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DINOFLAGELLATE AND ACRITARCH BIOSTRATIGRAPHY OF THE MIDDLE EOCENE ROCKS OF A PART OF SOUTH-WESTERN KACHCHH, INDIA

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ABSTRACT

The morphotaxonomical treatment and biostratigraphical application of the dinoflagellate cysts and acritarchs, recovered from the Middle Eocene rocks exposed between Ratchelo up to Jhadwa in south-western Kachchh, form the subject of the present communication. A total of 48 microplankton taxa are recognised. Out of these, six species, viz., *Glaphyrocysta kachchhensis*, *Cyclopsiella coniata*, *Impletosphaeredium granulosum*, *Polysphaeridium ornamentum*, *Araneosphaera consociata* and *Achomosphaera multifurcata*, are new. Five informal microplankton zones are proposed based on the maximum change in microfloral constituents.

INTRODUCTION

The Middle Eocene rocks of south-western Kachchh are continuously exposed in nala sections from Ratchelo, a place about 3.2 km south of Baranda (23°34′20″ : 68°43′10″) up to Jhadwa (23°30′30″ : 68°36′30″) (Fig. 1). One of us (K.K.T.) collected the stratigraphically located rock samples during four field seasons (1969—1972). Tandon (1976) published the biostratigraphy

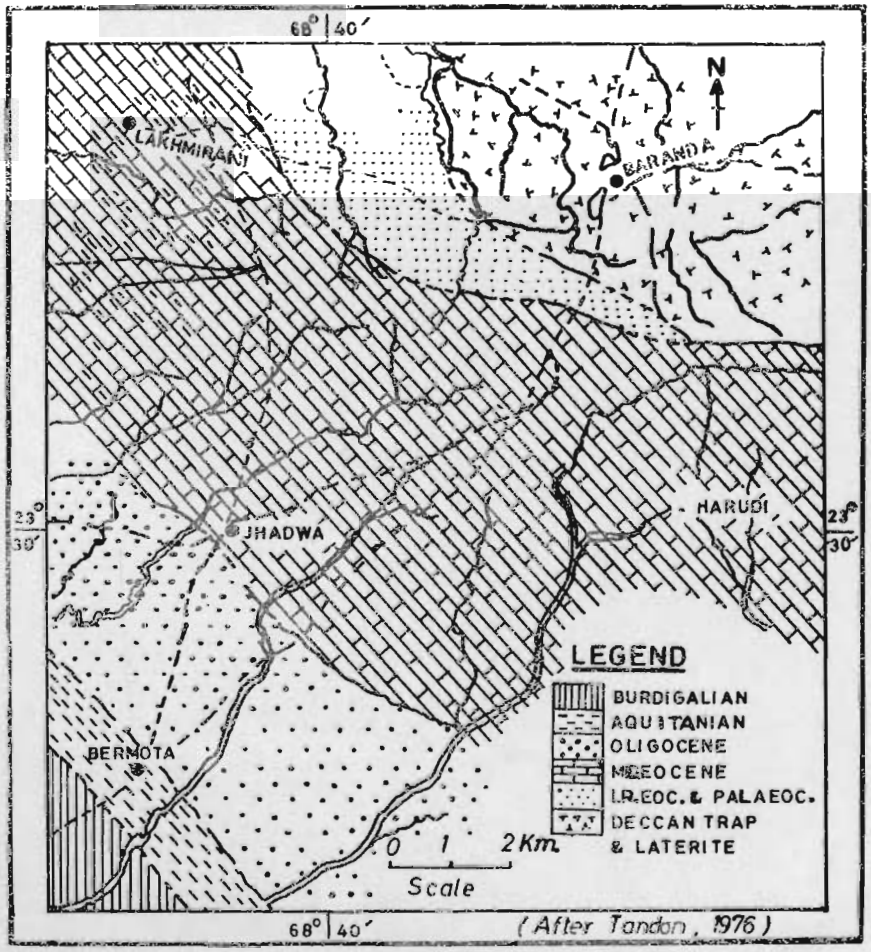

Fig. 1. Geological map of a part of south-western Kachchh.

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of the area taking into consideration, mainly the larger foraminifera but in their absence other fossils viz., invertebrates (molluscs), vertebrates and plant leaf impressions, were also included. He (1976) proposed ten biozones and two unfossiliferous zones. The total thickness of the Middle Eocene sequence in the area alongwith the extent of biozones and the lithological details are reproduced in Fig. 2.

Tandon (1976, p. 73) remarked, "It has now been observed that the Dicot leaf zone does not underlie *Crocodylus* zone as reported earlier (1971) but overlies the same". This statement needs correction, *Crocodylus* is a misprint there and should be read as *Corbula subexarata*.

The present dinoflagellate and acritarch analysis is based on the same material used by Tandon (1966, 1971 & 1976) to build up the Middle Eocene biostratigraphy of the area. The purpose to undertake this project is to develop another biostratigraphic control parallel to larger foraminiferal biozonation and to use them for local regional and interregional correlations.

All the figured and type slides are housed at the museum of Birbal Sahni Institute of Palaeobotany, Lucknow. The coordinates refer to Jena Amplival microscope. The following are the sample numbers followed by the museum slide numbers in parenthesis : BH4 (6421), BH5 (6556), BH7 (6438 & 6439), BH9 & 10 (6425, 6426), J2a (6428 & 6429), J2b (6430, 6431, 6432), J2c (6433, 6434, 6435) ; J2d (6436, 6437), J4a (6440, 6441, 6442, 6443, 6422, 6423, 6427) ; J4b (6424).

SYSTEMATIC DESCRIPTION

Genus *Achomosphaera* Evitt, 1963

Achomosphaera ramulifera (Deflandre) Evitt. 1963

(Pl. I—8)

Remarks : Kachchh specimens attributed to *spiniferites ramulifera* differ from London Clay forms in having shorter processes.

Geologic and Geographic distribution :

Albian to Pliocene (Eaton, 1976) ; Lower, Middle and Upper Eocene of England (Eaton, 1976).

Achomosphaera multifurcata sp. nov.

(Pl. I—10);

Holotype: Pl. I—10 BSIP Slide No. 6443; coordinates : 104.6 × 18.9.

Diagnosis : Cyst body subspherical, moderately thick, smooth ; processes variable in width, paracingular processes usually slendrical, trifurcate, tips bifid ; usually processes proximally broad, branched 2 to 3 times, last branching followed with thread like extensions. Paratabulation that of genus with precingular archaeopyle.

Measurements :

	Holotype	Range
Cyst body size	40 μm	..40 - 50 μm
Overall size	80 μm	80—100 μm
Process length up to ..	26 μm	30 μm

Comparison : Multifurcate nature of processes with thread like last branching separates the present species from the other species of the genus.

Type Locality : Baranda, S-W Kachchh, India.

Age : Middle Eocene.

Genus *Adnatosphaeridium* Williams & Downie, 1966

Adnatosphaeridium vittatum Williams & Downie, 1966

(Pl. III—48)

Measurements :

Cyst body size ..	45 × 55 μm
Overall size ..	85 × 85 μm
Length of processes ..	up to 26 μm

Remarks : Kachchh specimens possess distinct, densely coarse granulate periphragm having both distally free and united processes, and regular serrate terminations on the outer margin of the distal branches of the processes.

In the present form 3-4 apical processes are present which are not known in the genotype. The reflected tabulation of the genus is thus 3-4', 6", 5"', 1p and 1"".

Geologic and Geographic distribution :

Lower Eocene, southern England (Williams & Downie, 1966) ; Lower, Middle and Upper Eocene, southern England (Eaton, 1976).

Genus *Araneosphaera* Eaton, 1976

Araneosphaera consociata sp. nov.

(Pl. II—36-37 & Pl. III—47)

Holotype : Pl. III—47 ; BSIP Slide No. 6442 ; coordinates : 129.9 × 14.8.

Diagnosis : Cyst body spherical, surface fibrorecticulate; paracingulum raised, equally divides cyst body. Periphragm gives rise to fibrous apical, precingular, postcingular and antapical processes only. Cingular processes absent. Apical and precingular processes usually short, distally united by fenestrate membrane. Postcingular and antapical processes usually longer than apical and precingular ones, distally united by fibrous, fenestrate membrane. Paratabulation that of genus ; archaeopyle broader than long, precingular (3").

Measurements :

	Holotype	Range
Cyst size ..	150 × 100 μm	100-180 × 90-120 μm
Diameter of cyst body ..	86 μm	60-90 μm
Length of processes up to ..	50 μm	60 μm

Remarks : The processes on both apical and antapical sides are irregularly branched, fibrous and thin, at times their identification as separate process becomes difficult. *Araneosphaera consociata* sp. nov. differs from the genotype *A. araneosa* Eaton (1976) in its distally united apical and precingular processes.

Type Locality : Baranda, S-W Kachchh, India.

Age : Middle Eocene.

Genus *Areoligera* Lejeune-Carpentier emend. Downie & Williams, 1966

Areoligera coronata (Wetzel) Lejeune-Carpentier, 1938

(Pl. IV—70)

1966 *Areoligera* cf. *coronata* (Wetzel) I ; Williams & Downie ; p. 288 ; pl. 25 ; fig. 5, text-fig. 63.

Remarks : Kachchh specimens possess process complexes on both ventral and dorsal sides. The surface is coarsely granulate.

Geologic and geographic distribution :

Lower & Middle Eocene, southern England (Williams & Downie 1966 ; Downie, Husain & Williams, 1971 ; Eaton, 1976).

Areoligera sp. A

(Pl. IV—58)

Description : Cyst lenticular, 54 × 48 μm in size ; two layered, endophragm granular, periphragm smooth gives rise to soleate complexes and single processes, up to 30 μm in length, soleate complexes variable, proximal membrane fenestrate to nonfenestrate, processes arise from distal margin of the membrane, distally united by trabeculae, in some cases processes distally serrate. Reflected tabulation 4', 6", 1-3c, 5", 1p, 1" ". Cingular processes single, distally fenestrate, only a few (?1-3) could be located, others usually in soleate complexes. Archaeopyle apical, operculum detached.

Remarks : Only a single specimen has been recovered from J2b sample. Soleate complexes having proximal fenestration and distal connection by trabeculae in the present form suggest its best comparison with *Areoligera coronata* (Wetzel) Lejeune-Carpentier (1938) but differs mainly in having granular endophragm.

Genus *Areosphaeridium* Eaton, 1971

Areosphaeridium arcuatum Eaton, 1971

(Pl. II—23-24)

Geologic and Geographic distribution :

Middle-Upper Eocene, Bracklesham beds and Hampshire basins, southern England (Eaton, 1971, 1976).

Genus *Chiropteridium* Gocht, 1960

Chiropteridium sp. A

(Pl. IV—64)

Description : Cyst 66 × 50 μm in size, lenticular, flattened, consisting of two layers, periphragm thin, reticulate, forming processes along margin, antapical lobation distinct. Archaeopyle apical, parasulcal notch deep.

Remarks : Only a single specimen of this type has been recovered.

Genus *Cleistosphaeridium* Davey *et al.*, 1966

Cleistosphaeridium sp. A

(Pl. IV—61)

Description : Cyst spherical, double walled, endophragm smooth, periphragm reticulate, covered with numerous processes ; processes broader at base, simple or branched, distally bifid or recurved, closed ; stem fibrous, striated with fenestration. Archaeopyle apical, margin zigzag.

Measurements :

Size of cyst body	.. ..	54 μm
Length of processes up to	..	15 μm

Remarks : Reticulate periphragm of the present form distinguishes it from rest of the *Cleistosphaeridium* species.

Genus *Cordosphaeridium* Eisenack, 1963 emend. Morgenroth, 1968 emend. Davey, 1969

Cordosphaeridium fibrospinosum Davey & Williams, 1966

(Pl. III—45)

Geologic and Geographic distribution :

Upper Cretaceous (Senonian), South Africa (Davey, 1969) ; Palaeocene, North Germany (Gocht, 1969), northern Spain (Caro, 1973) ; Lower Eocene, North Germany (Gocht, 1969), southern England (Davey & Williams, 1966 ; Downie, Husain & Williams, 1971) and Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975) ; Middle Eocene, North Germany (Gocht, 1969) ; ?Upper Eocene, North Germany (Gocht, 1969) ; Middle and Upper Oligocene, North Germany (Benedek, 1972); Lower and Middle Eocene, Isle of Wight, southern England (Eaton, 1976).

Cordosphaeridium latispinosum Davey & Williams, 1966

(Pl. II—25)

Geologic and Geographic distribution :

Lower Eocene, London Clay (Davey *et al.*, 1966).

Genus *Diphyes* Cookson emend. Davey & Williams in Davey *et al.*, 1966

Diphyes colligerum (Deflandre & Cookson) Cookson, 1965

(Pl. III—49)

Geologic and Geographic distribution :

Upper Cretaceous to Oligocene from different parts of Europe, Australia and U.S.A. (for details see Eaton, 1976, p. 262) ; Early Eocene, DSDP Sites 367 & 370 (Williams, 1978).

Genus *Eatonicysta* STOVER & EVITT, 1978

Eatonicysta ursulae (MORGENROTH) STOVER & EVITT, 1978

(Pl. III—39)

Dimensions :

Diameter of central body	..	60 μm
Length of processes up to	..	26 μm

Geologic and geographic distribution :

Lower Eocene, Belgium (Morgenroth, 1966 ; De Coninck, 1968, 1972), North Germany (Morgenroth, 1966), southern England (Williams & Downie, 1966 ; Eaton, 1971a, 1976) ; Middle Eocene, North Germany Gocht, 1969), southern England (Eaton, 1976).

Genus *Eocladopyxis* MORGENROTH emend. STOVER & EVITT, 1978

Eocladopyxis sp. A

(Pl. II—34)

Description : Cyst oblong in shape, 70×64 μm in size, double layered, periphragm reticulate and covered with sparsely placed processes having semicircular bulbous base, distally pointed, closed, proximally touching the wall only at a point. Archaeopyle ?apical. Paracingulum indistinct, broken area marks paracingulum position ; Paratabulation area suggestive.

Remarks : Only a single specimen has been recovered from BH9-10 level. Presence of characteristic, proximally bulbous processes, indication of paracingulum and archaeopyle suggests its placement under the genus *Eocladopyxis*. *Eocladopyxis peniculata* described by Williams & Brideaux (1975, pl. 31, fig. 2) shows best comparison with the present form.

So far the genus is known from the Eocene sediments (Morgenroth, 1966 ; Williams & Brideaux, 1975).

Genus *Glaphyrocysta* STOVER & EVITT, 1978

Glaphyrocysta kachchhensis sp. nov.

(Pl. I—17-19)

Holotype : Pl. I—17-18 ; BSIP Slide No. 6421 ; co-ordinates : 113.8×8.9.

Diagnosis : Cyst dorso-ventrally flattened, double layered, periphragm coarsely granulate, gives rise to two types of processes along peripheral zone ; on one side short, stout, broad, variously branched, proximal fenestration distinct, some distally united and a few remain free ; on other side processes long, thin, stem of single process branched several times, distally not united with each other, arcuate process complexes distinct. Archaeopyle apical with zig-zag margin.

Measurements :

	Holotype	Range
Cyst size	50×32 μm	40-60×25-35 μm
Length of short process up to	18 μm	32 μm
Length of long process up to	30 μm	30 μm

Comparison : *Glaphyrocysta achchhensis* sp. nov. differs from the known species of the genus in its thin variable type of processes and coarsely granulate periphragm.

Type locality : Baranda, S-W Kachchh, India.

Age : Middle Eocene.

Glaphyrocysta exuberans (DEFLANDRE & COOKSON) STOVER & EVITT, 1978

(Pl. IV—66)

Remarks : Kachchh specimens assigned to *G. exuberans* possess coarsely granulate outer membrane.

Geologic and Geographic distribution :

Lower Eocene, Belgium (Pastiels, 1948) ; southern England (Williams & Downie, 1966c) ; Lower, Middle and Upper Eocene, England (Eaton, 1976).

Glaphyrocysta intricata (EATON) STOVER & EVITT, 1978

(Pl. VI—55-56)

Remarks : Kachchh specimens possess a coarsely granulate outer surface having broad processes along the peripheral zone. Processes proximally connected or free, when connected forming semicircular ridges, distally expanded and mostly bifurcate, bifurcation varies from recurved to patulate; in recurved condition the marginal extensions united together by trabeculae which are distally dentate.

Geologic and Geographic distribution :

Lower, Middle and Upper Eocene, Alum bay, Isle of Wight, southern England (Eaton, 1971a and 1976).

Glaphyrocsyta ordinata (WILLIAM & DOWNIE) STOVER & EVITT, 1978

Measurements :

Overall size	..	84-80 μm
Diameter of central body	..	58 μm
Length of processes up to..	..	30 μm

Geologic and Geographic distribution :

Palaeocene, Tasmania (Cookson & Eisenack, 1967) ; Palaeocene—Lower Eocene, Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975).

Glaphyrocysta pastielsii (Deflandre & Cookson) Stover & Evitt, 1978

(Pl. IV—69)

Geologic and Geographic distribution :

Lower-Middle Eocene (see Eaton, 1976, p. 259) ; Lower Eocene, Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975).

Glaphyrocysta sp. A

(Pl. IV—57)

Description : Cyst body subcircular, surface granular, processes restricted to peripheral zone only, stem narrow, distally united by fenestrate membrane, meshes with thick wall. Archaeopyle apical, tetratabular.

Measurements :

Central body diameter ..	..	62 × 46 μm
Length of processes up to ..	..	25 μm

Remarks : Present specimen recovered from BH9 & 10 level shows its best comparison with *Glaphyrocysta exuberans* and *G. pastielsii* in having fenestrate membrane distally uniting the processes together but differs in having thicker mesh walls and short stem.

Genus Hemicystodinium Wall, 1967

Hemicystodinium zoharyi (Rossignol) Wall, 1967

(Pl. I—22)

Measurements :

Cyst diameter ..	..	46 μm
Length of process up to	..	6 μm

Geologic and Geographic distribution :

Lower Eocene to Pleistocene (see, William & Bujak, 1977).

Genus Homotryblium Davey & Williams, 1966

Homotryblium plectilum Drugg & Loeblich, 1967

(Pl. IV—51-54)

Geologic and Geographic distribution :

Oligocene, Gulf Coast, U.S.A. (Drugg & Loeblich, 1967) ; Upper Eocene-Oligocene, Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975) ; Upper Eocene, Kopili Formation, Assam, India (Dutta & Jain, 1980).

Homotryblium pallidum Davey & Williams, 1966

(Pl. I—20)

Remarks : The elongate shape of central body with indistinct granular surface ornamentation creates doubt for the placement of the present form under *H. pallidum*. It compares best with Palaeocene forms described by Schumacker and Chatcauneuf (1976, pl. 2, fig. 5) as *Homotryblium* cf. *pallidum*.

Genus Hystrichokolpoma Klumpp emend. Williams & Downie, 1966

Hystrichokolpoma cincta Klumpp, 1953

(Pl. I—6-7)

Description : Central body ovoidal, both endophragm and periphragm layers smooth and thin. Processes of two types formed from periphragm, broad, tapering, slightly branched along distal margin corners. Antapical process longer than broad. Archaeopyle apical.

Measurements :

Size of central body ..	..	32 × 40 μm
Length of broad processes up to	..	14 μm
Width of broad processes up to	..	16 μm

Geologic and Geographic distribution :

Upper Eocene, Germany (Klumpp, 1953) ; Oligocene-Miocene, Germany (Gerlach, 1961) ; Brosius, 1963) ; Middle and Upper Oligocene, Germany (Benedek, 1972).

Hystrichokolpoma unispinum Williams & Downie, 1966

(Pl. IV—65)

Geologic and Geographic distribution :

London Clay, Eocene (Williams & Downie 1966a) ; Lower Eocene, Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975).

Hystrichokolpoma sp. cf. *granulata* Eaton, 1976

(Pl. I—1-3)

Description : Cyst central body spherical, two layered, both appressed ; endophragm smooth to finely granulate, periphragm coarsely granulate, gives rise to two types of processes with granular surface, broad processes distally closed, with small distally open tubules, base quadrate, longitudinal folds over broad processes frequent, slender processes simple or sometimes distally branched, open, tubiform. Antapical process considerably larger than other processes, tapering, closed. Archaeopyle apical, tetratabular. Paratabulation that of genus.

Measurements :

Central body diameter ..	..	55-60 μm
Length of broad processes	..	20-26 μm
Width of broad processes	..	16-24 μm

Remarks : *Hystrichokolpoma* sp. cf. *granulata* is mainly characterised by its coarsely granulate periphragm and well defined plate areas. These features differentiate the present forms from *H. granulata* Eaton (1976). *Hystrichokolpoma granulata* Eaton has been described from Middle Eocene of Isle of Wight, England.

Hystrichokolpoma rigaudiae Deflandre & Cookson, 1955

(Pl. I—4)

Measurements :

Size of central body	..	.. 40×32 μm
Length of processes up to		.. 25 μm
Width of processes up to		.. 16 μm

Geologic and Geographic distribution :

Eocene to Pleistocene from different parts of the world (for details see Williams & Downie, 1966a ; p. 180 and Verdier, 1970 ; p. 11).

Hystrichokolpoma rigaudiae subsp. *granuliosa* nov.

(Pl. I—5)

Description : General morphology and measurements of cyst similar to *H. rigaudiae*, but outer surface. distinctly granular.

Hystrichokolpoma sp. A

(Pl. I—13)

Description : Cyst central body spherical, double layered, both appressed, finely granulate ; periphragm gives rise to two types of processes, broader ones with quadrate base, dome shaped, distally projected into nipple like structure, devoid of tubules ; slender processes narrow, swollen at base, tubiform. Four apical processes tapering, distally closed ; antapical process much longer than broad. Paratabulation that of the genus. Archaeopyle apical, tetratabular.

Measurements :

Diameter of Central body	..	56 μm
Process size up to	..	.. 26×22 μm

Remarks : The present specimen differs from the so far known species of the genus in having characteristic shape of broader processes having nipple like projection on the distal side.

Hystrichokolpoma sp. B

(Pl. IV—71)

Description : Cyst central body spherical, outer surface smooth, gives rise to slender processes, arranged in generic tabular manner, distally expanded or bifurcated and open. Apical process four, tubiform, distally much expanded, one or two bifurcate, stem surface spongy, six precingular, six cingular and 6 post-cingular processes are almost similar. Antapical process typically broad, stem fenestration marked, sulcal process not seen. Archaeopyle apical.

Measurements :

Diameter of central body	..	38 μm
Length of apical processes up to	..	25 μm
Size of antapical processes	..	24×20 μm
Size of other processes up to	..	26×30 μm

Remarks : Present specimen in its broad antapical process, apical archaeopyle and similar paratabulation has been placed under the genus *Hystrichokolpoma*. It differs from rest of the known species in having fenestrate antapical process with distally expanded, bifurcate apical processes.

Genus Impagidinium Stover & Evitt, 1978

Impagidinium sp.

(Pl. IV—67)

Description : Cyst oval, 70×60 μm in size, without horn, plates coarsely granular, bordered by high ledges. Paratabulation indistinct. Archaeopyle precingular, operculum intact.

Remarks : The present form compares best with *Impagidinium dispertitum* (Cookson & Eisenack) Stover & Evitt (1978) described from Middle Eocene of Australia in having high ledges and granular surface. Indistinct paratabulation precludes further comparison.

Genus Impletosphaeridium Morgenroth, 1966

Impletosphaeridium granulosum sp. nov.

(Pl. II—30-31 & III—50)

Holotype : Pl. II—30 ; BSIP Slide No. 6436 ; co-ordinates : 135.1×13.8.

Diagnosis : Cyst body spherical, surface granular, covered with numerous erect, simple or branched, solid processes ; process stem striate, fenestrate, distal termination recurved or serrate or bifid. Archaeopyle precingular, triangular.

Measurements :

	Holotype	Range
Diameter of central body	.. 72 μm	66—72 μm
Length of processes up to	.. 14 μm	12—16 μm

Comparison : *Impletosphaeridium granulosum* sp. nov. differs from the known species of the genus in its large size and granular surface.

Locality : Baranda, S—W. kachchh, India.

Horizon : Middle Eocene.

Impletosphaeridium insolitum Eaton, 1976

(Pl. I—12)

Remarks : Except for capitate distal termination of the processes rest of the features are similar to *I. insolitum* Eaton (1976, p. 308). Eaton's species is known from the Middle Eocene of Isle of Wight, England.

Impletosphaeridium sp. A

(Pl. III—46)

Description : Cyst body ovoidal, 70×50 μm in size, surface granulate, covered with simple to branched fiberous processes, distal terminations recurved. Archaeopyle and paratabulation not seen.

Genus *Lingulodinium* WALL, 1967 emend. WALL & DALE in WALL, DALE & HARADA, 1973

Lingulodinium machaerophorum (DEFLANDRE & COOKSON) WALL, 1967

(Pl. II—28)

Remarks : The occurrence of archaeopyle in the Kachchh specimens could not be ascertained, otherwise in general morphological features these are identical to *L. machaerophorum*.

Measurements :

Diameter of cyst body	46—52 μm
Length of processes up to ..	20 μm

Geologic and Geographic distribution :

Danian to Recent from various parts of the world (for details see Verdier, 1970, p. 7 and Eaton, 1976, p. 276) ; Late Palaeocene to Pleistocene, Offshore, Florida (Williams & Bujak, 1977).

Lingulodinium solarum (DRUGG) WALL & DALE in WALL, DALE & HARADA, 1973

(Pl. II—29)

Measurements :

Central body diameter	50 μm
Length of processes up to ..	16 μm

Geologic and Geographic distribution :

Lower Tertiary, Gulf Coast, U.S.A. (*Drugg*, 1970).

Genus *Muratodinium* DRUGG, 1970

Muratodinium sp. A

(Pl. III—42)

Description : Cyst ovoidal, double layered, endophragm smooth to finely granulate, gives rise to apical and antapical horns ; periphragm fibrous in nature, appears to form vail like fringes which mark plate areas ; paratabulation ?4′, 1a, ?6″, 5″′, 1″″. Archaeopyle precingular (3″).

Measurements :

Overall cyst size	106×90 μm
Size of central body including horns	86×60 μm
Length of apical horn	8 μm
Length of antapical horn ..	10 μm

Remarks : Present specimen shows features common to both *Muratodinium* Drugg (1970) and *Kenleyia* Cookson & Eisenack (1965) but the occurrence of tabulation precludes its placement under *Kenleyia*. The vail like outer extension similar to *Thalassiphora pelagica* is due to the distortion of the specimen.

Muratodinium sp. B

(Pl. III—43)

Description : Cyst oblong, double-layered, distorted, antapical projection present, apical not observed, endophragm smooth to finely granulose, periphragm extends beyond central body, fenestrate. Archaeopyle present but position remains doubtful.

Measurements :

Overall size	100×90 μm
Central body size	66×50 μm

Remarks : Presence of an antapical horn with slight indication of paratabulation suggests its provisional placement under the genus *Muratodinium*. Only a single specimen of this type has been recovered in sample no. BH9.

Genus *Operculodinium* WALL, 1967

Operculodinium centrocarpum (DEFLANDRE & COOKSON) WALL, 1967

(Pl. IV—60)

Remarks : Archaeopyle position in the present forms is not distinctly marked.

Geologic and Geographic distribution :

Ypresian, Belgium (De Coninck, 1965) ; Oligocene of Kachchh, India (Jain, 1980) ; Miocene, Australia (Deflandre & Cookson, 1955); Middle Oligocene to Upper Miocene, Germany (Maier, 1959) ; Middle Oligocene to Middle Miocene, Germany (Gerlach, 1961) ; Late Palaeocene—Pleistocene, Offshore Florida and Scotian Shelf (Williams & Bujak, 1977).

Genus *Peridictyocysta* COOKSON & EISENACK, 1974

Peridictyocysta sp. A

(Pl. IV—68)

Description : Cyst elongate, ellipsoidal, periphragm thin, scabrate, covered with slendrical, narrow, branched processes, arranged in district longitudinal rows, distally united by trabeculae, forming a sort of net work around apical and antapical sides. Archaeopyle apical (EA).

Measurements :

Size of central body	50×28 μm
Length of processes up to ..	30 μm

Remarks : Only a single specimen has been recovered and therefore no specific comparison has been attempted.

Genus *Polysphaeridium* DAVEY & WILLIAMS, 1966

Polysphaeridium ornamentum sp. nov.

(Pl. II—35)

1975 *Cordosphaeridium* sp. A., in WILLIAMS & BRIDEAUX ; pg. 15, fig. 8.

Holotype : Pl. II—35 ; BSIP Slide No. 6430 ; co-ordinates : 120.5×14.5.

Diagnosis : Cyst ovoidal, periphragm thick, surface coarsely granulate to verrucate ; processes numerous,

more than 60, long, simple or sometimes branched, spongy at point of origin, distally open, recurved. Archaeopyle not clearly marked, probably apical.

Measurements :

Over all cyst size	..	140—170 μm
Central body size	..	70-90×90-110 μm
Length of processes up to	..	55 μm

Comparison : *Polysphaeridium ornamentum* sp. nov. compares best with *P. giganteum* Caro (1973) in having large size but differs in its prominent periphragm ornamentation and recurved distal end of the processes.

Type Locality : Jhadwa, S-W Kachchh, India.

Horizon : Middle Eocene.

Polysphaeridium pastielsii Davey & Williams, 1966

(Pl. I—11)

Remarks : Kachchh specimens assigned to *P. pastielsii* Davey & Williams (1966) resemble best with those illustrated by Williams and Brideaux (1975, pl. 24, fig. 3).

Geologic and Geographic distribution :

Eocene, London Clay (Davey & Williams, 1966) ; Lower Tertiary ; Grand Banks, Atlantic Continental Margin (Williams & Brideaux, 1975).

Genus Samlandia Eisenack, 1954

Samlandia chlamydophora Eisenack, 1954

(Pl. IV—72)

Measurements :

Cyst size..	..	95×80 to 105×75 μm
Cyst body size	..	55×65 μm
Apical horn length		22 μm
Height of pillars up to		18 μm
Archaeopyle size	..	21×24 μm

Remarks : Wilson (1967b, p. 229 ; figs. 21-22) described the specimen as *Samlandia* aff. *augustivela* having an apical archaeopyle. But the position of archaeopyle appears to be doubtful.

Geologic and Geographic distribution :

Upper Eocene, North Germany (Eisenack, 1954) ; Lower Eocene, Belgium and North Germany (Morgenroth, 1966 and De Coninck, 1972) ; Middle Oligocene, North Germany (Benedek, 1972) ; Lower, Middle and Upper Eocene, southern England (Eaton, 1976).

Genus Spiniferites Mantell emend. Sarjeant, 1970

Spiniferites ramosus subsp. *granomembranaceus* (Davey & Williams) Lentin & Williams, 1973

(Pl. I—9 & IV—62-63)

Geologic and Geographic distribution :

Eocene, London Clay, England (Davey & Williams, in *Davey et al.*, 1966).

Spiniferites ramosus subsp. *granosus* (Davey & Williams) Lentin & Williams, 1973

(Pl. IV—59)

Geologic and Geographic distribution :

Lower Eocene, London Clay of England (Davey & Williams, in Davey *et al.*, 1966).

Genus Systematophora Klement, 1960

Systematophora placacantha (Deflandre & Cookson) Davey *et al.*, 1969

(Pl. I—14-15)

Description : Cyst body spherical or subspherical, outer surface coarsely granulate, processes arranged in soleate manner, five precingular plates distinct but sixth obscure, fields separated from each other by an area of no process. Processes in each field equally developed, branched, spongy in nature along the point of origin, distally united by trabeculae. Archaeopyle apical.

Measurements :

Central body size	..	35×50 μm
Length of processes up to	..	25 μm

Geologic and Geographic distribution :

Middle Miocene, Australia (Deflandre & Cookson, 1955) ; Verdier (1970, p. 13) includes Lower Eocene form described by Morgenroth (1966) as *Impletosphaeridium*, under *Systematophora placacantha*.

Genus Thalassiphora Eisenack & Gocht emend. Gocht, 1968

Thalassiphora pelagica (Eisenack) Eisenack & Gocht emend. Gocht, 1968

(Pl. III—44)

Measurements :

Overall cyst size	..	120×100 μm
Central body size	..	60×50 μm

Geologic and Geographic distribution :

Maestrichtian to Miocene from different parts of the world (for details see Eaton, 1976 ; p. 287).

Genus Turbiosphaera Archangelsky, 1968

Turbiosphaera sp.

(Pl. II—26-27)

Description : Cyst body subcircular to oval, rounded at apex, slightly drawn out into a short extension at antapical pole, periphragm fibrous; apical, precingular,

cingular, post-cingular and antapical zones marked. Processes fibrous, broad, distally free, flared. Paratabulation distinct, 1′, 6″, 6c, 6′ ″, 1p, 1″ ″. Antapical process largest. Epithecal processes comparatively much smaller than hypothecial. Archaeopyle broadly triangular, pre-cingular, formed by the detachment of plate 3″.

Measurements :

Overall cyst size	.. ..	130×80 μm
Cyst body size	.. ..	90×80 um
Length of process up to	..	40 μm

Remarks : Present specimens have been placed under *Turbiosphaera* due to the distinct paratabulation having single apical and antapical, six precingular, six paracingular and six post-cingular plates. In the elliptical shape of the cyst body, distribution of free processes, single apical plate and antapical extension, it approaches nearest to the Danian species *Palmnickia californica* Drugg (1967), but differs in having distinct paratabulation with greater number of plates.

Genus *Wilsonidium* Lentin & Williams, 1975

Wilsonidium lineidentata (Deflandre & Cookson) Lentin & Williams, 1975

(Pl. III—38)

Geologic and Geographic distribution :

Probably Lower Tertiary, Denmark (Deflandre & Cookson, 1955) but according to Lentin & Williams (1976, p. 139) it is Eocene.

Genus *Wetzeliella* Eisenack emend. Lentin & Williams, 1975

Wetzeliella sp.

(Pl. III—40-41)

Description : Cyst broadly pentagonal, horns reduced; central body ovoidal, surface vermiculate ; pericoel totally enclosing endocoel. Periphragm gives rise to tubular processes arranged in rows, distally united by thin perforate membrane. Apical horn short, formed from periphragm extension ; antapical horn two, unequal in length ; lateral horns much reduced (seen only on one side). Archaeopyle intercalary, hexagonal. Tabulation indistinct.

Remarks : Only a single badly preserved specimen has been recovered from sample No. J2b. It compares best with *?Kisselovia clathrata* (Eisenack) Lentin & Williams (1977) in having common features, viz., reduced horns and arrangement of processes. But differs in the absence of processes arranged in simulate complexes.

Genus *Cyclopsiella* Drugg & Loeblich, 1967

Cyclopsiella coniata sp. nov.

(Pl. II—32-33)

Holotype : Pl. II—33 ; BSIP Slide No. 6435 ; coordinates : 119.1×7.0.

Diagnosis : Cyst ovoidal, double layered, endophragm thick, ornamented with regular coni on one side and smooth on other ; periphragm thin, delicate, loose, spongy, extending beyond endophragm margin from all over. Aperture circular, apical (sensu Jain & Dutta, in Dutta & Jain, 1980), margin thickened forming a ring. Operculum free.

Comparison : *C. coniata* sp. nov. compares best with *C. elliptica* Drugg & Loeblich (1967) but differs mainly in having only one side of the endophragm ornamented with coni and loose widely separated periphragm. *C. vieta* Drugg & Loeblich (1967) resembles in common loose periphragm but differs in endophragm ornamentation. Due to lack of distinct collar like neck over the aperture, the present forms are separated from *Collumosphaera* Jain & Dutta (in Dutta & Jain, 1980).

Locality : Baranda Section, S-W Kachchh, India.

Horizon : Middle Eocene.

Genus *Pterospermopsis* Wetzel, 1952

Pterospermopsis sp.

(Pl. I—21)

Description : Cyst circular, 68 μm in diameter, central body round, 46 μm in diameter, flange 12 μm broad, folded. Central body characterised by a ring of small pores arranged along the peripheral margin.

DISCUSSION

The Middle Eocene (Lutetian) rock sequence exposed in between Baranda and Jhadwa has been reclassified by one of us (Tandon, 1976) which is better developed there than the type section of Babia Stage of Biswas (1965). Mohan and Soodan (1970) worked out another equivalent Middle Eocene (Lutetian) sequence on the basis of the planktonic foraminifera, exposed between Baranda (Beranda) (N. Lat. 23°33′40″, E. Long. 68°40′35″) and Berwana (N. Lat. 23°26′35″, E. Long. 68°37′) in western Kachchh. They proposed four planktonic foraminiferal zones in ascending order viz., *Hantkenina aragonensis* zone, *Globigerinoides kugleri—Globigerina frontosa* assemblage zone, *Orbulinoides beckmanni* zone and *Catapsydrax unicavus—Truncorotaloides rohri* assemblage zone.

Samanta (1970) described planktonic foraminifera from the Middle Eocene rocks exposed around Lakhpat (23°50′N, 68°47′E). His observations compare well with those of Mohan and Soodan (1970).

MICROPLANKTON ZONATION

The present Middle Eocene sequence (corresponding to the Babia Stage of the Berwali Series of Biswas, 1965) has been divided into five informal microplankton

zones (Fig. 2). These zones are described below in ascending order. The boundaries between the zones are marked where maximum change in microfloral constituents is observed by their first appearance.

Microplankton Zone-I : This zone is about 10 metres thick and covers the topmost 1.3 metres clays of the unfossiliferous zone and the three consequently higher zones of TANDON (1976) viz., *Corbula subexarata* zone, Dicot leaf zone and *Crocodylus* zone.

The rock samples of this zone are rich in organic detritus, pteridophytic spores, angiospermic pollen grains, dinoflagellates, acritarchs and colonial algae (*Pediastrum* and *Botryococcus*). The microplankton constituents are poor in number and variety. The following species of dinocysts and acritarchs, appear for the first time at BH_4 level and continue in the younger zones viz., *Glaphyrocysta ordinata*, *G. intricata*, *G. kachchhensis* sp. nov., *G. pastielsii*. *Diphyes colligerum*, *Homotryblium pallidum*, *Hystrichokolpoma unispinum*, *H. rigaudiae*, *Thalassiphora pelagica*, *Cordosphaeridium funiculatum* and *Eocladopyxis* sp. Out of these, *Glaphyrocysta* spp. (56%) dominate the total assemblage having *Glaphyrocysta kachchhensis* sp. nov. as its characteristic element. This species along with *Cordosphaeridum funiculatum* alone does not extend into the younger zones and remain restricted to Zone-I.

From the base to the top of this zone several fluctuations with regard to the occurrence and abundance of microplankton have been observed, the dicot zone of Tandon (1976) is totally barren of microplankton and is rich in spores and pollen grains. But again in the *Crocodylus* zone some microplankton species reappear, though the spores and pollen grains remain common.

Microplankton Zone-II : This zone covers in part *Nummulites perforatus* and *N. beaumonti* zones of Tandon (1976). The *Nummulites perforatus* zone probably overlies unconformably over the barren zone, the lowest sample studied for palynological contents comes from a slightly higher level within the *N. perforatus* zone and therefore, the gap between the boundary of barren zone—*N. perforatus* zone and sample No. BH_9 (Fig. 2) remains uncertain. We for the present keep it open.

The characteristic species which appear for the first time in this zone and some extending in younger zones but do not occur in Microplankton Zone I are : *Lingulodinium machaerophorum*, *Glaphyrocysta exuberans*, *Cyclopsiella coniata*, *Operculodinium centrocarpum*, *Homotryblium plectilum*, *Impletosphaeridium granulosum* sp. nov., *Cordospharedium latispinosum*, *Muratodinium* sp. A., *Muratodinium* sp. B and *Spiniferites cingulata*.

The palynological assemblage of this zone is further characterised by the dominance of *Homotryblium plectilum* (60%) and the subdominance of *Glaphyrocysta* spp. (18%), with no spores and pollen grains. The combination of hese two dinocyst genera persists up to J2a level at the base of the *Nummulites beaumonti* zone, where they are represented by 40% and 35% respectively, the spore-pollen contents reappear (10%) with the first appearance of *Polysphaeridium ornamentum* sp. nov. The upper limit of Microplankton Zone-II and the lower limit of Zone-III might fall some where within J2a & J2b. It is for the present kept open.

Microplankton Zone-III : The dinoflagellate and acritarch contents recovered from sample J2b show a marked change in the appearance of many species for the first time and indicate the beginning of another zone. The characteristic species apart from the long ranging ones are : *Cordosphaeridium fibrospinosum*, *Areosphaeridium arcuatum*, *Systematophora placacantha*, *Hystrichokolpoma cincta*, *Impagidinium* sp., *Eatonicysta ursulae*, *Wetzeliella* sp., *Areoligera* sp., *Polysphaeridium subtile*, *Lingulodinium solarum*, *Hystrichokolpoma* sp. A., *Peridictyocysta* sp., *Spiniferites ramosus* subsp. *granomembranaceous*. Only the first five species mentioned above extend to the younger zone and the remaining restrict within this zone.

The palynological assemblage as a whole is characterized by an absolute majority of microplankton. The *Homotryblium plectilum* dominance persists and becomes 55% as compared to 40% at the top of the Microplankton Zone-II. The percentage of the associated subdominant *Glaphyrocysta* spp. of the Microplankton Zone-III sharply declines with an increase of *Spiniferites* spp. But as we ascend in this zone, the frequency of *Homotryblium plectilum* and *Glaphyrocysta* spp. become nearly equal, though much lesser in number.

Microplankton recovery from the sandy marls of *Fasciolites* (*F.*) *elliptica* zone represented by a single sample No. J3 remains very poor and therefore at the moment, it is difficult to include this set of sediments as the top of the underlying Microplankton Zone-III. We, for the present limit this zone within *Nummulites beaumonti* zone of Tandon (1976).

Microplankton Zone-IV : This zone covers whole of *Discocyclina dispansa* zone and the base of the *Assilina cancellata* zone, represented by sample Nos. J4a, J4b and J5. (Fig. 2). The palynological assemblage is exclusively represented by dinocysts and acritarchs.

The zone is characterised by the incoming of some species for the first time in the sequence. These are viz., *Araneosphaera consociata* sp. nov., *Turbiosphaera* sp., *Achomosphaera multifurcata* sp. nov., *Areoligera* sp., *A. coronata*, *Samlandia chlamydophora*, *Hemicystodinium zoharyi*, *Wilsonidinium lineidentata*, *Achomosphaera ramulifera*, *Impletosphaeridium multispinosum* and *Adnatosphaeridium vittatum*.

The quantitative analysis revealed the dominance of *Spiniferites* (26%) and the subdominance of *Glaphyrocysta* spp. (9%) with the total absence of *Homotryblium plectilum* which made its last appearance in Microplankton Zone-III.

The recovery of microplankton in the upper part of the sequence, between sample No. J5 to J7, is almost negligible and therefore the upper limit of Microplankton Zone-IV remains open.

Microplankton Zone-V : The top marl horizon of the *Asterocyclina alticostata* Zone only proved to be productive (sample No. J7). It contains monospecific dominance of *Hystrichosphaeridium tubiferum*. None of the older species extend into this zone.

The limestone samples from the top *Nummulites maculatus* Zone are unproductive. The lower and upper limits of the Zone, therefore, remain obscure.

A comparison with well known Eocene microplankton assemblages described from different parts of the world, viz., Grand Banks, Atlantic Continental Margin (Williams & Bridcaux, 1975), Off-shore Eastern Canada (Williams, 1975), Bracklesham beds, southern England (Eaton, 1976 ; Downie *et al.*, 1971) ; D.S.D.P. Sites 367 and 370 (Williams, 1978 ; Cocht, 1969), indicates that taxa have long stratigraphic and wide palaeogeographic distribution but are useful in defining local and regional biostratigraphic zones. A multidisciplinary approach is therefore, emphasized here.

The Middle Eocene age of the present and the other equivalent sections in the Kachchh area has been ascertained by the stratigraphic distribution of planktonic and larger foraminifera (Biswas, 1965 ; Sen Gupta, 1964 ; Samanta, 1970 ; Mohan & Soodan, 1970 ; Tandon, 1976).

The *Areoligera* association, described by Downie *et al.*, (1971) ranging in age from Upper Palaeocene to Lower Eocene including Thanet sands, part of the Woolwich beds and the Oldhaven Bed, comprises the dominance of *Glaphyrocysta* (*Cyclonephelium*) and *Areoligera*. The species identified are *G. ordinata*, *G. exuberans*, *G. pastielsii*, *G. divaricata*, *Areoligera* sp. and *A. coronata*. The first three species of *Glaphyrocysta* are common throughout the present Middle Eocene sequence though less frequent. *Areoligera* and *G. exuberans* appear late in the Middle Eocene sequence of Kachchh. In Meghalaya, *G. exuberans* appears at the base of the Upper Eocene, Kopili Formation (Dutta & Jain, 1980).

Hystrichosphaeridium tubiferum is present throughout the London Clay at Whitecliff Bay and persist into Zone-I of the Bracklasham Beds (Eaton, 1976, p. 310). In the Middle Eocene sequence of Kachchh it appears for the first time in Microplankton Zone-V at the top of the *Asterocyclina alticostata* Zone. This situation corresponds well with the common occurrence of *H. tubiferum* in l'argile de Saint-Gobain (top of Lutetian or base of Auversian) though also present (27%) in the Middle Lutetian of Damery (Marine) and dominant in Upper Bracklasham bed and Fisher beds XXI (Gruas-Cavagnetto, 1971a & 1972).

The only, so far, known Middle Eocene dinoflagellate assemblage from India is Microplankton Assemblage-C described from the Prang Limestone Member of the Sylhet Formation exposed around Lumshnong area, South Shillong Plateau, Meghalaya (Dutta & Jain, 1980). This assemblage, from the sample S/N/13, represents the middle part of the Prang Limestone Member containing Middle Eocene (Lutetian) larger foraminifera viz., *Assilina spira corrugata* and *Discocyclina sowerbi*. The palaeontological assemblage corresponds well with the Siju Limestone larger foraminiferal assemblage zone-I, established in Garo Hills, Assam (Samanta, 1968).

The microplankton assemblage C correlates well with the Microplankton Zone-IV in having common elements, viz., *Turbiosphaera*, *Araneosphaera* and *Samlandia*. The stratigraphic position of the Microplankton Zone IV in the lithologic sequence also represents the middle part of the sequence and hence strengthens the regional correlation potential of dinoflagellate cysts.

PALAEOENVIRONMENT

The presence of *Pediastrum*, *Botryococcus*, plant detritus, spores and pollen grains together with dinoflagellate cysts at the base of Microplankton Zone-I and the gradual decline in microplankton diversity higher in the zone suggests a very near shore deposit.

The diversity of dinoflagellate suddenly flared up at the beginning of Microplankton Zone-II. The benthonic foraminifer species *Nummulites perforatus* dominates which is consistent with dinoflagellate species *Homotryblium plectilum*. This marks the onset of true marine transgression in the area which continued throughout the Middle Eocene.

Microplankton Zone-V needs special mention as it contains the dominance of a single species viz., *Hystrichosphaeridium tubiferum*. Low diversity of forms at this level indicates a change in sea water salinity, probably quite low. The palaeoenvironmental derivations through palynoflora are in complete accordance with those derived from faunal and petrographic data (Tandon, 1976 ; Singh, 1978).

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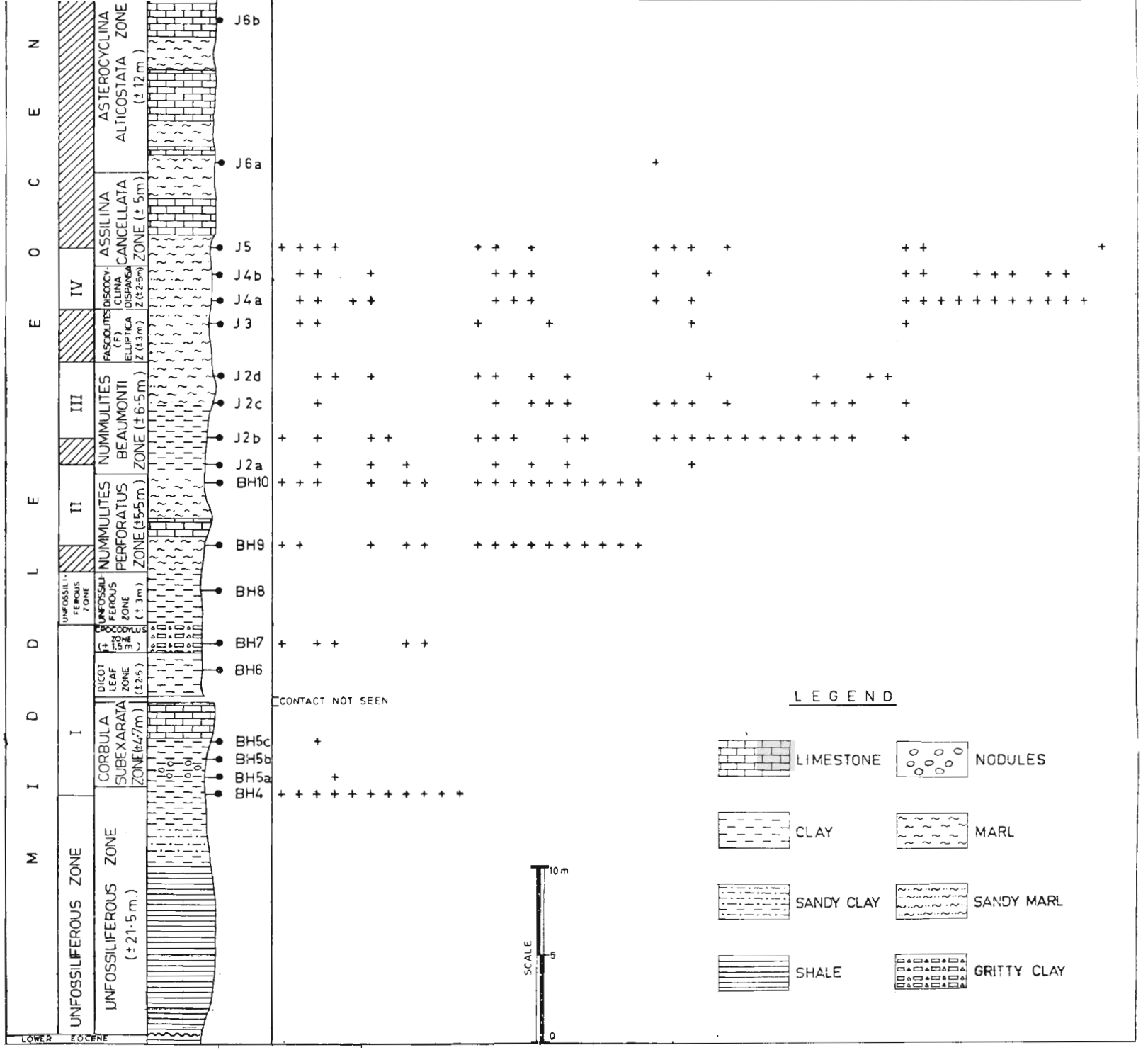
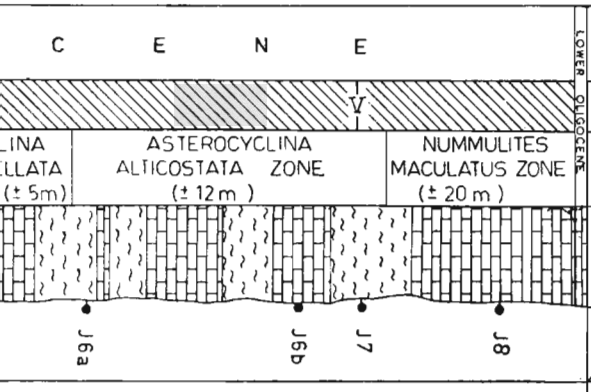


Fig. 2. Stratigraphic distribution of microplankton through Middle Eocene rock sequence of a part of south-western Kachchh.



GEOLOGIC AGE

MICROPLANKTON ZONES

PALAEONTOLOGIC ZONES
(AFTER TANDON , 1976)

LITHOLOGIC COLUMN

SAMPLE NUMBER

TAXA

GLAPHYROCYSTA ORDINATA
DIPHYES COLLIGERUM
GLAPHYROCYSTA INTRICATA
THALASSIPHORA PELAGICA
HOMOTRYBLIUM PALLIDUM
HYSTRICHOKOLPOMA RIGAUDIAE
HYSTRICHOKOLPOMA UNISPINUM
GLAPHYROCYSTA PASTIELSII
EOCLADOPYXIS Sp.
GLAPHYROCYSTA KUTCHENSIS Sp. Nov.
CORDOSPHAERIDIUM FUNICULATUM
IMPLETOSPHAERIDIUM GRANULOSUM
GLAPHYROCYSTA EXUBERANS
LINGULODINIUM MACHAEROPHORUM
CYCLOPSIELLA CONIATA Sp. Nov.
OPERCULODINIUM CENTROCARPUM
HOMOTRYBLIUM PLECTILUM
CORDOSPHAERIDIUM LATISPINOSUM
MURATODINIUM Sp. A
MURATODINIUM Sp. B
SPINIFERITES CINGULATA
AREOSPHAERIDIUM ARCUATUM
SYSTEMATOPHORA PLACACANTHA
POLYSPHAERIDIUM ORNAMENTUM Sp. Nov.
CORDOSPHAERIDIUM FIBROSPINOSUM
HYSTRICHOKOLPOMA CINCTA
IMPAGIDINIUM Sp.
EATONICYSTA URSULAE
WETZELIELLA Sp.
AREOLIGERA Sp.
SPINIFERITES RAMOSUS GRANOMEMBRANACEUS
POLYSPHAERIDIUM SUBTILE
HYSTRICHOKOLPOMA Sp. A
PERIDICTYOCYSTA Sp. A
LINGULODINIUM SOLARUM
SPINIFERITES RAMOSUS RAMOSUS
TURBIOSPHAERA Sp.
ACHOMOSPHAERA MULTIFURCATA Sp. Nov.
AREOLIGERA CORONATA
ARANEOSPHAERA CONSOCIATA Sp. Nov.
SAMLANDIA CHLAMYDOPHORA
HEMICYSTODINIUM ZOHARYI
WILSONIDINIUM LINEIDENTATA
ACHOMOSPHAERA RAMULIFERA
IMPLETOSPHAERIDIUM MULTISPINOSUM
HYSTRICHOKOLPOMA RIGAUDIAE GRANULOSA Sub Sp.nov
ADNATOSPHAERIDIUM VITTATUM
HYSTRICHOSPHAERIDIUM TUBIFERUM

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EXPLANATION OF PLATES

(All microphotographs magnified × 500 unless otherwise stated)

PLATE I

1. *Hystrichokolpoma* sp. cf. *granulata* Eaton ; B.S.I.P. Slide No. 6431; coordinates : 115.8×9.7.
2-3. *Hystrichokolpoma* sp. cf. *granulata* Eaton ; B.S.I.P. Slide No. 6431 ; coordinates : 117.6×19.2 ; same specimen in two views ; 3, ventral ; 2, dorsal.
4. *Hystrichokolpoma rigaudiae* Deflandre & Cookson ; B.S.I.P. Slide No. 6426 ; coordinates : 109.9×20.3.
5. *Hystrichokolpoma rigaudiae* subsp. *granulosa* nov.; B.S.I.P. Slide No. 6423 ; coordinates : 102.1×17.3.
6-7. *Hystrichokolpoma cincta* Klumpp ; B.S.I.P. Slide No. 6431 ; coordinates : 120.4×22.6 ; same specimen in two views ; 6, dorsal ; 7, ventral.
8. *Achomosphaera ramulifera* (Deflandre) Evitt ; B.S.I.P. Slide No. 6424 ; coordinates : 121.1×9.5.
9. *Spiniferites ramosus* subsp. *granomembranaceous* (Davey & Williams) Lentin & Williams ; B.S.I.P. Slide No. 6443 ; coordinates : 118.0×18.4.
10. *Achomosphaera multifurcata* sp. nov.; B.S.I.P. Slide No. 6443 ; coordinates : 104.6×18.9.
11. *Polysphaeridium pastielsii* Davey & Williams ; B.S.I.P. Slide No. 6423 ; coordinates : 142.2×10.9.
12. *Impletosphaeridium insolitum* Eaton ; B.S.I.P. Slide No. 6426 ; coordinates : 141.7×3.2.


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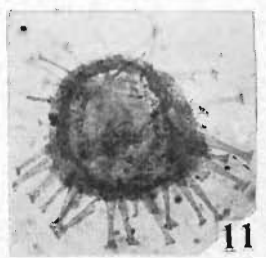
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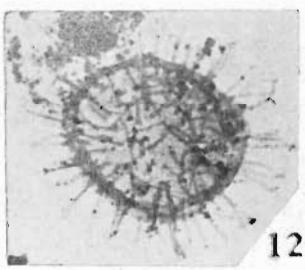
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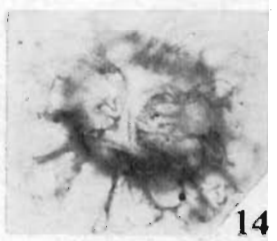
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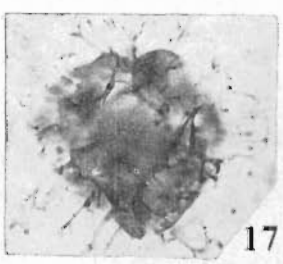
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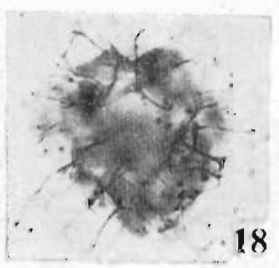
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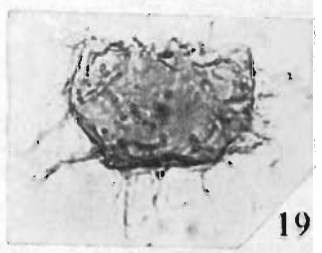
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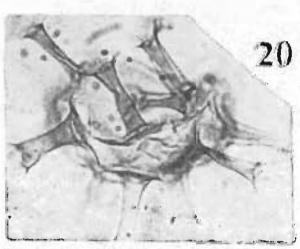
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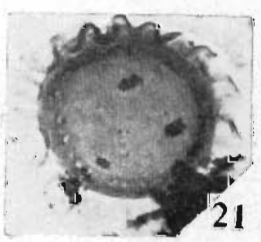
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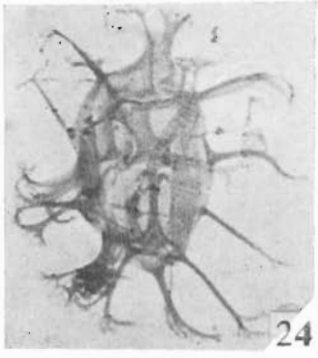
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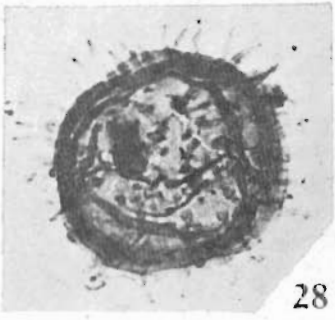
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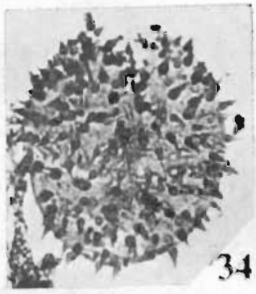
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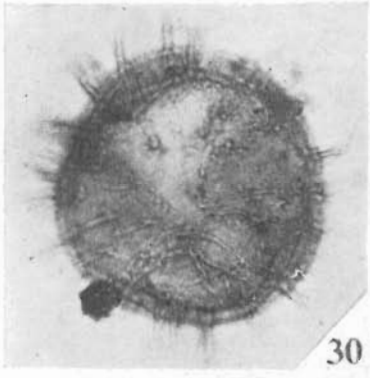
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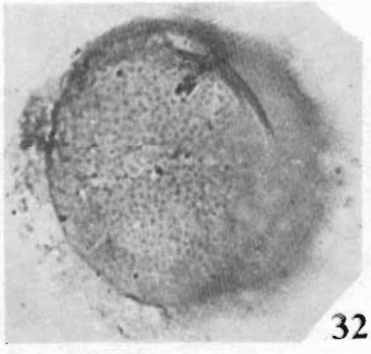
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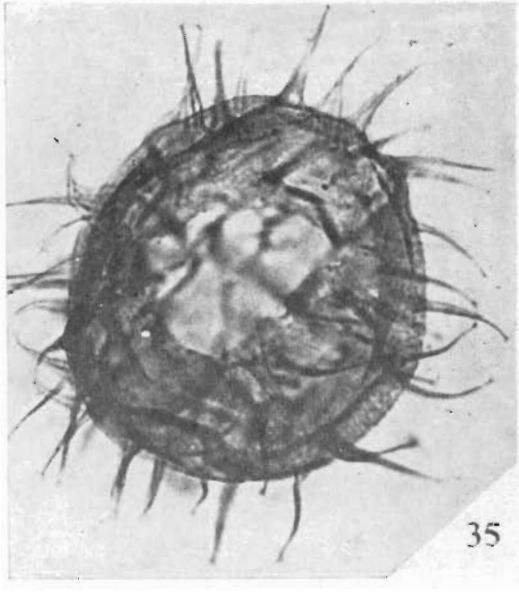
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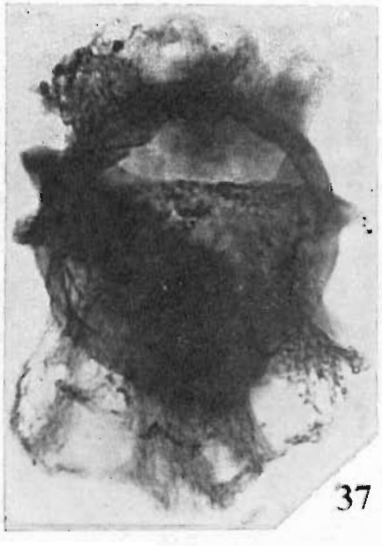
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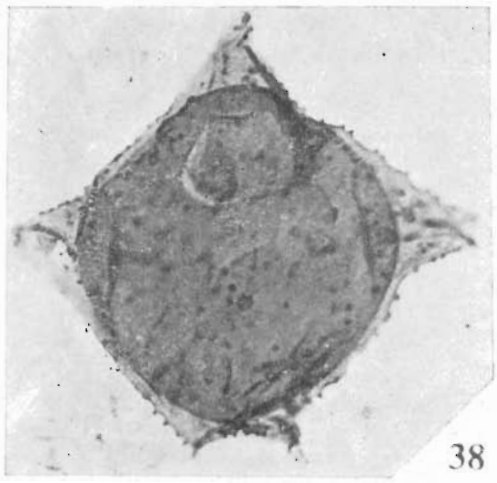
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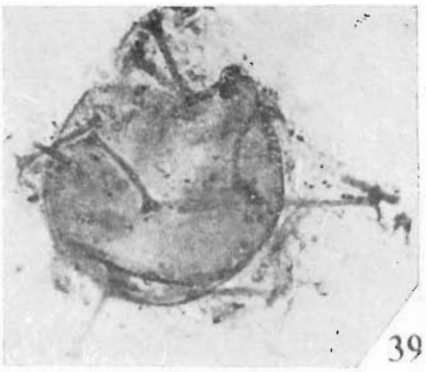
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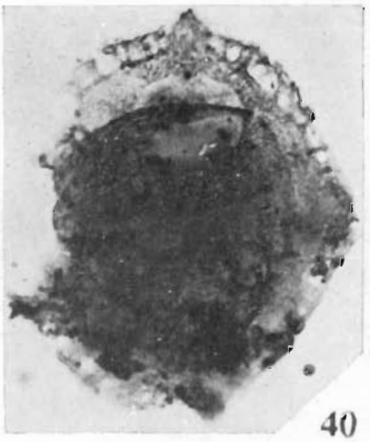
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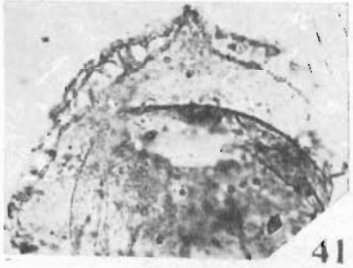
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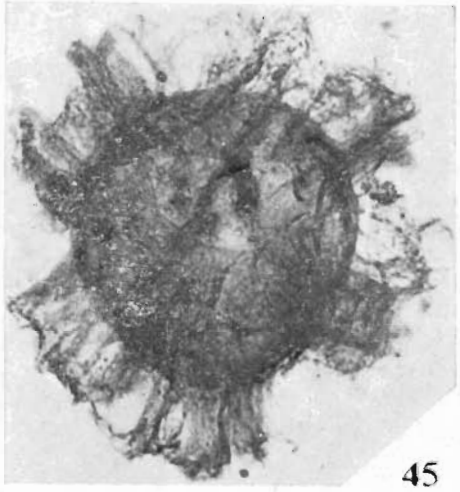
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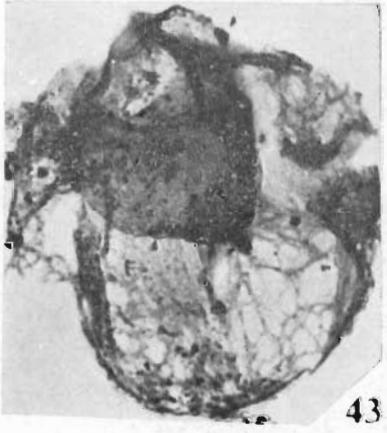
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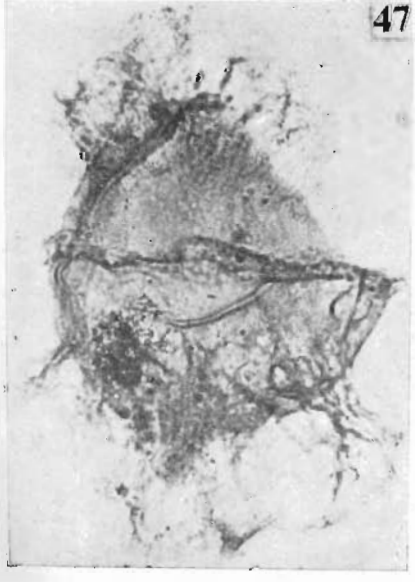
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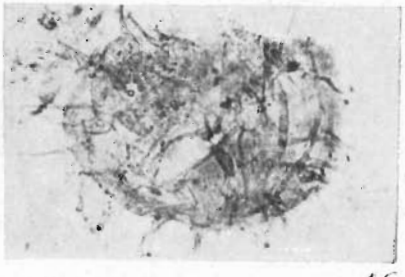
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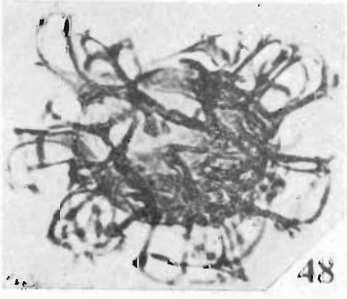
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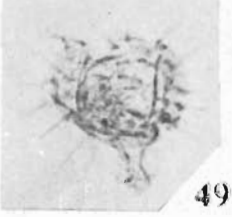
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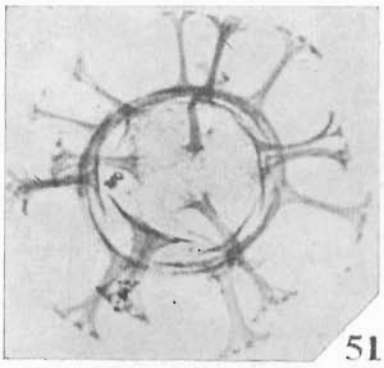
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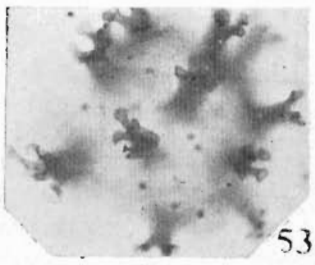
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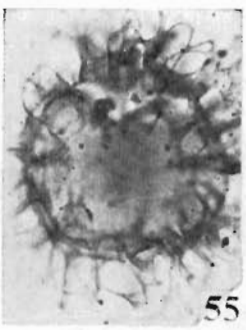
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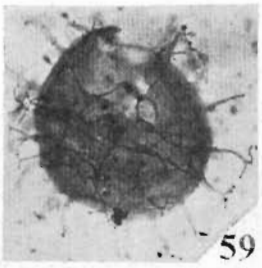
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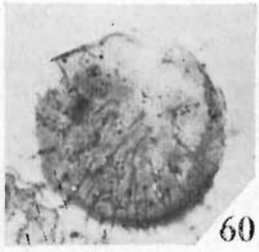
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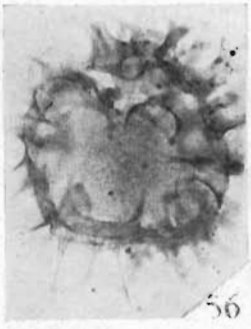
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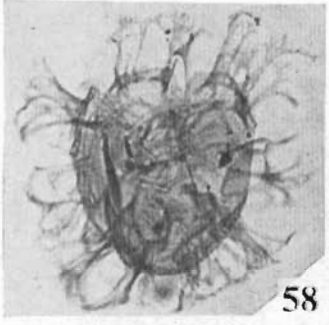
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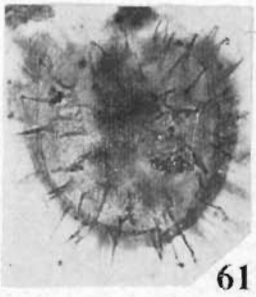
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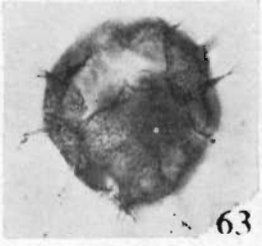
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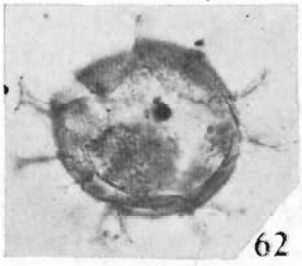
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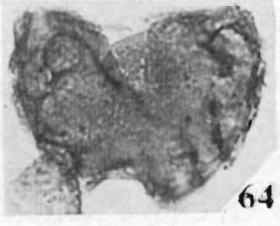
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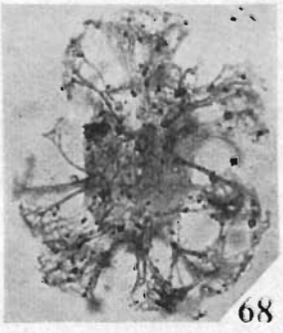
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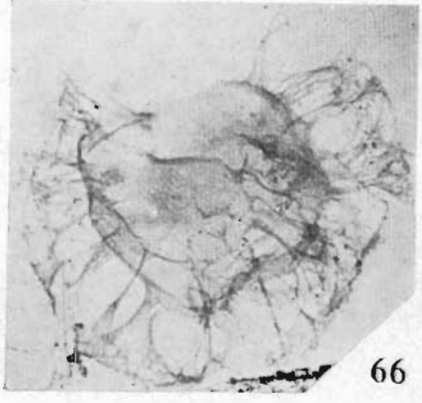
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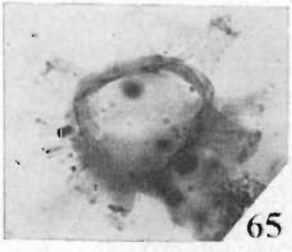
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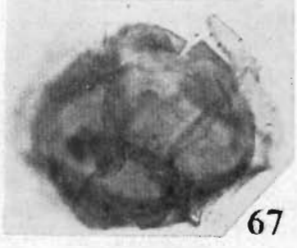
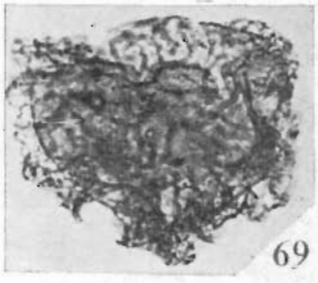
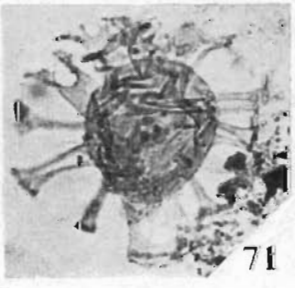

67


72


69


70


71

13. *Hystrichokolpoma* sp. A.; B.S.I.P. Slide No. 6433 ; coordinates : 109.8×8.8.
14. *Systematophora placacantna* (Deflandre & Cookson) Davey *et al*; B.S.I.P. Slide No. 6435 ; coordinates : 113.5×15.3.
15. *Systematophora placacantha* (Deflandre & Cookson) Davey *et al.* ; B.S.I.P. Slide No. 6430 ; coordinates : 125.5×12.6.
16. *Spiniferites? cingulatum* (Wetzel) Sarjeant ; B.S.I.P. Slide No. 6425 ; coordinates : 123.7×115.

17-19. *Glaphyrocysta kachchhensis* sp. nov.; B.S.I.P. Slide Nos. 6439 & 6421 ; coordinates : 129.0×14.2 & 113.8×8.9 respectively ; one specimen in two views ; 18, dorsal, 19, ventral.

20. *Homotryblium pallidum* Davey & Williams ; B.S.I.P. Slide No. 6421 ; coordinates : 100.6×18.2.
21. *Pterospermopsis* sp.; B.S.I.P. Slide No. 6433 ; coordinates : 99.9×20.9.
22. *Hemicystodinium zoharyi* (Rossignol) Wall ; B.S.I.P. Slide No. 6443 ; coordinates : 108.7×20.7.

Plate II

23-24. *Areosphaeridium arcuatum* Eaton ; B.S.I.P. Slide Nos. 6425 & 6435 ; coordinates : 112.5×8.5 & 113.5×6 respectively.
25. *Cordosphaeridium latispinosum* Davey & Williams ; B.S.I.P. Slide No. 6431 ; coordinates : 117.5×21.0.

26-27. *Turbiosphaera* sp.; B.S.I.P. Slide Nos. 6424 & 6443 ; coordinates : 103.3×19.1 & 116.5×19.3 respectively.

28. *Lingulodinium machaerophorum* (Deflandre & Cookson) Wall ; B.S.I.P. Slide No. 6424 ; coordinates : 127.7×22.5.
29. *Lingulodinium solarum* (Drugg) Wall & Dale ; Slide No. B.S.I.P. 6437 ; coordinates: 113.7×16.4.

30-31. *Impletosphaeridium granulosum* sp. nov.; B.S.I.P. Slide Nos. 6436 & 6430 ; coordinates : 135.1×13.8 & 120.0×13.9 respectively.

32-33. *Cyclopsiella coniata* sp. nov.; B.S.I.P. Slide Nos. 6427 & 6435 ; coordinates : 138.9×13.8 & 119.1×7.0 respectively.

34. *Eocladopyxis* sp. A.; B.S.I.P. Slide No. 6425 ; coordinates : 118.7×7.0.
35. *Polysphaeridium ornamentum* sp. nov.; B.S.I.P. Slide No. 6430 ; coordinates : 120.5×14.5.

36-37. *Araneosphaera consociata* sp. nov.; B.S.I.P. Slide No. 6424 ; coordinates : 96.3×6.9 ; same specimen in two views ; 36, ventral, 37, dorsal.

Plate III

38. *Wilsonidinium lineidentata* (Deflandre & Cookson) Lentin & Williams ; B.S.I.P. Slide No. 6440 ; coordinates : 120×14.
39. *Eatonicysta ursulae* (Morgenroth) Stover & Evitt ; B.S.I.P. Slide No. 6430 ; coordinates : 135.3×6.2.

40-41. *Wetzeliella* sp.; B.S.I.P. Slide No. 6430 ; coordinates : 126.8×11.2 ; 40, showing the intercalary archaeopyle.

42. *Muratodinium* sp. A.; B.S.I.P. Slide No. 6425 ; coordinates : 133×15.4.
43. *Muratodinium* sp. B.; B.S.I.P. Slide No. 6425 ; coordinates : 95×9.6.
44. *Thalassiphora pelagica* (Eisenack) Eisenack & Gocht emend. Gocht; B.S.I.P. Slide No. 6438 ; coordinates : 131.2×6.4.
45. *Cordosphaeridium fibrospinosum* Davey & Williams ; B.S.I.P. Slide No. 6424 ; coordinates : 125.2×22.7.
46. *Impletosphaeridium* sp. A.; B.S.I.P. Slide No. 6423; coordinates : 131.9×20.5.
47. *Araneosphaera consociata* sp. nov.; B.S.I.P. Slide No. 6442 ; coordinates : 129.9×14.8.
48. *Adnatosphaeridium vittatum* Williams & Downie ; B.S.I.P. Slide No. 6424 ; coordinates : 108.9×4.3.
49. *Diphyes colligerum* (Deflandre & Cookson) Cookson ; B.S.I.P. Slide No. 6421 ; coordinates : 134.6×20.9.
50. *Impletosphaeridium granulosum* sp. nov.; B.S.I.P. Slide No. 6426; coordinates : 103.8×15.7.

Plate IV

51-54. *Homotryblium plectilum* Drugg & Loeblich ; B.S.I.P. Slide No. 6430 ; coordinates : 123.5×23.4 & 105.5×6.5 respectively ; 51, showing process striations, ×1000 ; 52, showing buccinate distal ends of the processes.

55-56. *Glaphyrocysta intricata* (Eaton) Stover & Evitt; B.S.I.P. Slide No. 6431 ; coordinates : 102×9×22.6 same specimen in two views; 55, ventral, 56, dorsal.

57. *Glaphyrocysta* sp. A.; B.S.I.P. Slide No. 6426 ; coordinates : 97.5×12.7.
58. *Areoligera* sp. A.; B.S.I.P. Slide No 6431 ; coordinates : 131.1×6.8.
59. *Spiniferites ramosus* subsp. *granosus* (Davey & Williams) Lentin & Williams ; B.S.I.P. Slide No. 6433 ; coordinates : 112.4×10.5.
60. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall ; B.S.I.P. Slide No. 6426 ; coordinates : 114.2×22.7.
61. *Cleistosphaeridium* sp. A.; B.S.I.P. Slide No. 6434 ; coordinates : 106.3×12.0.

62-63. *Spiniferites ramosus* subsp. *granomembranaceus* (Davey & Williams) Lentin & Williams ; B.S.I.P. Slide No. 6430 ; coordinates: 106.8×24.8 ; same specimen in two different views ; 62, ventral, 63, dorsal.

64. *Chiropteridium* sp. A. ; B.S.I.P. Slide No. 6425 ; coordinates : 125.8×16.6.
65. *Hystrichokolpoma unispinum* Williams & Downie ; B.S.I.P. Slide No. 6432 ; coordinates : 112×23.4.
66. *Glaphyrocysta exuberans* (Deflandre & Cookson) Stover & Evitt ; B.S.I.P. Slide No. 6429 ; coordinates : 140.4×11.5.
67. *Impagidinium* sp. ; B.S.I.P. Slide No. 6432 ; coordinates ; 107.8×19.5.
68. *Veridictyocysta* sp. A. ; B.S.I.P. Slide No. 6436 ; coordinates ; 125.0×10.0.
69. *Glaphyrocysta pastielsii* (Deflandre & Cookson) Stover & Evitt ; B.S.I.P. Slide No. 6443a ; coordinates ; 113.4×6.9.
70. *Areoligera coronata* (Wetzel) Lejeune-Carpentier ; B.S.I.P. Slide No. 6442 ; coordinates : 113.3×18.1.
71. *Hystrichokolpoma* sp. B. ; B.S.I.P. Slide No. 6425 ; coordinates : 115.7×6.7.
72. *Samlandia chlamydophora* Eisenack ; B.S.I.P. Slide No. 6442 ; coordinates : 107.7×16.7.