CRETACEOUS MICROPLANKTON FROM SENEGAL BASIN, W. AFRICA, Pt. II. SYSTEMATICS AND BIOSTRATIGRAPHY

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ABSTRACT

Present communication incorporates systematic study of Cretaceous microplankton from Senegal Basin, ranging in age from Aptian to Maestrichtian. Our previous remark (1973) of Barremian to Maestrichtian is corrected here. Dinoflagellates and acritarchs have been recovered from five deep wells viz., CM-4, CM-1, BR-1, KtF-1 and DgF-1. It includes 37 genera and 52 species. Out of these 17 species are new. Biostratigraphic study on the basis of qualitative and quantitative analysis has revealed the presence of five assemblage zones viz., Zone-I (Lower-?Upper Aptian); Zone-II (Albo-Aptian); Zone-III(?) (? Albian-Cenomanian); Zone-IV (Campanian-Maestrichtian) and Zone-V (Maestrichtian).

INTRODUCTION

Mesozoic and Tertiary sediments in the African continent are best developed along the northern, eastern and western borders (Text-fig. 1). Senegal Basin in particular is situated at the north-western border of the African shield. It covers about 500 Km² area.

The basin provides a sedimentary sequence from Jurassic to Oligocene from east to west. Along the eastern margin of the basin patches of Palaeozoic sediments have also been marked (CASTELAIN, 1964, p. 159; pl. 3).

A detailed palaeontological work in the basin has been carried out by SPENGLER *et al.* (1964) and CASTELAIN (1964) dealing with foraminifers. Palynological study has been made by STOVER (1963), JARDINE AND MAGLOIRE (1964), KIESER (1967) but no phytoplankton work has so far been published from this basin except for the authors (1973), which is a part of this work.

STRATIGRAPHIC AND GEOGRAPHIC LOCATION OF THE SAMPLES

The analysis of present Cretaceous dinoflagellates and acritarchs is based upon the bore-hole samples collected at various depths from five deep wells viz., CM-4, CM-1, BR-1, DgF-1 and KtF-1. Other two deep wells Sk-1 and CM-2 remained unproductive. The distance between the productive bore holes ranges within 200 km.

The average thickness of Cretaceous sediments in the Senegal Basin has been reported to be 6,370 metres (CASTELAIN, 1965, p. 140; Fig. 1) representing all stratigraphic divisions from Neocomian to Maestrichtian. Of these, Albo-Aptian and Maestrichtian sediments are reported to be best developed.

The details of sample depths (numbers refer to the true depth in the bore hole), their gross lithology, stratigraphic position both in relation to fauna and flora, and palynological zones are reproduced in Text-figs. 2 to 6. Except for the floral age and palynozones, rest has been reproduced from the logs prepared by S.A.P.; COPETAO; S.P.S. and C.F.P.

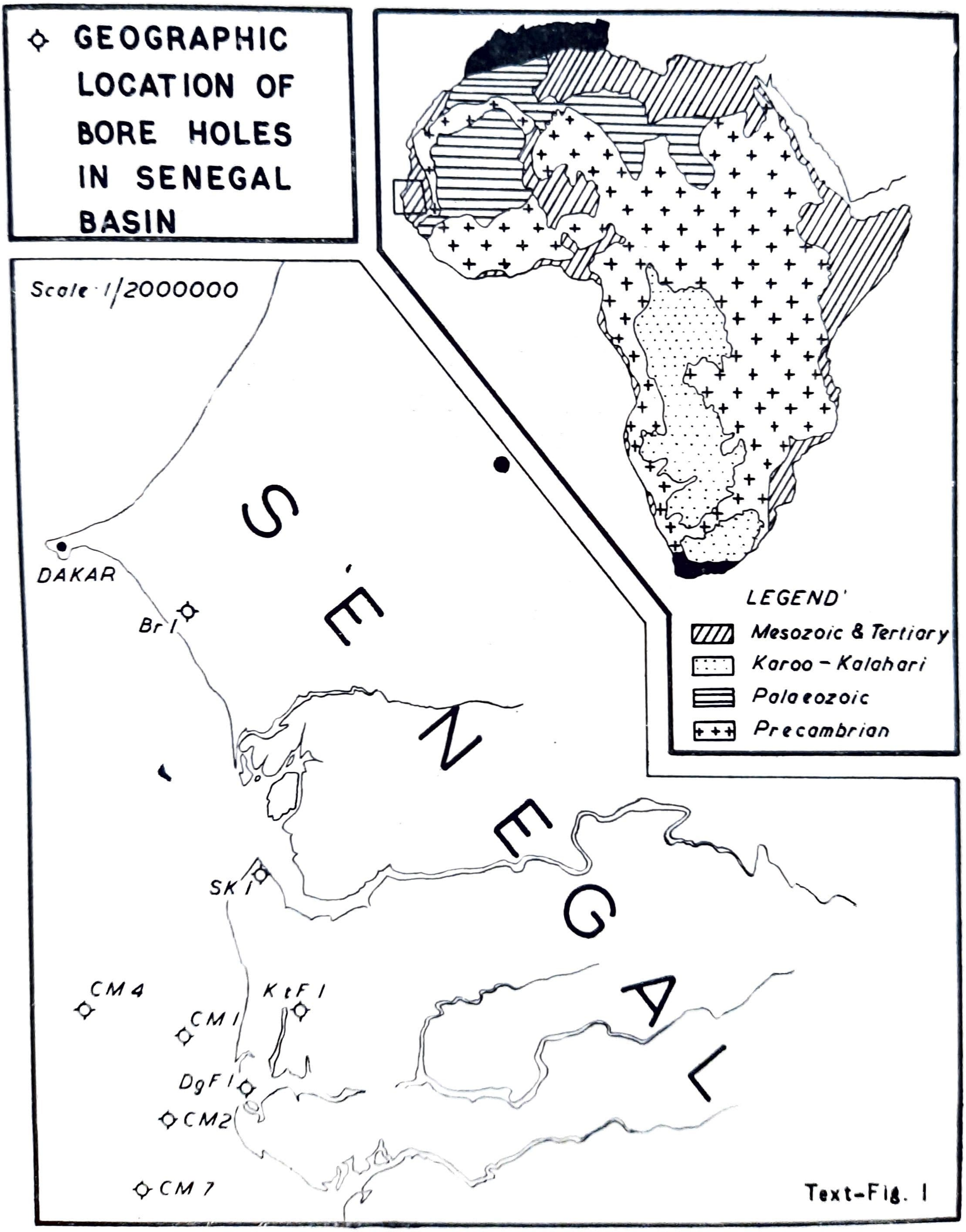
All the samples considered for chemical analysis consisted of standard cores, calbes

Geophytology, **5** (2): 126-171, 1975

and a few cuttings. These were macerated under the conventional Acid/Alkali treatment. The final slides were prepared in glycerine gelly.

The figured slides are housed at the Laboratoire Central, Compagnie Francaise des Pétroles, Talence, France.

The classification of fossil dinoflagellates and acritarchs followed in the present work is in accordance with the system proposed by Sarjeant and Downie (1974) and Downie *et al.* (1963) respectively.



Text-Fig. 1

SYSTEMATIC PALYNOLOGY

Class—Dinophyceae Pascher
Subclass—Diniferophycidae Bergh
Order—Gymnodiniales Schütt
Family—Dinogymniaceae Sarjeant & Downie
Genus—*Dinogymnium* Evitt, Clarke & Verdier
- *D. major* sp. nov.
- *D. biconicum* sp. nov.
- *D. acuminatum* Evitt *et al.*
- *D. westralium* (Cookson & Eisenack) Evitt *et al.*
- *D. denticulatum* (Alberti) Evitt *et al.*
- *D.* sp. A
- *D.* sp. B
- *D.* sp. C.

Order—Peridiniales Schütt
Family—Gonyaulacystaceae (Sarjeant & Downie) Sarjeant & Downie
Genus—*Gonyaulacysta* Deflandre emend. Sarjeant
- *G. orthoceras* (Eisenack) Sarjeant
- *G. edwardsi* (Cookson & Eisenack) Clarke & Verdier
- *G. helicoidea* (Cookson & Eisenack) Sarjeant
- *G.* sp. cf. *C. hadra* Sarjeant
- *G.* sp. A
- *G.* sp. B
- *G.* sp. C

Genus—*Leptodinium* Klement
- *L. micropunctatum* sp. nov.

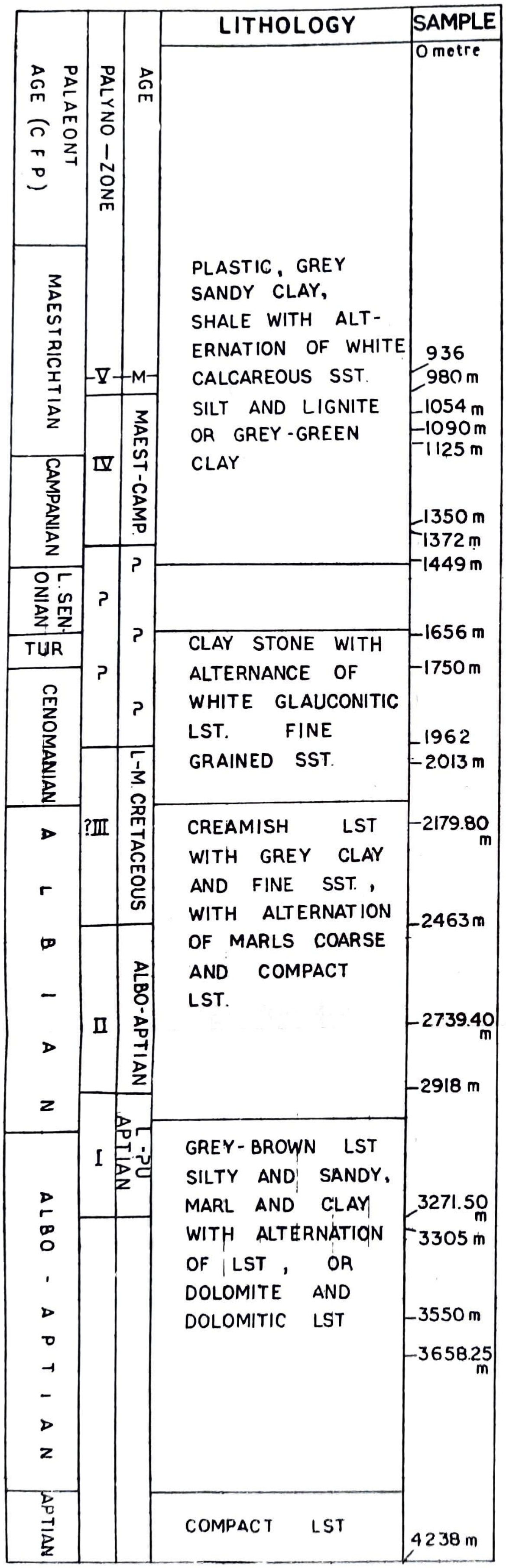
Family—Apteodiniaceae Eisenack emend. Sarjeant & Downie
Genus—*Apteodinium* Eisenack
- *A. spinosum* sp. nov.
- *A.* sp. A

Genus—*Trichodinium* Eisenack & Cookson
- *T. bifurcatum* sp. nov.
- *T.* sp. A

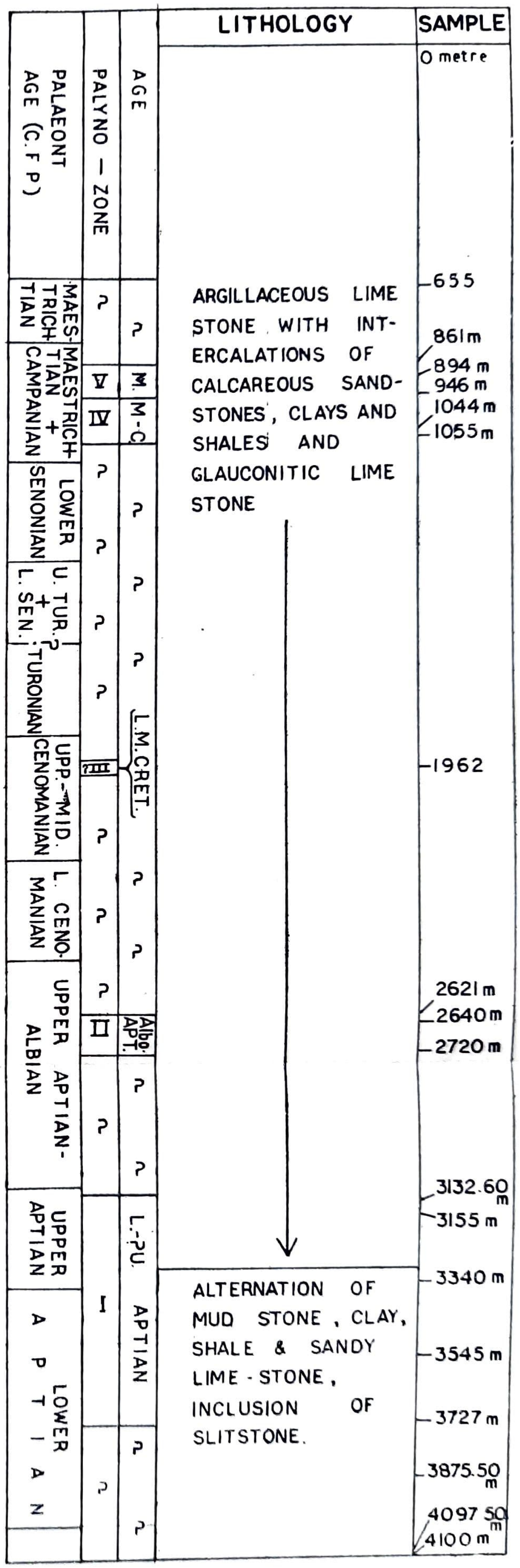
Family—Fromeaceae Sarjeant & Downie emend. Sarjeant & Downie
Genus—*Fromea* Cookson & Eisenack
- *F. elongata* sp. nov.

Family—*Spiniferitaceae* Sarjeant emend. Sarjeant & Downie
Genus—*Spiniferites* Mantell emend. Sarjeant
- *S. cingulatus* (Wetzel) Sarjeant
- *S. crassimuratus* (Davey & Williams) Sarjeant
- *S. ramosus* subsp. *granosus* (Davey & Williams) Lentin & Williams
- *S. ramosus* subsp. *ramosus* (Ehrenberg) Lentin & Williams
- *S. ramosus* var. *reticulatus* (Davey & Williams) Davey & Verdier
- *S. ramosus* subsp. *multibrevis* (Davay & Williams) Lentin & Williams

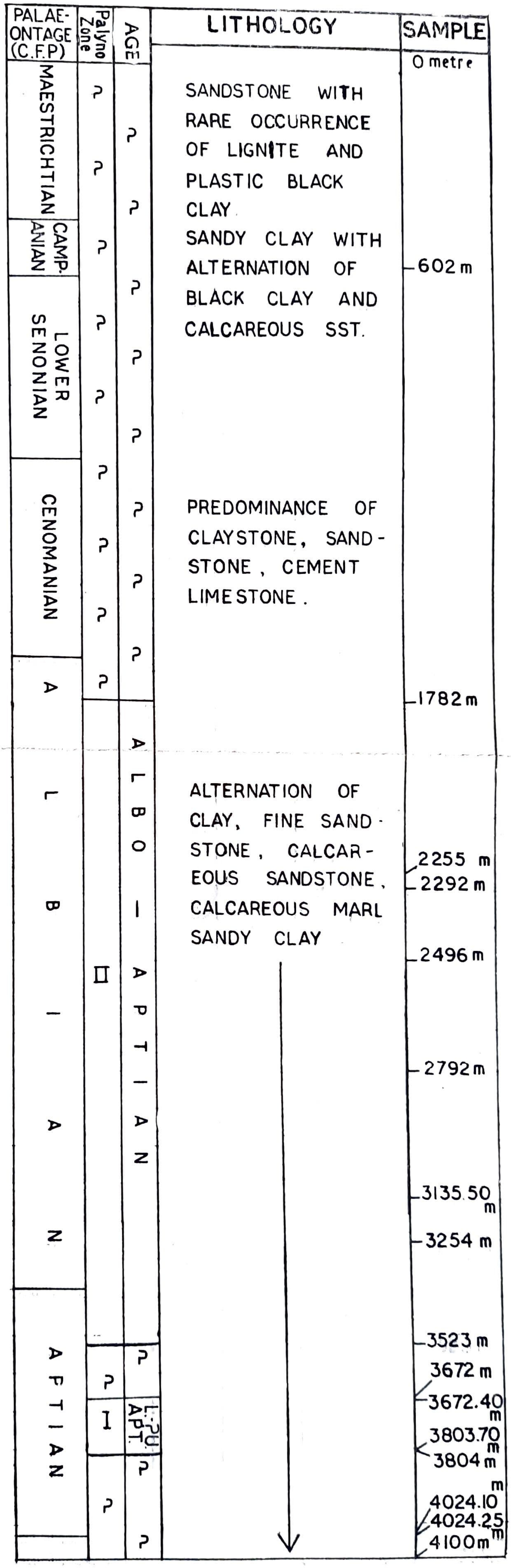
Genus—*Hystrichodinium* Deflandre emend. Sarjeant
- *H.* sp. A



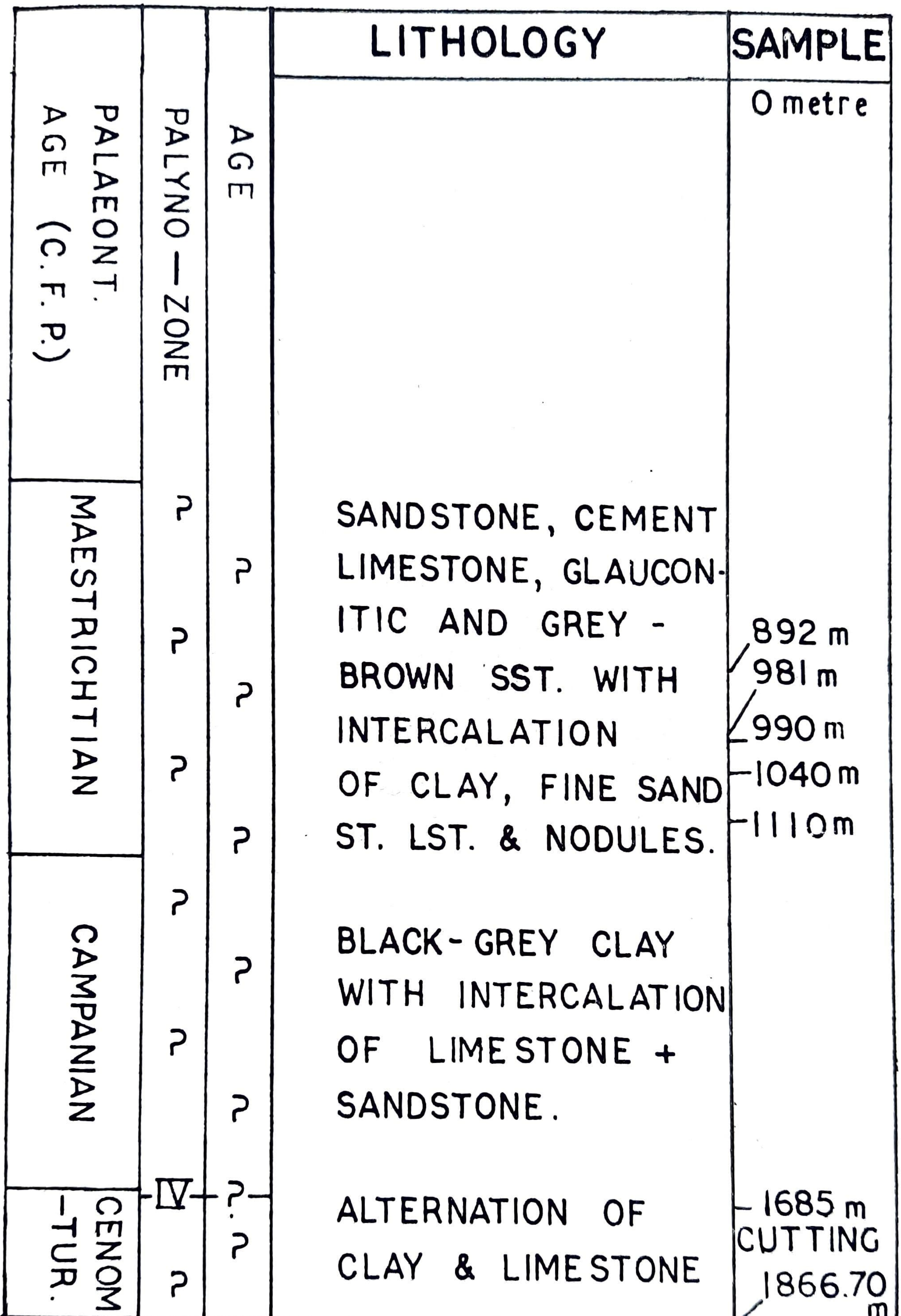
Text-fig. 2. Bore hole no. CM-4



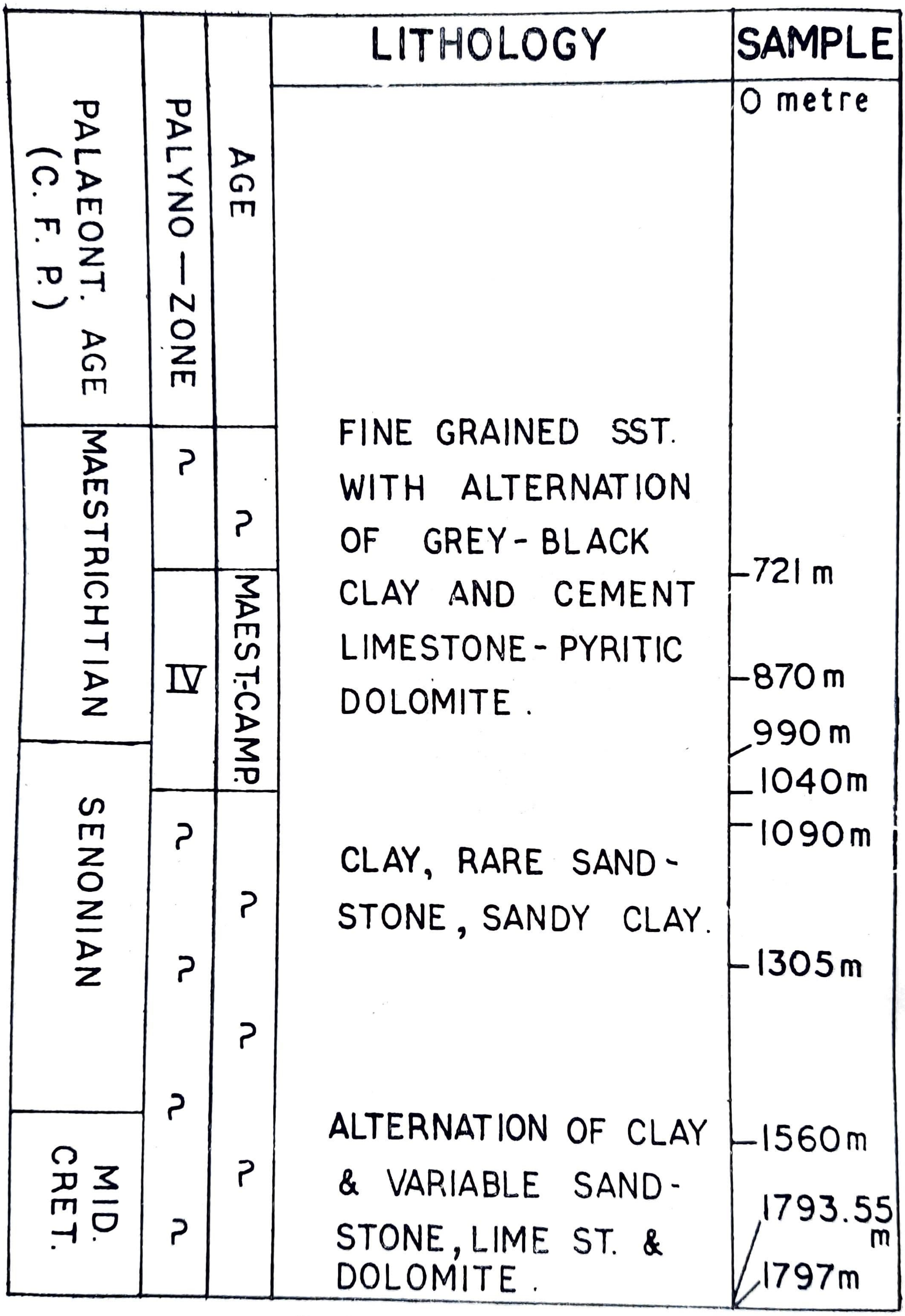
Text-fig. 3. Bore hole no. CM-1



Text-fig. 4. Bore hole no. GM—1



Text-fig. 5. Bore hole no. DgF-1.



Text-fig. 6. Bore hole no. KtF-1.

Genus—*Pterodinium* Eisenack

P. cornutum Cookson & Eisenack

Genus—*Achomosphaera* Evitt

A. sagena Davey & Williams

A. sp. A

A. sp. B

Family—Pareodiniaceae Gocht emend. Sarjeant & Downie

Genus—*Pareodinia* Deflandre emend. Gocht

P. psilata sp. nov.

Family—Toolongiaceae Sarjeant & Downie emend. Sarjeant & Downie

Genus—*Toolongia* Cookson & Eisenack

Toolongia sp. A

Genus—*Dinopterygium* Deflandre

D. sp. A

Family—Deflandreaceae Eisenack emend. Sarjeant & Downie

Genus—*Senegalinium* Jain & Millepied

S. bicavatum Jain & Millepied

S. psilatum Jain & Millepied

S. granulostriatum Jain & Millepied

S. trisinum Jain & Millepied

S. dubium Jain & Millepied

S. sp. A. in Jain & Millepied

S. sp. B. in Jain & Millepied

S. sp. C. in Jain & Millepied

S. sp. *D.* in Jain & Millepied

Genus—*Subtilisphaera* Jain & Millepied

S. senegalensis Jain & Millepied

S. scabrata Jain & Millepied

S. crassigranulosa Jain & Millepied

S. ventriosa (Alberti) Jain & Millepied

S. sp. A. in Jain & Millepied

Genus—*Geiselodinium* Krutzsch

G. psilatum Jain & Millepied

Genus—*Palaeocystodinium* Alberti

P. microgranulatum Jain & Millepied

P. punctatum Jain & Millepied

Family—Pseudoceratiaceae Eisenack emend. Sarjeant & Downie

Genus—*Aptea* Eisenack

A. polymorpha Eisenack

Genus—*Odontochitina* Deflandre emend. Davey

O. costata Alberti emend. Clarke & Verdier

O. operculata (Wetzel) Deflandre & Cookson

Family—Netrelytraceae Sarjeant & Downie

Genus—*Kalyptea* Cookson & Eisenack

K. distincta sp. nov.

K. sp. A

Family—Thalassiphoraceae Gocht emend. Sarjeant & Downie

Genus—*Thalassiphora* Eisenack & Gocht emend. Gocht
Th. maxima sp. nov.
Th. sp. A
Family—Stephodiniaceae Eisenack emend. Sarjeant & Downie
Genus—*Actinotheca* Cookson & Eisenack
Actinotheca sp. A
Family—Scriniocassiaceae Sarjeant & Downie emend. Sarjeant & Downie
Genus—*Gardodinium* Alberti
G. deflandrei Clarke & Verdier
Family—Hystrichosphaeridiaceae Evitt emend. Sarjeant & Downie
Genus—*Hystrichosphaeridium* Deflandre emened. Davey & Williams
H. sp. cf. *H. simplicispinum* Davey & Williams
Genus—*Oligosphaeridium* Davey & Williams
O. complex (White) Davey & Williams
O. sp. cf. *O. pulcherrimum* (Deflandre & Cookson) Davey & Williams.
Genus—*Litosphaeridium* Davey & Williams emend. Davey & Verdier
L. sp. A
L. sp. B
Family—Cordosphaeridiaceae Sarjeant & Downie
Genus—*Cordosphaeridium* Eisenack emend. Davey
C. senegalensis sp. nov.
Family—Systematophoraceae Sarjeant & Downie
Genus—*Coronifera* Cookson & Eisenack
C. oceanica Cookson & Eisenack
Family—Cleistosphaeridiaceae Sarjeant & Downie
Genus—*Cleistosphaeridium* Davey *et al.*
C. brevispinosum sp. nov.
C. sp. A
C. sp. B
Genus—*Polysphaeridium* Davey & Williams
P. elongatum sp. nov.
P. punctatum sp. nov.
P. granulosum sp. nov.
Family—Areoligeraceae Evitt emend. Sarjeant & Downie
Genus—*Cyclonephelium* Deflandre & Cookson emend. Cookson & Eisenack
C. distinctum Deflandre & Cookson
C. sp. A
Family—Canningiaceae Sarjeant & Downie emend. Sarjeant & Downie
Genus—*Tenua* Eisenack
T. dubius sp. nov.
T. anaphrissa (Sarjeant) Benedek
T. sp. cf. *T. hystricella* Eisenack emend. Sarjeant
T. rioulti Sarjeant
Family—Cannosphaeropsitaceae Sarjeant & Downie emend. Sarjeant & Downie

Genus—*Cannosphaeropsis* Wetzel emend. Williams & Downie
C. sp. A.
Family—Exochosphaeridiaceae Sarjeant & Downie
Genus—*Exochosphaeridium* Davey *et al.*
E. sp. cf. *E. bifidum* (Clarke & Verdier) Clarke *et al.*
Family—Homotrybliaceae Sarjeant & Downie emend. Sarjeant & Downie
Genus—*Callaiosphaeridium* Davey & Williams
C. sp. A
Family—Uncertain
Genus—*Diconodinium* Eisenack & Cookson
D. acutum Jain & Millepied
D. distinctum sp. nov.
Group—*Acritarcha* Evitt
Subgroup—Pteromorphitae Downie, Evitt & Sarjeant
Genus—*Pterospermopsis* Wetzel
P. ovatus sp. nov.
P. concentricus sp. nov.
P. barbarae Gorka
P. sp. A
P. sp. B
P. sp. C
Subgroup—Acanthomorphitae Dow ie, Evitt & Sarjeant
Genus—*Baltisphaeridium* Eisenack emend. Downie & Sarjeant
B. whitei (Deflandre & Courteville) Sarjeant
B. sp. A
B. sp. B

DESCRIPTION

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

Type species—*D. acuminatum* E. C. & V., 1967

Dinogymnium major sp. nov. (Pl. 1, Figs. 1—2).

Holotype—Pl. 1, Fig. 2; Slide No. 8668a—12.

Type locality—Bore hole no. CM—4, depth 980 m; Senegal Basin, W. Africa.

Horizon—Campanian—Maestrichtian.

Diagnosis—Shell biconical, cingulum prominent, dividing shell into two unequal halves, epitract much longer and wider than hypotract; apical and antapical ends rounded; longitudinal folds many, linear, regular, running in both epi-and hypotract from cingulum to poles, leaving short unfolded area at apex in epitract. Wall canals seen. Sulcus in hypotract present. Shell surface granulate. Archaeopyle apical.

Measurement	*Holotype*	*Range*
Shell length	147 μm	147—227 μm
Shell width	91 μm	60—120 μm
Cingulum Index	60	56— 66

Comparison—*Dinogymnium maior* sp. nov. compares best with the type species *D. acuminatum* Evitt *et al.* (1967) in having scabrate-granulate shell surface, similar apical and antapical ends and the presence of wall canals. But differs mainly in its much larger size and greater cingulum index which is much beyond the range of *D. acuminatum*.

Dinogymnium biconicum sp. nov. (Pl. 1, Figs. 3-4)

Holotype—Pl. 1, Fig. 4; Slide No. 8668a-7.

Type Locality—Bore hole no. CM-4, depth 980 m; Senegal Basin, W. Africa.

Horizon—Campanian—Maestrichtian.

Diagnosis—Shell biconical, apical and antapical ends acutely pointed; cingulum distinct, dividing shell into two unequal halves, epitract much longer than hypotract; longitudinal folds running from cingulum to poles in both epi- and hypotract, simple, distantly placed, converging at poles; shell surface scabrate. Wall canals not discernible. Sulcus present. Archaeopyle apical, elongate.

Measurements	*Holotype*	*Range*
Shell length ..	.. 270 μm ..	.. 217—270 μm
Shell width ..	.. 133 μm ..	.. 98—133 μm
Cingulum Index ..	.. 62 ..	.. 60— 62

Comparison—*D. biconicum* sp. nov. differs from *D. major* sp. nov. and other species of the genus in its larger size and acutely pointed apical and antapical ends.

Dinogymnium acuminatum Evitt *et al.*, 1967 (Pl. 1, Figs. 5—8)

Syn.

1967—*Gymnodinium nelsonense* Cookson, in Drugg, p. 72; Pl. 1, Figs. 4-5.

Remarks—This species is restricted to Maestrichtian sediments in Senegal Basin. But some specimens have been recovered from the Turonian level also in the bore hole CM-4. Since the Turonian specimen comes from a cutting sample, the possibility of contamination can not be ruled-out. The vertical distribution of this species is here maintained only at the Maestrichtian level.

Geologic and geographic distribution—Maestrichtian of California, U.S.A. (Evitt *et al.* 1967); Maestrichtian of California U.S.A. (Drugg, 1967); Maestrichtian of Lower Assam, India (Jain *et al.*, 1975); Maestrichtian of Senegal Basin, W. Africa (Present study).

Dinogymnium westralium (Cookson & Eisenack) Evitt *et al.*, 1967 (Pl. 1, Fig. 9)

Remarks—In the Senegal sequence this species marks its first appearance at Campanian-Maestrichtian level of bore hole CM-4 and is very poorly represented. It has been recorded from a cutting sample at a depth of 1400 m in bore hole CM-4.

Geologic and geographic distribution—Senonian of W. Australia (See Evitt *et al.*, 1967); Campanian-Maestrichtian of Senegal Basin, W. Africa (Present study).

Dinogymnium denticulatum (Alberti) Evitt *et al.*, 1967 (Pl. 1, Fig. 10)

Geologic and geographic distribution—Senonian of Germany (ALBERTI, 1961); Campanian-Maestrichtian of Senegal Basin, W. Africa (Present study).

Dinogymnium sp. A (Pl. 1, Fig. 11)

Description—Shell biconical, elongated, apices broadly rounded; epitract larger than hypotract, cingulum index 61. Transverse furrow distinct, not deep. Longitudinal folds or ridges few in both epi- and hypotract, running from transverse furrow to poles. Shell surface finely structured. Archaeopyle apical.

Remarks—It has been recorded from bore hole CM-1, at a depth of 1055 metres.

Dinogymnium sp. B (Pl. 1, Fig. 12)

Description—Shell oblong, 53×48 μm in size, epi- and hypotract ± equal, cingulum broad; cingulum index 43; epitract dome shaped, hypotract broadly convex; longitudinal folds very few or almost nil, only full length folds seen due to thinness of shell membrane. Surface granular. Archaeopyle apical.

Remarks—Only a single specimen has been recovered from bore hole BR-1 at a depth of 602 metres.

Dinogymnium sp. C (Pl. 1, Fig. 13)

Description—Shell biconical, 80×34 μm in size, transverse furrow 8.5 μm broad, equally dividing shell into epi- and hypotract; cingulum index 25; apices rounded; longitudinal ribs many in both halves, some longitudinal ribs in epitract show dentation along margin. Surface finely granular. Archaeopyle apical, elongate.

Remarks—Specimens have been recovered from bore hole no. CM-4 at a depth of 1656 metres. At this level cutting samples were collected and therefore its Turonian age is doubtful.

Genus—**Gonyaulacysta** Deflandre emend. Sarjeant, 1966

Type species—*Gonyaulacysta jurassica* (Deflandre) Deflandre, 1964

Gonyaulacysta orthoceras (Eisenack) Sarjeant, 1966 (Pl. 2, Fig. 20)

Remarks—Senegal specimens show the presence of only three apical (3′) and four cingular plates.

Geologic and geographic distribution—Upper Valanginian to Turonian (SARJEANT, 1966; SINGH, 1971); Albo-Aptian of Senegal Basin, W. Africa (Present study).

Gonyaulacysta edwardsi (Cookson & Eisenack) Clarke & Verdier, 1967 (Pl. 2, Fig. 19)

Geologic and geographic distribution—Albian-Campanian (See SINGH, 1971, p. 304); Albo-Aptian of Senegal Basin, W. Africa (Present study).

Gonyaulacysta helicoidea (Eisenack & Cookson) Sarjeant, 1966 (Pl. 2, Fig. 25)

Geologic and geographic distribution—Barremian to Middle Albian (See SINGH, 1971, p. 307); Albo-Aptian of Senegal Basin, W. Africa (Present study).

Gonyaulacysta sp. cf. **G. hadra** Sarjeant, 1966 (Pl. 2, Fig. 26)

Description—Shell spheroidal, 58.5×80 μm in size; apical horn tapering, 20 μm high. Tabulation 4′,oa, 6″,? 3C, 4‴, op, 1⁗; crests very low; surface granulate; cingulum spiral, 4 μm wide. Wall two layered with thin periphragm and thick endophragm.

Remarks—Present fossils possess all the important features of *Gonyaulacysta hadra* Sarjeant (1966) but differ only in its smaller size and doubtful tabulation. It has been recovered from bore hole no. BR-1 at a depth of 3135.50 metres (Albo-Aptian).

Gonyaulacysta sp. A (Pl. 2, Figs. 21-22)

Description—Shell pentagonal in shape, 97×80 μm in size; cingulum helicoid, seen displaced in two halves. Tabulation 4′, 2a, 3″, ?C, 6‴, 1p, 1⁗. Cingular plates not discernible. Archaeopyle elongate, preicingular plate 3 occupying most of precingular dorsal area. Apical horn narrow, 1/4 of theca length (20 μm long), longitudinal furrow present. Crest low, at places ornamented with short spines or processes. Process end usually bifurcate.

Remarks—A single specimen has deen recovered from a cutting sample of bore hole no. BR-I at a depth of 2492.00 metres (Albian). It shows its closest resemblance with *Gonyaulacysta* (*Gonyaulax*) *cladophora* subsp. *cladophora* (Deflandre) Lentin & Williams (1973) described from Jurassic sediments, in having more or less similar archaeopyle position, bifid processes on the crest surface and size. But differs in indeterminable cingular plates.

Gonyaulacysta sp. B (Pl. 2, Fig. 28).

Description—Shell spherical, 84.5×61 μm in size, thick walled (1.5 μm), double layered; periphragm develops long apical horn (28 μm) having bifid apex. Cingulum narrow, 3 μm wide, dividing theca into two unequal halves. Tabulation present, not well preserved.

Remarks—Figured specimen has been recovered from bore hole no. BR-1 at a depth of 3911 metres (Lower- ? Upper Aptian).

Gonyaulacysta sp. C (Pl. 2, Fig. 24)

Description—Shell ± spherical, 119×77 μm in size, cingulum circular, dividing cyst into two ± equal halves. Apical horn very long, 42×14 μm in size, periphragm spinose, marked with plates, sutures low. Tabulation that of genus. Archaeopyle not discernible.

Remarks—This form has been recovered from bore hole no. BR-I at a depth of 3523 metres (Albo-Aptian). This is distinguished from other species of the genus in having very long apical horn with almost spherical shell shape.

Genus—**Leptodinium** Klement emend. Sarjeant, 1969

Type Species—*Leptodinium subtile* Klement, 1960

Leptodinium micropunctatum sp. nov. (Pl. 2, Figs. 32-33)

Holotype—Pl. 2, Fig. 32; Slide No. 7949-2.

Type locality—Bore hole no. CM-1; depth 3340 metres; Senegal Basin, W. Africa.

Horizon—Lower—?Upper Aptian.

Diagnosis—Shell ovoidal, tabulation not clearly descernible; 4′, 0a, ? 4″, 7C, ?3‴, 1⁗; crests high, scabrate with smooth outer margin. Girdle distinct, laevorotatory, spiral, broad; sulcus remains in hypotract. Archaeopyle not seen. Body wall thick, micropunctate.

Measurements	*Holotype*	*Range*
Body size ..	.. 52×36 μm ..	.. 45—55×35—40 μm
Over all size ..	.. 64×60 μm ..	.. 50×64×50—60 μm
Crest height ..	.. 4—8 μm ..	.. 4—12 μm

Comparison—*Leptodinium micropunctatum* sp. nov. differs from other species of the genus in its micropunctate body wall and scabrate boundary crest surface; *L. alectrolophum* Sarjeant (1966) resembles best but differs in having granulose body and perforate crests.

Remarks—Present forms in their most of the features, e.g., shape, size and tabulation resemble *Leptodinium* but the absence of archaeopyle leaves a doubt for their exact placement. It differs from *Pterodinium* in having cingular plates, but compares well with *Meiourogonyaulax* Sarjeant (1966) in having similar tabulation and raised boundary crests.

Genus—**Apteodinium** Eisenack, 1958

Type species—*Apteodinium granulatum* Eisenack, 1958

Elaborate diagnosis—Shell globular, oval to ovoid with short pointed apical horn without tabulation or only slight indication of tabulation; periphragm ornamented including spines and ridges. Epi- and hypovalves separated by a poor scarcely depressed, unspiraled girdle to well developed one, longitudinal furrow not present. Archaeopyle frequent, precingular (3″) on dorsal side of epivalve. Occasionally a small antapical horn occurs.

Remarks—The generic circumscription has been extended to include forms having spiny or ridged covering and also showing slight indication of tabulation.

Apteodinium spinosum sp. nov. (Pl. 2, Fig. 27)

Holotype—Pl. 2, Fig. 27; Slide No. 7298-19.

Type locality—Bore hole no. BR-1; depth 3135. 50 metres; Senegal Basin, W. Africa.

Horizon—Albo-Aptian.

Diagnosis—Shell ellipsoidal to globular, apical horn well developed, 1/4 of whole shell length, both periphragm and endophragm used in forming apical horn. Girdle distinct, circular, extending slightly laterally, ridges low; epi- and hypotract ± equal; hypotract obtusely rounded. Periphragm spinose, specialized along apical horn, spines at apex giving an appearance of brush; endophragm granular. Archeopyle precingular (3″). Tabulation indication present.

Measurements	*Holotype*	*Range*
Shell length	91 μm	80—120 μm
Shell width	65 μm	55—105 μm
Apical horn length	24.7 μm	15— 25 μm
Apical horn width	16 μm	12— 20 μm
Shell wall thickness	4 μm	2.5-6.5 μm

Comparison—*Apteodinium spinosum* sp. nov. is differenciated from all the other known species of the genus in having spinose periphragm, granular endophragm, brushy apical horn, slight indication of tabulation and large size.

Apteodinium sp. A (Pl. 2, Fig. 23)

Description—Shell large, globular, 117×104 μm in size; apical horn short, surface spiny. Transverse girdle distinct, circular, extending slightly laterally. Both epi- and hypotract equal.

Remarks—Present form has been recovered from bore hole CM-4 at a depth of 327150 metres (Lower—? Upper Aptian). Tabulation in Senegal specimens is not very conclusive otherwise it might have been possible to place it under *Acanthogonyaulax* Sarjeant, (1966).

Genus—**Trichodinium** Eisenack & Cookson emend. Clarke & Verdier, 1967

Type species—*T. pellitum* Eisenack & Cookson, 1960.

Trichodinium bifurcatum sp. nov. (Pl. 1, Fig. 14-16)

Holotype—Pl. 1, Fig. 14; Slide No. 8668-7.

Type locality—Bore hole no. CM-4, depth 980 metres; Senegal Basin, W. Africa.

Horizon—Maestrichtian.

Diagnosis—Shell oval to spherical, girdle narrow; apical horn made up of three large spines with a short central rounded hump in between; longitudinal furrow present, mostly restricted to hypotheca; shell membrane spongeous, punctate, sparcely covered with short spines; spine base broader, tips blunt or bifid, both types occur together. Archaeopyle precingular, formed of one complete plate extending from apex to cingulum. Tabulation indeterminable.

Measurements	*Holotype*	*Range*
Overall shell size	65.5×65.5 μm	60—70 μm
girdle width	5 μm	5—7 μm
apical horn	4×4 μm	4—6×4—6 μm
spine size	4×2.6 μm	2—6×1—3 μm

Comparison—*Trichodinium bifurcatum* sp. nov. resembles best with *T. paucispinum* Eisenack & Cookson (1960) in having apical horn formed by three divergent spines, sparsely placed spines with broader base; but differs in its much smaller size, bifurcated spine types, shorter apical horn with hump like rounded projection in between three divergent spines.

Trichodinium sp. A (Pl. 1, Figs. 17-18)

Description—Shell spherical, 58 μm in diameter; girdle distinct, circular; longitudinal furrow restricted to hypotheca; apical horn dome shaped, formed by the coalescence of several small flat topped processes. Shell surface covered with small flat topped sculpture mixed with grana and baculae. Archaeopyle precingular formed by semicircular plate covering most of the distal diameter of shell along cingulum.

Remarks—Only a single specimen has been recovered from bore hole no. CM-1 at 1055.35 metres (Campanian—Maestrichtian).

Genus—**Fromea** Cookson & Eisenack, 1958

Type species—*F. amphora* Cookson & Eisenack, 1958

Fromea elongata sp. nov. (Pl. 2, Figs. 29-30)

Holotype—Pl. 2, Fig. 30; Slide No. 7299-16.

Type locality—Bore hole no. BR-1, depth 3523 m; Senegal Basin, W. Africa.

Horizon—Albo-Aptian.

Diagnosis—Shell ellipsoidal, without cingulum, sulcus or tabulation. Wall single layered, surface coarsely granulate to some times baculate. Archaeopyle apical, ± circular.

Measurements	*Holotype*	*Range*
Shell size	50×42 μm	50—60×40—42 μm
wall thickness	0.5 μm	0.5 μm

Comparison—*Fromea elongata* sp. nov. compares best with *F. amphora* Cookson & Eisenack (1958) in having ellipsoidal shell but differs in the absence of girdle. *F. acambra* Sah *et al.* (1970) differs in having elongated neck with opening and pitcher shaped shell. The elongated neck with opening in *F. acambra* creates doubt to retain the species under the genus *Fromea. F. warlinghamensis* Gitmez & Sarjeant (1972) differs in its large size and spherical shape.

Genus—**Spiniferities** Mantell emend. Sarjeant, 1970

Type species—*Spiniferites ramosus* (Ebrenberg) Mantell, 1854

Spiniferites cingulatus (Wetzel) Sarjeant, 1970 (Pl. 3, Fig. 34)

Geologic and geographic distribution—Cenomanian to Pleistocene (See Davey & Williams, in Davey *et al.* 1966; p. 39); Albo-Aptian of bore hole no. BR-1, Senegal Basin, W. Africa (Present study).

Spiniferites crassimuratus (Davey & Williams) Sarjeant, 1970 (Pl. 3, Figs. 38-39)

Geologic and geographic distribution—Middle to Upper Cenomanian of England (Davey & Williams, in Davey *et al.*, 1966); Campanian-Maestrichtian of bore hole no. BR-1, Senegal Basin, W. Africa (Present study).

Spiniferites ramosus subsp. granosus (Davey & Williams) Lentin & Williams, 1973 (Pl. 3, Fig. 40)

Geologic and geologic distribution—London clay of England (in Davey *et al.*, 1966); Lower Cretaceous of South India (Jain & Taugourdeau-Lantz, 1973); Maestrichtian of bore hole no. BR-I, Senegal Basin, W. Africa (Present study).

Spiniferites ramosus subsp. ramosus (Ehrenberg) Lentin & Williams, 1973 (Pl. 3, Fig. 36)

Geologic and geographic distribution—Middle Barremian to the Ypresian (Davey & Williams, in Davey *et al.* 1966); Lower Cretaceous of India (Jain & Taugourdeau-Lantz, 1973); Albo-Aptian of bore hole no. BR-1, Senegal Basin, W. Africa, (Present study).

Spiniferites ramosus var. reticulatus (Davey & Williams) Davey & Verdier, 1971 (Pl. 3, Fig. 37)

Remarks—Present specimens have been recovered from Campanian-Maestrichtian samples of bore hole no. CM-4 at a depth of 1055.35 metres. They come under the morphological range of the variety but differs only in having microreticulate surface without much raised crests. These may be taken as extent of variation.

Geologic and geographic distribution—Albian, Canada (Davey, 1969); Cenomanian, England & France (Davey & Williams, 1966; Davey, 1969); Albian, Paris (Davey & Verdier, 1971); Campanian—Maestrichtian of Senegal basin, W. Africa. (Present study).

Spiniferites ramosus subsp. multibrevis (Davey & Williams) Lentin & Williams, 1973 (Pl. 3, Fig. 35)

Geologic and geographic distribution—Hauterivian to early Eocene (See Singh, 1973, p. 352); Albo-Aptian of bore hole no. BR-1, Senegal Basin, W. Africa (Present study).

Genus—**Hystrichodinium** Deflandre emend. Sarjeant, 1966

Type species—*Hystrichodinium pulchrum* Deflandre, 1935

Hystrichodinium sp. A (Pl. 3, Fig. 41)

Description—Shell spherical; 43 μm in diameter, transverse furrow distinct, helicoid, dividing both epi- and hypotract in equal halves. Surface covered with long, finger like processes of uniform height, cylindrical, rounded at top, more than 30 in number, 6.5 × 1.5 μm in size. No distinct tabulation seen. ?Archaeopyle precingular.

Remarks—The figured specimen has been recorded from bore hole no. CM-4 at a depth of 1656 metres from a cutting sample (?Senonian). It shows characteristic finger like processes on the surface which suggest a clear distinction from the known species of the genus. Genus *Hystrichodinium* Deflandre (1935) has been emended by Sarjeant (1966, in Davey *et al.*, 1966) and Clarke and Verdier (1967). The emendations suggested by the authors are the same and therefore, the former has priority over the latter.

Genus—**Pterodinium** Eisenack, 1958

Type species—*Pterodinium aliferum* Eisenack, 1958

Pterodinium cornutum Cookson & Eisenack, 1962 (Pl. 3, Figs. 42-43)

Geologic and geographic distribution—Aptian-Albian (See SINGH, 1971, p. 358); Albo-Aptian of bore hole no. CM-1, Senegal Basin, W. Africa (Present study).

Genus—**Achomosphaera** Evitt, 1963

Type species—*Achomosphaera ramulifera* (Deflandre) Evitt, 1963

Achomosphaera sagena Davey & Williams, 1966 (Pl. 3, Fig. 48)

Remarks—Present specimens possess almost all morphological features similar to *A. sagena* except distinct bifurcate or trifurcate extremeties of the processes and moderately thick wall of central body with finner reticulations. These features may be treated as the extent of variation.

Geologic and geographic distribution—English Lower Chalk, Cenomanian (DAVEY & WILLIAMS, in DAVEY *et al.* 1966); Cenomanian of Chalk of the Isle of Wight, England (CLARKE & VERDIER, 1967); Campanian-Maestrichtian of bore hole no. CM-1, Senegal Basin, W. Africa (Present study).

Achomosphaera sp. A (Pl. 3, Fig. 47)

Description—Shell ± spherical, 65 μm in size (without processes), archaeopyle precingular; wall double layered, periphragm covered with numerous processes, processes 11-12 μm in length, base rounded, distally closed, capitate or bifid; shell surface granular.

Remarks—Only a few specimens have been recorded from the bore hole no. BR-1 at a depth of 552 metres (Maestrichtian).

Achomosphaera sp. B (Pl. 3, Fig. 46)

Description—Cyst ± spherical, 60 μm in diameter, double layered, periphragm granular, ornamented with short processes, less than 30 in number, tips bifid, 8—10 μm long. Archaeopyle not seen.

Remarks—The specimen has been recovered from a cutting sample in the bore hole no. CM-4 at a depth of 1656 metres. The form poses doubt for the presence of epitractial archaeopyle as seen in *Cauca* Davey & Verdier (1971). Placement under *Achomosphaera* is therefore provisional.

Genus—**Pareodinia** Deflandre, emend. Gocht, 1970

Type species—*Pareodinia ceratophora* Deflandre, emend. Gocht, 1970

Pareodinia psilata sp. nov. (Pl. 3, Fig. 51)

Holotype—Pl. 3, Fig. 51; Slide No. 7298-11.

Type locality—Bore hole no. BR-1, depth 3135.50 metres; Senegal Basin, W. Africa.

Horizon—Albo-Aptian.

Diagnosis—Ambitus oval, no tabulation, capsule or furrows. Apical horn strong. Archaeopyle absent. Surface smooth.

Measurements	*Holotype*	*Range*
Overall size	71.5×46.8 μm	67—73×43—50 μm
Apical Horn size	26×8 μm	20—26×6—8 μm

Comparison—*P. aphelia* Cookson & Eisenack (1958) differs in having granulate surface. *P. spinosa* Alberti (1961) differs in its spiny surface. *P. psilata* sp. nov. differs from the other known species in its psilate surface.

Genus—**Toolongia** Cookson & Eisenack, 1960

Type species—*Toolongia medusoides* Cookson & Eisenack, 1960

Toolongia sp. A (Pl. 3, Fig. 45)

Description—Shell flat, ± circular, 65 μm in diameter; central boc y microstructured, covered with thin, smooth membrane, two concentric zones distinct; ledges high, developed in centre on one side of periphragm, bases appear to meet in centre, giving an indication of field. Only a few ledges go beyond last concentric zone. Archaeophyle not present.

Remarks—The specimen has been recovered from bore hole CM-4 at a level of 1756.50 metres. (probably Cenomanian-Turonian).

Genus—**Dinopterygium** Deflandre, 1935

Type species—*Dinopterygium cladoides* Deflandre, 1935

Dinopterygium sp. A (Pl. 3, Figs. 44 & 49)

Description—Shell circular to broadly oval in outline, 60×80 μm in size with a slight indication of an embayment produced by longitudinal furrow. Transverse furrow bordered by single membraneous flange, 8-10 μm wide. Tabulation present but indistinct.

Remarks—In polar view the present fossil resembles with *Wanaea* forms described by Cookson and Eisenack (1958) and Eisenack (1958; pl. 25, fig. 2) but differs in the absence of radially arranged processes to make the edge.

Present fossils have been recovered from bore hole no. CM-4 at a depth of 2739.40 metres (Albo-Aptian).

Genus—**Aptea** Eisenack, 1958

Type species—*Aptea polymorpha* Eisenack, 1958

Aptea polymorpha Eisenack, 1958

Remarks—*Aptea* specimen have not been included in the plate.

Geologic and geographic distribution—Aptian-Albian (Singh, 1971, p. 370); Lower Aptian of France (DAVEY AND VERDIER, 1974); Albo-Aptian of Senegal Basin, W. Africa. (Present study).

Genus—**Odontochitina** Deflandre emend. Davey, 1970

Type species—*Odontochitina operculata* (Wetzel) Deflandre & Cookson, 1955

Odontochitina costata Alberti emend. Clarke & Verdier, 1967 (Pl. 3, Fig. 52)

Remarks—Present specimens possess distinct surface perforation with long apical horn. This treatment is made in *Sensu* SINGH (1971, p. 373). No regular striation are seen in Senegal specimens

Geologic and geographic distribution—Albian-Cenomanian (See CLARKE & VERDIER 1967, p. 59); Albo-Aptian of bore hole no. CM-4, Senegal Basin, W. Africa, (Present study).

Odontochitina operculata (Wetzel) Deflandre & Cookson, 1955 (Pl. 4, Fig. 55)

Geologic and geographic distribution—Late Hauterivian to Maestrichtian (see SINGH, 1971, p. 372); Albo-Aptian of bore hole no. CM-4, Senegal Basin, W. Africa; (Present study).

Genus—**Kalyptea** Cookson & Eisenack, 1960

Type species—*Kalyptea diceras* Cookson & Eisenack, 1960

Remarks—The taxonomic position of the genus *Kalyptea* Cookson & Eisenack (1960) needs consideration. Recently GOCHT (1970) considered it to be a junior synonym of *Pareodinia* Deflandre (1947). *Pareodinia* has been diagnosed by DEFLANDRE (1947), EISENACK (1964) and NORRIS AND SARJEANT (1965). They concluded that it has a cellulosic shell but never possesses an extra membrance covering the shell, as is mostly the case with *Kalyptea.* It is therefore, maintained as a separate genus than *Pareodinia.*

DRUGG (1970, p. 814-815)instituted a new genus *Caligodinium* to accommodate dinoflagellates having *Kalyptea* morphology with an additional feature of three plate operculum. He subsequently placed forms without an operculum under *Kalyptea.* In fossil state this condition is quite common, that all morphological feature are not preserved in a single form. It is therefore, suggested that the diagnosis of *Kalyptea* should be elaborated, incorporating the occurrance of 3 plate operculum.

The following transfers are proposed —

Kalyptea amiculum (Drugg) comb. nov.—*Caligodinium ameculum* Drugg (1970), p. 815, figs. 8a&b; 9a&e; Danian.

Kalyptea aceras Manum & Cookson (1964) Lentin & Williams, 1973; Cenomanian.

Kalyptea distincta sp. nov. (Pl. 4, Fig. 65)

Holotype—Pl. 4, Fig. 65; Slide No. 7882-3.

Type locality—Bore hole no. CM-1, depth 2640 metres. Senegal Basin, W. Africa.

Horizon—Albo—Aptian.

Diagnosis—Shell broadeı than long, thick walled, without any horn; covered in thin and smooth veil like membrane on both sides. Shell surface verrucate, verracae low. Archaeopyle apical, formed only by inner layer (endophragm), broader than long.

Measurements	*Holotype*	*Range*
Overall size	48—74 μm	48—60 × 70—80 μm
Shell size	46—66 μm	40—48 × 55—70 μm
Wall thickness	1.5 μm	1.5—2.6 μm
Varrucae height	0.6 μm	0.4—0.6 μm

Comparison—*Kalyptea distincta* sp. nov. is characterised by its broader than long shape and verrucate shell surface. Other species of the genus are longer than broad and do not possess verrucate ornamentation.

Kalyptea sp. A (Pl. 3, Fig. 50)

Description—Shell elongate, 67 × 45.5 μm in size, apex and antapex rounded, wall thick; covered with delicate micro-reticulate membrance, not well preserved. Archaeopyle apical.

Remarks—The specimen has been recorded from Albo-Aptian sample of bore hole no. CM-I at a depth of 2720 metres.

Genus—**Thalassiphora** Eisenack & Gocht emend. Gocht, 1968

Type species—*Thalassiphora pelagica* (Eisenack) Eisenack & Gocht, 1960

Thalassiphora maxima sp. nov. (Pl. 4, Figs. 53—54)

Holotype—Pl. 4, Fig. 54; Slide No. 8456-2.

Type locality—Bore hole no. CM-1; depth 1055.05 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagonosis—Capsule spherical, thick walled with ovoidal pylome; boundary wall thick, surrounded by an equatorially placed wide membraneous wing, double walled with radially arranged broad folds, spongeous, with slight perforations. No tabulation discernible.

Measurements	*Holotype*	*Range*
Shell size	80 × 128 μm	70—80 × 110—145 μm
Central body diameter	80 μm	70—80 μm
Flange width	31.5 μm	30—45 μm

Comparison—*Thalassiphora maxima* sp. nov. differs from other known species of the genus in having large spongeous membrane with perforations. *Thalassiphora delicata* Williams & Downie (1966) resembles in having perforate ornamentation of periphragm but differs in its delicate membraneous flange with no radial foldings. The present specimens are also much bigger in size.

Thalassiphora sp. A (Pl. 4, Figs. 61-62)

Description—Shell spherical, 56 μm in diameter; inner body oval, 40 μm in diameter, thick walled, covered with thick membrane placed sub-equatorially, microgranulate, 6.5 μm wide, radial folds few. Pylome present.

Remarks—These specimens differ from other species of the genus in their smaller size and microgranulose membrane. It has been recorded from bore hole no. CM-1 at a depth of 1055.50 metres (Campanian-Maestrichtian).

Genus—**Actinotheca** Cookson & Eisenack, 1960

Type species—*Actinotheca aphroditae* Cookson & Eisenack, 1960

Actinotheca sp. A (Pl. 4, Fig. 56)

Description—Shell almost circular, flat, 87 μm in diameter; body ± shell shaped; wing two layered, 9—11 μm broad outside body margin. Seven pairs of fibres support wing on one side, running radially up to circum ference of wing forming loops. Wing thin, smooth, not well preserved throughout body margin. Body wall thick, scabrate.

Remarks—Only a single specimen has been recovered from Maestrichtian level of bore hole no: CM-1 at a depth of 861 metres. Present form differs from *Dinopterygium* Deflandre (1936) in the absence of a transverse furrow.

Genus—**Gardodinium** Alberti, 1961

Type species—*Gardodinium eisenacki* Alberti, 1961

Gardodinium deflandrei Clarke & Verdier, 1967 (Pl. 4, Figs. 66-67)

Geologic and geographic distribution—Senonian of Isle of Wight, England (Clarke & Verdier, 1967); Campanian-Maestrichtian of bore hole no. CM-4, Senegal Basin, W. Africa (Present study).

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

Type species—*Hystichosphaeridium tubiferum* (Ehrenberg) Deflandre, 1937

Hystrichosphaeridium sp. cf. **H. simplicispinum** Davey & Williams, 1966. (Pl. 4, Fig. 63)

Description—Central body spherical, 47 μm in diameter, periphragm and endophragm smooth, processes variable in size, tubiform, margin digitate, up to 15 μm long. Archaeopyle indistinct.

Remarks—Senegal forms differ from the holotype of *H. simplicispinum* in having digitate margin of tubiform processes. The specimens do not show reticulate thickening at the base of the processes. It has been recorded from Albo-Aptian level of BR-1 bore hole at a depth of 3135.50 metres. *H. simplicispinum* is known from Lower Cretaceous (Middle Barremian) of Yorkshire, England.

Genus—**Oligosphaeridium** Davey & Williams, 1966

Type species—*Oligosphaeridium complex* (White) Davey & Williams, 1966

Oligosphaeridium complex (White) Davey & Williams, 1966 (Pl. 4, Fig. 57)

Geologic and geographic distribution—Valanginian to Early Eocene (See SINGH, 1971, p. 334); Albo-Aptian of bore hole no. BR-I, Senegal Basin, W. Africa (Present study).

Oligosphaeridium sp. cf. **O. Pulcherrimum** (Deflandre & Cookson) Davey & Williams, 1966 (Pl. 4, Fig. 62)

Description—Cyst ± spherical, body 48 μm in diameter, reflected tabulation not clearly discernible; processes 11 in number, apical narrow and short, antapical broader and long, distally open, terminal expansion wide with vacuolate wall without spines. Archaeopyle apical. Cyst wall smooth.

Remarks—Present forms differ from other records of the species in having unrecognisable tabulation, lesser number of processes and lack of spines on the expanded distal rim of processes.

Geologic and geographic distribution—Early Cretaceous to Early Eocene (See SINGH, 1971; p. 339); Lower—? Upper Aptian of bore hole no. BR-I, Senegal Basin, W. Africa (Present study).

Genus—**Litosphaeridium** Davey & Williams, emend. Davey & Verdier, 1973

Type species—*Litosphaeridium siphoniphorum* (Cookson & Eisenack) Davey & Williams, 1966

Litosphaeridium sp. A (Pl. 4, Fig. 59)

Description—Shell spherical, 65 μm in diameter (including processes), double layered; body 40 μm in diameter; periphragm ornamentation not clear. Processes variable in shape, cylindrical to subconical with denticulate distal margin, hollow. Number of processes more than 15. Archaeopyle not discernible.

Remarks—Present form approaches nearest to *L. siphoniphorum* (Cookson & Eisenack) Davey & Williams (1966) in having similar size, shape and process distribution. But differs in having more than 15 processes. It has been recorved from bore hole no. BR-1 at a depth of 3523 m (Albo—Aptian).

Litosphaeridium sp. B (Pl. 4, Fig. 58)

Description—Central body spherical (figured specimen not well preserved), 43 μm in diameter; periphragm granular; processes buccinate, 10—13 × 2—9 μm in size, distal margin recurved, hollow. Number of processes 13. Tabulation typical of genus. Archaeopyle apical.

Remarks—Figured specimen has been recorded from bore hole no. CM-1 at a depth of 2621 metres (Albo-Aptian).

Genus—**Cordosphaeridium** Eisenack, 1963 ex. Davey & Williams, 1966 emend. Davey, 1969

Type species—*Cordosphaeridium inodes* (Klumpp) Eisenack, 1963

Cordosphaeridium senegalensis sp. nov. (Pl. 5, Fig. 68)

Holotype—Pl. 5, Fig. 68; Slide No. 7880-3.

Type locality—Bore hole no. CM-1; depth 1044 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagnosis—Cyst spherical, chorate, double layered; endophragm smooth, periphragm well developed, granulate with less than 30 processes; processes fibrous, variable in size and shape, hollow, dorsally open, tubiform with slightly recurved dorsal margin. Cingular processes broader, remaining slender. Tabulation typical of genus. Archaeopyle apical with one convex side, margin smooth.

Measurements	*Holotype*	*Range*
Cyst size with processes	110 μm	100—120 μm
Body diameter	84 μm	80—90 μm
Cingular processes size	28 × 10 μm	25—30 × 9—12 μm
Wall thickness	2 μm	1.5—2 μm

Comparison—*Cordosphaeridium inodes* (Klumpp) Eisenack (1963) described in detail by Gocht (1969) comes nearest to *C. senegalensis* sp. nov. in having similar processes and shape of the cyst. But differs in having fiberous body wall and shorter processes. Present forms differ from other known species of the genus in having broader cingular processes as compared to apical, precingular, postcingular and antapical processes.

Genus—**Coronifera** Cookson & Eisenack, 1958

Type species—*C. oceanica* Cookson & Eisenack, 1958

Coronifera oceanica Cookson & Eisenack, 1958 (Pl. 4, Fig. 64)

Description—Cyst ovoidal in shape; double layered, endophragm thin, smooth, periphragm thick, ornamented with simple processes, apices truncate. Single, four-sided, distinct process develop an antapical horn. Archaeopyle precingular, margin simple, smooth, circular to oval.

Measurements	*Range*
Shell diameter with processes	60—63 μm
Body diameter	40—47 μm
Length of antapical process	14—17 μm
Simple process length	8—14 μm

Geologic and geographic distribution—Upper Hauterivian to Lower Aptian, France (Millioud, 1969); Albian to basal Coniacian, England (Cookson & Hughes, 1964; Clarke & Verdier, 1967; Davey, 1969); Albian, France (Davey & Verdier, 1971); Albian, Cenomanian, Santonian, Lower Campanian, Australia (Cookson & Eisenack, 1958, 1968, 1969). Albo-Aptian, Senegal Basin, W. Africa (Present study).

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

Type species—*Cleistosphaeridium diversispinosum* Davey *et al.*, 1966

Cleistosphaeridium brevispinosum sp. nov. (Pl. 5, Figs. 80—82)

Holotype—Pl. 5, Figs. 80—81; Slide No. 8966-3.

Type locality—Bore hole no. CM-4; depth 2918 metres; Senegal Basin, W. Africa.

Horizon—Lower-?Upper Aptian.

Diagnosis—Shell spherical, surface moderately thick, densely punctate; processes numerous, short, broader at base, uniform in size, tips furcate or slightly bifid, distally closed. Archaeopyle apical.

Measurements	*Holotype*	*Range*
Shell diameter	48 μm	45—50 μm
Process size	2.6×1.3 μm	2.4—2.8×1—1.3 μm

Comparison—*C. brevispinosum* sp. nov. is characterised by its very short processes and densely punctate test surface. These features separate it from the other known species of the genus. *C. multispinosum* (Singh) Brideaux (1971) compares well in size and morphology but differs in not having punctate surface.

Cleistosphaeridium sp. A (Pl. 5, Fig. 78)

Description—Shell rectangular, 46×48 μm in size, wall 2.5—3 μm thick, surface perforate. Processes numerous, distally closed. Archaeopyle apical, margin zig-zag.

Remarks—Present specimen has been recovered from bore hole no. CM-4 at a depth of 980 metres (Campanian-Meastrichtian). Its rectangular shape and perforate surface distinguishes it from other known species.

Cleistosphaeridium sp. B (Pl. 5, Fig. 79)

Description—Central body ovoidal, 36×26 μm in size, over all size 48×34 μm. Surface covered with 8-10 μmlong processes, distally closed, some blunt or bifid. Archaeopyle apical.

Remarks—Only a single specimen has been recovered from Albian of bore hole no. BR-1 in Senegal Basin. It differs from most of the species of the genus in its smaller size and ±circular archaeopyle margin.

Genus—**Polysphaeridium** Davey & Williams, 1966

Type species—*Polysphaeridium subtile* Davey & Williams, 1966

Polysphaeridium elongatum sp. nov. (Pl. 5, Figs. 73-74)

Holotype—Pl. 5, Fig. 74; Slide No. 7762-7.

Type locality—Bore hole no. CM-1; depth 861 metres; Senegal Basin, W. Africa.

Horizon—Maestrichtian.

Diagnosis—Cyst oval to elliptical in outline, wall thick, periphragm ornamented with short, numerous processes, broader at base, truncate or tubiform, hollow distally, unequal in size; perforate. Endophragm smooth. Archaeopyle apical, slit like.

Measurements		*Holotype*		*Range*
Cyst size ..	..	.. 78×52 μm	..	.. 70—80×50—60 μm
Size of processes	..	.. 13×2.5—3 μm ..		.. 5—13×2—4 μm
Wall thickness	..	.. 1.5 μm	..	.. 1—3 μm

Comparison—*Polysphaeridium elongatum* sp. nov. differs from all the known species of the genus in having mixed type of shorter and longer processes with perforate periphragm.

Polysphaeridium punctatum sp. nov. (Pl. 5, Figs. 71-72)

Holotype—Pl. 5, Fig. 72; Slide No. 7762-7.

Type locality—Bore hole no. CM-1, depth 861 metres; Senegal Basin, W. Africa.

Horizon—Maestrichtian.

Diagnosis—Cyst spherical in outline, wall thick, periphragm micropunctate, processes of two types, one shorter, distally truncate and other longer with bifid or spinose apex; both hollow distally. Archaeopyle apical with angular margin.

Measurements		*Holotype*		*Range*
Cyst diameter	..	.. 65 μm	..	.. 60—80 μm
Process size	..	.. 10×6.5 μm	..	.. 10—13×5—7 μm
Wall thickness	..	.. 1.5 μm	..	.. 1.5×2 μm

Comparison—*P. punctatum* sp. nov. comes nearest to *P. elongatum* sp. nov. in having similar mixed type of processes and punctate test surface. But differs in having spherical shape than elongate with dropping processes.

Polysphaeridium granulosum sp. nov. (Pl. 5, Figs. 69-70)

Holotype—Pl. 5, Fig. 69; Slide No. 7762-1.

Type locality—Bore hole no. CM-1, depth 861 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagnosis—Cyst spherical, chorate, double layered, both endophragm and periphragm granulate; processes fibrous, short, variable in size and shape, tubifeorm to flared, expanded distally, narrow in middle, margin slightly recurved, hollow, nearly 60 in number. Tabulation not clearly confirmed. Archaeopyle apical, margin angular.

Measurements		*Holotype*		*Range*
Cyst size ..	..	.. 90 μm	..	.. 90—100 μm
Body diameter	..	.. 70 μm	..	.. 70—75 μm
Wall thickness	..	.. 1.5 μm	..	.. 1.5—2.6 μm
Size of process	..	.. 6.5—14×2—6 μm		.. 6.5—20×2—6 μm

Comparison—*Polysphaeridium granulosum* sp. nov. is characterised by its granulate walls with tubiform to flared processes having apical archaeopyle. These features distinguish it from other known species of the genus.

Genus—**Cyclonephelium** Deflandre & Cookson emend. Williams & Downie, 1966

Type species—Cyclonephelium compactum Deflandre & Cookson, 1955

Cyclonephelium distinctum Deflandre & Cookson, 1955 (Pl. 5, Fig. 77)

Geologic and geographic distribution—Albian-Senonian. Senonian of Western Australia (Deflandre & Cookson, 1955); Cenomanian of England and France (Davey, 1969); Albian-Senonian of Australia (Cookson & Eisenack, 1962); Campanian-Maestrichtian of bore hole no. CM-4, Senegal Basin, W. Africa (Present study).

Cyclonephelium sp. A (Pl. 5, Fig. 83)

Description—Shell spheroidal, flattened, 70 μm in diameter, ornamentation of periphragm perforate, provided with processes of different sizes, broader at base, formed by joining two or more processes, short, apices pointed (acute) or truncate, texture spongy. Archaeopyle apical.

Remarks—The specimen has been recorded from bore hole no. CM-1 at a depth of 894.80 metres (Campanian-Maestrichtian).

Genus—**Tenua** Eisenack emend. Sarjeant, 1968

Type species—*Tenua hystrix* Eisenack, 1958

Tenua dubius sp. nov. (Pl. 5, Figs. 75—76)

Holotype—Pl. 5, Fig. 76; Slide No. 8632-5.

Type locality—Bore hole no. CM-4, depth 1090 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagnosis—Shell slightly biconical with short rounded apical horn; antapical side obtusely rounded. Surface covered with long, bifurcate processes. Epitract smoothly slops into an apical horn. Surface finely granulate. Archaeopyle apical with angular detachment margin.

Measurements	*Holotype*	*Range*
Overall size	78×70 μm	70—80×62—75 μm
Process length	10—15 μm	10—15 μm

Comparison—Tenua dubius sp. nov. differs from *Tenua anaphrissia* (Sarjeant) Benedek (1972) in having only one type of characteristic long, bifurcate processes.

Tenua anaphrissa (Sarjeant) Benedek, 1972 (Pl. 6, Fig. 84)

Remarks—Present specimens are quite common in bore hole no. BR-1 at a depth of 3523.00 metre. (Lower-?Upper Aptian). The size range of the holotype is 120—145× 105—130 μm, whereas the Senegal forms range in length from (without apical portion)

70—80 μm and in breadth measuring 80—90 μm. Other features are similar to Specton clay *Tenua* (*Doidyx*) forms.

Geologic and geographic distribution—Lower Barremian of Specton Clay (SARJEANT 1968); Lower-?Upper Aptian of Senegal Basin, W. Africa (Present study).

Tenua sp. cf. **T. hystricella** Eisenack emend. Sarjeant, 1968 (Pl. 2, Fig. 31)

Description—Shell ovoidal, longer than broad, 57×38 μm in size, wall thin, covered with short processes, mostly concentrated near apical and antapical ends. Archaeopyle apical, margin even, circular. No cingulum, sulcus or tabulation.

Remarks—These specimens have been recorded from bore hole no. BR-I at depth of 4024.25 metres. (Lower-?Upper Aptian). It differs from *T. hystricella* in having smaller and circular archaeopyle. It has not been included in *Prolixosphaeridium* Davey *et al.* (1966) due to lack of antapical processes. In its longer than broad shell shape, it approaches nearer to *Pyxidiella* Cookson & Eisenack (1958) but differs in having circular archaeopyle than squarish.

Tenua rioulti Sarjeant, 1968 (Pl. 6, Fig. 88)

Remarks—Senegal forms possess less than 200 spines otherwise are covered within the diagnostic range of *T. rioulti.*

Geologic and geographic distribution—Upper-most Callovian of Villers Sur-Mer (SARJEANT, 1968); Albo-Aptian of bore hole no. BR-1, Senegal Basin, W. Africa (Present study).

Genus—**Cannophaeropsis** Wetzel emend. Williams & Downie, 1966

Type species—*Cannosphaeropsis utinensis* Wetzel, 1932

Cannosphaeropsis sp. A (Pl. 6, Fig. 93)

Description—Shell circular in outline, 35-40 μm in diameter, thick walled with smooth surface, radial appendages develop on distal side, equal in size, distal portion of appendages bifurcate into secondary and tertiary branches which in turn anastomose forming a fine net of mesh work, periphery irregular but smooth. Overall diameter 60-65 μm. An opening on one side is indicated.

Remarks—The forms are not many and have been recovered from bore hole no. CM-4 at a depth of 1449.00 metres (Upper Turonian-Santonian).

Genus—**Exochosphaeridium** Davey *et al.*, 1966

Type species—*E. phragmites* Davey *et al.*, 1966

Exochospheridium sp. cf. **E. bifidum** (Clarke & Verdier) Clarke *et al.*, 1968 (Pl. 6, Figs. 86 & 92)

Description—Cyst ± circular, 90 μm in size, body 60 μm in diameter, double layered, periphragm perforate, processes numerous, long, 18-22 μm in length, narrow, tips recurved and bifid, bases circular, bulbous. Archaeopyle not seen.

Remarks—Recently VERDIER *et al.* (1968) have transferred *Baltisphaeridium bifidum* Clarke & Verdier (1967) to *Exochosphaeridium* Davey *et al.* (1966), which possesses precingular archaeopyle. In most of the features Senegal specimens have an accord with figured forms of *Baltisphaeridium bifidum* by CLARKE & VERDIER (1967, pl. 17, figs. 5-6). But differs in having mixed type of process endings (recurved and bifid). The archaeopyle is indeterminable.

Present forms have been observed at Campanian-Maestrichtian level of bore hole no. CM-1 at a depth of 946 metres. *E. bifidum* comes from Senonian of Isle of Wight (CLARKE & VERDIER, 1967).

Genus—**Callaiosphaeridium** Davey & Williams, 1966

Type species—*C. asymmetricum* (Deflandre & Courtville) Davey & Williams, 1966

Callaiosphaeridium sp. A (Pl. 6, Fig. 85)

Description—Cyst spherical, 100 μm in size with processes, body 54 μm in diameter, wall thick, double layered. Periphragm finely granulate, two types of processes present, one series with large and hollow while other smaller and solid, tips in both bifurcating. Archaeopyle apical. Tabulation typical of genus.

Remarks—Present form shows its best comparison with the figured forms described under *Hexasphaera asymmetrica* (pl. 7, fig. 1-3) by CLARKE AND VERDIER (1967) from Senonian of Isle of Wight.

Genus—**Diconodinium** Cookson & Eisenack, 1960

Type species—*D. multispinum* (Deflandre & Cookson) Cookson & Eisenack, 1960

Diconodinium distinctum sp. nov. (Pl. 6, Figs. 98-99)

Holotype—Pl. 6, Fig. 98; Slide No. 8459-5.

Type locality—Bore hole no. CM-I; depth 1055.30 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagnosis—Shell fusiform without capsule; girdle circular, distinct, dividing unequally into larger epitract than hypotract. Clear lines run from apex to antapex forming distinct longitudinal aperture on one side, broader near girdle. Shell membrane thickly ornamented with bifid, short spines, arranged in longitudinal lines giving an indication of tabulation. Apex and antapex pointed.

Measurements	*Holotype*	*Range*
Shell length	78 μm	70—90 μm
Shell width	33 μm	30—60 μm
Spine length	1.5 μm	1.5—3 μm

Comparison—*Diconodinium distinctum* sp. nov. compares closest with *D. dispersum* (Cookson & Eisenack) Eisenack & Cookson (1960), *D. multispinum* (Deflandre & Cookson) Eisenack & Cookson (1960), *D. pelliferum* (Cookson & Eisenack) Eisenack & Cookson (1960) in having spinose shell surface. But differs in its distinct longitudinal aperture running from pole to pole and slight indication of tabulation. The aperture is comparable to archaeopyle of dinoflagellates though unique in its situation. It is formed from plate detachment. The indication of tabulation, cingulum and longitudinal archaeopyle suggests its inclusion in dinoflagellate and confirm the view of COOKSON AND EISENACK (1960, p. 490).

Genus—**Pterospermopsis** Wetzel, 1952

Type Species—*Pterospermopsis danica* Wetzel, 1952

Pterospermopsis ovatus sp. nov. (Pl. 6, Fig. 96)

Holotype—Pl. 6, Fig. 96; Slide No. 9704a-4.

Type Locality—Bore hole no. CM-4; depth 1054 metres; Senegal Basin, W. Africa.

Horizon—Campanian-Maestrichtian.

Diagnosis—Shell oval in apical view, equatorial wing wide, oval, slightly undulating, radially folded; surface minutely structured to smooth.

Measurements	*Holotype*	*Range*
Overall size	100 × 66 μm	85—100 × 60—75 μm
Shell size	58 × 40 μm	50—60 × 35—45 μm
Flange width	20—30 μm	20—30 μm

Comparison—The Australian species of *Pterospermopsis* described by DEFLANDRE AND COOKSON (1955) are much smaller in size. *P. ovatus* sp. nov. differs from the other known species of the genus in having oval shell and larger size with micro-structured to smooth outer membrane.

Pterospermopsis concentricus sp. nov. (Pl. 6, Fig. 87)

Holotype—Pl. 6, Fig. 87; Slide No. 7299-20.

Type locality—Bore hole no. BR-1; depth 3523 metres; Senegal Basin, W. Africa.

Horizon—Albo-Aptian.

Diagnosis—Shell rounded, equatorial wing moderate, foamy, folds concentric, parallel to the shell periphery, shell surface granulate.

Measurements	*Holotype*	*Range*
Overall shell diameter	69 μm	50—70 μm
Shell diameter	56 μm	40—60 μm
Flange width	10 μm	8—10 μm

Comparison—*P. concentricus* sp. nov. differs from all the known species of the genus in having characteristic concentric folds parallel to shell periphery and foamy equatorial wing.

Pterospermopsis barbarae Gorka, 1963 (Pl. 6, Fig. 91)

Geologic and Geographic distribution—Upper Cretaceous, Poland (GORKA, 1963); Campanian-Maestrichtian of bore hole nos. BR-1 & CM-1, Senegal Basin, W. Africa (Present study).

Pterospermopsis sp. A (Pl. 6, Fig. 97)

Description—Shell large, 140 × 102 μm in size, ellipsoiodal; body 133 × 84 μm in size, surface micrograniulate, covered with thin membrane, flange very narrow, 6.4 μm wide, folds irregular in centre, radial folds absent.

Remarks—It has been recovered from bore hole no. CM-4 at a depth of 1400 metres (Campanian-Maestrichtian).

Pterospermopsis sp. B (Pl. 6, Fig. 95)

Description—Shell 83 × 58.5 μm in size, margin irregular; body spherical, 56 μm in diameter, surface smooth; covering membrane thin, micropunctate, loosely folded, forming convoluted marginal flange.

Remarks—This single record comes from bore hole No. CM-4, at a depth of 2918.00 metres (Lower-?Upper Aptian).

Pterospermopsis sp. C (Pl. 6, Fig. 90)

Description—Shell circular in outline, 75 μm in size, body ± circular, 52 μm in diameter, surface granulate; equatorial flange thin, spongy, extending 10-15 μm beyond body margin, perforate.

Remarks—Present single fossil has been recovered from bore hole no. BR-1 at a depth of 3135.50 metres (Albo-Aptian).

Genus—**Baltisphaeridium** Eisenack, emend. Downie & Sarjeant, 1963

Type species—*Baltisphaeridium longispinosum* (Eisenack) Eisenack, 1958

Baltisphaeridium whitei (Deflandre & Courteville) Sarjeant, 1959. (Pl. 6, Fig. 100)

Description—Shell spherical, 40-45 μm in diameter, surface granulate, covered with long thread like processes, vary in length from 12-18 μm, tips pointed.

Geologic and geographic distribution—Middle Albian-Senonian (See SINGH, 1971, p. 396); Albo-Aptian of bore hole no. BR-1, depth 3135.50 metres, Senegal Basin, W. Africa (Present study).

Baltisphaeridium sp. A (Pl. 6, Fig. 89)

Description—Shell ovoid to spherical, 36×28 μm in size, wall 0.5—1 μm thick, surface covered with long, simple thread like processes, 6-8 μm long, tips capitate or bifid, some times pointed. Surface unornamented. Archaeopyle not seen.

Remarks—This specimen has been recovered from bore hole no. CM-4 at a level of 1449 metres (Upper Turonian—Santonian). It resembles best with *B. fimbriatum* (White) Sarjeant (1959).

Baltisphaeridium sp. B (Pl. 6, Fig. 94)

Description—Shell spherical, 42.5 μm in diameter. surface granulate, covered with long simple, pointed processes of uniform length, process length mostly 10-14 μm. Archaeopyle not seen.

Remarks—It has been recorded from bore hole no. CM-4 at a level of 980 metres (Maestrichtian). These forms approach nearest to *B. multispinosum* Singh (1964) but differs in having granular periphragm surface.

DISCUSSION

The bore hole samples from deep wells viz., CM-4, CM-1, BR-1, DgF-1 and KtF-1 in the Senegal Basin, W. Africa have yielded both miospores (spore and pollen grains) and microplankton (dinoflagellate and acritarchs). The palynomorphs from these wells could be recovered at irregular depths which has made it difficult to attempt boundary problems. Thus, the present discussion is confined to establish only the assemblage zones for the purpose of regional correlation.

PALYNOLOGICAL ZONATION

Zone-1: It is represented in bore holes CM-1, CM-4, and BR-1; each ranging in depths from 4097 to 3132.60 metres; 3271.50 to 2918 metres and 3804 to 3672 metres respectively (Text-figs. 2—4 & 11).

This zone is characterised by the dominance of *Subtilisphaera* and the subdominance of *Diconodinium* associated with poor representation of *Gonyaulacysta, Cleistosphaeridium, Tenua, Oligosphaeridium, Pterospermopsis* and *Apteodinium*, as is evidenced by the generic frequency charts (Text-figs. 7, 8, 9). But Text-fig. 7 shows the dominance of *Apteodinium* and the absence of *Subtilisphaera* in the bottom samples. This percentage plotting has been calculated from total 25 specimens collected at 4097 m (CM-1) and 3271. 50 m (CM-4). A closer examination of bottom samples in Zone-1 shows frequent fluctuations in the generic percentage due to paucity of individuals and preservation which led us to include them in the same zone.

Comparison with other phytoplankton assemblages:

The microplankton assemblage recovered from the above mentioned sediments establishing Zone-1 constitutes the following species: *Subtilisphaera senegalensis* Jain & Millepied (1973), *S. crassigranulosa* J. & M. (1973), *S. ventriosa* (Alberti) J. & M. (1973), *S. scabrata* J. & M. (1973), *Diconodinium acutum* J. & M. (1973). The forms ascribed to *Apteodinium, Gonyaulacysta, Cleistosphaeridium, Tenua* and *Oligosphaeridium* are few in number.

Recently DAVEY (1974) has described in detail a phytoplankton assemblage from the Barremian of Speeton Clay. His assemblage shows the presence of asymmetrical, thin walled forms designated as *Deflandrea perlucida* Alberti (Pl. 8, Figs. 1—2) and *Deflandrea terrula* sp. nov. (Pl. 8, Figs. 4-5). These are transferred here to *Subtilisphaera* viz., *S. perlucida* (Alberti) J. & M. (1973) and *S. terrula* (Davey) comb. nov. MILLIOUD (1967) has also reported the occurrence of *Subtilisphaera pirnaensis* (=*Deflandrea pirnaensis*) from Barremian to Lower Aptian of Angles, France. This factor though common to both, does not allow to over-look the associated genera like *Muderongia, Pseudoceratium, Dingodinium* and *Ctenidodinium* which have been mostly recorded from Barremian sediments.

DAVEY (1974, p. 71) is of the opinion that the genus *Muderongia* and the species *Pseudoceratium pelliferum*, *Dingodinium albertii* and *Ctenidodinium elongatulum* have as yet never been reported from the Aptian. Though the type species of *Muderongia* comes from Aptian of Australia (COOKSON & EISENACK, 1958). Emphasizing the stratigraphical importance of *Muderongia*, DAVEY AND VERDIER (1974, p. 650) have remarked in their recent work on "Dinoflagellate cysts from the Aptian type section .." that unless these species of *Muderongia* have a younger range in Australia than in Europe their presence would indicate pre-Aptian age". The absence of above mentioned forms from the Zone-I assemblage precludes the possibility of its being Barremian in age, and supports the contention of DAVEY (1974).

Zone-I dinoflagellate assemblage when compared with Upper Aptian microplankton assemblage of North Germany (EISENACK, 1958) shows the presence of common genera like *Oligosphaeridium*, *Tenua*, *Gonyaulacysta* and *Apteodinium*. But the dominant element *Subtilisphaera* is totally absent in North German assemblage with the dominance of above listed general which have made their humble appearance in Zone-I. ALBERTI (1959) has shown that *Subtilisphaera* (=*Deflandrea*) *pirnaensis* (Alberti) J. & M. is common in Lower Aptian sediments of N. Germany.

Recently DAVEY AND VERDIER (1974) have described the Aptian microplankton assemblage from the type area of Aptian in France. They selected the following species to recognise the Lower and Upper Aptian in the type area. Lower Aptian species: *Achomosphaera neptuni*, *Dingodinium albertii*, *Gardodinium trabeculosum*, *Miourogonyaulax stoveri* and *Systematophora schindewolfi*; Upper Aptian forms are *Astrocysta cretaceae*, *Prolixosphaeridium parvispinum*, *Ovoidinium scabratum*, *Cleistosphaeridium polyps*, *Pareodinia* sp. and *Gonyaulacysta* sp.

Stratigraphic value of *Dingodinium albertii* remains doubtful for Barremian sediments because DAVEY AND VERDIER (1974) have also used it for the recognition of Lower Aptian in the type area.

Senegal Zone-I dinoflagellate assemblage is characterised by thin walled delicate and small sized forms with no floral diversity. This aspect makes it difficult to attempt an inter-continental comparison.

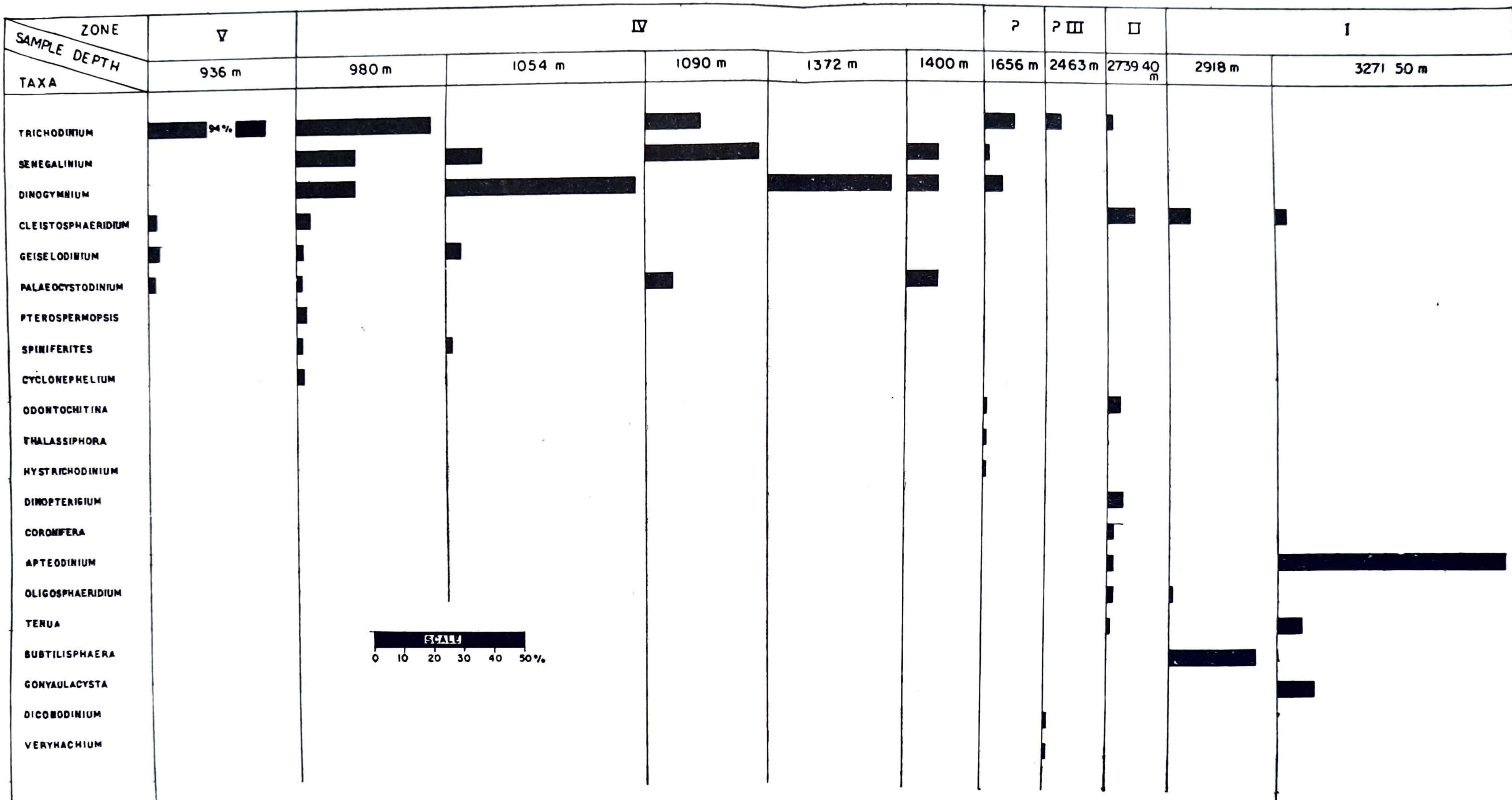
The foraminiferal dating of Zone-I, in different bore holes, is variable and is concluded to be Upper Aptian-Albian in Bore hole CM-4; Lower-Upper Aptian in Bore hole CM-1; and Aptian in BR-1, by C.F.P. and COPETAO (unpublished report). But the palynological fossils and the microplankton/miospore ratio in all sample included in Zone-I recovered from different bore holes provide a more or less uniform floral constituents with the dominance of thin walled asymmetrical dinoflagellates.

Since the palynological conclusions are derived mostly from the negative evidence, we at present conclude that the Zone-I assemblage is Lower-?Upper Aptian in age.

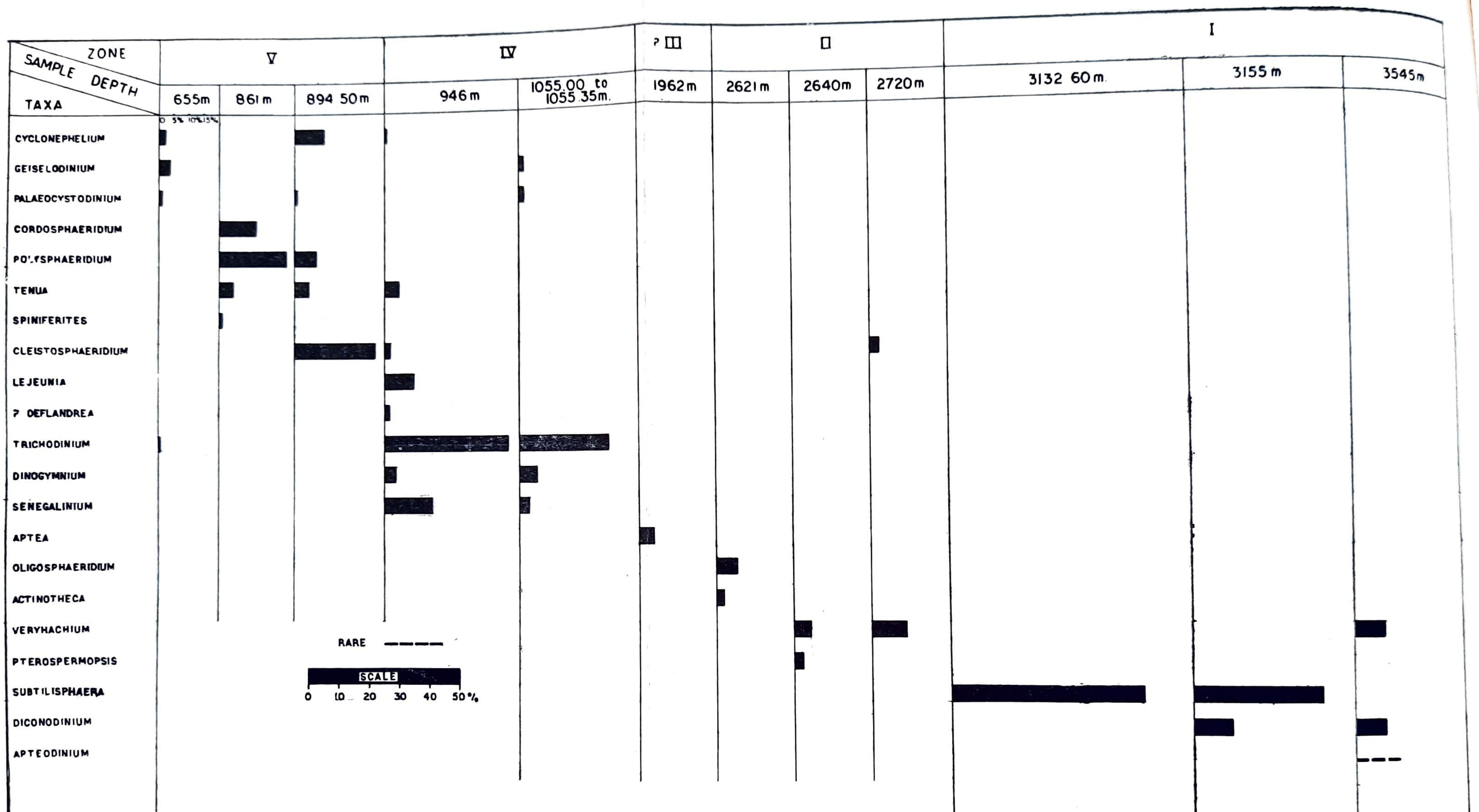
Characteristics of Zone-I:

(1) Lack of diversity in dinoflagellate flora.
(2) Thin walled, delicate and small sized dinoflagellates.
(3) Microplankton and miospore percentage ratio (Text-fig. 10) shows the dominance of microplankton (> 90%).
(4) Dominance of the genus *Subtilisphaera*.

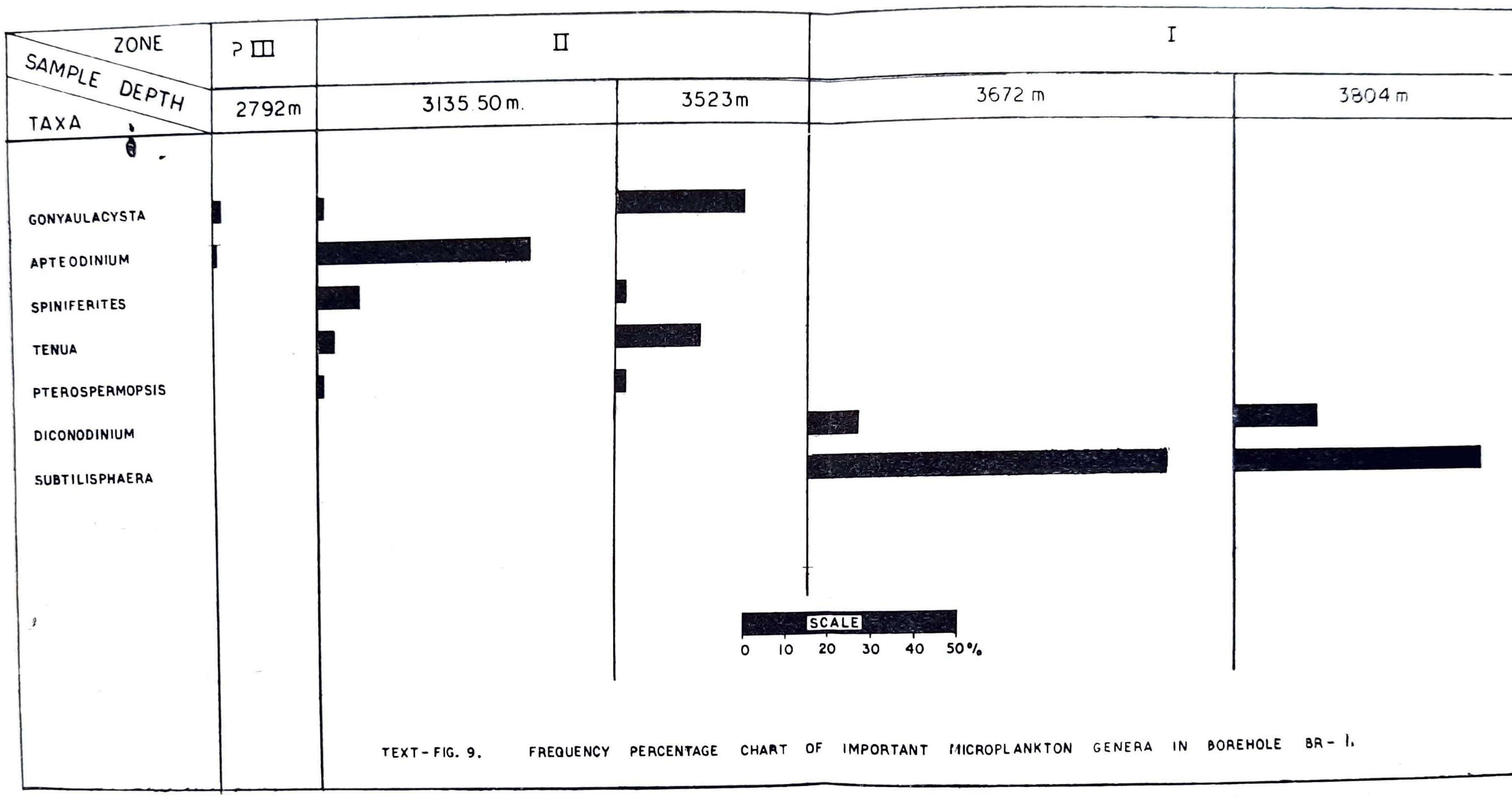
Zone-II: In this zone sediments have yielded a rich palynoflora. Thickness of the zone



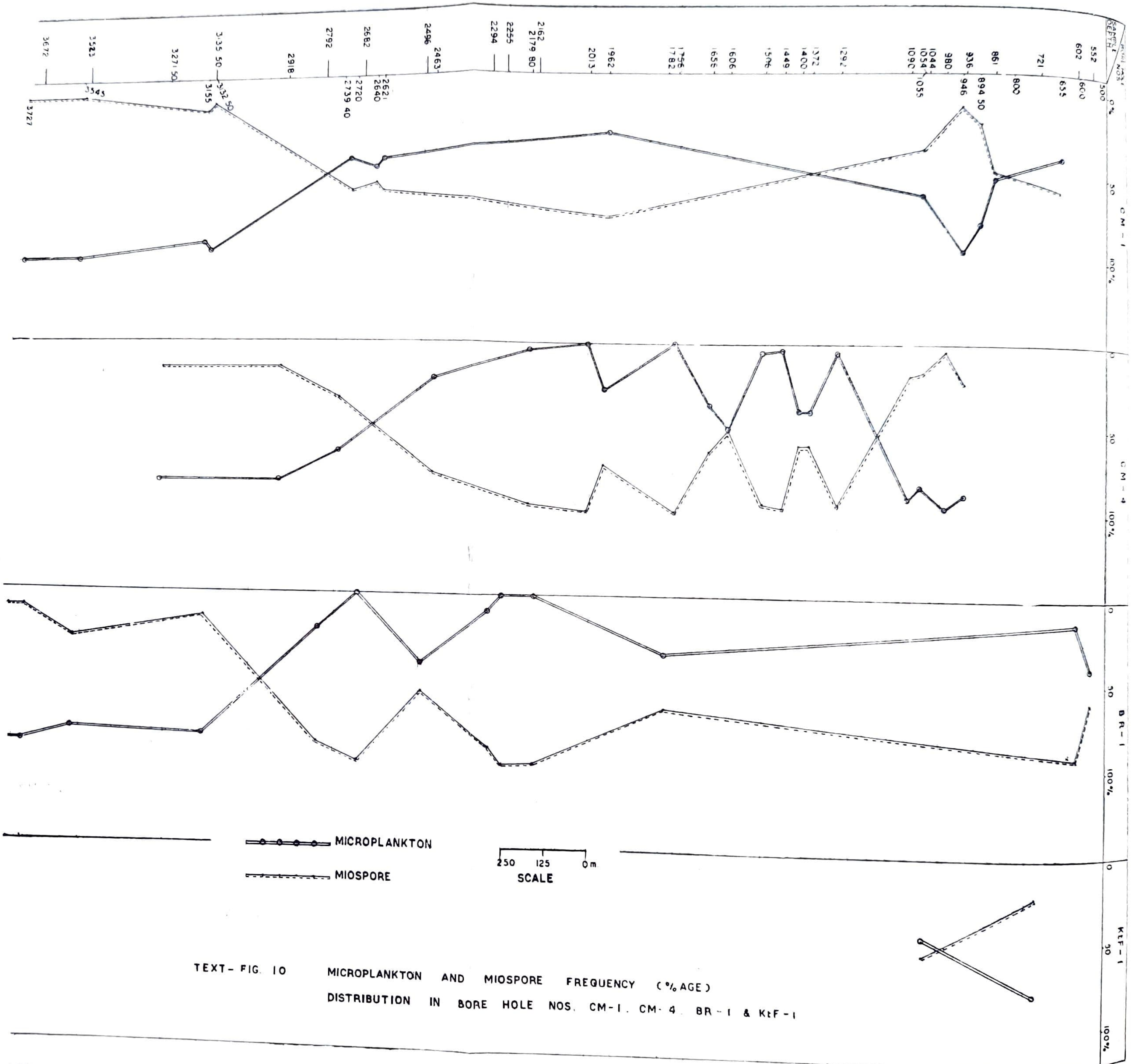
TEXT- FIG. 7. FREQUENCY PERCENTAGE CHART OF IMPORTANT MICROPLANKTON GENERA IN BOREHOLE CM-4.



TEXT-FIG. 8. FREQUENCY PERCENTAGE CHART OF IMPORTANT MICROPLANKTON GENERA IN BOREHOLE CM-1.



TEXT-FIG. 9. FREQUENCY PERCENTAGE CHART OF IMPORTANT MICROPLANKTON GENERA IN BOREHOLE BR-1.



TEXT-FIG. 10 MICROPLANKTON AND MIOSPORE FREQUENCY (%AGE) DISTRIBUTION IN BORE HOLE NOS. CM-1, CM-4, BR-1 & KtF-1 represented in bore-hole CM-1 ranges from 2720 to 2621 m; in CM-4 at 2739.40 m and in BR-1 from 3523 to 3135.50 metres. This zone is not represented in bore-hole DgF-1 and KtF (Text-figs. 2-4 & 11).

Following characteristic forms have been recorded:

Gonyaulacysta orthoceras, *G. edwardsi*, *G. helicoidea*, *G.* cf. *harda*, *Apteodinium spinosum* sp. nov., *Fromea elongata* sp. nov., *Spiniferites cingulatus*, *S. crassimuratus*, *S. ramosus* subsp. *granosus*, *S. ramosus* subsp. *ramosus*, *S. ramosus* var. *reticulatus*, *Pterodinium cornutum*, *Achomosphaera sagena*, *Aptea polymorpha*, *Odontochitina costata*, *O. operculata*, *Kalyptea distincta* sp. nov., *Gardodinium deflandrei*, *Oligosphaeridium complex*, *O.* cf. *pulcherrimum*, *Coronifera oceanica*, *Tenua dubius* sp. nov., *T. anaphrissa*, *T. rioulti*, *T.* cf. *hystricella*, *Exochosphaeridium* sp. cf. *E. bifidum*, and *Litosphaeridium* sp.

Apart from these, it is important to note that *Coronifera*, *Trichodinium*, *Litosphaeridium* and *Odontochitina* mark their first appearance in this zone. *Apteodinum* dominates the assemblage and is different from the ones recovered in zone-I.

Comparison with other known assemblages:

The above listed characteristic forms of this zone suggest a comparison with Upper Aptian-Albian assemblages.

The Upper Aptian microplankton assemblage described from North Germany (EISENACK, 1958) compares best with the present zone assemblage in having common occurrence of *Gonyaulacysta orthoceras*, *Aptea polymorpha*, *Tenua* cf. *hystricella*, *Odontochitina operculata*, *Apteodinium* spp., *Pterodinium* sp., *Coronifera oceanica*, *Actinotheca* sp., *Spiniferites* spp. *Oligosphaeridium* sp. Frequency of these forms is also quite similar in both.

The Australian Lower Cretaceous microplankton assemblage (EISENACK & COOKSON, 1960) shows a closer comparison in having common forms like *Gonyaulacysta*, *Apteodinium* and *Trichodinium*. Forms referred to *Deflandrea* and *Subtilisphaera* in Australian assemblage, are absent in the present zone.

The Indian Lower Cretaceous assemblage (JAIN & TAUGOURDEAU-LANTZ, 1973) is also comparable in the total absence of *Deflandrea* but differs in having *Hexagonifera* which mostly occurs in Albian and younger sediments. Other possible comparisons are with the Albian dinoflagellates reported from Paris Basin (DAVEY & VERDIER, 1971); from Australia (DEFLANDRE & COOKSON, 1955; COOKSON & EISENACK, 1958, 1960, 1969; EISENACK & COOKSON, 1960); Peace river area, North West Canada (Singh, 1964, 1971); Germany (ALBERTI, 1959, 1961); and Upper Green. and, Rumania (BALTES, 1968, 1967).

Of these above mentioned Albian contributions, the Middle Albian, Peace River Formation flora (SINGH, 1971) matches best in having most of the common genera viz., *Gonyaulacysta*, *Apteodinium*, *Fromea*, *Cleistosphaeridium*, *Oligosphaeridium*, *Prolixosphaeridium*, *Exochosphaeridium*, *Pterodinium*, *Aptea* and *Odontochitina*. But differs in having *Deflandrea limbata* and the absence of *Coronifera*. *Coronifera* is a long ranging genus. DAVEY AND VERDIER (1971, p. 193) suggest that the stratigraphic range of *Litosphaeridium* is at present latest Albian and Cenomanian. Occurrence of *Litosphaeridium* in Zone-II also indicates Albian probability.

Above comparisons show that the Zone-II assemblage is more akin to Upper Aptian than Albian. But there is no definite ground except for the negative evidence that the following genera are totally absent viz., *Carpodinium, Ellipsodinium, Hystriocysta, Phoberocysta, Psaligonyaulax, Cauca, Hexagonifera, Senoniasphaera, Stephodinium* which have so far been reported from sediments younger than Aptian.

Microforaminiferal dating proposed by C.F.P. and COPETAO (Unpublished report) suggests an Albo-Aptian age for zone-II sediments. Dinoflagellate are in accordance with the above dating.

Characteristics of Zone-II:

(1) Absence of *Deflandrea* and *Subtilisphaera.*
(2) First appearance of *Trichodinium, Odontochitina* and *Coronifera.*
(3) Abundance of *Apteodinium.*
(4) Dinoflagellates dominate over microspores.

Zone-III(?): It is represented only in three bore holes viz., CM-1, BR-1 and CM-4 at single depth, 1962 m, 2792 m and 2463 m respectively. In these samples miospores dominate over microplankton in the ratio of 3 : 1 which marks an environmental change.

The common microplankton genera encountered are *Aptea, Veryhachium, Diconodinium* and *Trichodinium.* The preservation of fossils is not up to the mark and therefore, the zone is provisional. According to palaeontological data (Reports of C.F.P. and OPETAO unpublished), these have been placed under Albian-Upper Cenomanian. On the basis of phytoplankton, we have no conclusive evidence to comment upon its age and hence provisionally maintain the same.

Zone-IV: In ascending stratigraphic order it occupies a younger stratigraphic position in the bore holes CM-1, CM-4, DgF-1 and KtF-1. This zone in bore-hole CM-1 is represented from 1055.35 to 946 m; in CM-4 from 1400 to 980 metres; in DgF-1 at 1685 m and in KtF-1 at 1040 m.

The composit assemblage recovered from the samples in this zone includes the following important constituents. viz., *Dinogymnium acuminatum, D. major* sp. nov., *D. biconicum* sp. nov., *D. westralium, D. denticulatum; Senegalinium bicavatum, S. psilatum, S. granulostriatum, S. trisinum, S. dubium; Geiselodinium microgranulosum; Palaeocystodinium punctatum; Cleistosphaeridium brevispinosum; Cyclonephelium distinctum; Diconodinium distinctum; Trichodinium bifurcatum* and *Lejeunia* sp.

The dinoflagellate assemblage in this zone is characterised by the dominance of *Trichodinium* (Text-figs. 7 & 8) with associated subdominant genera like *Dinogymnium, Palaeocystodinium* and *Senegalinium.*

Comparison with other Upper Cretaceous assemblages:

Recently Harland (1973) has described Campanian microplankton from Bearpaw Formation, Canada. It is characterised by the presence of *Deflandrea, Diconodinium* and *Lejeunia* along with *Cyclonephelium distinctum, Oligosphaeridium pulcherrimum.* The later two species are common to Zone-IV assemblage. *Senegalinium* can be treated as representative of the family Deflandreaceae.

Microplankton assemblage recovered from two samples from Gingin Brook No. 4 Borehole, Western Australia between 202 and 204 feet (Cookson & Eisenack, 1958) has been assigned to Campanian or possibly Santonian age, do not compare in its general appearance with the present assemblage. It lacks *Trichodinium, Dinogymnium* and *Senegalinium* though quite dominant in its *Deflandrea* contents.

Zaitzeff and Cross (1970) has discussed in detail the dinoflagellates and acritarchs of the Navarro Group (Maestrichtian) of Texas. The striking common feature between Texas and Zone-IV assemblage is the marked representation of *Dinogymnium* (*D. westralium*), *Deflandreaceae*, *Polysphaeridium*, *Cleistosphaeridium*, *Spiniferites*, *Achomosphaera*, *Cyclonephelium* and *Diconodinium*.

Jain *et al.* (1975) have discussed in detail the fossil dinoflagellates across Maestrichtian-Danian boundary in Lower Assam, India. On the basis of *Dinogymnium* spp. and in particular *D. acuminatum* Evitt *et al.* (1967), they have concluded Maestrichtian age for the Jadukata and the Mahadek formations. This species has been observed in all the samples of Zone-IV except at 1055.35 metres in CM-1 which may fall older than Maestrichtian.

Vozzhennikova (1967, in English translation 1971, p. 21) has also emphasized the predominance of *Dinogymnium* (*Gymnodinium*) in Senonian deposits of U.S.S.R. Similar results were obtained by Drugg (1967) while describing the palynology of the Upper Moreno Formation (Maestrichtian).

Davey (1969 a & b) has described Campanian-Maestrichtian microplankton from South Africa. His assemblage has very little in common with the present one except for *Diconodinium* and *Palaeocystodinium*.

Recently Kjellström (1973) has described Maestrichtian microplankton from Hollviken Bore hole No. 1 in Scania, which dominates in the occurrence of Cavate forms (*Deflandera*) with total absence of *Dinogymnium* and *Trichodinium*. The later two genera are the important constituents of Senegal microplankton assemblage. This difference in floral constituents can be explained in view of their widely separated geographic locations.

These observations and comparisons lead to conclude that the Zone-IV microplankton assemblage is Campanian-Maestrichtian in age. Palaeontological results of C.F.P. and COPETAO (unpublished) log data also support the above dating.

Characteristics of Zone—IV:

(1) Dominance of *Trichodinium*.
(2) Marked representation of *Dinogymnium* with common occurrence of *D. acuminatum*.
(3) Thick walled dinoflagellates, mostly Cavate or bicavate.
(4) Family Deflandreaceae well represented.
(5) Microplankton dominate over miospores.

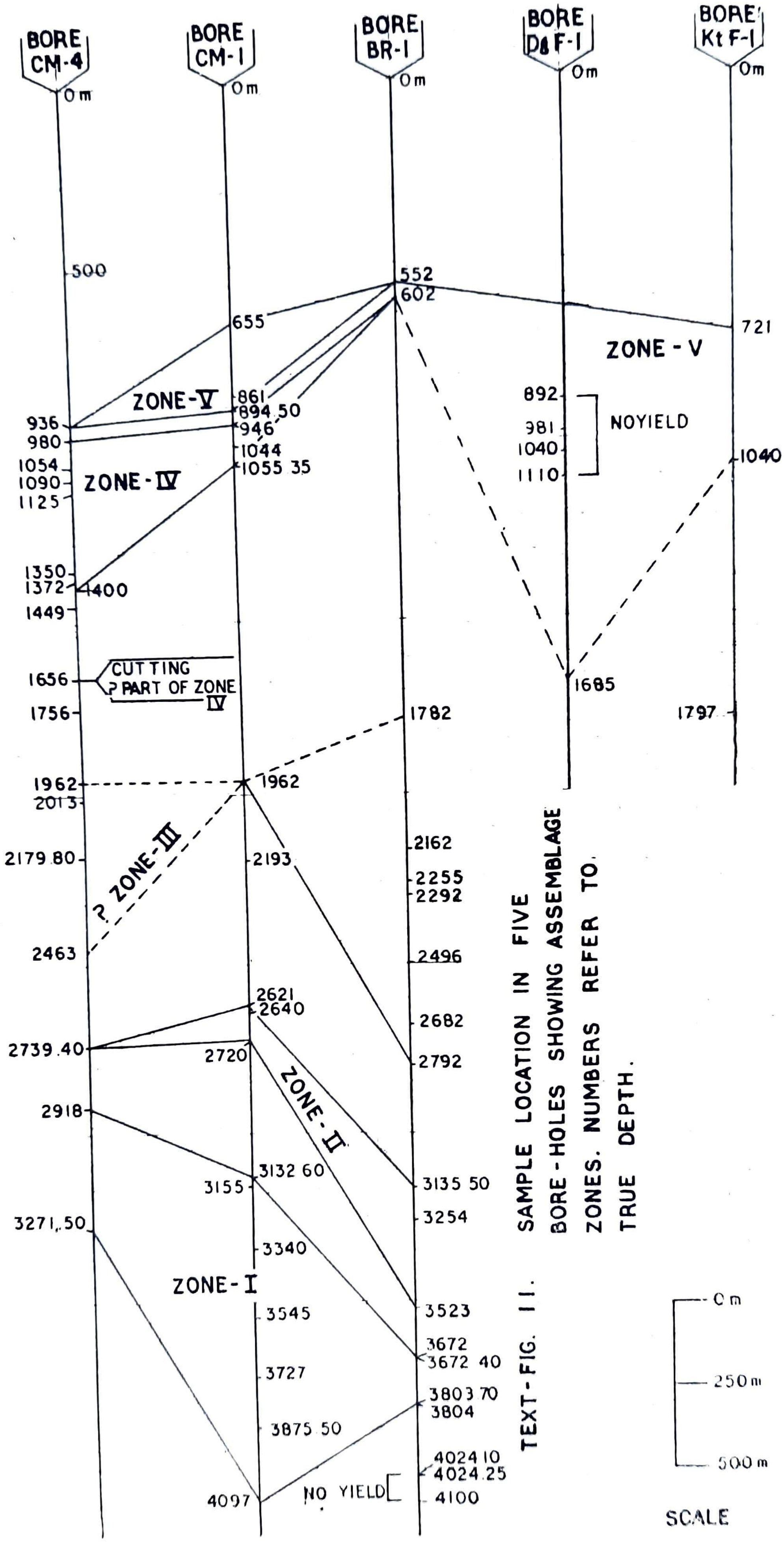
Zone-V: This has been marked at the top of the bore-hole CM-1, CM-4 and KtF-1 only. It ranges from 894.50 to 665 m in CM-1; at 936 metres in CM-4 and at 721 metres in KtF-1 (Text-figs. 2-6 & 11).

Main constituents of this zone are *Trichodinium*, *Cleistosphaeridium*, *Cyclonephelium*, *Geiselodinium*, *Polysphaeridium*, *Palaeocystodinium*, *Senegalinium* and *Achomosphaera*.

The zone has been separated in view of the total absence of *Dinogymnium* which characterised Zone-IV. Other constituents are similar to Zone-IV, with similar abundance of *Trichodinium*.

This assemblage does not possess any Palaeocene element like *Eisenackia* or *Wetzeliella* etc. It is therefore treated as an Upper most part of the Maestrichtian. Palaeontological dating supports this finding.

The absence of *Dinogymnium* at this level suggests the possibility that the genus has some restricted occurrence in Maestrichtian may be that it does not occur in the uppermost levels of Upper Maestrichtian. This requires more data to confirm the above contention.



TEXT-FIG. 11. SAMPLE LOCATION IN FIVE BORE-HOLES SHOWING ASSEMBLAGE ZONES. NUMBERS REFER TO TRUE DEPTH.

Zone-V is well represented in bore-hole CM-1. It includes microfloral assemblages recovered at three levels viz., 894.50, 861 & 655 m. The chief constituents of dinoflagellate assemblage at 894.50 m are *Cyclonephelium*, *Palaeocystodinium*, *Polysphaeridium*, *Cleistosphaeridium* and *Tenua* with total dominance of microplankton (80%) as compared to miospores (20%). The next assemblage in ascending order (at 861 m) includes *Polysphaeridium* as dominant element with *Achomosphaera*, *Tenua*, *Kalyptea* and *Spiniferites*. At this level the microplankton and miospore ratio becomes more or less equal. The common elements with previous assemblage are: *Polysphaeridium* and *Tenua*. The last and the topmost assemblage from 655 m possesses *Cyclonephelium* and *Palaeocystodinium* which are also recovered from Zone-IV. In this assemblage the miospores (60%) dominate over microplankton (40%).

Characteristics of Zone-V:

(1) Absence of *Dinogymnium*.
(2) Abundance of *Polysphaeridium* and *Cyclonephelium*.
(3) Diversity in dinoflagellate flora.
(4) Gradual decrease in the dinoflagellate percentage from base to top.

Palaeoenvironmental Conclusions:

From the characteristics of each zone and the miospore-microplankton percentage ratio (Text-fig. 10), it is quite evident that during Lower-?Upper Aptian (Zone I) the salinity of sea water was low, which is evidenced from the low diversity in dinoflagellate constituents (Hurlburt, 1963; Sarjeant, 1970). For *Subtilisphaera* a member of the family Deflandreaceae, we derive that it must have occurred in reduced salinity, and shallow depths.

The characteristics of Zone-II (Albo-Aptian) evidently suggest that the floral constituents are totally different from the Zone-I, but both zones show the dominance of dinoflagellate percentage over miospores. The diversity in dinoflagellate flora with an abundance of Gonyaulacacean forms than Peridiniacean in Zone-II indicates distinct change in salinity, temperature and depth.

With the present information available from the ?Zone-III (Albo-Upper Cenomanian) it is not possible to give any definite comment upon the palaeoenvironmental conditions except that the sediments were deposited under lagoonal or brakish water conditions, as is evidenced from high percentage of miospores than microplanktons (Text-fig. 10).

An examination of Zone-IV (Campanian-Maestrichtian) miospore-microplankton percentage chart (Text-fig. 10) clearly indicates a sudden rise in the microplankton percentage with the diversity of forms (specially thick walled). This again suggests fluctuation in salinity and depth. *Senegalinium* being the member of Deflandreaceae and an allied genus of *Deflandrea* it is quite likely that this also supports near shore deposits (Vozzhennikova, 1965; Davey, 1966).

The 230 metres thick sequence of zone-v shows a gradual decrease in dinoflagellate percentage from base (894.50 m) to top (665 m). This observation supports the conclusions of Spengler (1964, p. 87) that there was general regression at the end of Maestrichtian.

ACKNOWLEDGEMENTS

The authors sincerely thank the authorities of S.A.P.; COPETAO; S.P.S. and C.F.P. (Talence) for kindly permitting us to publish this report. One of us (K.P.J.) expresses his gratitude to the authorities of C.F.P., Talence, France for extending him all possible help and facilities during his stay there to work on this material. Thanks are also due to Dr. K. R. Surange (Director) and Dr. S.C.D. Sah (Head of Oil Palynology Department) of Birbal Sahni Institute of Palaeobotany, Lucknow, for kindly permitting one of us (K.P.J.) to continue and finalise the work at the Institute.

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EXPLANATION OF PLATES

(All magnifications × 500 until otherwise stated)

PLATE 1

1-2. *Dinogymnium major* sp. nov.; Slide nos. 8668-23 & 8668a-12.
3-4. *Dinogymnium biconicum* sp. nov.; Slide nos. 8668-22 & 8668a-7 (both magnified ×250).
5-8. *Dinogymnium acuminatum* Evitt *et al.*, 1967; Slide nos. 8674-3, 5957-1, -8703-4 & 8674-6.
9. *Dinogymnium westralium* (Cookson & Eisenack) Evitt. *et al.*, 1967; Slide no. 8634a-3.
10. *Dinogymnium denticulatum* (Alberti) Evitt *et al.*, 1967; Slide no. 8479-17.
11. *Dinogymnium* sp. A; Slide no. 8459a-10.
12. *Dinogymnium* sp. B; Slide no. 5957-5.
13. *Dinogymnium* sp. C; Slide no. 8674-14.
14-16. *Trichodinium bifurcatum* sp. nov.; Slide nos. 8668-7, 8668-29 & 8634b-1.
17-18. *Trichodinium* sp. A; Slide no. 8459-7. (Fig. 18 same in another focus).

PLATE 2

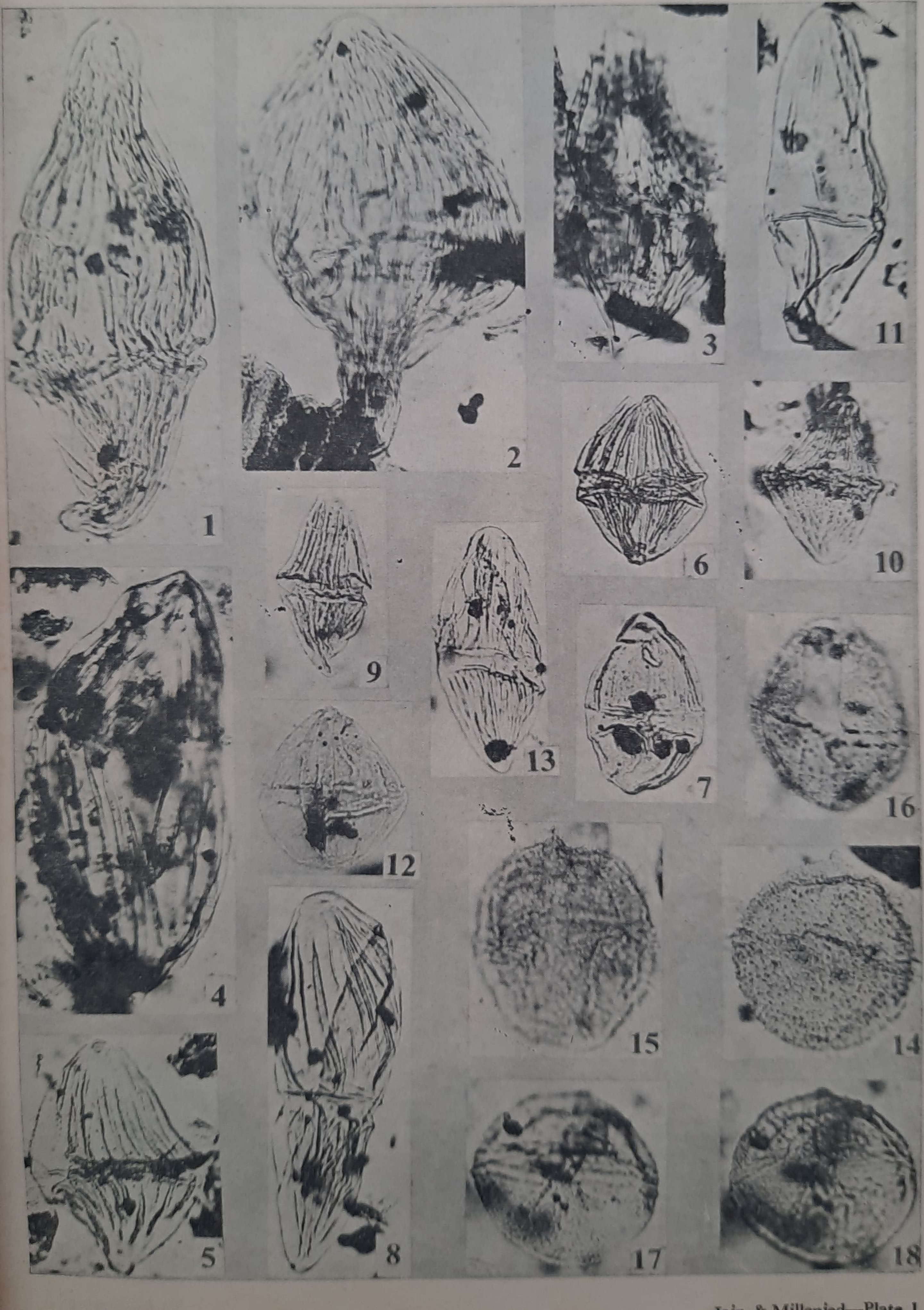
19. *Gonyaulacysta edwardsi* (Cookson & Eisenack) Clarke & Verdier, 1967; Slide no. 5976-8.
20. *Gonyaulacysta orthoceras* (Eisenack) Sarjeant, 1966; Slide no. 5976-6.
21-22. *Gonyaulacysta* sp. A; Slide no. 5976-7 (Fig. 21 showing dorsal view and Fig. 22 showing ventral view).
23. *Apteodinium* sp. A; Slide no. 8960-9.
24. *Gonyaulacysta* sp. C; Slide no. 7299-4.
25. *Gonyaulacysta helicoidea* (Eisenack & Cookson) Sarjeant, 1966; Slide no. 7299-17.
26. *Gonyaulacysta* sp. cf. *G. hadra* Sarjeant, 1966; Slide no. 7298a-2.
27. *Apteodinium spinosum* sp. nov.; Slide no. 7298-19.
28. *Gonyaulacysta* sp. B; Slide no. 5125a-1.
29-30. *Fromea elongata* sp. nov.; Slide nos. 7299-5 & 7299-16.
31. *Tenua* sp. cf. *T. hystricella* Eisenack emend. Sarjeant, 1968; Slide no. 7302c-2.
32-33. *Leptodinium micropunctatum* sp. nov.; Slide nos. 7949-2 & 7882-2.

PLATE 3

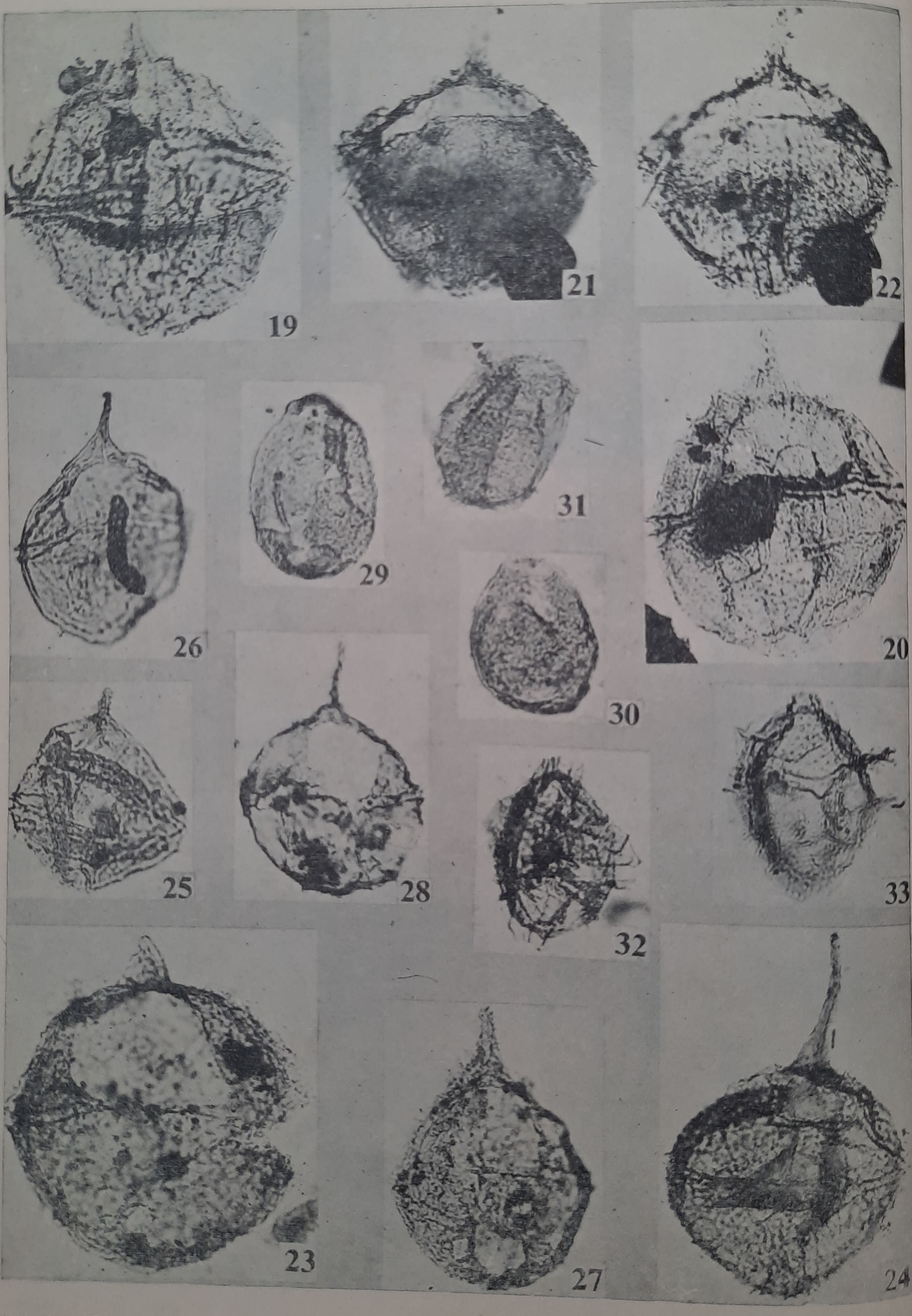
34. *Spiniferites cingulatus* (Wetzel) Sarjeant, 1970; Slide no. 7298-22.
35. *Spiniferites ramosus* subsp. *multibrevis* (Davey & Willaims) Lentin & Williams 1973; Slide no. 7298-22.
36. *Spiniferites ramosus* subsp. *ramosus* (Ehrenberg) Lentin & Williams, 1973; Slide no. 7299-30.
37. *Spiniferites ramosus* var. *reticulatus* (Davey & Williams) Davey & Verdier, 1971; Slide no. 8454a-6.
38-39. *Spiniferites crassimuratus* (Davey & Williams) Sarjeant, 1970; Slide no. 8454a-1 (Same specimen in two views).
40. *Spiniferites ramosus* subsp. *granosus* (Davey & Williams) Lentin & Williams, 1973; Slide no. 8456-12.
41. *Hystrichodinium* sp. A; Slide no. 8674-11.
42-43. *Pterodinium cornutun* Cookson & Eisenack, 1962; Slide nos. 7882-6 & 7883-4.
44. *Dinopterygium* sp. A; Slide no. 8967-5.
45. *Toolongia* sp. A; Slide no. 8667-6.
46. *Achomosphaera* sp. B; Slide no. 8674-15.
47. *Achomosphaera* sp. A; Slide no. 5956-1.
48. *Achomosphaera sagena* Davey & Williams, 1966; Slide no. 7879-2.
49. *Dinopterygium* sp. A; Slide no. 8967-3.
50. *Kalyptea* sp. A; Slide no. 7883-3.
51. *Pareodinia psilata* sp. nov.; Slide no. 7298-11.
52. *Odontochitina costata* Alberti emend. Clarke & Verdier, 1967; Slide no. 8967-1.

PLATE 4

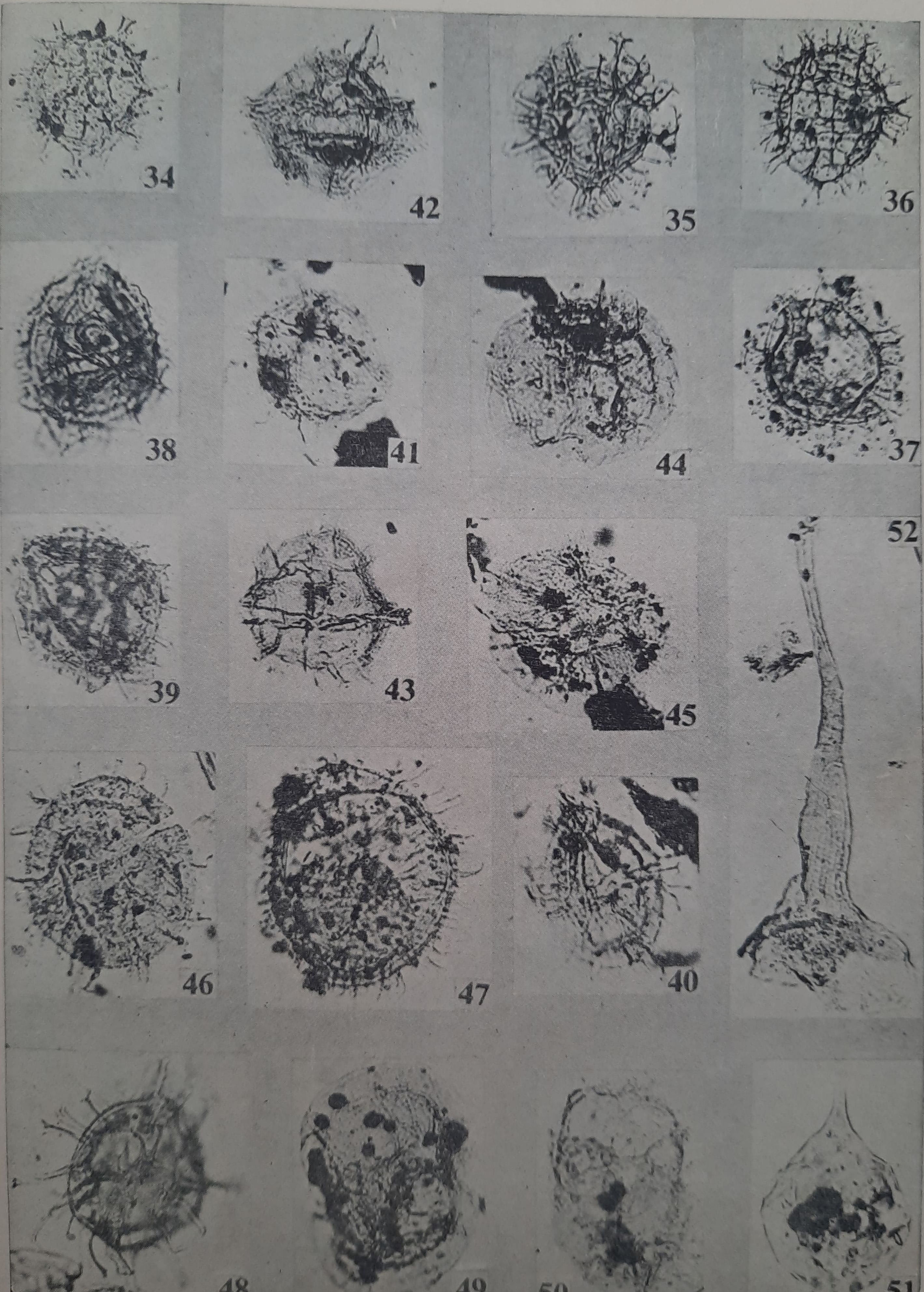
53-54. *Thalassiphora maxima* sp. nov.; Slide nos. 8456-1 & 8456-2.
55. *Odontochitina operculata* (Wetzel) Deflandre & Cookson, 1955; Slide no. 8967-21.
56. *Actinotheca* sp. A; Slide no. 7762a-2.
57. *Oligosphaeridium complex* (White) Davey & Williams, 1966; Slide no. 7298-27.
58. *Litosphaeredium* sp. B ; Slide no. 7903-1.



Jain & Millepied—Plate 1



Jain & Millepied—Plate 2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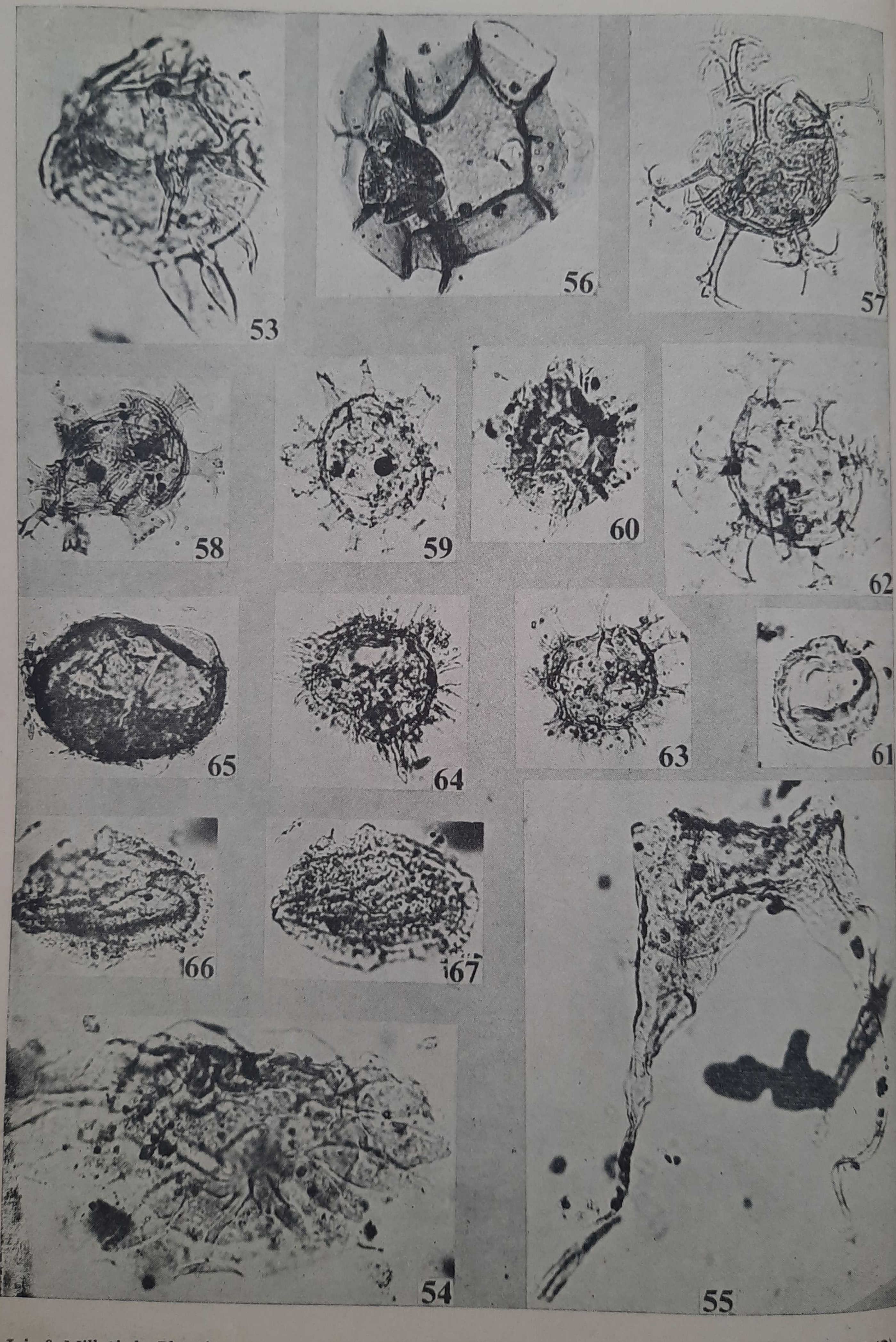
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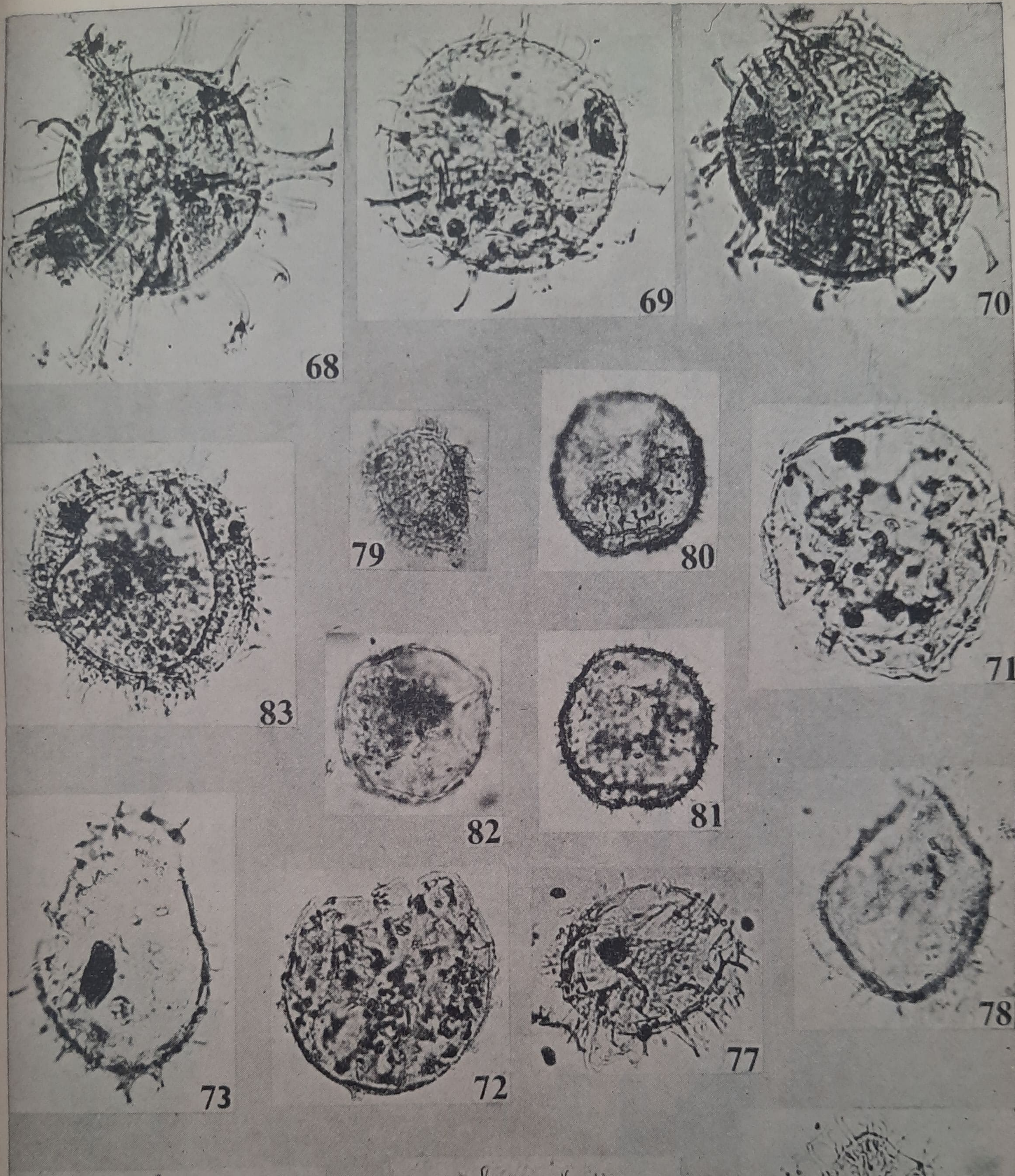
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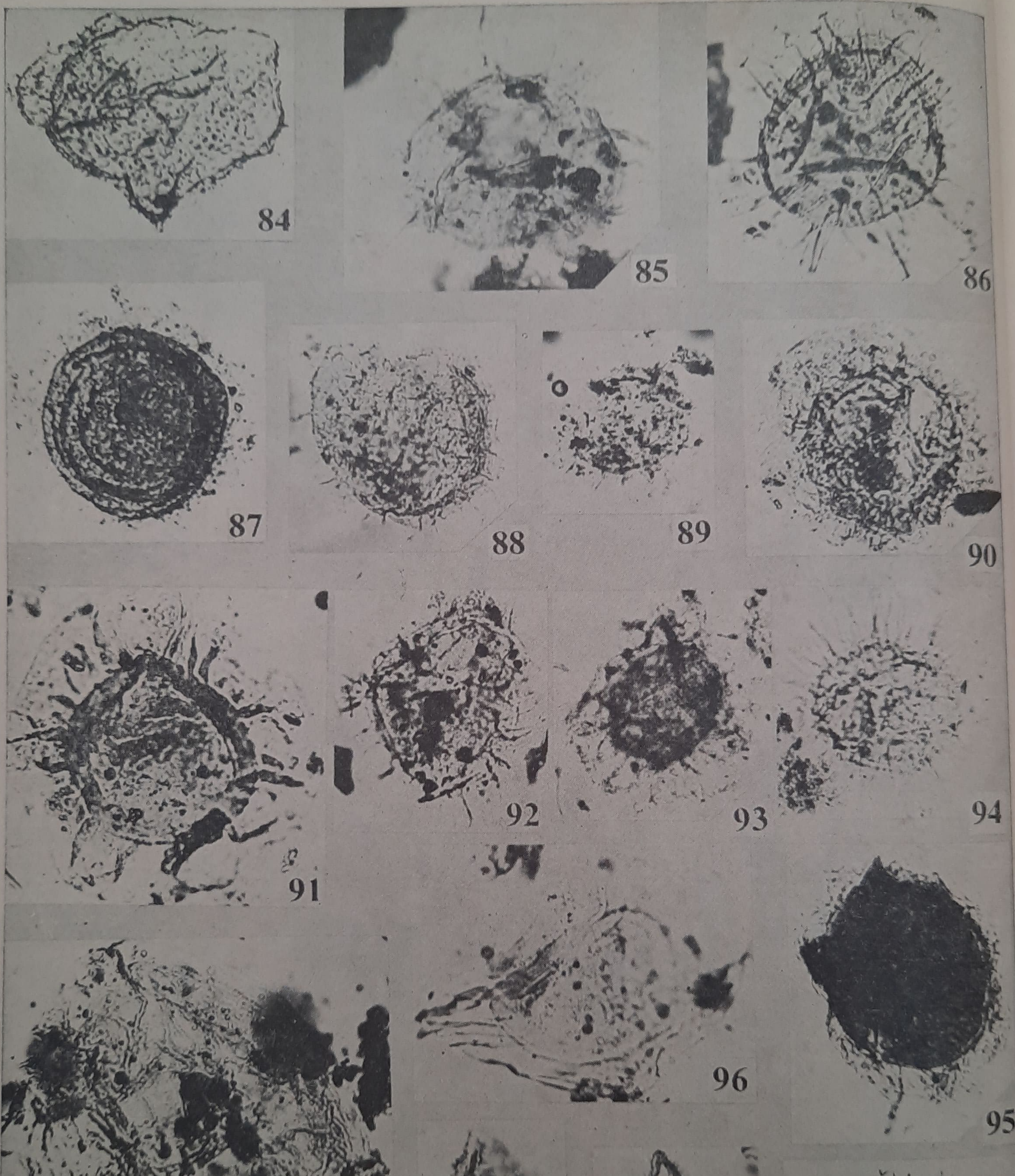
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59. *Litosphaeridium* sp. A; Slide no. 7299-35.

60-61. *Thalassiphora* sp. A; Slide nos. 8461-5 & 8674-4.

62. *Oligosphaeridium* sp. cf. *O. pulcherrimum* (Deflandre & Cookson) Davey & Williams, 1966.

63. *Hystrichosphaeridium* sp. cf. *H. simplicispinum* Davey & Williams, 1966; Slide no. 7298-19.

64. *Coronifera oceanica* Cookson & Eisenack; Slide no. 8967-11.

65. *Kalyptea distincta* sp. nov.; Slide no. 7882-3.

66-67. *Gardodinium deflandrei* Clarke & Verdier, 1967; Slide no. 8704-3 (same specimen in different foci).

PLATE 5

68. *Cordosphaeridium senegalensis* sp. nov.; Slide no. 7880-3.

69-70. *Polysphaeridium granulosum* sp. nov.; Slide nos. 7762-1 & 7762a-5.

71-72. *Polysphaeridium punctatum* sp. nov.; Slide nos. 7762a-4 & 7762-7.

73-74. *Polysphaeridium elongatum* sp. nov.; Slide nos. 7762a-2 & 7762-7.

75-76. *Tenua dubius* sp. nov.; Slide nos. 8632-9 & 8632-5.

77. *Cyclonephelium distinctum* Deflandre & Cookson, 1955; Slide no. 8667-8.

78. *Cleistosphaeridium* sp. A; Slide no. 8668-13.

79. *Cleistosphaeridium* sp. B; Slide no. 7299-10.

80-82. *Cleistosphaeridium brevispinosum* sp. nov.; Slide nos. 8966-3 & 8674-17. (fig. 80—dorsal view, fig. 81-Ventral view).

83. *Cyclonephelium* sp. A; Slide no. 8457-6.

PLATE 6

84. *Tenua anaphrissa* (Sarjeant) Benedek, 1972; Slide no. 7299-24.

85. *Callaiosphaeridium* sp. A; Slide no. 9405-5.

86. *Exochosphaeridium* sp. cf. *E. bifidum* (Clarke & Verdier) Clarke *et al.* 1968; Slide no. 7299-20.

87. *Pterospermopsis concentricum* sp. nov.; Slide no. 7299-20.

88. *Tenua rioulti* Sarjeant, 1968; Slide no. 7299-3.

89. *Baltisphaeridium* sp. A; Slide no. 8698-1.

90. *Pterospermopsis* sp. C; Slide no. 7298a-12.

91. *Pterospermopsis barbarae* Gorka, 1963; Slide no. 8459a-4.

92. *Exochosphaeridium* sp. cf. *E. bifidum* (Clarke & Verdier) Clarke *et al.*, 1968; Slide nol 8457-6.

93. *Cannosphaeropsis* sp. A; Slide no. 8698-5.

94. *Baltisphaeridium* sp. B; Slide no. 8668-16.

95. *Pterospermopsis* sp. B; Slide no. 8966-6.

96. *Pterospermopsis ovatus* sp. nov.; Slide no. 9704a-4.

97. *Pterospermopsis* sp. A; Slide no. 8634-1.

98-99. *Diconodinium distinctum* sp. nov.; Slide nos. 8459-5 & 8460-7.

100. *Baltisphaeridium whitei* (Deflandre & Courteville) Sarjeant, 1959; Slide no. 7298-10.