REEF-CONTROLLED DISTRIBUTION OF DEVONIAN MICROPLANKTON IN ALBERTA

by FRANK L. STAPLIN

ABSTRACT. Upper Devonian hystrichospherids of the off-reef Duvernay facies in Alberta, Canada, can be combined into three artificial groups that have different distribution patterns with regard to reefs. Simple spherical forms are widespread, from beds inter-fingering with reef carbonate into off-reef areas. Thin-spined species are also widespread, but are seldom found within one mile of reefs. Thick-spined and polyhedral forms occur in off-reef strata, but seldom near reefs. All types increase in abundance with increasing distance from reefs. Plant spore distribution is useful in determining major current patterns. Forty species of hystrichospherids are described. New genera proposed are *Duvernaysphaera*, *Multiplicisphaeridium*, and *Paleopedicystus*. *Micrhystridium* and *Leiosphaeridium* are emended. New morphological structures of Chitinozoa are described and *Hoegisphaera* is proposed as a name for a new type of Paleozoic microfossil possibly allied to the Chitinozoa.

THE Duvernay member is interpreted as the off-reef calcareous shale equivalent of the Leduc reef-bearing carbonates of the Woodbend formation in central Alberta. Acid-resistant microfossils, including hystrichospherids, plant spores, Chitinozoa, and scolecodonts, are present in Duvernay sediments. These fossils were studied in order to determine if reef trends had influenced their distribution in the near-reef equivalents. Approximately sixty wells penetrating the Duvernay shale were used in the study. For the most part, the samples were decontaminated rotary cuttings from the microlithologically recognizable upper part of the member.

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GENERAL GEOLOGY

During Upper Devonian time, much of western Canada and the United States was covered by epicontinental seas, with the exception of an interrupted volcanic belt located approximately along the present Pacific coastline (text-fig. 1). The sea at one time extended as far east as central New York, although in Middle and Lower Upper Devonian times the seas in western North America did not communicate with those to the east. On islands in the shallow seas and on the adjacent land masses grew a variety of spore-bearing plants. Reefs of biohermal form, composed of remains of algae, stromatoporoids, bryozoans, corals, and numerous other organisms, in addition to fragmental and chemically deposited carbonate, were formed in Alberta. These are now reservoirs for much of Canada's proven oil.

Woodbend formation. This group (text-fig. 2) includes a lower fragmental limestone, the Cooking Lake member; a middle portion grading laterally from the Leduc reef facies to the Duvernay dark calcareous shale; and an upper dolomite and calcareous shale, the Ireton member. These units can generally be recognized on electric logs, although their contacts are transitional. The generalized descriptions given below do not hold outside of the general Edmonton area of Alberta. Because of the essential unity and

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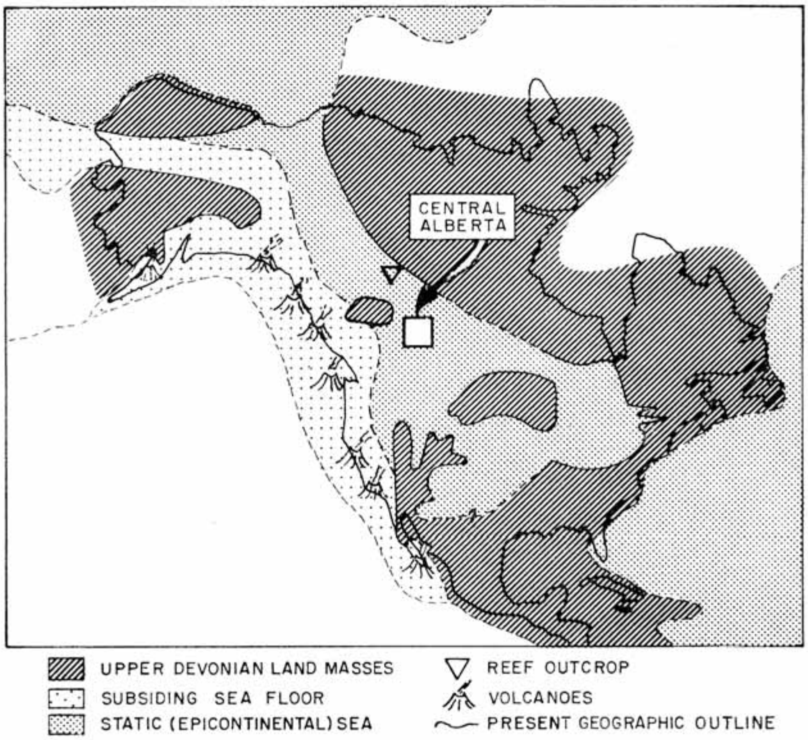
transitional nature of these sediments, they are here considered as members, following the original interpretation of the Imperial Oil staff (1950).

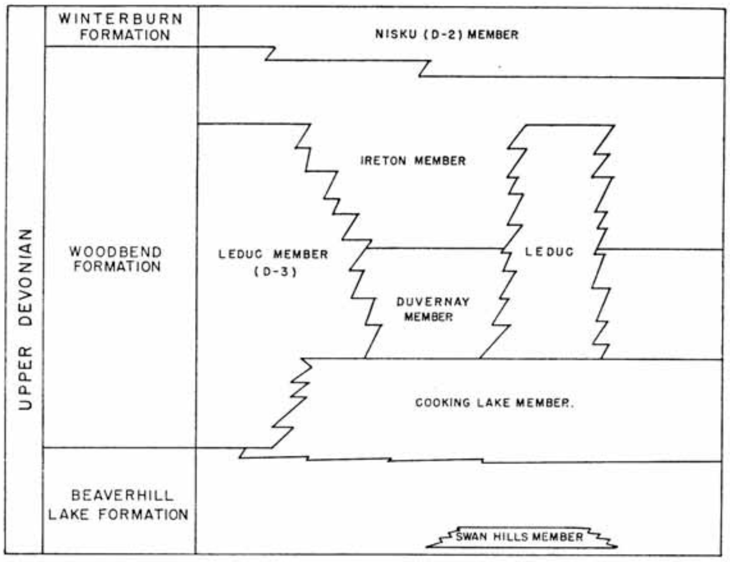
1. *Cooking Lake member*. The base of this member is placed at the change from the argillaceous limestones of the Beaverhill Lake formation to the fragmental limestones



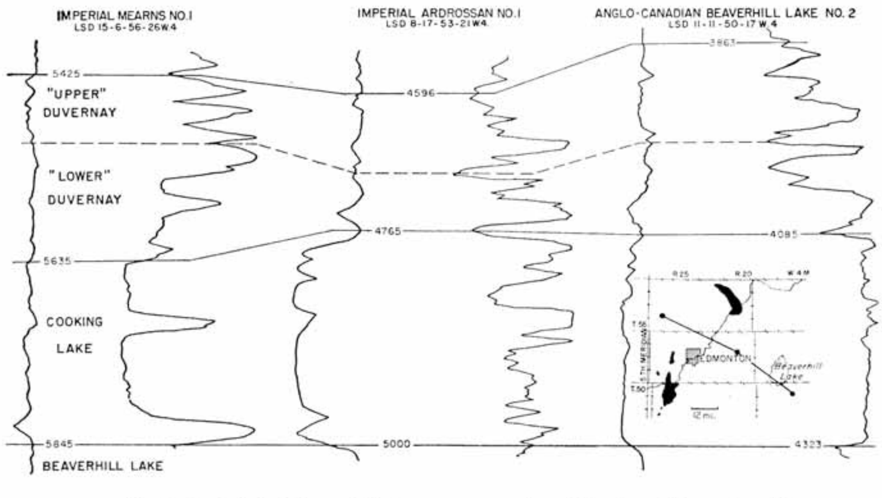
TEXT-FIG. 1. Upper Devonian paleogeograph of North America. Revised from H. and G. Termier 1952, with new limits.

above; the contact is transitional. At the upper contact, the limestones become interbedded with the shales of the Duvernay member in off-reef areas. In part, the unit is biostromal. In some areas the formation is continuous with the Leduc member, especially along the Morinville–Rimbey trend, the Bashaw trend, and in the Killam area (text-fig. 8). West of the Rimbey trend the Cooking Lake is often represented by a shale equivalent.

2. *Duvernay member*. The basal contact of the Duvernay with the Cooking Lake member is picked somewhat arbitrarily. The upper part of Cooking Lake contains black shale



TEXT-FIG. 2. Divisions of the Upper Devonian Woodbend formation, central Alberta.



TEXT-FIG. 3. Typical electric logs of the Duvernay member, Woodbend formation, Alberta.

stringers that are similar to the dark-brown to black calcareous shales and shaly limestone of the basal Duvernay. In reef areas the Duvernay is quite thin, but it may be more than 300 feet thick in off-reef areas. The upper part of the Duvernay has a characteristic curve on electric logs (text-fig. 3). Essentially, it consists of hard, dark brownish-black (5YR 2/1), impure interbedded limestone and shale having angular fracture and high organic content. Large volumes of sediment of equivalent age outside the immediate Edmonton area are grey to grey-green shales.

3. *Leduc member*. This member includes all biohermal and biostromal bodies of the carbonate complex of the Woodbend formation. Most Leduc reefs are dolomitized, but Golden Spike, Redwater, and others are limestone or are only partly dolomitized. The majority of the reefs of the Morinville–Rimbey trend seem to be equivalent, at least in part, to the off-reef Duvernay member.

4. *Ireton member*. The lower part of the Ireton, above the Duvernay, is generally a greenish calcareous shale but locally may be dark coloured and rich in organic matter. The upper part is argillaceous dolomite. Its thickness ranges from about 10 feet, above some of the Leduc biostromes, to 700 or more feet in off-reef areas, where it overlies the Duvernay member. In general, its residues are characterized by less organic material than are those from the Duvernay member.

TYPES OF MICROFOSSILS

Hystrichospherids, plant spores, scolecodonts, and Chitinozoa are the types of acid-resistant fossils on which the interpretations given in this report are based. Descriptions of the species of hystrichospherids, one new chitinozoan (?), and morphological notes on *Angochitina* are appended.

Hystrichospherids. A heterogeneous group of fossil and Recent microscopic organisms is included in the hystrichospherids. Some, particularly from Mesozoic and Tertiary sediments, are known to be stages in the life cycles of dinoflagellates and other algae. Others perhaps are encysted stages of Bryozoa and extinct flagellates and eggs of Crustacea, but many, particularly Paleozoic forms, cannot be assigned to any extant group. Some resemble chrysophytes.

These organisms vary from simple spherical bodies to complex forms having spines, enveloping lacy networks, membranes, and other ornamentation. Their size range is from 5 to over 120 microns. They are largely insoluble in most acids and can stand fairly long treatments with hydroxides. They occur in most marine clays and shales, in cherts and fine-grained limestones, and occasionally in evaporites. Hystrichospherids have been found mostly in saline waters or in sediments containing marine organisms. Some species are good for age determinations.

Plant spores. Because they represent land plants, plots of relative plant spore abundance will indicate land masses and islands that became stabilized above water-level. Upper Devonian plant spores are quite diversified and are valuable in correlations. Many of the types described from the U.S.S.R. by Naumova (1953) are present in sediments of western Canada.

Chitinozoa. These are extinct acid-resistant, tube- to flask-shaped organisms, which are frequently ornamented with spines. The normal size of Devonian species is at least 150 microns, and they can be picked from samples in the same way as ostracodes and foraminifera. Some workers attribute Chitinozoa to various phyla, but on little real evidence. They most closely resemble cysts of chrysomonads, especially *Ochromonas*, but the resemblance is probably superficial. Their known stratigraphic range is Ordovician to Lower Pennsylvanian, but their greatest abundance is in the Devonian. Chitinozoa are useful for determining both age and environment and therefore should be sought with other microfossils.

Other organisms. Scolecodonts (jaws of marine worms), mostly belonging to the genus *Arabellites*, are occasionally present, especially in the same samples with Chitinozoa.

INTERPRETATION

Hystrichospherid species and growth-forms. Approximately fifty species are recognized in the Duvernay member. With rare exceptions the species of hystrichospherids are the same as those of the Ireton and Cooking Lake members, although they occur in different proportions. Most of the species recognized in the Upper Devonian sediments of the Edmonton area can be combined artificially into three main types, or *growth-forms* (text-fig. 4), which have different patterns of distribution with regard to reefs. These three forms are the basis for the interpretations presented in this report.

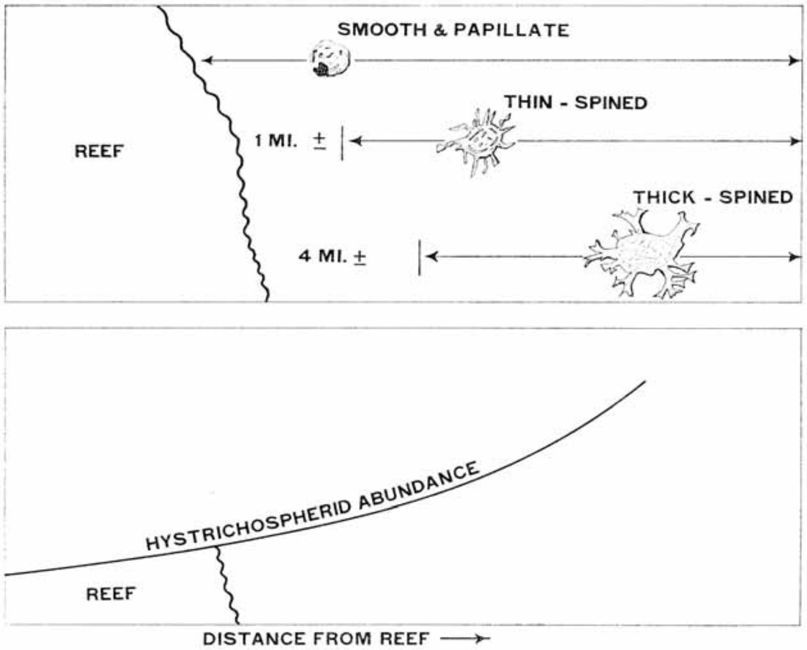
1. Simple, spherical forms. The surface is smooth, papillate, or ciliate.
2. Thin-spined forms. The spherical central body bears long, thin spines that do not seem to be an integral part of the central body.
3. Polyhedral, thick-spined and saccate forms. The processes are very broad at their bases, are often hollow and seem to be extensions of the central body of the organism.

Hystrichospherid distribution. Hystrichospherids are generally much more abundant in off-reef than in near-reef strata (text-fig. 4). This could be a result of several factors:

1. Their optimum environment is the quiet, deeper water of the off-reef areas.
2. Wave action in shallow water near the reefs may have destroyed or winnowed out their remains.
3. Diagenetic processes might have destroyed the microfossils in the coarser, near-reef sediments.
4. Scavengers might have destroyed the organisms.

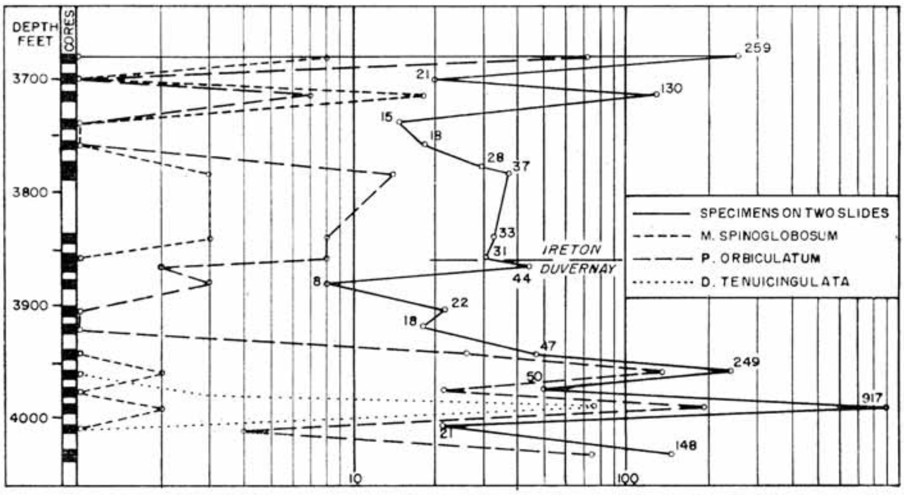
The environment factor is considered the most important because only one growth-form of hystrichospherid is most prevalent near the reefs, and the others are added with distance from the reefs. It is unlikely that there was selective destruction by wave action, scavengers, or diagenesis. Also, other acid-insoluble microfossils (Chitinozoa, plant spores) are not affected in this way. There are, moreover, areas of sediment moderately high in fragmental carbonate in which all types are present.

Considerable variations in the number of hystrichospherids occur at each sampled interval in cored wells. Text-figs. 5 and 6 show the total abundance of hystrichospherids in part of the Ireton–Duvernay section for the Anglo-Canadian Beaverhill Lake No. 2 well and for the A. H. C. and E. Camrose No. 1 well. In the former, the numbers increase, within less than 10 feet of vertical distance, from fifty individuals per two slides to 917 individuals per two slides (this represents, very approximately, 1 gramme of sample). The abundance of selected hystrichospherid species for the same two wells also varies greatly (text-fig. 7). The vertical sequence is similar for both wells, and for others counted in this manner, but long-cored intervals are not available from enough wells to check the feasibility of correlating Woodbend sediments by this method.

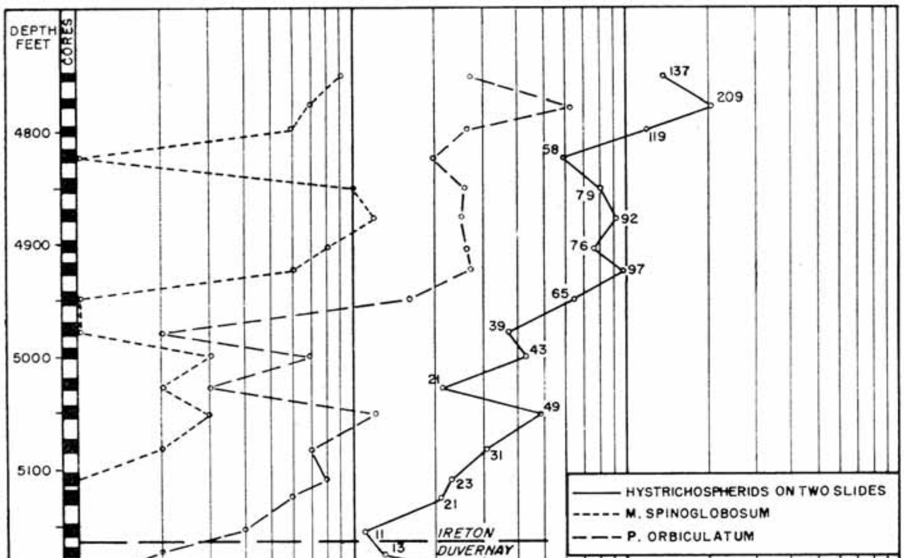


TEXT-FIG. 4. Diagrammatic representation of distribution of hystrichospherid growth forms, Upper Devonian, central Alberta.

Considering distribution by growth-form, simple spherical forms are widespread in the Duvernay strata of the Edmonton area (text-fig. 8). They occur all the way from shales interbedded with reef carbonate (Redwater Saltwater disposal well, T57, R21, W4th M.) to off-reef areas. Their abundance, however, increases away from the reefs, as do the numbers of species. Thin-spined forms are also widespread but are seldom found within one mile of reefs. Thick-spined and polyhedral forms occur in off-reef strata. They were found close to reefs, perhaps where currents carried them, in only two cases (north of Redwater and north of Willingdon—see Discussion of Current Patterns). The samples did not cover a sufficient number of wells to obtain adequate information on species distribution. If a more detailed study is made, records of individual species distribution may show that some of them are much more sensitive to environment than are the three growth-form groups.

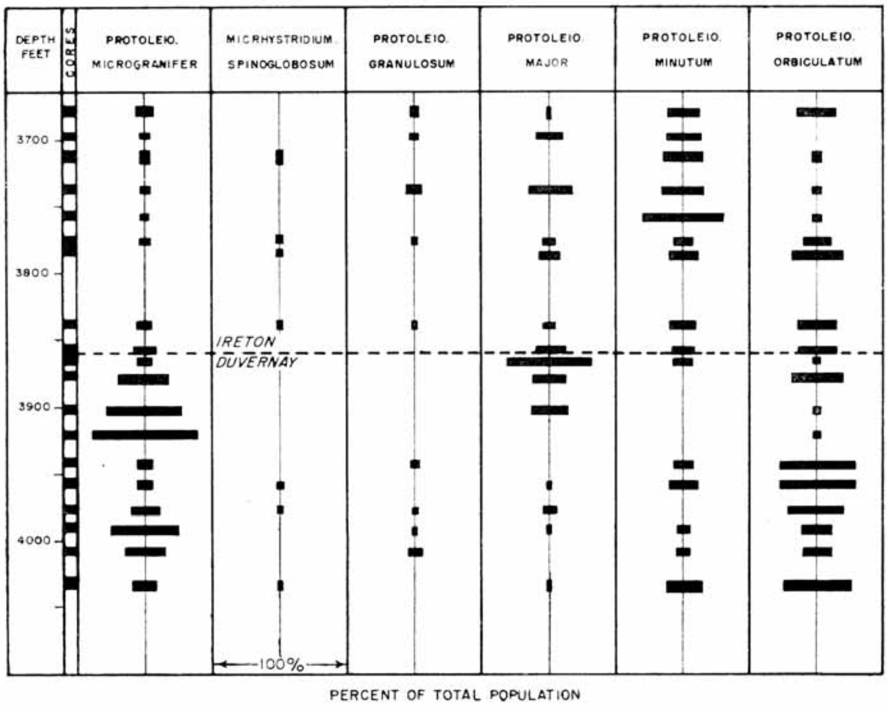


TEXT-FIG. 5. Hystrichospherids on two slides, Anglo-Canadian Beaverhill Lake No. 2. Total curve and selected species.



TEXT-FIG. 6. Hystrichospherids on two slides, A. H. C. and E. Camrose No. 1. Total curve and selected species.

Distribution of plant spores. Abundant plant spores (20 per cent. or more of the total acid-resistant microfossils) are found in the Duvernay member around Redwater reef (text-fig. 8). The percentages increase to the north. Plant spores are moderately abundant north of Township 53 and east of the main reef trend and rare to the south and west of this area. The source of the spores is therefore to the north of the Edmonton area.

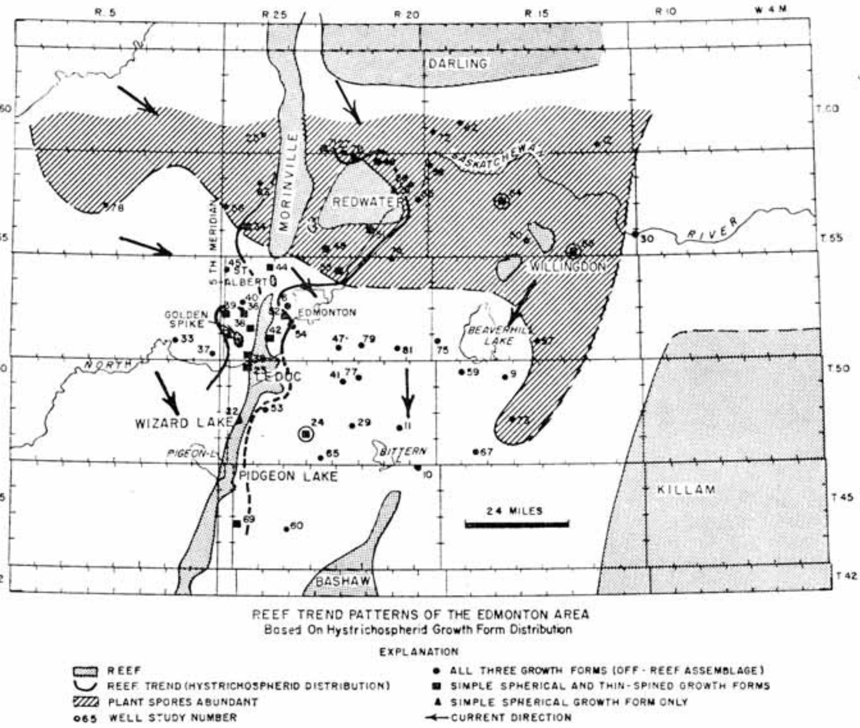


TEXT-FIG. 7. Variations in relative abundance of six selected hystrichospherid species, Anglo-Canadian Beaverhill Lake No. 2.

Water currents were probably most responsible for transporting the spores. Supporting evidence for a northern source is offered by many wells. In part of the Peace River area, the pre-Cambrian surface was emergent during Woodbend time.

Distribution of Chitinozoa. Work done by L. R. Wilson (1955) on the Lower Paleozoic Chitinozoa of the New York area indicates that this group of fossils is most abundant in shallower marine waters, especially near the margins of the basins. For this reason, it is thought that the Chitinozoa of the Duvernay member might indicate proximity to shallower 'platform' areas, on which reefs are more likely to form. The greatest abundance of Chitinozoa in the Duvernay shale is in the area just to the north and north-east of Redwater reef, to the north and west of Golden Spike reef, and in some wells between the Pigeon Lake and Bashaw reefs (text-fig. 8).

Current configurations. The relative abundance of the plant spores was plotted at each data point. The general pattern for the entire area showed a decrease in abundance to the south and east, but the southward decrease is much less pronounced east of the



TEXT-FIG. 8. Reefs, reef trend patterns, plant spore distribution, and interpreted current directions, Duvernay time. Names of wells and intervals used are given in the list at the end of the paper.

Morinville–Rimbey trend. These gradients in abundance suggest that the major currents were from the north-west and west on the west side of the reef chain, and from the north and north-east on the east side of the reef chain. Andrichuk (1960) came to similar conclusions on the basis of grain size and lithologic studies.

The presence of abundant and varied hystrichospherid assemblages north of Redwater and Willingdon reefs is explained if these current directions are correct, as the small organisms would be carried by the currents and concentrated on the north side of any high on the sea floor.

Further support for the current pattern may be arrived at in another manner.

Runcorn's work on paleomagnetic directions (1956) placed the earth's north pole during Devonian time at approximately 150 degrees east longitude and 35 degrees north latitude. The world distribution of Devonian reefs does not conflict with this interpretation, as they are confined to a broad equatorial belt with relation to this pole. Edmonton, Alberta, would have been at about 20 degrees north latitude. The major oceanic currents against a west-facing land mass at this latitude would have been from the west and north-west. Drag induced on the currents by reef trends, shelves, and land masses would bend them southward, as is the case with currents striking the present west-coast configuration. Currents in shallow-water regions of variable bottom topography are necessarily complex, therefore only major current directions can be suggested.

Reef trends from drilling. The over-all reef trend pattern found by drilling consists of biostromal developments to the north and east of the Edmonton area (Darling and Killam reefs, respectively) and a series of north–south trending barrier-type reefs and subsidiary platform reefs (text-fig. 8). In general, reef development progressed eastward in the Edmonton area during Woodbend time. Reefs east of the Morinville–Rimbey trend grew on Cooking Lake fragmentals; those of the Morinville–Rimbey trend itself have reefal Cooking Lake at their bases; while those to the west started growing during Beaverhill Lake time. The major reef development followed a transgressing sea.

Correlation with hystrichospherid distribution. The reef-trend patterns obtained on the basis of growth-form distribution are shown in text-fig. 8. In most cases, lines drawn about areas where simple and thin-spined growth-forms are present enclose reef trends defined by drilling. In nearly all cases the thick-spined growth-form is found only in off-reef areas.

There are exceptions to this pattern. For example, in the Millet Leduc well (number 24 on text-fig. 8), the off-reef thick-spined hystrichospherids are absent, although drilling has largely eliminated reef possibilities. In other cases, the data were limited by the small number of wells used in the study. Largely for this reason, the Flint–Duhamel reefs and the development at Willingdon are not outlined in text-fig. 8. There are five locations far from known reefs that have only simple and thin-spined growth-forms. These areas (text-fig. 8) are north of Golden Spike (T52, R26, W4th M.), east of Acheson and the northern part of Leduc (T52, R25–26, W4th M.), south of Redwater (T55, R23, W4th M.), the Millet Leduc area (T48, R24, W4th M., Millet Leduc No. 16–6) and around T57, R17, W4th M. (Canadian Superior Kozak No. 16–3). This distribution could indicate shallow water or, in other words, platforms on which reef growth was possible. Chitinozoa and scolecodonts, suggesting shallow water, are common in the first three areas. Two areas that have all three hystrichospherid growth-forms (off-reef assemblages) were found close to reefs. One is just north of Willingdon (T44, R15, W4th M.) at Imperial Willingdon No. 2, and the other is just north of Redwater Reef (T58, R22–23, W4th M.) at Imperial Opal No. 35 and Imperial Egremont West No. 16–36. If currents were from the north in this area, as suggested in the discussion of current patterns, the small hystrichospherids could easily have been carried to these positions on the reef flanks.

Summary. Data presented here show that acid-resistant microfossils can be used to outline broad reef trends and other major sedimentary structures. Because of the large amount of well control that is required in order to give the pattern any sort of precision, it is doubtful whether the method has immediate practical application to petroleum exploration.

Chitinozoa are generally abundant in areas of relatively coarser sediment. Concentrations of these fossils may help to indicate areas of shallow water where conditions were favourable to reef development. The relative increase in plant spore abundances to the north points toward land masses contemporaneous with the deposition of the Duvernay formation. On the basis of plant spore distribution, major currents to the west of the Leduc–Rimbey reef trend were from the north-west and west, while those to the east of this trend were generally from the north, as a result of southward drag induced by reef configurations and land masses.

SYSTEMATIC SECTION

Classification of hystrichospherids. Most Paleozoic hystrichospherids would fall into the following form categories:

1. Spherical sacs, laevigate to papillate.

1a. Spherical sacs, minor ornamentation, apical pore present.

2. Spherical sacs, apiculate, ciliate, spinose, baculate or pilose, the processes numerous and small in relation to body (vesicle) diameter.
3. Spherical sacs with long simple spines.
4. Spherical sacs with long processes, the tips expanded, branched, dissected or otherwise modified.
5. Roughly spherical sacs with short coarse broad-based apiculae or other structures.
6. Roughly spherical sacs with processes of more than one kind, sometimes with one very large process that lends a bilateral symmetry to the form. Internal structure is apparent on some.
7. Roughly spherical sacs with long processes that are hollow and expanded at the tips to resemble trumpets (almost entirely post-Paleozoic).
8. Lanceolate to fusiform bodies with various types of processes.
9. Reticulate spherical bodies, sometimes with short spinose or pilate processes.
10. Lenticular forms, rectangular to circular, with a thin flange or girdle. Rod-like structures often strengthen the connexion of the flange to the vesicle.
11. Geometrical to saccate forms—triangular and lenticular to tetrahedral and polyhedral, often with long processes at the angles. The processes are broad-based and are an integral part of the vesicle. Some have internal structures.
12. Subspherical to polyhedral forms enveloped in a membrane, the membrane commonly gathered into folds and attached to the vesicle by processes of various kinds.
13. Fusiform bodies.

The species described here belong to groups 1–4 and 9–12. Group 4 is represented only by few species, although it is a characteristic group in the Devonian of eastern North America. Many typical or index species from the eastern Devonian section are lacking in the Alberta assemblages. The reason for this probably lies in the fact that the seaways of the two areas were separate during the Middle Devonian and were not connected until some time in the Upper Devonian, perhaps too late to allow the more diverse eastern assemblages to migrate into the area of Duvernay–Ireton sedimentation.

Stratigraphic value of hystrichospherids. Published work on hystrichospherids is limited, making it difficult to compare assemblages of different stratigraphic and geographic locations. However, a few generalizations may be drawn on the basis of the scant literature, and control collections from various strata.

Ordovician hystrichospherids are mostly small, the vesicle diameter ranging from 5 to 20 microns for the most part. The most common growth-forms are groups 1 and 2. Groups 3, 4, and 13 are occasional, and forms similar to *Hystrichosphaeridium trispinosum* Eisenack represent group 11.

Silurian hystrichospherids are much more varied, and many are larger in size. Group 4 is very important, containing a number of species of relatively short stratigraphic range. A number of complex forms have processes of more than one type, and some possess bilateral, rather than radial, symmetry. Some possess internal structures. Devonian forms are similar to those of the Silurian, but many species are different. The polyhedral or geometrically shaped group, with processes broad-based and an integral part of the vesicle, is relatively more important, and species with the spines arranged in one plane or with stubby complex spines are also more prevalent. Deunff (1954, 1957), Radforth and McGregor (1954), White (1862), and theses prepared at the University of Massachusetts under L. R. Wilson, illustrate a few of the Siluro-Devonian hystrichospherids of eastern Canada and New York.

Upper Paleozoic forms are poorly known. Groups 5 to 6 and 8 are important but most of the others are present also. During the Permian, small forms of group 2 seem to be predominant, at least in the area from the north-western States to Alaska. Small triangular to tetrahedral rectangular forms of group 11 are common. Many of the same polyhedral forms are present in the Triassic sediments of western Canada, some with the single flagellum of certain chrysophyte swarmers in possibly fresh to brackish water deposits (J. Jansonius, study in progress). In the Permian rocks we also find the first hystrichospherids of known dinophycean affinities.

Nomenclatural considerations. The majority of Paleozoic hystrichospheres and leiospheres have been apportioned to the genera *Leiosphaeridia* Eisenack 1958, *Tasmanites* Newton 1875, *Micrhystridium* Deflandre 1937, *Baltisphaeridium* Eisenack 1958, *Veryhachium* Deunff 1954, *Cymatiosphaera* O. Wetzel 1933, *Dictyotidium* Eisenack 1955, and *Leiofusa* Eisenack 1938. Our knowledge of these forms is still small, and it is fortunate that so few genera have been proposed. A number of changes are now necessary. Timofeev (1959) has proposed several genera based on the type of ornamentation for leiospheres without pylom or canals. *Protoleiosphaeridium* (type species cited as *P. conglutinatum* in his 1960 paper) includes laevigate to shagreen (finely granulose) species and is here slightly expanded to include papillate and minutely spinulose forms. Many of these small leiospheres were formerly assigned to *Leiosphaera* Eisenack 1938. In 1951 Eisenack accepted the fact that the type species, *L. solida*, was similar to and possibly conspecific with *Sporangites huronensis* Dawson, following Krausel's work of 1941. Eisenack later (1958*a*) completed the transfer of *L. solida* to *Tasmanites huronensis* (Dawson). *Leiosphaeridia* was proposed by Eisenack (1958*a*) for thin-walled forms formerly included in *Leiosphaera*. However, the generic description clearly states that a pylom is present (page 3). The inclusion of the many small aporate spheres without pylom within the pylom-bearing genus *Leiosphaeridia* is unsatisfactory from stratigraphic and taxonomic standpoints, and the acceptance of *Protoleiosphaeridium* is recommended.

Micrhystridium Deflandre 1937 was defined with a maximum size of 20 microns. A number of species have size limits that extend above and below this arbitrary limit, and many species averaging over 20 microns have no other characteristic to distinguish them from smaller species. Most of these larger forms were originally assigned to *Hystrichosphaeridium* Deflandre 1937. Eisenack (1958*b*) proposed some important changes. *Hystrichosphaeridium* was restricted to forms with open-tipped spines similar to the type species, *H. tubiferum* (Ehrenberg) Deflandre, from the Mesozoic. *Baltisphaeridium* (ex *Hystrichosphaeridium*) was proposed for species with closed-tip spines. No revision was made of *Micrhystridium*. As of that date, *Micrhystridium* stood for species under 20 microns in size, with closed-tip spines of various kinds, and *Baltisphaeridium* included larger forms of similar type.

The type of *Micrhystridium*, *M. inconspicuum* (Deflandre) Deflandre 1937, has simple spines, all of one kind. The original illustration of the type of *Baltisphaeridium*, *B. longispinosum* (Eisenack 1931) shows a form with simple spines. In later papers, Eisenack (1938, 1951) placed in the species a number of specimens with forked spines, broad processes with constricted bases, and other types. He characterized illustrations of simple forms, however, as '. . . recht typische Stücke mit sehr langer und fast fadenförmigen Anhangen'. The true type of *Baltisphaeridium* is therefore morphologically similar to that of *Micrhystridium*, and overlap of the simply spined species is inevitable. *Micrhystridium* is here emended to include only simply spined forms, the spines closed at the tips and generally uniform in structure. The size limit of 20 microns is removed. The type species of *Baltisphaeridium* is considered as a species of *Micrhystridium* emend., and the genus abandoned. *Multiplicisphaeridium* new genus is proposed for species that possess forked or otherwise modified processes with closed tips, the processes generally uniform within a single species. No size limits are imposed. Formal reassignment of previously described species to these new or emended genera are not made here in order to avoid the problems of synonomy that would arise if these proposals are not generally accepted.

Veryhachium Deunff 1954 was proposed for more or less polyhedral (triangular to prismatic) forms with broad-based processes. The type species *V. trisulcum* (Deunff) was not described until 1959, although it had been illustrated (1951, 1954). A holotype and paratypes are listed with the description, and the genus is now considered to be properly validated. The concept of *Dictyotidium* is broadened slightly to include additional reticulate species, but the basic diagnosis is not changed. *Cymatiosphaera* is suitable for most Paleozoic species with enveloping membranes that are gathered into various reticulate patterns and stiffened by spine-like radial processes.

Other new hystrichosphere genera proposed are *Duvernaysphaera* and *Paleopedicystus*. A new type of acid-resistant microfossil is described under the name *Hoegisphaera* n. gen., new chitinozoan structures are illustrated, and a species of *Tasmanites* is described.

Many species of hystrichospherids are broadly defined and interpreted at this time, and much variation is allowed. The author believes that with further work many of these species will be separated into two or more distinct entities, with little overlap. The Upper Devonian hystrichospherids of western Canada are relatively constant in form, the variation being confined to slight differences in the number of spines or in the ratio of spine length to vesicle diameter.

Type specimens are available for study in the permanent collections of Imperial Oil Limited, 300 Ninth Avenue W., Calgary, Canada.

HYSTRICHOSPHERE GROUP

Genus PROTOLEIOSPHAERIDIUM Timofeev 1959

Type species. P. conglutinatum Timofeev 1959.

Revised diagnosis. Vesicle ellipsoidal to spherical; wall thin, aporate; canals absent; pylom absent; ornamentation absent or minor, including granules, papillae and small short spinules.

Remarks. The description given by Timofeev is expanded to include other types of minor overall ornamentation besides laevigate and shagreen. The change is not sufficiently important to warrant citation as a formal emendation. *P. cambriense* should be excluded from the genus, as it possesses characteristics not covered in the generic description. *P. nervatum* perhaps belongs to *Dictyotidium*.

Protoleiosphaeridium minutum sp. nov.

Plate 48, fig. 3

Holotype. Imperial Willingdon No. 2, Duvernay member, 2,975–3,050′ composited decontaminated cuttings. Slide 1, 47·5 109·2; 18 microns.

Diagnosis. Vesicle circular, laevigate, thin-walled; frequently folded; diameter 12–20 microns.

Remarks. Smooth sacs of similar appearance are present in many marine Paleozoic rocks.

Protoleiosphaeridium orbiculatum sp. nov.

Plate 48, fig. 12

Holotype. Imperial Willingdon No. 2, Duvernay member, 2,975–3,050′ composited decontaminated cuttings. Slide 1, 38·2 124·5; 40 microns.

Diagnosis. Vesicle circular, smooth, frequently folded, relatively thick-walled for the genus; diameter 24–48 microns.

Remarks. Abundant to frequent in the Woodbend and Beaverhill Lake formations. Wall thicker than *Leiosphaeridia wenlockia* Downie 1959.

Protoleiosphaeridium micrograrifer sp. nov.

Plate 48, fig. 4

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., 2,975–3,050′ composited decontaminated Duvernay cuttings. Slide 1, 39·8 121·5; 31 microns.

Diagnosis. Vesicle circular, microgranulose, commonly folded; diameter 35–45 microns.

Remarks. A. granulosa has distinct granules slightly more than 0·5 microns in diameter, whereas the granules in this species are near the limit of resolution of the microscope.

Protoleiosphaeridium major sp. nov.

Plate 48, fig. 6

Holotype. Imperial *et al.* Faust South 6-2, 6-2-72-11W5th. M., Beaverhill Lake fm., 6,750–5′ core. Slide 2, 31·5 120·2; 60 microns.

Diagnosis. Vesicle circular; laevigate; relatively thick-walled, folding occasional; size 55–85 microns.

Protoleiosphaeridium diaphanium sp. nov.

Plate 48, fig. 8

Holotype. Imperial Spruce Grove No. 1, 4-25-52-27W4th M., picked Duvernay cuttings, 6,065–120′. Slide 1, 34·7 110·9; 48 microns.

Diagnosis. Vesicle circular; surface minutely granulose, separation of granules 1–2 microns; wall very thin, folding common; diameter 40–50 microns.

Remarks. Granules are finer and the wall much thinner than in *P. granulosum* n. sp. The compound folding of the vesicle wall is a characteristic feature of the species.

Protoleiosphaeridium granulosum sp. nov.

Plate 48, fig. 1

Holotype. A. C. Beaverhill Lake No. 2, 11-11-50-17W4th M., Duvernay member, 4,030′ core. Slide 1, 31·9 120·2; 28 microns.

Diagnosis. Vesicle circular; densely and evenly granulose, granules rounded, one micron or less separation; minor folding common; diameter 16–28 microns.

Protoleiosphaeridium papillatum sp. nov.

Plate 48, figs. 10–11

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Ireton member, 5,238′ core. Slide 1, 42·7 111; 36 microns (fig. 10). Illustrated: same well, Ireton member, 5,142′ core, Slide A, 42·7 122·8; 35 microns.

EXPLANATION OF PLATE 48

Figs. 1–12. *Protoleiosphaeridium spp.* 1, *P. granulosum* sp. nov., holotype, 28 microns. 2, 5, *P. microsaetosum* sp. nov. 2, 27 microns. 5, Holotype, 33 microns. 3, *P. minutum* sp. nov., holotype, 18 microns. 4, *P. micrograrifer* sp. nov., holotype, 31 microns. 6, *P. major* sp. nov., holotype, 60 microns. 7, *P. cryptogranulosum* sp. nov., holotype, 20 microns. 8, *P. diaphanium* sp. nov., holotype, 48 microns. 9, *P. parvigranulosum* sp. nov., holotype, 14·5 microns. 10, 11, *P. papillatum* sp. nov. 10, Holotype, 36 microns. 11, 35 microns. 12, *P. orbiculatum* sp. nov., holotype, 40 microns.

Figs. 13–21. *Micrhystridium spp.* 13, *M. vigintispinum* sp. nov., holotype, vesicle 24 microns. 14, *M. echinosum* sp. nov., holotype, vesicle 21 microns. 15, *M. bistchoensis* sp. nov., holotype, vesicle about 17 microns. 16, *M. breviciliatum* sp. nov., holotype, vesicle 34 microns. 17, *M. spinoglobosum* sp. nov., holotype, vesicle 24 microns. 18, *M. octospinosum* sp. nov., holotype, vesicle 33 microns. 19, *M. albertensis* sp. nov., holotype, vesicle 18 microns. 20, *M. angustum* sp. nov., holotype, vesicle 15 microns. 21, *M. crassiechinatum* sp. nov., holotype, vesicle 30 microns.

Figs. 22–24. *Multiplicisphaeridium spp.* 22, *M.? sprucegrovensis* sp. nov., vesicle 42 microns. 23, *M. truncatum* sp. nov., holotype, vesicle 38 microns. 24, *M. ramispinosum* sp. nov., holotype, vesicle 29 microns.

Diagnosis. Vesicle circular; densely papillate, papillae short, variable in size, shape and spacing, height 0·8–1·3 microns; diameter 24–38 microns.

Remarks. Baltisphaeridium microspinosum (Eisenack) in Downie, 1959, is larger and seemingly more densely papillate.

Protoleiosphaeridium microsaetosum sp. nov.

Plate 48, figs. 2, 5

Holotype. Cal. Std. Winterburn Prov. No. 1, 10-4-53-25W4th M., 5,535′ core, Duvernay member. Slide 1, 40·9 113·5; 33 microns (fig. 5). Illustrated: same sample, Slide 1, 44·3 110·5; 27 microns.

Diagnosis. Vesicle circular; saetose, spines crowded, tubular, 2–4 microns long, tips rounded, separation about 2 microns; diameter 25–44 microns, often appears ragged.

Remarks. Longer spines than *P. papillatum.*

Protoleiosphaeridium cryptogranulosum sp. nov.

Plate 48, fig. 7

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., Duvernay member, picked composited cuttings, 2,975–3,050′. Slide 1, 43·3 109; 20 microns.

Diagnosis. Vesicle spherical-ellipsoidal; microgranulose, granules variable in size and spacing, separation 1–3 microns; size 17–20 microns.

Protoleiosphaeridium parvigranulosum sp. nov.

Plate 48, fig. 9

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., Duvernay member, picked composited cuttings, 2,975–3,050′. Slide 1, 46·3 112·4; 14·5 microns.

Diagnosis. Vesicle circular in outline; densely covered with minute granules that in part tend toward a tubular shape, one micron long at most, separation not over 1·5 microns; 13–16 micron size range.

Genus LEIOSPHAERIDIUM Timofeev 1959 emend.

Type species. L. eisenackii Timofeev 1959.

Emended diagnosis. Vesicle circular in outline; large (100–300 microns and larger); laevigate; wall thin to moderate in thickness, aporate, without canals; folding minor to prominent, commonly taper-point in thin-walled spherical species.

Remarks. Timofeev (1959) cited the genus as *Leiosphaeridium* Eisenack 1938 emend. Timofeev. The alteration of *Leiosphaera* to *Leiosphaeridium* is not valid. The name is here regarded as a new generic taxon. The original description by Timofeev (1959), 'vesicle thick with smooth surface', is correct only in comparison with *Protoleiosphaeridium*, as the wall is thin in comparison with *Tasmanites* of *huronensis* type. Timofeev proposed the names *Trachysphaeridium* and *Lophosphaeridium* for finely granulose (shagreen) and tuberculose species.

Leiosphaeridium fastigatirugosum sp. nov.

Plate 50, fig. 9

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Ireton member, 5,354′ core. Slide 1, 38·8 123·2; 125 microns.

Diagnosis. Body spherical; laevigate; wall structureless, relatively thin; compression accompanied by the formation of taper-point folds; size 120–150 microns and perhaps larger.

Remarks. Much larger similar specimens may or may not belong to this species. No 'pylom' could be demonstrated. Species described by Timofeev that have taper-point folds are all shagreen.

Genus MICRHYSTRIDIUM (Deflandre) emend.

1937 *Micrhystridium* Deflandre, pp. 79–80.

Genotype. Micrhystridium inconspicuum (Defl.) Defl. 1937.

Description. Vesicle subspherical to spherical; spinose, spines simple, generally uniform, numerous, their bases sometimes arranged in a subpolygonal pattern, tapering to tubular, tips closed.

Remarks. The upper size restriction is removed. Forms with forked or otherwise differentiated appendages are placed in *Multiplicisphaeridium* n. gen. Forms with distinct ridges defining polygonal areas are placed in *Dictyotidium*. Small polyhedral to asterate forms, the appendages an integral part of the vesicle, are considered species of *Veryhachium* Deunff.

Micrhystridium breviciliatum sp. nov.

Plate 48, fig. 16

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Duvernay member, 5,625′ core. Slide 8, 32·9 120·2; vesicle 34 microns.

Diagnosis. Vesicle circular in outline; densely ciliate, length of cilia about 3·4–4 microns, separation about 4 microns, tubular in shape with rounded tips, often curved; vesicle 32–37 microns.

Micrhystridium echinosum sp. nov.

Plate 48, fig. 14

Holotype. Calmont Std. Winterburn Province No. 1, 10-4-53-25W4th M., Ireton member, 5,375′ core. Slide 1, 40·8 120·3; vesicle 21 microns.

Diagnosis. Vesicle subcircular; echinate, spines approximately 4 microns long, less than 1 micron in diameter, about 2–4 microns apart, spine tips rounded or faintly enlarged (compressional?); vesicle 17–22 microns.

Remarks. The vesicle is smaller and the spines closer together than in *M. breviciliatum* n.sp.

Micrhystridium angustum sp. nov.

Plate 48, fig. 20

Holotype. Texaco (Shaw) Spruce Grove No. 1, 4-11-53-27W4th M., picked composited Duvernay cuttings, 5,915–90′. Slide 3, 40 109·6; vesicle 15 microns.

Diagnosis. Vesicle circular; processes ciliate, 3–5 microns long, tips pointed, 15–17 in number, evenly disposed; vesicle size 14–16 microns.

Remarks. *Micrhystridium bacilliferum* Deflandre 1946 is smaller and has a larger number of spines. *Hystrichosphaeridium* cf. *brevispinosum nanum* Defl. 1945 is twice the diameter of this species and has more spines.

Micrhystridium spinoglobosum sp. nov.

Plate 48, fig. 17

Holotype. Imperial Duvernay No 1, 6-30-55-11W4th M., 2,245–8′ core, Duvernay member. Slide 1, 48 111; vesicle 24 microns.

Diagnosis. Vesicle spherical; spinose, spines 12–18 in number, 6–9 microns long and 2 microns wide at base, spike-shaped and sharply pointed; vesicle size 17–24 microns.

Remarks. *M. inconspicuum* (Deflandre) Deflandre 1937 is much smaller and has a thicker wall. *M. parinconspicuum* Deflandre 1945 (Silurian) has a diameter of 10–15 microns and possibly a larger number of spines. Frequent.

Micrhystridium bistchoensis sp. nov.

Plate 48, fig. 15

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake (?) equivalent, 4,906′ core. Slide 3, 30 111·3; 24 microns overall, vesicle about 17 microns, spine length about 6 microns.

Diagnosis. Vesicle subspherical; laevigate; spines broad-based but taper rapidly to tubular processes with pointed tips, about twenty in number, length approximately one-third vesicle diameter; overall size 20–26 microns.

Micrhystridium vigintispinum sp. nov.

Plate 48, fig. 13

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Duvernay member, 5,546′ core. Slide 1, 41·6 114; vesicle 24 microns, spines 12 microns, overall size 40 microns.

Diagnosis. Vesicle subspherical-ellipsoidal; laevigate; spines narrow, tapered to fine ciliate tips, basal diameter about 1·5 microns, length about half vesicle diameter, about 20 in number; overall size about 40 microns.

Micrhystridium albertensis sp. nov.

Plate 48, fig. 19

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake (?) equivalent, 4,906–11′ core. Slide 1, 40 112; vesicle 18 microns, spines 10–11 microns.

Diagnosis. Vesicle subspherical; laevigate; spinose, spines simple, tapering, 13–14 in number, length half to five-eighths vesicle diameter; vesicle diameter 16–19 microns.

Micrhystridium octospinosum sp. nov.

Plate 48, fig. 18

Holotype. Imperial Egremont West No. 6-36, 6-36-58-23W4th M., composited Duvernay core, 3,948–4,008′. Slide 1, 48 116; vesicle 33 microns, spines about 24 microns.

Diagnosis. Vesicle roughly spherical; appendages eight in number, broad-based, tentacle-like, tips pointed, length 20–28 microns, width at base about 4–5 microns; folding common; vesicle diameter 24–33 microns.

Remarks. Number of spines constant. The polyhedral shape characteristic of *Veryhachium* is absent. *Hystrichosphaeridium spiciferum* Deunff 1955 has up to fifteen appendages that are longer than those of this species.

Micrhystridium duvernayensis sp. nov.

Plate 49, fig. 8

Holotype. A. C. Beaverhill Lake No. 2, 11-11-50-17W4th M., Duvernay member, 3,988′ core. Slide 1, 45·3 110; vesicle 40 microns.

Diagnosis. Vesicle circular; spines ciliate, about twenty in number, 10–12 microns long, tips pointed; vesicle wall thin; vesicle diameter 35–40 microns.

Remarks. The wide separation of the spines characterizes this species.

Micrhystridium crassiechinatum sp. nov.

Plate 48, fig. 21

Holotype. Bear Rodeo No. 1, 8-20-89-9W4th M., 471–81′ core, Beaverhill Lake fm. Slide 8, 37·4 117; vesicle 30 microns.

Diagnosis. Vesicle subcircular in outline; sub-spherical; spines long, straight, tapering to a sharp point, about twenty-two in number, length 10–15 microns; vesicle diameter 24–33 microns.

Remarks. The stiff, straight habit of the spines characterizes this species.

Genus MULTIPLICISPHAERIDIUM gen. nov.

Text-fig. 9*e*

Type species. *Multiplicisphaeridium ramispinosum* sp. nov.

Diagnosis. Vesicle ellipsoidal to spherical; processes separate, narrow-based, tips multifurcate, expanded, dissected or otherwise modified but not open; processes all of one type or variations of one type, not differentiated into distinctive orders or kinds of processes; wall surface exclusive of processes laevigate to finely granulose.

Remarks. All species with simple unmodified spine tips are referred to *Micrhystridium* emend. All species with broad-based processes that are an integral part of the vesicle shape are referred to *Veryhachium* Deunff. A new genus should be proposed for species with more than one order of processes, i.e. the different types of processes are distinct and have a constant spatial relationship to each other.

Multiplicisphaeridium truncatum sp. nov.

Plate 48, fig. 23; text-fig. 9*f*

Holotype. Imperial Paddle River No. 1, 5-17-56-8W5th M., Duvernay–Cooking Lake equivalent, 7,930–2′ core. Slide A, 38·7 124·6; vesicle 38 microns.

Diagnosis. Vesicle circular to egg-shaped; processes crowded, ciliate, approximately 8 microns long, seemingly set on low pedestals (compressional feature), spine tips pilose to bifurcate on the same specimen, spine separation about 3 microns; vesicle size 28–38 microns.

Remarks. *H. hirsutoides* Eisenack 1951 is larger (75–80 microns) and seems to have shorter processes.

Multiplicisphaeridium? *sprucegrovensis* sp. nov.

Plate 48, fig. 22, Plate 49, fig. 6; text-fig. 9*j*

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Duvernay member, 5,635′ core. Slide 3, 39·3 112·8; vesicle diameter 36 microns, processes 16 microns (Pl. 49, fig. 6). Illustrated: Imperial Paddle River No. 1, 5-7-56-8W5th M., Duvernay–Cooking Lake equivalent, 7,823–8′ core. Slide 1, 41·4 113·3; vesicle 42 microns maximum, spines about 13 microns.

Diagnosis. Vesicle circular; processes crowded, 10–16 microns long, 2 microns wide at base but tapering to about 1 micron near tips, tips enlarged and tetrafurcate, secondary tips 2–4 microns long; appendage separation 3–4 microns; vesicle diameter 35–44 microns.

Remarks. About twenty-five to thirty processes extend beyond the vesicle margin. The closed nature of the tips could not be definitely determined, even with oil immersion, and the assignment is therefore provisional.

Multiplicisphaeridium ramispinosum sp. nov.

Plate 48, fig. 24; text-fig. 9*g–h*

Holotype. Imperial Bistcho Lake No. 7-7, 7-7-124-2W6th M., Woodbend fm., 4,159–64′ core. Slide 5, 41·5 117·6; vesicle 29 microns.

Diagnosis. Vesicle subcircular; processes generally bifurcate, each branch again bifurcate or trifurcate, tips multiple; processes usually twelve in number, 10–15 microns long; vesicle size 19–29 microns.

Remarks. Processes variable. A much larger similar species has been described from Baltic Silurian sediments (240 microns; Eisenack 1938, pl. 4, figs. 3–5). *Hystrichosphaeridium ramusculosum* Defl. 1945 has some simple pointed processes and may be a species with two distinct orders of processes.

Multiplicisphaeridium spicatum sp. nov.

Plate 49, fig. 21; text-fig. 9*i*

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., picked composited Duvernay cuttings, 2,975–3,050′. Slide 1, 34·7 112·6; vesicle 65 microns.

Diagnosis. Vesicle circular in outline; processes densely crowded, 6–9 microns long, 1½–2 microns wide, cylindrical, mostly bifurcate; size 63–72 microns.

Remarks. H. ex aff. *multipilosum* Eisenack 1938 (pl. 3, fig. 9) from the Silurian has finer processes.

Genus VERYHACHIUM Deunff 1954

Type species. Veryhachium trisulcum (Deunff) Deunff 1959.

Description. Shape extended polyhedral; appendages an integral part of the vesicle, hollow, tips closed, usually long but short in some species.

Remarks. The type species was not described until 1959, although illustrated and given a new combination with the generic proposal in 1954.

Veryhachium brevitrispinum sp. nov.

Plate 49, fig. 1

Holotype. A. C. Beaverhill Lake No. 2, 11-11-50-17W4th M., Duvernay member, 3,988′ core. Slide 1, 38·1 118·2; size (centre of one side to tip of opposing spine) 29 microns.

Diagnosis. Outline convexly trigonal; appendages at each corner, broad-based, tapered rapidly to a point, sometimes curved, short for the genus; vesicle wall minutely granulose (oil); size measured from centre of one side to tip of opposing appendage, 24–32 microns.

Remarks. Granulose surface and short spine length distinguish this species from *Hystrichosphaeridium trispinosum* Eisenack 1938. No internal structures are present. *V. trisulcum* var. *reductum* Deunff 1959 is laevigate.

EXPLANATION OF PLATE 49

Figs. 1–5, *Veryhachium spp.* 1, *V. brevitrispinum* sp. nov., holotype, 30 microns overall. 2, 5, *V. sp.* cf. *H. trispinosum* Eisenack. 2, 30 microns, one side to opposing spine tip. 5, 36 microns, one side to opposing spine tip. 3–4, *V. octoaster* sp. nov., 3, Holotype, 54 microns overall. 4, 38 × 40 microns overall.

Fig. 6, *Multiplicisphaeridium? sprucegrovensis* sp. nov., holotype, vesicle 36 microns.

Fig. 7, *Veryhachium duodeciaster* sp. nov., holotype, 45 microns overall.

Fig. 8, *Micrhystridium duvernayensis* sp. nov., holotype, vesicle 40 microns.

Fig. 9, *Veryhachium minor* sp. nov., holotype, 24 microns overall.

Figs. 10, 11, *Duvernaysphaera tenuicingulata* sp. nov. 10, Holotype, vesicle 32 microns. 11, Vesicle 31 microns.

Fig. 12, *Veryhachium sedecimspinosum* sp. nov., holotype, 21 microns overall.

Figs. 13, 14, *Dictyotidium spp.* 13, *D. polosymmetrium* sp. nov., holotype, 21 microns. 14, *D. polygonium* sp. nov., holotype, 29 microns (lower magnification than fig. 13).

Figs. 15–18, *Cymatiosphaera spp.* 15, *C. tetraster* sp. nov., holotype, vesicle 20 microns (oil). 16–17, *C. perimembrana* sp. nov. 16, Holotype, vesicle 28 microns. 17, Vesicle 24 microns. 18, *C. pentaster* sp. nov., holotype, 29 microns overall, vesicle 18 microns.

Fig. 19, *Veryhachium polyaster* sp. nov., var. *hexaster* var. nov., type, 72 microns overall.

Fig. 20, *Verhachium polyaster* sp. nov., holotype, 60 microns overall.

Fig. 21, *Multiplicisphaeridium spicatum* sp. nov., holotype, vesicle 65 microns.

Veryhachium sp. cf. *H. trispinosum* Eisenack

Plate 49, figs. 2, 5

1938 *Hystrichosphaeridium trispinosum* Eisenack, 14, 16, text-figs. 2–3.

Description. Variable, sides of vesicle almost straight, size from centre of one side to tip of opposing appendage, 24–38 microns. No internal rods or structures. Laevigate.

Remarks. Species of this general shape range from Ordovician to Recent, but some have characteristics that enable them to be used in age determinations. A minute structure interpreted as a single flagellar sheath is present on some Triassic forms, providing a resemblance to the swarmer of *Phaeodermatium* (filamentous chrysophyte). The genus very likely includes representatives of several groups.

Figured specimen. Imp. Paddle River No. 1, 5-17-56-8W5th M., 7,519′ core, Lower Ireton member. Slide 6, 38·5 127·3; centre of one side to tip of opposing spine 36 microns (fig. 5). Imperial Bistcho Lake 7-7, 7-7-124-2W6 M., 4,906–11′ core, Beaverhill Lake? equivalent. Slide 1, 33·4 125·7; 30 microns, centre of one side to tip of opposing spine.

Veryhachium polyaster sp. nov.

Plate 49, fig. 20

Holotype. Imp. Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake? fm., 4,906–11′ core. Slide 1, 18·7 120·8; overall size about 60 microns, vesicle central area approx. 18 microns.

Diagnosis. Vesicle polyhedral, composed of central area and five long tapering appendages; appendages an integral part of the whole, broad-based, not arising in the same plane; laevigate; overall size 60–70 microns.

Veryhachium polyaster sp. nov., var. *hexaster* var. nov.

Plate 49, fig. 19

Holotype. Imp. Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake? fm., 4,906–11′ core. Slide 1, 25·9 124·1; overall size 72 microns.

Diagnosis. Vesicle polyhedral, composed of central area and six long tapering appendages, the appendages are broad-based and are an integral part of the whole, not arising in the same plane; laevigate; overall size 60–75 microns.

Remarks. Forms with five and six appendages occur together and seem to represent the same species. The appendages are tapered and pointed, unlike *Veryhachium hebetatum* Deunff 1957.

Veryhachium octoaster sp. nov.

Plate 49, figs. 3–4

Holotype. Imperial Leduc No. 253, 11-13-50-27W4th M., Ireton member, 5,515′ core. Slide 2, 41·2 114·3; overall size 54 microns (fig. 3). Illustrated—Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., 5,118′ core, Lower Ireton member. Slide A, 36·3 117; 38 × 40 microns overall dimensions.

Diagnosis. Vesicle irregularly polyhedral, star-shaped in outline, with eight broad-based appendages that are an integral part of the whole, appendages not arising in the same plane, tips bluntly pointed, dark thin lines radiating from the central part of the vesicle to the tips of the projections sometimes visible; laevigate to faintly roughened; overall size 35–55 microns.

Remarks. V. balticum (Eisenack 1951) has an overall size of 80–85 microns, and some specimens have bifurcate appendage tips. *H. oligospinosum* (Eisenack 1934) is much larger. *Xanthidium* sp. White 1862 (p. 386, figs. 7–8) from the Silurian Lockport fm. closely resembles *V. octoaster* n. sp. *V. exasperatum* Deunff 1955 is much larger, the spine tips are broader, and the thin fibres are missing. Occasional specimens with six or seven processes have been found.

Veryhachium minor sp. nov.

Plate 49, fig. 9

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake? equivalent, 4,906–11′ core. Slide 1, 20·4 121·9; 24 microns overall.

Diagnosis. Vesicle polyhedral, generally compressed to a subquadrate outline; five appendages, integral parts of the body, rapidly tapered to sharp points, one often not visible due to folding; laevigate; size 20–28 microns.

Remarks. This small species has fewer appendages than *Veryhachium polyaster* n. sp. *V. minutum* Downie 1958 has four or six appendages and is smaller.

Veryhachium duodeciaster sp. nov.

Plate 49, fig. 7

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Duvernay–Cooking Lake equivalent, 5,605′ core. Slide A, 36·6 112·3; 45 microns, central portion roughly 18 microns.

Diagnosis. Vesicle subspherical-polyhedral; laevigate; appendages broad-based, an integral part of the vesicle, tapering to fine tentacle-like spines, twelve in number; overall size about 45 microns.

Remarks. Spines are more broadly based than on the specimens referred to *Micrhystridium stellatum* Deflandre by Downie 1959.

Veryhachium sedecimspinosum sp. nov.

Plate 49, fig. 12

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., 2,975–3,050′, picked composited Duvernay cuttings. Slide 1, 39·6 113·8; 21 microns overall, spines about 6 microns.

Diagnosis. Vesicle polyhedral-subspherical; processes broad-based, an integral part of the vesicle, fifteen–sixteen in number; laevigate; size 19–25 microns.

Remarks. This species is almost transitional between *Veryhachium* and *Micrhystridium*.

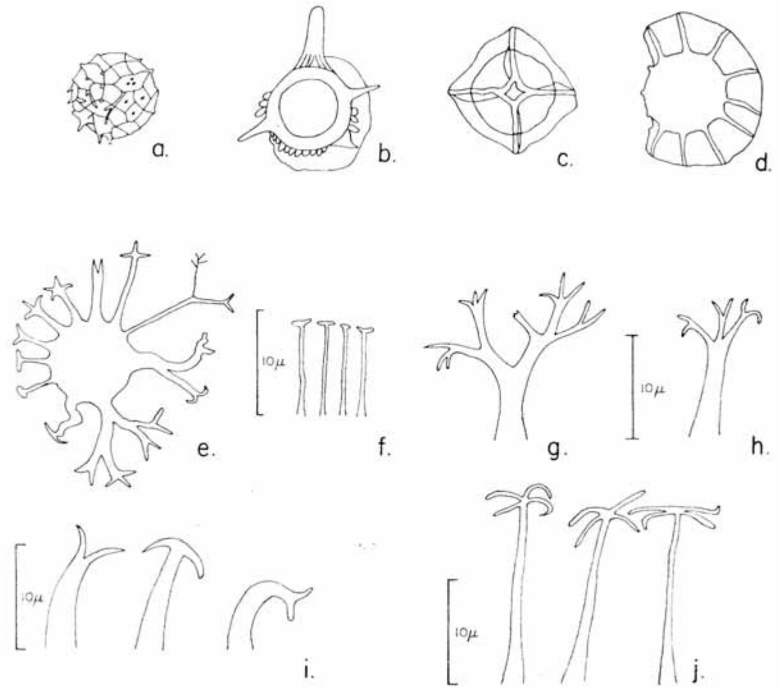
Genus DUVERNAYSPHAERA gen. nov.

Text-fig. 9*d*

Type species. Duvernaysphaera tenuicingulata sp. nov.

Diagnosis. Vesicle circular in outline, surrounded by an appressed diaphanous membrane that extends beyond the vesicle margin as a flange, the flange supported by simple rods or spokes arising from the vesicle that are present only in the equatorial plane, much like the fin of a fish.

Remarks. The outer layer is difficult to demonstrate except at the equatorial margins, and



TEXT-FIG. 9. *a*, *Dictyotidium*, composite of variations included in the author's concept. *b*, *Paleopedicystus* gen. nov. *c*, *Cymatiosphaera*, typical form. *d*, *Duvernaysphaera* gen. nov. *e*, *Multiplicisphaeridium*, composite of variations included in the author's concept. *f*, *M. truncatum* sp. nov., process detail. *g–h*, *M. ramispinosum* sp. nov., process detail. *i*, *M. spicatum* sp. nov., process detail. *j*, *M.? sprucegrovensis* sp. nov., process detail.

has been lost from most specimens, leaving the broken spine bases as a common characteristic. The shape seems to be lenticular. *Membranilarnax* has branched appendages. *Pterosperma* (*Pterospermopsis*) lacks the spokes, although short stiffening processes, radial thickenings or fluting are developed in some species. The membrane is also larger and heavier in *Pterosperma*.

Duvernaysphaera tenuicingulata sp. nov.

Plate 49, figs. 10, 11

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., 5,625′ core, Duvernay member. Slide

8, 42·9 120·6; vesicle 32 microns, membrane width 6 microns, rods about 6 microns apart (fig. 10). Illustrated: Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., 4,720′ core, Woodbend Group, Slide 5A, 41·2 112·3; vesicle 31 microns.

Diagnosis. Vesicle circular in outline; lenticular; surrounded by a diaphanous flange, both laevigate. Flange stiffened by a number of rods radiating from the vesicle margin, 8–12 microns long, and about 6–9 microns apart. Flange sometimes continued over vesicle surface as a membrane. Compression commonly off-centre. Size 26–33 microns.

Remarks. The membrane is often lost, leaving stubs of the rods to mark its places of attachment.

Genus CYMATIOSPHAERA O. Wetzel

Text-fig. 9*c*

Type species. *Cymatiosphaera radiata* O. Wetzel 1933.

Description. Spherical, ellipsoidal, or lenticular; often with radial ribs; provided with a membrane that is gathered into polygonal areas on the vesicle surface and that may extend considerably beyond the vesicle margin.

Cymatiosphaera pentaster sp. nov.

Plate 49, fig. 18

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake? equivalent, 4,906–11′ core. Slide 1, 28·2 114·9; vesicle 18 microns, 29 microns overall.

Diagnosis. Vesicle circular in outline; surface divided into five equal wedge-shaped areas by ridges originating at the poles and projecting as equatorial projections about 5 microns beyond vesicle equatorial margin, ridges often broadened and somewhat divided beyond the margin; spinose projections and ridges connected by a very thin appressed diaphanous membrane surrounding the vesicle, outer margin of each membrane segment almost straight; always compressed in the equatorial plane, suggesting a lenticular shape; size 28–33 microns overall, vesicle 18–20 microns.

Cymatiosphaera tetraster sp. nov.

Plate 49, fig. 15

Holotype. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Duvernay member, 5,625′ core. Slide A, 33·1 113·2; vesicle 20 microns.

Diagnosis. Vesicle circular; shape lenticular; polar areas of both hemispheres bear a diamond-shaped lacuna bounded by a low narrow ridge; from each angle of the lacuna low narrow ridges extend across the vesicle, dividing each hemisphere into four equal segments; ridges extend as spines about 3–4 microns beyond vesicle equator; spinose projections and ridges connected by a thin diaphanous membrane, giving the whole a sub-quadrate shape in polar view; vesicle size 28–34 microns.

Remarks. Polar diamond-shaped lacunae, slightly thicker vesicle wall, and four instead of five rays distinguish this species from *C. pentaster* sp. nov.

Cymatiosphaera perimembrana sp. nov.

Plate 49, figs. 16, 17

Holotype. Imperial Willingdon No. 2, 11-20-55-15W4th M., 2,975–3,050′; picked composited Duvernay cuttings. Slide 1, 36·3 113·2; vesicle 28 microns (fig. 16). Illustrated: same sample, Slide 1, 53·1 114·2; vesicle 24 microns.

Diagnosis. Vesicle spherical to ellipsoidal; laevigate; surrounded by a tightly fitting diaphanous membrane that is gathered into a fine reticulum; lacunae polygonal, 4–8 microns across, muri very fine; membrane stiffened by fine rods that arise from the muri, 3–5 microns long; membrane extends 2·5–5 microns beyond vesicle margin; size range 22–36 microns.

Remarks. The membrane is frequently lost in large part, but remnants of the reticulum remain on the vesicle, and remnants of the muri may be left as spines on the margin. The structure is generally visible only under oil.

Genus DICTYOTIDIUM Eisenack 1955 emend.

Text-fig. 9*a*

Type species. *Dictyotidium dictyotum* (Eisenack) Eisenack 1955.

Description. Vesicle spherical; surface reticulate, ridges low, distinct, lacunar areas polygonal; some species with two distinctly smaller lacunae, one at each pole; small apiculae or spines may arise from the ridges; papillae may be present in the floors of lacunae.

Remarks. The genus is enlarged to include forms with differentiated polar polygons and with short spines or apiculae on the ridges.

Dictyotidium polygonium sp. nov.

Plate 49, fig. 14

Holotype. Calmont Std. Winterburn Prov. No. 1, 10-4-53-25W4th M., Duvernay member, 5,515′ core. Slide 2, 47·2 119·3; 29 microns.

Diagnosis. Vesicle circular; surface divided into polygonal areas about 4 microns across with a small raised granule in the centre of each polygon; ridges narrow, rounded, slightly raised above vesicle surface; diameter 27–31 microns.

Dictyotidium polosymmetrium sp. nov.

Plate 49, fig. 13

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., Beaverhill Lake? equivalent, 4,906–11′ core. Slide 1, 32 113·3; 21 microns.

Diagnosis. Vesicle spherical; laevigate to faintly roughened (oil); surface divided into large polygonal areas by low narrow ridges; polygons up to 10–12 microns wide; a smaller polygon at each pole with a pore or papilla in its centre, polygon width about 6 microns; size 20–24 microns.

Genus PALEOPEDICYSTUS gen. nov.

Text-fig. 9*b*

Type species. Paleopedicystus rodeoensis sp. nov.

Diagnosis. Body subspherical, provided with a cylindrical stalk; body thick-walled, spinose, sometimes provided with an enclosing membrane.

Remarks. The superficial resemblance to cysts of some Ochromonadaceae (*Uroglena*) is striking, although no definitely identified members of this group are known from younger Palaeozoic or Mesozoic rocks. The complex structure of the body of *Paleopedicystus* (membrane, complex ornamentation) would seem to exclude hystrichospherids of the type of *Veryhachium clava* Deunff 1959, at least until more species are described and our understanding of the variations of these forms is more complete.

Paleopedicystus rodeoensis sp. nov.

Plate 50, figs. 1–3

Holotype. Bear Rodeo No. 1, 8-20-89-9W4th M., Beaverhill Lake fm., 731–41′ core. Slide 1, 30·6 122; overall length 48 microns, body diameter 33 microns, stalk length 21 microns, stalk width at mid-point 8 microns.

Diagnosis. Subspherical body with a cylindrical stalk; body thick-walled with five or more large cone-shaped processes in addition to densely packed irregular verrucose to pilose projections that are most prominent on the hemisphere opposite to the stalk; stalk finely striate at its connexion with the body and twice as broad as the stalk proper, remainder laevigate, pedal extremity constricted without distal opening; much of body covered with a diaphanous indefinite membrane that extends as much as 5 microns beyond the body wall; colour amber-yellow to amber-brown; body wall thickness about 4 microns.

CHITINOZOA

Most specimens of *Lagenochitina* and *Angochitina*, when cleared by chemical means, show a dark interior 'collar' in the neck of the body, convex at its base (Pl. 51, fig. 7). This 'collar' is the remnant of a plug-like cap, shaped much like a bottle stopper, that fits the neck of the body. The plug is spinose in *Angochitina*, the spines generally simpler than those of the body. Specimens of *Angochitina* cf. *devonica* with the plug in place are shown on Plate 51. The plug does not seem as resistant as the body of the chitinozoan. Cysts of certain recent Chrysophyceae (Ochromonadaceae) possess an analogous structure. In *Ochromonas*, the original cyst membrane is of cellulose. The

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EXPLANATION OF PLATE 50

Figs. 1–3, *Paleopedicystus rodeoensis* sp. nov., holotype, high, medium, and low focus respectively. Body diameter 33 microns; stalk length 21 microns.

Fig. 4, *Chomotriletes*? *bistchoensis* sp. nov., holotype, 49 microns.

Figs. 5–7, *Hoegisphaera glabra* sp. nov. 5, Holotype, 90 × 141 microns, operculum 57 microns. 6, 123 microns. 7, Operculum 70 microns.

Fig. 8, *Tasmanites* sp. A, 81 microns.

Fig. 9, *Leiosphaeridium fastigatirugosum* sp. nov., holotype, 125 microns.

outer siliceous coat is formed later by impregnation and is sculptured through the agency of external cytoplasm. The plug as a rule contains little or no silica. In germination the plug is dissolved and the contents of the cyst escape through the pore in the form of motile cells. Pascher (1924) noted that the cyst may be internal or external. If the periplast of the parent is coarse, it remains as an external envelope around the cyst. If the periplast is soft, it is absorbed into the cyst.

Angochitina cf. *devonica* Eisenack

Plate 51, figs. 1–7

1955 *A. devonica* Eisenack, p. 313, pl. 1, figs. 10–12.
1958 Collinson and Scott, pp. 13–15, pl. 1, 3, text-fig. 4.

Figured. Home Grizzly Mt. 10-16, 10-16-69-7W5th M., Beaverhill Lake fm., 7,020–5′ core. Slide 1, 36·8 114·5; 110×163 microns (fig. 7). Plug, Slide 2, 39·8 110·3, 43 microns, central part 33 microns (fig. 3). Plugged specimen, Slide 2, 39 115·6, plug 42×45 microns (fig. 5). Plugged fragment, Slide 2, 32·8 121·8, plug ±51 microns excluding processes (fig. 4). Wall detail, Slide 3, 43·6 120·6, ±13–21 microns between spine bases (fig. 6). Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., 5,403′ core, Lower Ireton, Slide 5, 34 117, body 93×126 microns, plug width 39 microns (figs. 1–2).

Remarks. The length varies from 150 to 210 microns. Spines of the plug and neck are simple, complex at the body mid-point, and simple at the base. The spine branching is dichotomous, with each branch again divided in some cases. The spines are arranged in about eight more or less vertical rows, but the arrangement is obscure on whole specimens. The neck is occupied by a plug that has a bulbous spinose termination above the neck. The small specimen (figs. 1–2) perhaps represents another species.

INCERTAE SEDIS

Genus HOEGISPHAERA gen. nov.

Type species. Hoegisphaera glabra sp. nov.

Diagnosis. Body spherical. One hemisphere provided with a thickened circular ring, enclosing an operculum. The operculum is often found detached from the body. Colour dark amber-brown. Known species are laevigate to wrinkled.

Remarks. Two additional species are present in the author's collections. One occurs in the type section of the Sylvan shale and the other in the type section of the Tulip Creek formation, both of Ordovician age, Oklahoma. The colour and texture of the wall are similar to those of Chitinozoa, but the analogy cannot be carried farther. The genus is named for Ove A. Høeg, for his contribution to our knowledge of Devonian floras.

Hoegisphaera glabra sp. nov.

Plate 50, figs. 5–7

Holotype. Socony Vegreville No. 1, 14-20-51-15W4th M., 3,500–600′, Duvernay decontaminated cuttings. Slide 6, 44·3 110·5; size 90×141 microns, width of thickened ring 4 microns, diameter of operculum 57 microns (fig. 5). Illustrated: same sample, Slide 6, 45·3 112; diameter 123 microns, operculum 60 microns. Operculum, Imperial Paddle River No. 1, 5-17-56-8W5th M., 7,823′ core, Duvernay–Cooking Lake equivalent, Slide 1, 26·8 116·8; 70 microns.

Diagnosis. Body spherical; laevigate; dark amber-brown. One hemisphere provided with a thickened circular ring, surrounding an operculum of the same thickness as the body wall. The operculum frequently is detached from the body. Diameter of body 110–130 microns, diameter of operculum 50–58 microns, width of thickened ring, 2–4 microns.

Remarks. The operculum, when etched, shows an indistinct concentric pattern not visible on normal specimens. Both Ordovician species are smaller.

Genus TASMANITES Newton 1875

In his description of *T. punctatus*, Newton remarked on minute lines ('tubes?') passing from the outer to the inner surface. Singh (1932) and this author failed to find these canals in Tasmanite available to them. However, J. M. Schopf (personal communication) and the Jersey Production Laboratory have ample material with the canals. Several species of leiospheres are probably present in the Tasmanite. A detailed discussion of the genus is contained in Schopf, Wilson, and Bentall (1944).

The small species described here has prominent canals that start at the inner wall surface, many not penetrating to the exterior surface. This is the reverse of the situation in *T. punctatus* and species of *Tytthodiscus* seen by the author. Most of the large cysts of the Devonian and Lower Mississippian of Western Canada have thin walls without canals. No 'pyloms' have been noted on North American species of *Tasmanites* (Schopf 1960).

Tasmanites sp. A.

Plate 50, fig. 8

Figured. Imperial Labyrinth Lake 15-14, 15-14-48-23W4th M., Cooking Lake member, 5,730′ core. Slide 1, 37·6 121·3; 81 microns, wall thickness 9 microns.

Description. Body spherical; thick-walled; wall punctured with narrow even canals, only part of which reach the outer wall surface, separation about 6 microns; surface laevigate except where canals reach the exterior; colour dark amber-brown.

Remarks. T. avelinoi Sommer 1953 (1956) is much larger. The description does not indicate whether all canals reach the outer surface.

Genus CHOMOTRILETES Naumova 1953

Remarks. Naumova published two views of the type species, one face showing a pattern of concentric overlapping arcs, the other two sets of intersecting arcs. The latter could not be demonstrated on the Alberta specimens. No haptotypic structures were noted, although an indistinct trilete was indicated for the Russian specimens. It is not certain that *C.*? *bistchoensis* sp. nov. is a plant spore, or that it belongs in *Chomotriletes*.

EXPLANATION OF PLATE 51

Figs. 1–7, *Angochitina* cf. *devonica* Eisenack. 1–2, Plugged individual from lower Ireton member, plug width 39 microns. 3–7, Specimens from Beaverhill Lake fm. 3, Isolated plug, 43 microns. 6, Detail of denuded wall (see text).

Chomotriletes? *bistchoensis* sp. nov.

Plate 50, fig. 4

Holotype. Imperial Bistcho Lake 7-7, 7-7-124-2W6th M., 4,159–64′ core, Woodbend fm. Slide 1, 21·8 124·5; 49 microns.

Diagnosis. Body circular in outline; surface covered by arc-like ridges that form a concentric pattern, the arcs overlapping, about twelve to sixteen crossed by a radius; ridges less crowded toward the poles, indistinct at the poles; no haptotypic structures noted; size 47–53 microns.

LIST OF WELLS USED IN REEF TREND STUDY

Well	*Location*	*Sampled interval*	*Map no.*
Royalite Texaco—Sharphead No. 1	8-18-44-25W4	6770–6800 ctg.	60
Canadian Superior—Rausch No. 1	12-21-44-27W4	7280–7320 ctg.	69
A. H. C. and E. Camrose No. 1	9-29-46-20W4	5169–5231 c.	10
Royalite Rosecam No. 1	4-14-47-18W4	4470–4560 ctg.	67
Sun Pipestone Creek Province No. 1	5-11-47-24W4	5955–5990 ctg.	65
Amerada Crown CF 42–24	9-24-48-17W4	4085–4170 ctg.	73
Imperial Armena No. 2	3-15-48-21W4	5162–5174 c.	11
Imperial Labyrinth No. 1	15-14-48-23W4	5610 core	29
Millet Leduc No. 16-6	16-6-48-24W4	5971–5986 c.	24
Imperial H. B. Wizard Lake No. 5-26L	5-26-48-27W4	6635–6650 ctg.	22
Imperial Ireton No. 1	4-10-49-26W4	6200–6245 ctg.	53
Anglo-Canadian Beaverhill Lake No. 2	11-11-50-17W4	3837–4038 c.	9
Imperial Tofield No. 1	9-18-50-18W4	4220–4280 ctg.	59
Imperial Joseph Lake West No. 1	15-7-50-22W4	5245–5320 ctg.	77
Imperial Looma No. 1	4-10-50-23W4	5370–5395 ctg.	41
Gas and Oil Offsets Reality No. 1	11-25-50-27W4	5926–5931 c.	23
Socony Vegreville No. 1	14-20-51-15W4	3500–3600 ctg.	57
Redwater Petroleum No. 2	1-29-51-19W4	4390–4435 ctg.	75
Calmont Leduc No. 3	4-14-51-21W4	4840–4895 ctg.	81
C. and S. Shaw No. 1	1-20-51-22W4	5160–5205 ctg.	79
Imperial Foley Lake No. 1	9-16-51-23W4	5265–5285 ctg.	47
Imperial Whitemud No. 1	15-14-51-25W4	5565–5605 ctg.	42
Imperial Graminia No. 2-12	2-12-51-27W4	6120–6170 ctg.	35
Time Texaco Holburn No. 1	4-11-51-1W5	6540–6650 ctg.	37
Texaco Time Brightbank No. 1	4-28-51-2W5	6800–6860 ctg.	33
Imperial Golf No. 1	2-11-52-25W4	5430–5470 ctg.	54
Pan Western West Edmonton No. 1	14-21-52-25W4	5450–5470 ctg.	52
Imperial Golden Spike No. 5	1-27-51-27W4	6005–6060 cores	13
Imperial Redwater Picadilly No. 1	4-17-52-26W4	5975–6005 ctg.	38
Imperial Spruce Grove No. 1	4-25-52-27W4	6065–6120 ctg.	36
Okalta Stony Plain No. 1	5-29-52-27W4	6140–6210 ctg.	39
Imperial Ardrossen No. 1	8-17-53-21W4	4595–4650 ctg.	76
Cal. Std. Winterburn Province No. 1	10-4-53-24W4	5435–5535 core	6

LIST OF WELLS USED IN REEF TREND STUDY (*cont.*)

Well	*Location*	*Sampled interval*	*Map no.*
Texaco (Shaw) Spruce Grove No. 1	4-11-53-27W4	5910–5990 ctg.	40
Scotford No. 1	8-33-54-21W4	4250–4295 ctg.	74
Imperial Riverbend No. 1	4-22-54-23W4	4695–4750 ctg.	55
Imperial Sturgeon No. 2	5-24-54-26W4	5395–5430 ctg.	44
Texaco McColl Onoway No. 1	16-18-54-27W4	6020–6080 ctg.	45
Imperial Duvernay No. 1	6-30-55-11W4	2237–2291 c.	30
Imperial Watt No. 5	5-11-55-14W4	2725–2820 ctg.	66
Imperial Willingdon No. 2	11-20-55-15W4	2975–3050 ctg.	50
Imperial L'Amoureux No. 1	12-8-55-23W4	4750–4820 ctg.	49
Lignora Redwater No. 1	3-1-56-22W4	4145–4180 ctg.	51
Imperial Mearns No. 1	15-6-56-26W4	5435–5525 ctg.	34
Pacific Deadman No. 1	7-32-56-27W4	5460–5590 ctg.	68
Imperial Paddle River No. 1	5-17-56-8W5	7730–7780 c.	4
Texaco McColl Cherhill No. 1	1-34-56-5W5	6590–6640 ctg.	78
Canadian Superior Kozak No. 16-3	16-3-57-17W4	3110–3170 ctg.	64
Imperial Skaro No. 1	15-2-57-20W4	3535–3620 ctg.	62
Imperial Eldorena No. 1	4-27-57-20W4	3577–3589 core	28
Redwater Saltwater Disposal Well	12-28-57-21W4	3628–3632 core	26
Imperial Alcomdale No. 1	14-27-57-26W4	5195–5275 ctg.	63
Royalite Seaboard Delph No. 1	10-17-58-19W4	3350–3410 ctg.	58
Imperial Redwater No. 2	3-29-58-21W4	3780–3315 ctg. 3850–3885 ctg.	48
Imperial Opal No. 35	7-29-58-22W4	3830–3910 ctg.	70
Imperial Egremont West No. 6-36	6-36-58-23W4	3835–3905 c. 3948–4008 c.	27
Barnsdall Vilna Time No. 1	5-12-59-13W4	2313–2341 c.	12
Imperial Jeffrey No. 1	6-4-59-23W4	4115–4225 ctg.	71
Imperial Westlock No. 14-24	14-24-59-26W4	4890–4925 c.	25
Falcon Seaboard Seminiuk No. 1	2-28-59-19W4	3250–3375 ctg.	72
Great Plains Seaboard Smoky Lake No. 2	14-12-60-18W4	2855–2970 ctg.	82

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NOTE

NORMANICYTHERE LEIODERMA (NORMAN) IN NORTH AMERICA

by JOHN W. NEALE

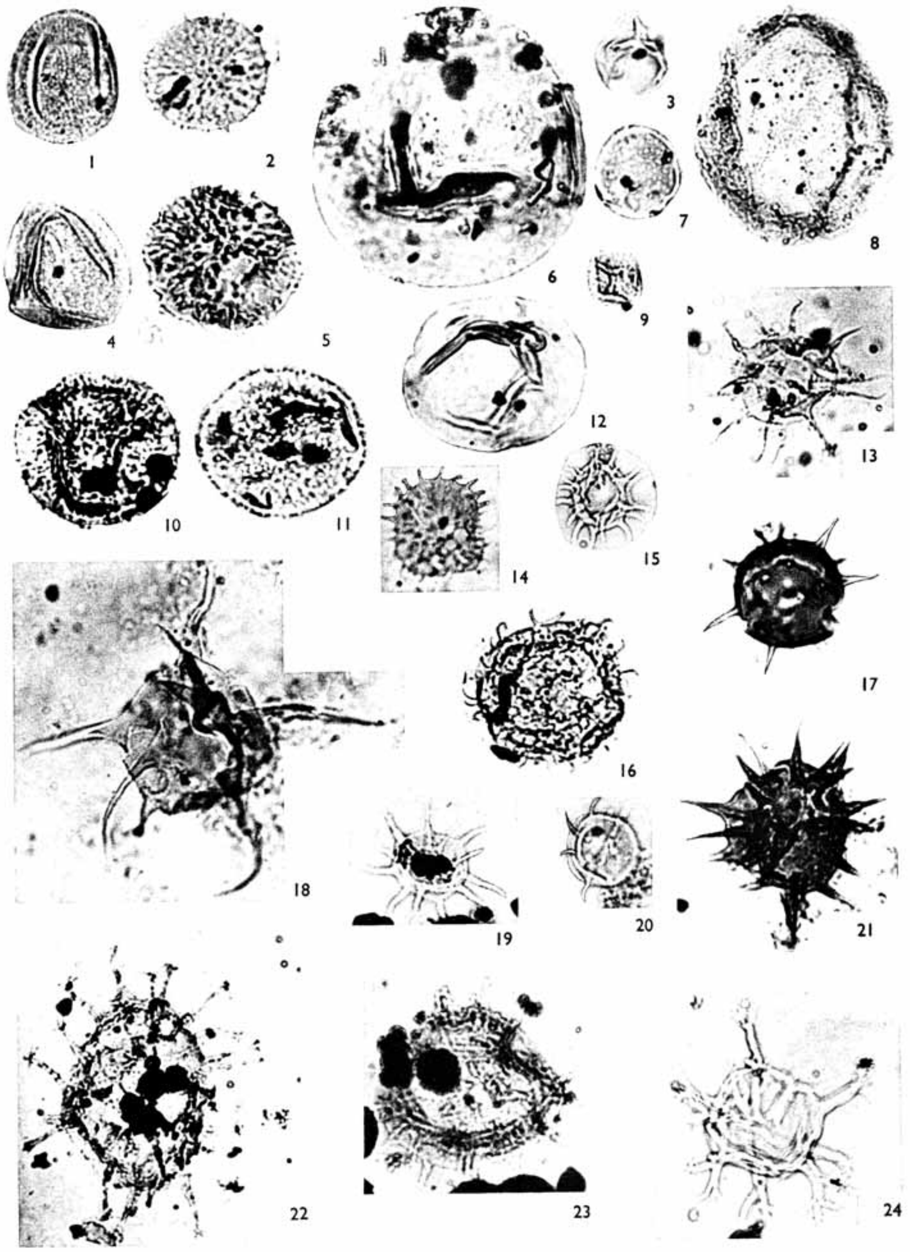
THE distribution of *Normanicythere leioderma* (Norman) has been examined in a recent paper (Neale, *Palaeontology* **2**, 1959, pp. 72–93) where it was shown to range from Spitsbergen (30° E.) to north-western Greenland (70° W.). Further information regarding its occurrence in North America has recently been obtained which considerably extends its western limits.

Dr. Frances Wagner of the Geological Survey of Canada informs me that she has found this species in a sample dredged from Cabot Strait (47° 30′ N., 60° W.) in autumn 1959, and that it is probably represented in two samples from Hudson Strait (61° 30′ N., 69° W.). The Cabot Strait specimens consist of one adult male right valve and one complete carapace which appears closest to instar 5. The material from Hudson Strait, which is questionably referred to *N. leioderma*, consists of one female left valve belonging to the penultimate instar dredged from a sandy clay bottom at a depth of 51 fathoms, and a complete female carapace, also belonging to the penultimate instar, obtained from a fine sand bottom at a depth of 145 fathoms. So far Dr. Wagner has not found this species in the Canadian Pleistocene.

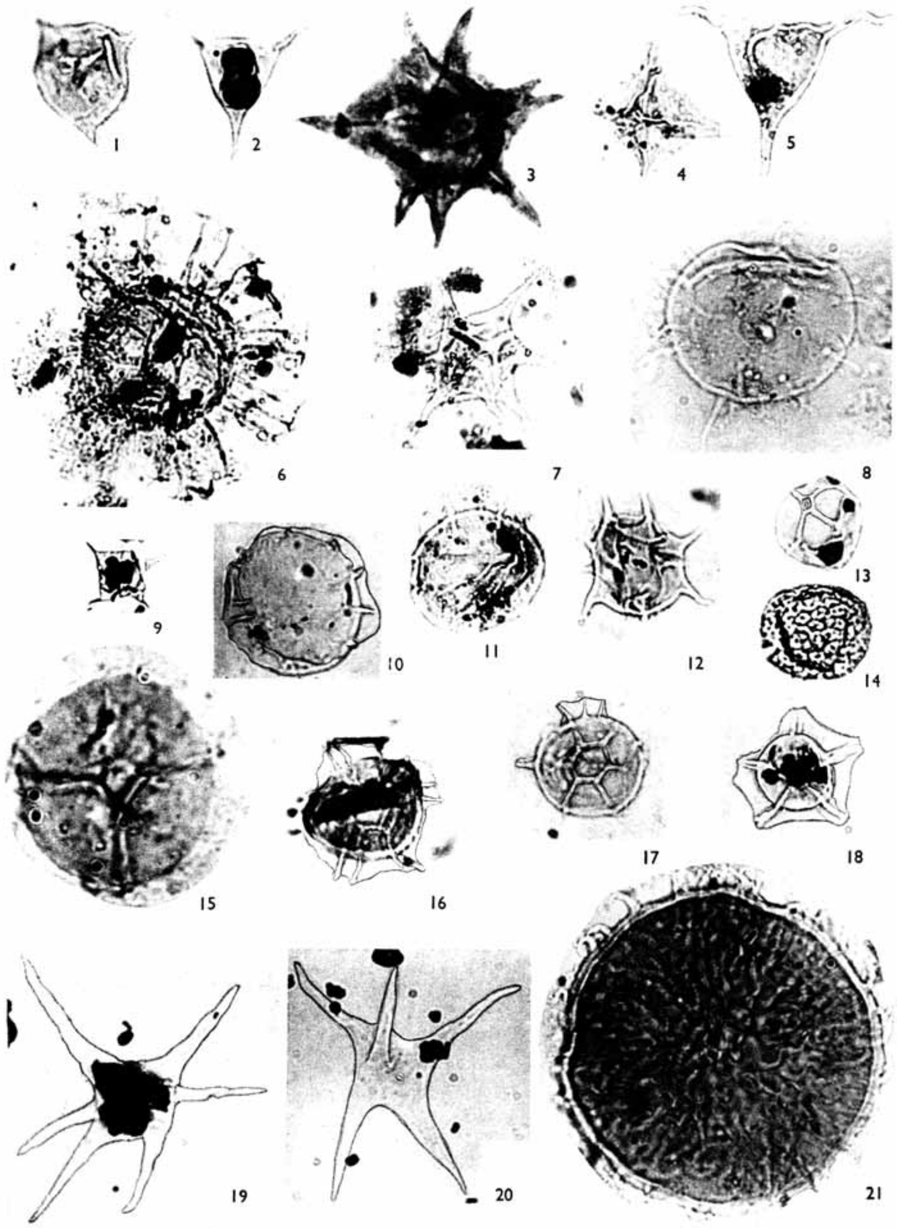
Professor F. M. Swain of the University of Minnesota writes that he has found this species in northern Alaska and also believes that it occurs in raised beaches in Lake Champlain, N.Y. The former record extends the range of *N. leioderma* at least another 70 degrees westwards so that it now ranges over more than 170 degrees of longitude. Although it remains to be seen whether any specimens will be forthcoming from the polar seas in the sector covered by the U.S.S.R. it seems probable that the distribution of this species is completely circum-polar, extending southwards to reach an extreme southern limit of approximately 44 degrees of north latitude.

23 March 1960

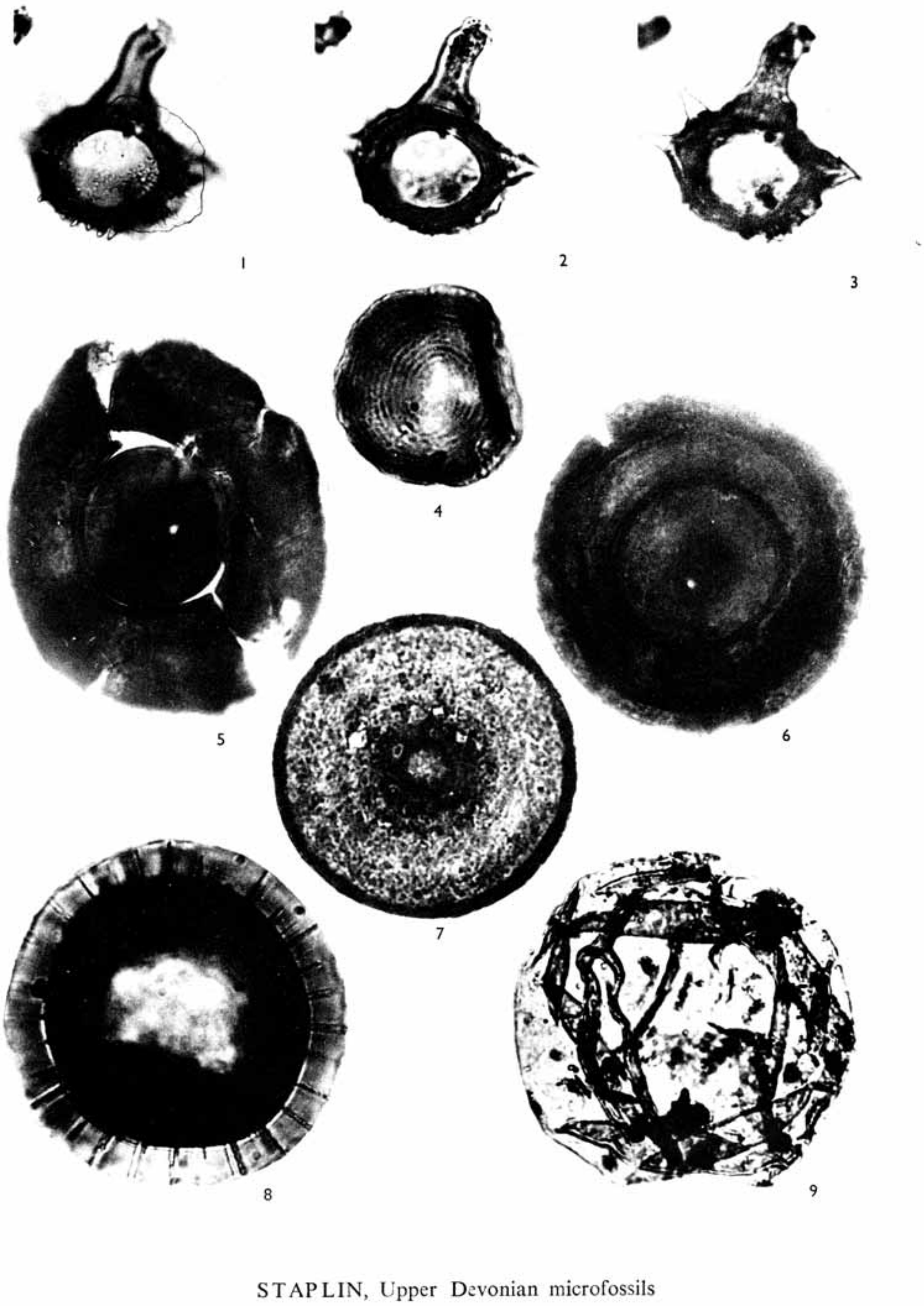
The University,
Hull



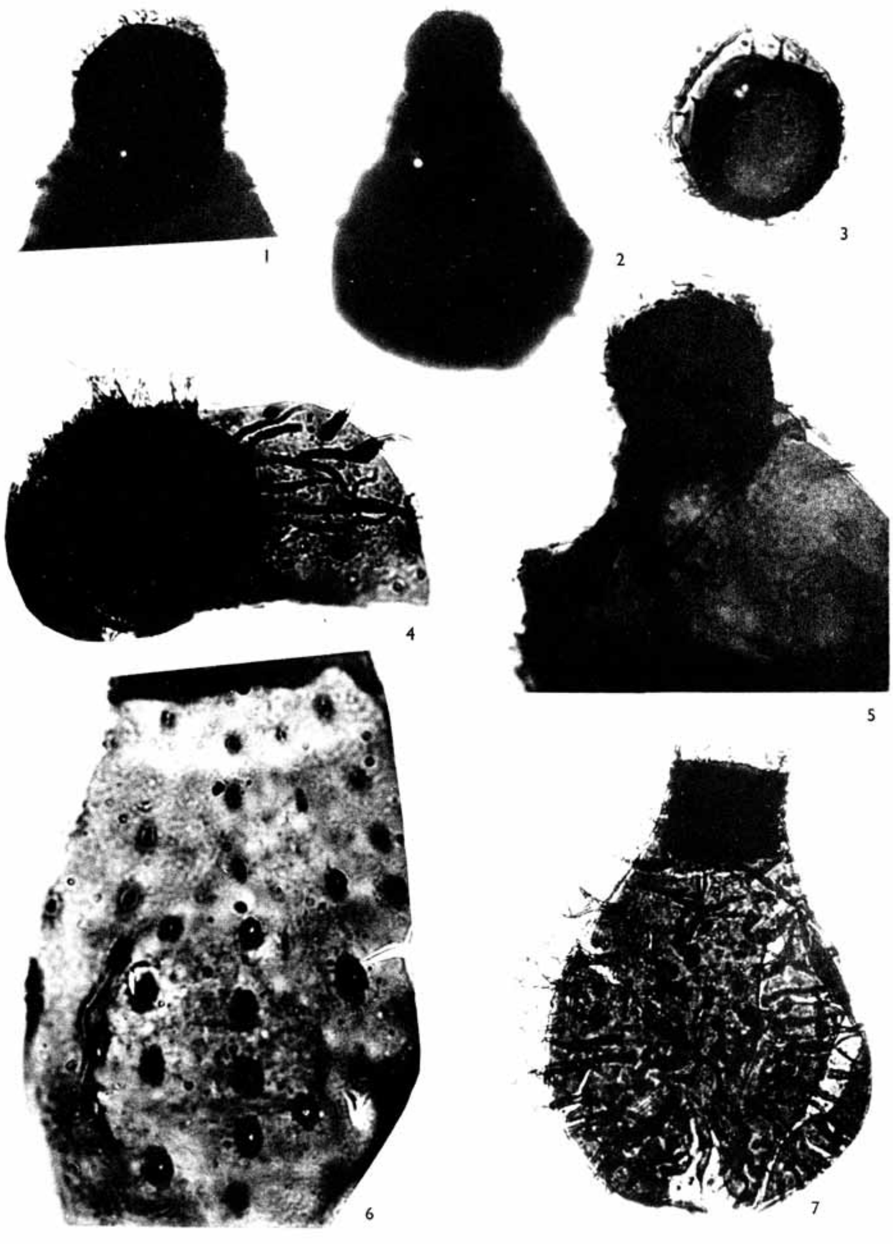
STAPLIN, Upper Devonian hystrichospherids



STAPLIN, Upper Devonian hystrichspherids



STAPLIN, Upper Devonian microfossils



STAPLIN, Upper Devonian Chitinozoa