CRETACEOUS MICROPLANKTON FROM SENEGAL BASIN, N. W. AFRICA. 1. SOME NEW GENERA SPECIES AND COMBINATIONS OF DINOFLAGELLATES*

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ABSTRACT

Preliminary results of authors' study of the microplankton in Cretaceous (Barremian-Maestrichtian) sequence of Senegal Basin, N.W. Africa, are given. In the present article only some non-tabulate fossil dinoflagellates are considered. They are assigned to five genera (two new), twelve species (all new) and eight combinations (all new).

The status of all the Lower Cretaceous species of the genus *Deflandrea* is discussed and it is suggested that they be segregated as a separate genus. The stratigraphic importance of these fossils has also been brought to light with the remark that *Deflandrea* can be treated as an Upper Cretaceous-Tertiary genus.

INTRODUCTION

THE study of Cretaceous dinoflagellates dates back to 1836 when Ehrenberg reported these forms from Saxony in Germany. Since then much has been contributed towards the Cretaceous phytoplanktonology (Alberti 1959, 1961; Eisenack 1958, 1962; Evitt 1961; Deflandre and Cookson 1955; Cookson and Eisenack 1962; and Clarke and Vardier 1967; Wetzel 1933, 1943, 1953 & 1961; Deflandre 1941 & 1943 and Sarjeant & Downie 1966 etc.).

Authors are presently occupied in the study of Cretaceous dinoflagellates and acritarchs from the Senegal Basin, N.W. Africa. The samples studied have been procured from four bore holes, viz., CM-1, CM-4, B.R.1 and SK-1 ranging in age from Barremian to Maestrichtian. In the present text only a few interesting types of non-tabulate forms are described and discussed. The major part of the assemblage will be published elsewhere.

The fossil microplankton records from African continent are rare. Davey (1969) has described some dinoflagellate-cysts from the Cretaceous of Northern Natal, S. Africa. A few works on palynomorphs have been published (Stover 1963; Jardine and Magloire 1964; and Kieser 1967).

Repository — The type slides are deposited at the Laboratoire Central, Compagnie Française des pétrole, Talence, France.

SYSTEMATIC DESCRIPTION

Class — Dinophyceae
Cyst-family — Deflandreaceae

Genus — *Senegalinium* gen. nov.

Derivation of name — In reference to its country "Senegal" from where it is described.

Diagnosis — Bicavate dinoflagellate cysts, spheriodal or ovoidal to rounded pentagonal, no tabulation; transverse furrow present or absent, circular; sulcus present (restricted to hypotract). Inner body (capsule) well developed, dark in colour, circular to rounded pentagonal in outline. Endophragm characteristically ornamented along pericoel areas. Periphragm smooth to ornamented, extending apically and antapically forming one apical and two anapical horns. Some times a third delicate layer enveloping periphragm also present. Archaeopyle well marked, trapezoidal, single plate, pentagonal or hexagonal, intercalary, below apical horn.

Description — Periphragm remains in close contact with endophragm except at the points of horn formation. Pericoel areas vary from two to three, large or small; periphragm frequently folded. In endophragm localized ornamentation starts as soon as periphragm separates from endophragm (Text-figs. 1a-b), ornamentation variable, granulose to verrucose or warty, rest surface of endophragm remains smooth to slightly ornamented. In most of the specimens it has been observed that both periphragm and endophragm are involved in

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the formation of archaeopyle. Archaeopyle limit extends maximum to endophragm margin towards apical horn.

Comparison — *Senegalinium* gen. nov. resembles closely with *Triblastula* wetzel (1933) in having similar bicavate cyst, but the latter differs mainly in having a precingular archaeopyle adjoining a girdle-like structure defined by rows of processes (Evitt, 1961; p. 395). The over-all outline of *Triblastula* is also quite different from the present genus. *Deflandrea* Eisenack (1938) comes very close to *Senegalinium* in having one apical and two antapical horns. The archaeopyle in both the genera is similar in shape and position. But *Deflandrea* differs mainly in its typical cavate cyst, with one complete pericoel and lack of endophragm thickening along the pericoel areas. Vozzhennikova (1963) instituted *Pentagonum* and *Ceratiopsis*, both having large capsule in close contact with periphragm but differ from the present genus in not having localized endophragm thickening starting from the periphragm-endophragm separation point. The exact taxonomic position of these genera is also doubtful (Norris & Sarjeant, 1964).

Nature and Affinities — The present fossils show a characteristic shape of dinoflagellate along with the presence of an archaeopyle, one apical and two antapical horns in the same position as in many other dinoflagellate cyst genera. These fossils also raise the question that the whole is a cyst within a cyst (Evitt, 1961; p. 397).

Remarks — A mention of similar fossil has been made by Evitt (1961; p. 397) quoting personal communication of Dr. Alberti (1959) that he found a well preserved specimen of *Deflandrea* in which the exterior is covered by a very thin and delicate often closely adherent membrane which could conceivably represent an original outer wall with the first cyst. Since no other detail of his specimen is known, it is difficult to have a true comparison, though it does reflect on the cyst within a cyst condition of the fossil as discussed and pointed out by Evitt.

Type species — *Senegalinium bicavatum* gen. et sp. nov., Pl. 1, Figs. 1-3; Maestrichtian, Senegal, N.W. Africa.

Geological and Geographic Range

Senegalinium gen. nov. is highly characteristic of Upper Cretaceous marine strata. The variety of forms and abundance of specimen and species appear to be maximum in Campanian-Maestrichtian sediments of Senegal basin.

Senegalinium bicavatum gen. et sp. nov.

Pl. 1, Figs. 1-4; Text-fig. 1B

Holotype — Pl. 1 Fig. 1; Slide No. 8461-1.

Type locality — Bore hole CM-1, Senegal, N.W. Africa.

Horizon — Campanian-Maestrichtian.

Diagnosis — Shell ovoid, non tabulate, bicavate; periphragm thin, zone of contact around equator large extending into one apical and two antapical horns leaving behind two or three pericoel areas, surface serrate or smooth. Endophragm thick, dark, granulose with localized verrucose thickening along margins in pericoel areas. Archaeopyle intercalary, penta to hexagonal, below the apical horn. Transverse furrow indistinct, indication of longitudinal furrow present.

Dimensions

Holotype — Shell-length 100 μ, breadth 65 μ; Capsule-length 63·7 μ, breadth 65 μ; Apical horn-length 6·5 μ, breadth (width of pericoel) 13·0 μ; Antapical horn-length 16·9 μ, breadth 19·5 μ.

Observed range — Shell-length 90-100 μ, breadth 55-70 μ; Capsule-length 60-70 μ, breadth 55-70 μ; Apical horn-length 6-22 μ, breadth 13-30 μ; Antapical horn-length 6-16 μ, breadth 10-20 μ.

Description — Epitract and hypotract nearly equal, epitract conical in outline, apical horn broader than long with apical pore; hypotract rounded antapically with two antapical horns of unequal size, acuminate. Intercalary archaeopyle lies upto or below the capsule margin.

Senegalinium psilatum sp. nov.

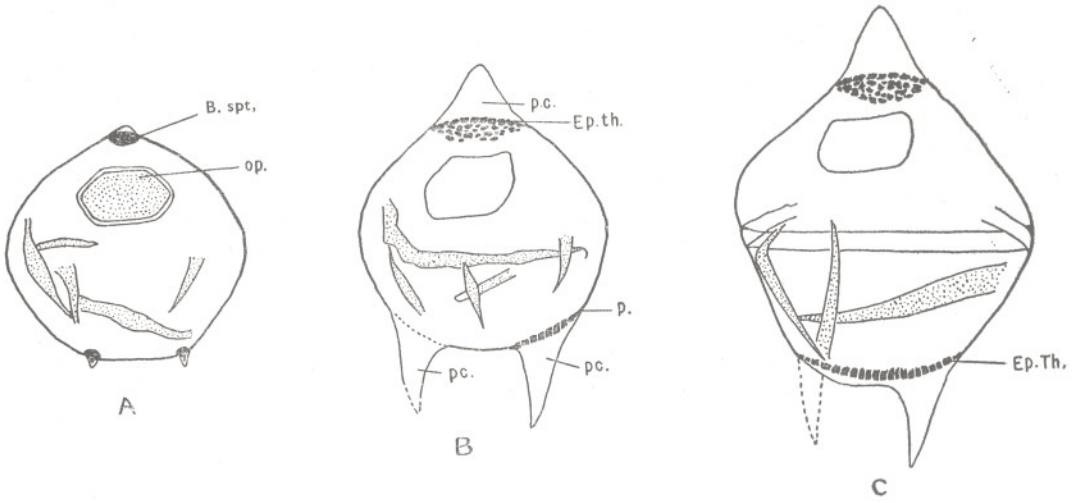
Pl. 1, Figs. 5-6; Text-fig. 1A.

Holotype — Pl. 1, Fig. 6; Slide No. 8459-16

Type locality — Bore Hole No. CM. 1, Senegal, N.W. Africa.

Horizon — Campanian-Maestrichtian.

Diagnosis — Shell pentagonal in outline, non-tabulate. Transverse furrow indistinct, longitudinal furrow present. Periphragm very thin, smooth, slightly extending apically and antapically forming one small



TEXT-TIG. 1 — Diagrammatic representation of *Senegalinium* species: (A) *Senegalinium psilatum* sp. nov. showing three black spots (B. spt.) along the small pericoel areas and archaeopyle with attached operculum (op.); (B) *S. bicavatum* gen. et sp. nov. showing three large zones of pericoel (pc) with endophragm ornamentation (Ep. th.) starting from the point of periphragm-endophragm separation (p); (C) *S.* sp. A. showing only two pericoel areas, with continuous hypothecal endophragm thickening × 500 Approximate.

apical and two antapical horns. Endophragm in close contact with periphragm, microgranulate, along small pericoel areas only dark patches visible representing localized thickening, no ditinct ornamentation. Archaeopyle penta to hexagonal, below apical horn.

Dimensions

Holotype — Shell-length 65·0 μ, breadth 62·5 μ; Capsule-length 58·5 μ, breadth 62·5 μ; Apical horn-length 6·5 μ, breadth 6·5 μ; Antapical horn rudimentary.

Description — Epi- and hypo-tract marked, thinness of the periphragm results into many folds in all directions. Operculum present.

Comparison — *Senegalinium psilatum* sp. nov. differs from *S. bicavatum* sp. nov., in having psilate periphragm, small pericoel and rudimentary horns. *Deflandrea obscura* Drugg (1967, p. 17) resembles very much with the present species in shape and thin delicate periphragm but differs mainly in not having thickened endophragm along pericoel areas and in possessing slight indication of tabulation.

Senegalinium granulostriatum sp. nov.
Pl. 1, Figs. 7-11; Pl, 2, Fig. 18; Pl. 3, Fig. 29

Holotype — Pl. 1, Fig. 7; Sl. No. 8455-5.

Type locality — Bore Hole No. CM-1, Senegal, N.W. Africa.

Horizon — Maestrichtian.

Diagnosis — Ambitus pentagonal, non-tabulate, periphragm fairly thin, extending to form one well marked apical horn and two antapical horns, granulostriate, striations longitudinal. Endophragm darker in colour, surface microgranulate, densely varrucose along the pericoel areas. Transverse furrow well developed, circular; longitudinal furrow seen, broader near girdle but narrows towards antapex. Archaeopyle intercalary, broad, below apical horn.

Dimensions

Holotype — Shell-length 104μ, breadth 75·4μ; Capsule-length 54·6μ, breadth 75·4μ; Apical horn-length 22·0 μ, breadth 17·5μ; Antapical horn-length 20·5 μ, breadth 13μ.

Observed range — Shell-length 100-155 μ, breadth 60-80 μ; Capsule-length 50-85 μ, breadth 60-80 μ; Apical horn-length 15-31 μ, breadth 15-35 μ; Antapical horn-length 10-25 μ, breadth 10-18 μ.

Description — Epi- and hypotract equally divided by circular, transverse, 8 μ wide girdle. Epitract conical, with a pore at the apex of apical horn. Formation of verrucae on endophragm surface along pericoel areas seem to have been formed as a result of grana fusion.

Comparison — *Senegalinium granulostriatum* sp. nov. differs from the two previously described new species in having distinct transverse furrow, granulo-striate periphragm and granulate endophragm.

Senegalinium trisinum sp. nov.

Pl. 2, Fig. 16

Holotype — Pl. 2, Fig. 16; Slide No. 8632-11.

Type locality — Bore Hole No. CM-4, Senegal, N.W. Africa.

Horizon — Maestrichtian.

Diagnosis — Ambitus oblong-ovoid, non-tabulate, periphragm thin, smooth, extending apically and antapically forming one apical and two antapical horns. Capsule completely filling periphragm, surface micro-granulate, localized tnickening verrucose along the pericoel areas. Periphragm covered exteriorly by a very thin layer, visible only along the horns. Transverse furrow distinct, Archaeopyle intercalary, pentagonal.

Dimensions

Holotype — Shell-length 109μ, breadth 65 μ; Capsule-length 71·5 μ, breadth 65 μ; Apical horn-length 13·4 μ, breadth 6·5 μ; Antapical horn-length 18·2 μ, breadth 10·4μ;

Description — Epitract and hypotract equally divided by transverse furrow. Hypotract show wrinklings along the girdle area,

Comparison — *Senegalinium trisinum* sp. nov. differs from all the known species of the genus in having three layers, one extra to periphragm and endophragm.

Remarks — The presence of third exterior most layer indicates that it is a cyst with in a cyst as discussed by Evitt (1961, p. 397).

Senegalinium dubium sp. nov,

Pl. 2, Figs. 12-13

Holotype — Pl. 2, Fig. 13; Slide No. 5930-1

Locality — Bore Hole No. BR-1, Senegal, N.W. Africa.

Horizon — Maestrichtian.

Diagnosis — Shell ovoid to spherical, non-tabulate, non-cavate, zone of contact around equator large. Transverse furrow distinct; longitudinal furrow present or absent. Endophragm smooth, periphragm ornamented, baculo-verrucose. Apical horn short; antapical horns absent or represented only by slight thickenings. Archaeopyle large, intercalary, below apical horn, trapezoidal.

Dimensions

Holotype — Shell 84 μ in diameter; Girdle 6·5 μ broad; Apical horn 6·5×6·5 μ in size; Wall thickness 1·5 μ.

Range — Shell 80-85 μ in diameter; Girdle 6-6·5 μ broad; Apical horn 5-7 μ long and broad; Wall thickness 1-1·5 μ.

Description — Epitract and hypotract almost equal in size. Large size of archaeopyle gives an indication of its precingular position; beculae formed on periphragm have slightly concave tips, some times fused to form varrucae.

Comparison — Forms described under *Geiselodinium miocenicum* Nagy (1967) compare closely with *Senegalinium dubium* sp. nov. in having similar shape and large zone of contact between peri- and endophragm, but readily differs in lack of an archaeopyle. *S. dubium* is different from other species of the genus in having rudimentary antapical horns and baculoverrucose periphragm ornamentation.

Senegalinium sp. A.

Pl. 2, Fig. 15

Description — Shell pentagonal, non-tabulate, zone of contact between periphragm and endophragm large, leaving small pericoel only at the horn bases; horns well developed, one apical and two antapical; cingulum distinct, circular, 6·5 μ broad; epi- and hypotract almost equal in size. Epitract ends apically into a sort of platform from where periphragm buldges out to form apical horn; horn characteristically bulbous at the base, tapering upwards; antapical horns unequal in size. Endophragm thickened along the pericoel region; body surface coarsely granulate with slight longitudinal striations. Archaeopyle not seen.

Dimension

Shell-length 104 μ, breadth 75 μ; Capsule-length 78 μ, breadth 78 μ; Apical horn-length 26 μ, breadth 15·6 μ; Antapical horn-length 6 μ, breadth 10 μ,

Remark — This specimen resembles closely with *S. granulostriatum* sp. nov. but differs mainly in having bulbous base of apical horn.

Senegalinium sp. B.

Pl. 2, Fig. 17; Text-fig. 1C

Description — Shell spheriodal, non-tabulate, bicavate, transverse furrow present, longitudinal furrow not observed. Endophragm ornamented only along the pericoel areas with baculae arranged in a row forming false slit-like appearance between two; size of baculae variable from point of contact between peri- and endophragm towards the centre. Periphragm granulose. Apical horn broader than long. Antapical horns two, unequal in size. Archaeopyle intercalary, below apical horn.

Dimensions

Shell — 104 × 71·5 μ; Apical horn — 22 × 26 μ; Antapical horn — 20 μ; Girdle — 8 μ; Capsule — 71·5 μ in diameter.

Senegalinium sp. C

Pl. 2, Fig. 19

Description — Shell spheroidal, pentagonal, non-tabulate, bicavate, transverse furrow distinct, longitudinal furrow absent. Periphragm smooth, endophragm ornamented along the pericoel areas. Single apical horn longer than broad; antapical horns two, well developed, equal in size. Periphragm between two antapical horns loose, with endophragm giving only one antapical pericoel. Archaeopyle intercalary below apical horn.

Dimensions

Shell— 56-110 μ in size; Capsule — 56 μ in diameter; Girdle — 8 μ broad; Apical horn — 32 × 30 μ in size; Antapical horn — 24 × 16 μ in size.

Senegalinium sp. D

Pl. 2. Fig. 14

Description — Shell pentagonal, capsule present, zone of contact large, periphragm thin, smooth, apical horn well developed. Antapical horns two, short; endophragm granular, only free from periphragm contact at base of apical horn and between the two antapical horns, ornamented with verrucae. Epi- and hypotract equally divided by girdle; longitudinal furrow not distinct. Archaeopyle pentagonal, below the apex, intercalary.

Dimensions

Shell-length 93·6 μ, breadth 61·1 μ; Capsule-length 65 μ, breadth 61 μ; Antapical horn-length 6·5 μ, breadth 10·4 μ.

Remarks — This form differs from all the described species of the genus in having granular endophragm with usual localized zones. Due to lack of many specimens no precise specific identification has been attempted.

Generic remarks — The study of *Senegalinium* species from Senegal suggests that there is a great variability in the size of pericoel. Its number also varies from two to three (one epithecal and one or two hypothecal.) The three pericoel condition is aquired only when the periphragm and endophragm between the two antapical horns remain in contact, otherwise it forms a large pericoel (*Senegalinium* sp. B., Text-fig. 1C).

It has been invariably observed that the margin of endophragm along the pericoel areas starting from the endophragm-periphragm (E-P) separation point shows distinct ornamentation which is directly proportional to pericoel size. Where the pericoel is very small, the endophragm ornamentation is represented only by black spots (*Senegalinium psilatum*; Text-fig. 1a). In others it is gradually increased and in *S.* sp. B. (Text-fig. 1c) it occupies major hypothecal portion.

Further extreme cases of this endophragm ornamentation along the pericoel area seem to occur in two Tertiary species of *Deflandrea*, *D. granulosa* Cookson and Eisenack (1965) and *D. heterophlycta* Deflandre & Cookson (1955). Out of these two species *D. heterophlycta* seems to represent the most extreme side having a cavate cyst with an ornamented endophragm all around.

This hypothesis remains open to question until more reliable evidences are available.

Subtilisphaera gen. nov.

Derivation of name — The generic name is from the latin *subtilis*, delicate plus *Spheara*, sphere.

Diagnosis — Shell pentagonal-ovoid, test cavate to bicavate non-tabulate, asymmetrical; cingulum (girdle) well developed, dividing the shell into almost equal halves. Epitract broadly rounded with pointed to broadly obtuse apical horn; hypotract rounded having one prominent antapical horn and second undeveloped or only as a slight projection placed away from median axis (non-axial). Periphragm smooth to granulate, thin, delicate. Endophragm well developed, smooth, thin, delicate; capsule circular, filling periphragm completely or leaving a small pericoel. Archaeopyle mostly not seen, if present intercalary.

Description — Periphragm extents apically to form a single short apical horn; antapically it again extents into one sided antapical horn, the second antapical horn is never completely developed but shows a slight projection at the place of second antapical horn. Single antapical horn never occupies the median axial position opposite to apical horn.

Comparison and Discussion

Subtilisphaera gen. nov. compares closest with *Diconodinium* Cookson & Eisenack (1960), *Spinidinium* Cookson & Eisenack (1962), *Astrocysta* Davey (1970) and *Deflandrea* Eisenack (1938). It differs from *Diconodinium* in having well developed capsule and non-axial position of antapical horns. *Spinidinium* is distinguisned only by its characteristic periphragm ornamentation. *Astrocysta* is differentiated in its proximate cyst. It resembles *Deflandrea* in its cavate cyst with well developed central body (capsule) and periphragm ornamentation. But differs mainly in having, always well developed girdle (cingulum), only one well developed antapical horn, as compared to two in *Deflandrea*. These fossils are also quite distinct from *Deflandrea* species in their asymmetrical test shape, small size and delicate periphragm and endophragm.

Deflandrea sverdrupiana Manum (1962) indicates the presence of tabulation in the present genus suggesting its peridinoid affinity.

Nature and affinities — The present fossils show a characteristic shape of dinoflagellate, along with the presence of one apical and one non-axial antapical horn in the same position as in many other dinoflagellates. It is therefore, treated as a dinoflagellate cyst.

Type species — *Subtilisphaera senegalensis* gen. et sp. nov., Pl. 3, Figs. 31-33; Senegal, N-W Africa; Aptian.

Other species of the genus

Deflandrea rotundata Eisenack & Cookson, 1960; p. 2; pl. 1, figs. 1-2. Albian.

Deflandrea pontis-mariae (Deflandre) Vozzhennikova, 1965; in Davey, 1970, p. 341; pl. 1, figs. 10-11; Albian-Cenomanian.

Deflandrea asymmetrica Davey and Verdier, 1971, p. 39; pl. 2, figs. 4 & 6; Albian.

Deflandrea pirnaensis Alberti, 1959, in Davey, 1970; p. 338; pl. 1, figs. 3-4; Albian-Turonian.

Deflandrea ventriosa Alberti, 1959; p. 101; pl. 9, figs. 14-15; Lower Aptian.

Deflandrea perlucida Alberti, 1959, p. 102; pl. 9; figs. 16-17; Upper Barramian.

Deflandrea pirnaensis Alberti, 1959, p. 100; pl. 8, figs. 1-5; Albian-Middle Turonian.

Deflandrea cf. *sverdrupiana* Manum, in Wilson, 1971; pl. 1, fig. 7; Upper Cretaceous.

Deflandrea sverdrupiana Manum, 1962; pl. 2, figs. 6-15; Middle Cretaceous.

Deflandrea pirnaensis Alberti, 1959, in Sarjeant and Anderson, 1969; pl. 1; figs. 1-3; text-fig. 1a. Maestrichtian.

Palaeoperidinium cretaceum Pocock, 1962 pl. 14, figs. 219-221; Cretaceous.

Dinoflagellate A in Burgess, 1971, pl. 1, fig. 5; Lower Cenomanian.

Subtilisphaera senegalensis sp. nov.

Pl. 3, Figs. 31-33

Holotype — Pl. 3, Fig. 31; Slide No. 7946-1.

Type locality — Bore Hole No. CM-1, Senegal, N.W. Africa.

Horizon — Aptian.

Diagnosis — Bicavate pentagonal cyst, periphragm thin, granulose with longitudinal striations. Apical horn one, short and pointed; antapical horns two, unequal in size, only one horn developed, non-axial, other absent or in the form of slight projection. Cingulum well developed extending laterally. Epitract and hypotract equal, in size. Endophragm smooth, thin, capsule completely filling the periphragm leaving pericoel below the apical and antapical horns. Archaeopyle absent.

Dimensions

Holotype — Shell-length 50μ, breadth 35·1 μ; Capsule-length 32·5 μ, breadth 32·4 μ; Apical horn-length 9 μ, breadth 13 μ; antapical horn-length 6·5 μ, breadth 3·9 μ; width of girdle 4 μ.

Observed range — Shell-length 50-55 μ, breadth 35-40 μ; Capsule-length 30-35 μ, breadth 30-35 μ; Apical horn-length 5-9 μ, breadth 7-13 μ; Antapical horn-length 6-11 μ, breadth 3-7 μ; Girdle width 4-6 μ.

Comparison — *S. senegalensis* sp. nov. differs from all the known species of the genus in its very small size and granulostriate periphragm ornamentation.

Subtilisphaera scabrata sp. nov.

Pl. 3, Figs. 36-39

Holotype — Pl. 3, Fig. 39; Slide No. 5123-2.

Type locality — Bore Hole No. BR-1, Senegal, N.W. Africa.

Horizon — Aptian.

Diagnosis — Cavate cyst, spindle in shape, biconical or pentagonal. Periphragm thin, divided equally into epitract and hypotract by a cingulum, extending apically, forming an apical and an antapical well developed horn, third completely absent or present as slight projection. Surface granuloscabrate. Capsule circular, endophragm smooth, pericoel complete around capsule. Archaeopyle absent.

Dimensions

Holotype — Shell-length 60 μ, breadth 50 μ; Capsule-length 40 μ, breadth 40 μ; Apical horn-length 12 μ, breadth 12 μ; Antapical horn-length 4 μ, breadth 4 μ.

Observed range — Shell-length 50-70 μ, breadth 40-55 μ; Capsule-diameter 40-45 μ; Apical horn-length 10-15 μ, breadth 10-20 μ; Antapical horn-length 10-15 μ, breadth 10-16 μ.

Comparison — *S. scabrata* sp. nov. differs from the type species in its larger size, distinct pericoel and granuloscabrate periphragm surface.

Remarks — The difference in endophragm thickness seen in some specimen may be the result of preservation.

Subtilisphaera crassigranulosa sp. nov.

Pl. 2, Fig. 25

Holotype — Pl, 2, Fig. 25; Slide No. 7300-4.

Type locality — Bore Hole No. BR-1, Senegal, N.W. Africa,

Horizon — Aptian.

Diagnosis — Shell small, biconical, lateral sides convex, periphragm thin, coarsely granular, divided by a well developed girdle into two almost equal halves. Epitract with one apical horn, broader than long; hypotract broadly rounded, periphragm extends to form two unequal horns. Capsule completely fills the periphragm, endophragm smooth.

Dimensions

Holotype — Shell-length 54 μ, breadth 43 μ; Capsule-length 45 μ, breadth 45 μ; Apical horn-length 5·2 μ; breadth 20 μ; Antapical horn-length 5·2 μ, breadth 5·2 μ.

Observed range — Shell-length 50-60 μ, breadth 40-50 μ; Capsule-diameter 40-50 μ; Antapical horn-length 5·8 μ; breadth 5-12 μ.

Comparison — *S crassigranulosa* sp. nov., differs from all the known species of the genus in its coarsely granular periphragm.

Subtilisphaera sp. A

Pl. 3; Fig. 40

Description — Cyst biconical, laterally bulging on one side. Capsule completely filling periphragm leaving small pericoel below horns. One apical and antapical horn seen, position of second antapical horn marked. Periphragm ornamented with small coni. Transverse girdle well represented. Epitract larger in size than hypotract, slight indication of tabulation. No archaeopyle.

Dimensions

Shell-length 80 μ, breadth 41·6 μ; Capsule-size 50×40 μ; Apical horn-length 23 μ, breadth 19·5 μ; Antapical horn-length 7·8 μ, breadth 7·8 μ; Girdle 3·9 μ wide.

Subtilisphaera ventriosa (Alberti) comb. nov.
Pl. 3, Figs. 34-35

Syn.

1959 — *Deflandrea ventriosa* Alberti, p. 101; pl. 9, figs. 14-15

Known distribution — Lower Aptian.
Present distribution — Aptian.

Genus — *Palaeocystodinium* Alberti 1961

P. microgranulatum sp. nov.
Pl. 2, Fig. 23; Pl. 3, Fig. 30

Holotype — Pl. 3, Fig. 30; Sl. No. 8454a-5.
Type locality — Bore Hole No. CM-1, Senegal, N.W. Africa.
Horizon — Maestrichtian.
Diagnosis — Test elongate to spindle-shaped, sometimes globular with convex lateral sides. Horns two, one at each end, tappering; periphragm microgranulate, horns spongy; endophragm smooth, in close contact with periphragm, leaving very small pericoel below horn bases; capsule ellipsoidal. Archaeopyle penta- to hexagonal below apical horn. No evidence of furrows except for periphragmal folds.

Dimensions

Holotype — Shell-length 120 μ, breadth 71 μ; Capsule-length 71·5 μ, breadth 65 μ; Apical horn-length 20 μ, breadth 9·1 μ; Antapical horn-length 16 μ, breadth 8 μ.
Observed range — Shell-length 110-130 μ, breadth 40-80 μ; Capsule-length 60-80 μ; Apical horn-length 15-20 μ, breadth 5-10 μ. Antapical horn same as apical horn.
Comparison — *P. microgranulatum* sp. nov. differs from all the known species of the genus in having smooth endophragm, microgranulate periphragm and broadly ovoid shape.

Palaeocystodinium punctatum sp. nov.
Pl. 2, Fig. 24; Pl. 3, Figs. 26-28

Holotype — Pl. 3, Fig. 27; Sl. Nc. 8457-5.
Type locality — Bore Hole No. CM-1, Senegal, N-W Africa.
Horizon — Maestrichtian
Diagnosis — Shell spindle-shaped, dorso-ventrally flattened, with two short appendages, one apical and one antapical; Antapical horn divided into another short horn. Archaeopyle trapezoidal below apical horn; periphragm micropunctate. Capsule large, filling completely periphragm cavity, endophragm smooth. Apical horn terminate into a dentate end on free side. No furrows seen. Archaeopyle not observed in all specimens. Another thin membrane exterior to periphragm is present, seen only around horns. The size ratio between horn and central vesicle (H-V ratio) remains mostly 1:4.

Dimensions

Holotype — Shell-length 144 μ, breadth 65 μ; Capsule-length 91 μ, breadth 65 μ; Apical horn-length 22·1 μ, breadth 9·1 μ; Antapical horns-length 31·2 μ, breadth 7·8 μ.
Observed range — Shell-length 140-150 μ, breadth 55-70 μ; Capsule-length 95-97 μ, breadth 60-70 μ; Apical horn-length 20-23 μ, breadth 8-11 μ; Antapical horn-length 9-32 μ, breadth 4-8 μ.
Comparison — *Palaeocystodinium punctatum* sp. nov. compares only with *P. benjaminii* Drugg (1967) in having two antapical horns but differs readily in having no fiber or hairs on the apical horn and having dentate apex, micropunctate periphragm and third exterior layer.
Remarks — The presence of two closely placed antapical horns and horn-vesicle ratio makes it difficult to place this species in *Palaeocystodinium* and the former evidence might permit the transfer of these forms under a new genus.

Genus — *Geiselodinium* Krützsch 1962

Geiselodinium psilatum sp. nov.
Pl. 2, Figs. 20-21

Holotype — Pl. 2, Fig. 21; Slide No. 7759b-5.
Locality — Bore Hole No. CM-1, Senegal, N.W. Africa.
Horizon — Maestrichtian-Campanian.
Diagnosis — Shell elongate to oval in outline, delicate. Capsule large, completely filling periphragm cavity. Periphragm extending both in epi-and hypotract forming one apical and two antapical horns. Transverse furrow or girdle circular. Shell walls smooth. No archaeopyle seen.

Dimensions

Holotype — Shell-length 70 μ, breadth 42 μ; Capsule-length 50 μ, breadth 42 μ, Girdle 4 μ broad; Apical horn-length 8 μ, breadth 8 μ; Antapical horn-length 16 μ, breadth 6 μ.

Observed range — Shell-length 60-100 μ, breadth 40-60 μ; Capsule length 50-60 μ, breadth 40-50 μ; Apical horn-length 8-35 μ, breadth 8-20; Antapical horn-length 6-30 μ, breadth 4-11 μ.

Comparison and Discussion

Forms presently described under *Geiselodinium* show close resemblance with general shell shape of *Deflandrea* but the non-cavate shell without archaeopyle prevents its treatment under *Deflandrea*. Norris and Sarjeant (1964, p. 30) have suggested that *Geiselodinium* can be treated as sub-genus of *Deflandrea* till its generic entity is not classified. But we maintain cavate cyst feature as most important for separating *Deflandrea* from other genera and therefore, propose to maintain *Geiselodinium* at generic level. *Astrocysta* Davey (1970) seems to be closely related to *Geiselodinium*.

Cyst-family — Uncertain

Genus — *Diconodinium* Eisenack & Cookson 1960

Diconodinium acutum sp. nov.

Pl. 3, Figs. 41-42

Holotype — Pl. 3, Fig. 1; Slide No. 5121-4.

Locality — Bore Hole No. CM-1, Senegal, N.W. Africa.

Horizon — Aptian.

Diagnosis — Shell fusiform, without tabulation and capsule, divided almost equally by a circular girdle. No indication of longitudinal furrow. Both epitheca and hypotheca terminate into an acute short conical end. Shell membrane thin, granulate.

Dimensions

Holotype — Shell-length 60 μ, breadth 36·4 μ; Girdle-breadth 5 μ.

Observed range — Shell-length 60-70 μ, breadth 30-40 μ; Girdle-breadth 4·6 μ.

Comparison — *D. acutum* sp. nov. compares well with *D. arcticum* Manum & Cookson (1964) and *D. glabrum* Eisenack and Cookson (1960) in having granular shell surface but differs in apical process termination. The comparable species have serrate and bifurcate processes.

General Discussion — From the perusal of dinoflagellate literature it seems that more than 60 species of the genus *Deflandrea* are known to occur from different parts of the world ranging in age from Lower Cretaceous to Tertiary. Manum and Cookson (1964, p, 31) are of the opinion that the genus *Deflandrea* has its main distribution in upper Cretaceous and younger beds.

Except for the recent report of *Deflandrea echinoides* Davey (1970), *D. granulifera* var. *tenuis* Davey (1970) and *D. acribis* Davey & Verdier (1971) from Albian-Cenomanian sediments, all the other species from Lower Cretaceous seem to form a single morphographic series having delicate, thin cavate cysts with marked girdle, only one non-axial strongly developed antapical horn and an apical horn. This made it possible to separate these forms from *Deflandrea* to *Subtilisphaera* gen. nov.

The *subtilisphaera* species listed earlier excludes the following four species viz. *Deflandea glomerata* Davey, *D. globosa* Davey, *D. suspecta* Davey and *D. euthema* Davey and Verdier, as they seem to be different from both *Deflandrea* and *Subtilisphaera* in one or the other features. We treat them as doubtful *Deflandrea* species. This leads to postulate that *Deflandrea* appeared first in Upper Albian, if the geological extension of *Deflandrea echinoidea* and occurrence of *D. granulifera* var. *tenuis* and *D. acribis* in Albian is certain. Otherwise, *Deflandrea* can be treated as an Upper Cretaceous — Tertiary genus.

The geologic distribution of *Subtilisphaera*, *Deflandrea* and *Wetzeliellia* (chart 1) shows that each genus evolved and reached its maximum independently marking distinct geological intervals. *Subtilisphaera* appeared in Lower Cretaceous and reached its maximum development both quantitatively and qualitatively in Aptian-Albian. Later, it dwindled in Upper Cretaceous where *Deflandrea* appeared, obtaining its optinum in Senonian. *Deflandrea* extends equally well in Tertiary but shows decline in frequency. At the dawn of Tertiary (Palaeocene) *Wetzeliellia* takes the lead.

Apart from their stratigraphic importance, it is also interesting to note that they suggest an evolutionary trend from simple thin walled to complex thick walled

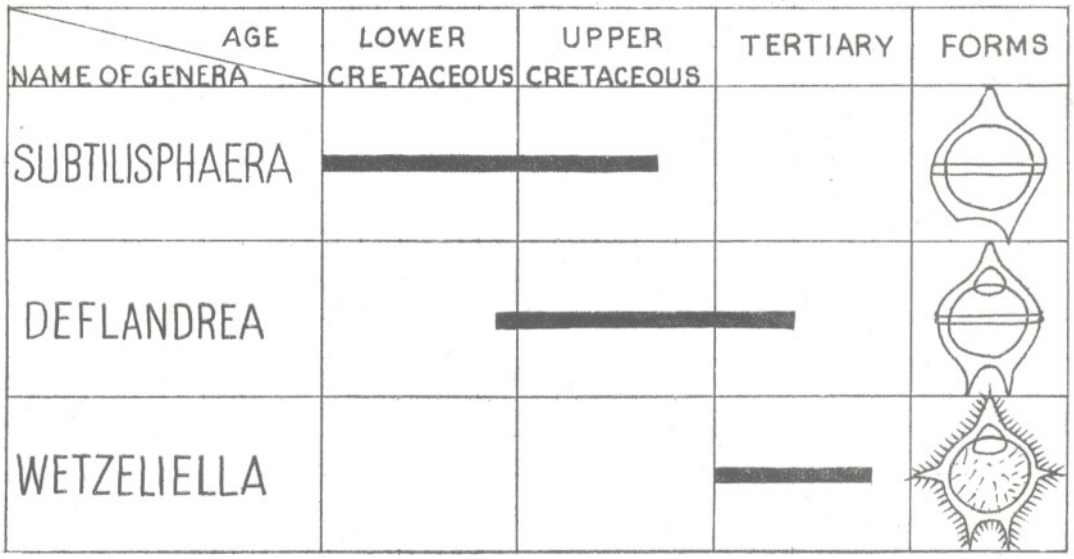


CHART 1 — Stratigraphic distribution of *Subtilisphaera, Deflandrea* and *Wetzeliella.*

dinoflagellate cysts. The development and number of horn in these forms seem to have evolved gradually, the maximum was obtained in *Wetzeliellia* which possess five horns, two extra lateral horns as compared to three horns in *Deflandrea* and two horns in *Subtilisphaera.* Alberti (1959) suggested evolutionary trends in the genus *Deflandrea,* tracing it from Lower Cretaceous species. The study of Senegal Cretaceous sequence shows that the true *Deflandrea* is unrepresented here and their place is taken by the other genera of the same family, viz. *Senegalinium* and *Geiselodinium.*

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EXPLANATION OF PLATES

(All photographs magnified 500 × unless otherwise stated).

PLATE 1

Senegalinium gen. nov.

1. *S. bicavatum* sp. nov. Slide No. 8461-1. Campanian.

2. Same, apical portion magnified 1000 × showing localized thickening of endophragm below the apical horn.

3. Same, antapical portion magnified 1000 × showing localized thickening of endophragm along the pericoel area, well developed along the right antapical pericoel.

4. *S. bicavatum* sp. nov. Slide No. 8632-12. Maestrichtian.

5-6. *S. psilatum* sp. nov. Slide Nos. 8459-16 and 8459a-4. Campanian-Maestrichtian.

7-11. *S. granulostriatum* sp. nov. Slide Nos. 8455-5, 8456-3, 10197a-1, 8704a-9 and 8454a-7. Maestrichtian.

PLATE 2

12-13. *Senegalinium dubium* sp. nov. Slide Nos. 5930-1 & 5930-2. Maestrichtian.

14. *S.* sp. D. Slide No. 8704-14. Maestrichtian.

15. *S.* sp. A. Slide No. 8460-7; Campanian-Maestrichtian.

16. *S. trisinum* sp. nov. Slide No. 8632-11. Maestrichtian.

17. *S.* sp. B. Slide No. 8704-5. Maestrichtiain.

18. *S. granulostriatum* sp. nov. Slide No. 8704-10. Maestrichtian.

19. *S.* sp. C. Slide No. 8457-5. Maestrichtian.

20-21. *Geisleodinium psilatum* sp. nov. Slide Nos. 8454-6 and 7759b-5. Campanian-Maestrichtian.

22. *Subtilisphaera* sp. Sl de No. 8455a-1. Maestrichtian.

23-24. *Palaeocystodinium microgranulatum* sp. nov. Slide Nos. 7763-1 and 8460-11; Campanan-Maestrichtian.

PLATE 3

26-28. *Palaeocystodinium punctatum* sp. nov. Slide Nos. 8457a-9, 8457b-5 and 8458-1. Maestrichtian.

29. *Senegalinium granulostriatum* sp. nov. Slide No. 8457a-4. Campanian-Maestrichtian.

30. *Palaeocystodinium microgranulatum* sp. nov. Slide Nos. 8454a-5; Maestrichtian.

31-33. *Subtilisphaera senegalensis* sp. nov. Slide Nos. 7911-1, 7946-3 and 7946-1; Aptian.

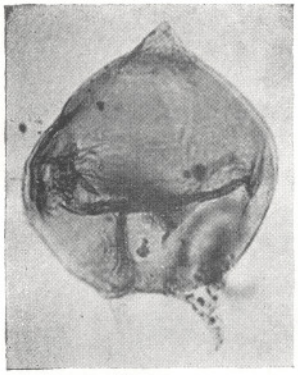
34-35. *S.* (*Deflandrea*) *ventriosa* (Alberti) comb. nov. Slide Nos. 5957-2 and 5121a-9; ? Campanian and Aptian.

36-37. *S. scabrata* sp. nov. Slide Nos. 5121a-10 and 7299-9. Aptian.

38-39. *S. scabrata.* Slide Nos. 8021-1 and 5123-2. Barremian-Aptian.

40. *Subtilisphaera* sp. A. Slide No. 7301-2. Aptian.

41-42. *Diconodinium acutum* sp. nov. Slide Nos. 5121-4 and 5121a-4. Aptian.



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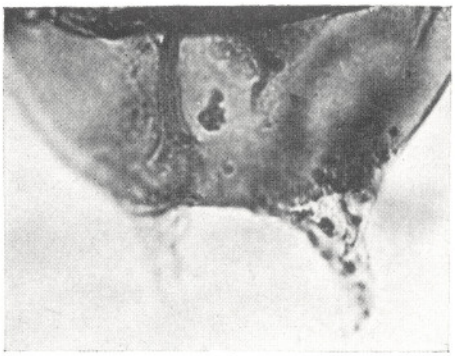

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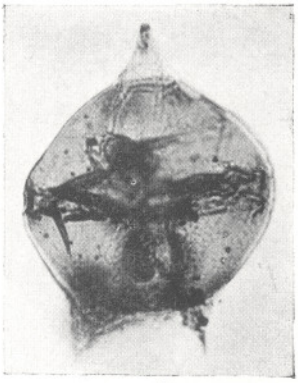

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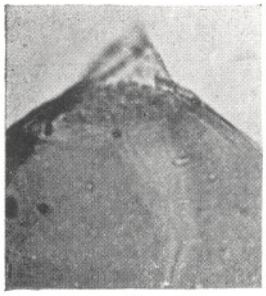

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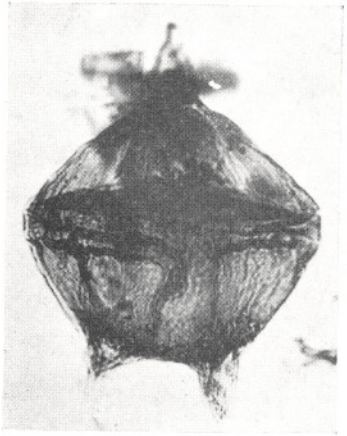

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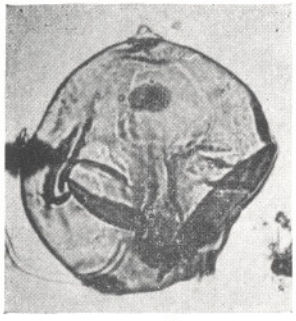

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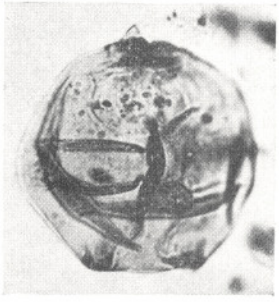

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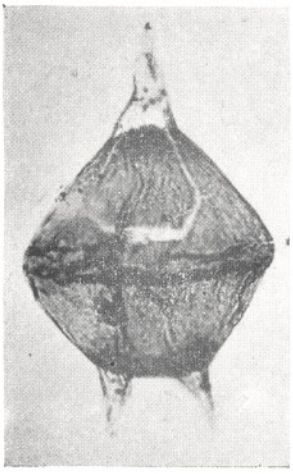

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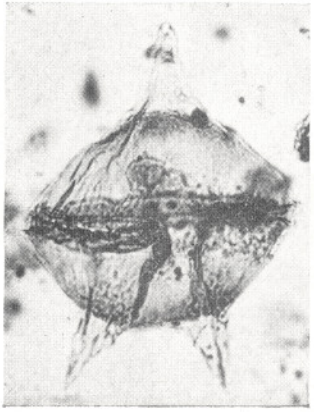

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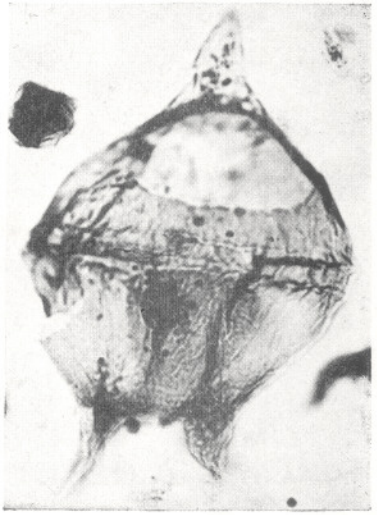

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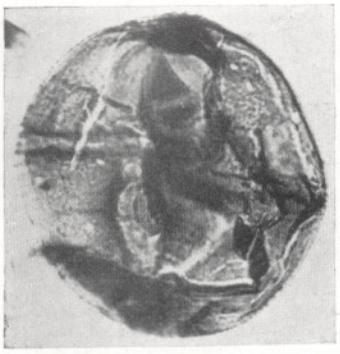

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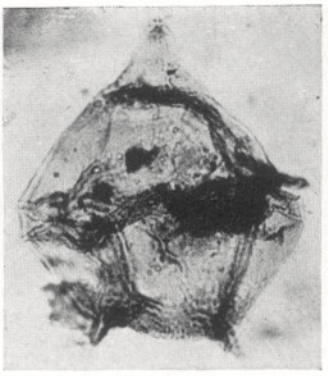

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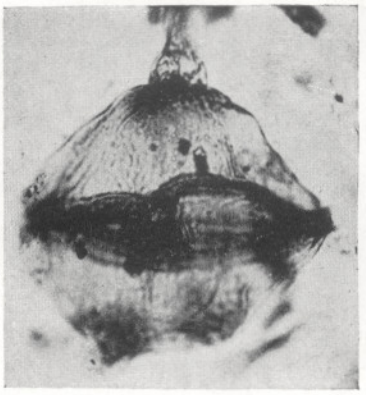

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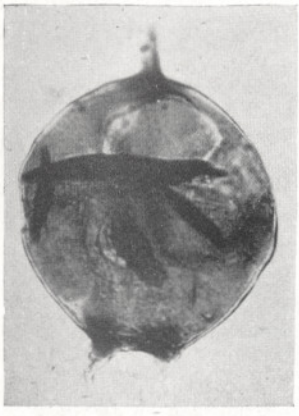

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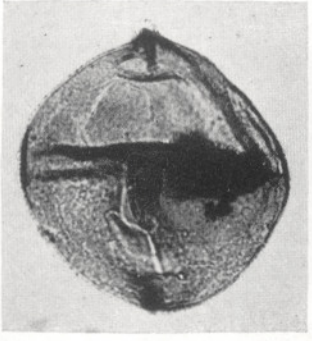

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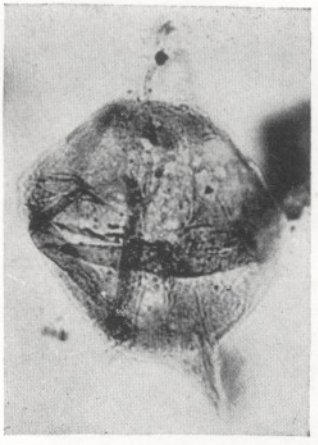

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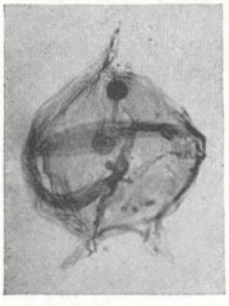

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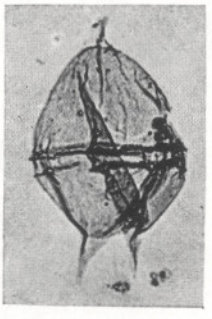

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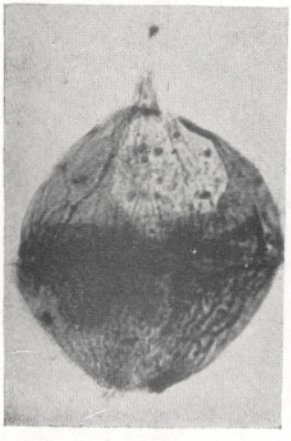

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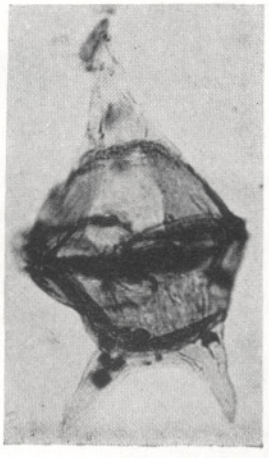

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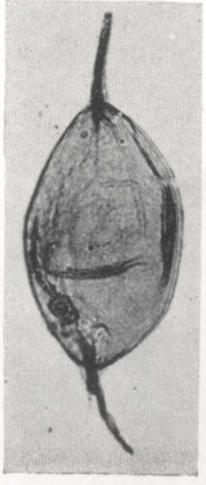

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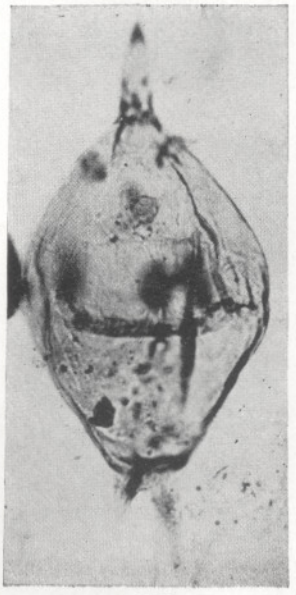

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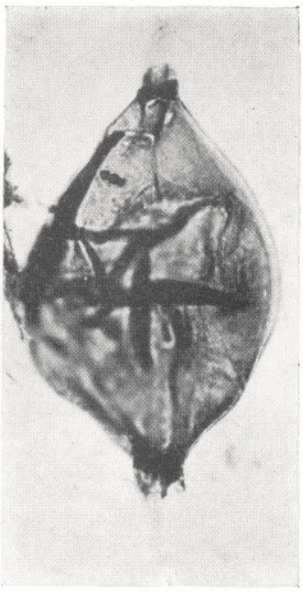

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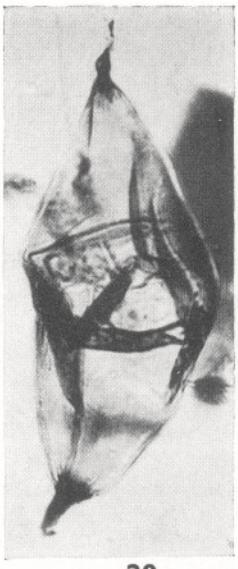

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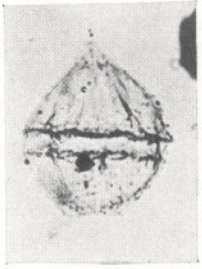

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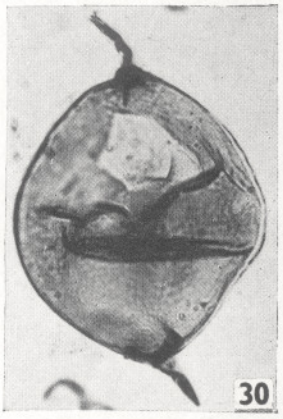

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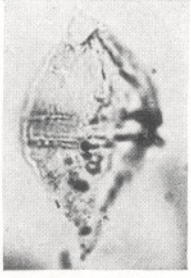

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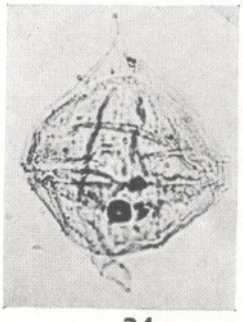

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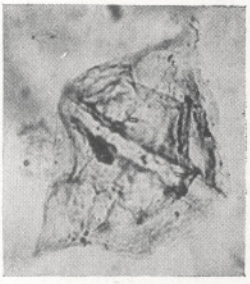

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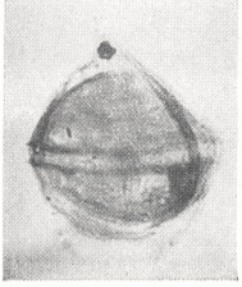

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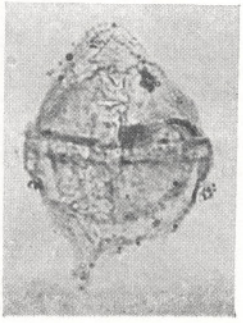

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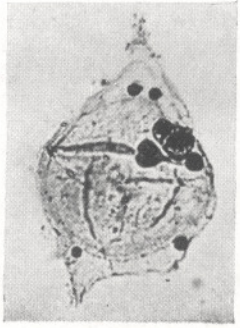

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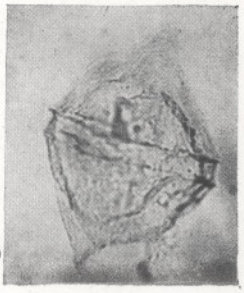

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