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

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ABSTRACT

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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, Cleistosphaeridiun brevispinosum, Collumosphaera fruticosa, Homotryblium floripes, H. pallidum, H. tenuispinum, Lingulodinium machaerophorum, Operculodinium centrocarpum, O. major, etc. Three species, viz., Cleistosphaeridiun sijuensis, Collumosphaera ganeosus and Thalassiphora indica, are proposed as new. On the basis of frequency and distribution of palynotaxa, two cenozones, viz., Homotryblium pallidum Cenozoone and Cleistosphaeridiun sijuensis Cenozoone, 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).
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 (1889), 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
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-I, corresponds to the Siju Formation (= part of the Sylhet Formation). Baksi (1974) formally named this zone as Polyepitites-Monosulcites (Colocasioidaeaeapites) 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. (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 Retipilanapites sp., Neocooperipollis brevispinosus, Cyathidites minor, Palmoideae laticlavae, Polyepitites cooksoniae, etc.

Chakraborty and Baks (1972) reported occurrence of Assilina spira corrugata, A. exponens, A. regularia, A. sinsangi, Alveolina elliptica nuttelli, Nummulites acutus, N. obtusus, Discocyclina javana, D. ommphalus, Orbitolites conpandatus, 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 inferring palaeoclimate, environment of deposition and age.
white, yellow and reddish, non-feldspathic, frequently current bedded, quartz-arenite type of sandstones intercalated with thin beds of grey shale, carbonaceous shale, lithomargic clay, 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 HNO₃, 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

*Achnomosphaera alcicornis* (Eisenack 1954) Davey & Williams 1966a
*Achnomosphaera ramulifera* (Deflandre 1937) Evitt 1963
*Achnomosphaera triangulata* (Gerlach 1961) Davey & Williams 1969 (Pl. 1, fig. 9)
*Adnotosphaeridium vitatum* Williams & Downie 1966
*Arroligera undulata* Eaton 1976

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**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...
Areosphaeridiurn arcuatum Eaton 1971 (Pl. 2, fig. 14)
Ascostomatocystis granulata Chateauneuf 1980
Cleistosphaeridiurn brevispinosum Jain & Milleped 1975 (Pl. 1, fig. 2)
*Cleistosphaeridiurn sijuensis* sp. nov. (Pl. 1, figs 7-8)
Collumosphaera fruticosa Jain & Dutta in Dutta & Jain 1980 (Pl. 2, fig. 13)
*Collumosphaera gareensis* sp. nov. (Pl. 1, figs 5-6)
Cordosphaeridiurn fibrosisporum Davey & Williams 1966b
Cordosphaeridiurn inodes (Klumpp 1953) Eisenack 1963 emend. Morgenroth 1968 (Pl. 2, fig. 4)
Distatodinium ellipticum (Cookson 1965) Eaton 1976
Exochosphaeridiurn 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
Hystrichosphaeridiurn arborispinum Davey & Williams 1969 (Pl. 2, fig. 5)
Hystrichosphaeridiurn latircicum Davey & Williams 1966b (Pl. 2, fig. 12)
Hystrichosphaeridiurn tubiferum (Ehrenberg 1838) Davey & Williams 1966b
Lingulodinium machaerophorum (Deflandre & Cookson 1955) Wall 1967
Muratodinium fimbriatum (Cookson & Eisenack 1967) Drugg 1970
Opeculodinium centrocarpum (Deflandre & Cookson 1955) Wall 1967 (Pl. 1, fig. 1)
Opeculodinium israeliaceum (Rossignol 1962) Wall 1967
Opeculodinium major Jain & Dutta in Dutta & Jain 1980 (Pl. 2, fig. 15)
Spiniferinembranous (Archangelsky 1969) Lentin & Williams 1973 (Pl. 1, fig. 4)
Surculosphaeridiurn cribratuliferum (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**

Callinathus assamicus Kar et al. 1972
Parmathyrites indicus Jain & Gupta 1970 (Pl. 1, fig. 3)
Staphylosporionites multicipular Saxena & Singh 1982
Staphylosporionites tristatus Shefy & Dilcher 1971
Trichothyrites anomorphus (Kar & Saxena 1976) Saxena & Misra 1990

**Pteridophytic spores**

Eximispora tuberculata Saluja et al. 1972
Lygodiumsporites lakshensis Sah & Kar 1969
Todiosporites minor Couper 1958

**Angiospermous pollen**

Compositapollenites conicus Sah 1967 (Pl. 2, figs 10-11)
Graminidites media Cookson 1947 (Pl. 2, fig. 1)
Melalopolis ravi Sah & Kar 1970

Neocouperipollis brevispinus (Biswas 1962) Sarkar & Singh 1988
Neocouperipollis kutchensis (Venkatachala & Kar 1969a) Kar & Kumar 1987 (Pl. 2, fig. 7)
Neocouperipollis pyrrippinus Sarkar & Singh 1988
Palmaepollenites plicatus Sah & Kar 1970 (Pl. 2, fig. 2)
Palnidiurns assamicus Singh 1977
Pelliteipollis langenheimi Sah & Kar 1970 (Pl. 2, fig. 6)
*Pilatricolporites* sp. (Pl. 2, fig. 3)
Triangularitites 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, 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, non-tabular, 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 Cleistosphaeridiurn 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 μm in diameter.
**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

**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.


**Comparison**—The present species differs from 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 palynofoa of the assemblage are: *Achomosphaera ramulifera*, *Cleistosphaeridium brevi-spinosum*, *C. sijuensis*, *Collumosphaera fruticosa*, *Homo-tryblium floripes*, *H. pallidum*, *H. teunispinosum*, *Lingulodinium machaerophorum*, *Operculodinium centrocercum*, *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. On the basis of abundance, decline, restricted occurrence and absence of palynofoa, the studied sequence has been divided into two cenozones, viz., *Homotryblium pallidum* Cenzone and *Cleistosphaeridium sijuensis* Cenzone. The cenozones are recognized on the basis of abundance, decline, restricted occurrence and absence of palynofoa. A formal description of these cenozones is given below.

**Homotryblium pallidum** Cenzone

**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 cenzone is composed of greyish yellow and yellow, arenaceous, foraminiferal limestone interbedded with thin calcareous shale and marl bands.

**Significant palynofoa**—*Achomosphaera allicornu*, *Adnatosphaeridium vittatum*, *Cleistosphaeridium brevispinosum*, *Homotryblium pallidum*, *H. teunispinosum*, *Operculodinium centrocercum* and *O. major*.

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**PLATE 1**

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

2. *Cleistosphaeridium brevispinosum* Jain & Millepied. Slide no. BSIP 12398 (65 x 106).
3. *Paralthyrites indicus* Jain & Gupta. Slide no. BSIP 12399 (22 x 102.5).
4. *Spiniferites membranaceus* (Archangelsky) Lentin & Williams. Slide no. BSIP 12400 (32 x 100.5).
5-6. *Collumosphaera garensis* 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).
11-12. *Thalassiphora indica* sp. nov., Slide no. BSIP 12402 (53 x 99), BSIP 12406 (48 x 102).
Restricted palynotaxa—Achomosphaera aleicorona, Areoligeria undulata, Areosphaeridium araeutum 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.


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 (Eximisporites) along with angiosperm pollen assignable to Araceae (Neocouperipollis spp., Palmaepollenites plicatus, Palmidites maximus), Pelliceraceae (Pellicieropollis langenheinii), Meliaceae (Meliapollis), and Onagraceae (Triangularites bellus) reflects that these plants had a luxuriant growth nearby. Arecaceous plant constitute coastal vegetation whereas Pellicieropollis is an element of mangrove vegetation. Astereaceae, grasses and pteridophytes constituted the herbaceous flora growing as undergrowth in a moist and shady habitat. Abundance of epiphyllous fungi e.g., Phragnothyriseaeocacicus, Trichothyris amorphus and Parmathyris 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...
environment having open marine influence. *Honotryblium 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 sijensis* Cenozoic demonstrates the onset of brackish water environment. The occurrence of angiosperm pollen belonging to the families Arecaceae (*Neocouperipollis brevispinosus*, *N. kutchensis*, *N. pyrisspinus*, *Palmidites assamicus*, *Palmae pollenites plicatus*) and Pelliceraceae (*Pellicerolitellipollis longhenii*) 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 *Palmae pollenites plicatus*). Sah and Singh (1977) reported *Retipilonapites* spp., *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 Kopil formations exposed around Lumshnong in Jaintia Hills. *Collumosphaera fruticosa*, *Cordosphaeridium inodes*, *Operculodinium centrocarpum* and *O. major* recorded from the Sylhet Limestone, are common to the present assemblage. *Operculodinium* spp. are dominant in both the assemblages. However, at generic level, *Ascostomatocystis*, *CollumospaHera*, *Cordosphaeridium*, *Distatodinium*, *Honotryblium*, *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*, *Tricolporopolis ruber*, *Tricolpites alevolatus* 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*, *Lygotiumsporites lakensis*, *Osmandicaites kutchensis*, *Cyathidites minor*, *Striatriletus susannae*, *Podocarpidites khasiensis*, *Polypodiaceaesporites chatterji*, *Polypodisporites repandus*, *Lakiapolles ovatus* and *Pellicereotolpis longhenii*. 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 assemblages recorded from the Subathu Formation of Himachal Pradesh (Singh et al., 1978, Sarkar & Singh 1988, Singh & Sarkar 1992, Sarkar 1997, Sarkar & Prasad in press, a). Singh et al. (1978) proposed eight cenozones and two subzones in the Subathu Formation (Late Paleocene to Late Eocene) of Kalka-Shimla area. The present palynofloral assemblage corresponds to the lower horizons of *Cordosphaeridium multispinosum* Cenzone (Early Lutetian). Several taxa are found to be common between the two assemblages viz., *Cordosphaeridium fibrospinosum*, *C. inodes*, *Honotryblium floripes*, *H. pallidum*, *H. tenuispinosum*, *Fromea amphaora*, *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 palynomorphs in the Siiju 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 ramuliflora, Cordosphaeridium fibrosinum, C. inodes, Homotryblium floripes, H. pallidum, H. tenuispinum, Hystrichosphaeridium tubiferum, Lingulodinium machaeorhizum, Operculodinium centrocarpum, Thalassiphora patula, Phragmothyrites cocaenica, 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 ramuliflora, Cleistosphaeridium brevispinum, Hystrichosphaeridium cinctum, Lingulodinium machaeorhizum, Operculodinium centrocarpum, Thalassiphora patula, Phragmothyrites cocaenica and Neocouperipollis pyrissinosus.

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 ramuliflora, Cordosphaeridium fibrosinum, Lingulodinium machaeorhizum, Operculodinium centrocarpum, Neocouperipollis brevispinosus, N. pyrissinosus, 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. tenuispinum, Hystrichosphaeridium tubiferum, Cleistosphaeridium brevispinosum, Cordosphaeridium fibrosinum, 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 Adunatosphaeridium vittatum, Achomosphaera ramuliflora, Hystrichokolpoma cinctum, Cordosphaeridium fibrosinum, Areosphaeridium arcuatum, Operculodinium centrocarpum and Lingulodinium machaeorhizum.

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. Homotryblium pallidum Cenozone and Cleistosphaeridium siquens 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

SAXENA et al. — PALYNOCLOGICAL INVESTIGATION OF THE SIJU FORMATION


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