेघालय प्रान्त की दक्षिणी गारो पर्वत श्रेणियों में उत्कृष्टतः अनावरित मध्य इओसीन युगीन सीजू शैलसमूह का परागाणविक विश्लेषण

रमेश कुमार सक्सेना एवं समीर सरकार

सारांश

मेघालय की दक्षिणी गारो पर्वत श्रेणियों में सीजू के निकट सिमसांग नदी के आस-पास अनावरित सीजू शैलसमूह (मध्य इओसीन) से एक परागाणविक समुच्चय अंकित किया गया है, जिसमें 37 वंश तथा 53 प्रजातियाँ प्राप्त हुई हैं. समुच्चय में घूर्णीकशाभ पुटियों एवं एक्रीटार्कों की प्रचुरता (73%) है, जिसके पश्चात कवकीय अवशेष (26%) आते हैं, जबकि बीजाणु-परागकण अत्यल्प (1%) हैं. समुच्चय में विद्यमान प्रमुख परागाणु वर्गकों में *एकोमास्फ़ेयरा रैम्यूलीफ़ेरा, क्लीस्टोस्फ़ेयरीडियम ब्रीविस्पाइनोसम, सी. सीजुएन्सिस, कॉल्यूमोस्फ़ेयरा फ्रूटिकोसा, होमोट्राइब्लियम फ्लोरिपिस, एच. पैलिडम, एच. टेन्युइस्पिनोसम, लिंगुलोडिनियम मैकेयरोफ़ोरम, ऑपरक्युलोडिनियम सेन्ट्रोकॉर्पम, ओ. मेजर* इत्यादि आते हैं. समुच्चय से *क्लीस्टोस्फ़ेयरीडियम*

सीजुएन्सिस, कॉल्यूमोस्फ़ेयरा गारोएन्सिस एवं *थैलस्सीफ़ोरा इण्डिका* नामक तीन प्रजातियाँ नई प्रजातियों के रूप में प्रस्तावित की गई हैं. सीजू शैलसमूह में परागाणु वर्गकों की आवृत्ति एवं वितरण के आधार पर *होमोट्राइक्लियम पैलिडम* समुच्चय मण्डल एवं *क्लीस्टोस्फ़ेयरीडियम सीजूएन्सिस* समुच्चय मण्डल नामक दो समुच्चय मण्डल स्थापित किए गए हैं. इन समुच्चय मण्डलों को उनके अभिलक्षणित एवं प्रतिबन्धित परागाणु वर्गकों के आधार पर अभिनिर्धारित किया जा सकता है. परागाणु वनस्पतिजात उष्ण-उपोष्ण कटिबन्धीय (आर्द्र-ऊष्ण) जलवायु की प्रमुखता तथा समुद्र तट के आस-पास मैंग्रोव तत्वों की उपस्थिति संकेतित करता है तथा भीतरी अन्तःस्थल में आर्द्र सदाबहारी वनों की उपस्थिति का भी संकेत करता है. यहाँ का निक्षेपणीय वातावरण सीमान्त समुद्री वातावरण की भाँति विश्लेषित हुआ है. इस परागाणु वनस्पतिजात की भारत की विभिन्न अवसादी द्रोणियों से निकाले गए इओसीन समुच्चयों के साथ तुलना की गई तथा इसकी आयु मध्य इओसीन काल नियत की गई.

संकेत शब्द—परागाणुविज्ञान, जैवस्तरिकी, घूर्णीकशाभ पुटी, सीजू शैलसमूह, मध्य इओसीन, गारो पर्वत श्रेणियाँ, मेघालय (भारत).

INTRODUCTION

A thick Cretaceous-Tertiary sedimentary sequence, overlying the Precambrian Basement Complex, occupies the southern portion of Meghalaya state, bordering the Bangladesh plains. These sediments are mainly sandstone and shales with a few well defined fossiliferous limestones. Pioneering geological studies on these sediments have been published by Oldham (1859), Medlicott (1868, 1869, 1874), LaTouche (1882, 1883a, b, 1884, 1887, 1889, 1890a, b), Hayden (1897), Pinfold (1919), Palmer (1923), Evans (1932), Fox (in Heron 1937) and Ghosh (1954). Raja Rao (1981) published an account of the coalfields of northeastern India. Evans (1932) proposed a stratigraphic classification for the Tertiary sediments of northeastern India, which is still widely used in the geological literature. Chakraborty (1972) and Chakraborty and Baksi (1972) realized that Evans's stratigraphic units are not applicable to the sedimentary sequence developed in Garo Hills and western Khasi Hills of Meghalaya and proposed another lithostratigraphic classification for the Cretaceous-Tertiary sequence of this region. Fox (in Heron 1937), for the first time, used the term "Siju

Age	Stratigraphic Unit	Lithology
Post-Eocene	Post-Rewak (Kherapara, Boldamgiri, Angartoli, Bilkona, Rangapani and Dalu formations)	—
Late-Eocene	Rewak Formation	Thinly bedded, splintery, grey shales and carbonaceous shales with interbeds of fine grained, ferruginous, current bedded sandstones and coal streaks. Thin foraminiferal limestone beds occur in the upper part.
Middle-Eocene	Siju Formation	Banded alternations of hard, greyish yellow and yellow, arenaceous foraminiferal limestone and calcareous shales or marl. Hard, massive limestone occur in the upper part.
----------	Unconformity	----------
Palaeocene-Early Eocene	Tura Formation	Medium to coarse grained and gritty, clayey, dirty white, yellow and reddish, nonfeldspathic, frequently current bedded sandstones intercalated with thin argillaceous beds and coal seams.
----------	Unconformity	----------
Precambrian	Basement Complex	Granite and granite gneisses

Fig. 1—Lithostratigraphic succession in the South Garo Hills, Meghalaya.

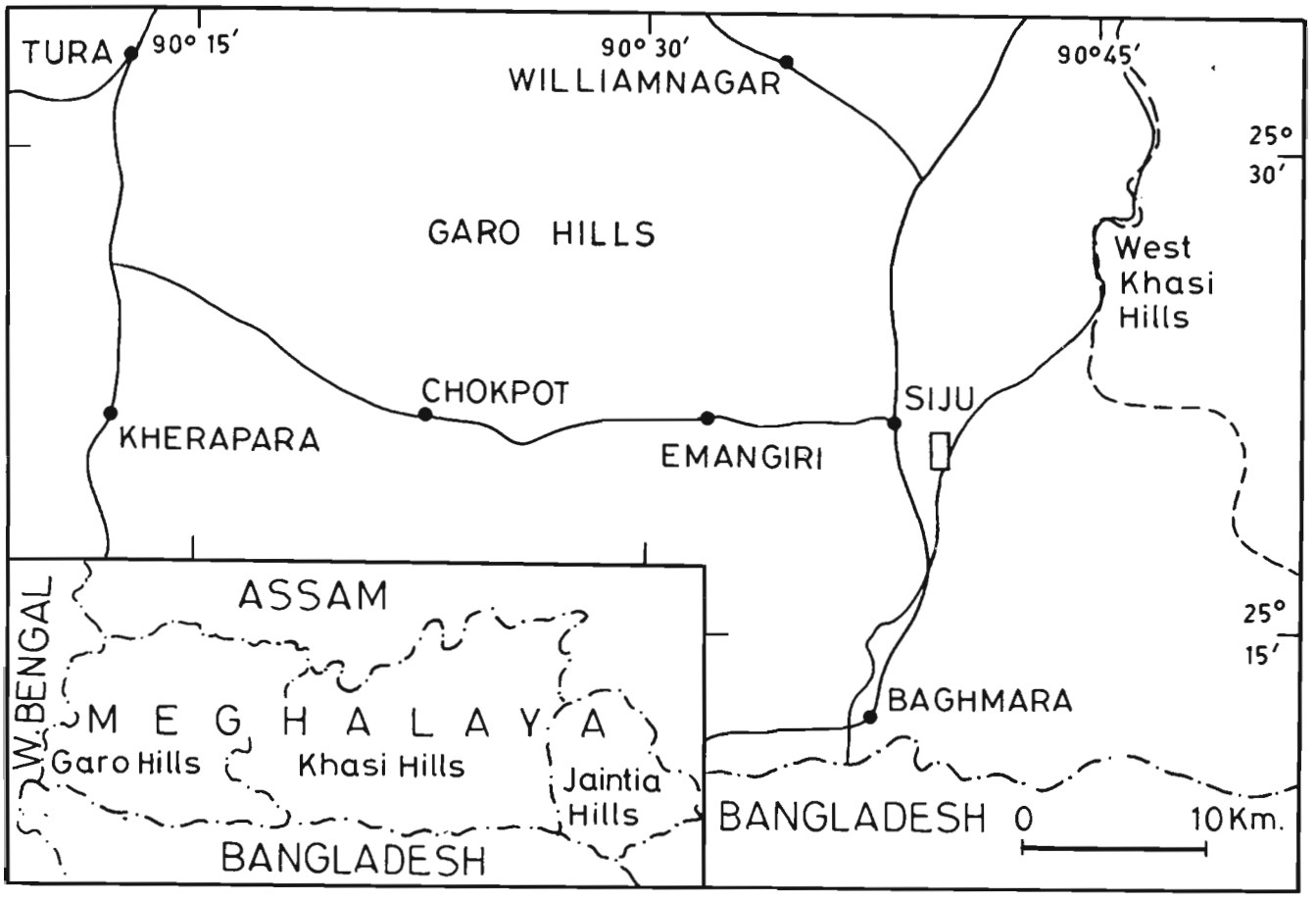

Fig. 2—Locality map.

Limestone" for the foraminiferal limestone of Garo Hills, which overlies the Tura Sandstones and underlies the Kopili Formation. Murthy *et al.* (1976) placed this limestone into the Upper Sylhet Limestone Member and underlying Tura Formation (sandstone) into the Sylhet Sandstone Member of the Sylhet Formation.

While a considerable amount of palynological work has been done on the underlying Tura Formation and its equivalents (Cherra, Therria and Mikir formations), only a few papers have been published on the palynology of the Siju Formation. Baksi (1962) studied Tertiary palynosuccession of the Simsang River Section and divided the whole sequence into four zones. His basal zone, viz., Simsang Palynological Zone-1, corresponds to the Siju Formation (= part of the Sylhet Formation). Baksi (1974) formally named this zone as *Polycolpites-Monosulcites (Colocasioideaepites)* Zone and provided an elaborate description. The main elements of this zone are pollen of Arecaceae and Caesalpiniaceae together with a large number of hystrichospherids (dinoflagellate cysts). Salujha *et al.* (1972) described 42 genera and 65 species of palynofossils from the Palaeogene sediments (Tura, Siju, Rewak and Darik formations) of Garo Hills, Meghalaya. However, they did not give a list of formation-wise palynotaxa. Salujha *et al.* (1974) recorded palynofossils from the Palaeogene sediments (including Sylhet Formation) from the Khasi and Jaintia Hills, Meghalaya. Sah and Singh (1977) recorded a scanty palynoassemblage from the Siju Formation comprising *Retipilonapites* sp., *Neocouperipollis brevispinosus, Cyathidites minor, Palmidites plicatus, Polycolpites cooksoniae,* etc.

Chakraborty and Baksi (1972) reported occurrence of *Assilina spira corrugata, A. exponens, A. regularia, A. simsangi, Alveolina elliptica nuttelli, Nummulites acutus, N. beaumonti, N. obtusus, Discocyclina javana, D. oamphalus, Orbitolites companulatus, Eorupertia, Fabiona, Linderina, Calcarina,* etc. from the Siju Formation and named this sequence as *Assilina spira corrugata - Alveolina elliptica nuttelli* Assemblage Zone. This zone is equivalent to *Assilina spira corrugata* Zone of Samanta (1971) established for the Garampani Limestone of Mikir-North Cachar Hills, Assam.

The present palynological study has been carried out on the Siju Formation exposed in the type area. The objectives of the study are to record palynofossils and to utilize the palynodata in biostratigraphic zonation and in infering palaeoclimate, environment of deposition and age.

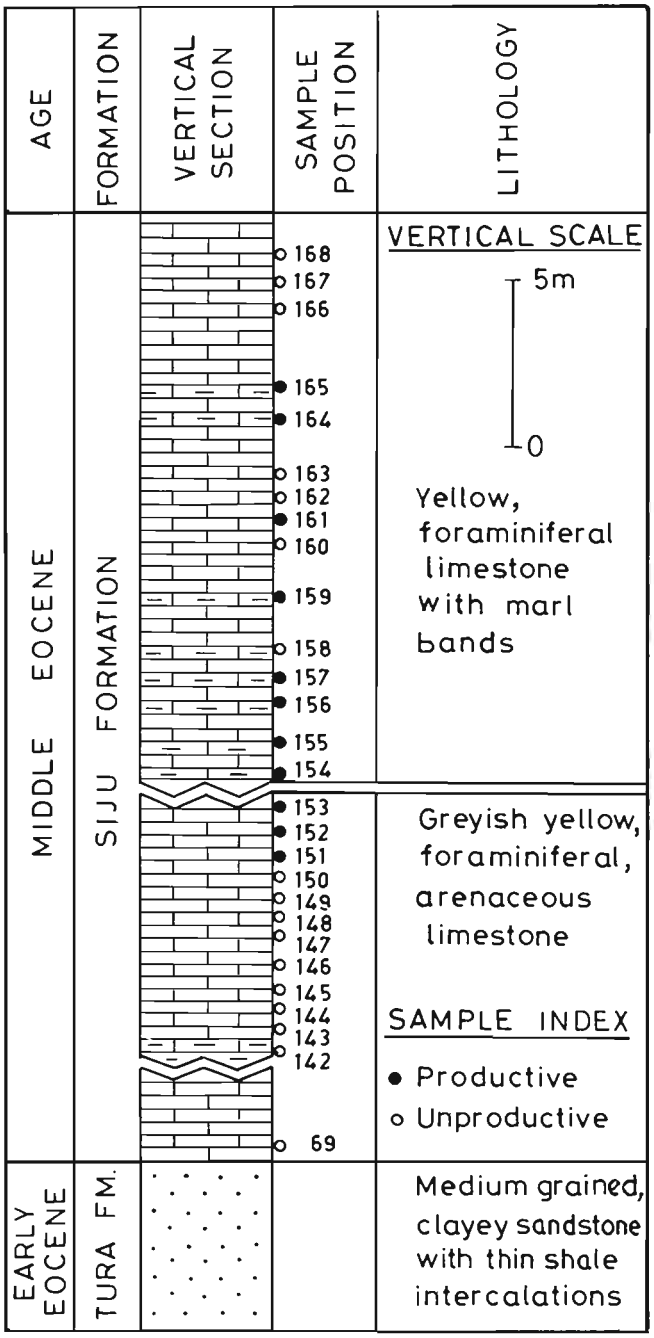

Fig. 3—Lithocolumn of the studied stratigraphic sequence showing positions of samples.

LITHOSTRATIGRAPHY

The oldest stratigraphic unit, occupying a major portion of Garo Hills, is Basement Complex (Precambrian) which is made up of granite and granite gneisses. Its upper part is highly weathered and altered into kaolinitic clays. The basement is unconformably overlain by the Tura Formation which is composed of medium to coarse grained and gritty, clayey, dirty white, yellow and reddish, nonfeldspathic, frequently current bedded, quartz-arenite type of sandstones intercalated with thin beds of grey shale, carbonaceous shale, lithomargic clay, siltstone and a few coal seams. The Tura Formation is conformably overlain by the Siju Formation. The Siju Formation is made up of greyish yellow and yellow, arenaceous, foraminiferal limestone interbedded with highly calcareous shale or marl bands. In the upper part, the limestone becomes hard and massive. The Siju Formation exhibits high degree of lateral variation. Towards west, in the Tura-Dalu Section, its thickness sharply decreases to only a few metres and only thin arenaceous limestone with alternations of shale are found whereas to the east of Rongra it is represented by massive limestone of about 250 metres thickness. The Siju Formation is overlain by the argillaceous Rewak Formation which is composed of thinly bedded, splintery, grey shales and carbonaceous shales intercalated with fine grained, ferruginous, current bedded sandstones and a black shale with phosphatic nodules and pebbles at the base. The stratigraphic succession in the South Garo Hills is summarized in Fig.1.

MATERIAL AND METHODS

Material for the present palynological study was collected from the Siju Formation exposed between Siju Songmong and Siju Cave in South Garo Hills District, Meghalaya. Altogether, 28 samples (sample no. 142-169) were collected. Of these, one sample (sample no. 169), representing base of the Siju Formation, was collected from near Siju Songmong; 12 samples (sample no. 142-153) were collected from the Siju Cave; and 15 samples (sample no. 154-168) were collected from a section about 500 metres south-west of Siju Songmong, on the right bank of Simsang River (Fig. 2). Of these, 11 samples are palynologically productive. During collection of samples, special care was taken to avoid contamination or mixing. Only bigger pieces and chips of sediments were collected. Stratigraphic positions of the samples are shown in the composite section (Fig. 3).

For recovery of palynofossils, samples were treated with HCl, HF and HNO_3 followed by 5% KOH solution. The slides were mounted in canada balsam. All the slides and negatives of the figured specimens are stored in the museum of the Birbal Sahni Institute of Palaeobotany, Lucknow, India.

PALYNOFLORAL ASSEMBLAGE

Dinoflagellate cysts and acritarchs

Achomosphaera alcicornu (Eisenack 1954) Davey & Williams 1966a
Achomosphaera ramulifera (Deflandre 1937) Evitt 1963
Achomosphaera triangulata (Gerlach 1961) Davey & Williams 1969 (Pl. 1, fig. 9)
Adnatosphaeridium vittatum Williams & Downie 1966
Areoligera undulata Eaton 1976

Areosphaeridium arcuatum Eaton 1971 (Pl. 2, fig. 14)
Ascostomatocystis granulata Chateauneuf 1980
Cleistosphaeridium brevispinosum Jain & Millepied 1975 (Pl. 1, fig. 2)
**Cleistosphaeridium sijuensis* sp. nov. (Pl. 1, figs 7-8)
Collumosphaera fruticosa Jain & Dutta in Dutta & Jain 1980 (Pl. 2, fig. 13)
**Collumosphaera garoensis* sp. nov. (Pl. 1, figs 5-6)
Cordosphaeridium fibrospinosum Davey & Williams 1966b
Cordosphaeridium inodes (Klumpp 1953) Eisenack 1963 emend. Morgenroth 1968 (Pl. 2, fig. 4)
Distatodinium ellipticum (Cookson 1965) Eaton 1976
Exochosphaeridium brevispinosum Matsuoka 1984
Fromea amphora Cookson & Eisenack 1958
Homotryblium floripes (Deflandre & Cookson 1955) Stover 1975 (Pl. 1, fig. 10)
Homotryblium pallidum Davey & Williams 1966b (Pl. 2, fig. 8)
Homotryblium tenuispinosum Davey & Williams 1966b
Hystrichokolpoma cinctum Klumpp 1953
Hystrichosphaeridium arborispinum Davey & Williams 1969 (Pl. 2, fig. 5)
Hystrichosphaeridium latiricum Davey & Williams 1966b (Pl. 2, fig. 12)
Hystrichosphaeridium tubiferum (Ehrenberg 1838) Davey & Williams 1966b
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Muratodinium fimbriatum (Cookson & Eisenack 1967) Drugg 1970
Operculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967 (Pl. 1, fig. 1)
Operculodinium israelianum (Rossignol 1962) Wall 1967
Operculodinium major Jain & Dutta in Dutta & Jain 1980 (Pl. 2, fig. 15)
Spiniferites membranosus (Archangelsky 1969) Lentin & Williams 1973 (Pl. 1, fig. 4)
Surculosphaeridium cribrotubiferum (Sarjeant 1960) Davey *et al.* 1966 (Pl. 2, fig. 9)
**Thalassiphora indica* sp. nov. (Pl. 1, figs 11-12)
T. patula (Williams & Downie 1966) Stover & Evitt 1978
T. pelagica (Eisenack 1954) Eisenack & Gocht 1960

Fungal remains

Callimothallus assamicus Kar *et al.* 1972
Parmathyrites indicus Jain & Gupta 1970 (Pl. 1, fig. 3)
Phragmothyrites eocaenica Edwards 1922 emend. Kar & Saxena 1976
Staphlosporonites multicellatus Saxena & Singh 1982
Staphlosporonites tristratosus Sheffy & Dilcher 1971
Trichothyrites amorphus (Kar & Saxena 1976) Saxena & Misra 1990

Pteridophytic spores

Eximispora tuberculata Salujha *et al.* 1972
Lygodiumsporites lakiensis Sah & Kar 1969
Todisporites minor Couper 1958

Angiospermous pollen

Compositoipollenites conicus Sah 1967 (Pl. 2, figs 10-11)
Graminidites media Cookson 1947 (Pl. 2, fig. 1)
Meliapollis raoi Sah & Kar 1970
Neocouperipollis brevispinosus (Biswas 1962) Sarkar & Singh 1988
Neocouperipollis kutchensis (Venkatachala & Kar 1969a) Kar & Kumar 1987 (Pl. 2, fig. 7)
Neocouperipollis pyrispinosus Sarkar & Singh 1988
Palmaepollenites plicatus Sah & Kar 1970 (Pl. 2, fig. 2)
Palmidites assamicus Singh 1977
Pelliceiroipollis langenheimii Sah & Kar 1970 (Pl. 2, fig. 6)
**Pilatricolporites* sp. (Pl. 2, fig. 3)
Triangulorites bellus (Sah & Kar 1970) Kar 1985

Palynotaxa marked with an asterisk (*) have been described or commented upon below. Plate and figure numbers given in the above list in parentheses refer to the illustrations of the present paper.

Genus—CLEISTOSPHAERIDIUM Davey *et al.* 1966

CLEISTOSPHAERIDIUM SIJUENSIS sp. nov.

Pl. 1·7-8

Holotype— Pl. 1.8, slide no. BSIP 12402 (46 x 98).
Type locality—Siju, South Garo Hills, Meghalaya.
Type horizon and age—Siju Formation, Middle Eocene.
Diagnosis—Cysts skolochorate, spherical-subspherical; autophragm with numerous, nontabular, solid processes; processes long, proximally flattend, distally narrow with pin heads or small aciculae; autophragm in between the processes smooth. Archaeopyle apical (type TA). Operculum free.
Dimensions – Holotype - Cyst body: 98 x 56 µm (without operculum); length of processes: 35-45 µm; width of processes (proximal side): up to 4 µm. Observed size range - Cyst body: 85-100 x 70-100 µm; length of processes: 30-45 µm; width of processes (proximal side): 3-5 µm.
Comparison—The present species is distinguished from the other species of *Cleistosphaeridium* by its long, solid processes with pin-heads or aciculae.
Derivation of name—The species is named after Siju Formation.

Genus—COLLUMOSPHAERA Jain & Dutta in Dutta & Jain 1980

COLLUMOSPHAERA GAROENSIS sp. nov.

Pl. 1·5-6

Holotype—Pl. 1·5, slide no. BSIP 12401 (56 x 96).
Type locality—Siju, South Garo Hills, Meghalaya.
Type horizon and age—Siju Formation, Middle Eocene.
Diagnosis—Cysts spherical-subspherical, double layered, major axis slightly longer than minor; endophragm thin, infrapunctate; periphragm smooth. aperture subapical, circular, surrounded by a rim.
Dimensions—Holotype - Cyst body: 106 x 100 µm; aperture: 16 µm in diameter. Observed size range - Cyst body: 106-120 x 100-115 µm; aperture: 16-24 um in diameter.

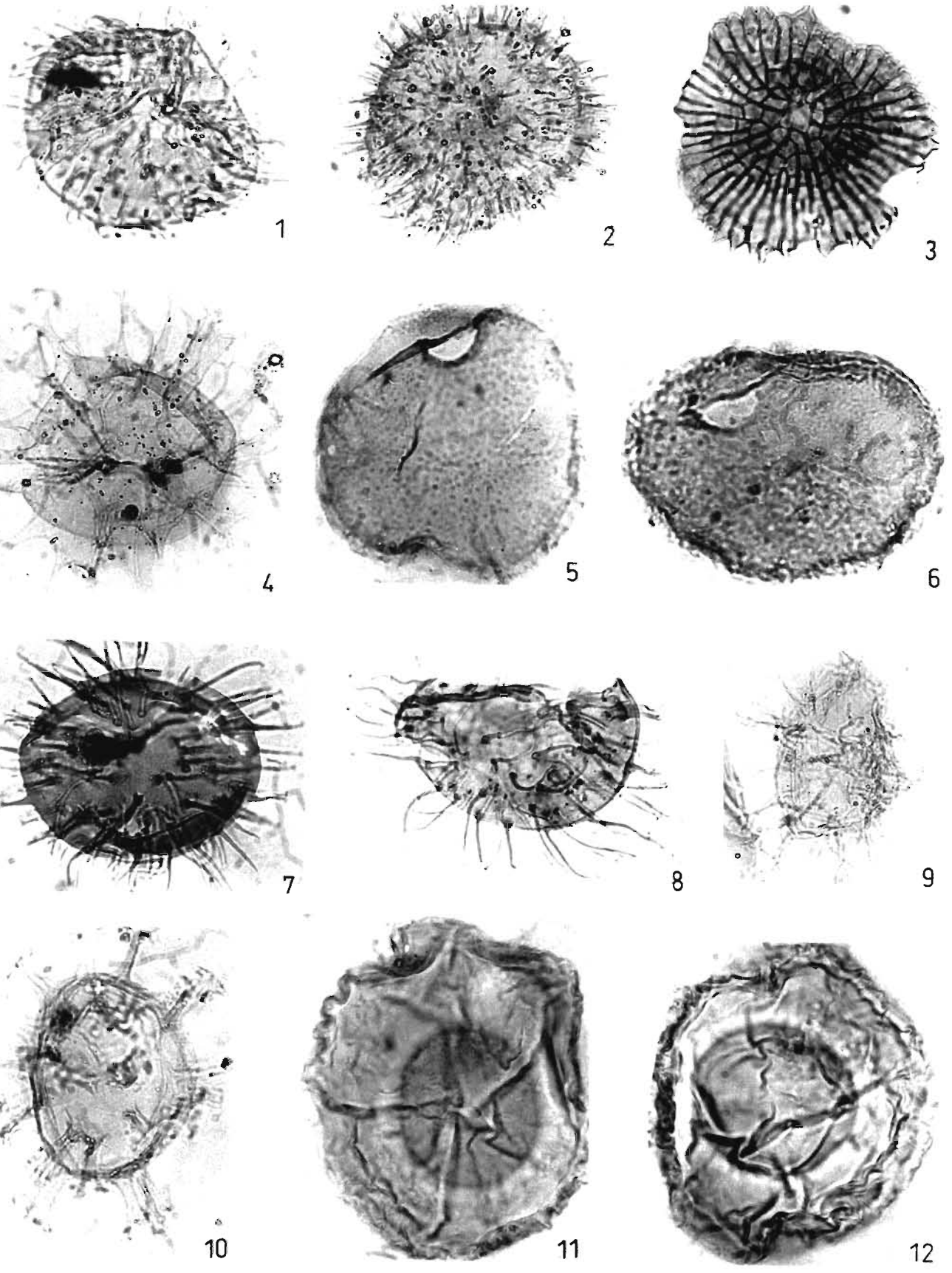

PLATE 1

Comparison—The present species is distinguished from *Collumosphaera fruticosa* Jain & Dutta in Dutta & Jain (1980) in having infrapunctate endophragm.

Derivation of name—The species is named after Garo Hills in Meghalaya.

Genus—THALASSIPHORA Eisenack & Gocht 1960 emend. Benedek & Gocht 1981

THALASSIPHORA INDICA sp. nov.

Pl. 1·11-12

Holotype—Pl. 1.12, slide no. BSIP 12406 (48 x 102).

Type locality—Siju, South Garo Hills, Meghalaya.

Type horizon and age—Siju Formation, Middle Eocene.

Diagnosis—Cysts cavate, subspherical; endocyst spherical, endophragm thin, granulose, grana uniformly distributed; periphragm subspherical, thin walled, linear marking impart pseudoreticulate ornamentation. Archaeopyle precingular.

Dimensions—Holotype - Periphragm: 116 x 108 µm; endophragm: 60 µm in diameter. Observed size range - Periphragm: 116-145 x 108-135 µm; endophragm: 55-70 µm in diameter.

Comparison—The present species differs from the other species of *Thalassiphora* by its granulose endocyst.

Derivation of name—The species is named after India.

Remarks—Due to the presence of wide outer covering, specimens are generally found in folded condition.

Genus—PILATRICOLPORITES Kar 1985

PILATRICOLPORITES sp.

Pl. 2·3

Remarks—The present species differs from *Pilatricolporites eocenicus* Kar (1985) in the absence of reticuloid pattern. Only a single specimen of this type has been recovered.

BIOSTRATIGRAPHIC ZONATION

The palynoflora from the Siju Formation of the type area consists of 20 genera and 33 species of dinoflagellate cysts and acritarchs, 5 genera and 6 species of fungal remains, 3 genera and 3 species of pteridophytic spores and 9 genera and 11 species of angiospermous pollen. The assemblage is dominated by dinoflagellate cysts (73%, including acritarchs) followed by fungal remains (26%) whereas spores-pollen are rare (1%). Predominant palynotaxa of the assemblage are: *Achomosphaera ramulifera, Cleistosphaeridium brevi-spinosum, C. sijuensis, Collumosphaera fruticosa, Homo-tryblium floripes, H. pallidum, H. tenuispinosum, Lingulo-dinium machaerophorum, Operculodinium centrocarpum, O. major,* etc. Three species, viz., *Cleistosphaeridium sijuensis, Collumosphaera garoensis* and *Thalassiphora indica* are proposed as new.

For quantitative analysis of the assemblage, 100 to 150 specimens per sample were counted. Frequencies of all the species per hundred specimens were calculated and plotted, according to their vertical distribution, in the range chart under 4 slabs, viz., 1-5%, 6-15%, 16-25% and more than 25% (Fig. 4). On the basis of frequency and distribution of palynotaxa, the studied sequence has been divided into two cenozones, viz., *Homotryblium pallidum* Cenozone and *Cleistosphaeridium sijuensis* Cenozone. The cenozones are recognized on the basis of abundance, decline, restricted occurrence and absence of palynotaxa. A formal description of these cenozones is given below.

Homotryblium pallidum Cenozone

Type section—The lower part of the type section is located at Siju Cave and the upper part at 500 metres southwest of Siju Songmong, South Garo Hills, Meghalaya.

Lithology—The stratigraphic sequence of this cenozone is composed of greyish yellow and yellow, arenaceous, foraminiferal limestone interbedded with thin calcareous shale and marl bands.

Significant palynotaxa—Achomosphaera alcicornu, Adnatosphaeridium vittatum, Cleistosphaeridium brevispinosum, Homotryblium pallidum, H. tenuispinosum, Operculodinium centrocarpum and *O. major.*

← **PLATE 1**

(All photomicrographs are magnified *ca.* x 700 and the microscope co-ordinates are within the parenthesis)

1. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall, Slide no. BSIP 12397 (30 x 95).
2. *Cleistosphaeridium brevispinosum* Jain & Millepied, Slide no. BSIP 12398 (65 x 106).
3. *Parmathyrites indicus* Jain & Gupta, Slide no. BSIP 12399 (22 x 102·5).
4. *Spiniferites membranosus* (Archangelsky) Lentin & Williams, Slide no. BSIP 12400 (32 x 100·5).
5-6. *Collumosphaera garoensis* sp. nov., Slide nos. BSIP 12401 (56 x 96), BSIP 12402 (55 x 99).
7-8. *Cleistosphaeridium sijuensis* sp. nov. Slide nos. BSIP 12403 (52 x 96), BSIP 12402 (46 x 98).
9. *Achomosphaera triangulata* (Gerlach) Davey & Williams, Slide no. BSIP 12404 (56 x 111).
10. *Homotryblium floripes* (Deflandre & Cookson) Stover, Slide no. BSIP 12405 (63 x 106).
11-12. *Thalassiphora indica* sp. nov., Slide no. BSIP 12402 (53 x 99), BSIP 12406 (48 x 102).

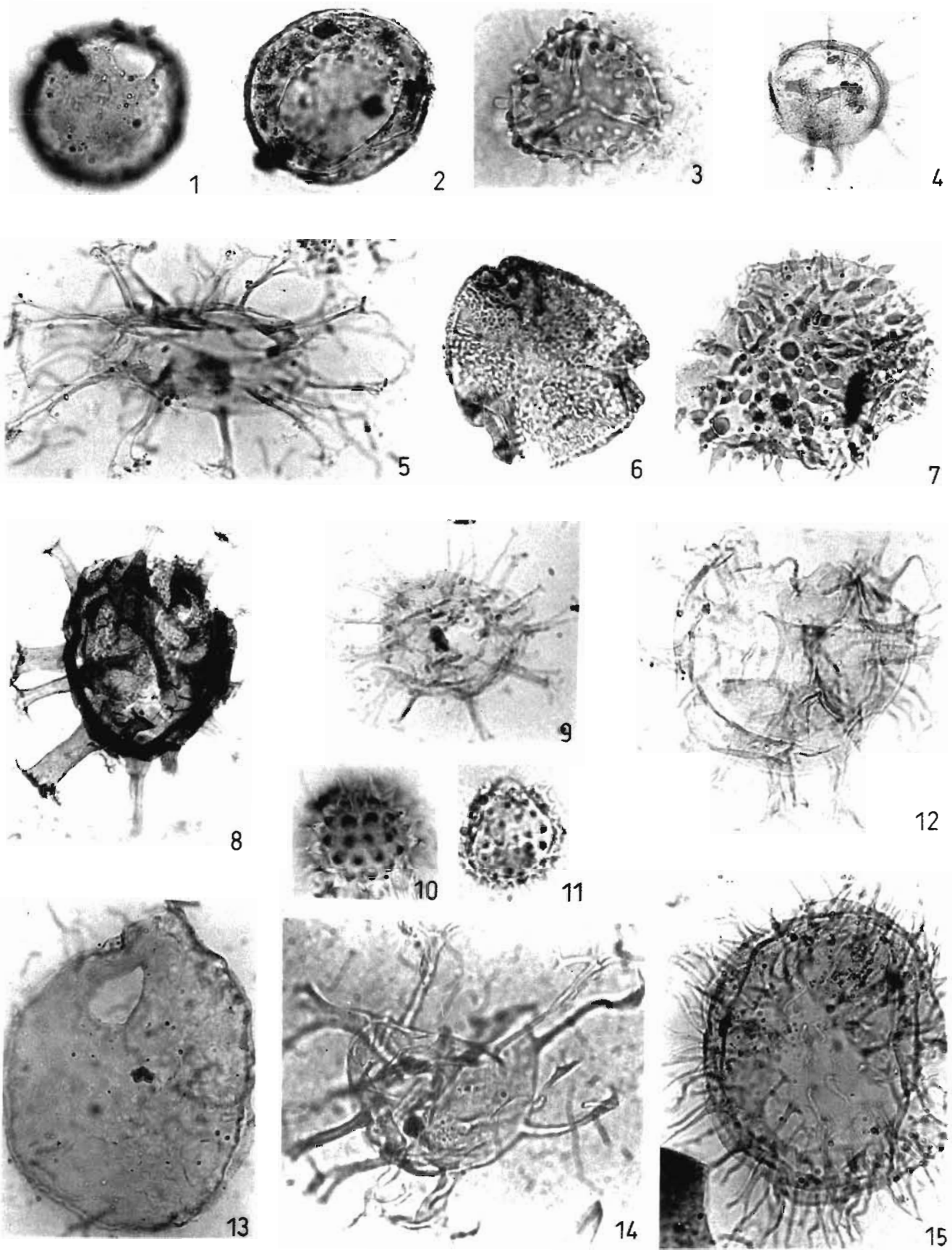

PLATE 2

Restricted palynotaxa—*Achomosphaera alcicornu, Areoligera undulata, Areosphaeridium arcuatum* and *Exochosphaeridium brevispinosum.*

Remarks—The dominant palynotaxa of this cenozone are: *Operculodinium centrocarpum* (20%), *Cleistosphaeridium brevispinosum* (16%), *Homotryblium pallidum* (10%) and *Operculodinium major* (8%). All these species, except *Homotryblium pallidum,* continue to be the important elements in the overlying cenozone. However, *Homotryblium pallidum* has negligible representation therein in only one sample.

Cleistosphaeridium sijuensis Cenozone

Type section—The type section is located at about 500 metres southwest of Siju Songmong, South Garo Hills, Meghalaya.

Lithology—The lithology of this cenozone is the same as that of the underlying *Homotryblium pallidum* Cenozone.

Significant palynotaxa—*Achomosphaera ramulifera, Cleistosphaeridium brevispinosum, C. sijuensis, Collumosphaera fruticosa, Homotryblium floripes, H. tenuispinosum, Hystrichosphaeridium arborispinum, H. latirictum, Lingulodinium machaerophorum, Operculodinium centrocarpum* and *O. major.*

Restricted palynotaxa—*Achomosphaera ramulifera, Ascostomatocystis granulata, Cleistosphaeridium sijuensis, Collumosphaera fruticosa, Cordosphaeridium inodes, C. fibrospinosum, Hystrichosphaeridium arborispinum, H. latirictum, Muratodinium fimbriatum, Spiniferites membranosus* and *Surculosphaeridium cribrotubiferum.*

Remarks—The marker taxa of this cenozone, viz., *Cleistosphaeridium sijuensis,* is dominant (13%) as well as restricted to this Cenozone. *Cleistosphaeridium brevispinosum* (17%) and *Operculodinium centrocarpum* (13%) continue to be significant throughout this zone. *Operculodinium major* is significantly represented in the lower part of this zone and is rare in the upper part. *Lingulodinium machaerophorum* dominantly occurs only in the upper part. *Homotryblium pallidum,* a zonal marker of the underlying zone, rarely occurs in this cenozone only in one sample.

PALAEOCLIMATE AND ENVIRONMENT OF DEPOSITION

The spore-pollen taxa, though poorly represented in the present assemblage, are significant in deducing the palaeoclimate. The spores and pollen are land-derived elements and therefore their parent plants must be growing near the coast. The occurrence of pteridophytic spores assignable to Lygodiaceae (*Lygodiumsporites, Todisporites*) and Polypodiaceae (*Eximispora*) along with angiosperm pollen assignable to Arecaceae (*Neocouperipollis* spp., *Palmaepollenites plicatus, Palmidites maximus*), Pelliceraceae (*Pelliceiroipollis langenheimii*), Meliaceae (*Meliapollis*), and Onagraceae (*Triangulorites bellus*) reflects that these plants had a luxuriant growth nearby. Arecaceous plants constitute coastal vegetation whereas *Pelliceiroipollis* is an element of mangrove vegetation. Asteraceae, grasses and pteridophytes constituted the herbaceous flora growing as undergrowth in a moist and shady habitat. Abundance of epiphyllous fungi e.g., *Phragmothyrites eocaenicus, Trichothyrites amorphus* and *Parmathyrites indicus*, indicates the existence of a characteristic warm and humid condition with heavy rainfall suitable for growth of a mesophytic forest. It is therefore evident that the area enjoyed tropical, warm humid climate during the sedimentation of the Siju Formation.

The Siju palynofloral assemblage is dominated by dinoflagellate cysts like *Homotryblium, Cordosphaeridium* and *Cleistosphaeridium,* which constitute about 70% of the total dinocyst population. The distribution pattern of dinocysts in the present succession shows changes in the environment of deposition from older to younger horizons. The lower part of the sequence represented by *Homotryblium pallidum* Cenozone exhibits presence of *Homotryblium* spp., *Cordosphaeridium* spp. and *Adnatosphaeridium vittatum,* which are known to inhabit near shore shallow marine

←

PLATE 2

(All photomicrographs are magnified *ca.* x 700)

1. *Graminidites media* Cookson, Slide no. BSIP 12407 (21 x 106).
2. *Palmaepollenites plicatus* Sah & Kar, Slide no. BSIP 12408 (51 x 105·5).
3. *Pilatricolporites* sp., Slide no. BSIP 12401 (31 x 99).
4. *Cordosphaeridium inodes* (Klumpp) Eisenack emend. Morgenroth, Slide no. BSIP 12409 (60 x 101·5).
5. *Hystrichosphaeridium arborispinum* Davey & Williams, Slide no. BSIP 12398 (41 x 99).
6. *Pellicieroipollis langenheimii* Sah & Kar, Slide no. BSIP 12411 (46 x 98).
7. *Neocouperipollis kutchensis* (Venkatachala & Kar) Kar & Kumar, Slide no. BSIP 12404 (33 x 96·5).
8. *Homotryblium pallidum* Davey & Williams, Slide no. BSIP 12410 (52 x 97).
9. *Surculosphaeridium cribrotubiferum* (Sarjeant) Davey *et al.*, Slide no. BSIP 12403 (29 x 96).
10-11 *Compositoipollenites conicus* Sah, Slide no. BSIP 12399 (33 x 102), BSIP 12411 (56 x 102·5).
12. *Hystrichosphaeridium latirictum* Davey & Williams, Slide no. BSIP 12402 (31 x 95·5).
13. *Collumosphaera fruticosa* Jain & Dutta in Dutta & Jain, Slide no. BSIP 12398 (34 x 105).
14. *Areosphaeridium arcuatum* Eaton, Slide no. BSIP 12412 (52 x 109).
15. *Operculodinium major* Jain & Dutta in Dutta & Jain, Slide no. BSIP 12404 (56 x 94·5).

environment having open marine influence. *Homotryblium pallidum, H. tenuispinosum* and *Cordosphaeridium fibrospinosum* decline considerably in the upper part of the sequence and are taken over by *Cleistosphaeridium, Operculodinium* and *Achomosphaera*. The abundance of *Cleistosphaeridium* and *Operculodinium* in *Cleistosphaeridium sijuensis* Cenozone demonstrates the onset of brackish water environment. The occurrence of angiosperm pollen belonging to the families Arecaceae *(Neocouperipollis brevispinosus, N. kutchensis, N. pyrispinosus, Palmidites assamicus, Palmaepollenites plicatus)* and Pelliceraceae *(Pelliceiroipollis langenheimii)* in this part also provides cogent evidence for this contention. The presence of terrestrial palynomorphs shows proximity to the shore line. As a whole, the variation in the dinocyst populations may be due to the fluctuating environment of deposition on an unstable shelf.

PALYNOFLORAL COMPARISON AND AGE

A comparison of the present palynoflora from the Siju Formation with the known contemporaneous assemblages from India is attempted below.

Meghalaya

Palynofloras from the Siju/ Sylhet Limestone formations have been recorded by Baksi (1962) and Sah and Singh (1977) from the Garo Hills and by Dutta and Jain (1980), Tripathi and Singh (1984) and Kar (1992) from the Jaintia Hills.

Baksi (1962) studied palynoflora from the Sylhet Limestone (= Siju Formation) of Simsang River Section and designated the sequence as Simsang Palynological Zone I. Main elements of this palynoflora are pollen of Arecaceae and Caesalpiniaceae together with inaperturate and polycolpate/ polycolporate pollen and a large number of hystrichospherids (= dinoflagellate cysts). The present assemblage is closely comparable to this assemblage in having abundance of dinoflagellate cysts and presence of arecaceous pollen (*Neocouperipollis* spp., *Palmidites assamicus* and *Palmaepollenites plicatus*. Sah and Singh (1977) reported *Retipilonapites* sp., *Neocouperipollis brevispinosus, Cyathidites minor, Palmidites plicatus* and *Polycolpites cooksoniae* from the Siju Formation of Garo Hills. Of these, *Cyathidites minor* and *Neocouperipollis brevispinosus* are found in the present assemblage also. It is noteworthy that Sah and Singh (1977) did not make any mention of dinoflagellate cysts, which form the dominant element of the present assemblage.

Dutta and Jain (1980) recorded dinoflagellate cysts from the Sylhet Limestone (Lakadong Limestone, Lakadong Sandstone and Prang Limestone) and Kopili formations exposed around Lumshnong in Jaintia Hills. *Collumosphaera fruticosa, Cordosphaeridium inodes, Operculodinium centrocarpum* and *O. major*, recorded by them from the Sylhet Limestone, are common to the present assemblage. *Operculodinium* spp. are dominant in both the assemblages. However, at generic level, *Ascostomatocystis, Collumosphaera, Cordosphaeridium, Distatodinium, Homotryblium, Hystrichokolpoma, Operculodinium, Spiniferites* and *Thalassiphora* are common between the two assemblages.

Tripathi and Singh (1984) recorded a scanty palynoflora from the Sylhet Limestone exposed along Jowai-Sonapur Road in Jaintia Hills. This assemblage includes *Neocouperipollis brevispinosus, Liliacidites giganticus, Dandotiaspora telonata, Tricolporopollis ruber, Tricolpites alveolatus* and *Operculodinium major*. Of these, *Operculodinium major* and *Neocouperipollis brevispinosus* occur in the present assemblage also.

Kar (1992) recorded a scanty palynoflora from the Prang Limestone (top member of the Sylhet Limestone Formation) exposed near 13·2 km post on Jowai-Sonapur Road. This palynoflora is represented by *Todisporites kutchensis, Lygodiumsporites lakiensis, Osmundacidites kutchensis, Cyathidites minor, Striatriletes susannae, Podocarpidites khasiensis, Polypodiaceaesporites chatterjii, Polypodiisporites repandus, Lakiapollis ovatus* and *Pellicieroipollis langenheimii*. Of these, only *Cyathidites minor* has been recorded from the present assemblage. It is striking to note that dinoflagellate cysts, which are abundant in the present assemblage, have not been found in the Prang assemblage.

Himachal Pradesh

The present assemblage is closely similar to palynofloral assembalge recorded from the Subathu Formation of Himachal Pradesh (Singh *et al.*, 1978, Sarkar & Singh 1988, Singh & Sarker 1992, Sarkar 1997, Sarkar & Prasad in press, a). Singh *et al.* (1978) proposed eight cenozones and two subzones in the Subathu Formation (Late Palaeocene to Late Eocene) of Kalka-Shimla area. The present palynofloral assemblage corresponds to the lower horizons of *Cordosphaeridium multispinosum* Cenozone (Early Lutetian). Several taxa are found to be common between the two assemblages viz., *Cordosphaeridium fibrospinosum, C. inodes, Homotryblium floripes, H. pallidum, H. tenuispinosum, Fromea amphora, Hystrichosphaeridium arborispinum, Hystrichosphaeridium tubiferum, Lingulodinium machaerophorum* and *Operculodinium centrocarpum*. The Middle Eocene palynofloral assemblages (Singh & Sarkar, 1992; Sarkar, 1997) of the Subathu Formation exhibit abundance of *Operculodinium* spp., *Lingulodinium machaerophorum, Spiniferites* spp. and *Achomosphaera* spp. The same trend has also been noticed in the Siju assemblage. A large number of

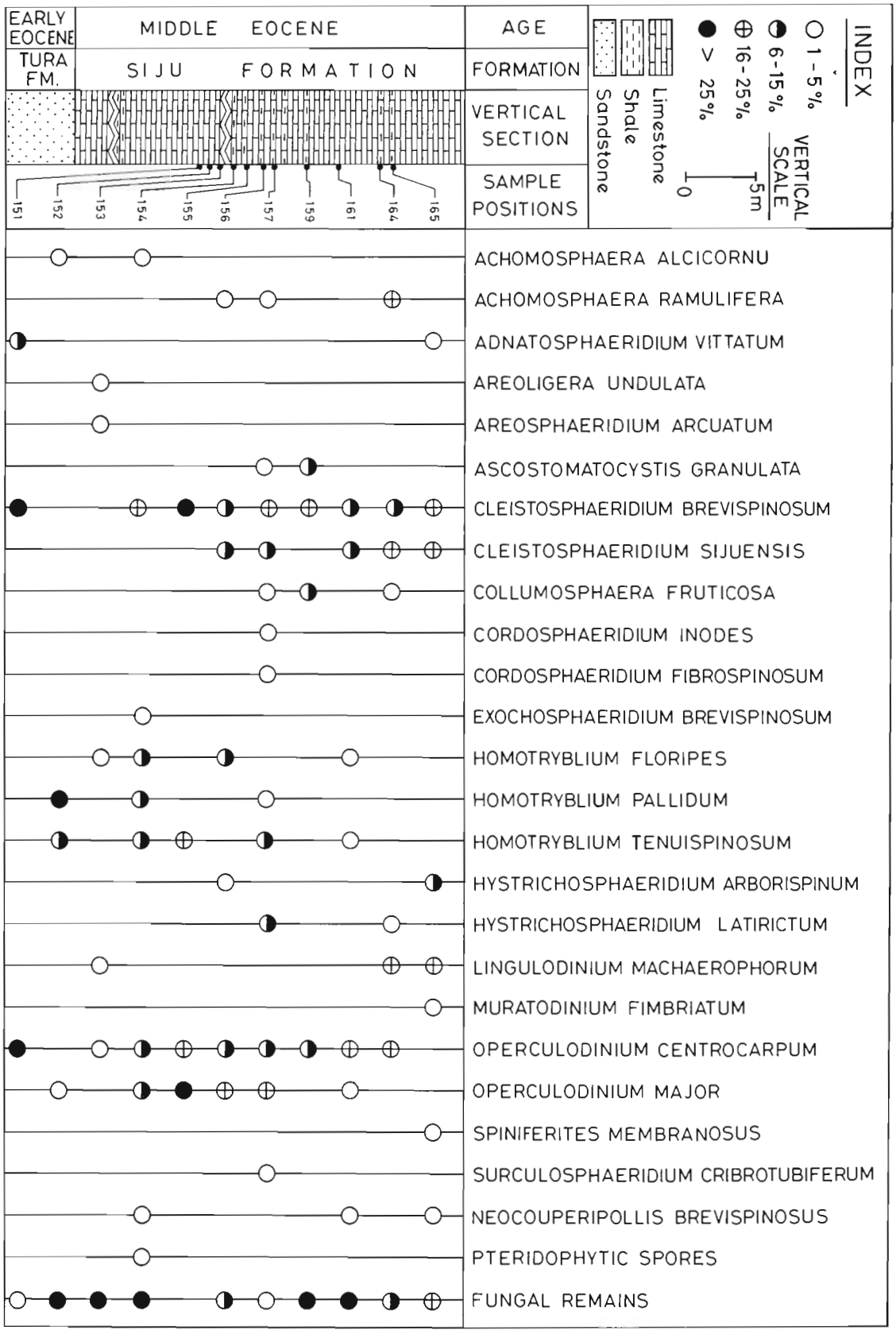

Fig. 4—Vertical distribution of palynotaxa in the Siju Formation.

spore/ pollen and dinoflagellate cyst taxa encountered in the Subathu palynofloral assemblage from Bilaspur area are common to the present palynological assemblage. Some of the significant forms are *Achomosphaera ramulifera, Cordosphaeridium fibrospinosum, C. inodes, Homotryblium floripes, H. pallidum, H. tenuispinosum, Hystrichosphaeridium tubiferum, Lingulodinium mechaerophorum, Operculodinium centrocarpum, Thalassiphora patula, Phragmothyrites eocaenica,* etc.

A Middle Eocene palynofloral assemblage has been recorded by Sarkar and Prasad (in press, a) from the Koshalia Nala Section near Koti. Taxa common between the two assemblages are *Achomosphaera triangulata, Cleistosphaeridium brevispinosum, Hystrichokolpoma cinctum, Lingulodinium machaerophorum, Operculodinium centrocarpum, Thalassiphora patula, Phragmothyrites eocaenica* and *Neocouperipollis pyrispinosus.*

Haryana

Sarkar and Prasad (in press, b) carried out palynological investigation of the Subathu Formation exposed along Kharak River Section of Morni Hills, Haryana and recognized four distinct assemblage zones ranging in age from Late Ypresian to Middle Lutetian. It is noteworthy that palynotaxa recorded from the upper part of Zone B and Zone C of this sequence also occur in the present assemblage. These are: *Achomosphaera ramulifera, Cordosphaeridium fibrospinosum, Lingulodinium machaerophorum, Operculodinium centrocarpum, Neocouperipollis brevispinosus, N. pyrispinosus,* etc.

Jammu

Palynological information from the Eocene sediments of Jammu is rather meagre. Khanna *et al.* (1985) described 17 genera and 23 species of dinoflagellate cysts from the Subathu sediments of Kalakot and adjoining areas. The Siju dinocyst assemblage is closely comparable with the top of *Cordosphaeridium multispinosum* Assemblage Zone and base of *Homotryblium* spp. Assemblage Zone. The palynotaxa common between the two assemblages are *Homotryblium pallidum, H. tenuispnomum, Hystrichosphaeridium tubiferum, Cleistosphaeridium brevispinosum, Cordosphaeridium fibrospinosum, Operculodinium centrocarpum, Areosphaeridium arcuatum,* etc.

Kutch

The palynofloral assemblages from the Eocene sediments of Kutch have been recorded by Mathur (1963, 1966), Sah and Kar (1969, 1970), Venkatachala and Kar (1969a, b), Kar (1978) and Jain and Tandon (1981). Of these, only the Middle Eocene palynoflora from Jhadwa and Baranda in southwestern Kutch (Jain & Tandon 1981) shows similarity with the Siju palynofloral assemblage. Of the five informal microplankton zones proposed by Jain and Tandon (1981), only Zone IV resembles the present palynofloral assemblage. The dinocyst taxa common between the two assemblages are *Adnatosphaeridium vittatum, Achomosphaera ramulifera, Hystrichokolpoma cinctum, Cordosphaeridium fibrospinosum, Areosphaeridium arcuatum, Operculodinium centrocarpum* and *Lingulodinium machaerophorum.*

The present palynoflora was also compared with the Eocene palynofloras recorded from the Cauvery Basin (Venkatachala & Rawat 1972) and the Godawari-Krishna Basin (Venkatachala & Sharma 1984) but was found to be distinctly different.

CONCLUSIONS

1. On the basis of frequency and distribution of palynofossils, two palynozones, viz. *Homotrylium pallidum* Cenozone and *Cleistosphaeridium sijuensis* Cenozone, have been recognized in the Siju Formation exposed in the type area. These zones are characterized by their dominant and restricted palynotaxa.

2. The present day distribution of the extant counterparts of the palynotaxa indicates prevalence of tropical (warm-humid) climate during the sedimentation of the Siju Formation and presence of mangrove elements along the shore and also wet evergreen forest further inland.

3. The lower part of the sequence was deposited in a near-shore, shallow marine environment having open marine influence whereas the upper part was deposited in a brackish water environment.

4. The Siju palynofloral assemblage is characterized by the presence of *Areosphaeridium arcuatum, Areoligera undulata* and *Distatodinium ellipticum.* These forms flourished mainly in the Middle Eocene sediments throughout the globe. Moreover, present assemblage is closely comparable with the Middle Eocene assemblages known from Meghalaya, Himachal Pradesh, Haryana, Jammu and Kutch. The present Siju palynofloral assemblage is therefore assigned a Middle Eocene age.

REFERENCES

Archangelsky S 1969. Estudio del paleomicroplankton de la Formacion Rio Turbio (Eoceno), Provincia de Santa Cruz; Ameghiniana 6 : 181-218 (in Spanish).

Baksi SK 1962. Palynological investigation of Simsang River Tertiaries, South Shillong Front, Assam. Bulletin of the Geological, Mining and Metallurgical Society of India 26 : 1-22.

Baksi SK 1974. Significant pollen taxa in the stratigraphical analysis of the Tertiary sediments of Assam. *In:* Surange KR, Lakhanpal RN & Bharadwaj DC (Editors)—Aspects and Appraisal of Indian

Palaeobotany. Birbal Sahni Institute of Palaeobotany, Lucknow : 502-515.

Benedek PN & Gocht H 1981. *Thalassiphora pelagica* (Dinoflagellate, Tertiar) electronenmikroskopische Untersuchung und Gedanken zur Palaobiologie. Palaeontographica Abt. B 180 : 39-64 (in German).

Biswas B 1962. Stratigraphy of the Mahadeo, Langpar, Cherra and Tura formations, Assam. Bulletin of the Geological, Mining and Metallurgical Society of India 25 : 1-48.

Chakraborty A 1972. On the rock stratigraphy, sedimentation and tectonics of the sedimentary belt in the south-west of the Shillong Plateau, Meghalaya. Bulletin of the Oil and Natural Gas Commission 9 : 133-141.

Chakraborty A & Baksi SK 1972. Stratigraphy of the Cretaceous-Tertiary sedimentary sequence, south-west of Shillong Plateau. Quarterly Journal of the Geological, Mining and Metallurgical Society of India 44 : 109-127.

Chateauneuf JJ 1980. Palynostratigraphie et Paleoclimatologie de l'Eocene superieur et de l'Oligocene du Bassin de Paris. Bureau des Recherches Geologiques et Minieres Memoire 116: 1-360 (in French).

Cookson IC 1947. Plant microfossils from the lignites of Kerguelen Archipelago. Report of the B.A.N.Z. Antarctic Research Expedition, Series A 2: 127-142.

Cookson IC 1965. Cretaceous and Tertiary microplankton from South eastern Australia. Proceedings of the Royal Society of Victoria 78: 85-93.

Cookson IC & Eisenack A 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. Proceedings of the Royal Society of Victoria 70: 204-216.

Cookson IC & Eisenack A 1967. Some microplankton from the Paleocene Rivernook Beel, Victoria. Proceedings of the Royal Society of Victoria 80 : 247-257.

Couper RA 1958. British Mesozoic microspores and pollen grains. A systematic and stratigraphical study. Palaeontographica Abt. B 103: 75-179.

Davey RJ, Downie C, Sarjeant WAS & Williams GL 1966. Fossil dinoflagellate cysts attributed to *Baltisphaeridium*. *In:* Davey RJ, Downie C, Sarjeant WAS & Williams GL (Editors)—Studies on Mesozoic and Cainozoic dinoflagellate cysts. Bulletin of the British Museum (Natural History) Geology, Supplement 3 : 157-175.

Davey RJ & Williams GL 1966a. The genera *Hystrichosphaera* and *Achomosphaera*. *In:* Davey RJ, Downie C, Sarjeant WAS & Williams GL (Editors)—Studies on Mesozoic and Cainozoic dinoflagellate cysts. Bulletin of the British Museum (Natural History) Geology, Supplement 3 : 28-52.

Davey RJ & Williams GL 1966b. The genus *Hystrichosphaeridium* and its allies. *In:* Davey RJ, Downie C, Sarjeant WAS & Williams GL (Editors)—Studies on Mesozoic and Cainozoic dinoflagellate cysts. Bulletin of the British Museum (Natural History) Geology, Supplement 3 : 53-106.

Davey RJ & Williams GL 1969. Generic reallocations. *In:* Davey RJ, Downie C, Sarjeant WAS & Williams GL, Appendix to studies on Mesozoic and Cainozoic dinoflagellate cysts. Bulletin of the British Museum (Natural History) Geology, Appendix to Supplement 3 : 4-7.

Deflandre G 1937. Microfossiles des silex Cretaces. Deuxieme partie. Flagelles incertae sedis. Hystrichosphaerides Sarcodines Organismes divers. Annales de Paleontologie 26 : 51-103.

Deflandre G & Cookson IC 1955. Fossil microplankton from Australian Late Mesozoic and Tertiary sediments. Australian Journal of Marine and Freshwater Research 6 : 242-313.

Drugg WS 1970. Some new genera, species and combinations of phytoplankton from the Lower Tertiary of the Gulf Coast, U.S.A. North American Palaeontological Convention, Chicago, 1969, Proc. G : 809-843.

Dutta SK & Jain KP 1980. Geology and palynology of the area around Lumshnong, Jaintia Hills, Meghalaya, India. Biological Memoirs 5 : 56-81.

Eaton GL 1971. A morphogenetic series of dinoflagellate cysts from the Bracklesham Beds of the Isle of Wight, Hampshire, England. *In:* Farinacci A (Editors)—Proceedings of the Second Planktonic Conference, Rome, 1970. Edizioni Technoscienza, Rome 1 : 355-379.

Eaton GL 1976. Dinoflagellate cysts from the Bracklesham Beds of the Isle of Wight, southern England. Bulletin of the British Museum (Natural History) Geology 26 : 227-332.

Edwards WN 1922. An Eocene microthyriaceous fungus from Mull, Scotland. Transactions of the British Mycological Society 8 : 66-72.

Ehrenberg CG 1838. Uber das Massenverhaltniss der Jetzt. lebenden Kiesel Infusorien und uber ein neues Infusorien Conglomerat als Polirschiefer von Jastraba in Ungarn. Abhandlungen der Preussischen Akademic der Wissenschaftten 1836 : 109-135 (in German).

Eisenack A 1954. Microfossilien aus Phosphoriten des samlandischen Unteroligozans und uber dee Einheitlichkeit der Hystrichosphaerideen. Palaeontographica, Abt. A 105 : 49-95. (in German).

Eisenack A 1963. *Cordosphaeridium* n. g. ex *Hystrichosphaeridium, Hystrichosphaeridea*. Neues Jahrbuch fur Geologia und Palaontologie, Abhandlungen 118: 260-265 (in German).

Eisenack A & Gocht H 1960. Neue Namen fur einige Hystrichospharen der Bernsteinformation Ostpreussens. Neues Jahrbuch fur Geologie und Palaeontologie, Monatshefte: 511-518. (in German).

Evans P 1932. Explanatory notes to accompany a table showing Tertiary succession in Assam. Transactions of the Mining and Metallurgical Institute of India 27 : 155-260.

Evitt WR 1963. A discussion and proposals concerning fossil dinoflagellates, hystrichospheres and acritarchs I. Proceedings of the National Academy of Sciences, Washington 49 : 158-164.

Gerlach E 1961. Microfossilien aus dem Oligozan und Miozan Nordwest deutschlands, unter besonderer. Berucksichtigung der Hystrichospharen und Dinoflagellaten. Neues Jahrbuch fur Geologie und Palaontologie, Abhandlungen 112 : 143-228.(in German).

Ghosh AMN 1954. The Tura Sandstone Stage of the Garo Hills – its possible stratigraphic position. Records of the Geological Survey of India 83 : 423-444.

Hayden HH 1897. Jaintia coal. Records of the Geological Survey of India 30 : 249.

Heron AM 1937. General Report of the Geological Survey of India for the year 1936. Records of the Geological Survey of India 72 : 85-90.

Jain KP & Gupta RC 1970. Some fungal remains from the Tertiaries of Kerala Coast. Palaeobotanist 18 : 177-182.

Jain KP & Millepied P 1975. Cretaceous microplankton from Senegal Basin, W. Africa, Pt. II. Systematics and biostratigraphy. Geophytology 5 : 126-171.

Jain KP & Tandon KK 1981. Dinoflagellate and Acritarch biostratigraphy of the Middle Eocene rocks of a part of Southwestern Kachchh, India. Journal of the Palaeontological Society of India 26 : 6-21.

Kar RK 1978. Palynostratigraphy of the Naredi (Lower Eocene) and the Harudi (Middle Eocene) formations in the district of Kutch, India. Palaeobotanist 25 : 161-178.

Kar RK 1985. The fossil floras of Kachchh-IV. Tertiary palynostratigraphy. Palaeobotanist 34 : 1-280.

Kar RK 1992. Stratigraphical implications of Tertiary palynological successions in north-eastern and western India. Palaeobotanist 40 : 336-344.

Kar RK & Kumar M 1987. *Neocouperipollis* - a new name for *Couperipollis* Venkatachala & Kar. Palaeobotanist 35 : 171-174.

Kar RK & Saxena RK 1976. Algal and fungal microfossils from Matanomadh Formation (Palaeocene), Kutch, India. Palaeobotanist 23 : 1-15.

Kar RK, Singh RY & Sah SCD 1972. On some algal and fungal remains from the Tura Formation of Garo Hills, Assam. Palaeobotanist 19 : 146-154.

Khanna AK 1978. Stratigraphy and palynology of the Subathu Formation of the Punjab Basin, India. Unpublished Ph. D. Thesis, Lucknow University.

Khanna AK, Sarkar S & Singh HP 1985. Stratigraphical significance of dinocysts from the Subathu Formation of Jammu. Geoscience Journal 6 : 103-112.

Klumpp B 1953. Beitrag zur Kenntnis der Mikrofossilien des mittleren und oberen Eozan; Palaeontographica Abt. A 103 : 377-406. (in German).

LaTouche THD 1882. The Daranggiri Coalfield. Records of the Geological Survey of India 15 : 175-178.

LaTouche THD 1883a. Cretaceous coal measures in the Khasia Hills. Records of the Geological Survey of India 16 : 164-165.

LaTouche THD 1883b. Notes on a traverse through the eastern Khasia-Jaintia and North Cachar Hills. Records of the Geological Survey of India 16 : 198-203.

LaTouche THD 1884. On Khasi coal. Records of the Geological Survey of India 17: 143-144.

LaTouche THD 1887. Geology of Garo Hills. Records of the Geological Survey of India 20: 40-43.

LaTouche THD 1889. On Cherrapunji Coalfield. Records of the Geological Survey of India 22: 167-171.

LaTouche THD 1890a. On Lakadong Coalfield. Records of the Geological Survey of India 23: 14-17.

LaTouche THD 1890b. On some Khasi Hills coalfields. Records of the Geological Survey of India 23: 120-124.

Lentin JK & Williams GL 1973. Fossil dinoflagellates: index to genera and species. Geological Survey of Canada, Paper no. 7342: 1-176.

Mathur YK 1963. Studies in the fossil microflora of Kutch. India-1. On the microflora and the hystrichospherids in the Gypseous Shales (Eocene) of Western Kutch, India. Proceeding of the National Institute of Sciences of India 29B : 357-371.

Mathur YK 1966. On the microflora in the Supra-Trappeans of Western Kutch, India. Quarterly Journal of the Geological, Mining and Metallurgical Society of India 38 : 33-51.

Matsuoka K 1984. Some dinoflagellate cysts from the Nanggulan Formation in Central Java, Indonesia. Transactions and Proceedings of the Palaeontology. Society of Japan, N.S. no. 134: 374-387.

Medlicott HB 1868. On the prospects of coal being found in Garo Hills. Records of the Geological Survey of India 1 : 11-16.

Medlicott HB 1869. Geological sketch of Shillong Plateau. Memoirs of the Geological Survey of India 7 : 151-207.

Medlicott HB 1874. Coal in Garo Hills. Records of the Geological Survey of India 7 : 50-62.

Morgenroth P 1968. Zur Kenntnis der Dinoflagellaten und Hystrichosphaeridien des Danien. Geologisches Jahrbuch 86: 533-578 (in German).

Murthy MVN, Chakrabarti C & Talukdar SC 1976. Stratigraphic revision of the Cretaceous-Tertiary sediments of Shillong Plateau. Records of the Geological Survey of India 107 : 81-89.

Oldham T 1859. On the geological structure of a portion of the Khasi Hills. Memoirs of the Geological Survey of India 1 : 99-210.

Palmer RW 1923. Geology of a part of the Khasi and Jaintia Hills. Records of the Geological Survey of India 55 : 143-187.

Pinfold ES 1919. Two new fossil localities in the Garo Hills. Records of the Geological Survey of India 50 : 126-129.

Raja Rao CS (Editor) 1981. Coalfields of India – vol. 1. Coalfields of Northeastern India. Bulletin of the Geological Survey of India, Series A, 45 : 1-76.

Rossignol M 1962. Analyse pollinique de sediments marins Quaternaires en Israel II. Sediments Pleistocenes. Pollen et Spores 4 : 121-148.

Sah SCD 1967. Palynology of an Upper Neogene profile from Rusizi Valley (Burundi). Musee Royal de L'Afrique Centrale - Tervuren, Belgique Annales - Serie In 8 - Sciences Geologiques 57 : 1-173.

Sah SCD & Kar RK 1969. Pteridophytic spores from the Laki Series of Kutch, Gujarat, India. *In:* Santapau H, Ghosh AK, Roy SK, Chanda S & Chaudhuri SK (Editors)—J. Sen Memorial Volume, Botanical Society of Bengal, Calcutta : 109-112.

Sah SCD & Kar RK 1970. Palynology of the Laki sediments in Kutch-3. Pollen from the boreholes around Jhulrai, Baranda and Panandhro. Palaeobotanist 18 : 127-142.

Sah SCD & Singh RY 1977. Status of palynology in the Tertiary stratigraphy of Assam and Gujarat. *In:* Venkatachala BS & Sastri VV (Editors)—Proceedings of the 4th Colloquium on Indian Micropalentology and Stratigraphy, Dehradun, 1974-75. Institute of Petroleum Exploration, Oil and Natural Gas Commission, Dehradun : 134-143.

Salujha SK, Kindra GS & Rahman K 1972. Palynology of the South Shillong Front-Part I. The Palaeogene of Garo Hills. *In:* Ghosh AK, Chanda S, Ghosh TK, Baksi SK & Banerjee M (Editors)-Proceedings of the Symposium on Palaeopalynology and Stratigraphy, Calcutta, 1971. Botany Department, Calcutta University : 265-291.

Salujha SK, Kindra GS & Rehman K 1974. Palynology of the South Shillong Front-Part Palaeogene of Khasi and Jaintia Hills. Palaeobotanist 21 : 267-284.

Samanta B 1971. Early Tertiary Stratigraphy of the area around Garampani, Mikir-North Cachar Hills, Assam. Journal of the Geological Society of India 12 : 318-327.

Sarjeant WAS 1960. New hystrichospheres from the Upper Jurassic of Dorset. Geological Magazine 97 : 137-144.

Sarkar S 1997. Palynostratigraphy and palaeoenvironment of the Subathu Formation (Eocene) of Lesser Himalaya, Himachal Pradesh, India. Indian Journal of Petroleum Geology 6 : 99-115.

Sarkar S & Prasad V (in press), a. Palaeoenvironmental significance of dinoflagellate cysts from the Subathu Formation (Late Ypresian to Middle Lutetian) of Koshalia Nala Section, Shimla Hills, India. Himalayan Geology.

Sarkar S & Prasad V (in press), b. Palynostratigraphy and depositional environment of the Subathu Formation (Late Ypresian to Middle Lutetian), Morni Hills, Haryana, India. Journal of the Palaeontological Society of India.

Sarkar S & Singh HP 1988. Palynological investigation of the Subathu Formation (Eocene) in the Banethi-Bagthan area of Himachal Pradesh, India. Palaeontographica Abt. B Palaeophytology 209 : 29-108.

Saxena RK & Misra NK 1990. Palynological investigation of the Ratnagiri Beds of Sindhu Durg District, Maharashtra. Palaeobotanist 38 : 263-276.

Saxena RK & Singh HP 1982. Palynological investigation of the Upper Siwalik sediments exposed along Hoshiarpur-Una Road Section in Punjab and Himachal Pradesh. Geophytology 12 : 287-306.

Sheffy MV & Dilcher DL 1971. Morphology and taxonomy of fungal spores. Palaeontographica Abt. B 133(1-3) : 34-51.

Singh HP, Khanna AK & Sah SCD 1978. Palynological zonation of the Subathu Formation in the Kalka-Shimla area, Himachal Pradesh. Himalayan Geology 8 : 33-46.

Singh HP & Sarkar S 1992. Palynology and palaeoenvironment of Lower Tertiary sediments around Garkhal, Himachal Pradesh, India. Geophytology 22 : 181-191.

Singh RY 1977. Stratigraphy and palynology of the Tura Formation in the type area. Part II (Descriptive palynology). Palaeobotanist 23 : 189-205.

Stover LE 1975. Observations on some Australian Eocene dinoflagellates. Geoscience and Man 11 : 35-45.

Stover LE & Evitt WR 1978. Analysis of pre-Pleistocene organic walled dinoflagellates. Stanford University Publications, Geological Sciences 15 : 1-300.

Tripathi SKM & Singh HP 1984. Palynostratigraphical zonation and correlation of the Jowai-Badarpur Road Section (Palaeocene-Eocene), Meghalaya, India. *In:* Tiwari RS, Awasthi N, Suresh C Srivastava, Singh HP & Sharma BB (Editors)—Proceedings of the 5th Indian Geophytological Conference, Lucknow, 1983, Special Publication, The Palaeobotanical Society, Lucknow : 316-328.

Venkatachala BS & Kar RK 1969a. Palynology of the Tertiary sediments of Kutch-1. Spores and pollen from the borehole no. 14. Palaeobotanist 17 : 157-178.

Venkatachala BS & Kar RK 1969b. Palynology of the Tertiary sediments of Kutch-2. Epiphyllous fungal remains from the borehole no. 14, Palaeobotanist 17 : 179-183.

Venkatachala BS & Rawat MS 1972. Palynology of the Tertiary sediments in the Cambay Basin-1. Palaeocene-Eocene palynoflora from the subsurface. *In:* Ghosh AK, Chanda S, Ghosh TK, Baksi SK & Banerjee M (Editors)—Proceedings of the Seminar on Palaeopalynology and Indian Stratigraphy, Calcutta, 1971 : 292-335 Botany Department, Calcutta University.

Venkatachala BS & Sharma KD 1984. Palynological zonation in subsurface sediments in Narsapur Well no. 1, Godavari-Krishna Basin, India. *In*: Badve RM, Borkar VD, Ghare MA & Rajshekhar C (Editors)—Proceedings of the 10th Indian Colloquium on Micropalaeontology and Stratigraphy, Pune, 1982: 445-465, Maharashtra Association for the Cultivation of Science, Pune.

Wall D 1967. Fossil microplankton in deep-sea cores from the Carribean Sea. Palaeontology 10: 95-123.

Williams GL & Downie C 1966. Further dinoflagellate cysts from the London Clay. *In*: Davey RJ, Downie C, Sarjeant WAS & Williams GL (Editors)—Studies on Mesozoic and Cainozoic dinoflagellate cysts. Bulletin of the British Museum (Natural History) Geology, Supplement 3 : 215-235.