FOSSIL DINOFLAGELLATES ACROSS MAESTRICHTIAN-DANIAN BOUNDARY IN LOWER ASSAM, INDIA

K. P. JAIN, S. C. D. SAH & R. Y. SINGH
Birbal Sahni Institute of Palaeobotany, Lucknow, India

ABSTRACT

An analysis of palynological samples, collected from Dawki and Cherrapunji areas in Shillong Plateau, Lower Assam, have revealed the occurrence of both miospores and phytoplankton. The samples represent three different formations, viz., Jadukata, Mahadek and Langpar. Present account deals with the taxonomic study of dinoflagellates and acritarchs with a discussion on the age of these formations. Microplankton forms recovered have been described under 21 recognisible genera and 19 species. Out of these, 9 species are new.

Jadukata and Mahadek formations have been assigned an Upper Cretaceous (Maestrichtian) age whereas Langpar Formation has been dated Palaeocene (Danian).

INTRODUCTION

UPPER Cretaceous outcrops of Assam are confined to the southern foot hills of the Khasi and Jaintia hills of the Shillong Plateau. The Cretaceous sediments are developed as thin veneer throughout the outcrop area and appear to be confined between longitude 91°41′0″ E-91°45′0″E and latitude 25°13′0″N-25°24′ 0″N. Along the northern part, the basal member of the Cretaceous succession is a conglomerate, while an arkose zone seems to form the basal member towards the southern fringes. Both the conglomerate and the arkose have been found in direct contact with the underlying Sylhet Trap. At many sections, however, the arkose is seen to overlie the conglomerate and so the latter naturally forms the basalmost member of the Cretaceous succession. Field observations reveal that this conglomerate band occurs in patches and greatly varies in thickness (60′-100′). Its lateral extension can be traced in patches from east to west throughout the Shillong Plateau. The patchy distribution of this lithic unit is explained by the presence of deep undulating surface of Sylhet Trap in the Dawki region and over the Shillong Series or Archaeans in the main mass of the Shillong Plateau. The basal Cretaceous conglomerate appears identical to the one occurring below the Cherra Formation, which might have led Pascoe (1959, p. 1264) to believe that the basal conglomerate might be a time transgressive lithofacies, and hence the northern outcrops are younger than the southern. Typical sections of the basal conglomerate are found along Linghat, Shella and Kynshiang rivers. Dutta and Sah (1970, pp. 6-8) have also described two outcrops from Umstew and Umsohra rivers in the Cherrapunji Plateau. The Lynghat river section is about 16 km from Dawki on Pynursla-Punktung road. In this section the basal conglomerate is developed only south of the Raibah fault. No conglomerate outcrop occurs towards east beyond this section. Similarly, Umstew, Umsohra and Shella outcrops represent the central part of the area while Kynshiang river section limits its western extension.

The litho-stratigraphic status of the basal conglomerate has been a matter of controversy. Biswas (1972, p. 11) considers it to be a part of Mahadeo Formation, while the Assam Circle, Geological Survey of India, based on field data, are in favour of giving it an individual status of a formation. They have even proposed the name Jadukata Formation for this lithofacies (Balasundaram, 1972; p. 181). Chaterji (1972, p. 133) is of the opinion that Jadukata and Mahadek formations are parts of the Mahadek group. Recently Chakraborty and Baksi (1972) have described this rock unit under a new name "Gumaghat Formation".

This lithic unit is conformably succeeded by coarse grained, massive, glauconitic sandstones with thin fossiliferous bands of limestone. This sandstone-limestone unit is named as the Mahadek Formation. The limestone band forming the top of the formation is characterized by the abundance of *Alectryonia ungulata*. Typical exposures of the Mahadek Formation are observable regionally near Dawki (along Punktung road); Cherrapunji (around Maosmai fall, Umstew, Umsohra rivers); Mahadeo village;

Shella river; Therriaghat and at Mawsynram Plateau.

The Mahadek Formation is conformably overlain by the Langpar Formation. The latter is characterized by alternating bands of sandstones, limestones and sandy shales. The Langpar Formation is extensively well developed in Upper Prang rivulet between Lakadong and Pushinala, Boreghat-Lakadong path, Therriaghat and Hathi Bhanga sections. A black shale band has been observed continuously throughout the outcrop extent of the formation. This shale band can be conveniently used as a lithologic marker in the area. The Langpar Formation is conformably overlain by the Cherra Formation, except at the Fall section 1,023', where an angular unconformity has been observed between the Langpar and Cherra formations.

Thus, the Pre-Therria (Cherra) succession of the Shillong Plateau is lithologically divisible into the following three principle lithofacies in ascending order:

3. Langpar Formation — Sandstones, sandy shales and thin sandy limestones; average thickness of about 300 feet.
2. Mahadek Formation — Massive, coarse to medium grained sandstones (mostly glauconitic but sometimes arkosic), with thin fossiliferous limestone bands; the top limestone band remains persistent; average thickness 600 feet.
1. Jadukata Formation — Alternation of conglomerate and fine grained sandstones; average thickness 80 feet.

During the course of field season 1970-71 one of us (R.Y.S.) made an extensive collection of representative samples from basal conglomerate horizon (Jadukata Formation), Mahadek and Langpar formations of Dawki and Cherrapunji areas. Palynological fossils could be recovered from the basal conglomerate (Jadukata Formation) and Langpar Formations exposed in Dawki area. Mahadek sediments in the area remained unfossiliferous. Along the Cherra Shella road section only Mahadek and Langpar formations are developed which proved productive.

Extensive palynological investigations of the Cretaceous-Tertiary sediments of the Shillong Plateau have shown that these sediments abound in palynological fossils. Palynology of the Cherra (Therria) Formation and microplanktons from the Langpar Formation of Therriaghat have been published by Kar *et al.* (1972), Baksi (1962), Sah & Dutta, (1966) Sah *et al.* (1970), Recently, rich palynological assemblages have been recovered from the Jadukata, Mahadek and Langpar formations. The present paper includes only the microplankton assemblages from all the three lithostratigraphic units. Stratigraphic evaluation of spores and pollen grains will have to await the completion of their morphologic and taxonomic studies.

The description of the dinoflagellate taxa follows the morphographic classification proposed by Sarjeant and Downie (1966) and subsequently, revised by them (1974) to avoid the usage of prefix "cyst" in the family classification. Acritarchs have been treated according to the artificial system of classification proposed by Downie *et al.* (1963).

SYSTEMATIC PALYNOLOGY

Class — DINOPHYCEAE Pascher
Subclass — DINIFEROPHYCIDAE Bergh
Order — GYMNODINIALES Schütt
Family — DINOGYMNIACEAE Sarjeant & Downie
Genus — *Dinogymnium* Evitt, Clarke & Verdier
D. assamicum sp. nov.
D. acuminatum Evitt, Clarke & Verdier
D. vozzhennikovae (*Vozzhennikova*) Lentin & Williams
D. longicornis (Vozzhennikova) Harland
D. denticulatum (Alberti) Evitt, Clarke & Verdier
D. hyalinum (Vozzhennikova) Lentin & Williams
D. albertii Clarke & Verdier
D. digitus var. *indicus* nov.
D. sp. cf. *D. sibiricum* (Vozzhennikova) Lentin & Williams
? *D.* sp. A
D. sp. B
D. sp. C
D. sp. D
D. sp. C.
D. sp. F.
? *Dinogymnium*
Genus — *Amphidinium* Claparde & Lachmann
A. sibericum Vozzhennikova

Order — PERIDINIALES Schütt
Family — GONYAULACYSTACEAE (Sarjeant & Downie) Sarjeant & Downie
Genus — *Gonyaulacysta* Deflandre emend. Sarjeant
Gonyaulacysta sp. A.
Gonyaulacysta sp. B.
? *Gonyaulacysta* sp.
Family — APTEODINIACEAE Eisenack emend. Sarjeant & Downie
Genus — *Apteodinium* Eisenack
Apteodinium maculatum Eisenack &Cookson
Family — SPINIFERITACEAE Sarjeant emend. Sarjeant & Downie
Genus — *Achomosphaera* Evitt
Achomosphaera recurvata sp. nov.
Genus — *Hexasphaera* Clarke & Verdier
Hexasphaera sp. cf. *H. asymmetricum* (Deflandre) Clarke & Verdier
Family — DEFLANDREACEAE Eisenack emend. Sarjeant & Downie
Genus — *Deflandrea* Eisenack
Deflandrea crassistriata sp. nov.
Deflandrea sp. A
Genus — *Ceratiopsis* Vozzhennikova
Ceratiopsis leptoderma Vozzhennikova
Genus — *Palaeocystodinium* Alberti
Palaeocystodinium scabratum sp. nov.
Palaeocystodinium sp. A
Family — HEXAGONIFERACEAE Sarjeant & Downie emend. Sarjeant & Downie
Genus — *Ascodinium* Cookson & Eisenack
Ascodinium sp.
Family — PSEUDOCERATIACEAE Eisenack emend. Sarjeant & Downie
Genus — *Odontochitina* Deflandre
Odontochitina sp. A.
Odontochitina sp. B
Family — THALASSIPHORACEAE Gocht emend. Sarjeant & Downie
Genus — *Thalassiphora* Eisenack & Gocht emend. Gocht
Thalassiphora sp. A
Thalassiphora sp. B
Family — HYSTRICHOSPHAERIDIACEAE Evitt emend. Sarjeant & Downie
Genus — *Hystrichosphaeridium* Deflandre emend. Davey & Williams
? *Hystrichosphaeridium* sp.
Family — EXOCHOSPHAERIDIACEAE Sarjeant & Downie
Genus — *Lanternosphaeridium* Morgenroth
Lanternosphaeridium licium sp. nov.
Family — CORDOSPHAERIDIACEAE Sarjeant & Downie
Genus — *Cordosphaeridium* Eisenack emend. Davey
Cordosphaeridium inodes (Klumpp) Eisenack
Family — AREOLIGERACEAE Evitt emend. Sarjeant & Downie
Genus — *Cyclonephelium* Deflandre & Cookson Emend. Cookson & Eisenack
Cyclonephelium assamicum sp. nov.
Cyclonephelium sp. A
Family — MICRODINIACEAE Eisenack
Genus — *Eisenackia* Deflandre & Cookson
Eisenackia sp. A
Family — HYSTRICHODINIACEAE Deflandre
Genus — *Hystrichodinium* Deflandre
Hystrichodinium infundibulum sp. nov.
Family — UNCERTAIN
Genus — *Lejeunia* (Gerlach) Kjellström, 1972
Lejeunia sp.
Genus — *Codoniella* Cookson & Eisenack
Codoniella langparenis sp. nov.
Group — ACRITARCHA Evitt
Subgroup—PTEROMORPHITAE Downie, Evitt & Sarjeant
Genus — *Pterospermopsis* Wetzel
Pterospermopsis sp. cf. *Pt. barbarae* Górka

DESCRIPTION

Genus — *Dinogymnium* Evitt, Clarke & Verdier, 1967

Remarks — Genus *Dinogymnium* was instituted by Evitt *et al.* (1967) to include the fossil forms previously referred to the living genus *Gymnodinium* Stein. The, main argument placed to do so was that the fossils show a combination of characters without known counterpart in any living representative of *Gymnodinium*. The occurrence of an archaeopyle in the fossil forms reported by Evitt (1967) is another important criterion to describe the fossil forms under a separate genus. This scheme has also been followed here.

Dinogymnium assamicum sp. nov.

Pl. 2, figs. 28-29

Holotype — Pl. 2, fig. 28; Slide 4502-1
Type locality — Cherrapunji area, Assam, India.
Horizon — Mahadek Formation, Upper Cretaceous (Maestrichtian).
Diagnosis — Shell oblong, poles broadly rounded, sides convex, epitheca slightly longer than hypotheca. Cingulum broad, deep, circular. Hypotheca bowl shaped without longitudinal ribs. Epitheca conical, longitudinal ribs few, distantly placed, broad, with straight to undulating margin; surface granulate. Archaeopyle apical.

Measurements	*Holotype*	*Range*
Length of Shell	60 μ	50-60 μ
Width of Shell	50 μ	45-50 μ
Width of cingulum	11 μ	8-11 μ
Cingulum index	50	50-57

Comparison — *Dinogymnium assamicum* sp. nov. is mainly characterized by its bowl shaped hypotheca without longitudinal ribs or folds. This feature separates it from the other known species of the genus. *Gymnodinium* sp. A, described by Drugg (1967) from Maestrichtian of California, compares well in general shape and ill-developed longitudinal folds but differs in having punctate surface.

Dinogymnium acuminatum Evitt, Clarke & Verdier, 1967

Pl. 1, figs. 1 & 8-12

Description — Shell biconical, outline elongated, girdle almost equatorial, sulcus restricted on hypotract; longitudinal folds numerous, present both in epi- and hypothical regions running from transverse furrow to poles. Archaeopyle distinct in some specimen with operculum. Surface granulate. Wall canals not discernible. In some specimens entire shell surface remains covered with grana.

Measurements	*Range*
Shell length	42-114·5 μ
Shell width	35-52 μ
Width of Transverse furrow	6-10 μ
Cingulum index	50-55

Remarks — Assam specimens possess most of the important common features with *D. acuminatum* Evitt *et al.* (1967) except the observable presence of wall canals in some. Some specimens possess shell ornamentation all over the theca without leaving small portions at the apex and antapex. This latter feature may be considered an extent of variation.
Geologic and geographic distribution — Uhalde Formation, Panoche group, California (Maestrichtian) (Evitt *et al.* 1967); Jadukata and Mahadek formations, Assam (Present study).

Dinogymnium vozzhennikovae Lentin & Williams, 1973

Pl. 1, figs. 2-3

Synonymy

1967 — *Gymnodinium albertii* Vozzhennikova (in english translation 1971, "Fossilized peridinid algae. . ."); p. 61; pl. 5, figs. 7-8.
1973 — *Dinogymnium vozzhennikovae* Lentin & Williams, p. 70.

Description — Shell broadly elliptical, epi-and hypotheca more or less equal, apex and antapex broadly rounded; cingulum circular, wide; longitudinal folds few, running from cingulum to poles. Surface, smooth to finely granular. Archaeopyle elongate, apical.

Measurements		
	Overall Size	52×28 μ
	Cingulum width	3 μ
	Cingulum index	48

Geologic and geographic distribution — Upper Cretaceous (Turonian) *W.* Siberia (Vozzhennikova, 1967; in English Translation, 1971; p. 61); Mahadek Formation, Assam. (Present study).

Dinogymnium longicornis (Vozzhennikova) Harland, 1973

Pl. 1, figs. 5-6

Synonymy

1967 — *Gymnodinium longicornis* Vozzhennikova, (in english translation "Fossilized peridinid algae. . . . . ." 1971); p. 67; pl. 1, fig. 8; pl. 4, figs. 6a, b, c & 7.

1973 — *Dinogymnium longicornis* (Vozzhennikova) Harland; p. 678; pl. 85, figs. 2-4.

Geologic and geographic distribution — Upper Cretaceous (Senonian) *W.* Siberia. (Vozzhennikova, 1967); Upper Campanian, Canada (Harland, 1973); Jadukata Formation, Assam (Present study).

Dinogymnium denticulatum (Alberti) Evitt, Clarke & Verdier, 1967

Pl. 1, fig. 13

Synonymy

1961 — *Gymnodinium denticulatum* Alberti; p. 5; pl. 3, figs. 2-3.

1967 — *Dinogymnium denticulatum* (Alberti) Evitt, *et al.*; p. 18.

Geologic and geographic distribution — Senonian, Germany (Alberti, 1961); Upper Cretaceous, Isle of Wight, England (Clarke & Verdier, 1967). Mahadek Formation, Assam. (Present study).

Dinogymnium hyalinum (Vozzhennikova) Lentin & Williams, 1973.

Pl. 2, figs. 22-23

Synonymy

1967 — *Gymnodinium hyalinum* Vozzhennikova (in english translation, "Fossilized peridinial algae....." 1971); p. 65; pl. 1, fig. 9; pl. 2, fig. 6; pl. 3, fig. 4; pl. 5, fig. 11

Remarks — Present specimens slightly differ from *D. hyalinum* (Vozzhennikova) Lentin & Williams in having faint cingulum and larger epitheca than hypotheca. These differences may be considered to lie within the extent of variation.

Geologic and geographic distribution — Upper Cretaceous (Senonian), *W.* Siberia (Vozzhennikova, 1967); Jadukata Formation, Assam (Present study).

Dinogymnium albertii Clarke & Verdier, 1967

Pl. 2, fig. 31

Geologic and geographic distribution — Senonian of Chalk of the Isle of Wight, England (Clarke & Verdier, 1967); Jadukata Formation, Assam (Present study).

Dinogymnium digitus var. *indicus* nov.

Pl. 1, fig. 7; Pl. 2, figs. 18-19

Discription — Shell elongate, digitate, epitheca longer than hypotheca, poles rounded, longitudinal ribs few, running from transverse furrow to poles, some short, giving costate appearance. Transverse furrow faint, circular; theca surface perforate. Longitudinal furrow distinct, running both in epi- and hypothical regions. Archaeopyle apical.

Measurements	*Range*
Shell length	85-130 μ
Shell width	28-32 μ
Cingulum width	7-11 μ
Cingulum index	54-72

Comparison — Present forms possess most of the similar features like shape, size and rounded poles, common to *D. digitus* (Deflandre) E. C. & V. (1967) as originally described by Deflandre (1935, 1936). Apart from these similarities Assam forms differ in having longer epitheca than hypotheca and high cingulum index. These features are of no specific value and have been treated only as intra-specific variations. It is therefore, proposed here to describe them under a new variety.

The high cingulum index of the present forms suggests a close comparison with the Campanian forms assigned to *D. nelsonense* (Cookson) E. C. & V. by Góczán (1962). Evitt *et al.* (1967, p. 22) are of the opinion that Góczán's specimens illustrated in Pl. 1, figs. 3-4 do not belong to *D nelsonense*.

Present forms also show marked difference from *Gymnodinium digitus* Deflandre (1935) described by Vozzhennikova (1967) in having perforated than finely grannulate theca surface.

Geologic and geographic distribution of D. digitus (Deflandre) E. C. & V. Senonian of France (Deflandre, 1935), Turonian of Ayatsk Series, Kazakhstan (Vozzhennikova, 1967); Jadukata Formation, Assam (Present study).

Dinogymnium sp. cf. *D. sibiricum* (Vozzhennikova) Lentin & Williams

Pl. 2, figs. 20, 21 & 27

Synonymy

1967 — *Gymnodinium sibiricum* Vozzhennikova (in English Translation 1971, "Fossilized peridinid algae....."); p. 69; pl. 2, figs. 2, 3a-b pl. 3, fig. 2-3.

Description — Shell biconical, poles rounded; epitheca smaller or equal to hypotheca, slightly helmet shaped; cingulum broad, deep; epithecal sides convex, hypothical sides curved; longitudinal furrow not discernible; longitudinal ribs fold-like, closely to distantly placed, running from transverse furrow to poles. Surface finely granulate. Archaeopyle apical.

Measurement	*Range*
Shell length	80-120 μ
Shell width	35-45 μ
Width of transverse furrow	5-7 μ
Cingulum index	46-50

Remarks — Present specimens differ from *D. sibiricum* (Vozzhn.) Lentin & Williams (1973) in its larger size.

? *Dinogymnium* sp. A

Pl. 1, fig. 4; Pl. 6, fig. 72

Description — Shell oblong or lemon shaped, 69×46 μ in size, sides convex, cingulum not distinctly seen, epitheca pointed at apex, antapex broadly rounded; longitudinal fold in epitheca prominent converging towards apex. Hypothecal longitudinal folds not regular. Surface smooth, wall thin. Archaeopyle absent.

Remarks — Present specimens can be compared with *Gymnodinium ventriosum* Alberti (1961) in having almost similar shell shape. But differs in having smooth surface and pointed antapical tip.

The forms have been provisionally placed under the genus *Dinogymnium* due to the distinct presence of epithecal longitudinal folds, otherwise the occurrance of a pointed apex and obtusely rounded antapex suggests its placement elsewhere.

Dinogymnium sp. B

Pl. 2, fig. 26

Description — Shell elongate, 146 μ long, 24 μ broad; poles rounded. Cingulum circular, deep; longitudinal ribs raised, undulating, running from transverse furrow to pole; epitheca much longer than hypotheca. Cingulum index 64. Archaeopyle apical. Theca surface scabrate.

Remarks — A single specimen has been recorded from Jadukata Formation, Assam.

Dinogymnium sp. C

Pl. 1, fig. 14

Description — Shell outline elongate, fusiform, 171·5×16·5 μ in size, apex and antapex narrow, cingulum and archaeopyle not discernible; surface granulate, granulation prominent at extremeties. Longitudinal folds few, more on narrower side than wider.

Remarks — Only a single specimen has been recovered. Its general shape, surface ornamentation, presence of longitudinal folds suggest its placement under the genus *Dinogymnium*.

Dinogymnium sp. D

Pl. 2, fig. 17

Description — Shell elongate, epitheca and hypotheca almost equal in size. Transverse furrow distinct, broad, poles flattened or rounded; longitudinal folds few, running from transverse furrow to poles, some short, margins undulating or dentate. Surface granular all round, grana arranged in linear lines. Archaeopyle elongate, operculum attached.

Remarks — Mahadek specimen suggests its best comparison with *D. denticulatum* (Alberti) E. C. & V. (1967) in having almost heterocostate dentate longitudinal folds, but differs in the distribution of ornamentation throughout the theca surface. It also differs from *D. microgranulosum* Clarke Verdier (1967) in having undulating ribs.

Dinogymnium sp. E

Pl. 2, fig. 25

Description — Shell elongate, broader near cingulum, epitheca broader and shorter than hypotheca, poles acutely pointed; cingulum faintly developed, narrow; epitheca broad, margin undulating, folds numerous, some running from transverse furrow to poles, others short. Hypotheca broader near cingulum, narrower towards antapex, longitudinal folds extend only half of hypothecal length along broader zone. Surface granular. Longitudinal furrow distinct, broader near cingulum, extending more in hypotheca. Archaeopyle not seen.

Measurements		
	Shell length	200 μ
	Shell width	40 μ
	Cingulum index	46

Remarks — Only a single specimen has been recovered from Jadukata Formation, Assam.

Dinogymnium sp. F

Pl. 2, fig. 24

Description — Shell incomplete, measuring about 220 μ in length and 70 μ in width; longitudinal folds running from pole to transverse furrow. Cingulum indistinct; epitheca and hypotheca ± equal; longitudinal furrow broad; surface perforate. Archaeopyle not seen.

Remarks — Only a single specimen of this size and shape has been recovered from Jadukata Formation, Assam.

? *Dinogymnium*

Pl. 2, fig. 30

Description — Shell elliptical, sides convex, poles acute, divided into epi-and hypotract by circular cingulum formed due to fold, longitudinal folds 3-7 near cingulum, no archaeopyle seen. Surface smooth to finely structured.

Genus — *Amphidinium* Claparde & Lachmann, 1958

Amphidinium sibericum Vozzhennikova, 1963

Pl. 1, figs. 15-16

Geologic and geographic distribution — Upper Cretaceous (Senonian), *W.* Siberia (Vozzhennikova, 1967); Jadukata Formation, Assam (Present study).

Genus — *Gonyaulacysta* Deflandre emend. Sarjeant, 1968

Gonyaulacysta sp. A

Pl. 3, figs. 40, 41

Description — Shell oval, thin walled, 70×50 μ in size, apical horn short, blunt; tabulation indistinct; longitudinal furrow not discernible; plate surface granular. Archaeopyle precingular.

Remarks — Present forms recovered from Jadukata Formation samples show some comparision with *Gonyaulacysta ambigua* Deflandre (in Vozzhennikova, 1967, in english translation 1971, pl. 25, fig. 3a-b).

Gonyaulacysta sp. B

Pl. 3, fig. 48

Description — Shell oval, thin walled, 80×60 μ in size, horn short, 6 μ in height; plates distinctly seen, surface finely granular, sutures spiny. Specimen badly preserved; epitheca and hypotheca ± equal in size. Girdle prominent, circular, 5 μ broad. No antapical horns. Archaeopyle precingular.

? *Gonyaulacysta* sp.

Pl. 3, fig. 47

Description — Shell thin walled, 75 × 65 μ in size, sides convex, apical horn well developed. Antapical horns widely separate, short, marked by notching at base of hypotheca. Girdle 6 μ broad, much broader in middle; epi- and hypotheca ± equal in size. Tabulation present, not clearly defined, surface ornamentated with grana and coni. Archaeopyle not discernible.

Genus — *Apteodinium* Eisenack, 1958

Apteodinium maculatum Eisenack & Cookson 1960

Pl. 3, figs. 42-44

Description — Shell ± spherical to globular, apical horn well developed, short, 1/9 of whole shell length, both peri- and endophragm used in forming apical horn; epitract and hypotract ± equal; girdle distinct, circular, extending slightly laterally. Hypotract obtusely rounded. Periphragm smooth to slightly granulate. Slight indication of tabulation present. Archaeopyle precingnlar. Wall thin. Groups of thickened areas with circular outline present.

Measurements	*Range*
Shell length	55-75 μ
Shell width	50-65 μ
Apical horn length	6-10 μ
Cingulum width	4-6 μ

Remarks — Present forms bring down the size range of this species from 74 to 55 μ in length and 70 to 50 μ in width.

Geologic and geographic distribution — Albian of South Australia Cookson &

(Eisenack 1960); Jadukata Formation (Upper Cretaceous), Assam, (Present study).

Genus – *Achomosphaera* Evitt, 1963

Achomosphaera recurvatum sp. nov.

Pl. 3, figs. 36, 37 39

Holotype — Pl. 3, fig. 36; Slide No.: 4495-7.

Type Locality — Dawki area, Assam, India.

Horizon — Jadukata Formation, Upper Cretaceous (Maestrichtian).

Diagnosis — Cyst spherical to oblong, wall moderately thick endophragm and periphragm in close contact, surface ornament perforate. Processes thin, long, hollow, bases broad, in close contact with test wall layers, termination acuminate and recurved; sometimes processes branched. Archaeopyle precingular.

Measurements	*Holotype*	*Range*
Cyst size	50×40 μ	40-60×38-50 μ
Length of processes	14 μ	12-20 μ

Comparison — *Achomosphaera recurvatum* sp. nov. is mainly characterized by its perforate outer surface and two types of process terminations (acuminate and recurved). The process termination features of *A. recurvatum* distinguish it from other known species of the genus.

Genus – *Hexasphaera* Clarke & Verdier, 1967

Hexasphaera sp. cf. *H. asymmetricum* Clarke & Verdier, 1967

Pl. 3, figs. 32-34 & 38

Description — Cyst spherical to ovoid with typical generic tabulation; archaeopyle apical; processes distinctly of two types, one series having large, broad, recurved processes while second series having only slender, bi-or trifurcate, solid processes, a ledge connects each process. Surface (periphragm) punctate.

Comparison — The present forms compare closest with the genotype *H. asymmetricum* (Defl.) Clarke & Verdier (1967) in having similar size, shape and ornamentation. It differs only in not having very broad cingular processes.

Genus – *Ceratiopsis* Vozzhennikova, 1963

Ceratiopsis leptoderma Vozzhennikova, 1963

Pl. 4, fig. 49; Pl. 6, fig. 67

Description — Cyst strongly elongate, capsule rounded to oblong, smooth, completely filling pericoel, periphragm thin, delicate, extending towards poles forming a long apical horn and two antapical horns. Transverse furrow faint or indistinct, surface smooth to micro-punctate. Archaeopyle intercalary, trapizoidal, some times operculum remains attached.

Measurements		
	Shell length	115-140 μ
	Shell width	55-65 μ
	Capsule size	60-70×60-75 μ
	Apical horn length	20-40 μ

Remarks — Assam specimens described from Langpar Formation of Dawki and Cherrapunji areas under *Ceratiopsis leptoderma* Vozzhennikova (1967) show almost similar morphologic features described by Vozzhennikova, specially in its elongate capsule.

Geologic and geographic distribution — Palaeocene of W. Siberia (Vozzhennikova, 1967, in english translation "Fossilized peridinian algae....." 1971); Langpar Formation Assam, India (present study).

Genus – *Deflandrea* Eisenack, 1938

Deflandrea crassistriata sp. nov.

Pl. 6, figs. 64-65

Holotype — Pl. 6, fig. 65; Slide no. 4517-4.

Type locality — Dawki area, Assam, India.

Horizon — Langpar Formation, Lower Palaeocene (Danian).

Diagnosis — Shell ovoidal, two layered; periphragm thin, granulate, grana arranged in longitudinal rows forming narrow ridges; forming a broad and tapering apical and two antapical horns. Endophragm moderately thick, ornamented with broad longitudinally thickened strips, each strip followed by a narrow thin, unornamented zone. Capsule rounded to oblong, nearly as big as pericoel, periphragm and endophragm remain in close contact, apically giving a bicavate appearance to cyst. Archaeopyle intercalary, below apical horn.

Measurements	*Holotype*	*Range*
Cyst length	90 μ	90-110 μ
Cyst width	75 μ	75-90 μ
Capsule size	55×75 μ	55-70×75-90 μ

Comparison — *Deflandrea striata* Drugg (1967) comes nearest to *D. crassistriata* sp. nov. in having similar cyst shape, size and periphragm ornamentation. Present species is distinguished from *D. striata* in having broad strips of endophragm and having grana arranged parallel to longitudinal axis of the test.

Deflandrea sp. A

Pl. 4, fig. 50

Description — Shell spherical, two layered, outer periphragm smooth, very thin and delicate, extending apically forming an apical horn and antapically extending in broad expansion giving an impression of two horns. Endophragm thick, dark brown in colour, granulate. Girdle indistinct. Archaeopyle intercalary, faintly visible.

Remarks — General shape of the shell and presence of intercalary archaeopyle suggests its placement under the genus *Deflandrea*.

Genus — *Ascodinium* Cookson & Eisenack, 1960

Ascodinium sp.

Pl. 6, fig. 70

Description — Shell flat, oval in outline, no apical or antapical horns and girdle; capsule distinct, ovoidal; periphragm smooth, extending 4-8 μ beyond the capsule margin. Archaeopyle apical.

Measurements		
	Overall shell diameter	52 μ
	Capsule diameter	44 μ
	Periphragm extension	4-8 μ

Remarks — Only a few specimens have been recorded from Jadukata Formation samples.

Genus — *Odontochitina* Deflandre, 1935

Odontochitina sp. A

Pl. 7, figs. 75, 76

Description — Body rectangular, broader than high; microgranulate. Apical horn moderately high, pointed, broad, perforated along margins, distinct striations or ridges seen running from apex to base. Antapical horns two, almost equal in length, tapering; surface perforated in between striations, longitudinal ridges or striations on antapical horns distinct.

Measurements		
	Body	80×60 μ
	Apical horn size	60×20 μ
	Antapical horn	76×16 μ

Remarks — Present specimens of *Odontochitina* show their closest resemblance to *O. striatoperforata* Cookson & Eisenack (1962a) but differ in having rectangular body and absence of endophragm projection into the base of the horn.

***Odontochitina* sp. B.**

Pl. 7, fig. 74

Description — Shell incomplete, showing an apical archaeopyle and two well developed antapical horns, antapical horns unequal in size, pointed, with no perforations. Body indistinct. Surface microgranulate.

Measurements		
	Overall size	150×90 μ
	Size of Ist antapical horn	100×30 μ
	Size of IInd antapical horn	80×25 μ

Genus — *Thalassiphora* Eisenack & Gocht, 1960

Thalassiphora sp. A

Pl. 7, fig. 78

Description — Shell spherical to ovoid, dark brown in colour, thick walled, double layered, outer layer extending out to form wing-like structure all round; wing folded, surface perforate. Archaeopyle precingular.

Measurements		
	Shell diameter	75 μ
	Overall diameter	140 μ
	Wing extension	30-40 μ

Remarks — Single specimen has been recovered from Langpar Formation of Cherrapunji area.

Thalassiphora sp. B

Pl. 6, fig. 71

Description — Shell spherical, 50 μ in diameter, double layered, outer layer extends outside forming a wing-like structure alround, wing only 10 μ wide, thin, smooth to scabrate. Archaeopyle precingular.

Remarks — Only a single specimen has been recovered from Mahadek Formation, Assam.

Genus — *Hystrichosphaeridium* Deflandre, 1937 emend. Davey & Williams, 1966

? *Hystrichosphaeridium* sp.

Pl. 6, fig. 68

Description — Cyst ovoidal to spheroidal, 75 μ in diameter; double layered; reflected tabulation indeterminable; processes mostly on one side, nearly 30 or slightly more, spongy, distally closed; outer surface granular. Archaeopyle apical.

Remarks — These forms have been recorded from Langpar Formation of Cherrapunji area. Due to the presence of processes on one side of the cyst it is doubtfully placed under the genus *Hystrichosphaeridium*. The present forms compare well with *Hystrichosphaeridium assamicum* Sah *et al.* (1970) described from Langpar Formation of Therriaghat, South Shillong plateau, Assam.

Genus — *Lanternosphaeridium* Morgenroth, 1966

Lanternosphaeridium licium sp. nov.

Pl. 4, figs. 51-53

Holotype — Pl. 4, fig. 51; Slide No. 4522-1.

Type locality — Cherrapunji area, Assam, India.

Horizon — Langpar Formation, Lower Palaeocene (Danian).

Diagnosis — Cyst ellipsoidal to ovoid, broadly convex, bilaterally symmetrical, chorate, endophragm smooth; periphragm ornamented with long, thread like or broad fiberous processes arranged all over, closed both distally and proximally. Surface coarsely granulate; process size and distribution irregular, apex truncate to pointed or bifid; periphragm extending apically and antapically forming single apical and antapical horn, part of endophragm extends into horns. Cingulum region discernible only due to densely arranged processes and occasional folds. Archaeopyle more or less rectangular, precingular, broad.

Measurements	*Holotype*	*Range*
Cyst size (including processes)	130×90 μ	90-130 × 80-90 μ
Apical horn length	20 μ	20-25 μ
Antapical horn length	20 μ	20-25 μ
Wall thickness	1.5-2 μ	1.5-2 μ
Length of processes	10-30 μ	10-30 μ

Comparison — Present forms show close resemblance with *Palmnickia* Eisenack (1954) and *Lanternosphaeridium* Morgenroth (1966) in having ellipsoid to avoid cyst outline, apical and antapical horns, a precingular archaeopyle and ornamented periphragm with processes. With these common characters it is difficult to separate them from each other. Recently Drugg (1967, p. 30, pl. 9, fig. 8a-b) has shown that *Palmnickia* probably has tabulation. Where as *Lanternosphaeridium* has irregularly arranged processes (Drugg, 1970, p. 812-813), similar to our Assam forms.

Lanternosphaeridium licium sp. nov. compares best with *L. lappaceum* Drugg (1970) in most of its morphological features but differs in having long, thread like processes. *L. licium* sp. nov. also shows close affinities with the Australian Palaeocene species *L. bipolare* (Cookson & Eisenack) Gocht (1969) in having granular periphragm. But the latter differs in its fewer appendages.

Derivation of specific name — After Latin word *licium* means thread like.

Genus — *Cordosphaeridium* Eisenack, 1963

Cordosphaeridium inodes (Klumpp) Eisenack, 1963

Pl. 5, figs. 59, 60; Pl. 4, fig. 55

Geologic and geographic distribution — Danian, Upper Moreno Formation (Drugg 1967); Eocene (Klumpp, 1953); Carnnonball member, Fort Union Formation (Palaeocene) of New South Dakota (Stanley, 1965); Langpar Formation, Assam, India (Present study).

Genus — *Cyclonephelium* (Deflandre & Cookson) Cookson & Eisenack, 1962

Cyclonephelium assamicum sp. nov.

Pl. 5, figs. 61, 62; Pl. 6, fig. 73

Holotype — Pl. 5, fig. 61; Slide no. 4523-2.
Type locality — Dawki area, Assam, India.

Horizon — Langpar Formation, Lower Palaeocene (Danian).

Diagnosis — Shell flat, more or less spherical, one pole (apical) mostly detached forming apical archaeopyle; surface ornamented with fibrous processes (6-10) along periphery or equator only, processes broad, spongy, proximally narrow, distally open, expanded and branched, interconnected by thin membrane, giving an appearance of thin flange around shell. Shell surface finely granular.

Measurements	*Holotype*	*Range*
Overall shell diameter	160 μ	130-160 μ
Body size	76×52 μ	75-100×50-80 μ

Comparison — *Cyclonephelium assamicum* sp. nov compares well with *C. membraniphorum* Cookson & Eisenack (1963) in its general shape and appearance but differs mainly in having thin and broad radial processes without tangentially connected bases. Other species of the genus viz., *C. vitilare* Cookson (1965); *C. distinctum* Deflandre & Cookson (1955) and others can be distinguished by its characteristic thin wing-like membrane connecting the radial processes having spongeous appearance.

Geologic and geographic distribution — Genus *Cyclonephelium* (Deflandre & Cookson) Cookson & Eisenack is known to occur from Jurassic to Oligocene. (See Cookson & Eisenack, 1960, 1962; Deflandre & Cookson, 1955; Gerlach 1961; Stanley, 1965)

Cyclonephelium sp. A

Pl. 6, fig. 69

Description — Shell ± spherical, apical pole detached forming apical archaeopyle, equatorial ornamentation characterized by extension of wing around shell except apex. Wing supported by a few solid processes. Surface perforate.

Remarks — Single specimen has been recorded from Langpar Formation, Assam.

Genus — *Eisenackia* Deflandre & Cookson, 1955

Eisenackia sp. A

Pl. 7, fig. 79

Description — Cyst thick walled, spherical, compressed, both epi- and hypotheca equal. Longitudinal furrow not seen. Tabulation typical of genus (3′6″5g, 6‴, 2p, 1‴). Plates pentagonal or polygonal, plate surface and space between girdle and plates ornamented with small meshes. *Measurements* — Theca diameter 48 μ.

Remarks — Only a single specimen has been recorded from the Langpar Formation sample collected from Dawki area.

Geologic and geographic distribution — Genus *Eisenackia* is an important Palaeocene-Eocene form. It has been reported from Danian, Califormia, USA (Drugg, 1967); Lower Eocene? South Chile (Cookson & Cranwell, 1967) and Danian? Northern Natal, South Africa (Davey, 1969).

Genus — *Hystrichodinium* Deflandre, 1935 emend. Clarke & Verdier, 1967

Hystrichodinium infundibulum sp. nov.
Pl. 3, fig. 35

Holotype — Pl. 3, fig. 35; Slide No. 4496-14.
Type locality — Dawki area, Assam, India.
Horizon — Jadukata Formation, Upper Cretaceous (Maestrichtian).

Diagnosis — Cyst ovoidal, girdle indistinct to sometimes distinct, epi- and hypotheca ± equal in size, with rounded apex; surface ornamented with hollow processes, mostly arranged at poles and long transverse girdle margin. Apical processes conical, blunt or bifid; antapical processes infundibular with recurved or blunt terminations. Surface of processes granular. Archaeopyle precingular; tabulation indistinct.

Measurements	*Holotype*	*Range*
Shell size (excluding processes	40×50 μ	40-50 ×50-65 μ
Length of processes	14-20 μ	14-20 μ
Width of cingulum	4-6 μ	4-6 μ

Comparison — *H. infundibulum* sp. nov. differs from *H. pulchrum* Defl. (1935) and *H. dasys* Davey (1969) and other species of the genus in having mixed type of processes and granular outer surface.

Genus — *Lejeunia* (Gerlach,) Kjellström, 1972

Lejeunia sp.

Pl. 6, fig. 66

Description — Cyst pentagonal, capsule absent, transverse furrow deep, circular, dividing theca into almost two equal parts, epitheca triangular with short blunt apical horn. Hypotheca flattened with two antapical horns having nipple like ends. Archaeopyle broadly triangular, precingular. Surface smooth, thin with irregular folds on both epi- and hypotract.

Measurements	Cyst length	62 μ
	Cyst width	82 μ

Remarks — Present specimen from Langpar Formation, Assam, resembles best with *Lejeunia* sp. described from Maestrichtian-Danian of Upper Moreno Formation of California by Drugg (1967, p. 14; pl. 1, fig. 16). Presence of a precingular archaeopyle creates doubt to place it under *Lejeunia* though in *L. hyalina* Gerlach (1961) an archaeopyle is reported. Only a single specimen has been recovered, its taxonomic status will be taken up with accummulation of more data.

Genus — *Codoniella* Cookson & Eisenack, 1961

Generic Remarks — Cookson & Eisenack (1960, p. 11) instituted the genus *Codonia* to accommodate microplankton having spherical to oval shell, with two opposite hollow, equatorial projections open to exterior, the delicate membrane of which is supported by fibrous loops. Since the generic name *Codonia* was preoccupied, therefore, Cookson & Eisenack (1961a, p. 75) proposed the substitute name *Codoniella*.

Our recent study of Langpar (Assam) microplankton has revealed a good representation of well preserved forms of the genus *Codoniella*. They possess spherical to oval shell, with two opposite, hollow, equatorial projections open to exterior. In addition to these similar generic features, they are also characterized by an apical and an antapical projection or horns which may be short and broad or long and narrow, the shell distinctly shows the presence of a broad archaeopyle below the apex. The position of archaeopyle appears to be combined precingular (?), made up of more than one plate.

Affinity — Presence of an apical and an antapical horn with a distinct archaeopyle and its general appearance suggest its affinity with dinoflagellates. Its familial assignment remains doubtful due to uncertain archaeopyle position.

Codoniella langparensis sp. nov.

Pl. 5, figs. 57, 58; Pl. 4, fig. 56

Holotype — Pl. 5, fig. 58 ; Slide No. 4516-2.

Type Locality — Dawki area, Assam, India.

Horizon — Langpar Formation, Lower Palaeocene (Danian).

Diagnosis — Shell spherical to oval, symmetrical, thin, extending apically and antapically to form single apical and antapical horn. Horns short and broad or long and narrow. Equatorial projections distally connected with thin delicate membrane giving an appearance of wings. Transverse and longitudinal furrows not discernible. Archaeopyle distinct, broad, combined precingular (?). Shell surface scabrate.

Measurement	*Holotype*	*Range*
Shell length	110 μ	80-110 μ
Shell width	120 μ	115-120 μ
Body diameter	80 μ	75-85 μ

Comparison — *Codoniella langparensis* sp. nov. differs from *C. campanulata* Cookson & Eisenack (1960) in having an apical, an antapical horn and a distinct archaeopyle. ? *Cannosphaeropsis* sp. described by Wilson (1971, p.; pl. 3, fig. 10) from the Upper Maestrichtian to Lower Danian of Holland and Belgium, comes very near to *C. langparensis* sp. nov.

Genus — *Palaeocystodinium* Alberti, 1961

Palaeocystodinium scabratum sp. nov.

Pl. 6, fig. 63

Holotype — Pl. 6, fig. 63; Slide No. 4510-4.

Type Locality — Dawki area, Assam, India.

Horizon — Langpar Formation, Lower Palaeocene (Danian).

Diagnosis — Shell spindle shaped, dorsoventrally flattened. Appendages two, one on each end. Single apical and antapical horns taper at ends. Periphragm scabrate; inner body ellipsoidal, in contact with periphragm, smooth, granular along the pericoel area. Archaeopyle intercalary, trapezoidal, below apical horn.

Measurements	*Holotype*	*Range*
Shell length	144 μ	120-155 μ
Shell width	58.5 μ	58.6-70 μ
Apical horn length	40 μ	25-40 μ
Antapical horn length	26 μ	20-30 μ
Capsule Size	78×58.5 μ	75-100×60-70 μ

Comparison — *Palaeocystodinium scabratum* sp. nov. shows its closest resemblance with *P. benjaminii* Drugg (1967) but differs in not having fine hairs or processes on the horns and having granular endophragm along the pericoel areas. The latter feature suggests an affinity with the genus *Senegalinium* Jain & Millepied (1973).

Palaeocystodinium sp. A

Pl. 4, fig. 54

Description — Shell spindle shaped, thin walled, double layered, smooth; appendages short, one on each pole; endophragm in contact with periphragm, thicker and pointed along pericoel areas. Archaeopyle intercalary, below apical horn. No girdle observed.

Measurements		
	Shell Size	150×65 μ
	Horn size	20×20 μ

Remarks — Present fossil has been placed under the genus *Palaeocystodinium* because it possesses similar general shape of the shell, distinct inner body and an archaeopyle below the horn.

Genus — *Pterospermopsis* Wetzel, 1952

Pterospermopsis sp. cf. *barbarae* Górka, 1963

Pl. 7, fig. 77

Description — Shell spheroidal to ovoid, thick walled, depressed on one side; surrounded by thin broad, irregularly folded wing; wing microstructured.

Measurements		
	Overall shell diameter	120 μ
	Shell diameter	74 μ
	Equatorial wing width	30-40 μ

Remarks — Only a few specimens have been recorded from Langpar Formation of Cherrapunji area. It differs from *P. barbarae* Górka (1963) in having distinct microstructure on the wing surface.

Incertae-sedis

Forma A.

Pl. 7, fig. 80

Description — Shell oblong in shape, double layered, inner wall remains in contact with outer, no apical or antapical appendages seen. Epitheca and hypotheca ± equal, not marked by a girdle but a prominent transverse fold. Surface granular, grana irregular in size. Archaeopyle large, oval, appears to be at intercalary plate position. No tabulation discernible.

Remarks — Single specimen has been recovered from Mahadek Formation. It shows marked similarity with *Nilsoniella aceras* Cookson & Eisenack (1960) in having broad pylome and shape of the shell. The presence of broad fold in the middle of the shell only divides it in equal halves but true capsule filling the hypotheca is not distinctly seen.

Forma B.

Pl. 3, fig. 45

Description — Shell 90×60 μ in size ± pentagonal, transverse furrow not clearly seen. Surface smooth; apical horn 37×7 μ in size, antapical horns two, short. Archaeopyle absent.

Remarks — Only a single specimen has been recorded from Jadukata Formation.

Forma C.

Pl. 3, fig. 46

Description — Shell bell shaped, 78×70 μ in size, epitheca pointed with short, pointed apical horn; hypotheca narrower, broadly rounded, no antapical horns.

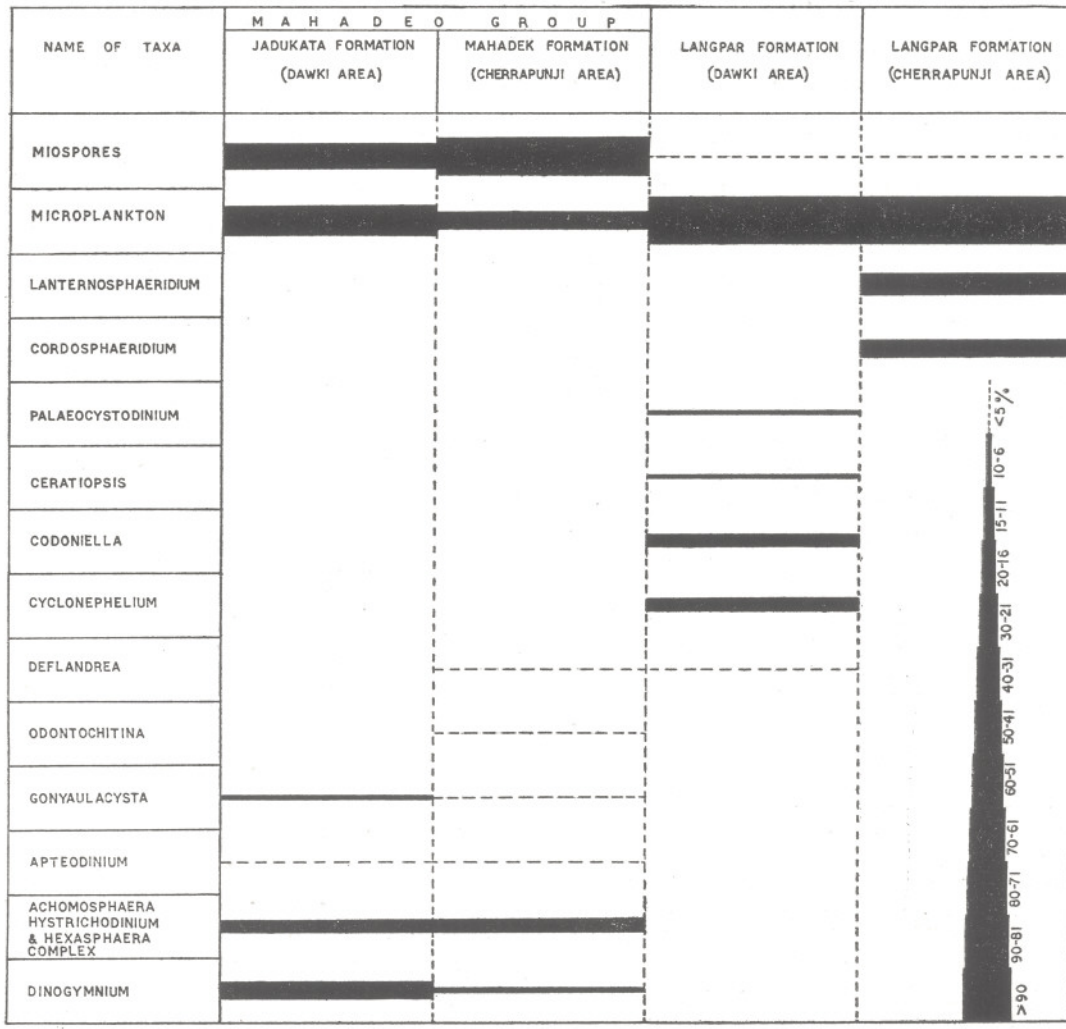
Transverse furrow distinct, helicoid. Longitudinal furrow present, shell surface granular; tabulation discernible; archaeopyle not seen.

Remarks — Only a single specimen has been recorded from Jadukata Formation.

Discussion — Palynological studies of the samples collected from Jadukata, Mahadek and Langpar formations of South Shillong Plateau reveal that the microplankton elements dominate in the two of the three above named formations. Although the miospore frequency in the Mahadek Formation is more than the microplankton yet the latter are represented in fairly good numbers. The microplankton assemblages are mainly represented by dinoflagellates but acritarchs are also not negligible. The frequency break up of important taxa is given below and is reproduced in Table 1.

The Jadukata miofloral assemblage has an evenly distributed representation of miospores and dinoflagellates (45% and 55% respectively). The miospore elements are dominated by megaspores referable to *Ariadnaesporites*. These are characterized by long thread-like processes on the

TABLE 1 — STRATIGRAPHIC DISTRIBUTION OF SIGNIFICANT DINOFLAGELLATE TAXA ACROSS MAHADEK AND LANGPAR BOUNDARY



distal side. The significant dinoflagellate genera met with are *Dinogymnium* (25%), *Achomosphaera-Hystrichodinium-Hexasphaera* (15%) and *Gonyaulacysta* (6%). The same floral constituents, though less in frequency, pass upwards on to the overlying Mahadek Formation with the exception of *Gonyaulacysta*. The latter can also be marked by the first appearance of *Odontochitina*. The miospore-microplankton percentage relationship changes to 75% and 25% respectively.

The third and the youngest formation which conformably overlies the Mahadek Formation is the Langpar. The miofloral assemblage of this formation provides an altogether different picture. The microplankton flora dominates over the miospore (95% & 5% respectively). Two Langpar floral assemblages have been recovered from Dawki and Cherrapunji areas. The significant dinoflagellate taxa recovered from Dawki Langpar assemblage are *Codoniella* (18%), *Ceratiopsis* (10%), *Deflandrea* (4%), *Palaeocystodinium* (10%), *Cordosphaeridium* (6%), *Cyclonephelium* (19%) and the reworked *Liofusa* type (20%). The Cherrapunji Langpar is characterized by the presence of only two dominant genera *Lanternosphaeridium* (60%) and *Cordosphaeridium* (30%) with some reworked striate bisaccate pollen grains of late Palaeozoic age.

From the above comparative analysis it is evident that the Jadukata and Mahadek assemblages are more or less similar in dinoflagellate constituents. The genus *Dinogymnium* alongwith the megaspore genus *Ariadinaesporites* remains the dominant element in both the microfloras whereas these two are totally absent in the Langpar microflora.

The Langpar microfloral assemblage can also be differentiated from the underlying Mahadek assemblage in having elements like *Codoniella, Ceratiopsis, Cyclonophelium, Lanternosphaeridium* and *Palaeocystodinium*. These constituents seem to appear for the first time in the Langpar Formation when traced in the present sequence.

Age of the assemblages — The age equivalence of the Mahadek Formation has been mainly based on smaller formainifera recovered from this stratigraphic unit exposed at other places except the type locality. Nagappa (1959) recorded the occurrence of *Gumbelina plummerae, Orbitolites* sp., *Pseudotextularia* sp. and *Ciderolites calcitrapoides* from the top bed of the formation and ascribed it a Maestrichtian age. Biswas (1962, p. 18) reported *Pyrina ataxensis* along with other forms and concluded a Campanian-Maestrichtian age.

The present investigation shows the dominance of Upper Cretaceous genus *Dinogymnium* which has its greatest abundance, both qualitative and quantitative, in Campanian and Maestrichtian. Evitt *et al.* (1957, p. 5) are of the opinion that no species of the genus has been recorded from Lower Cretaceous or older strata. They also restrict the species of the genus to Upper Cretaceous. Vozzhennikova (1967, in English translation, 1971) has shown that the genus *Dinogymnium* (*Gymnodinium*) occurs only in Upper Cretaceous. Jain & Millepied (MS) while studying the subsurface palynology of Senegal Basin, N. W. Africa, (ranging from Aptian to Maestrichtian) have also noted the dominance of *Dinogymnium* in Campanian-Maestrichtian levels.

The presence of *Dinogymnium acuminatum* Evitt *et al.* in both Jadukata and Mahadek formations is indicative of an Upper Cretaceous (Maestrichtian) age. So far, this species is known only from the Maestrichtian levels of California and Alabama (Evitt *et al.* 1967) and Senegal Basin, N. W. Africa (Jain & Millepied, MS). The other known species recorded from Mahadek and Jadukata formations are viz., *D. hyalinum, D. albertii, D. vozzhennikovae, D. longicornis* and *D. denticulatum*. All these species are described from the Senonian sediments of U.S.S.R., France, England and Germany.

The Langpar Formation conformably overlies the Mahadek and is consequently younger in age. The limestone member of the Langpar Formation has yielded, typical Danian foraminifera-like *Globigerina pseudobulloides* and *G. triloculinoides* (Nagappa, 1959, p. 163) and ammonites like *Nautilus danicus*. The Langpar dinoflagellate microflora, is characterized by the total absence of *Dinogymnium*, conforms to this dating. Moreover, the present assemblage also shows closest comparison to the Danian assemblage of Upper Moreno Formation of California described by Drugg, (1967) in having common genera like *Eisenackia, Deflandrea, Lejeunia, Cyclonephelium, Palaeocystodinium* and *Lanternosphaeridium* (similar to *Palmnickia*). The

Langpar microplankton assemblage is also closely comparable to other Palaeocene assemblages described by Deflandre and Cookson (1955), Alberti (1961), Stanley (1965), Cookson and Eisenack (1967), Drugg (1967), Vozzhennikova (1967, translation 1971) and Cookson and Eisenack (1967), indicating a closer affinity of the present assemblage with the Lower Palaeocene rather than Upper Cretaceous miofloras. The occurrence of *Eisenackia* and *Lanternosphaeridium* together with *Ceratiopsis leptoderma* Vozzh. (1967), *Cordosphaeridium inodes* (Klumpp) Eisenack and the absence of *Wetzeliella* also favours a Lower Palaeocene (Danian) dating for the Langpar Formation, though Stanley (1965) has reported some species of *Wetzeliella* from the Palaeocene of northwestern South Dakota, but these species need taxonomic confirmation till then their value in dating becomes limited.

It is thus evident that in the Shillong Plateau sharp changes in the nature and distribution of the dinoflagellate population took place across the Mahadek (Maestrichtian)-Langpar (Danian) boundary. The stratigraphically significant changes can be marked by the decline and disappearance of important Maestrichtian taxa at the top of the Mahadek Formation together with the first appearance of new forms at the basal levels of the Langpar Formation. There are a few long ranging forms which extend into the Langpar but their frequency sharply decreases. Faunal evidence also shows sharp changes across this boundary. The lithological contact between the Mahadek and the overlying Langpar is conformable and so lithology does not provide any evidence indicating corresponding sharp changes in the depositional evnironment. However, field evidences in the outcrop area suggest that the Mahadek strata were deposited in highly shelving shores of a transgressing sea while the Langpar rocks were probably deposited in a slowly sinking basin under an open marine condition. These shoreline changes were sufficient to bring about changes in depth, salinity and temperatures which in turn might have been the principal factors responsible for the change in the dinoflagellate population.

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EXPLANATION OF PLATES

(All microphotographs are enlarged ca. × 500)

PLATE 1

1. *Dinogymnium acuminatum* Evitt, Clarke & Verdier; Slide No. 4500-7.

2-3. *Dinogymnium vozzhennikovae* Lentin & Williams; Slide No. 4503-2 & 4506-3.

4. ? *Dinogymnium* sp. A; Slide No. 4505-4.

5-6. *Dinogymnium longicornis* (Vozzhennikova) Harland; Slide Nos. 4504-1 & 4506-4.

7. *Dinogymnium digitus* var. *indicus* nov.; Slide No. 4488-1.

8-12. *Dinogymnium acuminatum* Evitt, Clarke & Verdier; Slide Nos. 4497-1; 4505-3; 4499-4; 4500-3; 4509-1.

13. *Dinogymnium denticulatum* (Alberti) Evitt, Clarke & Verdier; Slide No. 4508-2.

14. *Dinogymnium* sp. C; Slide No. 4493-11.

15-16. *Amphidinium sibericum* Vozzhennikova; Slide Nos. 4493-3 & 4521-5.

PLATE 2

17. *Dinogymnium* sp. D; Slide No. 4522-1.

18-19. *Dinogymnium digitus* var. *indicus* nov.; Slide Nos. 4492-18 & 4490-5.

20-21. *Dinogymnium* sp. cf. *D. sibiricum* (Vozzhennikova) Lentin & Williams.; Slide Nos. 4488-98 & 4491-14.

22-23. *Dinogymnium hyalinum* (Vozzhennikova) Lentin & Williams; Slide Nos. 4491-9 & 4492-13.
24. *Dinogymnium* sp F.; Slide No. 4495-6.
25. *Dinogymnium* sp. E.; (specimen up side down) Slide No. 4495-5.
26. *Dinogymnium* sp. B.; Slide No. 4496-15.
27. *Dinogymnium* sp. cf. *D. sibiricum* (Vozzhennikova) Lentin & Williams. Slide No. 4491-19.
28-29. *Dinogymnium assamicum* sp. nov.; Slide Nos. 4496-6 & 4502-1.
30. ? *Dinogymnium*; Slide No. 4521-5.
31. *Dinogymnium albertii* Clarke & Verdier; Slide No. 4489-2.

PLATE 3

32-34. *Hexasphaera* sp. cf. *H. asymmetricum* (Deflandre) Clarke & Verdier. Slide Nos. 4489-10 & 4490-1.
35. *Hystrichodinium infundibulum* sp. nov. Slide No. 4496-14.
36-37. *Achomosphaera recurvatum* sp. nov. Slide Nos. 4495-7 & 4490-7.
38. *Hexasphaera* sp. cf. *H. asymmetricum* (Deflandre) Clarke & Verdier. Slide No. 4496-1.
39. *Achomosphaera recurvatum* sp. nov. Slide No. 4491-8.
40-41. *Gonyaulacysta* sp. A. 4491-2 & 4492-5.
42-44. *Apteodinium maculatum* Eis. & Cooks Slide Nos. 4491-13; 4494-2 & 4491-17.
45. Forma B; Slide No. 4494-5.
46. Forma C; Slide No. 4521-4.
47. ? *Gonyaulacysta* sp.; Slide No. 4488-8.
48. *Gonyaulacysta* sp. B; Slide No. 4491-10.

PLATE 4

49. *Ceratiopsis leptoderma* Vozzhennikova; Slide No. 4511-5.
50. *Deflandrea* sp. A; Slide No. 4508-3.
51-53. *Lanternosphaeridium licium* sp. nov.; Slide Nos. 4518-1, 4522-7 & 4518-4.
54. *Palaeocystodinium* sp. A.; Slide No. 4512-6.
55. *Cordosphaeridium inodes* (Klumpp) Eisenack; Slide No. 4522-2.
56. *Codoniella langparensis* sp. nov.; Slide No. 4516-2.

PLATE 5

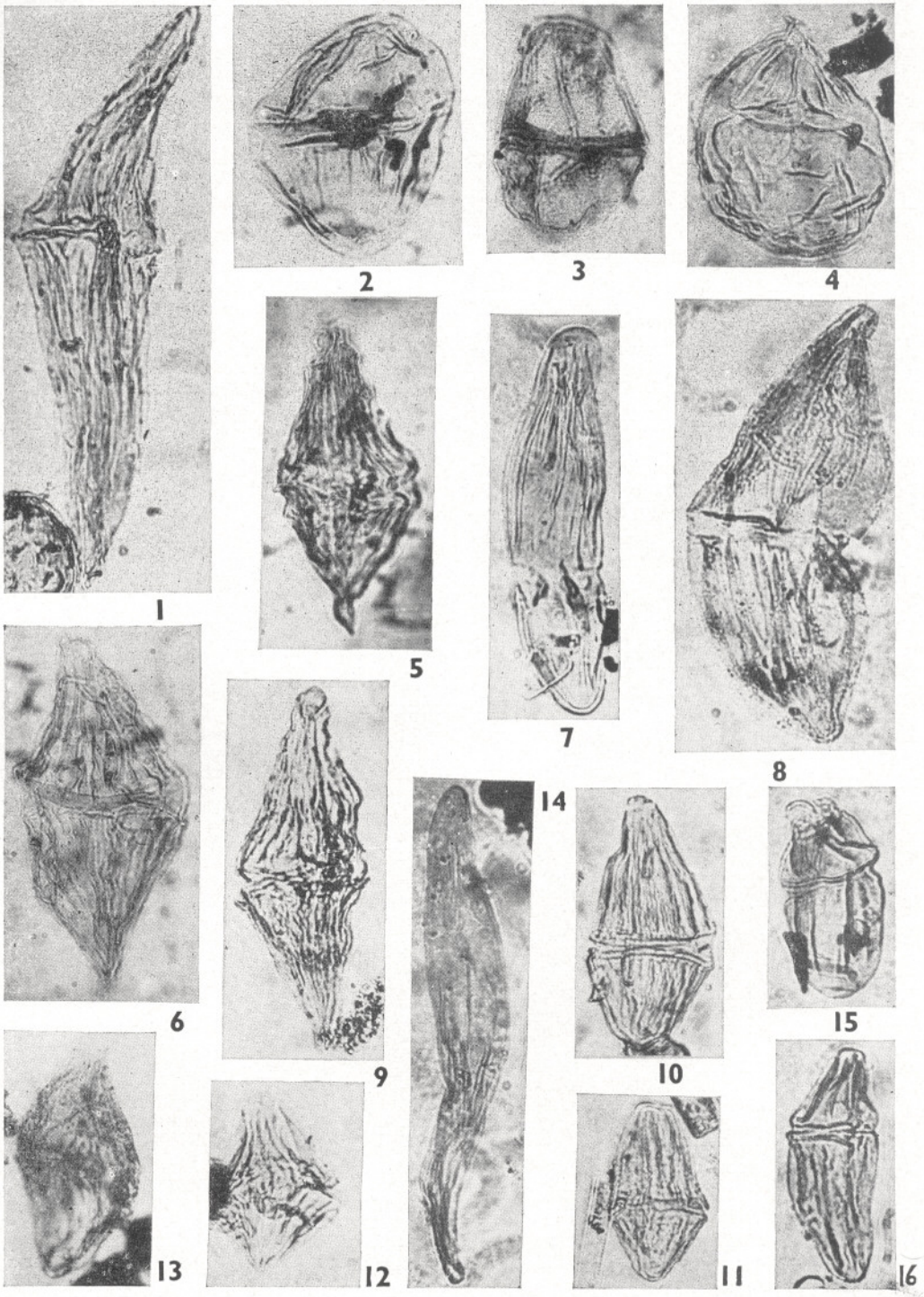
57-58. *Codoniella langparensis* sp. nov.; Slide Nos. 4517-6 & 4517-3.
59-60. *Cordosphaeridium inodes* (Klumpp) Eisenack; Slide Nos. 4510-5 & 4515-6.
61-62. *Cyclonephelium assamicum* sp. nov.; Slide Nos. 4517-1 & 4523-2.

PLATE 6

63. *Palaeocystodinium scabratum* sp. nov.; Slide No. 4510-4.
64-65. *Deflandrea crassistriata* sp. nov.; Slide Nos. 4514-1 & 4517-4.
66. *Lejeunia* sp.; Slide No. 4514-6.
67. *Ceratiopsis leptoderma* Vozzhennikova; Slide No. 4519-1.
68. ? *Hystrichosphaeridium* sp. Slide No. 4520-8.
69. *Cyclonephelium* sp. A.; Slide No. 4510-5.
70. *Ascodinium* sp.; Slide No. 4491-20.
71. *Thalassiphora* sp. B.; Slide No. 4501-5.
72. ? *Dinogymnium* sp. A.; Slide No. 4502-8.
73. *Cyclonephelium assamicum* sp. nov.; Slide No. 4510-7.

PLATE 7

74. *Odontochitina* sp. B.; Slide No. 4507-4.
75-76. *Odontochitina* sp. A.; Slide Nos. 4507-6 & 4507-3.
77. *Pterospermopsis* sp. cf. *P. barbarae* Górka; Slide No. 4520-5.
78. *Thalassiphora* sp. A.; Slide No. 4518-3.
79. *Eisenackia* sp. A. (Hypotheca focused); Slide No. 4513-3.
80. Forma A; Slide No. 4507-8.
81. *Striatites* sp. (reworked striate bisaccate pollen grain); Slide No. 4518-7.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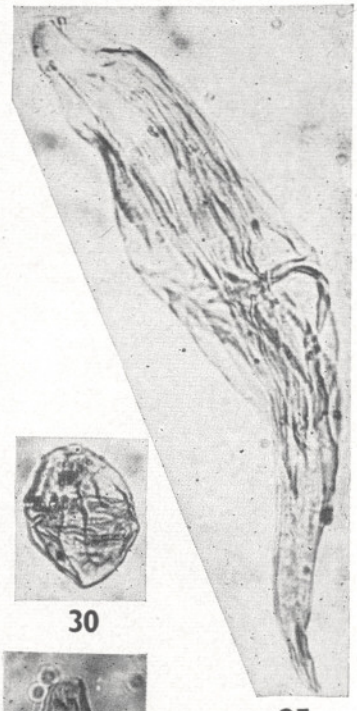

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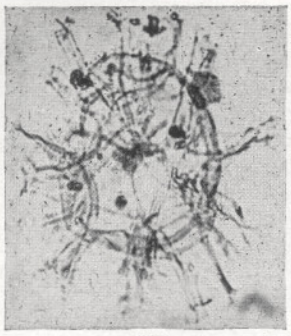

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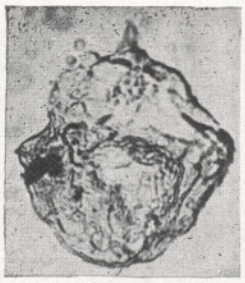

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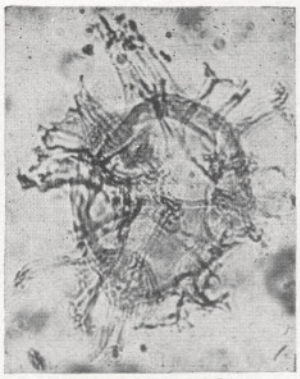

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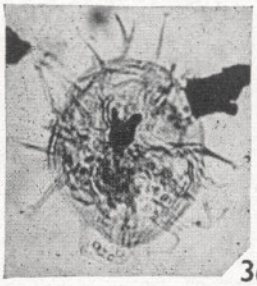

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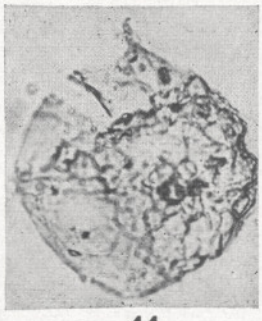

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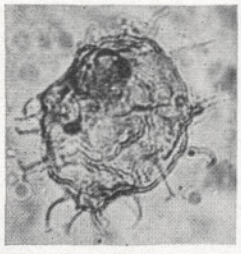

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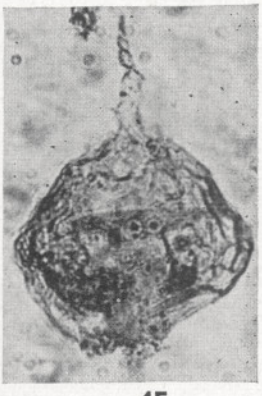

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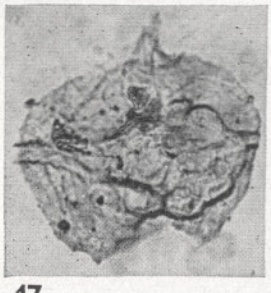

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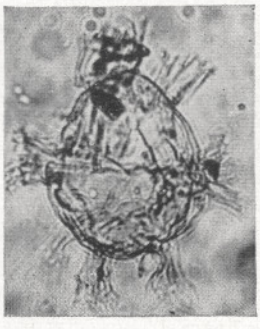

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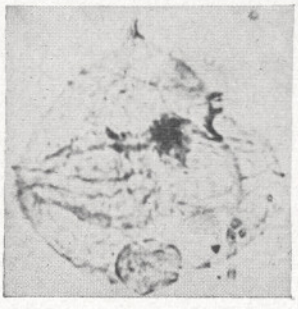

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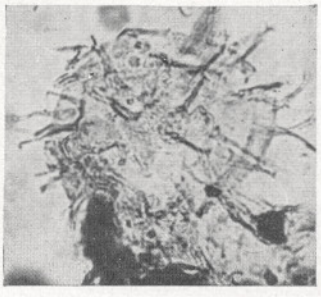

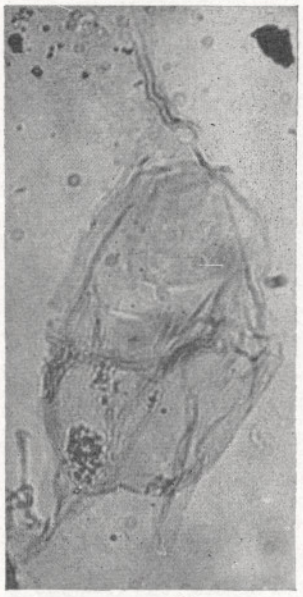

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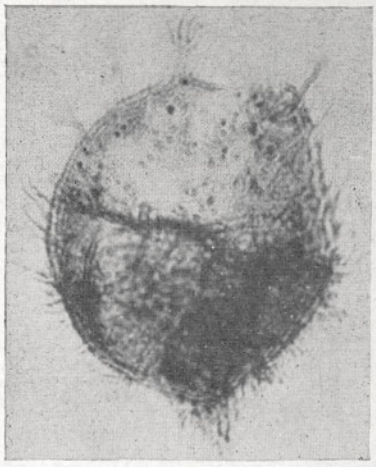

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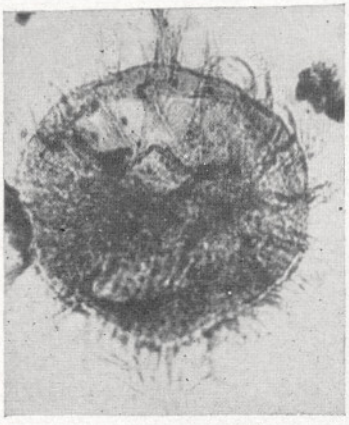

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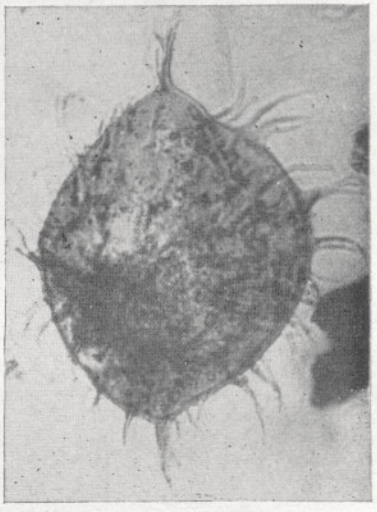

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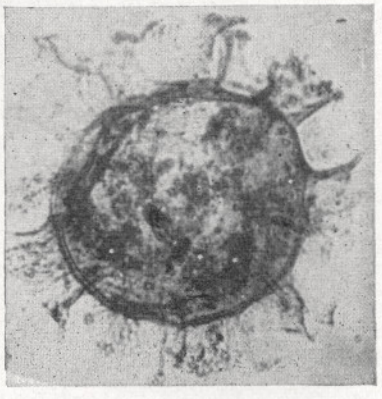

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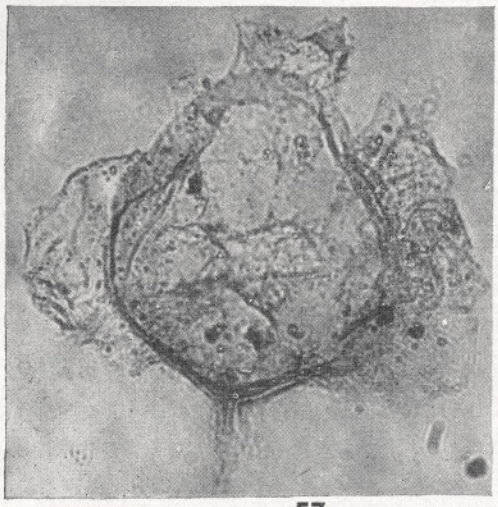

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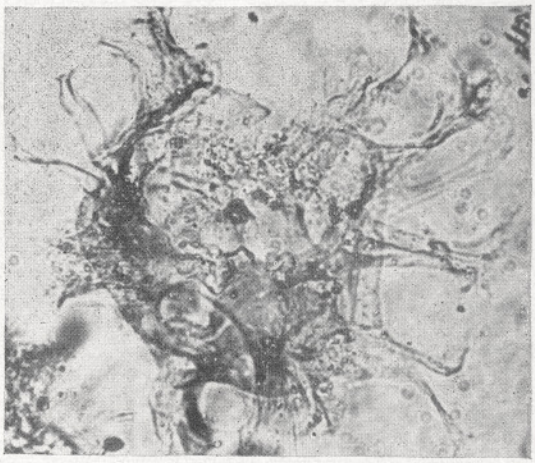

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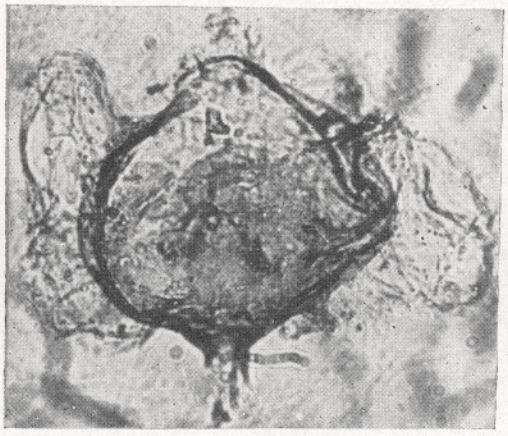

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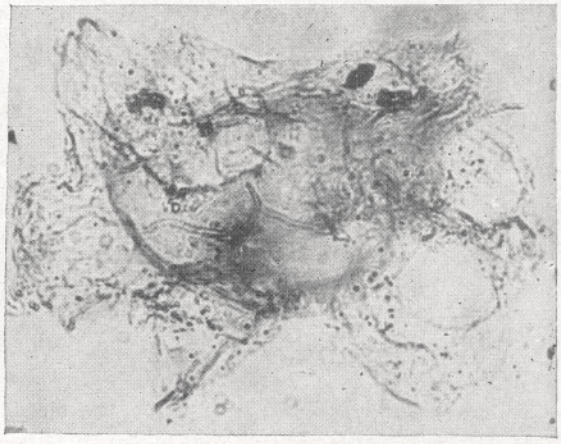

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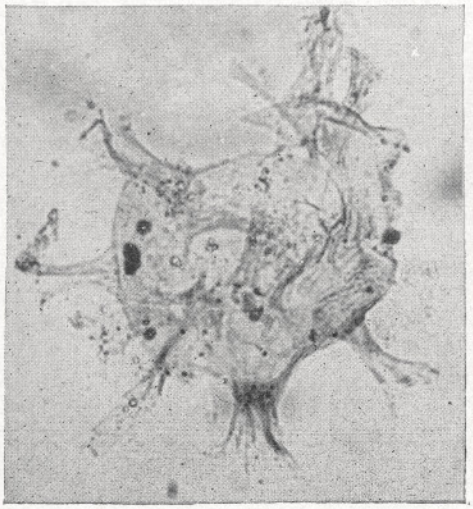

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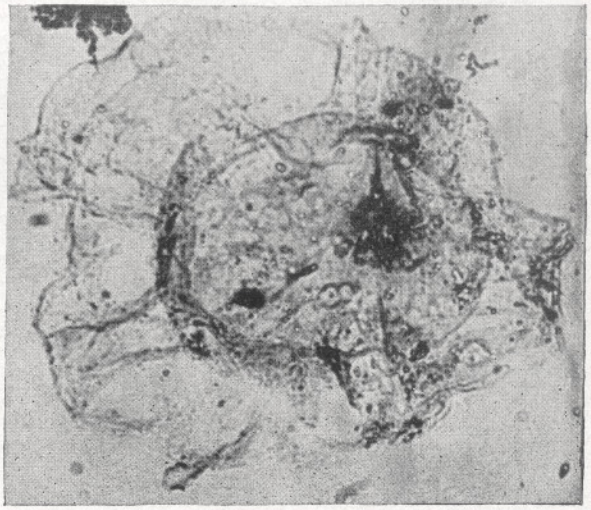

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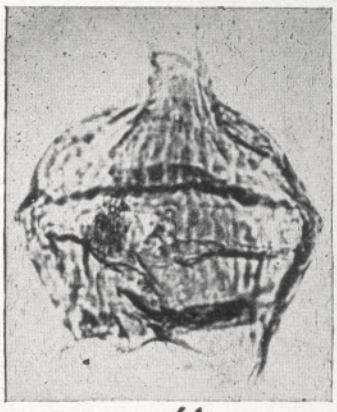

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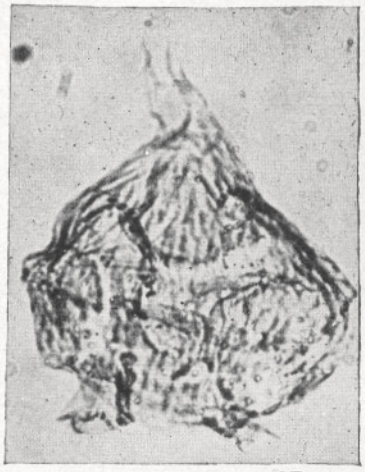

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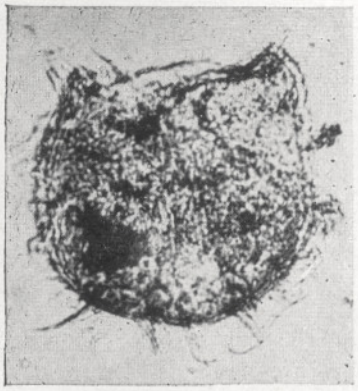

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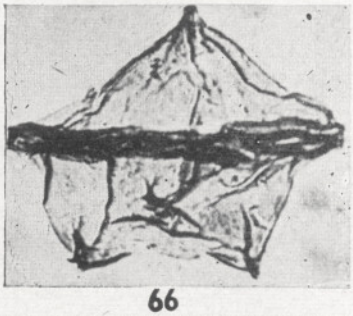

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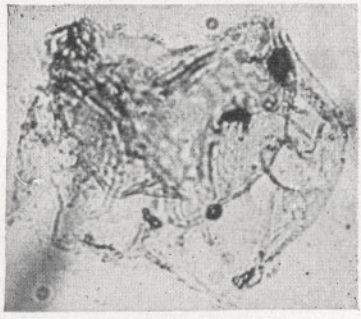

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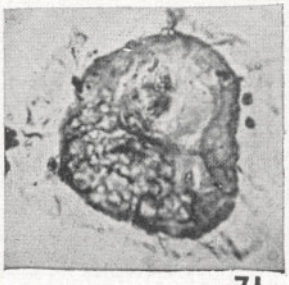

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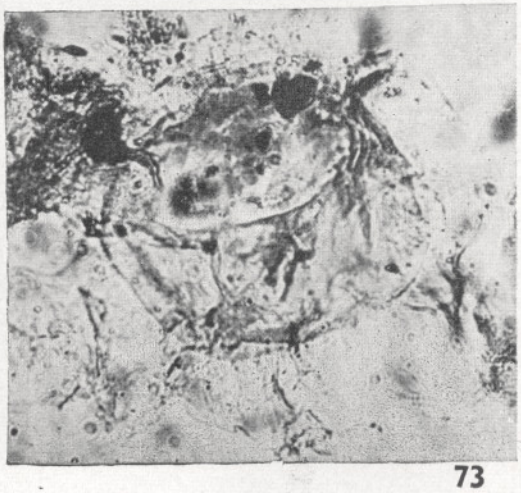

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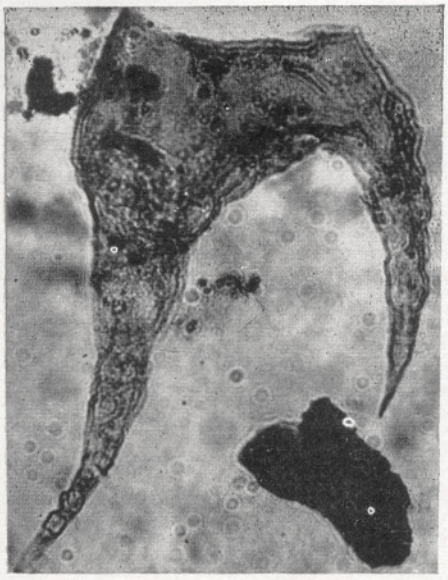

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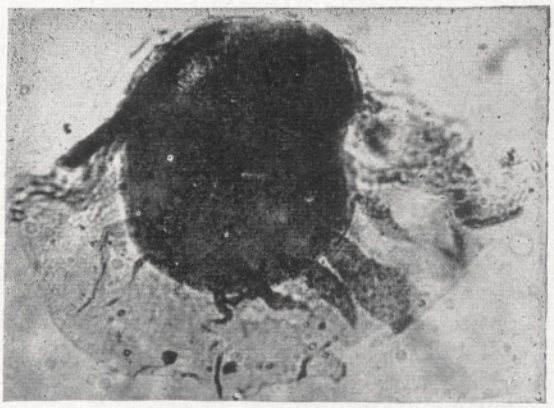

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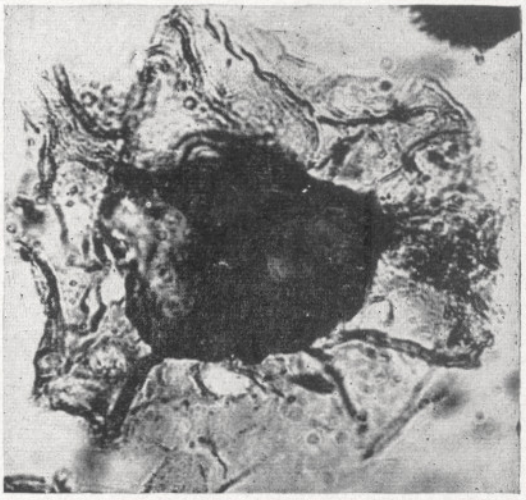

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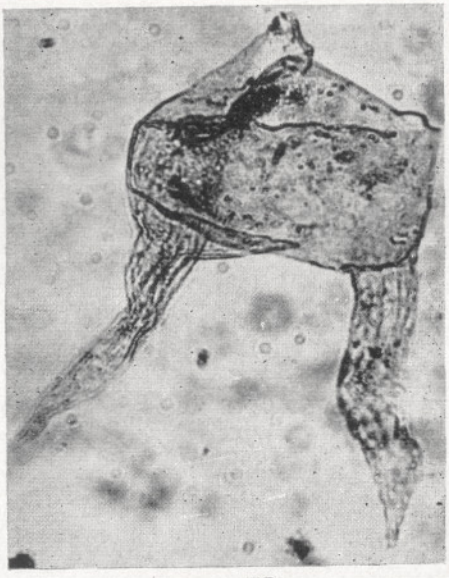

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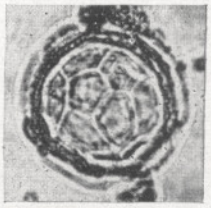

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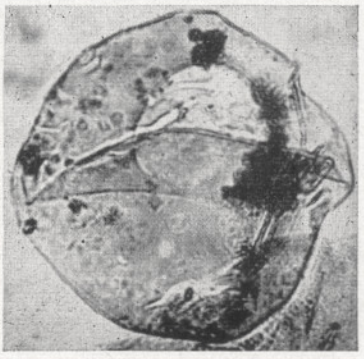

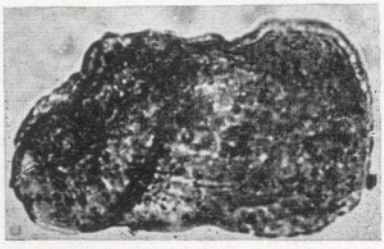

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