

PALYNOLogy OF THE BARAIL (OLIGOCENE) AND SURMA (LOWER MIOCENE) SEDIMENTS EXPOSED ALONG SONAPUR-BADARPUR ROAD SECTION, JAINTIA HILLS (MEGHALAYA) AND CACHAR (ASSAM). PART-I. DINOFLAGELLATE CYSTS

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ABSTRACT

The present paper deals with the systematic description of 15 species belonging to 9 genera of dinoflagellate cysts recovered from the Barail (Oligocene) and Surma (Lower Miocene) sediments exposed along Sonapur-Badarpur Road Section, Meghalaya and Assam. The following genera have been recorded: *Polysphaeridium*, *Impletosphaeridium*, *Adnatosphaeridium*, *Membranilarnacia*, *Cordosphaeridium*, *Operculodinium*, *Achnospaera*, *Homotryblium* and *Tuberculodinium*. Two species, viz., *Membranilarnacia dohaensis* and *Homotryblium meghalayaensis* are proposed as new. An analysis of the assemblage reveals that the dinoflagellate cysts are dominant in the lower part of the Laisong Formation (Barail Group), and decrease in frequency towards the top (Surma Group). The Barail dinoflagellate assemblage has been compared with the Maniyara Fort Formation (Oligocene) assemblage from Kachchh.

INTRODUCTION

The palynological studies on the Tertiary sediments of north-eastern India have been done by various workers, viz., Ghosh (1941), Sahni, Sitholey and Puri (1947), Sen (1948), Meyer (1958), Biswas (1962), Baksi (1962, 1965), Ghosh and Banerjee (1963), Ghosh, Jacob and Lukose (1964), Banerjee (1964a, b), Bose and Sah (1964), Sah and Dutta (1966, 1968, 1974), Dutta and Sah (1970, 1974), Salujha, Kindra and Rehman (1972, 1974), Salujha, Rehman and Kindra (1973), Banerjee, Misra and Koshal (1973), Sein and Sah (1974), Shrivastava, Ganeshan and Ray (1974), Sah and Singh (1974), Singh, Singh and Sah (1975), Singh (1977a, b), Singh and Singh (1978), Singh and Tewari (1979), Dutta and Singh (1980), Sah, Singh and Singh (1980) and Mehrotra (1981 a, b, 1983). The above papers mainly deal with the spore-pollen assemblages whereas the dinoflagellate cysts are either meagrely represented therein or have been ignored by the palynologists. The assemblages recorded by Biswas (1962), Baksi (1962, 1965), Salujha, Kindra and Rehman (1972, 1974) and Salujha, Rehman and Kindra (1973) mainly consist of the spores and pollen grains with sporadic representation of dinoflagellate cysts, whereas those by Sah, Kar and Singh (1970), Banerjee and Misra (1972), Kar, Singh and Sah (1972), Jain, Sah and Singh (1975), Dutta and Jain (1980), Salujha and Kindra (1981), Mehrotra (1981a, b) and Jain and

Garg (1982) mainly consist of the dinoflagellate cysts. These cysts have mainly been recorded from the Palaeocene-Eocene sediments whereas those from the Oligocene and Miocene sediments have largely remained uninvestigated. This paper is therefore the first to deal with the systematic description of the dinocysts from the Oligocene and Lower Miocene sediments exposed along the Sonapur-Badarpur Road Section in Meghalaya and Assam.

This section is 60 km long and is shared by Jaintia Hills district (Meghalaya) and Cachar district (Assam). Traversing from Sonapur towards Badarpur along Sonapur-Badarpur Road, the Barail Group (Oligocene) is first developed, being represented by Laisong, Jenam and Renji formations. The Laisong Formation (about 1750 metres thick) is mainly arenaceous consisting of grey, very hard, thinly bedded, very fine to medium grained sandstones alternating with subordinate hard sandy shales. The Jenam Formation (about 850 metres thick) is mainly argillaceous and consists of shales and sandy shales, generally being carbonaceous, with fine to medium grained sandstones. The Renji Formation (about 800 metres thick) is again arenaceous, being made up of thickly bedded or massive, fine to medium grained, hard, ferruginous sandstone alternated by thin shales. The Renji Formation is unconformably overlain by the Surma Group (Lower Miocene) which is divisible into lower, Bhutan and upper, Bokabil forma-

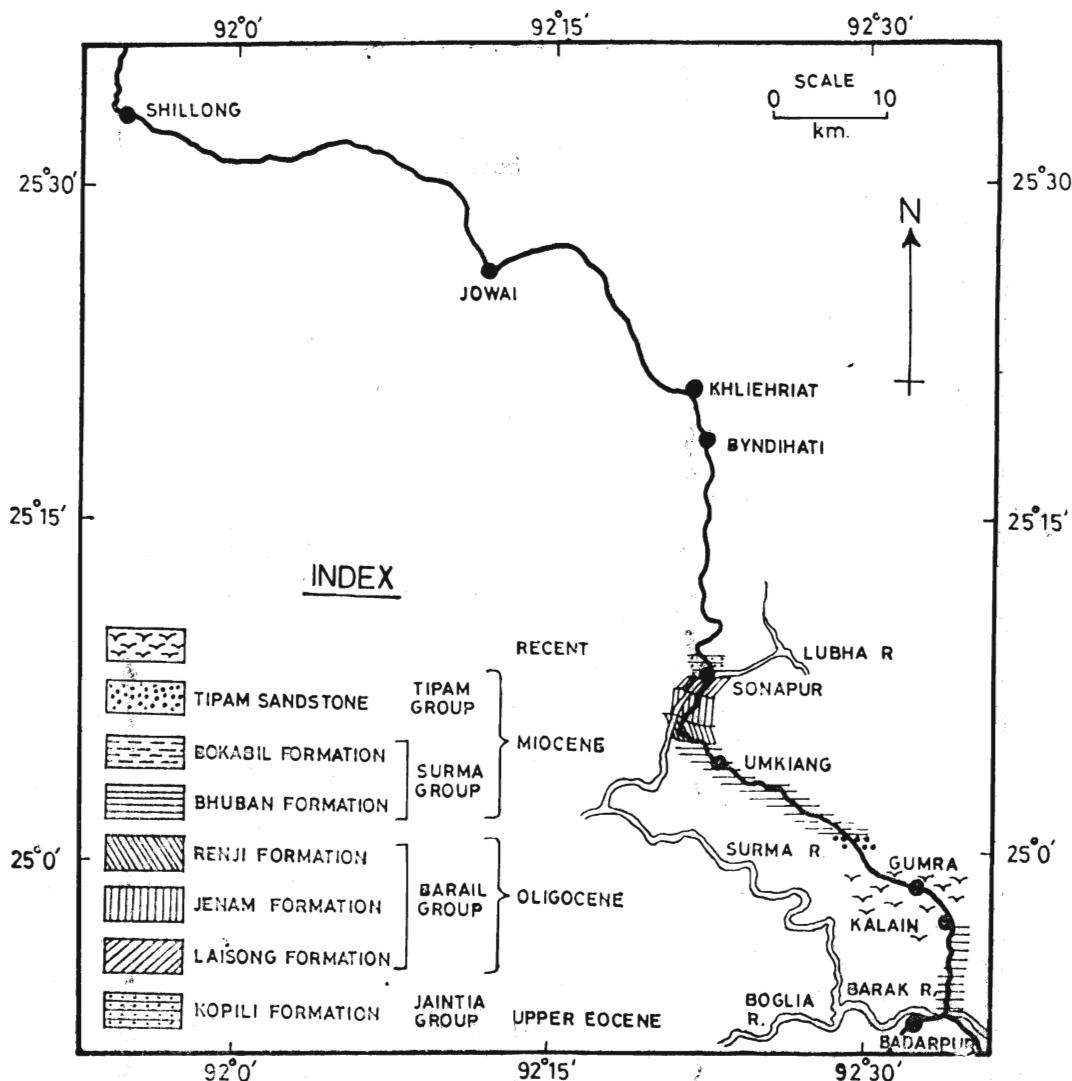


Fig. 1. Geological map of the Sonapur-Badarpur Road section in Jaintia Hills (Meghalaya) and Cachar (Assam) (modified after Saxena and Tripathi, 1982).

tion. The Bhuban Formation (about 1850 metres thick) is divided into Lubha, Umkiang and Dona members, the lower and upper members being mainly arenaceous and the middle member argillaceous. The Bokabil Formation (about 150 metres thick) is made up of thick sandy shales with alternations of very fine grained laminated sandstone (Fig. 1). The detailed lithostratigraphy of this section has been published by Saxena and Tripathi (1982).

For palynological investigation, 288 rock samples were collected from the various formations exposed along the above section by one of us (R.K.S.). Of these, 216 samples were proved to be palynologically productive. The details of samples are given in Table-1.

The palynoflora recovered include dinoflagellate cysts, fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen grains and some

Table 1

Group	Formation	Samples collected	Productive samples	Exposures ¹
Surma	Bokabil	9	6	177.5—180.0 km
	Bhuban	172	124	147.5—177.5 km
	Renji	15	10	145.6—147.5 km
Barail	Jenam	43	31	143.2—145.6 km
	Laisong	49	45	140.0—143.2 km

¹ The distances are given with reference to Shillong along Shillong-Badarpur Highway.

other microremains of obscure origin. The present paper exclusively deals with the dinoflagellate cysts and constitutes the first part of the study.

For the recovery of palynomorphs, the samples were treated with HCl, HF and HNO₃ for 2-7 days followed by 5% KOH treatment and acetolysis. The dinoflagellate cysts are classified as per system proposed by Sarjeant and Downie (1974). The slides, negatives and unused material have been housed at the museum of Birbal Sahni Institute of Palaeobotany, Lucknow.

SYSTEMATIC DESCRIPTION

<i>Class</i>	Dinophyceae PASCHER
<i>Subclass</i>	Diniferophycidae BERGH
<i>Order</i>	Peridiniales SCHÜTT
<i>Family</i>	Cleistosphaeridiaceae SARJEANT & DOWNIE, 1974
<i>Genus</i>	<i>Polysphaeridium</i> DAVEY & WILLIAMS in DAVEY et al., 1966
<i>Type species</i>	<i>Polysphaeridium subtile</i> DAVEY & WILLIAMS in DAVEY et al., 1966
<i>Polysphaeridium subtile</i>	DAVEY & WILLIAMS in DAVEY et al., 1966 (Pl. I-1-2)

Number of specimens studied: 15

Description: Cysts chorate, body ovoidal in shape. Parasutural features not indicated. Processes numerous, non-tabular, hollow, distally open and slightly expanded, distal ends of the processes sometimes very finely serrate. Autophragm only, smooth to finely granulose. Paratabulation not indicated. Archaeopyle apical, type tĀ, sometimes not distinctly observed. Paracingulum and parasulcus not indicated.

Dimensions: Size of cyst body—50-58×46-50 μm. Length of the processes 10-18 μm.

Occurrence: Laisong Formation, Barail Group.

Distribution: Lower Eocene of London Basin in northern England (Davey & Williams in Davey et al., 1966, Grus-Cavagnetto, 1970; Palaeocene and Lower Eocene of northern Spain (Caro, 1973); and Lower, Middle and Upper Eocene of Isle of Wight, southern England (Eaton, 1976).

Polysphaeridium sp.

(Pl. I-3-4)

Number of specimens studied: 6

Description: Cysts chorate, body subspherical in shape. Parasutural features not indicated. Processes numerous, non-tabular, cylindrical, distal ends of the processes blunt, sometimes pointed. Autophragm only, smooth to finely granulose. Paratabulation not clear. Archaeopyle apical, type not clearly seen. Paracingulum and parasulcus not indicated.

Dimensions: Size of cyst body—60-75×50-60 μm. Length of the processes—5-10 μm. Width of the processes—5-7 μm.

Comparison: *Polysphaeridium subtile* Davey & Williams in Davey et al. (1966) can be distinguished from the present species in having simple, slender, tubular processes with usually serrate distal margin.

Occurrence: Dona Member, Bhuban Formation, Surma Group.

<i>Genus</i>	<i>Impletosphaeridium</i> MORGENROTH, 1966
<i>Type species</i>	<i>Impletosphaeridium transfodum</i> MORGENROTH, 1966

Impletosphaeridium insolitum EATON, 1976
(Pl. I-6)

Number of specimens studied: 10

Description: Cysts chorate, body spherical to subspherical in shape. Parasutural features not observed. Processes numerous, slender and solid, simple with small bulbous spherical or subspherical distal terminations. Autophragm only, being finely granulose. Paratabulation and archaeopyle not clear.

Dimensions: Size of cyst body—40-50×38-43 μm. Length of the processes—10-19 μm.

Remarks: Eaton (1976) reported *Impletosphaeridium insolitum* from the Lower, Middle and Upper Eocene of Isle of Wight, southern England. The specimens described by him are smaller in size (cyst-body 15-24 μm, processes up to 9 μm long) as compared to those described from the present assemblage.

Occurrence: Laisong Formation, Barail Group

Distribution: Lower, Middle and Upper Eocene, Isle of Wight, southern England (Eaton, 1976).

<i>Family</i>	Adnatosphaeridiaceae SARJEANT & DOWNIE, 1966
<i>Genus</i>	<i>Adnatosphaeridium</i> WILLIAMS &

<i>Type species</i>	<i>Adnatosphaeridium vittatum</i> WILLIAMS & DOWNIE in DAVEY et al., 1966
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Adnatosphaeridium vittatum WILLIAMS & DOWNIE in

DAVEY et al., 1966

(Pl. I-5, 7)

Number of specimens studied: 10

Description: Cysts chorate, body subspherical to spherical in shape. Parasutural features not indicated. Processes intratabular, numerous, hollow, tubular rarely branched at distal ends, connected distally by trabeculae, distal margin sometimes finely serrate. Ectophragm smooth forming the trabeculae, autophragm finely granulose. Paratabulation not clearly indicated. Archaeopyle apical, type tĀ, operculum free, paracingulum and parasulcus not discernible.

Dimensions: Size of cyst body—40-48×38-44 μm. Length of the processes—13-20 μm.

Occurrence : Laisong Formation, Barail Group.

Distribution : Lower Eocene of southern England (Williams & Downie in Davey et al., 1966); Palaeocene of northern Spain (Caro, 1973); and Lower and Upper Eocene of southern England (Eaton, 1976).

Family Membranilarnaciaceae EISENACK, 1963
emend. SARJEANT & DOWNIE, 1966

Genus *Membranilarnacia* EISENACK, 1963 emend.
WILLIAMS & DOWDIE in DAVEY et al.,
1966

Type species : *Membranilarnacia leptoderma* (COOKSON & EISENACK, 1958) EISENACK, 1963

Membranilarnacia donaensis n. sp.

(Pl. I—8-9)

Holotype : Pl. 1—8, size 115 μm , slide no. 8374.

Number of specimens studied : 15

Diagnosis : Cysts cavate, body spherical to subspherical in shape. Cyst consisting of thick walled endocyst and thin walled pericyst. Pericoel with a few rods or pillars, rods stout, fibrous, expanded at the distal ends, ranging 10-12. Archaeopyle apical, type uncertain, probably type tA. Paracingulum and parasulcus not indicated.

Dimensions : Overall cyst size—115-122 \times 105-110 μm . Length of the processes—10-14 μm . Width of the processes—8-12 μm .

Comparison : *Membranilarnacia leptoderma* (Cookson & Eisenack, 1958) Eisenack (1963) can be distinguished from the present new species in having the granular body surface. *M. polycladiata* (Cookson & Eisenack, 1958) Eisenack (1963) is differentiated by possessing thick granular wall and numerous fine processes which divide in such a way as to give a funnel-like appearance. *M. reticulata* Williams & Downie in Davey et al., (1966) differs in possessing a reticulate membrane enveloping the central body.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

Type locality : 160.5 km-stone, Sonapur-Badarpur Road Section, Meghalaya.

Type horizon : Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Family Cordosphaeridiaceae SARJEANT & DOWNIE, 1974

Genus *Cordosphaeridium* EISENACK, 1963 emend. DAVEY, 1969

Type species : *Cordosphaeridium inodes* (KLUMPP, 1953) EISENACK, 1963

Cordosphaeridium inodes (KLUMPP, 1953) EISENACK, 1963 emend. MORGENTHOTH, 1968

(Pl. I—10)

Number of specimens studied : 10

Description : Cysts chorate, body subspheroidal to ovoidal in shape. Processes intratabular, fibrous, hollow, distally branched and open. Endophragm and periphragm appressed in between the processes. Archaeopyle precingular, type P (3" only). Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body—46-52 \times 40-52 μm . Length of the processes—13-17 μm .

Occurrence : Laisong and Jenam formations, Barail Group; Lubha and Dona Members, Bhuban Formation, Surma Group.

Distribution : This species is known to occur from Lower Eocene to Middle Miocene (Davey & Williams, in Davey et al., 1966).

Cordosphaeridium multispinosum DAVEY & WILLIAMS in DAVEY et al., 1966

(Pl. I—11)

Number of specimens studied : 8

Description : Cysts chorate, body subspheroidal to ovoidal in shape. Processes intratabular, numerous, fibrous, hollow distally branched and open, margin sometimes serrate or irregular, 2 or more processes per plate. Periphragm granulose, endophragm smooth, Archaeopyle precingular type P (3" only). Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body—55-57 μm . Length of the processes—3-17 μm . Width of the processes—2-5 μm .

Occurrence : Laisong Formation, Barail Group.

Distribution : Lower Eocene of London Clay and White Cliff Bay, Isle of Wight, Hampshire and Isle of Sheppey, Kent, England (Downie & Williams in Davey et al., 1966); Lakadong Limestone Member, Upper Palaeocene, India (Dutta & Jain, 1980).

Remarks : The present occurrence of this species is younger than its known range. This may be attributed either to reworking, though no such evidence is found, or its range may be extended up to Lower Oligocene.

Cordosphaeridium fibrospinosa DAVEY & WILLIAMS in DAVEY et al., 1966

(Pl. I—12-14)

Number of specimens studied : 6

Description : Cysts chorate, body spheroidal to ovoidal in shape. Processes intratabular, fibrous, often very broad, entire or undulose margin. Endophragm thin and smooth and periphragm fibrous, Archaeo-

pyle precingular type P (3" only). Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body— $65-77 \times 62-75 \mu\text{m}$. Length of the processes— $10-30 \mu\text{m}$. Width of the processes— $20-35 \mu\text{m}$.

Occurrence : Laisong and Jenam formations, Barail group and Dona Member, Bhuban Formation, Surma Group.

Distribution : London Clay (Eocene), England (Davey & Williams in Davey et al., 1966; Downie, Hussain & Williams, 1971). Middle and Upper Oligocene, North Germany (Benedek, 1972), Lower and Middle Eocene, Isle of Wight, southern England (Eaton, 1976), Atlantic corehole, Blake Plateau, Lower Oligocene (Stover, 1977) and Maestrichtian to Lower Oligocene, Offshore Eastern Canada (Williams & Bujak, 1977a).

Cordosphaeridium gracilis (EISENACK, 1954)

DAVEY & WILLIAMS in DAVEY et al., 1966

(Pl. II—15)

Number of specimens studied : 5

Description : Cyst chorate, body subspheroidal in shape. Processes intratabular, cylindrical, solid, erect and slightly digitate, branched and have characteristic Y-shape. Endophragm and periphragm appressed in between the processes: periphragm smooth and endophragm granulose. Archaeopyle precingular, type P (3" only). Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body— $75 \times 79 \mu\text{m}$. Length of the processes—upto $23 \mu\text{m}$.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

Distribution : Upper Eocene of East Prussia (Eisenack, 1938, 1954), Middle Oligocene and Middle Miocene of North Germany (Gerlach 1961, Gocht 1969, Benedek 1972). Lower Eocene of Belgium (Morgenroth, 1966) of North Germany (Morgenroth, 1966, Gocht, 1969) and of the Hampshire and London Basin in southern England (Davey & Williams 1966, Downie, Hussain and Williams, 1971), Middle and Upper Eocene of North Germany (Agelopoulos, 1967, Gocht, 1969), Lower Eocene of Northern France (Gruas-Cavagnetto, 1970), Upper Oligocene of North Germany (Benedek, 1972), Lower, Middle and Upper Eocene of England (Eaton, 1976) and Maestrichtian to Lower Oligocene, Offshore Eastern Canada (Williams & Bujak, 1977a).

Family Lingulodiniaceae SARJEANT & DOWNIE, 1974

Genus *Opercudinium* Wall, 1967

Type species : *Opercudinium centrocarpum* (DEFLANDRE & COOKSON, 1955) WALL, 1967

Opercudinium sp. cf. *O. major* JAIN & DUTTA in DUTTA & JAIN, 1980

(Pl. II—16)

Number of specimens studied : 4

Description : Cyst chorate, body subspheroidal in shape. Parasutural features not observed. Processes intratabular, numerous, hollow, distally open expanded. Periphragm sculptured and endophragm smooth. Paratabulation indistinct. Archaeopyle precingular, type P (3" only). Paracingulum and parasulcus not observed.

Dimensions : Size of cyst body— $59 \times 51 \mu\text{m}$. Length of the processes— $15-23 \mu\text{m}$.

Comparison : The present specimen closely compares with *Opercudinium major* Jain & Dutta in Dutta & Jain (1980) but the former can be distinguished by its finely granulose periphragm and smaller size range ($59 \times 51 \mu\text{m}$).

Occurrence: Laisong Formation, Barail Group.

Family Spiniferitaceae SARJEANT, 1970 emend. SARJEANT & DOWNIE, 1974

Genus *Achomosphaera* EVITT, 1963

Type species : *Achomosphaera ramulifera* (DEFLANDRE, 1937) EVITT, 1963

Achomosphaera ramulifera (DEFLANDRE, 1937) EVITT, 1963

(Pl. II—17)

Number of specimens studied : 6

Description : Cysts chorate, body subspherical in shape. Body wall smooth, two layered; endophragm and periphragm being appressed in between the processes. Processes hollow and bifurcated, having trifurcated extremities. Archaeopyle precingular, type P (3" only). Paracingulum and parasulcus not observed.

Dimensions : Size of cyst body— $55-65 \times 45-60 \mu\text{m}$. Length of the processes— $17-21 \mu\text{m}$.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

Distribution : Lower Eocene of the Hampshire and London Basin in southern England (Davey & Williams in Davey et al., 1966), Albian (Davey & Verdier, 1971), Pliocene (Habib, 1971). Lower, Middle and Upper Eocene of England (Eaton, 1976) and Middle Eocene of Kachchh (Jain & Tandon, 1981).

Achomosphaera sagena DAVEY & WILLIAMS in DAVEY et al., 1966

(Pl. II—18-19)

Number of specimens studied : 4

Description : Cysts chorate, body subspherical-

spherical in shape. Endophragm and periphragm appressed in between the processes. Central body is finely granulose and 3 μm thick. Surface coarsely reticulate. Processes hollow, with bifurcate and/or trifurcate extremities and commonly possessing reticulate bases. Precingular archaeopyle present.

Dimensions : Size of the cyst—47-60 \times 50-60 μm . Length of the processes—upto 15 μm .

Occurrence : Renji Formation, Barail Group.

Distribution : Lower Chalk, Upper Cretaceous (Cenomanian) of England (Davey & Williams in Davey et al., 1966).

Remarks : Davey and Williams in Davey et al. (1966) recorded this species from the Upper Cretaceous sediments. The present occurrence extends its range up to Upper Oligocene.

Family Homotrybliaceae SARJEANT & DOWNE, 1966 emend. SARJEANT & DOWNE, 1974

Genus *Homotryblium* DAVEY & WILLIAMS in DAVEY et al., 1966

Type species : *Homotryblium tenuispinosum* DAVEY & WILLIAMS in DAVEY et al., 1966

Homotryblium floripes (DEFLANDRE & COOKSON, 1955)
STOVER, 1975
(Pl. II—20)

Number of specimens studied : 25

Description : Cysts chorate, body spherical to subspherical with granulose endophragm and periphragm. Periphragm slightly thinner than the endophragm. Parasutural features not indicated. Processes intratabular, tubular, hollow, finely striated and fibrous, distally open with 2-6 lobes. Paratabulation not clearly seen. Archaeopyle combination type, formed by the removal of apical and preingular plates. Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body—45-63 μm . Length of the processes—10-17 μm .

Occurrence : Laisong and Jenam formations, Barail Group and Bhuban Formation, Surma Group.

Distribution : Upper Eocene of North Germany (Agelopoulos, 1964, 1967), Oligocene of U.S.A. (Drugg & Loeblich, 1968), Upper Eocene of Meghalaya, India (Dutta & Jain, 1980) and Middle-Upper Eocene of Isle of Wight, southern England (Eaton, 1976), Upper Eocene to Middle Miocene, Offshore Eastern Canada (Williams & Bujak, 1977a), Upper Eocene to Middle Miocene, North Atlantic margins (Williams & Bujak, 1977b).

Homotryblium meghalayaensis n. sp.

(Pl. II—21-23)

Holotype : Pl. II—23, size 62 \times 65 μm , slide no. 8374

Number of specimens studied : 15

Diagnosis : Cysts chorate, body subspherical to spherical in shape. Endophragm and periphragm appressed between the processes. Both walls smooth to faintly granulose. Parasutural features not indicated. Processes intratabular, tubular, hollow, distally open and secate. Paratabulation not clearly seen. Archaeopyle combination type, formed by the removal of apical and preingular plates. Paracingulum and parasulcus not indicated.

Dimensions : Size of cyst body—57-75 \times 55-67 μm . Length of the processes—14-28 μm .

Comparison : *Homotryblium tenuispinosum* Davey & Williams in Davey et al. (1966) can be differentiated from the present species in having outer strongly granular periphragm and smaller diameter of the central body (48 \times 41 μm). *H. pallidum* Davey & Williams in Davey et al. (1966) is distinct by possessing granular periphragm and the processes of variable width forming a circle where they arise from the central body. *H. floripes* DeLandre & Cookson, 1955 Stover, (1975) differs in possessing striate and fibrous processes; the striations being formed by three or four nerve-like delicate thickenings which extend from the distal terminations to the basal areas. *H. tasmaniense* Cookson & Eisenack (1967) can be distinguished by its granular to spinulose body with radially arranged tubular and distally open appendages.

Type locality : 160.5 km-stone, Sonapur-Badarpur Road Section, Meghalaya.

Type horizon : Dona Member, Bhuban Formation, Surma Group, Lower Miocene.

Family Scrinicassiacaceae SARJEANT & DOWNE, 1966 emend. SARJEANT & DOWNE, 1974

Genus *Tuberculodinium* WALL, 1967 emend. WALL & DALE, 1971

Type species : *Tuberculodinium vancampoae* (ROSSIGNOL, 1962) WALL, 1967 emend. WALL & DALE, 1971

Tuberculodinium vancampoae (ROSSIGNOL, 1962)
WALL, 1967 emend. WALL & DALE, 1971

(Pl. II—24)

Number of specimens studied : 6

Description : Cyst subspherical with two wall layers. The endophragm forming the central body is about 2.5 μm thick. Central body bears 11 tuberculate processes. Tubercles circular in surface view, but vary from spherical to 8-shaped in lateral view. The thin membranous periphragm is supported by tubercles arising from the central body. The periphragm

damaged at some places due to its fragile nature. Archaeopyle large, polyhedral and antapically placed.

Dimensions: Size of the cyst body— $108 \times 114 \mu\text{m}$. Size of the tubercles— $12 \times 14 \mu\text{m}$.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

Distribution : Pleistocene-Recent, Israel (Rossignol, 1962; 1964) Quaternary, Venezuela (Wall, 1967), Post-Miocene, Florida Hatteras Slope (Drugg, 1970), Middle to Late Miocene, Grand Banks, Atlantic continental margin (Williams & Brideaux, 1975), Late Miocene, Eastern Canada (Williams, 1975), Middle Oligocene to Pliocene, Offshore Eastern Canada (Williams & Bujak, 1977a), Atlantic corehole, Blake Plateau, Lower Miocene (Stover, 1977) and Oligocene of Kachchh of western India (Jain, 1980).

Incertae-sedis

Dinocyst type-1

(Pl. II—28)

Number of specimens studied : 10

Description : Cyst oval in shape with thick margin. Body covered with hair-like structures and small scales. A slight depression present in the centre. Tabulation and archaeopyle not discernible.

Dimensions : Size of cyst body— $72 \times 63 \mu\text{m}$. Length of the processes— $6-8 \mu\text{m}$.

Occurrence : Laisong Formation, Barail Group.

Dinocyst type-2

(Pl. II—25-26)

Number of specimens studied : 10

Description : Cyst subcircular in shape, golden yellow in colour. Autophragm only. Body covered with spines having bulbous bases and narrower tips.

Dimensions: Size of cyst body— $47 \times 56-37-45 \mu\text{m}$. Length of the spines— $6-19 \mu\text{m}$. Width of the spines— $2-6 \mu\text{m}$.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

Dinocyst type-3

(Pl. II—27)

Number of specimens studied : 1

Description : Cyst subcircular in shape, dark brown in colour. Autophragm only. Paratabulation and archaeopyle not discernible. Processes numerous, long, tubular.

Dimensions : Diameter of cyst— $50 \times 45 \mu\text{m}$. Length of the processes— $19-25 \mu\text{m}$.

Occurrence : Dona Member, Bhuban Formation, Surma Group.

DISCUSSION

The dinoflagellate cysts described here from the Barail and Surma groups (Oligocene-Lower Miocene) are represented by 9 genera and 15 species. An analysis of the assemblage reveals that the dinoflagellate cysts are dominant in the lower part of the Laisong Formation (Barail Group), decrease in the Jenam and Renji formations and again become important in the Bhuban Formation with appreciable representation at few levels. The distribution of the different species is given in Table-2.

Table 2

Groups	BARAIL			SURMA		
	Laisong	Jenam	Renji	Lubha	Umkiang	Dona
Formations						Bokabil
Members						
<i>Polysphaeridium subtile</i>	+	—	—	—	—	—
<i>Polysphaeridium</i> sp.	—	—	—	—	+	—
<i>Adnatosphaeridium vittatum</i>	+	—	—	—	—	—
<i>Cordosphaeridium inodes</i>	+	+	—	+	—	+
<i>C. multispinosum</i>	+	—	—	—	—	—
<i>C. fibrospinosum</i>	+	+	—	—	—	+
<i>C. gracilis</i>	—	—	—	—	—	—
<i>Achromosphaera ramulifera</i>	—	—	—	—	—	+
<i>A. sagena</i>	—	—	—	—	—	—
<i>Membranilarnacia donaensis</i>	—	—	—	—	—	+
<i>Tuberculodinium vancompoae</i>	—	—	—	—	—	+
<i>Homotryblium floripes</i>	+	+	—	+	+	+
<i>H. meghalayaensis</i>	—	—	—	—	—	+
<i>Operculodinium</i> sp. cf. <i>O. major</i>	+	—	—	—	—	—
<i>Impletosphaeridium insolitum</i>	+	—	—	—	—	—

Adnatosphaeridium vittatum, *Polysphaeridium subtile*, *Cordosphaeridium multisporosum*, *Impletosphaeridium insolitum* and *Operculodinium* sp. cf. *O. major* are dominant in the Laisong Formation and are restricted to Barail Group only. *Achomosphaera sagena* has been recovered only from the Renji Formation. *Tuberculodinium vancompoae*, *Membranilarnacia donaensis*, *Homotryblium meghalaensis*, *Cordosphaeridium gracilis* and *Achomosphaera ramulifera* are restricted to the upper part of Bhutan Formation only. *Homotryblium floripes*, *Cordosphaeridium inodes* and *G. fibrospinosum* occur in both Barail and Surma groups. Their frequency is high in the lower part of the Laisong Formation, decreases in the Jenam Formation; they are absent in Renji Formation and again reappear in the lower and upper parts of Bhutan Formation. In Bokabil Formation, these dinoflagellate cysts are completely absent.

Table 3

Taxa	Kar, 1979	Jain, 1980	Present study
<i>Polysphaeridium (Hystrichosphaeridium) microtriaenum</i>	+	—	—
<i>P. cephalum</i>	+	—	—
<i>Cleistosphaeridium heteracanthum</i>	+	—	—
<i>Spiniferites ramosus</i> cf. var. <i>multibrevis</i>	+	—	—
<i>Fromea pachyderma</i>	+	—	—
<i>Homotryblium</i> sp.	+	—	—
<i>Membranilarnacia delicata</i>	+	—	—
<i>Operculodinium centrocarpum</i>	—	+	—
<i>Tuberculodinium vancompoae</i>	—	+	—
<i>Hemicystodinium</i> sp. cf. <i>H. congregatum</i>	—	+	—
<i>Spiniferites ramosus</i> subsp. <i>granosus</i>	—	+	—
<i>Cordosphaeridium</i> sp.	—	+	—
<i>Polysphaeridium subtile</i>	—	—	+
<i>Cordosphaeridium inodes</i>	—	—	+
<i>G. fibrospinosum</i>	—	—	+
<i>G. multisporosum</i>	—	—	+
<i>Achomosphaera sagena</i>	—	—	+
<i>Adnatosphaeridium vittatum</i>	—	—	+
<i>Homotryblium floripes</i>	—	—	+
<i>Operculodinium</i> sp. cf. <i>O. major</i>	—	—	+
<i>Impletosphaeridium insolitum</i>	—	—	+

COMPARISON

The only dinoflagellate cyst assemblage known from the Indian Oligocene sediments is the one reported by Kar (1979) from the Maniyara Fort Formation of Kachchh. The present Barail (Oligocene) dinocysts have been compared with the dinocysts of the Maniyara Fort Formation. This assemblage consists of 39 genera and 52 species of pteridophytic spores, gymnospermous and angiospermous pollen grains and microplanktons. Of these, 6 genera and 7 species belong to the dinocysts. Jain (1980) re-examined these slides and reallocated the dinoflagellate cysts species described by Kar (1979). A comparative study of the present assemblage with the Kachchh assemblage is given in Table-3.

This reveals that the Maniyara Fort assemblage is not comparable with the present Barail assemblage. Dinoflagellate cysts from the Indian Miocene sediments have so far not been published.

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EXPLANATION OF PLATES

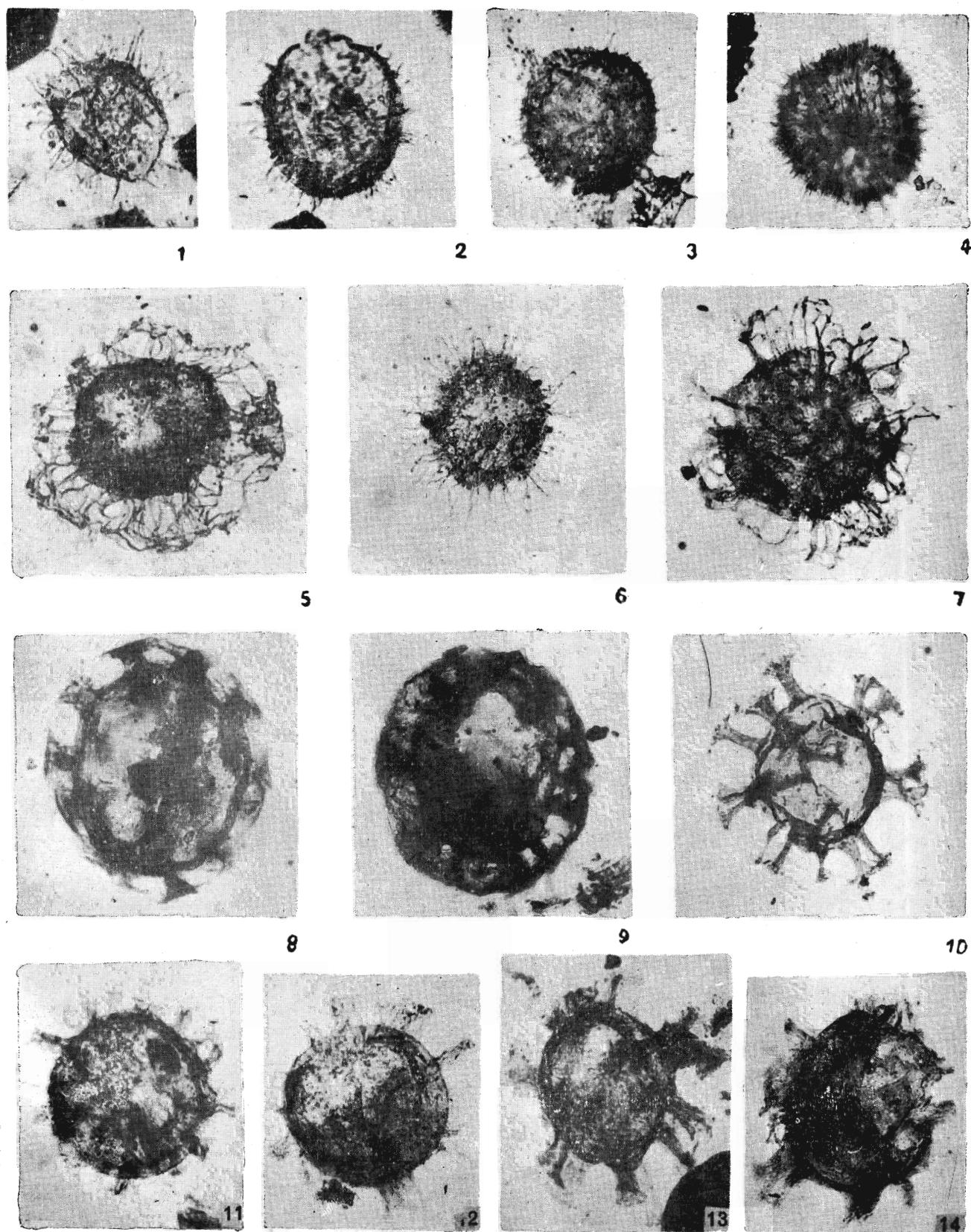
(All the photomicrographs are enlarged ca. $\times 500$, coordinates of specimens in slides refer to the stage of Censico microscope no. 13167).

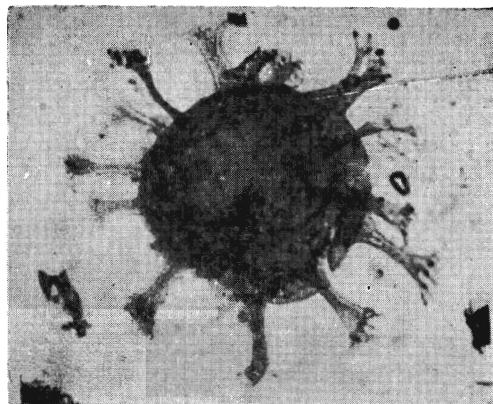
PLATE I

- 1, 2. *Polysphaeridium subtile* Davey & Williams in Davey et al., Slide no. 8369, Coordinates 62.2 \times 106.4; 55.0 \times 110.4.
- 3, 4. *Polysphaeridium* sp., Slide nos. 8370, Coordinates 46.0 \times 100.1; 8371, Coordinates 33.0 \times 104.6.
- 5, 7. *Adnatosphaeridium vittatum* Williams & Downie in Davey et al., Slide no. 8371, Coordinates 33.7 \times 98.3; 8372, Coordinates 52.2 \times 109.4.
6. *Impletosphaeridium insolitum* Eaton, Slide no. 8373, Coordinates 42.0 \times 110.5.
- 8, 9. *Membranilaracia donensis* sp. nov., Slide nos. 8374, Coordinates 61.0 \times 104.1 (Holotype); 8375, Coordinates 43.2 \times 100.8.
10. *Cordosphaeridium inodes* (Klumpp) Eisenack, Slide no. 8370, Coordinates 56.0 \times 110.3.
11. *Cordosphaeridium multispinosum* Davey & Williams in Davey et al., Slide no. 8369, Coordinates 35.6 \times 103.4.
- 12, 13, 14. *Cordosphaeridium fibrospinosum* Davey & Williams in Davey et al., Slide nos. 8369, Coordinates 53.3 \times 101.6; 8376, Coordinates 47.5 \times 110.3; 8377, Coordinates 59.4 \times 109.4.

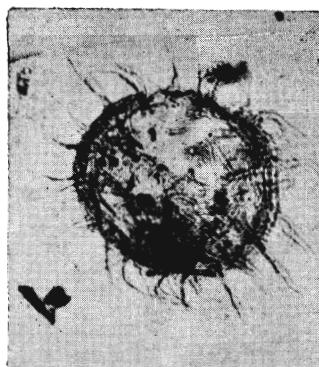
PLATE II

15. *Cordosphaeridium gracilis* (Eisenack) Davey & Williams in Davey et al., Slide no. 8377, Coordinates 34.0×110.2 .
16. *Operculodinium* sp. cf. *O. major* Jain & Dutta in Dutta & Jain, Slide no. 8378, Coordinates 60.7×105.8 .
17. *Achomosphaera ramulifera* (Deflandre) Evitt, Slide no. 8374, Coordinates 52.5×108.6 .
- 18, 19. *Achomosphaera sagena* Davey & Williams in Davey et al., Slide no. 8379. Coordinates 56.7×104.7 , 30.2×108.5 .
20. *Homotryblium floripes* (Deflandre & Cookson) Stover, Slide no. 8377, Coordinates 53.3×94.8 .
- 21, 22, 23. *Homotryblium meghalayaensis* sp. nov., Slide nos. 8370, Coordinates 30.0×101.3 , 53.3×97.8 ; 8374, Coordinates 36.1×100.8 (Holotype).
24. *Tuberculodinium varca nposz* (Rossig 191) Wallmenken. Wall & Dale, Slide no. 8375, Coordinates 61.1×110.1 .
- 25, 26. Dinocyst type 2, Slide nos. 8330, Coordinates 52.10×97.7 ; 8331, Coordinates 50.7×114.6 .
27. Dinocyst type 3, Slide no. 8121, Coordinates: 54.0×96.5
28. Dinocyst type 1, Slide no. 8382, Coordinates 62.5×110.5 .





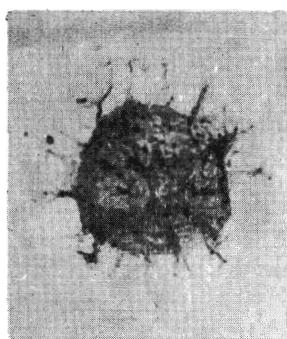
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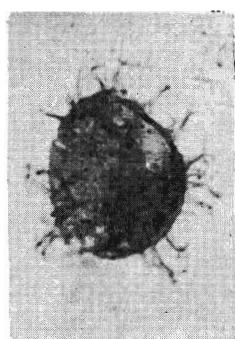
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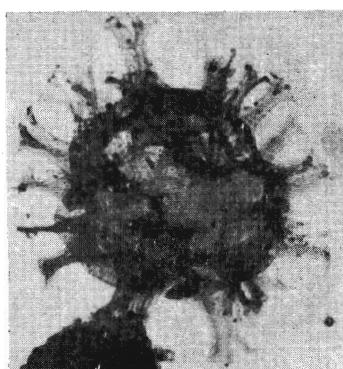
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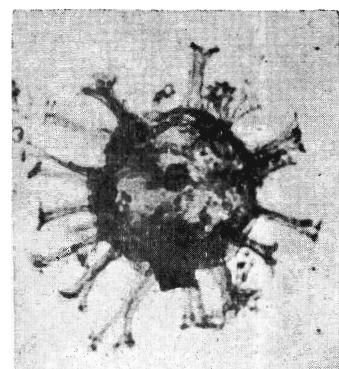
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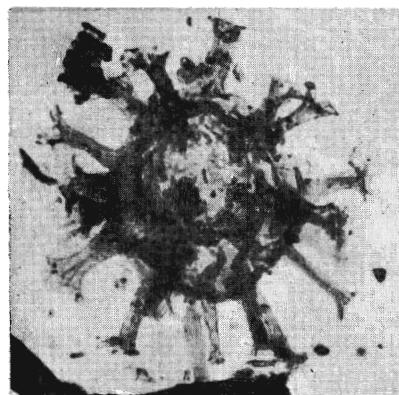
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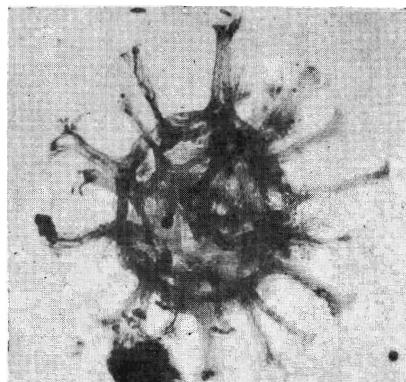
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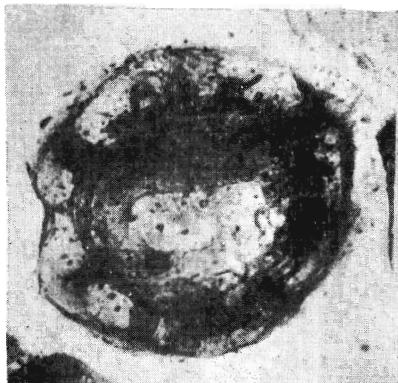
21



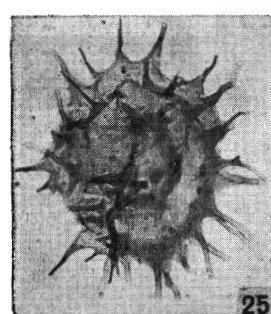
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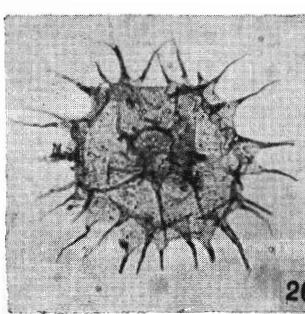
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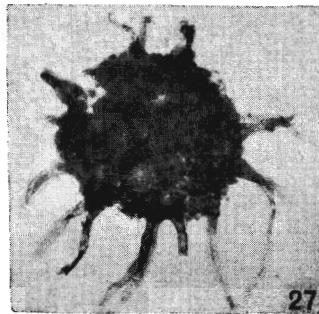
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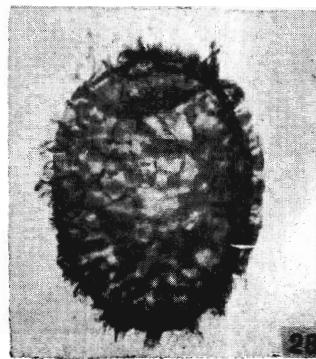
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