

CRETACEOUS MICROPLANKTON ASSEMBLAGES
FROM THE ALBIAN TO CAMPANIAN OF
WYOMING

by

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ABSTRACT

The marine microplankton (dinoflagellate and acritarch cyst) assemblages of late Albian to Campanian (Cretaceous) from the Thermopolis Shale, Mowry Shale, Frontier Formation, Carlisle Shale, Niobrara Formation, Steele Shale, Mesaverde Formation, and Cody Shale near Rawlins and Dubois, Wyoming are recorded, described and illustrated. The samples were collected from strata which are dated by independent paleontological evidence. Twenty-five genera containing 45 species are described. The distribution of these species is recorded in the form of a range chart. The Albian to Campanian strata are divided into three biostratigraphic zones based on the restricted stratigraphic range of 15 selected dinoflagellate cysts. Zone A (Albian) is characterized by Palaeohystrichophora sp. 1, Muderongia sp. 1, Spinidinium vestitum, Deflandrea sp. 1, Ovoidinium ostium, and Cribroperidinium orthoceras. Zone B (Cenomanian to Coniacian) has one species, Palaeohystrichophora sp. 2, restricted to it and is best identified by its stratigraphic relationship to zones A and C. Zone C (Santonian to Campanian) is defined by the occurrence of three diagnostic species, Deflandrea echi-noidea, Dinogymnium acuminatum, and Deflandrea acuminata.

INTRODUCTION

The purpose of this thesis is to investigate the occurrences of marine microplankton (dinoflagellate and acritarch cysts) found in two measured sections of late Albian to Campanian (Cretaceous) strata exposed in Wyoming with the following objects:

1. To record stratigraphic occurrences of the microplankton recovered from the marine strata.
2. To describe and photograph the important microplankton and compare them with others of the same age from other areas.
3. To develop a biostratigraphic zonation based on irreversible evolutionary changes in the microflora assemblages rather than reversible changes brought about by environmental (facies) changes.
4. To compare the formation age assignments of Cobban and Reeside (1952a, 1952b) based on invertebrate fossils against known ranges of dinoflagellates found in the strata.

Location

Samples from two composite sections were used in this study. These samples were supplied to me by the EXXON Production and Research Company. The Rawlins section outcrop samples were collected from a composite section located in secs. 12, 13, 14, 15, and 16, T. 22 N., R. 87 W. and secs. 7, 13, 23, 24, T. 22 N., R. 86 W., Carbon County, Wyoming (Fig. 1). The section is over 3,400 meters thick. One

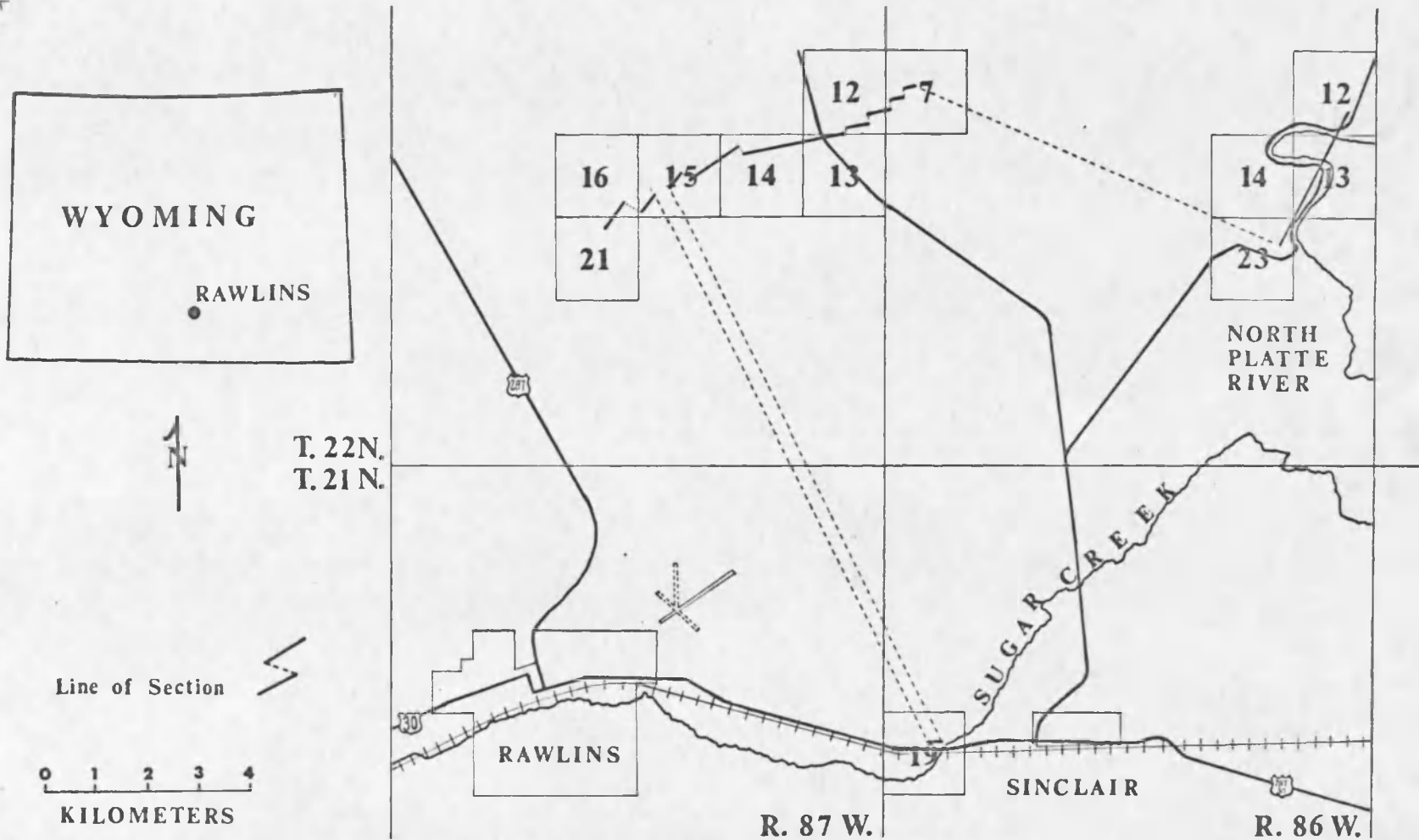


Figure 1. Location map of Rawlins measured section, Carbon County, Wyoming

hundred and fifteen samples were processed from the Rawlins section, with 67 samples yielding dinoflagellate cysts. The Horse Creek section outcrop samples were collected from a composite section from secs. 1 and 36, T. 42 N., R. 106 W., Fremont County, Wyoming (Fig. 2). This section is over 1,100 meters thick. Seventy samples were processed, with 37 samples containing identifiable dinoflagellate cysts.

Two stratigraphic sections situated over 260 km apart were used in an effort to separate apparent extinctions and apparent first occurrences of dinoflagellates caused by reversible facies changes from true extinctions and first occurrences caused by irreversible evolutionary changes which can be used for age dating and time correlation. The apparent evolutionary changes are used to delineate biostratigraphic zones for the study area. This study is limited to marine microflora and no land-derived pollen or spores were studied.

Methods of Study

Maceration Procedures

The material used in this thesis was obtained from outcrop samples collected from two measured sections. A total of 185 samples was processed. Some samples had to be processed more than once because of the paucity or poor preservation of the microflora. The maceration procedure that yielded the best results is the following.

1. The sample is crushed and approximately 5 g of the 1-mm size crushed material are placed in an acid-resistant plastic or Styrofoam cup.

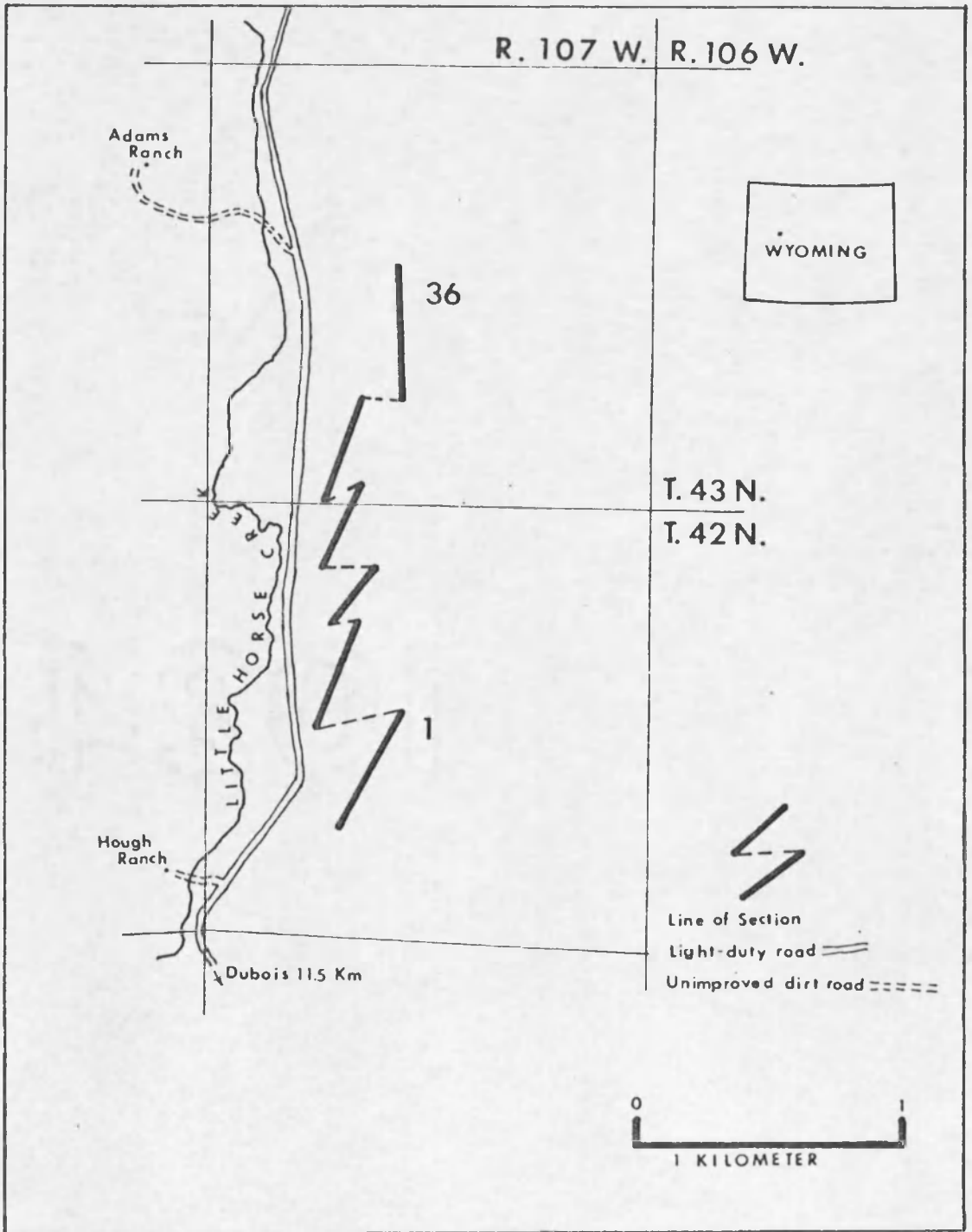


Figure 2. Location map of Horse Creek measured section, Fremont County, Wyoming

2. The sample is covered with cold hydrochloric acid for approximately 12 hours. The sample is then decanted, centrifuged, and washed twice with distilled water.
3. The sample is treated with 50 percent hydrofluoric acid for 24 hours. If possible, stir the solution several times during the 24-hour period. The sample is then centrifuged and the acid decanted. Hot hydrochloric acid is added to the residue to rid it of unwanted silica gel. The hot acid treatment is repeated at least three times, then the sample is washed twice with distilled water.
4. The sample is placed in a glass test tube and covered with concentrated nitric acid and heated gently over an open flame until yellow fumes are given off. After cooling, 10 percent sodium hydroxide is added and the sample is stirred, centrifuged, and decanted. Then distilled water is added, and the sample is again stirred, centrifuged, and decanted. This procedure is repeated until the liquid is clear.
5. Several drops of hydrochloric acid are added and the liquid is stirred, centrifuged, and decanted.
6. The residue is placed in a zinc bromide solution having a specific gravity of 2.0 and centrifuged at 2000 rpm for 20 minutes.
7. The residue floating on top of the zinc bromide is decanted into a clean centrifuge tube, and the material that sinks to the bottom of the solution is discarded.
9. Two drops of hydrochloric acid are added to the floated residue and the tube filled with distilled water. The liquid is stirred,

centrifuged, decanted, and the residue is washed with distilled water three times to remove the zinc bromide.

9. The residue is washed three times with 98 percent ethyl alcohol to remove water and is then placed in a glass storage vial with a solution of 40 percent ethyl alcohol and 60 percent glycerin.

Single Grain Mount Preparation

From each different species found, at least one specimen was chosen and preserved on a single grain mount slide and photographed. Identification was established by reference to published literature. The following procedure was used in making the slides.

1. One or two drops of residue, which is in a solution of 40 percent ethyl alcohol and 60 percent glycerin, was placed on a glass microslide and spread evenly on the center third of the slide.
2. The slide was inspected, using a 10X objective, until a well-preserved microfossil was located.
3. The microfossil was then isolated by "teasing" it with a fine needle held in the jaws of a mechanical pencil. If the needle tip is rubbed on an oily portion of the skin, the alcohol-glycerin solution is repelled away from the microfossil if the needle tip is placed near it.
4. The microfossil was lifted off the slide by a needle tip which has a small piece of glycerin jelly attached to it.
5. The glycerin jelly with microfossil was placed on a clean microslide and covered with a circular cover glass (size 5/8,

thinness O). The slide was placed on a slide warmer and colored beeswax (colored to allow contrast between glycerine jelly and beeswax) was melted around and under the cover glass to seal it permanently.

6. A label with sample number and microfossil name written on it was attached to the single grain mount slide.

Slide Collection

All illustrated specimens are from single grain mount slides. All slides are stored at the Department of Geosciences, The University of Arizona.

Photographic Procedures

All photographs are of single grain mount material and were taken with a Zeiss Standard Universal microscope with an automatic camera attached. Kodak Panatomic-X (ASA32) very fine grain film was used and developed in Kodak Microdal, a fine-grain film developer. The prints were made on AGFA BEH 1 high-contrast (grade 6), single weight paper. The final figures were made on Kodak Polycontrast A/LW paper. Many palynomorphs were so nearly transparent that they were photographed under phase contrast to bring out important features that would have been otherwise lost.

GENERAL GEOLOGY OF THE CRETACEOUS UNITS

The Cretaceous strata examined in this study were deposited during a number of transgressions and regressions of an epicontinental sea that covered a large portion of the western interior of the United States. The sea extended during maximum transgression from the Gulf of Mexico to the Arctic Ocean. The seaway received large quantities of clastic debris during this time from the Mesocordilleran highland.

The formations studied in this thesis were deposited in or adjacent to the Cretaceous seaway from Albian to Campanian time. Figure 3 shows the time-rock nomenclature used for the Cretaceous sections at Rawlins and Horse Creek, Wyoming.

Thermopolis Shale

The Thermopolis Shale was named by Lupton (1916) for exposures near Thermopolis, Wyoming. It overlies the Cloverly Formation and is overlain by the Mowry Shale. The Thermopolis can be divided into three units: a lower shale and siltstone unit; a middle sandstone unit, referred to as the Muddy Sandstone; and an upper shale unit. Most oil geologists restrict the name Thermopolis Shale to the lower shale and siltstone unit. The middle unit, the Muddy Sandstone, is considered a distinct unit. The upper shale unit is included in the overlying Mowry Shale. I have followed Lupton's terminology in this study. In the Rawlins measured section, the Thermopolis consists of approximately 60 meters of marine and marginal marine shales, siltstones, and

| EUROPEAN STAGES | | RAWLINS SECTION | | HORSE CR. SECTION | | |
|------------------|------------------|---------------------|--------------------|----------------------------|--------------------|--|
| UPPER CRETACEOUS | CAMPANIAN | MESAVERDE FORMATION | | COVERED ? CODY SHALE | | |
| | | STEELE SHALE | | | | |
| | | ? | | | | |
| | SANTONIAN | NIOBRARA FORMATION | | | | |
| | CONIACIAN | CARLILE SHALE | | | | |
| | TURONIAN | FRONTIER FORMATION | FRONTIER SANDSTONE | | FRONTIER FORMATION | |
| | | | FRONTIER SHALE | | | |
| | CENOMANIAN | | | | | |
| | LOWER CRETACEOUS | ALBIAN | MOWRY SHALE | | MOWRY SHALE | |
| | | | THERMOPOLIS SH. | | THERMOPOLIS SH. | |
| APTIAN | | CLOVERLY FORMATION | | CLOVERLY FORMATION | | |
| | | ? | | | | |

Figure 3. Time-rock nomenclature used at Rawlins and Horse Creek sections

sandstones. In the Horse Creek measured section, more than 150 meters of the Thermopolis are recorded.

Mowry Shale

The Mowry Shale was given formation rank by Hares (1916) based on exposures in the Wind River Basin. Hares defined the Mowry as being underlain by the Thermopolis Shale and overlain by the Frontier Formation. The Mowry consists of hard, siliceous shale with numerous interbeds of bentonite. The formation weathers to resistant silver-gray ridges. Over 70 meters are recorded at the Rawlins section and over 120 meters are present at the Horse Creek section.

Frontier Formation

The name Frontier Formation was first used by Knight (1902) for exposures near Kemmerer, Wyoming. Cobban and Reeside (1952a) formalized Knight's work and described an additional measured section at Cumberland Gap, located 15 miles south of Frontier, Wyoming. The formation consists of a series of interbedded marine and nonmarine sandstones, siltstones, and shales along with minor coal seams and numerous bentonite beds. The nonmarine portion of the Frontier formation consists of clastic sediments derived from the Mesocordilleran highland that interfinger with the marine siltstones and shales. The Frontier is over 270 meters thick at the Rawlins section and approximately 229 meters thick at the Horse Creek section.

Carlile Shale

The Carlile Shale, as originally defined by Rubey (1930) for exposures in the Black Hills of Wyoming and South Dakota, consists of three members, a lower shale member; a middle member, the Turner Sandy Member; and the upper member, the Sage Breaks Shale Member. At the Rawlins section, the Carlile Shale is equivalent to only part of the Carlile Shale described by Rubey; therefore, most workers place Carlile in quotation marks to indicate the restricted use of the name. At the Rawlins section, the Carlile overlies the Frontier Formation and underlies the Niobrara Formation. The Carlile is 61 meters thick at the Rawlins section but is not recognized at the Horse Creek section.

Niobrara Formation

The Niobrara Formation (Meek and Hayden, 1862) overlies the Carlile Shale and underlies the Steele Shale at the Rawlins section. The Niobrara is not recognized at the Horse Creek area. At the Rawlins section, the Niobrara consists of over 480 meters of calcareous and non-calcareous, dark-gray, marine shales.

Steele Shale

The Steele Shale (Darton and Siebenthal, 1909) overlies the Niobrara Formation and underlies the Mesaverde Formation in the Rawlins section. The Steele Shale is equivalent to the lower portion of the Pierre Shale. The Steele is over 60 meters thick at the Rawlins section and is characterized as being a dark-gray shale with thin interbeds of sandstone. The formation is not recognized in the Horse Creek section.

Mesaverde Formation

In the Rawlins section, the Mesaverde Formation (Holmes, 1877) overlies the Steele Shale and underlies the Lewis Formation. The Mesaverde is not recognized in the Horse Creek section. At the Rawlins section, the formation is characterized by white, friable, porous, massive to crossbedded, medium- to coarse-grained sandstones interbedded with gray to black shales, gray siltstones, brown carbonaceous shale, and thin coal seams. The Mesaverde Formation at the Rawlins section is over 1,333 meters thick. The upper half of the formation is largely nonmarine.

Cody Shale

The name Cody Shale (Lupton, 1916) is used to include strata above the Frontier Formation and below the Mesaverde Formation where the Niobrara Formation cannot be clearly distinguished. Cody Shale is not recognized at the Rawlins section because of the presence of the Niobrara Formation. In the Horse Creek section, the Cody Shale overlies the Frontier Formation and consists of approximately 900 meters of dark-gray marine shales and numerous interbedded sandstones. The formation is poorly exposed at the Horse Creek section and only the lowest 250 meters could be sampled.

BIOSTRATIGRAPHY

The biostratigraphic zonation developed in this study is based on only qualitative analysis of the samples. The paucity of microplankton in almost all samples processed made quantitative work with the material infeasible. The stratigraphic ranges of all described palynomorphs from the Rawlins and Horse Creek sections were plotted (Fig. 4, in pocket), and a biostratigraphic zonation was established based on the combined stratigraphic ranges of selected taxa from the two reference sections. The biostratigraphic zones and their correlation with the Cretaceous stages are shown in Figure 5.

Age determinations for the formations according to Cobban and Reeside's (1952b) invertebrate zones were used as a base. The age determinations were then slightly modified, based on dinoflagellate evidence from my study. The lowermost portion of the Frontier Formation is considered of Albian, not Cenomanian, age. Also the Coniacian-Santonian boundary has been adjusted so that now the Niobrara Formation is entirely Santonian except for the basal 46 meters.

A total of 45 palynomorphs were identified, photographed, and described from the two reference sections. The ranges of most of these palynomorphs are too long to be useful for correlation in this study. But based on 15 dinoflagellate species that appear to be restricted in their stratigraphic range, the Albian to Campanian strata have been divided into three zones.

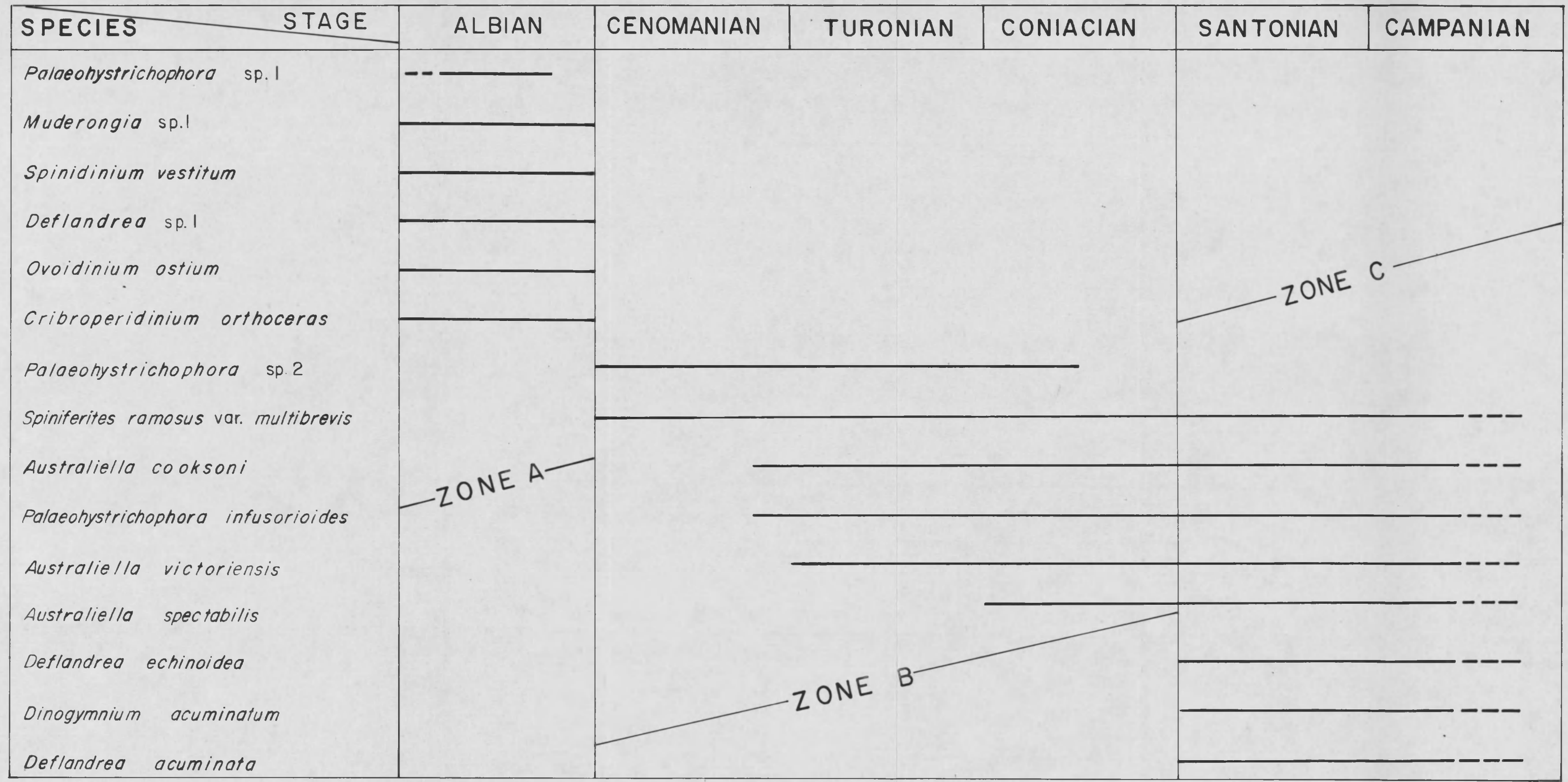


Figure 5. Microplankton biostratigraphic zonation

Zone A

Zone A is characterized by the occurrence of six species:

Palaeohystrichophora sp. 1

Muderongia sp. 1

Spinidinium vestitum

Deflandrea sp. 1

Ovoidinium ostium

Cribroperidinium orthoceras

The top of the zone is defined as being immediately below the first appearance of Palaeohystrichophora sp. 2. The upper limit of the zone coincides with the top of the Albian stage. Zone A includes the Thermopolis Shale, Mowry Shale, and the lowest portion of the Frontier Formation. Cobban and Reeside (1952b) include all of the Frontier Formation in the Cenomanian, but based on the occurrence of the dinoflagellates Spinidinium vestitum and Ovoidinium ostium, which are restricted to the Albian, an Albian age seems more appropriate.

Zone B

Only one morphologically distinctive species, Palaeostrichopora sp. 2, is restricted to Zone B. This species together with five other distinctive species that occur with regularity within this zone are listed below:

Palaeohystrichophora sp. 2

Spiniferites ramosus var. multibrevis

Australiella cooksoni

Palaeohystrichophora infusorioides

Australiella victoriensisAustraliella spectabilis.

The top of Zone B is defined as being immediately below the first occurrence of Deflandrea echinoidea, Dinogymnium acuminatum, and Deflandrea acuminata. Zone B is difficult to recognize because of the absence of restricted microplankton and is best identified by its stratigraphic relationship to Zones A and C. This zone includes the Frontier Formation, except its lowermost portion, the Carlile Shale, and the lowermost portion of the Niobrara Formation. Cobban and Reeside (1952b) assigned Cenomanian to Coniacian ages to these units based on invertebrate fossil evidence. Dinoflagellates found in these units corroborate but do not refine the age assignments.

Zone C

Zone C is the uppermost zone and has its base defined by the first occurrence of the three morphologically distinctive species:

Deflandrea echinoideaDinogymnium acuminatumDeflandrea acuminata.

The top of this zone is not defined in this study because it extends into late Campanian strata which are not in the study's scope. Zone C includes the Niobrara Formation, except its lowermost portion, the Steele Shale, the Mesaverde Formation in part, and the Cody Shale in part. Cobban and Reeside (1952b) assigned nearly all of the Niobrara Formation a Coniacian age except for the uppermost portion, which was assigned a Santonian age. The Steele Shale, Mesaverde Formation in part,

and the Cody Shale in part were assigned a Campanian age. The occurrence of three dinoflagellate species, which appear to be restricted worldwide to Santonian and younger strata, Deflandrea echinoidea, Dinogymnium acuminatum, and Deflandrea acuminata, in most of the Niobrara Formation strongly suggests a Santonian age for all but the lowermost portion of the Niobrara Formation. Marine palynomorphs found in the Steele Shale, Mesaverde Formation, and Cody Shale corroborate previous age assignments of Cobban and Reeside (1952b).

CONCLUSIONS

The stratigraphic occurrences of marine microplankton (dinoflagellate and acritarch cysts) from late Albian to Campanian strata have been recorded and described. All described species have been illustrated.

The microplankton assemblages from the strata consist of 25 genera containing 45 species. The strata are divided into three biostratigraphic zones based on the restricted occurrences of 15 diagnostic dinoflagellate species.

With two exceptions, formation age determinations based on dinoflagellates agree with those based on invertebrate fossils. The lowest portion of the Frontier Formation is considered late Albian, not early Cenomanian, and all but the lowermost portion of the Niobrara Formation is considered Santonian, not Coniacian.

Marine microplankton are useful and worthwhile in the determination of the zonation and age of Cretaceous strata in the study area, but before a precise biostratigraphic zonation can be developed a large number of stratigraphic sections must be studied to gather more data on the ranges of the taxa discussed in this study.

APPENDIX

SYSTEMATIC DESCRIPTIONS

Class Dinophyceae Pascher
 Subclass Dinoferothecidae Bergh
 Order Peridiniales Schütt 1869
 Family Gonyaulacystaceae Sarjeant and Downie 1966,
 emend. Sarjeant and Downie 1974
 Type Genus Gonyaulacysta Deflandre 1964, emend. Sarjeant 1966

Genus Cribroperidinium Neale and Sarjeant 1962, emend. Davey 1969
Cribroperidinium orthoceras (Eisenack) Davey 1969
 Fig. 6, nos. 1, 2

Selected Synonymy

- 1958 Gonyaulax orthoceras Eisenack, p. 388, Pl. 21, figs. 3-11,
 Pl. 24, fig. 1.
 1959 Gonyaulax orthoceras Eisenack; Gocht, p. 54, Pl. 5, figs.
 12-13.
 1961 Gonyaulax orthoceras Eisenack; Alberti, p. 6, Pl. 11, figs. 1-3.
 1967 Gonyaulax orthoceras Eisenack; Vozzhennikova, p. 86, Pl. 28,
 figs. 1-3.
 1969 Cribroperidinium orthoceras (Eisenack); Davey, p. 138.
 1971 Cribroperidinium orthoceras (Eisenack) Davey; Brideaux, p. 84,
 Pl. 24, fig. 48.
 1972 Gonyaulacysta orthoceras Eisenack; Benedek, p. 18, Pl. 1,
 fig. 3.

Description. Dinoflagellate cyst, ellipsoidal in outline; epitract possesses a long, well-developed apical horn; hypotract rounded without antapical horns; cingulum narrow, well defined by prominent ridges; plate boundaries defined by low narrow ridges; cyst wall thick, granular, and easily fracture.

Dimensions. Length of 5 measured specimens, 130-150 μ ;
 width, 85-110 μ .

Occurrence. This species ranges from late Albian to early Cenomanian in the study area.

Figure 6. Peridiniales: Gonyaulacystaceae, Apteodiniaceae, Canningiaceae, Broomeaceae, Spiniferitaceae

- 1,2. Criboperidinium orthoceras (Eisenack) Davey: 1, side view; 2, top view. X500.
3. Gonyaulacysta sp.: side view. X500.
4. Spinidinium vestitum Brideaux: side view. X450.
- 5,6. Canningia colliveri Cookson and Eisenack: 1, side view in phase contrast; 2, side view. X500.
- 7,8. Broomea sp.: 1, side view in phase contrast; 2, side view. X500.
9. Spiniferites ramosus var. ramosus (Davey and Williams) Sarjeant. X550.
10. Spiniferites ramosus var. gracilis (Davey and Williams) Lentin and Williams. X450.
11. Spiniferites ramosus var. multibrevis (Davey and Williams) Davey and Verdier. Phase contrast. X550.
12. Spiniferites cf. varmae Lentin and Williams. Phase contrast. X600.

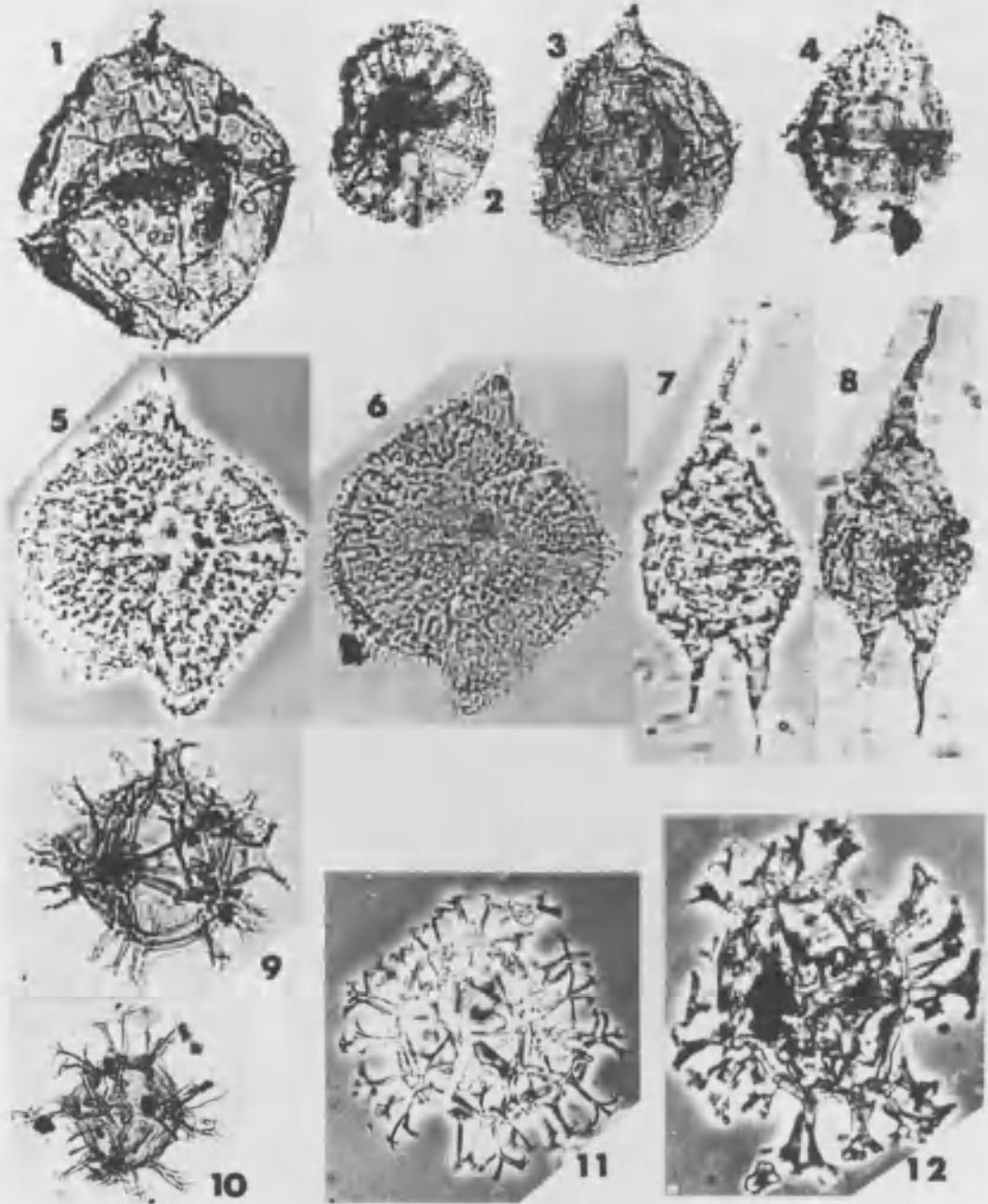


Figure 6. Peridinales: Gonyaulacystaceae, Apteodiniaceae, Canningiaceae, Broomeaceae, Spiniferitaceae

Genus Gonyaulacysta Deflandre 1964,
emend. Sarjeant 1966

Gonyaulacysta sp.

Fig. 6, no. 3

Description. Dinoflagellate cyst, ellipsoidal in outline; epi-tract possesses short apical horn; hypotract rounded without antapical horns; cingulum narrow, well defined by low ridges; capsule ellipsoidal, in close contact with outer wall; plate boundaries are defined by low ridges; cyst wall finely scabate.

Dimensions. Length of 3 measured specimens, 70-81 μ ; width, 78-84 μ .

Occurrence. This species was found only in strata of Albian age in the study area.

Family Apteodiniaceae Eisenack 1961,
emend. Sarjeant and Downie 1974
Type Genus Apteodinium Eisenack 1958

Genus Spinidinium Cookson and Eisenack 1958
Spinidinium vestitum Brideaux 1971
Fig. 6, no. 4

Selected Synonymy

- 1971 Spinidinium vestitum Brideaux, pp. 99-101, Pl. 29, figs. 99-103.
1971 Deflandrea limpida Singh, pp. 359-360, Pl. 61, figs. 1-12.

Description. Dinoflagellate cyst with elongate pentagonal outline; epitract has conelike apical horn which tapers to a blunt point; hypotract has two unequal apical horns; cingulum wide, nearly circular, well defined by ridges lined with short spines; archeopyle intercalary; cyst wall thick and granular.

Dimensions. Length of 5 measured specimens, 55-74 μ ; width, 34-52 μ .

Occurrence. Species found in samples of Albian to earliest Cenomanian age in study area.

Family Canningiaceae Sarjeant and Downie 1966,
 emend. Sarjeant and Downie 1974
 Type Genus Canningia Cookson and Eisenack 1960b

Genus Canningia Cookson and Eisenack 1960b
Canningia colliveri Cookson and Eisenack 1960b
 Fig. 6, nos. 5,6

Selected Synonymy

- 1960b Canningia colliveri Cookson and Eisenack, p. 251, Pl. 38,
 figs. 3,4.
 1967 Canningia colliveri Cookson and Eisenack; Clarke and Verdier,
 p. 20, Pl. 1, figs. 3,4.
 1971 Canningia colliveri Cookson and Eisenack; Davey and Verdier,
 p. 13.
 1971 Canningia colliveri Cookson and Eisenack; Singh, p. 323, Pl.
 50, figs. 2,3.

Description. Dinoflagellate cyst, subcircular in outline; epi-tract possesses apical horn which tapers distally to a blunt point; hypo-tract has two unequal antapical horns; faint suggestion of a cingulum; archaeopyle apical; cyst wall thick with pseudo-reticulate sculpture.

Dimensions. Length of 4 measured specimens 82-90 μ ; width, 60-71 μ .

Occurrence. This species ranges from Albian to earliest Coniacian age in the study area.

Family Broomeaceae Eisenack 1969, emend.
Sarjeant and Downie 1974
Type Genus Broomea Cookson and Eisenack 1958

Genus Broomea Cookson and Eisenack 1958

Broomea sp.

Fig. 6, nos. 7, 8

Description. Dinoflagellate cyst, elongate ellipsoidal in outline; epitract has one long apical horn, usually broken off; hypotract has two antapical horns, both horns are near being in direct axial continuation of the cyst; faint suggestion of a cingulum on several specimens.

Dimensions. Length of 5 measured specimens, 126-132 μ ; width, 40-44 μ .

Occurrence. This species was found in Albian strata from the Rawlins section, not found in the Horse Creek section.

Family Spiniferitaceae Sarjeant 1970, emend.
Sarjeant and Downie 1974

Type Genus Spiniferites Mantell 1850, emend. Sarjeant 1970

Genus Spiniferites Mantell 1850, emend. Sarjeant 1970
Spiniferites ramosus var. ramosus (Davey and Williams) Sarjeant 1970
Fig. 6, no. 9

Selected Synonymy

- 1955 Hystrichosphaera ramosa (Ehrenberg) Wetzel; Deflandre and Cookson, p. 263, Pl. 2, fig. 1; Pl. 5, fig. 8; Pl. 6, fig. 1.
- 1966 Hystrichosphaera ramosa (Ehrenberg) Wetzel; emend. Davey and Williams, pp. 29-38, Pl. 1, figs. 1-6; Pl. 3, fig. 1; Pl. 4, 6, 8, 9, 12; Pl. 5, fig. 6; text-figs. 8, 9.
- 1969 Hystrichosphaera ramosa var. ramosa (Ehrenberg) Wetzel; Davey, p. 172, Pl. 10, figs. 1, 2, 5.
- 1970 Spiniferites ramosus (Ehrenberg) Mantell; Sarjeant, p. 73.
- 1971 Spiniferites ramosus (Ehrenberg) Mantell; Davey and Verdier, p. 33, Pl. 4, figs. 1-3; Pl. 7, fig. 5.
- 1971 Hystrichosphaera ramosa var. ramosa Davey and Williams; Cookson and Eisenack, p. 219, Pl. 8, figs. 1, 2, .
- 1973 Spiniferites ramosus var. ramosus (Davey and Williams) Sarjeant; Harland, p. 689, Pl. 87, fig. 7.
- 1974 Spiniferites ramosus var. ramosus (Davey and Williams); Cookson and Eisenack, p. 56, Pl. 21, fig. 1.

Description. Chorate dinoflagellate cyst, subspherical in outline; central body possesses gonal processes; processes are narrow, solid, and trifurcate at distal ends; processes joined at base by low sutural ridge; cingulum levorotary; central body thin walled with smooth surface.

Dimensions. Diameter of 4 measured specimens, 64-70 μ ; central body diameter, 42-49 μ .

Occurrence. This species ranges in age from Cenomanian to Campanian in the study area.

Spiniferites ramosus (Ehrenberg) var. gracilis (Davey and Williams) Lentin and Williams 1973
Fig. 6, no. 10

Selected Synonymy

- 1966 Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey and Williams, p. 34, P. 1, fig. 5; Pl. 5, fig. 6.
1969 Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey and Williams; Davey, p. 172.
1971 Hystrichosphaera ramosa (Ehrenberg) var. gracilis Davey and Williams; Singh, pp. 350-351, Pl. 58, fig. 6.
1973 Spiniferites ramosus (Ehrenberg) var. gracilis (Davey and Williams) Lentin and Williams, p. 130.
1974 Spiniferites ramosus (Ehrenberg) var. gracilis (Davey and Williams) Lentin and Williams; Cookson and Eisenack, p. 57, Pl. 26, fig. 14.

Description. Chorate dinoflagellate cyst, subspherical outline; central body possesses gonial and sutural processes; processes are narrow, solid, and trifurcate at distal end; processes joined at base by low sutural ridge; cingulum levorotary; central body thin walled with smooth surface.

Dimensions. Diameter of 3 measured specimens, 61-66 μ ; central body diameter, 35-40 μ .

Occurrence. This species was found in samples of latest Coniacian to Campanian age from the Rawlins section; not found in the Horse Creek section.

Spiniferites ramosus (Ehrenberg) var. multibrevis
(Davey and Williams) Davey and Verdier 1971
Fig. 6, no. 11

Selected Synonymy

- 1966 Hystrichosphaera ramosa (Ehrenberg) var. multibrevis Davey and Williams, p. 35, Pl. 1, fig. 4; Pl. 4, fig. 6.
- 1969 Hystrichosphaera ramosa (Ehrenberg) var. multibrevis Davey and Williams; Davey, p. 173, Pl. 10, figs. 3, 4.
- 1971 Hystrichosphaera ramosa (Ehrenberg) var. multibrevis Davey and Williams; Singh, pp. 351-352, Pl. 58, figs. 7, 8.
- 1971 Spiniferites ramosus (Ehrenberg) var. multibrevis (Davey and Williams) Davey and Verdier, p. 33.
- 1973 Spiniferites ramosus (Ehrenberg) var. multibrevis (Davey and Williams) Davey and Verdier; Lentin and Williams, p. 130.
- 1974 Spiniferites ramosus (Ehrenberg) var. multibrevis (Davey and Williams) Davey and Verdier; Cookson and Eisenack, p. 56, Pl. 21, fig. 7.

Description. Chorate dinoflagellate cyst, spherical to sub-spherical in outline; central body possesses numerous solid, short, conical and sutural processes; processes trifurcate at distal end; central body thin walled with smooth surface.

Dimension. Diameter of 5 measured specimens, 70-76 μ ; center body diameter, 45-52 μ .

Occurrence. This species occurs in samples of Cenomanian to Campanian age in the study area.

Spiniferites cf. varmae Lentin and Williams 1973
Fig. 6, no. 12

Selected Synonymy

- 1966 Hystrichosphaera buccina Davey and Williams, pp. 42-43,
Pl. 4, fig. 1.
1970 Spiniferites buccinus (Davey and Williams) Sarjeant, p. 75.
1973 Spiniferites varmae Lentin and Williams, p. 131.
1974 Spiniferites buccinus (Davey and Williams) Sarjeant; Cookson
and Eisenack, p. 58, Pl. 21, fig. 3.

Description. Chorate dinoflagellate cyst; subspherical central body, bearing broad gonol processes; processes flare at distal end into three or more secas which are patulate; numerous processes are fenestrate; central body thick walled with granular surface.

Dimensions. Diameter of 1 measured specimen, 88 μ ; central body width (short axis), 47 μ .

Occurrence. One specimen found in the Niobrara Formation (Coniacian) from the Rawlins section; not found in the Horse Creek section.

Family Deflandreaceae Eisenack 1954, emend.
 Sarjeant and Downie 1974
 Type Genus Deflandrea Eisenack 1938

Genus Deflandrea Eisenack 1938
Deflandrea acuminata Cookson and Eisenack 1958
 Fig. 7, no. 1

Selected Synonymy

- 1958 Deflandrea acuminata Cookson and Eisenack, p. 27, Pl. 4, figs. 5-7.
 1960 Deflandrea acuminata Cookson and Eisenack; Douglas, pp. 19-20, Pl. 4, figs. 21a-21b.
 1964 Deflandrea acuminata Cookson and Eisenack; Manum and Cookson, pp. 7-8, Pl. 1, fig. 4.
 1967 Deflandrea acuminata Cookson and Eisenack; Clarke and Verdier, p. 25, Pl. 2, figs. 11, 12.
 1971 Deflandrea acuminata Cookson and Eisenack; Burgess, p. 133, Pl. 1, figs. 6, 7.
 1973 Deflandrea acuminata Cookson and Eisenack; Felix and Burbridge, p. 22, Pl. 4, fig. 1.
 1974 Deflandrea acuminata Cookson and Eisenack; McIntyre, Pl. 1, fig. 15.

Description. Cavate dinoflagellate cyst; elongate pentagonal in outline; epitract conelike, with blunt apical horn; hypotract has two unequal antapical horns, the longer tapers to a fine point; cingulum indistinct, shallow, broad, defined by two low ridges; capsule spherical, filling most of cyst except for the apical and antapical horns; cyst wall thin and finely granular.

Dimensions. Length of 5 measured specimens, 94-97 μ ; width, 64-68 μ .

Occurrence. This species ranges in age from earliest Santonian through Campanian in the study area.

Figure 7. Peridiniales: Deflandreaceae

1. Deflandrea acuminata Cookson and Eisenack. Phase contrast. X550.
2. Deflandrea denticulata Alberti. X450.
3. Deflandrea echinoidea Cookson and Eisenack. Phase contrast. X550.
4. Deflandrea macrocysta Cookson and Eisenack. Phase contrast. X600.
5. Australiella cooksoni (Alberti) Vozzhennikova. Phase contrast. X500.
6. Deflandrea sp. 1. Phase contrast. X550.
7. Australiella cooksoni (Alberti) Vozzhennikova. Phase contrast. X650.
8. Deflandrea sp. 2. X450.
9. Deflandrea sp. 3. Phase contrast. X500.
10. Australiella spectabilis (Alberti) Lentin and Williams. Phase contrast. X500.
11. Astrocysta cretacea (Pocock) Davey. X500.

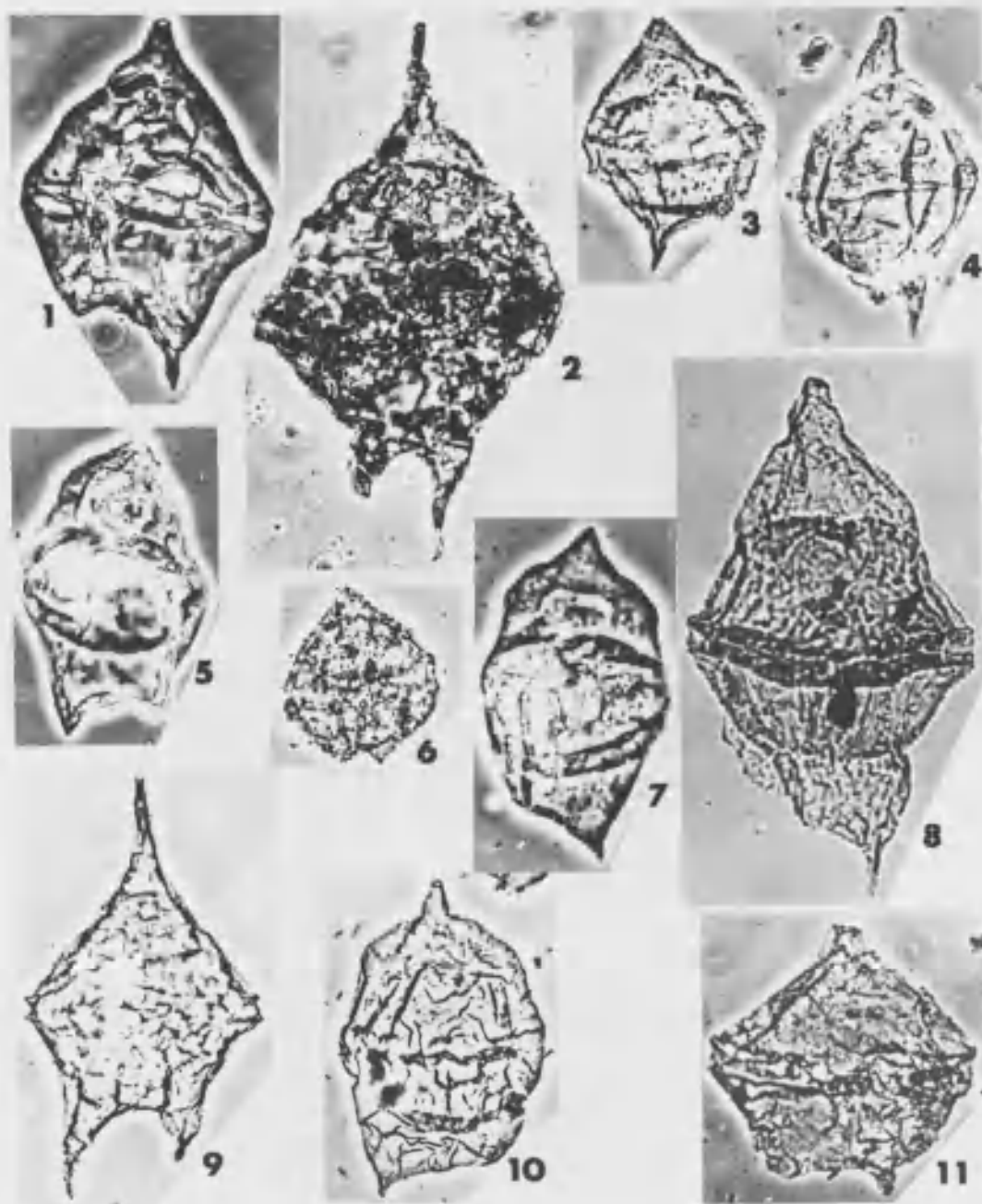


Figure 7. Peridinales: Deflandreaceae

Deflandrea denticulata Alberti 1959
Fig. 7, no. 2

Selected Synonymy

- 1959 Deflandrea denticulata Alberti, pp. 102-103.
1966 Deflandrea denticulata Alberti; Davey and Williams, p. 232.

Description. Cavate dinoflagellate cyst; fusiform outline with expanded mid-area; epittract cone shaped, with long, tapering apical horn; hypottract possesses two long, narrow antapical horns; cingulum well defined by two low ridges; archeopyle not observed; cyst wall thick and wrinkled.

Dimensions. Length of 1 measured specimen 180 μ ; width, 107 μ .

Occurrence. One specimen found in the Steele Shale (Campanian) from the Rawlins section; not found in the Horse Creek section.

Deflandrea echinoidea Cookson and Eisenack 1960a
Fig. 7, no. 3

Selected Synonymy

- 1960a Deflandrea echinoidea Cookson and Eisenack, p. 2, Pl. 1,
figs. 5, 6.
1967 Deflandrea echinoidea Cookson and Eisenack; Clarke and Ver-
dier, p. 26, Pl. 3, figs. 4, 5.
1969 Deflandrea cf. echinoidea Cookson and Eisenack; Cookson and
Eisenack, p. 5, Pl. 1, fig. 6.
1970 Deflandrea echinoidea Cookson and Eisenack; Davey, p. 339,
Pl. 1, fig. 5.
1973 Deflandrea echinoidea Cookson and Eisenack; Harland, p. 694,
Pl. 87, fig. 10.

Description. Dinoflagellate cyst, subpentagonal in outline;
epittract cone shaped with blunt apical horn; hypottract rounded with two
unequal antapical horns, one horn is greatly reduced; cingulum broad,
delimited by two low-spined ridges; plate boundaries indistinct, demar-
cated by low spine-covered ridges; cyst wall covered with short spines.

Dimensions. Length of 5 measured specimens, 52-57 μ ; width,
35-40 μ .

Occurrence. This species occurs in samples of Coniacian to
Campanian age from the study area.

Deflandrea macrocysta Cookson and Eisenack 1960a
Fig. 7, no. 4

Selected Synonymy

- 1960a Deflandrea macrocysta Cookson and Eisenack, p. 3, Pl. 1,
figs. 7, 8.
1973 Deflandrea macrocysta Cookson and Eisenack; Harland, p. 695,
Pl. 87, fig. 14.

Description. Cavate dinoflagellate cyst, elongate in outline; epitract rounded except for apical horn; apical horn tapers to a broad, round point; hypotract is rounded except for two unequal antapical horns; cingulum indistinct, broad and shallow; capsule elongate, filling entire cyst except for apical and antapical horns; archeopyle not observed; cyst wall thick and granular.

Dimensions. Length of 2 measured specimens, 75-79 μ ;
width, 44-46 μ .

Occurrence. Species found in one sample from Mesaverde Formation (Campanian) in the Rawlins section.

Deflandrea sp. 1
Fig. 7, no. 6

Description. Dinoflagellate cyst, subpentagonal in outline; epitract cone shaped with short, blunt apical horn; hypotract rounded with two short antapical horns; cingulum broad, well defined by two spine-covered ridges; archaeopyle polygonal when present; periphragm densely covered with short spines.

Dimensions. Length of 5 measured specimens, 45-50 μ ; width, 80-86 μ .

Occurrence. This species occurs only in the Mowry Shale (Albian) in both the Rawlins and Horse Creek sections. This distinctive species may be an excellent indicator for the Mowry Shale in the study area.

Deflandrea sp. 2
Fig. 7, no. 8

Description. Cavate dinoflagellate cyst; elongate-pentagonal outline with expanded mid-area; epittract larger than hypottract; epittract bell shaped, has apical horn which tapers to a broad, rounded point; hypottract bell shaped, possesses two unequal antapical horns; cingulum well defined by two broad ridges; capsule ovoidal in outline, in close contact with periphragm except in the apical and antapical horns; cyst wall thick and rugulate.

Dimensions. Length of 1 measured specimen, 160 μ ; width, 84 μ .

Occurrence. This species occurred in one sample from the Steele Shale (Campanian) in the Rawlins section; not found in the Horse Creek section.

Deflandrea sp. 3

Fig. 7, no. 9

Description. Dinoflagellate cyst, pentagonal in outline; epi-tract shoulderless with a long tapered apical horn; hypotract has two long, unequal antapical horns; apical and antapical horns taper to long, narrow tips; cingulum broad, demarcated by low ridges; plate boundaries faintly suggested; cyst wall thin, granular, and wrinkled.

Dimensions. Length of 2 measured specimens, 118-120 μ ; width, 60-64 μ .

Occurrence. Species found in one sample from the Mesaverde Formation (Campanian) in the Rawlins section; not found in the Horse Creek section.

Genus Astrocysta Davey 1970
Astrocysta cretacea (Pocock) Davey 1970
 Fig 7, no. 11

Selected Synonymy

- 1962 Palaeoperidinium cretaceum Pocock, p. 80, Pl. 14, figs. 219-221.
 1970 Astrocysta cretacea (Pocock) Davey, p. 359, Pl. 2, fig. 4.
 1971 ?Lejeunia cretacea (Pocock) Brideaux, p. 86.
 1973 Astrocysta cretacea (Pocock) Davey; Lentin and Williams, p. 17.
 1974 Astrocysta cretacea (Pocock) Davey; Davey and Verdier, P. 93, fig. 4.

Description. Dinoflagellate cyst, pentagonal outline; epitract has conelike apical horn with blunt top; hypotract possesses two ant-apical horns of unequal length; cingulum indistinct, defined by two low ridges; cyst wall thin and finely scabrate.

Dimensions. Length of 4 measured specimens, 70-74 μ ; width, 83-85 μ .

Occurrence. This species ranges in age from Albian to latest Coniacian in the study area.

Genus Australiella Vozzhennikova 1967
Australiella cooksoni (Alberti) Vozzhennikova 1967
 Fig 7, nos. 5, 7

Selected Synonymy

- 1959 Deflandrea cooksoni Alberti, p. 97, P. 9, figs. 1-6.
 1964 Deflandrea cf. D. cooksoni Alberti; Manum and Cookson, p. 8,
 Pl. 1, figs. 2, 3.
 1967 Deflandrea cf. D. cooksoni Alberti; Clarke and Verdier, p. 25,
 Pl. 3, figs. 1-3.
 1967 Deflandrea cooksonae Alberti; Drugg, p. 16, Pl. 2, fig. 2.
 1967 Australiella cooksoni (Alberti) Vozzhennikova, p. 132.
 1973 Deflandrea cooksoni Alberti; Kjellström, p. 18, fig. 13.
 1973 Deflandrea cooksoni Alberti; Stone, p. 52, Pl. 3, figs. 12, 13.
 1973 Australiella cooksoniae (Alberti) Vozzhennikova; Lentin and
 Williams, p. 18.
 1974 Deflandrea cf. D. cooksonii Alberti; McIntyre, Pl. 1, fig. 16.

Description. Cavate dinoflagellate cyst; dorsoventral outline fusiform with expanded mid-area; cingulum or sulcus rarely developed; epitract sometimes narrows to form shoulders; hypotract has two ant-apical horns of unequal length; one horn is sometimes absent; no tabulation observed; archeopyle intercalary; cyst wall thick and granular.

Dimensions. Length of 7 measured specimens, 70-90 μ ;
 width, 37-55 μ .

Remarks. There is a great deal of morphologic variation in this species.

Occurrence. This species is abundant in samples of latest Cenomanian to Coniacian age in the study area.

Australiella spectabilis (Alberti) Lentin and Williams 1973
Fig. 7, no. 10

Selected Synonymy

- 1959 Deflandrea spectabilis Alberti, p. 99, Pl. 9, figs. 7, 8.
1973 Australiella spectabilis (Alberti) Lentin and Williams, p. 18.
1973 Deflandrea spectabilis Alberti; Harland, p. 693, Pl. 87, figs.
9, 15.
1974 Deflandrea spectabilis Alberti; McIntyre, Pl. 1, figs. 8, 9, 13,
14.

Description. Cavate dinoflagellate cyst with an elongate oval outline; epitract rounded except for short apical horn; hypotract square with one short antapical horn; cingulum broad, defined by two low ridges; archeopyle intercalary; capsule oval, separated from periphragm; cyst wall thin, smooth, and wrinkled.

Dimensions. Length of 5 measured specimens, 82-89 μ ;
width, 52-60 μ .

Occurrence. This species occurs in strata of Turonian to Campanian age in the study area.

Australiella verrucosa (Manum) Lentin and Williams 1973
Fig. 8, no. 1

Selected Synonymy

- 1963 Deflandrea verrucosa Manum, p. 60, Pl. 3, figs. 1-4.
1973 Deflandrea cf. D. verrucosa Manum; Stone, p. 53, Pl. 4,
fig. 16.
1973 Australiella verrucosa (Manum) Lentin and Williams, p. 18.

Description. Cavate dinoflagellate cyst; subrectangular outline with expanded mid-area; epitract bell shaped with conelike apical horn; hypotract has two unequal antapical horns, one horn is greatly reduced; cingulum broad, delimited by two intermittent ridges; plate boundaries are indistinctly outlined by numerous short spines; archeopyle intercalary; cyst wall thick and granular.

Dimensions. Length of 3 measured specimens, 97-105 μ ;
width, 62-72 μ .

Occurrence. This species occurs in strata of latest Coniacian to Campanian age in the study area.

Figure 8. Peridinales: Deflandreaceae, Hexagoniferaceae, Endoscriniaceae, Pseudocerataceae, Muderongiaceae

1. Australiella verrucosa (Manum) Lentin and Williams. X450.
2. Australiella victoriensis (Cookson and Manum) Lentin and Williams. X450.
- 3-5. Ovoidinium ostium Davey: 3, apical horn attached; 4, apical horn lost, in phase contrast; 5, apical horn lost. X550.
6. Palaeohystrichophora sp. 1. Phase contrast. X650.
7. Palaeohystrichophora infusorioides Deflandre. Phase contrast. X1000.
8. Muderongia sp. 1. Phase contrast. X500.
9. Odontochitina operculata (Wetzel) Deflandre and Cookson. Phase contrast. X350.
10. Muderongia sp. 2. Phase contrast. X550.
11. Palaeohystrichophora sp. 2. Phase contrast. X650.

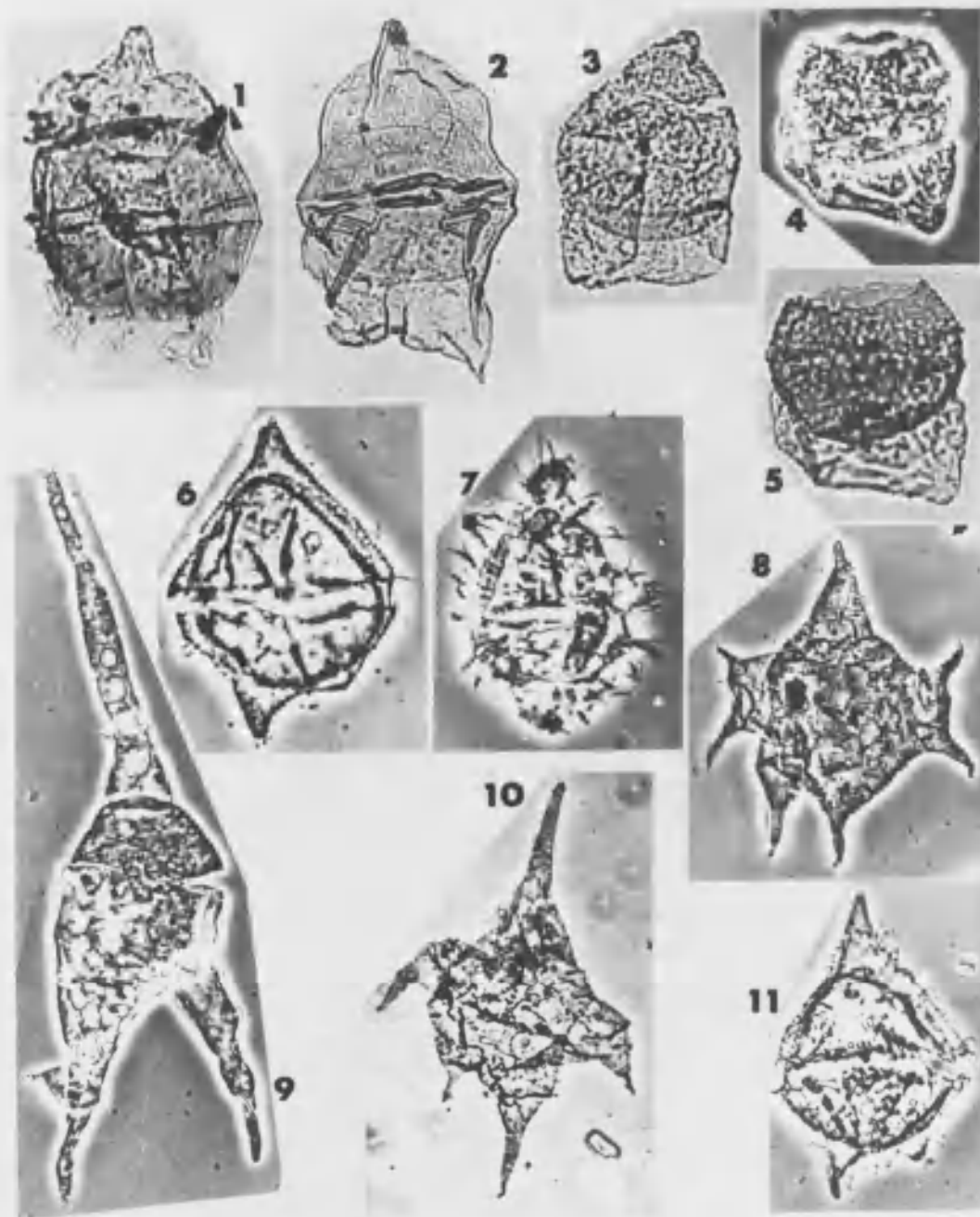


Figure 8. Peridinales: Deflandraceae, Hexagoniferaceae, Endosciniaceae, Pseudocerateaceae, Muderongiaceae

Australiella victoriensis (Cookson and Manum) Lentin and Williams 1973
Fig. 8, no. 2

Selected Synonymy

- 1964 Deflandrea victoriensis Cookson and Manum, p. 522, Pl. 76,
figs. 3-8.
1967 Deflandrea victoriensis Cookson and Manum; Clarke and Verdier,
p. 26, Pl. 3, figs. 8, 9.
1973 Australiella victoriensis (Cookson and Manum) Lentin and Wil-
liams, p. 19.
1974 Deflandrea cf. D. victoriensis Cookson and Manum; McIntyre,
Pl. 2, fig. 14; Pl. 3, fig. 1.

Description. Cavate dinoflagellate cyst; epitract bell shaped with well-developed shoulders; apical horn short, rounded, and roughly triangular; hypotract has two unequal antapical horns, one horn is triangular, tapers to a short point, other antapical horn greatly reduced; cingulum is demarcated by two intermittent ridges; capsule is flattened oval in outline, filling cyst except near the apical and antapical horns; cyst wall thick and scabrate.

Dimensions. Length of 5 measured specimens, 105-109 μ ;
width, 60-65 μ .

Occurrence. This species ranges in age from Turonian to Campanian in the study area.

Family Endoscriniaceae Vozzhennikova 1965, emend.
Sarjeant and Downie 1974

Type Genus Endoscrinium Klement 1960, emend. Vozzhennikova 1965

Genus Palaeohystrichophora Deflandre 1934, emend.
Deflandre and Cookson 1955

Palaeohystrichophora infusorioides Deflandre 1934
Fig. 8, no. 7

Selected Synonymy

- 1934 Palaeohystrichophora infusorioides Deflandre, p. 967, fig. 8.
1958 Palaeohystrichophora infusorioides Deflandre; Cookson and
Eisenack, p. 37, Pl. 10, fig. 10.
1964 Palaeohystrichophora infusorioides Deflandre; Cookson and
Hughes, p. 43, Pl. 5, fig. 8.
1964 Palaeohystrichophora infusorioides Deflandre; Manum and Ver-
dier, p. 28, Pl. 4, fig. 10.
1970 Palaeohystrichophora infusorioides Deflandre; Boltenhagen,
p. 124, Pl. 19, figs. 1-3.
1970 Palaeohystrichophora infusorioides Deflandre; Davey, p. 346,
Pl. 3, figs. 2, 6.
1973 Palaeohystrichophora infusorioides Deflandre; Davey and Ver-
dier, p. 199, Pl. 2, figs. 5, 8.
1974 Palaeohystrichophora infusorioides Deflandre; Cookson and
Eisenack, p. 50, Pl. 27, fig. 5.

Description. Chorate dinoflagellate cyst, biconical in outline;
epitract larger than hypotract; epitract triangular with well-developed
apical horn; hypotract round in outline with one antapical horn; cingulum
broad, demarcated by two spine-covered ridges; capsule suboval, fill-
ing cyst except near the apical and antapical horns; cyst wall covered
by long, narrow, solid, hairlike spines.

Dimensions. Length of 5 measured specimens, 40-45 μ ;
width, 28-31 μ ; length of spines, 4 μ .

Occurrence. The species ranges in age from the Cenomanian
to Campanian in the study area.

Palaeohystrichophora sp. 1

Fig. 8, no. 6

Description. Cavate dinoflagellate cyst biconical in outline; epitract triangular with one apical horn; hypotract rounded except for two unequal antapical horns, one horn is greatly reduced; cingulum broad, well defined by two spine-covered ridges; archeopyle not observed; capsule large, filling cyst except for apical and antapical horns; cyst wall thin, wrinkled, and covered unevenly with fine hairlike spines.

Dimensions. Length of 5 measured specimens, 69-73 μ ; width, 48-50 μ .

Occurrence. This species is restricted to the Thermopolis Shale (Albian) in the Horse Creek section; not found in the Rawlins section.

Palaeohystrichophora sp. 2

Fig. 8, no. 11

Description. Cavate dinoflagellate cyst; biconical in outline; epitract larger than hypotract; apical horn long, tapered, rounded apex; antapical horns short, unequal, one horn poorly developed; cingulum broad, well defined by thin marginal spine covered ridges; capsule subspherical filling cyst except for apical and antapical horns; archeopyle not observed; cyst wall covered by numerous fine hairlike spines.

Dimensions. Length of 5 measured specimens, 63-68 μ ; width, 38-45 μ .

Occurrence. The species ranges in age from the Cenomanian to Coniacian in the study area.

Family Hexagoniferaceae Sarjeant and Downie 1966, emend.
Sarjeant and Downie 1974

Type Genus Hexagonifera Cookson and Eisenack 1961a

Genus Ovoidinium Davey 1970

Ovoidinium ostium Davey 1970

Fig. 8, nos. 3-5

Selected Synonymy

1970 Ovoidinium ostium Davey, p. 353, Pl. 4, figs. 5-6.

Description. Bicavate dinoflagellate cyst; apical horn poorly developed, cone shaped, broad, rounded at apex; antapical horns usually poorly developed; hypotract possesses subrectangular opening on ventral surface; cingulum defined by two low marginal ridges; archeopyle apical; cyst wall densely granular.

Dimensions. Length of 5 measured specimens, 60-65 μ ;
width, 42-45 μ .

Occurrence. This species is only found in strata of Albian age in the study area.

Family Pseudoceratiaceae Eisenack 1961, emend.

Sarjeant and Downie 1974

Type Genus Pseudoceratium Gocht 1957

Genus Odontochitina Deflandre 1935

Odontochitina operculata (Wetzel) Deflandre and Cookson 1955

Fig. 8, no. 9

Selected Synonymy

- 1955 Odontochitina operculata (Wetzel) Deflandre and Cookson, p. 291, Pl. 3, figs. 5, 6.
- 1967 Odontochitina operculata (Wetzel) Deflandre and Cookson; Clarke and Verdier, p. 59, Pl. 13, figs. 1, 7.
- 1970 Odontochitina operculata (Wetzel) Deflandre and Cookson; Davey, p. 355, Pl. 4, fig. 7.
- 1971 Odontochitina operculata (Wetzel) Deflandre and Cookson; Davey and Verdier, p. 25.
- 1973 Odontochitina operculata (Wetzel) Deflandre and Cookson; Kjellström, pp. 34-35, fig. 29.
- 1974 Odontochitina operculata (Wetzel) Deflandre and Cookson; McIntyre, Pl. 7, fig. 10.

Description. Dinoflagellate cyst; central body subspherical; apical and antapical horns long, tapered to blunt points; apical horn constricted where it attaches to central body; archeopyle apical; cyst wall thick and granular.

Dimensions. Total length of 5 measured specimens, 289-300 μ ; length of central body, 75-84 μ ; width of central body, 37-45 μ .

Occurrence. This ubiquitous species is found in Albian to Campanian strata in the study area.

Family Muderongiaceae Neale and Sarjeant 1962, emend.
Sarjeant and Downie 1974

Type Genus Muderongia Cookson and Eisenack 1958

Genus Muderongia Cookson and Eisenack 1958

Muderongia sp. 1

Fig. 8, no. 8

Description. Dinoflagellate cyst, stellate in outline; apical horn triangular, rounded at apex; antapical horns of equal length, well developed, long, tapering to narrow points; lateral horns attached on equator, horns bifurcate into two smaller horns; cingulum not observed; archeopyle apical; cell wall very thin, almost transparent, easily folded or ripped.

Dimensions. Length of 5 measured specimens, 88-94 μ ;
width, 57-63 μ .

Occurrence. This species is restricted to the Albian in the study area.

Muderongia sp. 2

Fig. 8, no. 10

Description. Dinoflagellate cyst, roughly rhomboidal in outline; epitract possesses apical horn and two lateral horns; apical horn well developed, long, tapering to slender point; lateral horns curved downward toward hypotract; cingulum not observed; archeopyle apical; cyst wall very thin, almost transparent; easily wrinkled or damaged.

Dimensions. Length of 5 measured specimens, 105-115 μ ;
width, 63-69 μ .

Occurrence. This species is restricted to the Thermopolis Shale (Albian) in the study area.

Family Hystrichosphaeridiaceae Evitt 1963, emend.
Sarjeant and Downie 1974

Type Genus Hystrichosphaeridium Deflandre 1937, emend.
Davey and Williams 1966

Genus Hystrichokolpoma Klumpp 1953, emend.
Williams and Downie 1966

Hystrichokolpoma ferox (Deflandre) Davey 1969
Fig. 9, no. 4

Selected Synonymy

- 1937 Hystrichosphaeridium ferox Deflandre, p. 72, Pl. 14, figs. 3,4.
1967 Baltisphaeridium ferox (Deflandre) Downie and Sarjeant; Clarke
and Verdier, p. 73, Pl. 15, fig. 4.
1969 Hystrichokolpoma ferox (Deflandre) Davey, p. 159, Pl. 9, figs.
5, 7.
1971 Hystrichokolpoma ferox (Deflandre) Davey; Singh, p. 326, Pl. 5,
figs. 1-5.
1973 Hystrichokolpoma ferox (Deflandre) Davey; Lentin and Williams,
p. 71.

Description. Chorate dinoflagellate cyst, subspherical in outline; central body ovoidal possessing two types of processes; one type is cylindrical, hollow, slender, slightly tapering toward the distal tip; the other type consists of wide cylindrical processes, bifurcated or trifurcated at distal tips; cingulum not observed; archeopyle apical; cyst wall thick and granular.

Dimensions. Diameter of 3 measured specimens, 92-97 μ ;
central body diameter, 57-63 μ .

Occurrence. This species ranges in age from Cenomanian to Coniacian in the study area.

Figure 9. Peridiniales: Exochosphaeridiaceae, Hystrichosphaeridiaceae, Areoligeraceae, Cleistosphaeridiaceae, Systematopharaceae

1. Exochosphaeridium sp. X750.
2. Hystrichosphaeridium cf. arundum. Phase contrast. X550.
3. Oligosphaeridium complex (White) Davey and Williams. X350.
4. Hystrichokolpoma ferox (Deflandre) Davey. X450.
5. Cyclonephelium cf. distinctum (Deflandre) Cookson. X450.
6. Lithosphaeridium siphoniphorum (Cookson and Eisenack) Davey and Williams. Phase contrast. X450.
7. Cleistosphaeridium cf. polypes (Cookson and Eisenack) Davey. X450.
8. Chiropteridium sp. X450.
- 9-10. Diphyes colligerum (Deflandre and Cookson) Cookson. 10, phase contrast. X500.
11. Coronifera sp. X450.

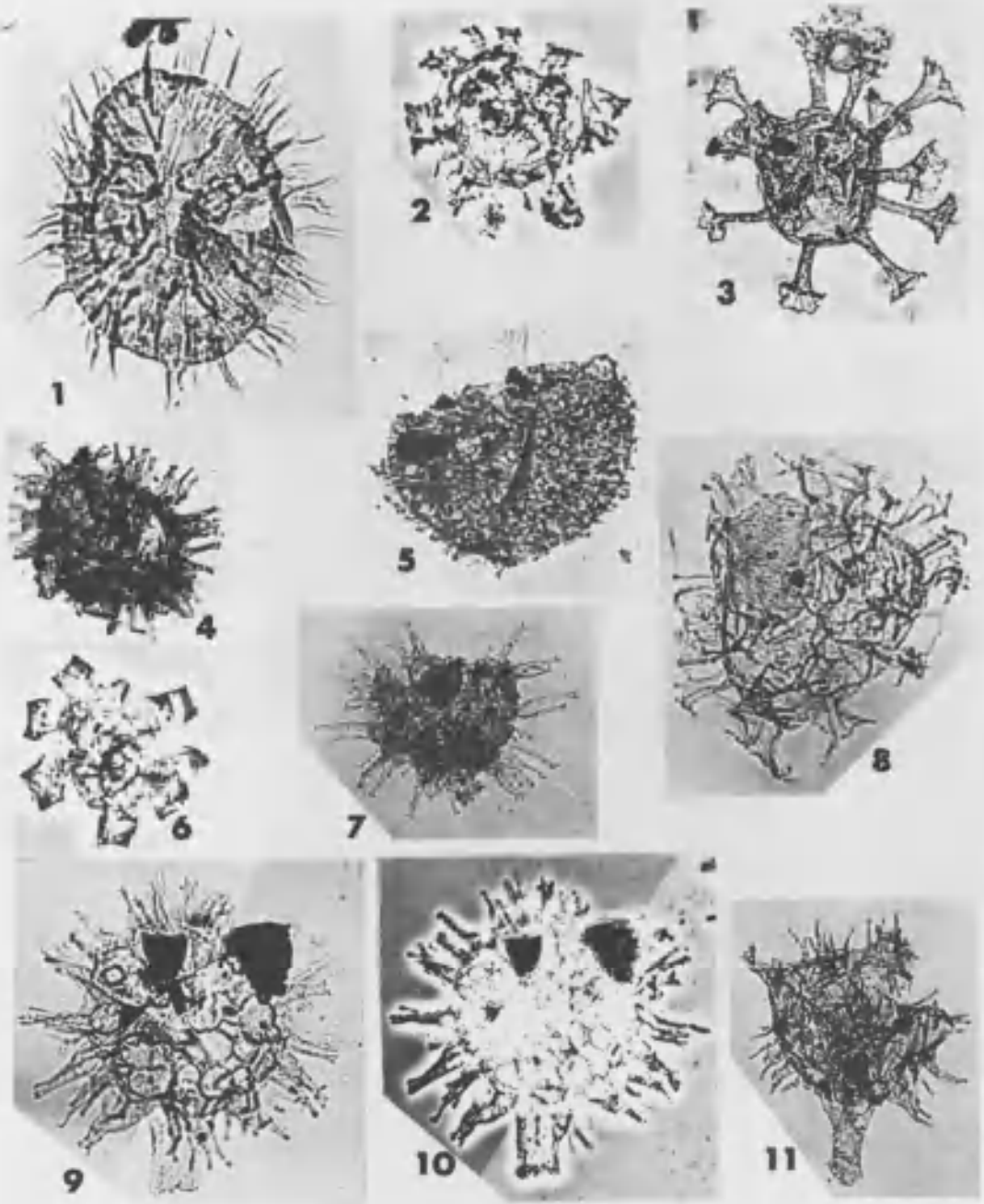


Figure 9. Peridinales: Exochosphaeridiaceae, Hystrichosphaeridiaceae, Areoligeraceae, Cleistosphaeridiaceae, Systematopharaceae

Genus Hystrichosphaeridium Deflandre 1937, emend.

Davey and Williams 1966

Hystrichosphaeridium cf. arundum Eisenack and Cookson 1960a
Fig. 9, no. 2

Selected Synonymy

- 1960a Hystrichosphaeridium arundum Eisenack and Cookson, p. 8, Pl. 3, fig. 7.
1966 Hystrichosphaeridium arundum Eisenack and Cookson; Davey and Williams, p. 70.
1971 Hystrichosphaeridium arundum Eisenack and Cookson; Davey and Verdier, p. 22.
1973 Hystrichosphaeridium arundum Eisenack and Cookson; Lentin and Williams, p. 73.

Description. Chorate dinoflagellate cyst, subspherical in outline; spherical central body bearing numerous short, thick, cylindrical processes; all processes are hollow, few flare at distal tips; no cingulum or archeopyle observed; cyst wall thin and easily wrinkled.

Dimensions. Diameter of 1 measured specimen, 52 μ ; central body diameter, 35 μ .

Occurrence. One specimen was found in the Frontier Formation (Cenomanian) from the Rawlins section, not found in the Horse Creek section.

Genus Lithosphaeridium Davey and Williams 1966
Lithosphaeridium siphoniphorum (Cookson and Eisenack)
 Davey and Williams 1966
 Fig. 9, no. 6

Selected Synonymy

- 1958 Hystrichosphaeridium siphoniphorum Cookson and Eisenack,
 p. 44, Pl. 11, figs. 8-10.
- 1964 Hystrichosphaeridium siphoniphorum Cookson and Eisenack;
 Cookson and Hughes, p. 48, Pl. 9, fig. 15.
- 1966 Lithosphaeridium siphoniphorum (Cookson and Eisenack) Davey
 and Williams, p. 80, Pl. 7, figs. 7,8.
- 1967 Hystrichosphaeridium siphoniphorum Cookson and Eisenack;
 Clarke and Verdier, p. 55, Pl. 11, figs. 1,2.
- 1969 Lithosphaeridium siphoniphorum (Cookson and Eisenack) Davey
 and Williams; Davey, p. 148, Pl. 6, figs. 3,4.
- 1973 Lithosphaeridium siphoniphorum (Cookson and Eisenack) Davey
 and Williams; Lentin and Williams, p. 89.

Description. Chorate dinoflagellate cyst, subspherical in outline; central body spherical; processes thick, cylindrical, hollow, and open at distal end; cingulum not observed; cyst wall finely granular.

Dimensions. Diameter of 2 measured specimens, 38-40 μ ;
 central body, 29-31 μ .

Occurrence. This species is present in the Frontier Formation (Cenomanian) in the Rawlins section; not found in the Horse Creek section.

Genus Oligosphaeridium Davey and Williams 1966
Oligosphaeridium complex (White) Davey and Williams 1966
 Fig. 9, no. 3

Selected Synonymy

- 1966 Oligosphaeridium complex (White) Davey and Williams, p. 71, Pl. 7, figs. 1, 2,; pl. 10, fig. 3.
- 1967 Oligosphaeridium complex (White) Davey and Williams; Clarke and Verdier, p. 53, Pl. 11, figs. 10, 11.
- 1967 Hystrichosphaeridium complex (White) Davey and Williams; Drugg, p. 26, Pl. 4, fig. 14.
- 1967 Hystrichosphaeridium complex (White) Davey and Williams; Millioud, p. 164.
- 1969 Oligosphaeridium complex (White) Davey and Williams; Davey, p. 146, Pl. 5, figs. 6, 7.
- 1971 Oligosphaeridium complex (White) Davey and Williams; Davey and Verdier, p. 26.
- 1971 Oligosphaeridium complex (White) Davey and Williams; Brideaux, p. 89.
- 1971 Oligosphaeridium complex (White) Davey and Williams; Singh, p. 333, Pl. 53, figs. 4-6.
- 1973 Oligosphaeridium complex (White) Davey and Williams; Lentin and Williams, p. 99.
- 1974 Oligosphaeridium complex (White) Davey and Williams; Cookson and Eisenack, p. 66, Pl. 29, figs. 1-4.

Description. Chorate dinoflagellate cyst, spherical in outline; central body spherical, possessing cylindrical to trumpetlike, distally open processes, each process corresponds to the center area of a reflected plate; cingulum not observed; archeopyle apical; cyst wall coarsely granular.

Dimensions. Diameter of 5 measured specimens, 115-127 μ ; diameter of central body, 54-63 μ .

Occurrence. This species is found in strata of Albian to Santonian age in the study area.

Family Exochosphaeridiaceae Sarjeant and Downie 1966,
emend. Sarjeant and Downie 1974
Type Genus Exochosphaeridium Davey and Williams 1966

Genus Exochosphaeridium Davey and Williams 1966
Exochosphaeridium sp.
Fig. 9, no. 1

Description. Chorate dinoflagellate cyst, subspherical to spherical in outline; processes numerous, slender, tapering distally to a fine point, few bifurcate; cyst wall thin and granular.

Dimensions. Diameter of 5 measured specimens, 87-95 μ ;
diameter of central body, 67-74 μ .

Occurrence. The species is found in strata of Cenomanian to Coniacian age in the study area.

Family Systematophoraceae Sarjeant and Downie 1974
Type Genus Systematophora Klement 1960

Genus Coronifera Cookson and Eisenack 1958
Coronifera sp.
Fig. 9, no. 11

Description. Chorate dinoflagellate cyst; subspherical to spherical central body; central body covered with numerous fine hairlike processes which taper distally to fine points; processes do not appear to be joined proximally; epittract has large antapical process which tapers slightly distally but flares out at extreme distal end; process hollow; cyst wall thin and granular.

Dimensions. Diameter of central body of 1 measured specimen, 48 μ ; length of antapical process, 25 μ .

Occurrence. One specimen was recovered from the Frontier Formation (Cenomanian) in the Rawlins section.

Genus Diphyes Cookson 1965, emend. Davey and Williams 1966
Diphyes colligerum (Deflandre and Cookson) Cookson 1965
 Fig. 9, nos. 9,10

Selected Synonymy

- 1955 Hystrichosphaeridium colligerum Deflandre and Cookson, p. 278,
 Pl. 7, fig. 3.
 1961b Hystrichosphaeridium colligerum Deflandre and Cookson; Cook-
 son and Eisenack, p. 44, Pl. 2, fig. 9.
 1965 Diphyes colligerum (Deflandre and Cookson) Cookson, p. 86,
 Pl. 9, fig. 1-12.
 1965 Hystrichosphaeridium colligerum Deflandre and Cookson; Stanley,
 p. 231, Pl. 24, figs. 7,8.
 1966 Hystrichosphaeridium colligerum Deflandre and Cookson; Morgen-
 roth, p. 29, Pl. 8, figs. 1,2.
 1966 Diphyes colligerum (Deflandre and Cookson) Cookson; Davey
 and Williams, p. 96, Pl. 4, figs. 2,3.
 1973 Diphyes colligerum (Deflandre and Cookson) Cookson; Stone,
 p. 57, Pl. 8, figs. 28-29.

Description. Chorate dinoflagellate cyst; subspherical to spherical central body; central body covered with numerous processes; processes taper distally from a broad attachment base, distal end blunt and occasionally bifurcate; epittract possesses large, hollow, antapical process.

Dimension. Central body diameter of 5 measured specimens, 54-62 μ ; length of antapical process, 22-28 μ .

Occurrence. This species ranges in from Albian to Cenomanian in the study area.

Family Cleistosphaeridiaceae Sarjeant and Downie 1974
Type Genus Cleistosphaeridium Davey and Williams 1966

Genus Cleistosphaeridium Davey and Williams 1966
Cleistosphaeridium cf. polypes (Cookson and Eisenack) Davey 1969
Fig. 9, no. 7

Selected Synonymy

- 1962 Hystrichosphaeridium recurvatum subsp. polypes Cookson and Eisenack, p. 491; Pl. 4, figs. 11-13.
1969 Cleistosphaeridium polypes (Cookson and Eisenack) Davey, p. 154, pl. 6, figs. 7, 8.

Description. Chorate dinoflagellate cyst; subspherical central body bearing 30-50 distally closed, hollow processes; processes taper distally to a single point or are occasionally bifurcating; cyst wall moderately to strongly granular.

Dimensions. Entire cyst diameter of 3 measured specimens, 75-79 μ ; central body diameter, 43-46 μ .

Occurrence. Species found in strata of Cenomanian to Coniacian age in the Rawlins section; not found in the Horse Creek section.

Family Areoligeraceae Evitt 1963, emend. Sarjeant and Downie 1974
Type Genus Areoligera Lejeune-Carpentier 1938

Genus Chiropteridium Gocht 1960

Chiropteridium sp.

Fig. 9, no. 8

Description. Chorate dinoflagellate cyst, spherical to sub-spherical in outline; spherical central body covered with cylindrical processes of a highly variable nature; process tips flaring, bifurcate or trifurcate; cyst wall thick, scabrate, usually folded or wrinkled.

Dimensions. Entire cyst diameter of 4 measured specimens, 92-95 μ ; central body diameter, 66-69 μ .

Occurrence. This species occurs in strata of Turonian to Coniacian age in the Horse Creek section; not found in the Rawlins section.

Genus Cyclonephelium Deflandre and Cookson 1955, emend.
 Cookson and Eisenack 1962
Cyclonephelium cf. distinctum Deflandre and Cookson 1955
 Fig. 9, no. 5

Selected Synonymy

- 1955 Cyclonephelium distinctum Deflandre and Cookson, pp. 285-286,
 Pl. 2, fig. 14.
- 1967 Cyclonephelium distinctum Deflandre and Cookson; Clarke and
 Verdier, p. 22, Pl. 1, figs. 6, 7.
- 1967 Cyclonephelium distinctum Deflandre and Cookson; Drugg, p.
 22, Pl. 3, fig. 7.
- 1967 Cyclonephelium distinctum Deflandre and Cookson; Millioud,
 P. 2, fig. 13.
- 1969 Cyclonephelium distinctum Deflandre and Cookson; Davey, p.
 166, Pl. 11, figs. 6-8, 10.
- 1969 Cyclonephelium distinctum Deflandre and Cookson; Millioud,
 p. 427, Pl. 1, fig. 7.
- 1971 Cyclonephelium distinctum Deflandre and Cookson; Davey and
 Verdier, p. 17.
- 1971 Cyclonephelium distinctum Deflandre and Cookson; Cookson
 and Eisenack, p. 219, Pl. 8, fig. 5.
- 1973 Cyclonephelium distinctum Deflandre and Cookson; Harland,
 p. 689, Pl. 87, figs. 1, 4.

Description. Chorate dinoflagellate cysts; subspherical to
 spherical central body; central body covered with densely spaced pro-
 cesses which are interconnected distally.

Dimensions. Diameter of 1 measured specimen, 77 μ .

Occurrence. One specimen was recovered from the Frontier
 Formation (Cenomanian) from the Rawlins section; not found in the
 Horse Creek section.

Order Gymnodiniales Schütt 1896Family Dinogymniaceae Sarjeant and Downie 1974Type Genus Dinogymnium Evitt, Clarke, and Verdier 1967Genus Dinogymnium Evitt, Clarke, and Verdier 1967Dinogymnium acuminatum Evitt, Clarke, and Verdier 1967

Fig. 10, no. 1

Selected Synonymy

- 1967 Dinogymnium acuminatum Evitt, Clarke, and Verdier, pp. 8-16,
Pl. 1, 2, 3, figs. 1-8, 10, 12, 20.
- 1970 Dinogymnium acuminatum Evitt, Clarke, and Verdier; Zaitzeff
and Cross, p. 352.

Description. Dinoflagellate cyst, biconical in outline; numerous longitudinal folds extend from apex to antapex; cingulum prominent, deep, broad, and delimited by two ridges; sulcus well developed; archeopyle apical, flaplike, usually remains attached; cyst wall thick and granular.

Dimensions. Length of 5 measured specimens, 55-59 μ ;
width 31-34 μ .

Occurrence. This distinctive species occurs in strata of Santonian to Campanian age in the Rawlins section; not found in the Horse Creek section.

Figure 10. Gymnodiniales, Pteromophetae

1. Dinogymnium acuminatum Evitt, Clarke, and Verdier. X650.
2. Dinogymnium nelsonense (Cookson) Evitt, Clarke, and Verdier. Phase contrast. X550.
3. Dinogymnium westralian (Cookson and Eisenack) Evitt, Clarke, and Verdier. Phase contrast. X600.
4. Pterospermella aureolata (Cookson and Eisenack) Eisenack and Cramer. X400.
5. Pterospermella australiensis (Deflandre and Cookson) Eisenack and Cramer. X400.
6. Pterospermella eurypteris (Cookson and Eisenack) Eisenack and Cramer. X400.
7. Pterospermella harti (Sarjeant) Eisenack and Cramer. X400.

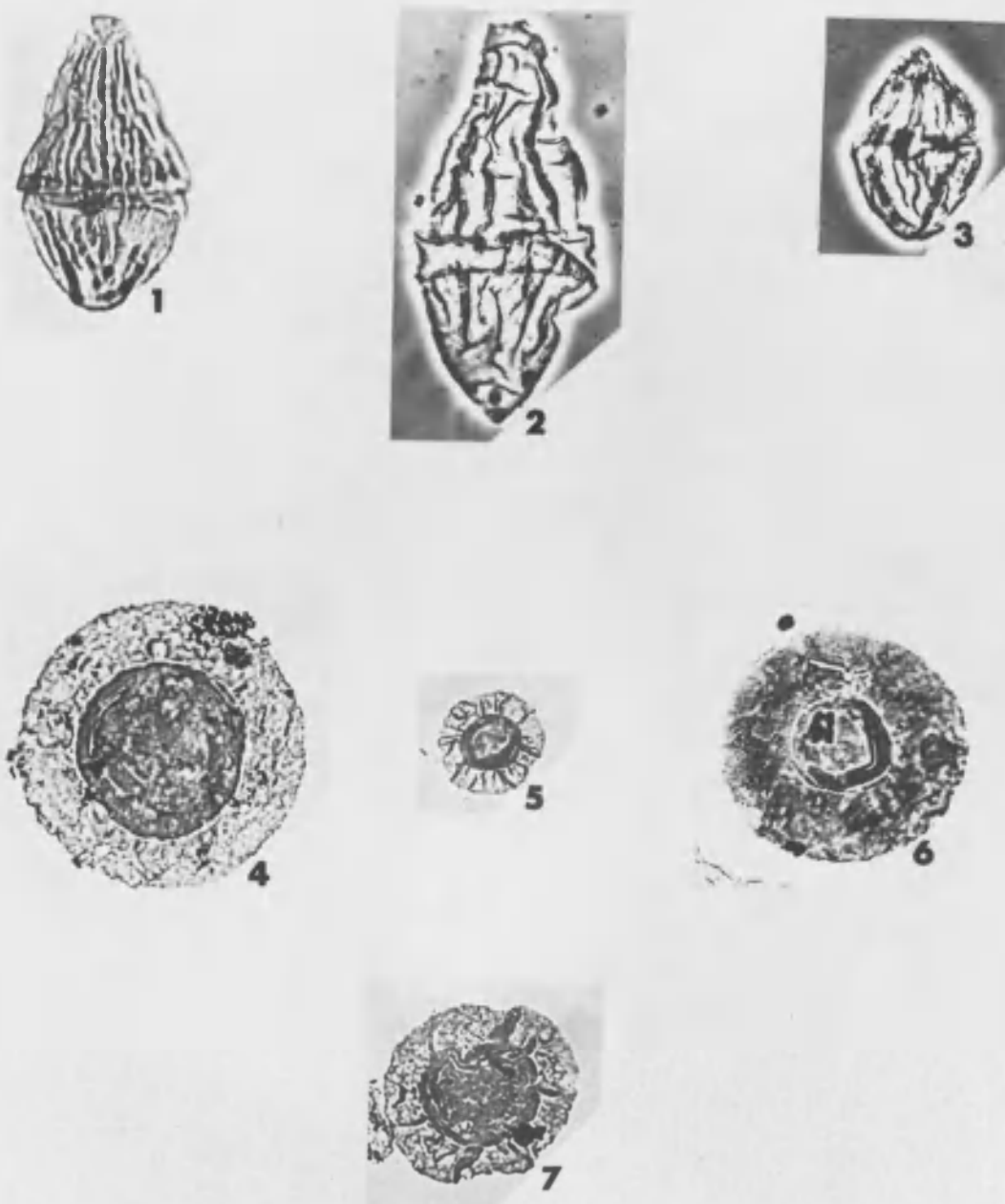


Figure 10. Gymnodiniales, Pteromophetae

Dinogymnium nelsonense (Cookson) Evitt, Clarke, and Verdier 1967
Fig. 10, no. 2

Selected Synonymy

- 1956 Gymnodinium nelsonense Cookson, p. 183, Pl. 1, figs. 8-11.
1958 Gymnodinium nelsonense Cookson; Cookson and Eisenack,
p. 26, Pl. 1, fig. 8.
1967 Gymnodinium aff. G. nelsonense Cookson; Drugg, p. 12, Pl. 1,
fig. 6.
1967 Dinogymnium nelsonense (Cookson) Evitt, Clarke, and Verdier,
pp. 21-23, Pl. 3, figs. 21, 22.
1970 Dinogymnium nelsonense (Cookson) Evitt, Clarke, and Verdier;
Zaitzeff and Cross, p. 352, Pl. 4, fig. 35.
1973 Dinogymnium nelsonense (Cookson) Evitt, Clarke, and Verdier;
Stone, p. 50, pl. 2, fig. 4.

Description. Dinoflagellate cyst; biconical with wide sub-equatorial cingulum dividing cyst into two unequal portions; epitract larger than hypotract; hypotract tapers into a rounded tip; wide longitudinal folds on epitract and hypotract; archeopyle apical; cyst wall thin.

Dimensions. Length of 2 measured specimens, 95-96 μ ;
width, 42-44 μ .

Occurrence. Species is restricted to the Mesaverde Formation (Campanian) in the Rawlins section; not found in the Horse Creek section.

Dinogymnium westralian (Cookson and Eisenack)
Evitt, Clarke, and Verdier 1967
Fig. 10, no. 3

Selected Synonymy

- 1958 Gymnodinium westralian Cookson and Eisenack, p. 25, Pl. 1,
fig. 9.
1967 Dinogymnium westralian (Cookson and Eisenack) Evitt, Clarke,
and Verdier, pp. 23-24.

Description. Dinoflagellate cyst; biconical with narrow equatorial cingulum dividing cyst into two equal portions; hypotract more rounded than epitract; longitudinal folds few, running full length of cyst; cyst wall thick, subject to folding.

Dimensions. Length of 4 measured specimens, 42-46 μ ;
width, 27-31 μ .

Occurrence. Species found in strata of Coniacian to Santonian age in the Rawlins section; not found in the Horse Creek section.

Group Acritarcha Evitt 1963
 Subgroup Pteromophetae Downie, Evitt, and Sarjeant 1963
 Family Pterospermellaceae Eisenack 1972
 Type Genus Pterospermella Eisenack 1972

Genus Pterospermella Eisenack 1972
Pterospermella aureolata (Cookson and Eisenack)
 Eisenack and Cramer 1973
 Fig. 10, no. 4

Selected Synonymy

- 1958 Pterospermopsis aureolata Cookson and Eisenack, p. 49, Pl. 9, figs. 10-12.
 1971 Pterospermopsis aureolata Cookson and Eisenack, Cookson and Eisenack, p. 22, Pl. 10, fig. 1-3.
 1971 Pterospermopsis aureolata Cookson and Eisenack; Singh, p. 419, Pl. 77, figs. 7-9.
 1972 Pterospermella aureolata (Cookson and Eisenack) Eisenack, p. 597.
 1973 Pterospermella aureolata (Cookson and Eisenack) Eisenack; Eisenack and Cramer, p. 957.

Description. Acritarch cyst, circular in polar view; central body circular, surrounded equatorially by an infrareticulate lamella; cyst wall thick and granular.

Dimensions. Diameter of 5 measured specimens, 97-101 μ ; diameter of central body, 57-60 μ .

Occurrence. Species occurs in strata of Albian to Coniacian age in the study area.

Pterospermella australiensis (Deflandre and Cookson)
Eisenack and Cramer 1973
Fig. 10, no. 5

Selected Synonymy

- 1955 Pterospermopsis australiensis Deflandre and Cookson, p. 286, Pl. 3, fig. 4.
- 1965 Pterospermopsis australiensis Deflandre and Cookson; Cookson and Eisenack, p. 222, Pl. 10, figs. 4-6.
- 1971 Pterospermopsis australiensis Deflandre and Cookson; Brideaux, p. 75, Pl. 21, fig. 15.
- 1971 Pterospermopsis australiensis Deflandre and Cookson; Singh, p. 420, Pl. 77, figs. 11, 12.
- 1973 Pterospermella australiensis (Deflandre and Cookson) Eisenack and Cramer, p. 959.
- 1974 Pterospermella australiensis (Deflandre and Cookson) Eisenack and Cramer; Cookson and Eisenack, p. 81, Pl. 26, fig. 5.

Description. Acritarch cyst, circular in polar view; central body circular, encased in a folded lamellar structure; lamellar wall thin; central body wall thick, dense; radius of central body half of total radius of cyst.

Dimensions. Diameter of 5 measured specimens, 34-37 μ ; diameter of central body, 21-24 μ .

Occurrence. Species restricted to the Mesaverde Formation (Campanian) in the Rawlins section; not found in the Horse Creek section.

Pterospermella eurypteris (Cookson and Eisenack)
Eisenack and Cramer 1973
Fig. 10, no. 6

Selected Synonymy

- 1958 Pterospermopsis eurypteris Cookson and Eisenack, p. 49, Pl. 9, figs. 9, 13.
1961 Pterospermopsis eurypteris Cookson and Eisenack; Alberti, p. 40, Pl. 11, fig. 10.
1971 Pterospermopsis eurypteris Cookson and Eisenack; Cookson and Eisenack, p. 222, Pl. 10, fig. 11.
1971 Pterospermopsis eurypteris Cookson and Eisenack; Singh, p. 421, Pl. 78, figs. 1-3.
1973 Pterospermella eurypteris (Cookson and Eisenack) Eisenack and Cramer, p. 977.

Description. Acritarch cyst, circular in polar view; circular central body encased in infrareticular lamellar structure; radius of central body less than half of total radius of cyst.

Dimensions. Diameter of 3 measured specimens, 80-84 μ ; diameter of central body, 30-33 μ .

Occurrence. Species occurs in strata of Albian to Santonian age in study area.

Pterospermella harti (Sarjeant) Eisenack and Cramer 1973
Fig. 10, no. 7

Selected Synonymy

- 1960 Pterospermopsis harti Sarjeant, p. 402, Pl. 14, fig. 16.
1971 Pterospermopsis harti Sarjeant; Singh, p. 423, Pl. 78, figs. 4-7.
1973 Pterospermella harti (Sarjeant) Eisenack and Cramer, p. 987.

Description. Acritarch cyst, circular in polar view; central body circular, encased in a deeply folded infrareticulate lamellar structure; radius of central body slightly more than half of the total radius of cyst.

Dimensions. Diameter of 5 measured specimens, 65-69 μ ;
diameter of central body, 35-39 μ .

Occurrence. Species occurs in strata of Albian to Santonian age in study area.

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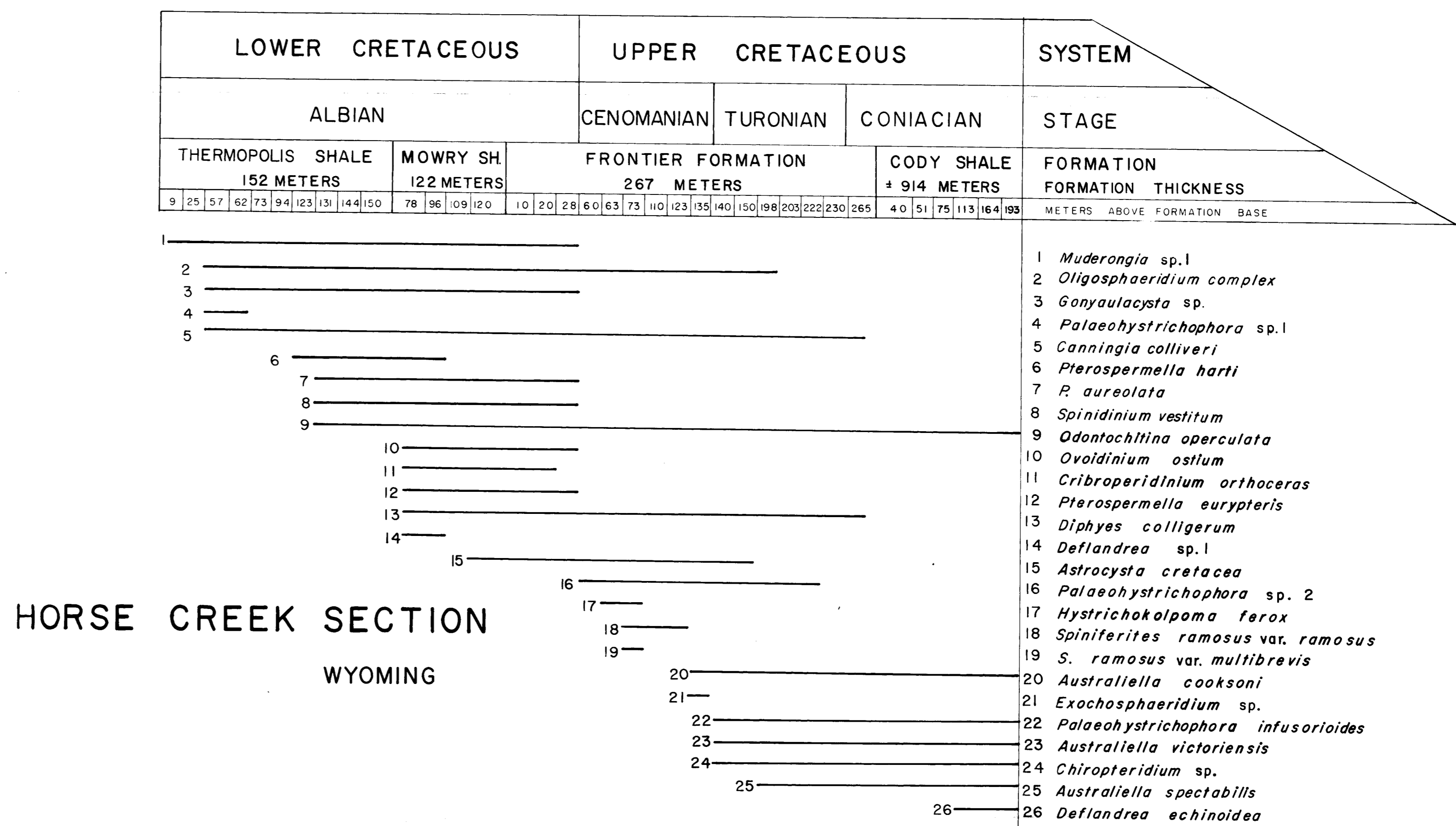
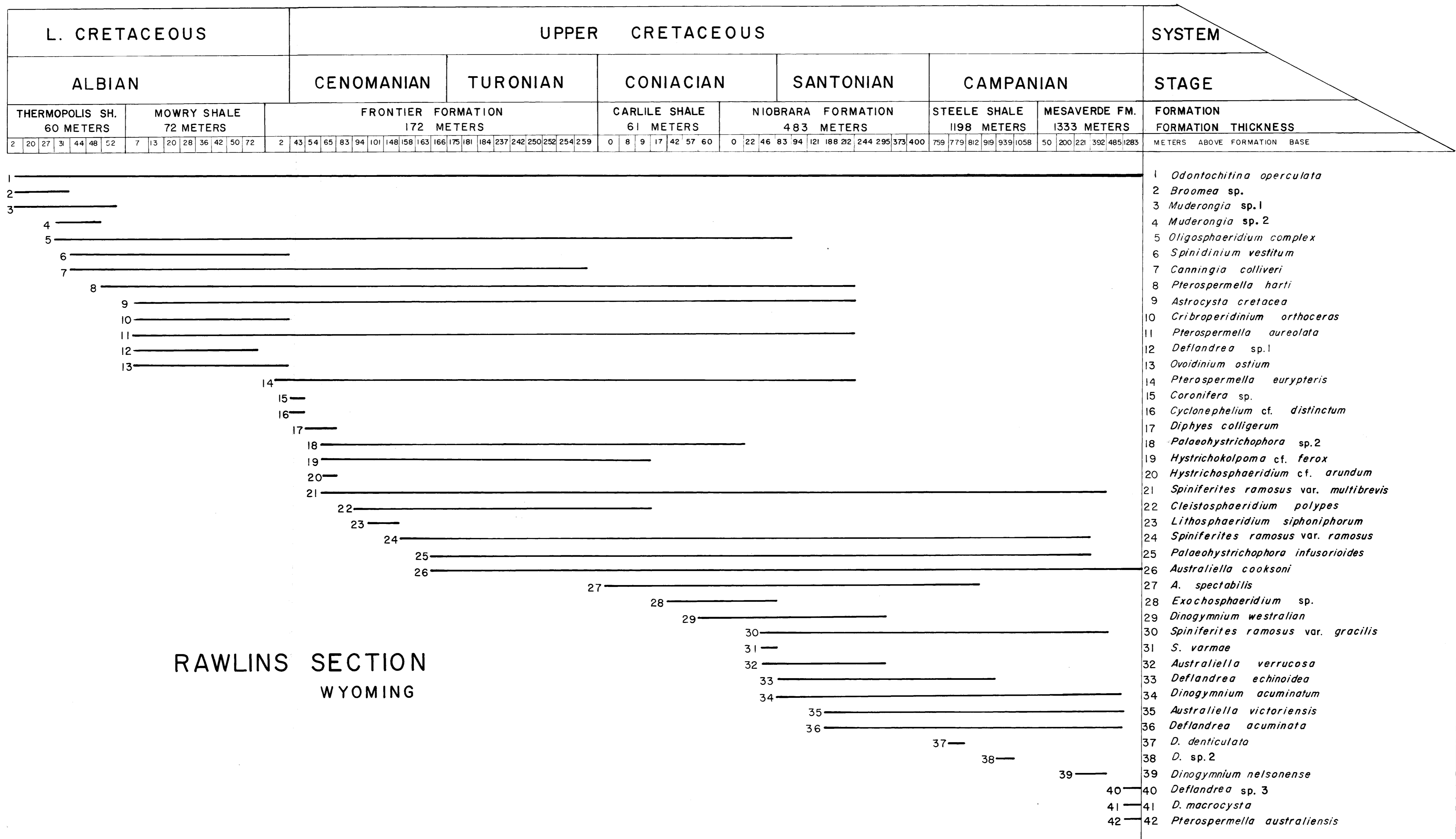


FIGURE 4. MICROPLANKTON RANGE CHARTS

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