INFORMATION TO USERS

This material was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

5. PLEASE NOTE: Some pages may have indistinct print. Filmed as received.

University Microfilms International
300 North Zeib Road
Ann Arbor, Michigan 48106 USA
St. John's Road, Tyler's Green
High Wycombe, Bucks, England HP10 8HR
JACOBSON, Stephen Richard, 1944-
ACRITARCHS FROM MIDDLE AND UPPER ORDOVICIAN
ROCKS IN NEW YORK STATE AND THE CINCINNATI
REGION IN OHIO AND KENTUCKY.
The Ohio State University,
Ph.D., 1978
Geology

University Microfilms International, Ann Arbor, Michigan 48106

© 1978

STEPHEN RICHARD JACOBSON

ALL RIGHTS RESERVED
ACRITARCHS FROM MIDDLE AND UPPER ORDOVICIAN ROCKS IN NEW YORK
STATE AND THE CINCINNATI REGION IN OHIO AND KENTUCKY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of the Ohio State University

BY

Stephen Richard Jacobson, B.S., M.A.

* * * * *

The Ohio State University
1978

Reading Committee
Stig M. Bergström
James M. Schopf
James W. Collinson

Approved by

Adviser

Department of Geology & Mineralogy

Stig M. Bergström
ACKNOWLEDGEMENTS

Dr. Stig M. Bergström suggested this project and supplied confidence, inspiration, enthusiasm, patience, and funding while serving as supervisor. His care and time provided for discussion, field work, and editing have made this a better work.

Dr. James M. Schopf, who with his wife Esther filled so many voids for me, shared, through countless discussions, their experiences, insights, and methods and thereby enriched my approach to Science.

Dr. James W. Collinson read the manuscript and offered helpful suggestions at various stages of its preparation.

Dr. Walter C. Sweet has offered time and discussion and shared unpublished data. These contributions have greatly improved the writer's understanding of the stratigraphy.

Dr. Rosemary A. Kyle generously shared time, her own palynological experience, and participated in numerous helpful discussions concerning taxonomy and the assembly of the manuscript. Her contributions are appreciated.

Dr. Göran Kjellström of the Geological Survey of Sweden and Dr. Fred May of the U. S. Geological Survey provided comparative material and Dr. Francine Martin, Dr. Milada Vavrdova, and Dr. Fritz Cramer have provided helpful comments and correspondence.

The writer is indebted to several others, who helped with specific portions of this work.

Robert Wilkinson helped with photography and offered appreciated
moral support. Jeffrey Franklin spent many hours on the SEM, taking photographs and recognizing acritarch morphology. Blythe Hoyle provided field assistance and prepared numerous samples. Kathy Rader crushed rock samples. Frank Holterhoff offered field assistance. Merrell Miller, Dr. Stan Finney, Lon McCullough, and Dr. Jack Carnes offered numerous suggestions and willingly shared experiences to the writer's profit. Karen Tyler and Ron Coffman did the drafting with speed and skill. Reggie Brown and Marge Tibbetts provided magic in the Orton Library by finding, acquiring, and borrowing often obscure literature.

I especially recognize the advantage of having had this report typed by Helen Jones, who beat my deadlines with her typewriter.

Funding for this study has been supplied by the Department of Geology and Mineralogy, the Friends of Orton Hall, the U. S. Geological Survey and a Grant-in-Aid from the College of Mathematics and Physical Sciences at The Ohio State University made to Dr. Stig M. Bergström. This financial assistance is much appreciated.
VITA

September 25, 1944

Born, New York, New York

1969

B.S. Dickinson College, Carlisle, Pennsylvania.

1972

M.A., Harvard University, Cambridge, Massachusetts

1974–1977

Teaching Assistant, Research Assistant, Department of Geology and Mineralogy, The Ohio State University, Columbus, Ohio

1975–1976

Geologist, United States Geological Survey, Coal Geology Laboratory, Columbus, Ohio

PUBLICATIONS

Jacobson, S. R., 1977, Acritarch Biostratigraphy of Middle and Late Ordovician Carbonate Rocks of the Trenton Group, New York and equivalent strata in the Cincinnati Region. (abs.): Geol. Soc. Amer., Abs. with Programs (Northeastern Section), V. 9, no. 3, p. 279.


# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>VITA</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>LIST OF PLATES</td>
<td>x</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
</tbody>
</table>

## Chapter

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. NOMENCLATURE OF ROCKS IN THE CINCINNATI REGION</td>
<td>8</td>
</tr>
<tr>
<td>II. NOMENCLATURE OF ROCKS IN NEW YORK STATE</td>
<td>17</td>
</tr>
<tr>
<td>III. HISTORY OF STUDY OF ORDOVICIAN ACRITARCHS</td>
<td>23</td>
</tr>
<tr>
<td>North America</td>
<td>24</td>
</tr>
<tr>
<td>Baltic Region</td>
<td>26</td>
</tr>
<tr>
<td>France</td>
<td>29</td>
</tr>
<tr>
<td>Bohemia</td>
<td>30</td>
</tr>
<tr>
<td>Poland</td>
<td>31</td>
</tr>
<tr>
<td>North Africa</td>
<td>31</td>
</tr>
<tr>
<td>British Isles</td>
<td>32</td>
</tr>
<tr>
<td>Other Areas</td>
<td>34</td>
</tr>
<tr>
<td>IV. STRATIGRAPHIC SIGNIFICANCE OF THE ACRITARCH ASSEMBLAGES</td>
<td>36</td>
</tr>
<tr>
<td>Biostratigraphic Potential of Acritarch Ranges</td>
<td>36</td>
</tr>
<tr>
<td>Acritarch Associations and their biostratigraphic Use</td>
<td>40</td>
</tr>
<tr>
<td>Ecologic Significance of the Acritarch Assemblages</td>
<td>50</td>
</tr>
<tr>
<td>Paleoenvironments</td>
<td>53</td>
</tr>
<tr>
<td>Relations between lithofacies and acritarchs distribution patterns</td>
<td>53</td>
</tr>
<tr>
<td>Acritarch Provinciality</td>
<td>67</td>
</tr>
<tr>
<td>Summary</td>
<td>69</td>
</tr>
<tr>
<td>V. PREPARATION TECHNIQUES</td>
<td>71</td>
</tr>
<tr>
<td>Introduction</td>
<td>71</td>
</tr>
<tr>
<td>Collection and Cleaning</td>
<td>71</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1.</td>
<td>Measurements of Specimens of <em>Aremoricanium squarrosum</em> from the Cincinnati Region</td>
</tr>
<tr>
<td>2.</td>
<td>Measurements of Specimens of <em>Aremoricanium squarrosum</em> from New York</td>
</tr>
<tr>
<td>3.</td>
<td>Measurements of Specimens of <em>Leiosphaeridia? extratubulata</em></td>
</tr>
<tr>
<td>4.</td>
<td>Measurements of Specimens Similar to <em>Leiovalia similis</em></td>
</tr>
<tr>
<td>5.</td>
<td>Acritarch Occurrences in Samples Used in New York State Composite Section</td>
</tr>
<tr>
<td>6.</td>
<td>Acritarch Occurrences in Samples at Maysville, Kentucky</td>
</tr>
<tr>
<td>7.</td>
<td>Acritarch Occurrences in Samples Used in Cincinnati Composite Section</td>
</tr>
<tr>
<td>8.</td>
<td>Acritarch Occurrences in Samples at Clay's Ferry, Kentucky</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Locality Map of New York State</td>
<td>2</td>
</tr>
<tr>
<td>2. Locality Map of the Cincinnati Region</td>
<td>7</td>
</tr>
<tr>
<td>3. Stratigraphic Sections Used to Compile Cincinnati Composite Section</td>
<td>10</td>
</tr>
<tr>
<td>4. Stratigraphic Section at Maysville, Kentucky</td>
<td>14</td>
</tr>
<tr>
<td>5. Stratigraphic Section at Clay's Ferry, Kentucky</td>
<td>16</td>
</tr>
<tr>
<td>6. Stratigraphic Units in New York State</td>
<td>22</td>
</tr>
<tr>
<td>7. Relative Abundances of Acritarch Associations at Maysville, Kentucky</td>
<td>44</td>
</tr>
<tr>
<td>8. Relative Abundances of Acritarch Associations in Cincinnati Composite Section</td>
<td>45</td>
</tr>
<tr>
<td>9. Relative Abundances of Acritarch Associations at Clay's Ferry, Kentucky</td>
<td>46</td>
</tr>
<tr>
<td>10. Relative Abundances of Acritarch Associations in New York State Composite Section</td>
<td>47</td>
</tr>
<tr>
<td>11. Conodont Relative Abundances and Composite Section Compiled by Sweet</td>
<td>49</td>
</tr>
<tr>
<td>12. Relative Abundances of Acritarch and Conodont Associations in New York State Composite Section</td>
<td>58</td>
</tr>
<tr>
<td>13. Relative Abundances of Acritarch, Chitinozoa and Conodont Associations at Maysville, Kentucky</td>
<td>61</td>
</tr>
<tr>
<td>14. Relative Abundances of Acritarch, Chitinozoa and Conodont Associations in Cincinnati Composite Section</td>
<td>63</td>
</tr>
<tr>
<td>15. Relative Abundances of Acritarch Associations at Clay's Ferry, Kentucky</td>
<td>64</td>
</tr>
<tr>
<td>16. Process Morphology. a, B. cf. klabavense; b, B. klabavense; c, B. calcispinae; d, B. constrictum; e, B. latiradiatum; f, B. distentum; g, B. plicatispinae; h, B. lancettispinae; i, B. areolatum</td>
<td>111</td>
</tr>
</tbody>
</table>
a, simple; b, bifurcate; c, d, e, multiple bifurcate...... 186

a, Solid Strand Formed by the Junction of the Veils Along
the Same Line; b, Hollow Prismatic Processes Formed by
the Intersection of Veils........................................ 187

19. Distribution of Vesicle Diameters for Specimens of
Ordovicidium groetlingboensis................................. 190

20. Distribution of Process Lengths for Specimens of
Ordovicidium groetlingboensis................................. 191

21. Distribution of Vesicle Diameter/Process Length for Speci-
mens of Ordovicidium groetlingboensis..................... 191

22. Distribution of Process Length/Number of Processes for
Specimens of Ordovicidium groetlingboensis............... 192

23. Distribution of Vesicle Diameter/Number of Processes for
Ordovicidium groetlingboensis............................... 192


25. Morphology of a) Polygonum nanum and b) Polygonum
polyancanthum.................................................. 224

26. Morphology of a-e) Veryhachium trispinosum; f) V. sp. A;
g) V. lairdii..................................................... 246
## LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>276</td>
</tr>
<tr>
<td>II</td>
<td>278</td>
</tr>
<tr>
<td>III</td>
<td>281</td>
</tr>
<tr>
<td>IV</td>
<td>284</td>
</tr>
<tr>
<td>V</td>
<td>287</td>
</tr>
<tr>
<td>VI</td>
<td>290</td>
</tr>
<tr>
<td>VII</td>
<td>293</td>
</tr>
<tr>
<td>VIII</td>
<td>296</td>
</tr>
<tr>
<td>IX</td>
<td>299</td>
</tr>
<tr>
<td>X</td>
<td>302</td>
</tr>
</tbody>
</table>
INTRODUCTION

The value of microfossils for interpreting sedimentary rocks of Early Paleozoic age has been recognized by the petroleum industry for about twenty-five years. Microorganisms that secreted mineral skeletons have commonly been used in younger rocks, but early Paleozoic rocks have been analyzed primarily with megafossils and only recently with conodonts. Conodonts have the advantage of being ubiquitous in Early Paleozoic marine sediments but they are difficult to extract from some rocks, especially shales. Therefore, organic-walled microfossils can provide information from rocks that otherwise represent gaps in the known microfossil record. In fact, organic-walled microfossils may prove as valuable or more valuable than conodonts for evaluating some marine environments in the Early Paleozoic.

Organic-walled microfossils of the Early Paleozoic include acritarchs, chitinozoa, and scolecodonts. They have been shown to occur in most of the rocks studied here. Study of these fossils is particularly useful in the case of the small samples available from cuttings and boring cores, as well as hand samples. However, the use of organic-walled microfossils is not without problems, for instance, they are susceptible to oxidation and to thermal alteration, both of which if carried to completion can totally destroy them. The degree of oxidation and/or thermal alteration necessary to destroy organic-walled microfossils is not rare in Early Paleozoic rocks.
Fig. 1 - Locality map of New York State. Solid black circles mark collecting sites. Stippled pattern indicates area of Ordovician outcrops.
Neither acritarchs nor chitinozoa are well known in Ordovician rocks from North America and scolecodonts have been studied even less. This study was undertaken to establish a foundation for acritarch biostratigraphy in some well-known and important Middle and Upper Ordovician rock units in North America. The stratigraphic units selected are the Trenton Group rocks from localities in New York State, (fig. 1) and rocks from localities in the Cincinnati Region (fig. 2) of the eastern Midcontinent. The acritarchs extracted from rocks of these two regions permit application of some techniques not commonly used in previous biostratigraphical studies of Ordovician acritarchs. The sediments studied in these two, probably separate, basins are for the most part not time equivalent, although there is some overlap of the younger part of the New York sequence with the older part of the Cincinnati succession. Somewhat different depositional environments have been suggested for the rocks of these two regions, and the two sedimentary wedges have subsequently undergone different degrees of thermal alteration. It might be expected that the different environments would yield both qualitatively and quantitatively different microfossil assemblages. If so, it is possible that the fossils in these rocks may provide clues for the interpretation of the kinds of variable factors responsible for these differences. It now appears that acritarchs can be used to distinguish these differences. However, differentiation of geographic or environmental factors can now be made only generally. Although the nature of the assemblages found in the two regions is substantially different, precisely what factors caused this difference are less certain. Yet, by examining rocks that have been
studied in many ways and for which many data have been accumulated, some idea of the variables responsible for the variations in acritarch assemblages can be postulated.

The first method used to accomplish this involves the traditional biostratigraphic technique of determining ranges for the fossils extracted from the units. This method helps to establish an acritarch biostratigraphic framework which is relatively crude but still useful. The reason why this framework is considered crude is that the ranges of acritarch taxa have not previously been established in type sections of stratigraphic units in the Ordovician. Therefore, the previously recognized ranges for Ordovician acritarch taxa are very imprecisely known. The concurrent range zones that can be constructed for the two regions studied here can only be interpreted as range zones for acritarchs from these particular basins. Obviously, the first occurrence of a particular taxon may represent the evolutionary appearance of the taxon, or just the appearance in the region studied of a previously existing particular environment containing the taxon. Previous investigations in other regions have not always reported the precise position at which the acritarch-bearing samples were obtained. Therefore, comparison of acritarch zonations in different regions is not always fruitful. Despite this, the concurrent ranges of the forty-four taxa discussed in this report have some biostratigraphic value and this is discussed in Chapter IV.

A second method has been used for recognition and correlation of smaller stratigraphic units than those obtainable from acritarch concurrent range zones. This is based on variations in acritarch
assemblages in terms of relative abundances of species associations. All the taxa present in each assemblage have been used for such evaluations. Abundances of individual acritarch species were grouped into associations of acritarch species. The relative abundances were plotted in relation to stratigraphic occurrences of the acritarch associations. The resultant graphs were then carefully examined and certain acritarch associations were grouped together. The variations of relative abundances of the acritarch associations were then compared to data compiled for other microfossils from the same stratigraphic sections. A similar method of compilation was used by Sweet (in press) for the conodonts, whereas a slightly different method was employed by Miller (1976) for the chitinozoa. Miller (1976) used only certain chitinozoan taxa which he felt best indicated environmental change, and determined relative abundances in terms of these selected forms only. Chitinozoa considered unimportant by him were eliminated from his calculations.

The results of this analysis show surprisingly similar distribution patterns between the two groups of organic-walled microfossils (i.e., acritarchs, chitinozoa) and the phosphatic fossils (i.e., conodonts). The variations observable in the graphs are similar enough to suggest that the relative abundances of three microfossil groups responded to some common factors.
The essential relationship between the mineral fraction of a lithotype and its acid-resistant residue must be understood before interpretation of environment can be made. The absolute abundance of a fossil is related to the rate of sediment accumulation. For example, in an open-sea environment, in which a relatively constant rain of plankton is produced, the quantity of non-planktonic material, such as mineral matter, controls the absolute abundance of the planktonic residue. Relative abundances of the plankton are largely independent of the amount of non-planktonic constituents.

The factors controlling the occurrences of microfossils are not independent of agents related to sedimentation. Quite the contrary is true, and the sedimentary factors involved can be interpreted in terms of more specific variables such as water depth and water agitation. This is a complex problem and requires data beyond the scope of this analysis. Nevertheless, some data are discussed bearing on the relations between acritarch distributional patterns and paleoenvironments.
Fig. 2 - Locality map of the Cincinnati Region. Solid black circles mark collecting sites. Hatchured pattern denotes area of Ordovician outcrops.
The nomenclature and stratigraphic framework used here for rocks in the Cincinnati Region is that adopted by Sweet and Bergström (1971). Although the general stratigraphy of the region has been understood for the most part since 1914, and has been reviewed by Weiss (1961), the nomenclature has undergone some revisions and refinements.

The lithostratigraphic and time-rock stratigraphic names used here are shown in fig. 3, 4, 5. At Cincinnati, the Kope Formation, Fairview Formation, Miamitown Shale and Grant Lake Formation were sampled, and at Maysville, the Kope Formation, Fairview Formation and Grant Lake Formation. At Clay's Ferry, the Lexington Limestone, Clays Ferry Formation, Garrard Siltstone, and Calloway Creek Formation were sampled.

The units at Cincinnati and Maysville are similar. The lowest unit examined, the Kope Formation, was named by Weiss and Sweet (1964). They defined it as "medium-bedded limy shales (mean clastic ratio, 2.5 to 3.8) resting between shaly Point Pleasant limestones (mean clastic ratio, 1.0) and unnamed shaly limestones (mean clastic ratio, 0.5)."

The Kope Formation is the same unit Edward Orton, Sr. in 1873 named the "Middle (or Eden) Shales". Because Eden has taken on a time connotation, Weiss and Sweet renamed the unit the Kope Formation on the basis of lithic characters.

The Fairview Formation was originally proposed by Bassler (1906, p. 10) for the carbonate sequence above the Kope (=Eden) Formation. It is essentially equivalent to the Hill Quarry Beds of Orton (1873). Ford
Fig. 3 - Sections used to compile the Cincinnati Composite Section. Stratigraphic classification of the sections at Clifton Avenue, Cincinnati, Ohio, Newport Shopping Center, Kentucky and Covington, Kentucky; lithologic symbols: bricks, limestone; broken lines, shale and mudstone. Samples of each section have been designated with prefixes 75MB, NSC, and Cov, respectively along with numerical suffixes.
(1967, p. 928-931) redefined the Fairview Formation as a sequence of interbedded limestone and pelitic rocks with no stratum persistently thicker than 1.5 feet. The Fairview Formation is thickest at its type section in Cincinnati, and thins in all directions from that area. The contact between the Kope and Fairview Formations, although sharp at some localities, is most commonly gradational. This contact at the type section of the Fairview Formation at Clifton Avenue in Cincinnati is defined as the Edenian-Maysvillian stadial boundary.

The Miamitown Shale (Ford, 1967, p. 931-132) overlies the Fairview Formation at Cincinnati. It thins to the southeast and does not occur at Maysville. The Miamitown Shale is pelitic and consists of shale and thin, widely spaced, interbedded limestone and nodular limestone.

The Great Lake Formation [=Bellevue Limestone] (Peck, 1966, p. B14-B16) overlies the Miamitown Shale at Cincinnati and the Fairview Formation at Maysville. It is a limestone unit with thicker beds than the Fairview Formation and fewer and smaller shale interbeds.

The Clays Ferry Formation at Clay's Ferry is above the Lexington Limestone. It is first described by Weir and Greene (1965, p. B1) as "thin-bedded shale, limestone and siltstone. It ranges from about 120 to 220 feet in thickness, and is of late Middle and early Late Ordovician age. The Clays Ferry Formation overlies and intertongues with thick-bedded limestone of the Lexington Limestone, it grades into the overlying Garrard Siltstone..."

McFarlan and Freeman (1935) placed the Middle Ordovician-Upper Ordovician boundary at about the middle of what is now called the Clays Ferry Formation at the type section. The lower contact of the Clays
Ferry Formation is time transgressive, and the Middle Ordovician—Upper Ordovician transition may occur somewhat lower than the middle of this formation as implied in Fig. 2 of Sweet and Bergström (1971).

The Garrard Siltstone overlies the Clays Ferry Formation and was first described under this name by Campbell (1898). Campbell (1898, p. 2) stated that the Garrard Siltstone "can not be distinctly separated from the superior and inferior formations as it grades into them by almost imperceptible changes in composition." Subsequently, the Garrard Siltstone has been described as "gray and very limy...most of the beds are commonly contorted" (Weir, Green and Simmons, 1965, p. D6).

Above the Garrard Siltstone is the Calloway Creek Formation, which was initially described (Weir, Greene and Simmons, 1965) as "chiefly gray, thin-bedded fossiliferous, fine to medium-grained limestone having partings and seams of greenish-gray shale". It grades into the overlying Ashlock Formation. The Calloway Creek Formation has been correlated with the Fairview Formation of the Cincinnati Region (McFarlan and Goodwin, 1930), thus suggesting a Maysvillian age. It has also been suggested that the Calloway Creek-Garrard formational contact is actually slightly older than the Edenian-Maysvillian stadial boundary (Sweet, pers. comm., 1976) and the samples studied here from the base of the formation are probably no younger than earliest Maysvillian and possibly may all fall within the Edenian.
Fig. 4 - Stratigraphic section at Maysville, Kentucky with lithostratigraphic and time-rock units. Samples have been designated with prefix 74MM and numerical suffixes that mark elevation from the base of the outcrop. Lithologic symbols as in Fig. 3.
Fig. 5 - Stratigraphic Section at Clay's Ferry, Kentucky with lithostratigraphic and time-rock units. Samples have been designated with short horizontal lines at right side of figure. Lithologic symbols as in Fig. 3.
Clay's Ferry,
Kentucky

Fig. 5
The Middle Ordovician rocks exposed along West Canada Creek near Barneveld, New York, and frequently referred to as the "Trenton", have been the subject of much study. Although these rocks are well exposed and structurally undeformed, much confusion surrounds their stratigraphic nomenclature. Therefore, it is useful to review previous work and to explain the nomenclature followed in this study.

A review of early literature concerning these rocks has been provided by Kay (1937). Although the outcrops along West Canada Creek were recognized by Eaton (1824), it was not until Conrad's writings (1837) that the "Blue Foetid Limestones and Shales of Trenton Falls" were given a stratigraphic name. Since 1837 the term Trenton or Trentonian has been used to describe a period, a group, a formation, a member, a series, a stage and/or a substage in the Middle Ordovician. It seems desirable, in accordance with suggestions presented by the International Subcommission on Stratigraphic Classification (1972), to simplify the usage of the term Trenton by applying it to a single kind of stratigraphic unit. Here Trenton is used for the Trenton Group in the sense of Fisher (1962), who used Trenton Group for a lithostratigraphic unit and this designation "should only be applied in New York and adjacent regions where lithologic identity can be demonstrated." This usage seems consistent with that intended by Conrad in 1837.

Subdivisions of the Trenton Group present a complex situation. Kay (1837) recognized, from oldest to youngest, the Rockland, Hull,
Sherman Fall, Cobourg, Collingwood, and Gloucester Formations. These formations were recognized in a composite section including units exposed in Ontario as well as in New York State.

Unfortunately, Rockland, Hull, Cobourg, Collingwood, and Gloucester were terms proposed as formations (Raymond, 1914, 1921) based on biostratigraphic rather than lithostratigraphic data. To this problem was added the Sherman Fall Limestone (Kay, 1929), which was also recognized on the basis of fossil content. Furthermore, Kay (1937) subdivided the biostratigraphically defined Rockland Formation into a lower part called the Selby Member from "the hill east of Dexter, New York" on the basis of lithic characters, and an upper part, the Napanee Member, which had been recognized in its type section as being "in contact with the Selby Member at the base, and [with beds which have] Triplecia cuspidata at the top." Therefore, the two members of the Rockland Formation recognized and defined in the same work use lithostratigraphic criteria for the lower member and biostratigraphic criteria for the upper member. Subsequently, these members were elevated to the rank of formations (Fisher, 1962), and it was noted that the name Rockland was preoccupied as an Ordovician name in Maine (Bastin, 1908).

The Kirkfield Formation (Johnston, 1911) was accepted by Kay (1953) as the preferred name for the Hull Formation by priority. However, the Kirkfield Formation was defined on fossil zones. Later Kay (1968) redefined the same rocks on lithologic features and renamed the unit the Kings Fall Limestone.
The Sherman Fall Formation was first recognized by fossil occurrences (Kay, 1929) and later subdivided (Kay, 1939) into the Shoreham Member, defined as constituting "the zone of Cryptolithus tessalatus Green, the limestones of lowest Sherman Fall age", and the Denmark Member, comprising "limestones of the Sherman Fall Formation of northwestern New York that overlie the Shoreham Member of the formation" or the "typical Trenton". Kay (1968) later renamed "a lithic unit approximating the Shorehamian Stage" (the Shoreham Member) as the Sugar River Limestone, and introduced the Denley Formation to include the Denmark Member and rocks above it in West Canada Creek up to the "thick-ledged Steuben Limestone at the top." Thus the Denley Formation includes not only the former Denmark Member but the overlying Rust Member which Kay (1943) has described on lithologic grounds and previously included in the younger Cobourg Limestone.

The Steuben Limestone, the highest exposed rock unit in the Trenton Falls gorge, was defined from this locality (Kay, 1943), where it was considered to be a member of the Cobourg Limestone. However, it was elevated to the rank of formation when the term Cobourg was abandoned by Kay (1968).

In Kay's redefinition (1968) of the Trenton Group, the Hillier Formation overlies the Steuben Limestone. This unit was originally referred to as the Hillier Member of the Cobourg Formation (Kay, 1937), which was considered the "Upper Cobourg Limestone of earlier reports" and separable lithologically and faunally from the subjacent Hallowell Member [Steuben Ls.] and the overlying Collingwood Formation [Holland Patent Shale, Utica Shale].
Later, Kay (1960, 1968) recognized Kirkfieldian, Shermanian, and Cobourgian as stages and Shorehamian and Denmarkian as substages of the Shermanian. As these are based on fossils they are retained as chronostratigraphic units. Sweet and Bergström (1971) have correlated rocks of the upper part of the Denley Formation with rocks of the Cincinnatian Series considered Edenian. They reasoned that the Edenian Stage could replace Cobourgian on the basis of priority, thereby solving a nomenclatural problem and a stratigraphic one as well. The nomenclature of Sweet and Bergström (1971) is adopted in this study (fig. 6).
Fig. 6 – Sampled Stratigraphic Units in New York State Composite Section. Short horizontal lines at left side of figure record acritarch-bearing horizons.
Fig. 6
HISTORY OF STUDY OF ORDOVICIAN ACRITARCHS

In the last two decades, interest in Ordovician acritarchs has grown rapidly. This growth is reflected by an increase in both the number of workers and the number of papers published. Hence, while only a total of ten papers were published in the 1930's and 1940's, more than 50 have been published to date in the 1970's. Regions where Ordovician acritarchs have been studied include the Baltic Platform, France, Bohemia, Poland, North Africa, the British Isles, North America, and the USSR. A few occurrences have also been reported from Belgium, Australia, Zambia, Bulgaria, and Portugal.

Early works were primarily concerned with taxonomy and the biological affiliations of acritarchs. However, the value of acritarchs as useful biostratigraphic, paleoenvironmental, and paleoecological tools with potential as provincial indicators has more recently become apparent. The additional quality of the susceptibility of the acritarch cyst wall to gradual thermal alteration has made acritarchs important for petroleum exploration and basin analysis. A valuable contribution to acritarch study, which should promote work in Ordovician rocks, has been the publication of a catalogue of acritarch taxa (Eisenack and Cramer, 1973, 1976). Important papers are also those of Díez and Cramer (1974, 1977) which give ranges of selected acritarch taxa, including forms described from Ordovician rocks.
North America

The first report on Ordovician microfossils possibly attributable to acritarchs is that by M. C. White (1862, p. 385, 386). They were reported from chert nodules in the Black River limestones near Watertown, New York. The microfossils found in both Ordovician and Devonian rocks by White were referred to as Xanthidia, sporangia of desmids, and gemmules of sponges. It is difficult to identify the Ordovician microfossils figured by White with any presently accepted species, although identification is possible in the case of his illustrations of Devonian forms in the same paper. Indeed, the one Ordovician form similar to an acritarch illustrated by White (1862, fig. 8), although showing a general resemblance to an acritarch, might well belong to another group.

Since White’s work, nothing was published on Ordovician acritarch-like fossils until Ruedemann and Wilson (1936) illustrated forms, which they called radiolarians, coprolites, and problematica, from Ordovician cherts in the Normaskill and Deepkill shales of New York. Some of their illustrations resemble acritarchs, but the nature of these specimens remains obscure.

In a reconnaissance study of 49 formations, Rotan (1952, unpublished M. S. thesis) used simple maceration methods and unsophisticated techniques for concentrating microfossils. He dealt with 11 Ordovician formations and reported and illustrated specimens, which are certainly acritarchs, from the Deepkill, Queenston, and Normanskill Formations of New York and the Oneota Formation of Minnesota.
In North America, Ordovician acritarchs have been recently studied from Oklahoma, the Cincinnati Region, New York State, Nova Scotia, Newfoundland, and the St. Lawrence Lowlands.

The first study using modern techniques of palynological preparation and producing useful information of taxonomic and biostratigraphic value is that by Hedlund (1960, unpublished M.S. thesis). He recognized 34 species of "hystrichospheres" from three stratigraphic sections of the Sylvan Shale in Oklahoma. The three sections were well-defined and collections were made from channel samples of units with thicknesses from one to twenty feet. Stratigraphic occurrences were reported only for photographed specimens. Loeblich (1970a), Loeblich and MacAdam (1971), and Loeblich and Tappan (1971a) published excellent taxonomic descriptions of eight new species from the Sylvan Shale. Additional taxonomic studies including descriptions of 15 new species were carried out on collections from the Bromide Formation of Oklahoma (Loeblich and Tappan, 1969; Loeblich, 1970a; Loeblich and MacAdam, 1971; Loeblich and Tappan, 1971b; Tappan and Loeblich, 1971).

Acritarchs were reported from the Middle Ordovician Viola Formation (Nygreen, 1970) in an abstract, although the reported presence of dinoflagellates, trilete spores, and vascular plant tissue confused a clear understanding of that assemblage.

Acid-resistant organic microfossils have also been reported from Middle and Upper Ordovician rocks of Ohio and Kentucky (Schopf and Schopf, 1962; Jacobson, 1977a, 1977b, 1977c, 1977d). The taxonomy of six species from the Eden Formation [= Kope Formation] and two species from the Dillsboro Formation in Indiana has been studied (Loeblich,
1970b; Tappan and Loeblich, 1971; Loeblich and MacAdam, 1971; Loeblich and Tappan, 1971b). Gray and Boucot (1972) used the morphologic groups described by Downie et al. (1963) and Evitt (1969) to interpret Ordovician/Silurian shorelines in southern Ohio.

Staplin, Jansonius, and Pocock (1965) reported on the occurrence of four species from the subsurface "Trenton Formation" of Anticosti Island, Nova Scotia and one additional "acritarchous hystrichosphere" was figured from the Upper Ordovician Vaureal Formation. Nautiyal (1966a, 1966b) has reported acritarchs from Newfoundland and Martin (1977) has reported acritarchs from a sequence of rocks of Chazyan through the early Upper Ordovician age in the St. Lawrence Lowlands of eastern Canada.

Acritarchs have been recovered from the Williston Basin in Montana (Jacobson, unpublished data) and from deep boreholes in Florida (Schopf, pers. comm.).

Swain (1977) has reviewed some published acritarch studies from rocks of the Atlantic margins.

**Baltic Region**

In the Baltic Region, samples from outcrops, borehole-cores, and erratics found in Quaternary deposits have yielded numerous assemblages of well-preserved Ordovician acritarchs. Studies of these acritarchs have been primarily taxonomical and relatively little has been published on acritarch biostratigraphy. However, Kjellström (1971a, 1971b, 1972, 1976) and, to some extent, Eisenack (1974, 1976) and Johansson et al. (1972) have made some significant contributions to the acritarch
biostratigraphy of the Baltic Region. No paleoecological or paleoenvironmental studies have been published and acritarch provincialism has been examined only recently (Rauscher, 1974; Vavrdova, 1974). The history of the Baltic Platform acritarch study dates back to Zalessky (1917) who described the colonial alga *Gleocapsomorpha* from the Middle Ordovician Kukruse Shale. It was in this region that Alfred Eisenack (1931) began research on Ordovician hystrichospheres with studies of the assemblages found in glacial erratics in Germany and in situ rocks in Sweden (Gotland and Öland), Estonia, and East Prussia (Eisenack 1934, 1937, 1938, 1939, 1951, 1954, 1955, 1958a, 1959b, 1961, 1962a, 1962b, 1965a, 1965b, 1967, 1968a, 1968b, 1969, 1974, 1976).

Based on study of Bohemian samples, Eisenack (1934) suggested that the hystrichospheres might have been eggs of invertebrates and he interpreted the round "depressions", the pylomes, as apertures through which young emerged. Eisenack later (1938) compared these microfossils to those described from Cretaceous rocks by Wetzel (1933) and concluded that since they chemically consist of cutin and not chitin, they might be terrestrial plant spores. Naumova (1950) accepted this idea and studied specimens that she recovered from the *Obolus-Dictyonema* beds of the Baltic Platform along 300 km of outcrop. The "spores" were found at the base of glauconitic interbeds and, to a significantly lesser extent, in the shales. Naumova reported the presence of several types of spores, including one group of specimens with a trilete dehiscence, and she illustrated many leiospheres and hystrichospheres with such a triradiate structure. Later, Timofeev (1966) described, from the same shales, many very similar forms, most of which lack a trilete scar.
Regnell (1955) described smooth spheres from the Ceratopyge Limesto-
ne (Upper Tremadoc) in southeastern Scania, southern Sweden.
Martinsson (1956) reported the occurrence of leiospheres from "dolomi-
tized pelmatozoan boulders (D3?)" of southwestern Finland. Tynni (1975) described hystrichospheres and Chitinozoa from in situ samples from the
Sylen Shoal and from erratics in Quaternary deposits of the Bothnian
Sea, Finland, which were dated as upper Middle Ordovician on the basis
of other fossils.

Kjellström (1971a, 1971b, 1972, 1976) recognized some acritarch rock-type associations in samples from southern Sweden. The samples,
which are from cores taken in Gotland, Öland, and Östergötland, were
considered to be of late Early Ordovician through early Late Ordovician
age on the basis of other fossils. Many of Kjellström's species were
new and it is likely that some of their described ranges may be ex-
tended by further study.

Timofeev (1963a, 1966) described many Ordovician taxa from the
Baltic Region and reviewed much of the work done in northwestern U.S.S.R.
Work on Ordovician acritarchs in Germany has been done by Burmann
(1968, 1970, 1973); although both localities and stratigraphic position
are reported cryptically by means of numbers, the age of these samples
has been interpreted by Burmann as Arenigian to Llanvirnian. These
papers are primarily taxonomic studies. Wetzel (1967) studied the
taxonomy of acritarchs from glacial erratics in Germany

Because acritarchs are so well-preserved in the Baltic Platform
rocks, more detailed studies may provide valuable solutions to complex
problems of paleoenvironments, taxonomy, biostratigraphy, and provincia-
ality.
Ordovician acritarch studies in France have been stimulated by the pioneer work of Deflandre, Deunff, and their students. Although French workers were initially mainly concerned with taxonomy, there have subsequently been some excellent studies on acritarch biostratigraphy and provincialism.

Deflandre (1942, 1945) pioneered the study of acritarchs in France on collections from the Montagne Noire. Since then many studies have been made on the group in that area and in the Massif Armoricain.

Acritarch assemblages from the Massif Armoricain in Normandy and Brittany have received particularly detailed attention. In Normandy, Llandeilian, Llanvirnian and Caradocian forms have been described in detail in a monograph (Rauscher, 1973). In Brittany, Caradocian forms have been studied by Deunff (1951, 1954a, 1955, 1959) and Henry (1969); Llandeilian ones by LeCorre and Deunff (1969) and by Chauvel, Deunff and LeCorre (1970); Llanvirnian forms by Henry (1964, 1966, 1969) and by Paris and Deunff (1970); and Arenigian ones by Deunff and Chauvel (1970). Forms dated as Middle Ordovician (Deflandre and Ters, 1966) and Late Ordovician (Deunff et al., 1973) have also been reported.

In the Montagne Noire, rocks of the Didymograptus extensus Zone have yielded acritarchs (Rauscher, 1971, 1973; Martin, 1972) as have shales of Caradocian and Ashgillian age (Deflandre 1942, 1945; Rauscher, 1973).

Guillot and Doubinger (1971) dealt with Ordovician acritarchs from strata at the edge of the Massif Central and Ordovician microplankton has been described by core samples in the Aquitaine basin (Rauscher, 1973).
Rauscher (1974) reviewed the literature concerning French acritarchs and showed that acritarch taxa can be used to separate Ordovician strata from those of the Cambrian and Silurian. Further, he distinguished acritarch taxa which can be used to recognize Upper, Middle and Lower Ordovician rocks. Finally, he defined all the series of the European Ordovician in terms of acritarch taxa, except the Llandeilian, which he could not characterize on the basis of these fossils.

**Bohemia**


"Hystrichospheres" from Bohemia were first described by Eisenack (1934, 1948). Extensive studies have been done on such fossils from Arenigian, Llandeilian, Llanvirnian, Caradocian and Ashgillian samples from both outcrops and cores by Vavrdova (1965, 1966, 1972, 1973, 1977). Primarily taxonomic work on Ashgillian collections has been carried out by Konzalova-Manzacova (1969). It is partly on the basis of this work that Vavrdova (1974) recognized two acritarch provinces in the Ordovician of Europe, namely a Baltic province characterized by occurrence of Acanthomorphid acritarchs and Mediterranean province characterized by Diacromorphid acritarchs. According to her, this provincialism is first distinguishable in the Arenigian.
Poland

All the papers that discuss acritarch occurrences in Poland deal primarily with collections from the Holy Cross Mountains (=Sventokshisk Mountains=Swietokrzyskie Mountains). Jaglieszka (1962a, 1962b) reported forms that come from rocks correlated with Tremadocian rocks of the Baltic Platform as well as species from rocks correlated with the British Arenigian. Timofeev (1963a, 1966) mentioned the occurrence of several forms from unpublished work and Gorka (1967) reported an occurrence of Tremadocian acritarchs. A more comprehensive study of rocks in the Holy Cross Mountains (Gorka, 1969) ranging in age from the Early to Late Ordovician revealed the presence of many well-preserved forms, including several new taxa.

North Africa

The distribution of knowledge of North African and Middle East acritarch biostratigraphy has been somewhat hampered by publication restrictions imposed by the petroleum industry in the case of such information. Well-preserved, diverse, and numerically abundant assemblages have been found in Libya, Algeria, Morocco, Tunisia, and Saudi Arabia, but few reports on the forms present and their biostratigraphy have appeared in the literature. In the Ordovician, this region appears to have been for the most part distinct provincially from presently more northern regions. The acritarch biostratigraphy in this region may hold a key to correlation of some of its Ordovician shelf sediments, especially with those of North America.
Deunff (1961) studied cores from the Sahara (Algeria) and described an acritarch assemblage from beds containing Obolus and Dictyonema which were considered Tremadocian in age. Wray (1964) reported on Cambro-Ordovician acritarchs from Libya. Studies on Tremadocian assemblages from Algeria (Combaz, 1967a, 1967b) and Morocco (Deunff, 1968a, 1968b), as well as much previously unpublished data, have been summarized in a review paper (Jardine et al., 1974) in which eight acritarch zones have been recognized from the Ordovician of Northern Algeria. The age determination of these units was based on evidence from both macrofossils and microfossils.

Preliminary data and some taxonomic descriptions have been published on collections from Arenigian to Llanvirnian rocks from cores in the Tadla Basin of Morocco (Cramer et al., 1974a, 1974b). Cramer and Díez (1976) recognized seven new Late Arenigian species of Coryphidium Vavrdova, 1972 from the same region and twenty-seven new species and two new genera were described (Cramer and Díez, 1977).

**British Isles**

Acritarchs from the British Isles have been studied rather extensively. Continued biostratigraphic research on key stratotypes and their equivalents has been carried out at the University of Sheffield by Charles Downie and numerous students. Much of this work is quite recent and remains in various stages of preparation for publication. Nevertheless, when this information becomes available, it will add significantly to our understanding of key stratigraphic sections of the British Ordovician.
Many of the papers on acritarchs of the British Isles are reports of only stratigraphic occurrences of taxa, discussion of taxonomy (e.g., Lister, 1970; Rasul, 1976, 1977), and stratigraphic distribution of taxa (Rasul and Downie, 1974), but some other aspects of Ordovician acritarchs have also been discussed (Downie, 1958, 1963).

Lewis (1940) reported the presence of organic microfossils in Caradocian rocks in England and briefly described a number of species. Subsequently, Downie began studies on acritarchs from British Ordovician rocks. From two samples of the Shineton Shales, Downie (1958) recognized and described many well preserved specimens. Downie and Ford (1966) described an acritarch assemblage from a single sample of the Manx Slate Series of the Isle of Man and assigned it a late Tremadocian to Arenigian age. Lister et al. (1969a) listed acritarchs found in rocks from a borehole in Kent, England, and dated the assemblage as Late Ordovician. Lister et al. (1969b) also listed the microfossils of the Skiddaw Slates and dated them as Arenigian-Llanvirnian. On the basis of specimens in the Tremadocian Habberly Shales, Lister (1970) interpreted the excystment aperture of Acanthodiacrodium ubui. Wadge et al. (1969) found acritarchs in strata of the Didymograptus murchisoni Zone in the Eastern Lake District. Lister and Holliday (1970) suggested an Arenigian-Llanvirnian age for acritarchs recovered in samples from the Teesdale inlier in County Durham, England. Dunham (1973) dated core samples in Derbyshire as basal Llanvirnian on the basis of palynomorph identifications by Downie.

Gardiner and Vanguestaine (1971) have reported Ordovician microfossils from southeastern Ireland.
Investigations in other areas either lack detail as in Zambia, Australia, Portugal, Bulgaria, and Romania or are in publications difficult to obtain as those from the U.S.S.R. A few excellent investigations have been carried out in Belgium.

Vavrdova and Utting (1972) reported poorly preserved acritarchs from the otherwise unfossiliferous Luapula Beds in Zambia. The acritarchs were identifiable at only the generic level and it was concluded that the studied rocks were Middle Cambrian to Ordovician and probably not younger than Arenigian.

In an evaluation of cores from the Canning Basin of northwestern Australia, Cambaz and Peniguel (1972) determined them to be of Arenigian-Llandeilionian age, although it is possible that these rocks are somewhat younger.

Henry and Thadeu (1971) described a Llandeilionian-Caradocian flora from the Serra Bucaco in Portugal. Kalvacheva (1972) reported a poorly preserved Ordovician flora from the Iskur Gorge in Bulgaria. An acritarch assemblage was used to date Lower to Middle Ordovician rocks in the Carpathian Mountains in Romania (Boldor and Visarion, 1971).

Vladimiriskaya et al. (1956) reported Ordovician acritarchs from the western slopes of the Urals. Timofeev (1963b) reported several forms from the Siberian platform and later described numerous other forms from other parts of U.S.S.R. (Timofeev, 1966).

Martin, after some brief reports (Martin, 1965, 1968a), carefully described many acritarch taxa monographically from Ordovician and Silurian rocks in Belgium (1968b, 1975). Poorly preserved specimens
from the Caradocian flysch at Ombret, Belgium, were reported by Martin, Michot and Vanguestaine (1970).

Ordovician rocks in many other areas will probably yield acritarch assemblages that will greatly enhance future interpretation of provincialism of the group. Areas from which we have virtually no published information on Ordovician acritarchs include South America, Antarctica, China, and much of the eastern Tethyan orogenic belt.
STRATIGRAPHIC SIGNIFICANCE OF THE ACRITARCH ASSEMBLAGES

Biostratigraphic potential of acritarch ranges

Most of the samples studied here from New York State and the Cincinnati Region have yielded acritarchs. Forty-four species or subspecies are treated taxonomically. One genus and three species are described formally for the first time. Several other informally designated species are probably new but they are too rare, or too poorly preserved, for adequate taxonomic treatment.

The occurrence of acritarchs in samples from New York State is shown in Table 5 and from the Cincinnati Region in Table 6, 7, 8. The taxa are listed in order of stratigraphic appearance in each particular region. In many cases, acritarch species that appear in the middle of the sequence studied in New York State occurred earlier or later in other parts of the world.

Three species ranged throughout the entire composite vertical sequence from the oldest rocks studied in New York State through the youngest studied in the Cincinnati Region. These forms are *Veryhachium trispinosum*, *Peteinosphaeridium intermedium*, and *Ordovicidium groetlingboensis*. Nineteen species have been recognized in the rocks from New York State. Specimens of two species, *Leiofusa cf. fusiformis* and *?Aremoricanium squarrosum*, found in New York State are poorly preserved and are therefore only questionably identified. They may, in fact, be unrelated to the better preserved, and therefore more definitely identified, specimens from the Cincinnati Region. Therefore, a question mark precedes their names on the range chart for New York State.
Species of *Micrhystridium* and a species designated *Baltisphaeridium* sp. B, which is known from only two specimens, are restricted to the New York State Region. Although most of the rocks studied in New York State are somewhat older than those in Cincinnati, the lower diversity of forms probably reflects the uniformity of the limestone types sampled in New York. No shales or siltstones from New York yielded acritarchs. Furthermore, the evolutionary radiation of acritarchs during the Middle and Upper Ordovician did not reach its acme until the upper part of the studied sequence. Another factor that could result in lower diversity is the unlikelihood of delicate forms withstanding the alteration caused by the deep burial that has affected the rocks in New York.

*Multiplicisphaeridium bifurcatum* is known from the oldest samples examined in the New York region and is found in the Cincinnati Region in the Kope Formation at Maysville and Cincinnati and also in the middle of the Clays Ferry Formation at Clay's Ferry. This uppermost occurrence of *Multiplicisphaeridium bifurcatum* in the Cincinnati Region, which is of youngest Edenian age, represents the latest reported occurrence of this species.

Forms found in the Cincinnati Region, which have not been recovered in New York, include *Dicommopalla macadamii, Leiowalia similis, Anomaloplaislum lumariacuspis, Baltisphaeridium cf. psilatum, Veryhachium lairdii*, and *Baltisphaeridium* sp. A. The species range throughout the sequence of rocks studied in this region. Some additional forms are restricted to a portion of the studied sequence in the Cincinnati Region. For example, *Aremoricanium squarrosum, Petaloferidium stigii, Rhopaliophora folatilis, Rhopaliophora impexa*, and *Peteinosphaeridium*
hypertrophicum are found in rocks that represent a relatively short span of time.

Positively identified specimens of *Aremoricanium squarrosum* have been found in the upper Kope Formation (Late Edenian) at both Maysville and Cincinnati. Other occurrences of this form have been reported from the Kope Formation in Indiana (Loeblich and MacAdam, 1971), the Ordovician subsurface of Saudi Arabia (Hemer, 1968), the Sylvan Formation (Upper Ordovician) of Oklahoma (Loeblich and MacAdam, 1971), and the Upper Ordovician subsurface in the Aquitaine Basin in France (Rauscher, 1973). Because this form has a limited range it may be an excellent guide to the Caradocian series and possibly lowest Ashgillian over a wide geographical area. It is rare in the Cincinnati Region. The age of the Cincinnatian rocks bearing this form correlates well with that of other known occurrences of *Aremoricanium squarrosum* and its synonym *A. syringosagis*. Furthermore, this species has been reported only from formations dominated by shale and may also be a lithic indicator.

*Petaloferidium stigii* has been found at Clay's Ferry only. It is rare and known from two horizons in the middle of the Clays Ferry Formation. This species marks an interval that is considered to be quite close to the Shermanian-Edenian stadial boundary. The stratigraphic value of this species is not yet certain as it has not been reported elsewhere.

*Rhopaliophora folatilis* and *Rhopaliophora impexa* have been recognized previously from the Kope Formation (=Eden Formation in Tappan and Loeblich, 1971). In the Cincinnati Region *R. folatilis* and *R. impexa*
are unknown from Clay's Ferry samples. Although specimens of both species are rare, they are found in the Fairview Formation at both Maysville and Cincinnati and seem to be restricted to the Maysvillian Stage, at least on the eastern side of the Cincinnati Arch. The stratigraphic interval from which Tappan and Loeblich (1971) obtained specimens of Rhopaliophora was not reported precisely. It is possible they sampled the upper part of the Kope [=Eden] Formation in Indiana, which is coeval with the Fairview Formation in Cincinnati and at Maysville. Should this be the case, the potential value of Rhopaliophora folatilis and Rhopaliophora impexa as guide fossils for the Maysvillian Stage, at least in the Cincinnati Region, would be improved.

Peteinosphaeridium hypertrophicum is rare in the Cincinnati Region. The few specimens found are known only from the Calloway Creek Formation at Clay's Ferry. This species may be a useful indicator of an environmental change in the basin as P. hypertrophicum is a form with fewer and longer processes than P. intermedium. The two species, although regarded in many previous studies as variants of a single species, have been described as occurring together from the horizons in the Vaginatumkalk in Öland (Eisenack, 1976). However, in the Cincinnati Region, as well as in New York State, Peteinosphaeridium intermedium occurs, commonly in great numbers, while P. hypertrophicum is commonly absent. In the Red River Formation of the Williston Basin, considered youngest Maysvillian in age, only P. hypertrophicum has been found (Jacobson, unpublished data). Therefore, the first appearance of P. hypertrophicum in the Cincinnati Region in the Maysvillian may signify either an environmental change or an evolutionary transition from the abundant P. intermedium, in the Upper Ordovician.
Acritarch Associations and their Biostratigraphic Use

Certain associations of taxa have been noted. These associations may make up an entire assemblage or only a portion of it. The associations are informally named the leiosphaerid association, the veryhachid association, the Dicommopalla association, the Polygonium association, the baltisphaerid association, the peteinosphaerid association, and the micrhystridid association.

The leiosphaerid association includes Leiosphaeridia baltica, L. tenuissima, L. tenuissima ssp. A, Leiofusa cf. fusiformis, Leiovalia similis, Lophosphaeridium sp. A and Lophosphaeridium sp. B. It may be entirely absent as in samples from New York State or constitute as much as 98% of 315 specimens of samples 74MM-294.2 from the Grant Lake Formation at Maysville, Kentucky. This association is found in both limestone and shale. The relative abundance of the acritarch constituents of this association varies with lithology, as discussed in the chapter on paleoecology, and may reflect a palynofacies related to environmental factors such as water depth.

The veryhachid association contains Veryhachium trispinosum, V. lairdii, and V. sp. A. These forms are all polygonal, usually triangular, in shape. The association may vary from 0% of 315 specimens in sample 74MM-294.2 of the Grant Lake Formation at Maysville to as much as 95% out of 86 specimens in the Steuben Limestone at Trenton Falls, New York.

The Dicommopalla association contains a single species, Dicommopalla macadamii. Although entirely absent in New York, this species varies from 0% in 17 samples in the Cincinnati Region to as much as 68% in
74MM-143.3a of the Kope Formation at Maysville. This form is unknown below the Edenian Stage and it is common enough in the Cincinnati Region to make its first occurrence a guide for the base of the Edenian. It is absent in the Clay's Ferry section below sample CF-8 in the lower portion of the Clays Ferry Formation. The lower portion of the Clays Ferry Formation is considered Shermanian since McFarlan and Freeman (1935) placed the Middle Ordovician–Upper Ordovician boundary in the stratigraphic interval representing the middle part of this formation. The only other area this form has been studied stratigraphically is in the St. Lawrence Lowlands of Canada, where its first occurrence is reported to be near the base of the Edenian Stage (Martin, 1977, pers. comm.). *Dicommopalla macadamii* had also been reported from the Dillsboro Formation of Indiana, which is considered late Maysvillian–early Richmondian in age (Loeblich, 1970b).

The *Polygonium* association includes *Polygonium nanum*, *P. polyacanthum*, and *P. cf. polygonale*. It is common in rocks from both New York State and the Cincinnati Region. Although absent in some samples, it may make up as much as 63% of 395 specimens in sample 75MB-114.5 in the Miamitown Shale at Cincinnati. The primary constituent of this association, *Polygonium nanum*, has a long stratigraphic range from rocks much older than those studied to those much younger.

The baltisphaerid association contains all the specimens of *Baltisphaeridium*, *Multiplicisphaeridium*, *Ordovicidium*, *Rhopaliophora*, *Anomaloplaisium*, *Aremoricanium*, and *Petaloferidium*. Commonly, only parts of the association are found in a single sample from either New York or the Cincinnati Region. Its abundance may vary from 0% in
several samples from both regions to 66% in sample Cov-5 from Cincinnati. This association is interesting because along with the peteinosphaerid association, it can make up nearly 100% of a sample, as it does in samples examined by Kjellström (1971a, 1971b, 1976) from southern Sweden.

The peteinosphaerid association includes *Peteinosphaeridium hyperthrophicum*, *P. intermedium*, *P. intermedium* ssp. A, and *P. sp. A*. Although the constituents vary somewhat in relative abundance within the association, the association occurs in all but three samples from the Cincinnati Region and may make up as much as 69% of 197 specimens in sample SA-0 of the Calloway Creek Formation at Clay's Ferry.

The micrhystridid association consists of all species of *Micrhystridium*. It occurs commonly in samples from New York State but is totally absent in samples from the Cincinnati Region. The absence of these forms from the Cincinnati Region is probably a consequence of environment and is discussed in the chapter on paleoecology.

The use of these associations in stratigraphy is based on interpretation of the significance of variations in relative abundance of the associations. However, an understanding of paleoenvironments is required to properly apply these data.

Where possible, the acritarch stratigraphy is compared and related to the biostratigraphic framework based on other fossil groups. The useful information available from New York includes the conodont data of Schopf (1966) and additional interpretation by Sweet and Bergström (1971). In the Cincinnati Region, studies on conodonts have been compiled by Sweet and Bergström (1971) and Sweet (in press), and a study
on the chitinozoans has been carried out by Miller (1976).

The relative abundances in percent of the acritarch associations are plotted graphically for each section in fig. 7, fig. 8, fig. 9, and fig. 10. Because the closest sampling interval is at Maysville, this section can be used as a standard. The Edenian-Maysvillian stadial boundary is presumed to occur in the upper Kope Formation at Maysville and by definition at the Kope-Fairview formational contact at Cincinnati. Near this boundary, relative abundances of some acritarch associations vary in a similar manner at both localities. Below the boundary, there are low abundances in the leiosphaerid, peteinosphaerid, Polygonium, and baltisphaerid associations and high relative abundances of the Dicommopalla association (fig. 8). Above the boundary, the Dicommopalla association decreases in relative abundance and first the leiosphaerid and peteinosphaerid associations increase, followed by increases of the veryhachid and Polygonium associations.

At Clay's Ferry, a similar fluctuation seems to begin near the Clays Ferry-Garrard formational contact (fig. 9). This may also suggest proximity to the Edenian-Maysvillian stadial boundary. However, this implication must be considered preliminary until more samples can be analyzed from Clay's Ferry. Other changes in relative abundances of acritarchs in the Cincinnati Region may prove useful for correlation.

At Maysville and Cincinnati, a dramatic increase in relative abundances is first shown by the leiosphaerid and peteinosphaerid associations, then by the veryhachid-Polygonium associations and then by the baltisphaerid association (fig. 7, 8). These variations take place both at Maysville and Cincinnati in the Kope Formation about 130-170
Fig. 7 - Relative abundances of acritarch associations in the Maysville, Kentucky section. Relative abundances in percent plotted against thickness in feet. Short horizontal lines at the left side of figure mark sampled horizons.
Fig. 8 - Relative abundances of acritarch associations in the Cincinnati Composite Section. Relative abundances in percent plotted against thickness in feet. Short horizontal lines at left side of figure mark sampled horizons.
Fig. 9 - Relative abundances of acritarch associations in the Clay's Ferry, Kentucky section. Relative abundances in percent plotted against thickness in feet. Short horizontal lines mark sampled horizons.
Fig. 10 - Relative abundances of acritarch associations in the New York State Composite Section. Relative abundances in percent plotted against thickness in feet. Short horizontal lines at left side of figure mark sampled horizons.
feet (40 m-52 m) below the base of the overlying Fairview Formation. An identical sequence of variation in relative abundances of the same associations is seen in the lower part of the Clays Ferry Formation at Clay's Ferry about 160 feet (49 m) below the base of the Garrard Siltstone.

The section at Maysville, Kentucky, has been examined for Chitinozoa by Miller (1976), who plotted relative abundances of selected taxa. He noted an increase of *Conochitina micracantha* a few feet below the Kope-Fairview formational contact and the appearance in relatively high abundances of *Cyathochitina halophrys* in the overlying Grant Lake Formation. Miller also illustrated similar data for the locality at Cincinnati studied here. The analogies with acritarch associations described here are obvious (see fig. 7). Similar patterns of variation in relative abundances has been shown for conodonts (Sweet, in press) at Maysville and Cincinnati.

The increase in relative abundances of the Chitinozoan *Cyathochitina halophrys* shown by Miller and the conodont genus *Rhipidognathus* shown by Sweet, seems to correspond to a relative increase in the abundance of the leiosphaerid association.

The three biostratigraphic methods used here have shown acritarchs to be useful in analysis of the Ordovician rocks in the Cincinnati Region; these methods are concurrent range zones (see Tables 6, 7, 8) fluctuations of relative abundances of acritarchs, and correlations with fluctuations of relative abundances of other microfossils.

In New York State, a different method of analysis was employed. Five sections were examined and acritarchs extracted from samples at
Fig. 11 - Conodont relative abundances in some New York sections and Composite New York Section (compiled by W. C. Sweet). Phragmodus undatus multielement conodont apparatus — black; other conodonts — dotted. Phragmodus undatus has been interpreted as indicator of open-marine, offshore environment. Other conodonts are interpreted as indicating shallower water. The conodont composite is compiled on the basis of conodont relative abundances in five sections, namely High Falls, Kings Falls, Martinsburg-Roaring Brook, Trenton Falls, and City Brook and also from concurrent range zones of selected conodont taxa.
each section. These sections were at High Falls (Deer River), Kings Falls (Deer River), Trenton Falls, Martinsburg (Roaring Brook), and City Brook (fig. 1).

The samples analyzed were splits taken from those collected and studied by Thomas J. M. Schopf for conodonts in the early 1960's (Schopf, 1966). These conodont data have been compiled into a composite section for the New York Region (fig. 11). This composite section is based on concurrent range zones for multielement conodont apparatuses as well as their relative abundances (Sweet and Bergström, 1971). This was not possible to repeat for the samples studied for acritarchs because too few samples yielded acritarchs at each section. However, the relative abundances of acritarchs obtained for the New York rocks has been plotted in the same way as the composite conodont section. These acritarch relative abundances show fluctuations similar to those obtained for conodonts (fig. 12).

It is likely that the variation in relative abundances of various micro- and megafossils in such composite sections may prove important in future interpretations of this basin and in correlation of its strata with rocks in other basins.

Ecologic Significance of the Acritarch Assemblages

Relatively little information is found in the literature concerning distribution of acritarchs in terms of paleoenvironments, lithotypes, and biogeographic provinces. Such distributional aspects have not been examined previously in Ordovician forms with the exception of some general discussions regarding provinciality. Also the relation between
the numerical variations of acritarch assemblages and these of other fossil groups has not been discussed in previous reports on Ordovician acritarchs.

The first useful study that investigated the environmental significance of early Paleozoic organic-walled microplankton distribution is on Devonian forms in Alberta by Staplin (1961). He examined cuttings from sixty-one wells in the region of the Leduc Reef and concluded that acritarch morphological groups could be used to recognize distance from reefs. His three morphologic groups were 1) "simple, spherical forms" with a "smooth papillate, or ciliate surface;" 2) thin-spined forms in which "the spherical central body bears long, thin spines that do not seem to be an integral part of the central body;" and 3) polyhedral, thick-spined and saccate forms" in which "the processes are very broad at their bases, are often hollow and seem to be extensions of the central body of the organism." Staplin (1961, p. 396) also concluded that "hystrichosphaerids [acritarchs] are generally much more abundant in off-reef than in near-reef strata." He reasoned that "their optimum environment is the quiet deeper water of the off reef areas" and that wave action, diagenetic processes, and destruction by scavengers were relatively unimportant factors in acritarch distribution. Furthermore, Staplin (1961, p. 397) stated that "simple, spherical forms occur all the way from shales interbedded with reef carbonate to off-reef areas; that thin-spined forms are also widespread but are seldom found within one mile of reef and that thick-spined and polyhedral forms occur in off-reef strata." Staplin also suggested that currents were probably responsible for the few "anomalous" occurrences of his three groups.
In the study of organic-walled microfossils from the Lower Jurassic of Britain, Wall (1965, p. 176) found two types of microplankton assemblages, "one showing a tendency towards uniformity of composition by virtue of strong domination by a single species, the other being more varied in composition." He concluded that assemblages dominated by a single species "were derived from algae inhabiting inshore waters, whereas the species-rich, heterogeneous assemblages were accumulated in an offshore environment", and that this distribution is analogous to that in modern environments. Wall also stated that members of the Acanthomorphitae (Micrhystridium & Baltisphaeridium) "appear to have favoured an inshore, partly enclosed environment, whereas members of the Polygonomorphitae (Veryhachium) and Netromorphitae (Leiofusa, Domasia & Cantulodinum) appear to have favoured the open-sea environment." This is consistent, according to Wall, with Staplin's (1961) findings. From microplankton distributions, independently interpreted, Wall was able to recognize transgressions by relating introduction of his offshore assemblages.

Smith and Saunders (1970), in a study of Silurian rocks of Pennsylvania, suggested that acritarchs reflected marine rather than fluvial conditions, that preservation was better in deeper, open marine sediments and depended on the energy of the depositional environment, and the acritarch distribution was in part controlled by directions of prevailing currents.
Paleoenvironments

These approaches to acritarch studies are of particular interest because land plant spores and pollen are apparently absent in Ordovician rocks. Relative abundances of land plant spores and pollen, in conjunction with marine microplankton, have been used to interpret proximity to shoreline (Sarmiento, 1967; Upshaw, 1964; Wall, 1965) in post-Paleozoic rocks where these organic-walled microfossils occur together. Gray and Boucot (1972) have used spore tetrads, acritarchs, scolecodonts, and chitinozoans from six Late Ordovician through Early Silurian samples from Ohio that straddle the Ordovician-Silurian paraconformity, and on the basis of palynomorph distribution, they provided suggestions about water depth and shorelines. They interpreted the presence of spore tetrads and smooth-walled acritarchs, which were found only in two samples directly below and one sample directly above the paraconformity that marks the Ordovician-Silurian systemic boundary, as an indication of the relatively shallowest water depth and closest proximity to the shoreline in the section studied.

Relations between lithofacies and acritarchs distribution patterns

Cramer (1970b, p. 88) was unable to find a direct relationship between palynofacies and lithofacies for 75 Silurian rock localities on both sides of the present Atlantic Ocean.

MacDaniel (1976, unpublished Ph.D. thesis) has considered sedimentary and benthic community patterns in the Cincinnati Arch area of Ohio, Kentucky, and Indiana. He recognized "four characteristic suites of carbonate and clastic rocks, which represent an onshore-offshore
array of four intergradational sedimentary environments." His
dolomitic intertidal and supratidal sequence has not been examined in
this study. However, I have examined his moderately agitated subtidal
environment, as recognized in the onshore facies of Calloway Creek and
Grant Lake Formations, the offshore shoal system of the Fairview Forma-
tion, and the quiet offshore environment of the Kope and Clays Ferry
Formations.

MacDaniel recognized a transgressive sequence reaching a maximum
in the Kope Formation to the north and in the Clays Ferry Formation to
the south, and a regressive phase represented by strata overlying these
units. His conclusions were based on community studies, primarily of
brachiopods, as well as characters of the sediments.

This same transgressive-regressive pattern has been observed in
the distribution of conodonts (Sweet and Bergström, 1971; Sweet, in
press) and chitinozoa (Miller, 1976, unpublished M.S. thesis). Acrit-
tarchs show the same pattern if one accepts the interpretation of
Staplin (1961) from Devonian rocks of Alberta, that smooth-walled
acritarchs indicate shallow water. These smooth-walled
acritarchs correspond to the leiosphaerid association described above.
The veryhachid Polygonium and baltisphaerid associations may represent
a facies of an open-marine environment and correspond to MacDaniel's
offshore environment. The three groups of acritarch associations can
be subdivided further and may yield interpretations of a more precise
nature.

Assemblages from southern Sweden (Kjellström, 1971a, 1972, 1976)
contain virtually no members of the leiosphaerid, Dicommopalla, or the
veryhachid associations, although a few constituents of the petenosphaerid association, the Polygonium (= Goniosphaeridium) associations, and many members of the baltisphaerid association are present.

That some of these associations are present and others are absent can be interpreted in several ways. The absence of the leiosphaerid association suggests that no very shallow, inshore environments were sampled in southern Sweden. The absence of the Dicommopalla association could signify the absence of part of the open-sea environment, or it could be that Dicommopalla is a provincial form, which is absent in the Baltic Region.

The absence of the veryhachid association in Sweden cannot be easily interpreted as indicating absence of the environment occupied by this association since both comparable baltisphaerid and Polygonium associations suggesting a shoal environment, as well as the deeper water petenosphaerid association, are present.

On the relative abundance graphs (figs. 8, 10) for the Cincinnati Region and for the New York State region, it can be seen that the Polygonium association and the veryhachid association generally conform with each other in variations of relative abundances. Although the actual percentage for these two associations does not seem to be related arithmetically or geometrically, their increases and decreases nearly always correspond to each other.

That the leiosphaerid association represents a nearshore shallow water environment is reinforced by the absence of this group from nearly all the studied intervals in the New York State Region, particularly the deeper water environment, and in equivalent strata in the St.
Lawrence Lowlands of Canada (Martin, 1977, pers. comm.). The presence of the leiosphaerid association in rocks of nearly equivalent age in Finland (Tynni, 1975) supports the notion that leiospheres are probably not provincial in the Middle and Upper Ordovician.

In New York State the presence of a relatively deep water environment, most commonly corresponding to an offshore environment, may be interpreted from the relative abundances of acritarch associations, as plotted in fig. 10. The acritarch relative abundances vary in a similar way as the relative abundances of multielement conodont apparatuses in the same region (T. J. M. Schopf, 1966; Sweet and Bergström, 1971, Sweet, in press). Conodonts regarded as shallow water indicators, like *Rhipidognathus* from the Cincinnati Region, are absent.

In the samples on which fig. 10 is based the leiosphaerid association is virtually absent. Only one sample in the lower part of the composite section contains carbonized leiosphaere-like forms that have been questionably assigned to the leiosphaerid association. The relative abundances of groupings of associations has been plotted for the New York section (fig. 12). The peteinosphaerid association is the only association present that can be attributed to an environment other than that of an open offshore sea. The *Dicommopalla* association of the shoal environment and members of the leiosphaerid association, the nearshore indicators are absent except for the one sample mentioned above, which has been shown in fig. 10 but omitted from fig. 12. The variation in the peteinosphaerid association has been plotted and the remainder of the assemblage is interpreted as representing an open sea offshore environment. Similarly the variation of conodonts has been plotted (fig.
Fig. 12 - Comparison between the relative abundances of acritarch and conodont associations in the New York State Composite Section. Acritarchs; peteinosphaerid association — dotted; others (veryhachid, Polygonium, baltisphaerid and micrhystridid associations) — black. Conodonts, Phragmodus undatus — black; others — dotted.
11, 12) from data supplied by Sweet from Schopf's (1966) study. Sweet (in press) recognized Phragmodus as an indicator of relatively deeper water and the remainder of the conodont fauna as relatively shallower water forms. The resemblance of the variations in relative abundances of conodonts and acritarchs in the composite section for New York State is remarkable and it is therefore reasonable to conclude that both the conodonts relative abundances and the acritarchs relative abundances are showing the same environmentally controlled variations.

At Maysville, Kentucky, the variation in acritarch relative abundances (fig. 13), especially in assemblages dominated by the inshore leiospharid association, corresponds closely with the appearance of *Rhipidognathus* (Sweet and Bergström, 1971) in the Grant Lake Formation. This same section was also examined for chitinozoa by Miller (1976), whose data show the same interval to be dominated by *Cyathochitina halophrys*, and other species of *Cyathochitina*. Likewise, at Cincinnati (fig. 14) Miller (1976) has shown that *Cyathochitina halophrys* and other species of *Cyathochitina* appear in the upper Fairview Formation, decrease in relative abundance in the Miamitown Shale, and increase further in the overlying Grant Lake Formation. *Rhipidognathus* is absent at Cincinnati but the presence of shallow water, although not quite as shallow as nearshore conditions is indicated by another association of conodonts, *Aphelognathus + Oulodus* (Sweet, in press). The relative abundance of this conodont association in the Maysville section has also been plotted and it varies in a similar way as the acritarchs. The acritarch leiosphaerid association relative abundance variation corresponds closely to those of the chitinozoa and the conodonts in the same sections and to the conodonts at Clay's Ferry, Kentucky (fig. 15).
Fig. 13 - Comparison between the relative abundances of acritarch, chitinozoa, and conodont associations in the Maysville, Kentucky section. Acritarchs: baltisphaerid, veryhachid, and Polygonium associations - black; peteinosphaerid and Dicomo-palla associations - dotted; leisophaerid association - white; Conodonts (after Sweet): Phragmodus undatus - black; Plectodina - dotted; Apheloganthus + Oulodus - white; Rhipidognathus - dark gray. Selected chitinozoans (after Miller): Cyathochitina kuckersiana - black; Conochitina micracantha - dotted; Desmochitina lata - white; Cyathochitina halophrys - dark gray.
Fig. 13
Fig. 14 - Comparison between relative abundances of acritarch, chitinozoa and conodont associations in the Cincinnati Composite Section. Relative abundances of acritarchs: baltisphaerid, veryhachid, and Polygonium associations - black; peteinosphaerid and Dicommopalla associations - dotted; leiosphaerid association - white; Relative abundances of conodonts (after Sweet): Phragmodus undatus - black; Plectodina - dotted; Apheloganthus + Oulodus - white. Relative abundances of selected chitinozoans (after Miller): Cyathochitina kuckersiana - black; Conochitina micracantha - dotted; Desmochitina lata - white; Cyathochitina halophrys - dark gray.
Fig. 15 - Relative abundances of acritarch associations at Clay's Ferry, Kentucky. Baltisphaerid, veryhachid and Polygonium associations - black; peteinosphaerid and Dicommopalla associations - dotted; leiosphaerid association - white.
Acritarch distribution patterns in Ordovician rocks in New York State and the Cincinnati Region are similar to distribution patterns of Devonian acritarchs from Alberta and they support the environmental interpretations made by Staplin (1961).

However, the Ordovician acritarch distribution pattern does not agree with the distribution patterns of Jurassic acritarchs from Great Britain studied by Wall (1965). Different distribution pattern of acritarchs from the Ordovician and the Jurassic is not surprising since both the nature of the oceans and their biota during these periods are very different in several respects.

Variations of acritarch relative abundances have great potential stratigraphic value as acritarchs occur in lithologies such as shaly mudstones that are unsuitable for extraction of conodonts and in facies that sometimes lack chitinozoa. Also, acritarch relative abundances in Ordovician and older rocks may provide a relatively simple, yet reasonably precise, method for interpreting rapidly facies, distance from shoreline, and water depth.

The relation of the microfossils to particular lithotypes has otherwise generally been ignored in paleoecological, paleoenvironmental, and provincial palynomorph studies, but it is examined here briefly. A small number of the samples studied, namely all the samples from the section at Maysville, Kentucky, and some from the Cincinnati composite section, have been identified as to lithotype.

Although only 40 samples have been examined lithologically, including 10 biosparites, 20 biomicrites, 4 siltstones, and 6 mudstones, some distinctions in acritarch distribution between different
lithologies are apparent. An arbitrary system was set up for evaluating abundance per sample. In most cases, the more specimens examined per sample, the more species were found.

All barren samples (3) found at Maysville and Cincinnati were biosparites and no biosparites yielded more than 79 specimens per slide. One biosparite interbed in the shaly Kope Formation yielded 10 species of acritarchs. None of the nine other biosparites examined had more than 6 species.

The next least productive lithotype was siltstone. Four samples were examined and one sample, also from the shaly Kope Formation, yielded 5 species or less and had less than 100 specimens per slide.

Biomicrites and mudstones provided the largest numbers of specimens and the most diverse assemblages. As many as 15 species and 463 specimens per slide have been recorded in these lithologies.

Ten examples of biosparite and four of siltstone generally contained members of the leiosphaerid association, Dicommopalla association, peteinosphaerid association, veryhachid association and, less commonly, the Polygonium association, whereas the baltisphaerid association was nearly absent in the biosparite and siltstone, but was common in biomicrite and mudstone. These findings, although based on few samples, suggest that the water energy level, as interpreted from lithology, is in some way related to the numbers of acritarchs found in a particular lithotype and also to some extent to the diversity and composition of the acritarch assemblages. The high-energy regimes, in which biosparites and possibly some silt could have been deposited, were probably environments in which acritarchs, if present in the water column, were
carried away with fine-grained calcareous clastics (micrite) and clays.

More complete petrographic examination of the lithologies in which acritarchs are preserved, with absolute abundance and relative abundance data, is likely to provide data to improve our understanding how acritarchs are deposited, and the significance of their relative frequency.

**Acritarch Provinciality**

Cramer (1968b, 1970a) and Cramer and Díez (1972, 1974) have shown a spatial arrangement of Silurian palynofacies that corresponds to paleolatitudes for that time. Cramer and Díez (1974, p. 185, 186) also imply that a similar regional provinciality should have been present in Ordovician time. Unfortunately, relatively few critical investigations on Ordovician acritarch provinciality exist at this time. However, Vavrdova (1974) has suggested two acritarch provinces for the Upper Ordovician in Europe: A Baltic province dominated by Baltisphaeridium longispinosum (Eisenack), B. multipilosum (Eisenack), B. digitatum (Eisenack), Peteinosphaeridium trifurcatum (Eisenack) Staplin et al., Goniosphaeridium polygonale (Eisenack), B. varsoviensis Gorka, B. plicatissinae Gorka, Orthosphaeridium octospinosum Eisenack, O. rectangulare (Eisenack), Pulvinosphaeridium pulvinellum Eisenack and Hystrichosphaeridium wimani Eisenack, and a Mediterranean province dominated by Baltisphaeridium eisenackium (Deunff) Downie, Baltisphaera ternata Burmann, B. quadrinata Burmann, B. transitoria Burmann, Veryhachium trispinosum (Deunff), V. rosendae Cramer, V. elenae Cramer, Multiplicisphaeridium ramusculosum (Deflandre) Staplin et al., M. arbusculiferum (Downie) Loeblich, and Diexallophasis granulatisspinosum (Downie) Loeblich.
Although the taxonomic names used by Vavrdova are not always the same ones as those used here, most of the forms she recognized as Baltic provincial indicators are found in the North American assemblages studied here. Vavrdova's Mediterranean forms are absent or extremely rare in the assemblages from North America except for Veryhachium trispinosum, which is common in assemblages from both New York State and the Cincinnati Region.
Summary

Nearly 5000 acritarchs were examined and counted from 41 acritarch-bearing samples from five stratigraphic sections in Middle and Upper Ordovician rocks of the Trenton group in New York State. Twenty additional samples from this region were found to be barren.

In the Cincinnati Region of Ohio and Kentucky, 6000 acritarchs were examined and counted from 49 acritarch-bearing limestone, calcareous mudstone and siltstone samples. Twenty-eight additional samples were found to be barren.

One new genus, Petaloferidium and three new species are proposed. These species are Petaloferidium stigii, Peteiniosphaeridium jimschopfii, and Leisophaeridias extratubulata. Anomaloplaisium lumariacuspis, Aremoricanium squarrosum, Dicommopalla macadamii, and Petaloferidium stigii are used for correlations as they are probably restricted to the Caradocian Series.

Variations in relative abundances of portions of acritarch assemblages, termed associations, are presented graphically and are related to facies differences in both regions. In addition, these acritarch associations can be used to explain the composition of acritarch assemblages from other regions of the world in which rocks of equivalent age have been described. It is shown that some acritarch taxa had a provincial distribution during the Middle and Late Ordovician whereas others were virtually cosmopolitan.

A leiosphaerid association is used to recognize a near shore, shallow water environment; a Peteiniosphaerid-Dicommopalla association
reflects a shoal environment; and the remainder of the acritarch assemblages, a baltisphaerid–veryhachid–Polygonium–michrystridid association, represents an offshore open-marine environment. Variations in relative abundances of acritarch associations are used to trace basin-wide changes of tectonic or eustatic nature and it is shown that they exhibit close similarity to variations in relative abundances of conodonts and chitinozoans in the same rocks.

Relative abundances for acritarchs so closely resemble the variations for conodonts that the two microfossils can be used interchangeably and augment gaps in the stratigraphic record. These gaps may be caused by the absence of either fossil groups in some rocks or the inability to extract either fossil group from particular lithologies. Data for chitinozoans suggest that they may be used in a comparable manner.
PREPARATION TECHNIQUES

Introduction

Acritarchs occur too sparsely to be readily studied in petrographic thin sections. Because they are small (usually <100 μm) and fragile, they require special techniques of preparation. In order to permit efficient study, it is necessary to concentrate these fossils; as is also the case with other palynomorphs such as pollen, spores, dinoflagellates, chitinozoa and scolecodonts.

Many techniques for extraction and concentration of palynomorphs from sedimentary rocks have been described (Funkhouser and Evitt, 1959; Staplin et al., 1960; Gray, 1965; etc.). However, each sample or group of samples usually requires a specific procedure to extract the palynomorphs.

In the present project, the rocks examined were primarily limestones, limy siltstones, and limy shales. Acritarchs were prepared for light microscopy and, in some cases, for scanning electron microscopy. The procedures followed for cleaning, mineral dissolution, heavy-liquid separation, mechanical concentration, slide preparation, photography, and storage are described below.

Collection and Cleaning

Each sample was washed with a metal brush to remove soil and plant and animal fragments that might later prove resistant to chemical preparation techniques and thereby contaminate the samples.
Dry samples were crushed into pieces about five millimeters long in a Massco-McCool Pulverizer. Special attention was given to removing residual dust from the apparatus to prevent subsequently processed samples from contamination.

**Chemical Treatment**

**Carbonate Dissolution**

Dry samples of 50 to 100 gms were placed in a 1000 ml glass beaker, covered with water, and 10% hydrochloric acid was added. A bubbling reaction followed. When the bubbling decreased in intensity even after addition of fresh 10% hydrochloric acid, addition of concentrated (37.6%) hydrochloric acid completed the dissolution of the carbonates (primarily calcium carbonate, although dolomite was present in some samples).

Sometimes a foam was produced, which filled the beaker to near overflow, and prevented further addition of hydrochloric acid. A few drops of acetone from a squeeze bottle, as suggested by Gray (1965), lowered the surface tension of the bubbles, thereby eliminating the foam. No effects on the palynomorphs were noted in the few instances when additional acetone was required to prevent overflow.

**Silicate Dissolution**

The washed and decanted sample was placed in a teflon beaker, to which 48-51% hydrofluoric acid was added slowly. As the hydrofluoric acid began to react with the silicates, heat was released which sometimes led to violent boiling within a few minutes. Prompt addition of
distilled water from a squeeze bottle always brought the reaction under control immediately. When boiling did not follow new addition of hydrofluoric acid or when the boiling did not dissolve most of the silicates, the teflon beaker was placed on a hot plate in a fume hood and heated to about 95°C for up to one hour. This usually completed silicate dissolution. The sample was then allowed to settle, usually overnight, before the hydrofluoric acid was decanted.

The residue undissolved in hydrofluoric acid was then placed in a 12 ml plastic centrifuge tube and hand centrifuged. Subsequently, the remaining residue was washed, first with 10% hydrochloric acid to dissolve any gels, and then carefully in water.

**Pyrite Dissolution**

In most samples, pyrite crystals either encrusted externally or filled the microfossils internally. In most cases enough dispersed, fine-grained pyrite was present to mask the organic residue. To remove the pyrite, concentrated nitric acid (70%) was added to the sample in a large watchglass which had been placed in a fume hood. By using a watchglass rather than a centrifuge tube, more surface area of the sample was exposed to acid. This enabled the sample to react more rapidly and evenly than in a centrifuge tube and entirely eliminated the hazard of overflow caused by violent boiling. Pyrite dissolution was completed in one to three minutes. Short exposure to nitric acid was desirable as prolonged exposure of acritarchs to nitric acid will oxidize the microfossils themselves. Definite alternation and partial dissolution of microfossils could be observed when treatment with concentrated
nitric acid exceeded about ten minutes. The residue was removed from the watchglass by pipette and placed in a 12 ml glass centrifuge tube. The sample was washed immediately several times with water.

**Mechanical Treatment**

**Removal of Clay and Concentration of Microfossils with Heavy-liquid**

After nitric acid treatment, the washed residue usually consisted of microfossils and clay only. A heavy-liquid was used to remove the clay, since the clay has a higher specific gravity than the microfossils. The heavy liquid was zinc bromide ($\text{ZnBr}_2$) diluted with distilled water to a specific gravity of 1.95-2.0.

Before adding zinc bromide, the sample was washed in a 12 ml glass centrifuge tube with 10% hydrochloric acid. This helped prevent the formation of zinc hydroxide ($\text{Zn[OH]}_2$) and other impurities. After hand-centrifuging and decanting the 10% hydrochloric acid, a few milliliters of zinc bromide solution was added to the centrifuge tube containing clay and the organic microfossil residue. Enough heavy liquid was used so that a partially filled centrifuge tube of heavy liquid and residue would counterbalance a centrifuge tube completely filled with water. A combined residue/heavy-liquid mixture sufficient to counterbalance the water-filled centrifuge tube was about five milliliters. The sample was mixed by pipette and a thin layer of 10% hydrochloric acid was added above the zinc bromide from a squeeze bottle. The hydrochloric acid did not mix with the zinc bromide and provided a cap on the zinc bromide, which permitted lightweight microfossils that floated in the zinc bromide to accumulate at the zinc bromide/hydrochloric acid
interface. This also inhibited upward movement of microfossils on the concave-up meniscus of the zinc bromide, thereby eliminating any loss of microfossils on the inner wall of the centrifuge tube.

A few turns on the hand centrifuge caused the relatively heavier clay particles to sink and the organic residue to accumulate at the zinc bromide/hydrochloric acid interface. This organic residue was removed by pipette to another 12 ml glass centrifuge tube and water was added and mixed to wash the zinc bromide. It was convenient to have the hydrochloric acid of the cap mixed with the zinc bromide as the hydrochloric acid inhibited the appearance of zinc hydroxide at this stage of preparation. After several washings with water, the sample was placed in a watchglass for observation under a binocular microscope. If the sample still contained clay, the heavy liquid procedure was repeated until all clay was removed. The entire heavy-liquid procedure for each sample was accomplished in a few minutes.

**Microscope Slide Preparation**

To prepare slides for light microscopy a water-soluble mountant, Clearcol, and a xylene-soluble adhesive, piccolyte resin, were used. This seemed desirable as such a combination allowed for subsequent removal of individual specimens, if necessary.

A single drop of Clearcol from a glass rod was added to one to three pipette drops of microfossil residue and mixed in a coverslip using a glass rod. The coverslip was placed to dry on a hotplate at about 55°C for about one-half hour. This coverslip with residue mounted in Clearcol was inverted and attached to a microscope slide
with piccolyte resin. The coverslip was weighted down to eliminate bubble formation and the slide was allowed to cure overnight on a hotplate at about 55°C. The slide was then ready for light microscopy.

**SEM Stub Preparation**

A residue of organic microfossils in water was placed on a watch-glass and observed under a binocular microscope at a magnification of about 50 X. A finely-drawn glass pipette was fitted with thin rubber tubing attached to the wide-diameter end. The tube was reflexed parallel to the pipette with an eye-dropper bulb at the position where the pipette narrowed. This apparatus was used as a picking tool for acritarchs in the same way as described by Miller (1976). Handled like a pencil, the pipette-assembly, after the operator became familiar with its manipulation, allowed for fairly delicate transport of individual microfossils. The individual acritarchs were removed from the residue along with fragments of other organisms including chitinozoa, scolecodonts, and graptolites. The microfossils were placed in water in a second watchglass. The residue in the second watchglass was further "cleaned" by evenly spreading the acritarchs and other microfossils in the liquid with jets of water produced by the pipette assembly. Unwanted material was removed by pipette and the residue concentrated by the swirling technique of Funkhouser and Evitt (1959). Drops of the microfossil slurry were then placed directly on an aluminum SEM stub and allowed to dry on a warm hotplate while covered to protect the stubs from contamination by dust in the laboratory. Examination of the stub showed that more than twenty-five acritarchs could
be routinely mounted on each stub. The acritarchs adhered to the stub without use of additional cement.

A thin (200 Ångströms) layer of gold was used to coat the specimens for examination with SEM.

_Preservation of Palynologic Specimens Examined by SEM for Later Study and Reference_

Advantages of the Scanning Electron Microscope (SEM) for micropaleontologic studies are increasingly recognized. No other method of observation can show morphologic features at very high magnification in sharp portrayal of different relative levels, and combine this advantage with excellent ultramicroscopic resolution of very fine surface detail. Disadvantages of the SEM include an image strictly limited to surfaces, with all internal structures concealed unless surfaces of these have been exposed by fractures. Also, specimens must be dry to withstand high vacuum and the surfaces must have electrolytic properties, generally provided by a tenuous film of a noble metal. The mounting stubs usually provided for use in the SEM are somewhat awkward to examine by the more customary methods of microscopical examination. Specimens to be retained are exposed, delicate and require special precautions for curating, and their premanence is not assured. In any event, specific objects are not always easy to relocate on the SEM stubs for repeated observation.

A new method is here described whereby specimens of palynomorphs, previously examined with the SEM, can be remounted for convenient permanent and repeated microscopical reference. This new method seems to have advantages over other methods that have been suggested (MacAdam,
1971; Urban and Padovani, 1970; Loeblich, 1970b). Remounting in this manner is most desirable if particular microspecimens studied are likely to be suitable for use as nomenclatural types in taxonomy. It avoids the disadvantages noted above and is essentially an adaptation of Walton's (1928) paleobotanical peel technique.

The new procedure requires a dispersion of palynomorphic specimens to be placed on a SEM stub in a drop of distilled water and allowed to dry. Such small specimens adhere to the stub satisfactorily by surface attraction without use of cement. The stub is then coated with a metallic electrolyte, and the fossil specimens examined and photographed under the SEM as desired. Subsequently, both the metallic coating and specimens are lightly covered with peel solution and, when dry, peeled directly from the stub. The peel with specimens can be mounted permanently in any suitable resinous medium on a glass microscope slide. A particular specimen or specimens observed with the SEM can then be relocated by search, using the conventional methods of transmitted light microscopy. Once located, a standard slide location address can be determined for direct future reference.

The adaptation of procedure for applying peels to SEM preparations is as follows. Palynomorphs mounted on a scanning electron microscope stub are coated with approximately 200 ångströms of gold, a thickness sufficient to give a clear image for observation with the SEM, and yet thin enough to transmit light when subsequently mounted on a glass microscope slide. After completion of scanning electron microscopy and micrography, the stub is placed in a horizontal position in a holder, for ease in manipulation, and peel solution is applied.
The peel solution we used has been described by Graham (1933) and by Darrah (1936). No doubt other peel solution formulae would be satisfactory. The standard solution should be diluted with sufficient solvent to form a thin bubbleless fluid. We found that five parts of amyl acetate added to one part of the standard nitrocellulose solution is suitable. If less solvent is used, the dried peel tends to wrinkle; if more solvent is used, the peel tends to tear during removal from the stub. A single drop of well-mixed peel solution from an eyedropper is sufficient to cover one stub.

After the liquid dries to a thin, cloudless, transparent sheet, it can be removed under a stereoscopic binocular microscope by working one edge free with a needle. The peel is then mounted on a glass microscope slide in piccolyte resin or any other permanent mounting medium and a coverslip affixed. After the mountant has dried, the slide is ready for regular study by light microscopy and fixed locations of particular specimens may be recorded for future reference.

Concentric markings shown by the thin gold coating, which replicate marks caused by milling the SEM stub, are retained on the peel after remounting. They aid in relocating particular specimens and also serve to reassure the observer that specimens seen in transmitted light are indeed the same specimens that had been observed and photographed using the SEM. On occasion appearances differ markedly because of added internal detail. Further, the thin gold coating imparts a greenish-gray color to the microfossils, producing an appearance similar to that of a biologic stain that enhances the appearance of almost transparent specimens for photomicrography.
Examples of SEM and light photos of the same acritarch are prepared by this method are shown in the accompanying illustrations.

**Photography**

Kodak Panatomic-X film was used for both light micrography on a Zeiss Photomicroscope and scanning electron micrography on a Cambridge Stereoscan S4-10 Scanning Electron Microscope.

**Repository of Specimens**

All figured specimens have been deposited in the collections of the Orton Geological Museum, The Ohio State University under OSU numbers 33851-33938. Unfigured specimens are deposited in micropaleontological collections of Department of Geology and Mineralogy, The Ohio State University.

Figured specimens including types can be located by slide coordinates given in Plate Explanations. These coordinates have been established on a Zeiss photomicroscope #62626 belonging to the U. S. Geological Survey and currently housed in the Coal Geology Laboratory, Department of Geology and Mineralogy, The Ohio State University, Columbus, Ohio.
INTRODUCTION TO SYSTEMATICS

In the following systematic descriptions, all new taxa are based on more than five measured specimens. When a new species is recognized and there are less than five specimens, or if the specimens are preserved in such a way (poor preservation, partially covered, pyrite encrusted) that certain identification is impossible, informal-letter designation (i.e., sp. A, sp. B) is used. When doubt exists regarding the degree of similarity between a form found here and a previously described form from another locality, the designation cf is used.

All descriptions in the systematics are based on forms found during this study. The descriptions often include information not found in the original diagnoses of taxa described elsewhere, and in some cases more information from previous descriptions has been omitted, such as measured wall-thicknesses. The acritarchs have been placed in what the author considers the appropriate taxonomic categories, in compliance with the rules of the International Code of Botanical Nomenclature.

The section in the systematics entitled "Remarks" usually contains comments on the distinctive morphological characters of the taxon as compared to previously described forms. The section entitled "Discussion" usually includes information concerning the evolution of the nomenclature, and the basis for selecting the chosen name for those of somewhat similar taxa. The section entitled "Dimensions" states the number of specimens used in determining the values for the following measurements. The actual number of identified specimens attributable to any one taxon can be found in the compilations on the charts found
in Tables 5, 6, 7 and 8. The first number given in the measurements is the lowest value found for the specimens measured, the number following and in parentheses is the average, and the last number is the highest value. The section entitled "Distribution" includes the occurrence by formation of the taxa described in the study. Exact stratigraphic position of an individual taxon can be determined by examining the data as presented in Appendix A. The section entitled "Previously reported occurrences" includes other occurrences of a particular taxon as determined from a search of the literature. The original author's interpretation of stratigraphic position is simply reported without reinterpretation by this author.

MORPHOLOGICAL CONSIDERATIONS

Acritarchs are classified on the basis of morphological features. The basis for establishing a hierarchy of morphological features to correspond with ranks of taxa is a complex matter in most other groups of organisms, living or fossil, and morphological features diagnostic for a particular taxonomic rank have not yet been firmly established for acritarchs. An artificial suprageneric classification proposed by Downie, Evitt and Sargeant (1963) for "sub-groups" and added to by others (Staplin et al., 1965; Brito, 1967, 1969; Sinha, 1969), or for families, in accordance with the Code of Botanical Nomenclature, as proposed by Eisenack (1938, 1954, 1969), Klement (1960), and Madler (1963), has been adhered to by most authors in a superficial way, at best. In general, the dominant and seemingly simplest practice appears
to be the alphabetic listing of the forms recognized. This procedure is followed here.

As acritarch taxa are better understood, and then removed from Incertae sedis, it may be possible to propose meaningful suprageneric classification for clearer biological insights.

At present, however, the various features of morphology can be associated in numerous ways and several quite different sets of lineages can be deduced for the very same forms. These lineages emphasize and thereby trace relations of different morphological features in the same samples, and in so doing, different lineages are the result.

Obvious features such as vesicle shape and process shape may reflect a more universal adaptation to, or functional morphology for, the marine planktonic environment that acritarchs are supposed to have occupied. It has been suggested (Schopf, in Tschudy and Scott, 1969, p. 175) that "the more obvious functional criteria are less likely to be useful indicators of phyletic alliance than incidental features of ornamentation or composition that do not interfere with the common functional objective and may have no apparent survival value...For purposes of taxonomic assignment it may be necessary to emphasize and attach more significance to incidental features and minor resemblances than seems on casual inspection reasonable."

Nevertheless, features used to define genera traditionally have been, and continue to be, features that are more likely morphologically functional.

In most cases, therefore, ornamentation has been a diagnostic generic character only for forms so simple that few other morphologic
features are observable. However, more complex forms with much variability in ornamentation are found described under a single genus.

Features of acritarchs, as well as those of most known plankton, have been formed inside some organic sheath or cellular material. Therefore, to distinguish between "similarity of appearance", ornamentation, or ultrastructure may be of questionable significance.

Tappan and Loeblich (1971, p. 386) have suggested that ultrastructure, "because it is not limited by the same environmental restrictions that may affect general morphology, should be taxonomically more useful." They also state (p. 386) that "internally formed morphological structures are less likely to be environmentally affected than are those in direct contact with the environment, whereas the major morphologic features are most influenced by physical factors."

In fact, the complexity of ultrastructure in acritarchs does seem to increase through time in the early Paleozoic as it does in other groups of organisms during other time periods. This might be partly due to the fact that ornamentation of various types, whether surface sculpture, process-tip morphology, or flange development, seems to develop on numerous seemingly unrelated forms through time, regardless of apparent lineages.

Circumscription of taxonomic groups, however, as used by most workers and followed here, is carried out by using the so-called "more obvious functional criteria" for distinguishing taxa of higher rank, and "incidental features of ornamentation" and the like for distinguishing taxa at the species, or in some cases, the generic rank.
The terminology used for morphological features is essentially that described and illustrated by Kjellström (1971a). The procedure of Tappan and Loeblich (1971), who defined the use of the prefix "micro-" for features of less than 1μm in diameter or width (e.g., microgranulate, microrugulate, etc.) is followed here. Sculpture is used interchangeably with ornamentation. "Sculpture absent" implies smooth, psilate or laevigate surface. To describe the thick or thin wall that separates the vesicle cavity from the hollow process cavity and is clearly visible only at the process/vesicle contact in many acritarch taxa, the term septation is preferred over terms such as separation, obstruction, plug, and double wall or membrane. Complete or incomplete septations may also be present in the process cavity as the "ladder-like structures" reported by Kjellström (1971a) and called trabeculae. A double-walled vesicle is one in which two complete or nearly complete walls can be recognized as in, for example, Dicommopalla macadamii Loeblich, 1970.
Genus *Anomaloplaisium* Tappan and Loeblich, 1971

Type species: *Anomaloplaisium lumariacuspis* Tappan and Loeblich, 1971.

**Description:** Vesicle single-walled, asymmetrically fusiform; one process at each pole, hollow, homomorphic; process tips closed, acuminate; process contact with vesicle wall straight; process with hollow spinules open to the process and therefore to the vesicle; vesicle wall thin, without sculpture.

**Remarks:** Diagnostic features of this genus include the asymmetric fusiform shape, the sculptural elements on the polar processes, and the smooth vesicle wall.

**Discussion:** Forms of this genus are similar to those of *Leiofusa* Eisenack, 1938, but differ in having hollow spinules on the polar processes. *Disparifusa* Loeblich, 1970 is characterized by the presence of echinate ornaments on the entire vesicle wall. *Dactylofusa* Brito and Santos, 1965, emended Combaz et al., 1967, restricted Cramer, 1970, has echinate ornaments arranged in rows on the vesicle wall.

Unfortunately, this genus, as established by Tappan and Loeblich (1971), is so narrowly defined that it almost exactly corresponds to the circumscription given for its type species, *A. lumariacuspis* Tappan
and Loeblich, 1971. This practice, which is common among some workers, results in large numbers of monospecific genera. This conflicts with one of the basic advantages of binomial nomenclature, that is, the advantage of grouping species with similar features in the same genus. In the particular case of Anomaloplasium, the similarity of the circumscriptions of both the genus and type species allows for little specific variation within the genus other than differences in actual measurements between specimens.
Anomaloplaisium lumariacuspis Tappan and Loeblich, 1971
Pl. I, fig. 6

1971 Anomaloplaisium lumariacuspis Tappan and Loeblich, p. 390,
Pl. 2, Figs. 1-8.

Description: Vesicle single-walled, asymmetrically fusiform; one
process at each pole, hollow, homomorphic; process tips closed,
acuminate; process contact with vesicle wall straight; process with
hollow spinules open to the process and therefore to the vesicle;
vesicle wall thin, without sculpture.

Remarks: Diagnostic features of this species (and the genus, see
Remarks for Anomaloplaisium) include its asymmetric fusiform shape,
sculptural elements on polar processes, and its smooth vesicle wall.

Dimensions: 3 specimens. Entire length 140 (166) 182 μ; vesicle
width 16 (18) 21 μ; process length 32 (47) 70 μ.

Discussion: The specimens at hand are similar in most dimensions to
those described by Tappan and Loeblich (1971) from the Dillsboro
Formation in Indiana. The specimens recovered from the stratigraphi-
cally older rocks in Kentucky are one-half to three-quarters as wide
as the Indiana specimens described by Tappan and Loeblich (1971).
Cramer and Díez (1977, p. 343) defined A. tappaniae as having processes
with "probably solid spines." This contradicts the original generic
description of Tappan and Loeblich (1971) who stated that Anomalo-
plaisium had processes with hollow spines.
**Distribution:** Kope Fm., Upper Ordovician [Edenian], Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.

**Previously reported occurrences:** Dillsboro Fm., Upper Ordovician [Richmondian], Indiana (Tappan and Loeblich, 1971).
Genus *Aremoricanium* Deunff, 1955

Type species: *Aremoricanium rigaudae* Deunff, 1955,

**Description:** Vesicle single-walled or double-walled, flask-shaped; processes absent to numerous, hollow to solid, usually homomorphic, usually restricted to the inflated bulb; process contact with vesicle angular to curved; septation between vesicle and process present or absent. Process sculpture absent to granulate; vesicle sculpture absent to coarse. Excystment may be through neck of vesicle.

**Remarks:** The flask-shaped vesicle is particularly diagnostic of this genus.

**Discussion:** When introducing *Aremoricanium*, Deunff (1955) based his observations on thin sections only. Representatives of the genus were said to be characterized by two concentric shells, the inner one globular with a low extension carrying a small, circular perforation, and the outer one ornamented with long processes and cylindrical-conical expansion corresponding to the orifice of the inner shell. Henry (1969), also from thin sections, described *A. deflandrei* and noted that the "inner body" was poorly distinguished and the pore not visible. Loeblich and MacAdam (1971) referred to the studies of Deunff (1955) and Henry (1969) and pointed out that in none of the specimens obtained from the acid-insoluble residues of North American
samples was there any evidence of the presence of two concentric shells with an inner body separated from an outer body by a space between the shells. The suggested that in the case of thin sections such as interpretation would be possible "if the flattened to undulating surface of the wall was intersected by the same section". This would easily explain both the variation in the so-called separation of the two concentric shells and the common joining of the two shells with no space between. In acid-insoluble residues from Sweden, prepared and studied by Kjellström (1971a, 1976), some specimens of some species of *Aremoricanium* do show an internal nearly spherical body and an outer thin-walled flask-shaped body with processes. The same observation has been made in this study. However, specimens from the Cincinnati Region have no internal body and are more similar to forms described by Loeblich and MacAdam (1971).
Description: Vesicle flask-shaped with bulbed end which is spherical to conical; neck narrowing distally and open to vesicle cavity. Processes more than 20, elongate and cylindrical to conical with blunt tips; septations between vesicle and processes. Vesicle thin-walled with scabrate to absent surface sculpture.

Remarks: Characteristic of this species are the numerous blunt-tipped processes and the absence of central inner body.

Discussion: The specimens recovered from the Cincinnati Region closely resemble those described by Loeblich and MacAdam (1971). The neck of the flask-shaped vesicle may be flared open or may be bluntly rounded and closed distally. All specimens referable to Aremoricanium found in the Cincinnati Region are darker and browner than other acritarchs in the same assemblages but lighter than superficially similar chitinozoans.

Aremoricanium squarrosum and A. syringosagis have been considered conspecific by Eisenack and Cramer (1973). The difference, as stated in the original diagnoses of these forms (Loeblich and MacAdam, 1971), is the number of processes present on the vesicle. Aremoricanium
syringosagis was said to be characterized by the presence of fewer processes than *A. squarrosum* but the concept of the species was based on very few specimens.

The processes of the specimens studied here often contain pyrite or have square holes in the vesicle wall suggesting the previous presence of pyrite. Frequently the process tips are open due to corrosion by pyrite or by abrasion of the tips. The forms found in Kentucky basically agree in size and form with previously described specimens although shorter (minimum length = 70 μ) individuals with more processes (up to 28) are known from Kentucky.

Achab (1976) has recognized a form designated *Aremoricanium? metapediensis* Achab, 1976 from the Silurian Awantjish Formation [Upper Llandoverian] of the Gaspé peninsula of Quebec, Canada, that resembles *A. squarrosum* Loeblich and MacAdam, 1971. Her specimens were only tentatively included in *Aremoricanium* (Achab, 1976, p. 1314) because they have one wall rather than the two walls described in the original generic diagnosis by Deunff (1955). Achab's species differs from *A. squarrosum* in having conical rather than cylindrical processes which are mostly concentrated at the "aboral" end, pointed process tips, granulate - rugulate surface, and different dimensions.

Three broken specimens, tentatively included in *Aremoricanium squarrosum*, were found in samples from New York. Their measurements are given below. The distribution of these specimens is marked by question marks to record the doubtful identification of these fragments.
Dimensions: Vesicle length 70–93 µ; vesicle width 47–70 µ; neck width 4–9 µ; process length 28–63 µ; number of processes 10–28.

Table 1. Measurements of specimens *Aremoricanium squarrosum* from Cincinnati Region

<table>
<thead>
<tr>
<th></th>
<th>74MMO-1</th>
<th>76JCov-6-1</th>
<th>76JCov-6-1</th>
<th>76JCov-6-1</th>
<th>76JCov-8-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesicle length</td>
<td>111.1, 8.9</td>
<td>108.0, 14.7</td>
<td>104.8, 11.5</td>
<td>98.1, 11.0</td>
<td>100.0, 9.5</td>
</tr>
<tr>
<td>Vesicle width</td>
<td>70+ µ</td>
<td>79 µ</td>
<td>88 µ</td>
<td>93 µ</td>
<td>88 µ</td>
</tr>
<tr>
<td>Neck width</td>
<td>53 µ</td>
<td>47 µ</td>
<td>54 µ</td>
<td>58 µ</td>
<td>70 µ</td>
</tr>
<tr>
<td>Process length</td>
<td>14 µ</td>
<td>14 µ</td>
<td>16 µ</td>
<td>16 µ</td>
<td>14 µ</td>
</tr>
<tr>
<td>Process width</td>
<td>46 µ</td>
<td>28 µ</td>
<td>–</td>
<td>63 µ</td>
<td>42 µ</td>
</tr>
<tr>
<td>Number of</td>
<td>4 µ</td>
<td>4 µ</td>
<td>4 µ</td>
<td>9 µ</td>
<td>7 µ</td>
</tr>
<tr>
<td>processes</td>
<td>10+ µ</td>
<td>21 µ</td>
<td>–</td>
<td>28 µ</td>
<td>18+ µ</td>
</tr>
</tbody>
</table>

Table 2. Measurements of specimens of *Aremoricanium squarrosum* from New York

<table>
<thead>
<tr>
<th></th>
<th>KDR-22A</th>
<th>KDR119B</th>
<th>KDR119B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesicle length</td>
<td>107.2, 12.3</td>
<td>100.7, 17.8</td>
<td>103.9, 17.8</td>
</tr>
<tr>
<td>Vesicle width</td>
<td>61 µ</td>
<td>70+ µ</td>
<td>70+ µ</td>
</tr>
<tr>
<td>Neck width</td>
<td>53 µ</td>
<td>42 µ</td>
<td>54 µ</td>
</tr>
<tr>
<td>Process length</td>
<td>–</td>
<td>7 µ</td>
<td>11 µ</td>
</tr>
<tr>
<td>Process width</td>
<td>–</td>
<td>11+ µ</td>
<td>26+ µ</td>
</tr>
<tr>
<td>Number of</td>
<td>–</td>
<td>8+ µ</td>
<td>8+ µ</td>
</tr>
<tr>
<td>processes</td>
<td>–</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky.

Possible *A. squarrosum* - Kings Falls Fm., Middle Ordovician [Kirkfieldian], Deer River, New York; Sugar River Fm., Middle Ordovician [Shermanian], Deer River, New York.

**Previously reported occurrences:** Eden Fm. [= Kope Fm.], Upper Ordovician [Edenian] Indiana, Ohio (Loeblich and MacAdam, 1971); Ordovician subsurface material, Saudi Arabia (Hemer, 1968); Sylvan Fm., Upper Ordovician, Oklahoma (Loeblich and MacAdam, 1971); subsurface, Upper Ordovician [Caradocian], Aquitaine, France (Rauscher, 1973).
Genus *Baltisphaeridium* Eisenack 1958, emended Eisenack, 1969


1931 *Ovum* Eisenack (pars), p. 110

1937 *Hystrichosphaeridium* Deflandre (pars), p. 51-103

1958 *Baltisphaeridium* Eisenack, p. 398

1969 *Baltisphaeridium* Eisenack, p. 246-250.

**Description:** Vesicle single-walled or double-walled, spherical to subspherical; outline circular to subcircular. Processes more or less homomorphic, regularly distributed; tips closed distally, usually simple, rarely branching, usually hollow, mostly acuminate; contact with vesicle usually angular; septation between vesicle and processes. Vesicle sculpture may be the same or different from process sculpture, echinate to absent. Processes number more than three.

**Remarks:** Distinguishing features are the spherical vesicle and simple processes without free communication to the vesicle. The concept of a double wall in some species is elucidated in the Discussion of *Baltisphaeridium latiradiatum* (p. 116).

**Discussion:** Deflandre (1937) proposed *Hystrichosphaeridium* for forms with a vesicle diameter exceeding 20 μ and *Micrhystridium* for forms with a vesicle diameter less than 20 μ. Eisenack (1958a) restricted *Hystrichosphaeridium* to forms with processes open at the tips,
retaining *Micrhystridium* for small forms with closed process tips. He introduced *Baltisphaeridium* for species with a vesicle diameter less than 20 μm and with closed process tips and without tabulation.

Staplin (1961) argued against the significance of 20 μm diameter as a distinctive generic character. He stated, therefore, that *Baltisphaeridium* Eisenack, 1958, should be regarded a junior synonym of *Micrhystridium*. He did, however, remove acritarchs with furcate tips from *Micrhystridium* Deflandre, emended Staplin, and introduced *Multiplicisphaeridium* Staplin, 1961. He felt all forms with simple processes were most appropriately referred to *Micrhystridium*.

Eisenack (1962b) rejected Staplin's suggestion on the grounds that it was too simple to differentiate genera on the basis of branched *Multiplicisphaeridium* Staplin, 1961] and unbranched [Micrhystridium Deflandre, emended Staplin, 1961] processes. Downie (1963) subdivided "acritarchs with relatively large spherical bodies and hollow spines (Baltisphaeridium)" into four subgroups: a) one with smooth and generally simple spines, which included *B. longispinosum* and *B. brevispinosum*; b) one with branched or unbranched spines [processes] which are ornamented with small tubercles. This subgroup included *B. granulatispinosum* and *B. robustispinosum*; c) one with forms with dark spherical bodies and pale-colored short processes which included *B. meson* and *B. dilatispinosum*; and d) one with forms with smooth, branching spines including *B. ramuculosum* [now mostly referred to *Multiplicisphaeridium*] and others.

Cramer (1964b) recognized three subgroups within *Baltisphaeridium*; a) one with "dark central bodies bearing pale-colored hollow processes;
b) one with dark central bodies enveloped by a transparent shell"; and
c) a heterogeneous group of baltisphaerids including species attribut­
able to groups a, b and d of Downie (1963). Later, Cramer (1970a)
disclaimed the value of using the number of wall layers as a diagnostic
character at the generic level. This philosophy is accepted here with
some discretionary exceptions.

Downie and Sarjeant (1963) reported data to support the idea that
a vesicle diameter greater or smaller than 20 μ is a useful criterion
for distinguishing two groups of taxa with closed-tipped processes and
untabulated vesicles. Among the 204 Paleozoic species examined by them,
only ten straddled the boundary of 20 μ.

Staplin et al. (1965) offered a restricted diagnosis for
Baltisphaeridium on the basis of process structure. This (1965) stated,
"spine wall...in structure differentiated from the vesicle...spine
initially hollow, gradually becoming solid in the mature stages," and
separated such forms from those with branching processes open to the
vesicle cavity (Multisplicisphaeridium (Staplin) restricted, 1965).
Staplin et al. (1965) proposed five other genera, all based on forms
removed from Baltisphaeridium on the basis of process type.

Eisenack (1969) accepted Multisplicisphaeridium Staplin et al.
(1965). He emended Baltisphaeridium to include spherical forms
greater than 30 μ with mostly unbranched, distally closed processes,
which in most cases are not open to the vesicle cavity. In this formal
emendation, Eisenack chose explicitly not to define the genus narrowly
on the basis of vesicle/spine communication, process-tip hollowness, or
the simple/furcate nature of the tips.
Cramer (1970a) skeptically discussed the evidence of bimodality of vesicle diameter in *Baltisphaeridium/Micrhystridium* as previously reported by Downie and Sarjeant (1963) and stated his strong disbelief in the significance of such a distinction. Cramer did, however, follow the emendation of *Baltisphaeridium* by Staplin et al. (1965) and considered process morphology to be of generic significance. Furthermore, Cramer added that "wall structure is not a stable generic differentiator" because it is "probably influenced by environmental factors."

Lister (1970) retained the emendation of Downie and Sarjeant (1963) whereas Kjellström (1971a, 1976) accepted Eisenack's (1969) emendation. In so doing, Kjellström noted that his own material supported "the structural differences between vesicle wall and process wall" as suggested by Staplin et al. (1965). Kjellström, (1971a) preferred "not to consider them [the structural differences] for the time being as a basis for generic differentiation."

Species assigned to *Baltisphaeridium* in this study show simple process tips. They have processes which are either solid, or hollow with a septation between process and vesicle. Forms that have hollow processes with free communication to the vesicle have not been assigned to *Baltisphaeridium*. 
Baltisphaeridium annelieae Kjellström 1976
Pl. I, fig. 1.

1976 Baltisphaeridium annelieae Kjellström, p. 10-12,
fig. 5.

Description: Vesicle single-walled, spherical; outline circular to elliptical; processes numerous, homomorphic, hollow, slightly conical to cylindrical, length not exceeding vesicle diameter; tips simple, acuminate; process contact with vesicle angular; septation between processes and vesicle; processes sculpture echinate, vesicle sculpture absent.

Remarks: Baltisphaeridium annelieae Kjellström, 1976, is part of a group of continuously variable forms that have a smooth to shagrinate vesicle with numerous smooth to echinate processes that range in length from about 1/10th the vesicle diameter to slightly less than the vesicle diameter. Baltisphaeridium multipilosum (Eisenack, 1931) is a member of this group. Although it was not described originally as having ornamented processes, photographs published later by Eisenack (e.g., 1965b, Pl. 12, fig. 14) show processes that are ornamented rather than smooth, as reported in the original description of B. annelieae. The combination of process sculpture, smooth vesicle, and the number of processes are considered the distinguishing characters of this species (Kjellström, 1976, p. 13, 20).

Discussion: In material from the Cincinnati Region, the process length is frequently significantly less than approximately one-half the
vesicle diameter as reported in the original description of the species by Kjellström (1976, p. 112). Nevertheless, the granulate to echinate process sculpture, sometimes found only on the process tips, combined with the unsculptured vesicle, justify reference of these forms to _B. anneliae_ Kjellström, 1976.

Excystment by partial rupture, as reported by Kjellström (1976), is seen in my specimens of this species as a straight tear or several tears forming a pseudopolygonal broken portion of the vesicle wall. It is possible that this "excystment structure" is in reality a consequence of vesicle breakage caused by compaction.

This species may be related to _Baltisphaeridium hirsutoides_ (Eisenack, 1931), which is characterized by wholly unsculptured, pointed processes and an unsculptured vesicle. These species often occur together.

**Dimensions:** 24 specimens. Vesicle diameter 35 (44) 55 μ; process length 6-40 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.

**Previously reported occurrences:** Subsurface, Middle Ordovician [Lower Viruan], Östergötland, Sweden (Kjellström, 1976).
Baltisphaeridium hirsutoides (Eisenack, 1951)
Pl. I, fig. 9, 10.

1931 Ovum hispidum cf. hirsutum Eisenack, p. 111, Pl. 5, fig. 19.

1938 Hystrichosphaeridium cf. hirsutum Eisenack, p. 12, Pl. 1, fig. 11.

1951 Hystrichosphaeridium hirsutoides Eisenack, p. 180, Pl. 3, fig. 8.

1959 Baltisphaeridium hirsutoides Eisenack, p. 196.

1959 Hystrichosphaeridium hirsutoides Timofeev, p. 52, Pl. 4, fig. 5.

1962 Baltisphaeridium hirsutoides Eisenack, p. 359, Pl. 44, fig. 4-7.

Description: Vesicle single-walled, spherical to ellipsoidal; outline circular to subcircular; processes homomorphic, hollow to solid, cylindrical to conical, length not exceeding vesicle diameter; tips simple, acuminate; process contact with vesicle angular; septations between processes and vesicle; vesicle and process without sculpture.

Remarks: This species is distinguished by its unsculptured vesicle and the acuminate, unsculptured, hollow processes with a length exceeding the vesicle diameter.

Process plugs are not recognized here as a specific character. Therefore, specimens with plugs have not been placed in Baltisphaeridium chistoferii Kjellström, 1976, which is a species with processes plugs but which is otherwise identical to B. hirsutoides.

Baltisphaeridium plicatispinae Gorka, 1969, has been distinguished from B. hirsutoides by having wrinkled processes. Some forms found in
my collections have part of one, or part of a few processes wrinkled. However, no specimens from the Cincinnati Region resembles closely the specimens of _P. plicatispinae_ illustrated by Gorka (1969) or Kjellström (1971b, 1976).

**Discussion:** Like _Baltisphaeridium longispinosum_, the present species lacks sculpture. It differs from _B. longispinosum_ in having shorter processes. _Baltisphaeridium hirsutoides_ belongs to a complex of forms with a variety of sculpture, and intergrading varieties are often found. The designation of _B. hirsutoides_ is here used only for forms which unambiguously possess all the characters mentioned in the description above.

_Baltisphaeridium hirsutoides_ is differentiated from _B. brevispinosum_ (Eisenack, 1931) by the presence of acuminate process tips in the former species and evexate or bulbous tips in the latter form.

_Baltisphaeridium bohemicum_ (Eisenack, 1934) has a much larger vesicle (ca. 120 μ) than that of _B. hirsutoides_.

_Baltisphaeridium nanum_ (Deflandre, 1945) differs by having a very different type of process. There is free communication between process and vesicle and the contact between process and vesicle is curved rather than angular. It is likely that _B. nanum_ actually represents a species of _Polygonium [= Goniosphaeridium]_ Vavrdova, 1965.

_Baltisphaeridium hirsutoides_ (Eisenack, 1931) is part of several continuous series of morphologic types. In one sense, it is the morphologically intermediate, unsculptured form between _B. multipiliosum_ (Eisenack, 1931) with its numerous, short processes and _B. longispinosum_,
which has fewer and longer processes. In another sense, *B. hirsutoides* is the unsculptured end-member of a series of smooth-walled forms with ornamented processes, *B. annelieae* Kjellström, 1976, being an echinate form.

*Baltisphaeridium hirsutoides* can also be considered as end-member of a series of baltisphaerids with no sculpture that have shorter processes than the vesicle diameter, and variable amounts of inflation of the processes and contriction of the process base. This series includes *B. lancettispinae* Gorka 1969, *B. plicatispinae* Gorka, 1969, and *B. latiradiatum* Eisenack, 1959.

Insofar as identification is concerned, *B. hirsutoides* is simpler to separate from the others on the basis of ornament than by evaluating process size. When well-preserved, as are the specimens from the Cincinnati Region, the lack of sculpture, when viewed with oil-immersion under transmitted light, is usually unambiguously visible. However, in the light microscope, it is not possible to distinguish finely granulate forms from forms with slightly corroded appendages. SEM examination of such related forms is useful for corroborating the presence of *B. hirsutoides*.

Because of the tentative identification of forms from New York, their distribution is preceded by a question mark.

**Dimensions:** 35 specimens. Vesicle diameter 40 (52) 71 μ; process length 12-49 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper
Ordovician [Maysvillian], Cincinnati, Ohio; Grant Lake Limestone, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry Kentucky. Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky. ?Denley Fm., Upper Ordovician [Edenian], Trenton Falls, New York; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, New York.

Previously reported occurrences: Erratics, Ordovician, Baltic Region (Eisenack, 1931, 1938, 1959, 1962b, 1965b, 1968b); Lower Ordovician, Estonia (Eisenack, 1951); Subsurface, Lower Ordovician [Upper Arenigian] Poland (Gorka, 1969); subsurface, Middle Ordovician [Lower Viruan], Gotland, Sweden (Kjellström, 1971a); Lower Ordovician [Arenigian], Montagne Noire, France (Rauscher, 1973); subsurface Lower-Middle Ordovician [Arenigian-Llanvirnian], Aquitaine Basin, France (Rauscher, 1973); Bothnian Sea, Middle Ordovician (Tynni, 1975), Finland; subsurface, Middle Ordovician (Lower Viruan), Östergötland, Sweden (Kjellström, 1976).
Baltisphaeridium ingerae Kjellström, 1976, Pl. I, fig. 4.


Description: Vesicle single-walled, spherical; outline circular to sub-circular; processes numerous, conical, hollow, homomorphic, their length not exceeding the vesicle diameter; tips simple, acuminate. Process contact with vesicle angular; septation between processes and vesicle cavity; process sculpture echinate, vesicle sculpture granulate.

Remarks: Kjellström (1976) distinguished this species from B. annelieae by its fewer processes and granulate vesicle surface.

Discussion: This form is clearly related to B. annelieae and others. The forms found in rocks from the Cincinnati Region and New York State exhibit a greater size range than those from the Baltic (Kjellström, 1976) and also have longer processes. Kjellström (1976) did not state how many specimens he examined in calculating the size range of this species.

Dimensions: 10 specimens. Vesicle diameter 35 (50) 70 μ; process length 14-35 μ.

Distribution: Kope Fm., Upper Ordovician [Edenian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Cincinnati, Ohio; Steuben
Fm., Upper Ordovician [Edenian], Trenton Falls, New York; Denley Fm., Upper Ordovician [Edenian], Martinsburg, New York.

Previously reported occurrences: Subsurface, Middle Ordovician [Lower Viruan], Östergötland, Sweden.
Baltisphaeridium cf. klabavense Vavrdova, 1965
Pl. I, fig. 2; fig. 16a

1964 Micrhystridium sp. Wray, p. 94, Pl. 1, fig. 9
cf. 1965 Baltisphaeridium longispinosum klabavense Vavrdova, p. 353,
Pl. 2, fig. 1.
non 1970 Baltisphaeridium uncinatum Burmann, p. 309
1971 Orthosphaeridium densiverrucosum Kjellström, p. 30, fig. 20.

Description: Vesicle single-walled, spherical; outline circular.
Processed hollow, conical, inflated proximally, homomorphic, radially
arranged; tips closed distally, simple, acuminate. Process constricted
at contact with vesicle; septations between processes and vesicle
cavity. Process and vesicle sculpture granulate.

Remarks: Baltisphaeridium cf. klabavense belongs to a group of several
species with hollow, conical processes, which are inflated and have a
constriction at the contact between the vesicle and process. Charac-
teristics in the vesicle and process structure separate species of
this group. Therefore, the type of process and the granulate sculpture
on both the vesicle and the process are the diagnostic characters of
this form.

Baltisphaeridium klabavense Vavrdova has been defined as having
"small spines about 1 micron in size" (Vavrdova, 1965). The sculpture
on this form was redefined as verrucate by Kjellström (1971b, p. 14).
By verrucate, Kjellström (1971a, p. 13) meant "wall with warty
projections greater than 0.5 microns." This verrucate sculpture is evenly distributed on both vesicle and processes in _B. klabavense_. The process length of _B. klabavense_ does not exceed the vesicle diameter (Kjellström, 1971b, p. 14).

Specimens from New York agree with the description of _B. klabavense_ in size, process/vesicle ratio, and evenness of sculpture distribution. My specimens do not have grana greater than 0.5 μ, therefore open nomenclature is used.

_Baltisphaeridium constrictum_ Kjellström, 1971a has a granulate vesicle, but no sculpture on the processes and the processes are longer than the width of the vesicle. The lack of these characteristics separates the New York forms from the latter species.

**Discussion:** Vavrdova (1965) described _Baltisphaeridium klabavense_ on the basis of specimens of imperfect or fair preservation from Bohemia as a form with "thick-walled central body...processes numerous...thin-walled, often curved, with narrow, sometimes thickened bases."

Kjellström (1971a) described a similar form from the Middle Ordovician of Gotland as having a thin vesicle wall. Neither author gave quantitative data on the wall thickness. Forms from New York are more similar in quality of preservation to those described by Vavrdova (1964) than are Kjellström's specimens.

_Baltisphaeridium klabavense_ is similar to _Orthosphaeridium densiverrucosum_ Kjellström, 1971a. In the diagnosis, Kjellström stated that _O. densiverrucosum_ had a thick vesicle wall, eight processes, transverse excystment structure, and that it had a subquadrate vesicle
of slightly smaller dimensions than that in \textit{B. klabavense}. His photograph of the holotype shows a compressed specimen with a darker vesicle than that of a specimen of \textit{B. klabavense}, which he obtained from two meters higher in the same core.

No measurements of the difference in wall thickness between the two species were given by Kjellström (1971a). However, judging from his plates, the vesicle wall thickness of \textit{O. densiverrucosum} seems to be less than 0.5μ and not significantly thicker, if at all, than the vesicle wall thickness of \textit{B. klabavense}.

In Vavrdova's diagnosis of \textit{B. longispinum klabavense}, she states that her specimens have 12 to 20 processes. It is likely, however, that individuals of this species with fewer than 12 processes have a subquadrate vesicle shape as is the case in veryhachid species (Cramer, 1970).

"Transverse excystment" versus "excystment formed as a partial rupture" cannot be considered significantly different unless bilateral symmetry can be recognized in the specimens. \textit{Orthosphaeridium densivernucosum}, as illustrated by Kjellström (1971a), shows some rounding in the wall outline of the compressed vesicles and no clear bilateral symmetry. Also, the size of the two species, as illustrated at 600x, is very similar.

The darkened vesicle wall may, in fact, be the only diagnostic feature separating the two species, especially considering the remarkable preservation of Kjellström's material. However, it is not well understood just what causes this difference in wall color between two species or two specimens in the same preparation. Unfortunately, the
Fig. 16 - Process morphology. a, *Baltisphaeridium* cf. *klabavense*. Process and vesicle finely granulate and process constricted at contact with vesicle; b, *B. klabavense*. Process and vesicle coarsely granulate and process constricted at contact with vesicle; c, *B. calcispinae*. Process and vesicle spinose and process constricted at contact with vesicle; d, *B. constrictum*. Sculpture absent on process. Vesicle granulate with process constricted at contact with vesicle; e, *B. latiradiatum*. Sculpture absent on process and vesicle, and process constricted at contact with vesicle; f, *B. distentum*. Sculpture absent on process and vesicle. Some processes constricted and some unconstricted at contact with vesicle; g, *B. plicatispinae*. Sculpture absent on process and vesicle. Processes faintly constricted at contact between vesicle and characteristic wrinkled process; h, *B. lancettispinae*. Sculpture absent on process and vesicle with process unconstricted at contact with vesicle; i, *B. areolatum*. Process and vesicle finely granulate with process constricted at contact with vesicle. Note depression in vesicle surrounding process insertion.
illustration of the holotype of _B. klabavense_ Vavrdoa, 1965, shows that it is less well preserved than Kjellström's material and the entire specimen is nearly opaque.

For reasons stated above, the two species are probably conspecific. They are treated here as synonyms until a clearer distinction in wall thickness can be recognized, modal analysis of process number has been conducted, or the cause of the difference in vesicle color is better understood.

The process morphology of _B. cf. klabavense_ (Text-fig. 16a) is similar to that in several other forms (Text-fig. 16a-i). These include _B. klabavense_ Vavrdoa, 1965 (Text-fig. 16b), _B. calcispinae_ Gorka, 1969 (Text-fig. 16c), _B. constrictum_ Kjellström, 1971 (Text-fig. 16d), _B. latiradiatum_ (Eisenack, 1959) (Text-fig. 16e), _B. distentum_ Playford, 1977 (Text-fig. 16f), _B. plicatispinae_ Gorka, 1969 (Text-fig. 16g), _B. lancettispinae_ Gorka 1969 (Text-fig. 16h) and _B. areolatum_ Jardine et al., 1974 (Text-fig. 16i). This process shape, characteristically inflated, conical, and constricted at the base, is probably a good basis for grouping these species in a separate genus. Loeblich (1970a) has proposed _Actipilion_ for such apparently double-walled, spherical acritarchs with thin-walled processes formed from the outer wall. The type-species, _A. druggi_ Loeblich, 1970, although probably more closely related to _B. plicatispinae_ Gorka, 1969, or _B. lancettispinae_ Gorka, 1969, is very similar in size and appearance to _B. latiradiatum_. However, _A. druggi_ has blunt process tips and absence of proximal process constriction. The reason why _Actipilion_ Loeblich has not been adopted here is that _Actipilion_ is defined (Loeblich,
1970, p. 710) as having "wall of processes thin, filmy and readily detached." It is believed that the thinness of the process wall is a feature that excludes from the genus several species like Baltisphaeridium klabavense, which I believe to be closely related to Baltisphaeridium latiradiatum. Baltisphaeridium constrictum with granulate sculpture on the vesicle only, B. latiradiatum with essentially no sculpture, and B. klabavense with verrucate sculpture are nearly identical in appearance except for their sculpture. Baltisphaeridium distentum differs from B. latiradiatum by having heteromorphic processes. Baltisphaeridium plicatisspinae is characterized by wrinkled processes and poorly defined, if any, constrictions. Baltisphaeridium areolatum has a depression in the vesicle surrounding the process insertion and may have only remote affinities with the other species in this group.

There seems to be little justification for the placement (Burmann, 1970) of B. longispinosum var. klabavense Vavrdova, 1965, in synonymy with Baltisphaeridium uncinatum (Downie, 1958).

**Dimensions:** 4 specimens. Vesicle diameter 70, 67, 61, 46, \( \mu \). process length 21-30 \( \mu \); process width 3-9 \( \mu \).

**Distribution:** Kings Falls Fm., Middle Ordovician [Kirkfieldian], City Brook, New York; Denley Fm., Upper Ordovician [Edenian], Martinsburg, New York; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, New York. Clays Ferry Fm., Upper Ordovician [Edenian] Clay's Ferry, Kentucky.
Previously reported occurrences: Klabava Shale, Lower Ordovician (Arenigian], Central Bohemia, Czechoslovakia (Vavrdova, 1965); subsurface, Ordovician, Libya, Tunisia, Saudi Arabia (Cramer, 1970a); subsurface, Middle Ordovician [Lower Virian], Gotland, Sweden; subsurface Middle Ordovician [Lower Virian], Öland, Sweden (Kjellström, 1972); Lower Ordovician [Arenigian], Montagne Noire, France (Rauscher, 1973); Middle and Upper Ordovician [Llanvirnian-Ashgillian], Algeria (Jardine, et al., 1974); Sarka Fm., Middle Ordovician [Llanvirnian], Central Bohemia (Vavrdova, 1977).
Baltisphaeridium latiradiatum (Eisenack, 1959)
Pl. I, fig. 5; fig. 16e.

1931 Ovum hispindum longispinosum Eisenack (pars), p. 110, Pl. 5, fig. 14, 15. (non Pl. 5, fig. 16, 17).

1938 Hystrichosphaeridium longispinosum Eisenack (pars), p. 121, Pl. 1, fig. 1-3.

1939 Baltisphaeridium longispinosum latiradiata Eisenack, p. 195, Pl. 15, fig. 4.

1959 Hystrichosphaeridium quadriradiatum Timofeev, p. 57, Pl. 4, fig. 25.

1959 Hystrichosphaeridium stellaformae Timofeev, p. 57, Pl. 4, fig. 26.


1960 Hystrichosphaeridium sp. 4 Hedlund [unpublished M.S.], p. 22, Pl. 2, fig. 7, 10, 11.

1960 Hystrichosphaeridium sp. 8 Hedlund [unpublished M.S.], p. 25, 26, Pl. 2, fig. 2, 3.

1960 New Genus B, sp 1, Hedlund [unpublished M.S.], p. 37, 38, Pl. 5, fig. 9.

1965 Baltisphaeridium latiradiatum Staplin et al., p. 189, Pl. 20, fig. 3-5, 9, text-fig. 13.

1966 Baltisphaeridium cognitum Timofeev, p. 183, Pl. XXXVI, fig. 8.

1966 Baltisphaeridium longispinosum Timofeev, Pl. 84, fig. 5.

1967 Ovum hispidum longispinosum W. Wetzel, p. 38, Pl. 1, fig. 3 non Pl. 1, fig. 4-6.

1970 Baltisphaeridium latiradiatum Burmann, p. 309, Pl. XIV, fig. 3, 4.

Description: Vesicle double-walled, spherical to oval; outline circular to subcircular. Processes homomorphic, hollow, conical, inflated, radially arranged; tips closed, simple, acuminate; process contact with
vesicle constricted; septations between processes and vesicle cavity.
Vesicle sculpture fine to absent; process sculpture absent.

Remarks: Baltisphaeridium latiradiatum is one of several species of this genus that has inflated conical processes, which are constricted at the junction with the vesicle. Sculpture of vesicle and processes are diagnostic of the species. Kjellström (1971a) states that the process length always exceeds the vesicle diameter. This is not the case in the specimens from the Cincinnati Region, and this may not be a dependable taxonomic criterion. Staplin et al. (1965, Pl. 9) also illustrated a specimen that appears to have a vesicle diameter exceeding the process length.

Discussion: In illustrations published by Staplin et al. (1965), it is clear that Baltisphaeridium latiradiatum is double-walled, yet the recognition of the two walls is probably a semantic problem rather than an observational one. Kjellström (1971a) illustrated the same species, and described it as having a single wall. It was found in this study, that one way to recognize a double wall is to observe hollow processes of a different wall thickness than the vesicle when a septation is present between the process and the vesicle cavity. These processes are separated from the vesicle interior by a wall (septation) continuous with, and apparently the same as, the inner vesicle wall. This way of recognition of two walls is useful for numerous acritarch specimens belonging to many genera.
There is a similarity between this species and several other taxa. It is distinguished from *B. distentum* Playford, 1977, which has heteromorphic processes, from *B. plicatispinae* Gorka, 1969, which lacks the constricted process base and has wrinkled processes, from *B. constrictum* Kjellström, 1971, which has granulate sculpture, from *B. klabavense* Vavrdova, 1965, which has echinate sculpture, and from *B. lancettispinae* Gorka, 1969, which has processes with no constriction at the vesicle junction. (For further discussion of this subgroup, see "Discussion" of *B. klabavense*, p. 109).

*Dilatisphaera laevigata* Lister, 1970 may be related to *B. latiradiatum*. The figured specimens from Ludlovian rocks in Shropshire are considerably smaller than *B. latiradiatum* and the process tips are open distally. The poor preservation of these specimens may account for the process tips being open and for interpretation of an excystment suture. Likewise, *D. [Hystrichosphaeridium] willeriae* Martin, 1965, may also be related to this group, and may have been separated on the basis of preservational artifacts.

**Dimensions**: 2 specimens. Vesicle diameter 65, 53 μ; process length 39 (47) 65 μ; process width 7 (10) 11 μ.

**Distribution**: Kope Fm., Upper Ordovician [Edenian], Cincinnati, Ohio.

**Previously reported occurrences**: Baltic erratics, Lower Ordovician (Eisenack, 1959); Lower Ordovician [Arenigian] Volgda, USSR (Timofeev, 1959); Sylvan Shale, Upper Ordovician [Ashgillian], Oklahoma, (Hedlund,
unpublished M.S., 1960); Schroeteri Ls. (=Folkeslunda Ls.), Middle Ordovician [Upper Llanvirnian] and lower Ludibundus Ls. (=Dalby Ls.), Middle Ordovician [Lower Caradocian], Öland, Sweden (Staplin et al., 1965); subsurface, Upper Ordovician, Kibatai, Litovsk, SSR (Timofeev, 1966); Locality A/39 a (only locality designation reported) Middle Ordovician [Upper Llanvirnian], D.D.R. (Burmann, 1970); subsurface, Middle Ordovician [Lower Viruan], Gotland, Sweden (Kjellström, 1971a); subsurface, Middle Ordovician [Lower Viruan], Öland, Sweden (Kjellström 1972); subsurface, Lower Ordovician [Arenigian-Llanvirnian—may be somewhat younger—author], Aquitaine Basin, France (Rauscher, 1973); Bothian Sea, Middle Ordovician, Finland (Tynni, 1975); Vaginatum-kalk, Lower-Middle Ordovician [Upper Arenigian-Lower Llanvirnian], Öland, Sweden (Eisenack, 1976).
Baltisphaeridium cf. psilatum Kjellström, 1971
Pl. I, fig. 7

1971a Baltisphaeridium psilatum Kjellström, p. 39, Pl. 2, fig. 10.

Description: Vesicle single-walled, spherical to subspherical; outline circular to subcircular; processes numerous, short, conical, hollow to solid, homomorphic; tips acuminate, simple; process contact with vesicle curved; septations between processes and vesicle cavity; vesicle sculpture fine to absent; process sculpture absent.

Remarks: Kjellström (1971a) considered the large excystment opening, the vesicle size, and the short, conical processes as the characteristic features of this species although the curved proximal process contact with the vesicle and lack of sculpture are also critical for identification.

Discussion: Apparently, it is the vesicle size range (77-86 μ) of Baltisphaeridium brevifilicum, as compared to the size range (55-61 μ) of B. psilatum Kjellström, 1971a, and the excystment type that characterize B. brevifilicum. However, specimens from the Cincinnati Region have the excystment type of B. brevifilicum and the size range of B. psilatum. For this reason, the cf. designation has been used. Kjellström (1971a) measured eight specimens of the larger B. brevifilicum and 13 specimens of the smaller B. psilatum. Therefore, to include the forms in only a single taxon requires determination if
the size or the mode of excystment is the more important taxonomic character. Because the so-called excystment structure is not a distinctive morphological feature and has excystment as its only function, and because it is not as distinctive as a pylome or a medial split but is rather an occasional multiple subpolygonal straight rupture, the relative size has been considered more important, although admittedly with ambivalence. Accordingly the specimens have been referred to as B. cf. *psilatum*.

Measurements of these specimens show the processes of B. cf. *psilatum* to be smaller than the ones from the Baltic Region measured by Kjellström.

*Baltisphaeridium multipilosum* (Eisenack, 1931), although similar to specimens of B. cf. *psilatum* in rupture and size of processes, has a larger vesicle size range (70-86 μ) and an angular process contact with the vesicle.

**Dimensions**: 20 specimens. Vesicle diameter 35 (51) 67 μ; process length 2-7 μ.

**Distribution**: Kope Fm., Upper Ordovician [Edenian], Covington and Maysville, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Cincinnati, Ohio.

**Previously reported occurrences**: subsurface, Middle Ordovician [Lower Viruan], Gotland, Sweden (Kjellström, 1971a).
Baltisphaeridium sp. A
PI. II, fig. 1, 2, 3.

Description: Vesicle single-walled, spherical to subspherical; outline circular to roundly polygonal. Processes about eight, longer than the vesicle diameter, conical, hollow, homomorphic, and radially arranged; tips closed distally, simple, acuminate; process contact with the vesicle angular; septations between processes and vesicle cavity; process sculpture granulate. Vesicle sculpture absent. Slightly constricted process at vesicle junction.

Remarks: This species is characterized by its process length, shape and sculpture, combined with the unsculptured spherical vesicle. In the SEM, well-spaced, equidimensional grana are visible on the processes and the lack of sculpture on the wall is obvious.

Baltisphaeridium sp. A is part of a continuously variable series including B. annelieae Kjellström, 1976, at one end and B. klabavense Vavrdova, 1965 [Orthosphaeridium densiverrucosum Kjellström, 1971] at the other end. Specimens of Baltisphaeridium sp. A, with few processes, resemble species of Orthosphaeridium Eisenack, 1968. Placing these specimens from the Cincinnati Region in Orthosphaeridium is unwarranted as the bilateral symmetry in these specimens is not recognizable and neither a medial split nor rectangular vesicle shape is apparent.

Discussion: Six species of Baltisphaera Burmann, 1970, show some resemblance to Baltisphaeridium sp. A. They have a spherical vesicle
and long processes with a constriction at the vesicle contact.

Eisenack and Cramer (1976, p. 93) consider *Baltisphaera* a synonym of *Orthosphaeridium*. The specimens illustrated by Burmann (1970) in some cases show a medial split in the vesicle, one of the diagnostic features of that genus. Loeblich and Tappan (1971b) consider the genus *Orthosphaeridium* to be characterized by pillow-shaped, ovoid to rectangular vesicles with vesicle ornamentation ranging from granulate to smooth, the unsculptured forms being evolutionarily advanced forms. Some of the species of *Baltisphaera* Burmann definitely have a spherical vesicle and the medial split is lacking. *Baltisphaeridium* sp. A has no vesicle sculpture, no medial split, and probably has a spherical vesicle. It is likely that these forms are related.

*Baltisphaeridium* sp. A closely resembles specimens figured by Burmann (1970) of *Baltisphaera abbreviata*, *Baltisphaera procera*, *Baltisphaera quadricornis*, *Baltisphaera transitoria*, and *Baltisphaera quadrinata* with major diagnostic characters being the number of processes, relatively minor variations in vesicle morphology, and the fine sculpture. *Baltisphaeridium* sp. A is distinct from *Baltisphaera tertatum* and *Baltisphaera occultata*, which have obviously different sculpture patterns.

*Baltisphaeridium* sp. A is not referable to *Orthosphaeridium* because it does not fall within the circumscription of *Orthosphaeridium* in terms of vesicle shape. For this reason, it is retained in *Baltisphaeridium*.

Loeblich and Tappan (1971b) suggested evolutionary trends for species of *Orthosphaeridium* that may apply also to *Baltisphaeridium* sp.
A, despite the legalistic reasons for excluding this species from *Orthosphaeridium*. Loeblich and Tappan found a relative decrease in the development of sculpture through time. Vesicle sculpture disappeared for the first time in the genus in rocks younger than Edenian. *Baltisphaeridium* sp. A shows no vesicle sculpture under SEM and can be well-documented in rocks collected from the upper nine feet of the Edenian Kope Formation at Maysville, Kentucky and in the Edenian Clays Ferry Formation at Clay's Ferry, Kentucky. It also appears in assemblages from the Maysvillian Stage.

**Dimensions:** 7 specimens. Vesicle diameter 74, 67, 65, 61, 47, 45, 41 µ; process length 18–70+ µ (broken).

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Grant Lake Limestone, Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
**Baltisphaeridium sp. B**

**Pl. I, fig. 3**

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to subcircular; processes homomorphic, conical, hollow, and of variable length; tips simple (?), acuminate; process contact with vesicle curved; septations between processes and vesicle cavity; vesicle and process sculpture coarsely echinate.

**Remarks:** Although the only two specimens found were damaged, a diagnostic, and previously not described, form is recognized. The process and vesicle sculpture consists of sharply pointed cone–shaped spines. This, combined with the unconstricted process base, separates the form from several similar species like *B. pustulatum* Kjellström, 1971, *B. pauciverrucosum* Kjellström, 1971, *B. klabavense* Vavrdova, 1965, and *B. verrucatum* Kjellström, 1971.

*Baltisphaeridium spinigerum* Gorka, 1969, has a process sculpture which is most similar to that in the present form, but has a reticulate vesicle, rare ellipsoidal pylome, and rare bifurcate processes.

However, because of the poor condition of the two specimens at hand, it appears unjustified to propose a new species and the designation *Baltisphaeridium* sp. B is used herein.

**Dimensions:** 2 specimens. Vesicle diameter 63 μ, 70 μ; process length 20-58+ μ; process width 3-7 μ; spine length 1-2.5 μ; spine width 1 μ.

**Distribution:** Denley Fm., Upper Ordovician [Edenian], Deer River, New York.
Genus *Dicommopalla* Loeblich, 1970

**Type species:** *Dicommopalla macadamii* Loeblich, 1970

**Description:** Vesicle double-walled, spherical to subspherical; outline circular to oval; inner wall thick, firm; outer wall thin, easily folded, easily eroded. No processes present. Pylome often present, with a thickened annulus or rim; double pylomes occur occasionally.

**Remarks:** Particularly diagnostic features of the genus are the presence of a double-walled vesicle, the characteristic folding of the outer wall and the presence of a double pylome.

**Discussion:** Loeblich (1970b) distinguished this genus from *Leiosphaeridia* Eisenack, 1958, by its double wall, the roughly finished surface of the outer wall, and the microgranulate inner wall sculpture.

*Granomarginata* Naumova, 1969 was described [translation in Norris and Sarjeant, 1965] as "spore circular or oval-circular. Exine fragile or desne with thickened edge. Surface of exine granular with or without crumped folds. Diameter 19-15 μ". Although *Granomarginata* has a superficial resemblance to *Dicommopalla* when examined in transmitted light, it differs by being smaller, single-walled, and lacking a pylome.

Eisenack (1965b, p. 144, Pl. 11, fig. 12a, b) reported *Cymatosphaera* sp. from the Ostseekalke, Gotland. From the illustration...
this form, with a diameter of about 80 µ, appears to have a two-layered wall. No pylome is visible in the illustration. There are examples of *Dicommopalla* from the Cincinnati Region that do not have pylomes.
**Dicommopalla macadamii** Loeblich, 1970
Pl. II, fig. 4-11.


**Description:** Vesicle double-walled, spherical to subspherical; inner layer thin, outer layer thinner with irregular folds which in some cases appear rugulate to reticulate in transmitted light. One or two circular pylomes with thickened rim; if two pylomes present, one may be covered by outer vesicle wall.

**Remarks:** The original description of this species is nearly identical to that of the genus. However, it has been modified in terms of wall thickness, vesicle diameter, pylome diameter and microtexture measurements by Loeblich (1970b).

**Discussion:** In flattened specimens, the vesicle seems to have a finely ribbed flange when the thin outer layer has collapsed around the sturdier inner layer. However, uncompresed specimens show irregular collapse of the larger outer layer, forming random ridges. Eroded specimens show fraying of the outer layer, and in badly eroded specimens all that remains of the outer layer is a hair-like fringe. Although uncommon, two pylomes can occur and they are located about 180 degrees from each other. The specimens from the Cincinnati Region studied here correspond in detail to the forms illustrated by Loeblich (1970) from the Dillsboro Formation in Indiana.
A single sample of Middle Ordovician limestone from the Bothnian Sea yielded two specimens designated as Granomarginata sp. (Tynni, 1975). The illustrations of these specimens suggest that they are con-specific with D. macadamii as indicated by their vesicle diameter (ca. 45 μ), apparent double-walled vesicle, wrinkled surface, and the presence of a pylome (ca. 6 μ) with thickened rim. The Bothnian Sea specimens of Tynni (1975) are nearly three times larger than the dimensions of Granomarginata prima Naumova, 1960.

**Dimensions:** 45 specimens. Vesicle diameter 27 (59) 92 μ; pylome diameter 7 (10) 14 μ; pylome rim 1.75 (1.9) 3.5 μ.

There seems to be an increase in vesicle diameter in stratigraphically younger sediments.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky, Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville and Newport, Kentucky; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky, Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian] Cincinnati, Ohio; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Garrard Siltstone, Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Calloway Creek Limestone, Upper Ordovician [Edenian-Maysvillian], Clay's Ferry, Kentucky.

**Previously reported occurrences:** Dillsboro Fm., Upper Ordovician [Richmondian], Indiana (Loeblich, 1970b); Bothnian Sea, Middle Ordovician,
Finland (Tynni, 1975); Upper Ordovician [Edenian-Maysvillian], St. Lawrence Lowlands, Canada (Martin, 1977).
Genus *Leiofusa* Eisenack, 1938

Type species: *Leiofusa fusiformis* (Eisenack, 1934) Eisenack, 1938.

**Description:** Vesicle single-walled, fusiform; process at each pole hollow, conical or threadlike, simple, acuminate or blunt; no septation between process and vesicle. Vesicle and process sculpture may be microgranulate or absent. Excystment by circular opening, median split, or longitudinal slit.

**Remarks:** *Leiofusa* is characterized by its vesicle shape and wall sculpture.

**Discussion:** Eisenack (1938, p. 65) first described *Leiofusa* as "oval to elongate spindle-shaped cysts with smooth wall". Combaz et al. (1967, p. 297) gave a more detailed generic description and included in *Leiofusa* forms with "fusiform or long test with, at each end, an appendage of variable length; surface smooth or striate." By using such a generic definition, *Leiofusa* was clearly differentiated from other leiofusid genera such as *Dactylofusa* Brito and Santos, 1965; *Leiovalia* Eisenack, 1965; *Navifusa* Combaz et al., 1967; *Lunulida* Eisenack, 1958; and *Metaleiofusa* Wall, 1965.

Subsequently, Cramer (1970a) restricted *Leiofusa* to fusiform acritarchs with "simple pointed processes at each pole, varying in length from less than one-tenth to as much as five times the length of the body. Vesicle wall unilayered, psilate to microgranulate."
Sculptural elements not arranged in longitudinal rows...". This definition more or less reiterates Eisenack's initial diagnosis. This detailed restriction by Cramer (1970a) has been followed in this study.

Cramer (1970a, p. 80-82) resurrected the concept of Poikilofusa Staplin et al., 1965, considered, in part, a junior synonym of Dactylofusa, by proposing Eupoikilofusa Cramer, 1970 for forms with vesicle sculpture of "striae, rugulae or uninterrupted rows of interconnected smaller sculptural elements". Cramer (1970a) further restricted Dactylofusa Brito and Santos, 1965, emended Combaz et al., 1967 to include only forms with "surface ornamented with elements of the echinate kind". It should also be noted that Anomaloplaisium Tappan and Loeblich, 1971 is similar to Leiofusa, but is distinguished by the presence of hollow spinules on each process.
Leiofusa cf. fusiformis (Eisenack, 1934) Eisenack, 1938
Pl. IV, fig. 1, 2.

1934 Ovum hispidum fusiformis Eisenack, p. 65, Pl. 4, fig. 19.
1938 Leiofusa fusiformis Eisenack, p. 28.

Description: Vesicle single-walled, fusiform. Processes at each pole, hollow, conical, simple; communication present between process and vesicle. Vesicle and process sculpture absent.

Remarks: This species is characterised by its shape, the presence of hollow appendages, its size, and the lack of vesicle sculpture. The holotype has been reported to be approximately 300 µ long and 50 µ wide. The cf. designation is used because specimens recognized from the Cincinnati Region are less than one-third the size of the holotype of Leiofusa fusiformis.

Discussion: The original description and illustration of Leiofusa estrecha Cramer, 1964 makes it virtually indistinguishable from L. cf. fusiformis. However, subsequent descriptions (Combaz et al., 1967; Cramer, 1970a) suggest the former form to be longer, narrower, and thicker-walled with less obvious distinction between the polar processes and the vesicle.

Leiofusa jurassica Cookson and Eisenack, 1958 shows similarity to L. cf. fusiformis in vesicle shape but is considerably smaller, the holotype measuring 72 µ by 14 µ. Leiofusa algerensis Cramer, 1970 has a
reduced process at one pole and a longer one at the opposite pole. Forms of this species reported by Cramer (1970a) from the Alger Shale of Ohio (Late Llandoveryan) have a vesicle that is shorter and narrower, and processes that are relatively longer than those in the Ordovician forms, but they otherwise show some similarity to the latter forms, especially in the different lengths of the processes in some specimens. *Leiofusa crassicula* Burmann, 1970, which is larger in all dimensions and has a greater width to length ratio, seems easily separable from *L. cf. fusiformis*. *Leiofusa elenae* Cramer, 1964 is distinguished by its shorter processes and greater size. *Leiofusa filifera* Downie, 1959 was described as having a vesicle to process length ratio of one-third as opposed to seven-tenths of *L. fusiformis*. Although similar in width *L. cf. fusiformis* is shorter in length than *Leiofusa rhinke* Loeblich, 1970. *Leiofusa tanaocyta* Loeblich, 1970, is longer and has small pits on its surface. *Leiofusa thomissa* Loeblich, 1970, has larger processes and scattered pits on the vesicle.

In the absence of biometric analyses it is difficult to properly understand variability within populations of each of the several similar taxa mentioned above from their descriptions. Therefore, because so few leiofusid specimens have been found in my samples from the Cincinnati Region, I prefer to use open nomenclature for this form. Measurements of the specimens found are included below.
<table>
<thead>
<tr>
<th>Sample</th>
<th>Slide Coord.</th>
<th>Vesicle Length</th>
<th>Vesicle Width</th>
<th>First Process Length</th>
<th>First Process Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>74MM-95-1</td>
<td>103.1,9.7</td>
<td>88</td>
<td>30</td>
<td>35</td>
<td>9</td>
</tr>
<tr>
<td>76J-Cov-2-1</td>
<td>105.8,12.9</td>
<td>53</td>
<td>25</td>
<td>47</td>
<td>21</td>
</tr>
<tr>
<td>76J-NSC-4-2</td>
<td>93.1,13.7</td>
<td>65</td>
<td>32</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>74MB-12-1</td>
<td>111.9,18.6</td>
<td>105</td>
<td>35</td>
<td>74</td>
<td>39</td>
</tr>
</tbody>
</table>

Distribution: Kope Fm., Upper Ordovician [Edenial], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Newport, Kentucky and Cincinnati, Ohio.
Leiofusa cf. parvitatis Loeblich, 1970
Pl. I, fig. 3.

1970 Leiofusa parvitatis Loeblich, p. 724–725, Pl. 18, fig. G.

Description: Vesicle single-walled, fusiform; long hollow processes at each pole communicating with the vesicle; processes conical, simple, acuminate, becoming solid near distal end. No sculpture on vesicle or process.

Remarks: Leiofusa cf. parvitatis is distinguished by its shape, lack of ornamentation, and, especially, its small size.

Discussion: A single specimen that resembles L. parvitatis has been recognized from the Cincinnati Region. Open nomenclature is used because the single specimen found is slightly wider than the measured specimens referred to in the original diagnosis (Loeblich, 1970a).

Dimensions: Vesicle length, 26 µ; vesicle width, 17 µ; process length 21 µ and 21 µ.

Distribution: Kope Fm., Upper Ordovician [Edenian], Cincinnati, Ohio.

Previously reported occurrences: Maplewood Shale, Middle Silurian, New York (Loeblich, 1970a).
Genus *Leiosphaeridia* Eisenack, 1958, emended Downie and Sarjeant, 1963

Type species: *Leiosphaeridia baltica* Eisenack, 1958

1963 *Leiosphaeridia* Downie and Sarjeant, p. 94, 95.

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to oval; wall thin, lacking processes; pylome present or absent. Walls without pores or radial canals; without divisions into fields and without transverse or longitudinal furrows or girdles; sculpture fine to absent. Color yellow to brown.

**Remarks:** The characteristic features of this genus are the smooth, thin wall, the spherical to subspherical shape, and the absence of radial canals and pores in the wall.

**Discussion:** The leiospheres are smooth-walled, nearly spherical acritarchs which have been discussed widely in the literature. They have potential as paleoecological indicators since they show wide variation in relative abundance, which may range from nearly 100 percent (to the extent of forming peats) to total absence in otherwise rich
assemblages. Some leiospheres resemble spores produced by early vascular plants, whereas others are more likely algae. The nomenclature of the leiospheres has been complicated by numerous, partly uncritical, studies, and by the many taxonomic changes proposed within the group.

Staplin et al. (1965), Combaz (1967c), Muir and Sarjeant (1971), and Downie (1973) have provided reviews of the literature, and therefore only a few matters will be dealt with here.

Eisenack (1938) designated *Leiosphaera [Bion] solidum* the type species of a new genus, *Leiosphaera*, to include forms with thick, porate walls. Soon, however, this genus came to include species with or without porate wall structure, as well as species with thin or thick walls. In 1958, when Eisenack removed two porate species from *Leiosphaera* and assigned them to *Tasmanites* Newton, 1875, he transferred forms with thin walls to a new genus, *Leiosphaeridia*. This new genus was proposed for "all species of *Leiosphaera* that do not agree with the diagnosis of *Tasmanites*". Although Eisenack's diagnosis of *Leiosphaeridia* included "pylome present", no pylome has been reported in *Leiosphaeridia baltica*, the type species, or in most other species of this genus. Downie and Sarjeant (1963) emended *Leiosphaeridia* to include forms "with or without a pylome". In the discussion accompanying their emendation, Downie and Sarjeant excluded Eisenack's reference to color which they stated "reflects a degree of staining by humic substances rather than any intrinsic differences".

Eisenack (1969, 1976) objected to the emendation by Downie and Sarjeant for two reasons: first, he believed their emendation included negative evidence, that is, characters not present in *Leiosphaeridia*
("without processes..., with or without divisions into fields..., without transverse or longitudinal furrows"); second and more importantly, Eisenack believed color to be an important feature, since he never oxidized his material and was able to recognize color differences between taxa in the same assemblages. However, the emendation of Downie and Sarjeant is followed here because the negative evidence is considered valuable, but the color variation diagnosed by Eisenack is also retained as it considered a potentially useful character in this group.

The introduction of a number of _Leiosphaeridium_ species has led to several taxonomic problems, one of which relates to preservation. Preservation plays an important part in determining the properties of a leiosphere wall. For example, when a specimen has been infiltrated by pyrite or flattened, it has features different from those of well-preserved uncompressed specimens. Therefore, it is possible to have morphotypes of the same taxon with characters that not only suggest separate species or end-members of a continuous series of species, but also permit the recognition of intermediate forms between the idealized end-member forms. If the factors that affect preservation can be isolated, it may be possible to recognize these factors by examination of particular properties of palynomorphs. This has commonly been done by recognizing color alteration and relating it to thermal alteration of palynomorphs.

Three of the subgeneric taxa of _Leiosphaeridium_ recognized in this study may, in fact, constitute a single biological entity, and the size measurements for these species suggest this possibility. The distinguishing characters are listed under "Remarks" for each species, but it is
necessary to keep in mind that the stratigraphic use of these three species, taken separately, should be done with caution in view of the fact that the separate ranges of each of these three species may reflect local "ranges" of particular depositional, post-depositional, or diagenetic conditions of the rocks, rather than evolutionary differences in the acritarchs.

The question of so-called spindle-formed *Leiosphaeridia* must be considered and the three *Leiosphaeridia* taxa below (*Leiosphaeridia baltica* Eisenack, 1958; *L. tenuissima* Eisenack, 1963; *L. tenuissima forma A*) may each show spindle-formed morphotypes. This spindle-formed morphotype seems to be the product of a leiosphere wall being opened along a rupture or slit, and flaps of the wall folding or rolling outwardly from the slit giving the form of lips around the slit. These lip-like structures may be further compressed and represent three or more thicknesses of folded wall. This multilayered fragment may be dislocated from the vesicle wall and may resemble a fusiform acritarch, similar in general appearance to a *Leiofusa* species (see Brito, 1967, Pl. 2, fig. 7). Many of these morphological artifacts have been noted by Eisenack (1958a, 1958b, 1963, 1974, 1976).
**Leiosphaeridia baltica** Eisenack, 1958

Pl. III, fig. 1-8.

1958 *Leiosphaeridia baltica* Eisenack, p. 8, Taf. 2, fig. 5.

**Description:** Vesicle single-walled, spherical to cylindrical-bacilliform; outline circular, subtriangular or fusiform; wall thin, rigid, smooth; vesicle rupture straight, forming a single-sided or three-sided slit; ruptured vesicle wall forms flaps that frequently fold over themselves. These overlapping flaps can separate from the rest of the vesicle and superficially resemble *Leiofusa* specimens. No canals present in vesicle wall. No pylome present.

**Remarks:** The rigid, smooth-walled vesicle and diagnostic rupturing distinguish this species.

**Discussion:** This form has numerous polymorphs. The vesicle, when ruptured, can vary from nearly spherical to fusiform. The latter was illustrated by Eisenack (1976) and called a spindle-formed *Leiosphaeridia* sp.

The diagnostic features of this species, that is the thin, rigid wall and various types of ruptures, can be altered by the presence of pyrite and probably most depositional, post-depositional, lithificational diagenetic, and erosional chemical changes resulting in an appearance of *Leiosphaeridia baltica* similar to that of *Leiosphaeridia tenuissima*. Distinct species are maintained here as it believed the difference in morphology, which may or may not distinguish different biological taxa,
may nevertheless prove a valuable tool for interpreting facies. For example, *L. baltica* or *L. tenuissima* can dominate numerically an assemblage diagnostic of sediments deposited in shallow water (Jacobson, 1977c).

*Leiosphaeridia baltica* may prove to be conspecific with *L. leptotheca* Eisenack, 1968, which has been distinguished by the presence of a pylome.

**Dimensions:** 65 specimens. Vesicle diameter 82 (158) 243 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Clays Ferry Fm., Middle and Upper Ordovician [Shermanian-Edenian], Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician Maysvillian, Clay's Ferry, Kentucky.

**Previously reported occurrences:** Ostseekalke, Upper Ordovician, Gotland, Sweden (Eisenack, 1965b); Middle Ordovician [Llanvirnian], France (Rauscher, 1973); dredgings, Middle Ordovician, Bothian Sea, Finland (Tynni, 1975).
Leiosphaeridia? extratubulata sp. nov.
Pl. IV, fig. 6.

Origin of specific name: Latin extra = outside, + Latin tubulata = tubular.

Description: Vesicle double-walled, spherical to subspherical; outline circular to subcircular; inner wall thin, rigid, smooth; outer wall very thin, enclosing inner wall, forming transparent collapsed tubular extension. No sculpture on inner or outer wall.

Remarks: The thin tubular extension of the outer wall is characteristic of this species. The species is tentatively assigned to Leiosphaeridia because of its double wall.

Discussion: This species is obviously not a laboratory contaminant as pyrite scars are found on the outer wall. Excellent quality of preservation in some units in the Cincinnati Region permits this delicate acritarch to be concentrated in preparations. This species is possibly related to Leiosphaeridia baltica which might be Leiosphaeridia? extratubulata without its outer wall.

The species is superficially similar to Leiosphaeridia tubulosa Eisenack, 1963, which has a tubular extension made up of the inner wall, whereas the tubular extension of L.? extratubulata is formed from the thin outer wall. Tasmanites martinssoni Eisenack, 1958, with its bubble-like bulge around its pylome, may be related to this form.
In elongate specimens the tube usually extends from the vesicle at one apex. Linear compressional folds are sometimes present on the inner wall. The outer wall and the tubular extension seem unrelated to excystment and no pylome is present in the inner wall of *L.? extratubulata*. It is more likely that the external layer is a membranous sheath, in which the acritarch cysts of *Leiosphaeridia? extratubulata* may have developed. It is possible that this represents an early stage of development of the encysting organism and that the overlapped flaps adjacent to the slit or triangular tear in *Leiosphaeridia baltica* reflect the mechanism of excystment and that *Leiosphaeridia? extratubulata* and *Leiosphaeridia baltica* represent two preservational aspects of the same entity. However, at this time, it is desirable to retain the separation of these two species until more specimens of *L.? extratubulata* have been examined. The measurements of six well-preserved specimens are given below:

Table 3 Measurements of specimens of *Leiosphaeridia? extratubulata*

<table>
<thead>
<tr>
<th>Slide number and coordinates</th>
<th>vesicle length</th>
<th>vesicle width</th>
<th>tube length</th>
<th>tube width</th>
</tr>
</thead>
<tbody>
<tr>
<td>74MM-166.3-1</td>
<td>94.4,19.0</td>
<td>108 μ</td>
<td>65 μ</td>
<td>65 μ</td>
</tr>
<tr>
<td>74MM-193.2-3</td>
<td>97.0,18.4</td>
<td>62</td>
<td>-</td>
<td>85</td>
</tr>
<tr>
<td>&quot;</td>
<td>102.3,3.7</td>
<td>62</td>
<td>47</td>
<td>105</td>
</tr>
<tr>
<td>74MM-274.8-1</td>
<td>98.1,5.9</td>
<td>81</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>74MM-294-1</td>
<td>99.5,10.7</td>
<td>120</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>74MM-297.3-2</td>
<td>107.0,19.0</td>
<td>81</td>
<td>80</td>
<td>50</td>
</tr>
</tbody>
</table>
Type locality and formation: Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky. Sample 74MM-193.2 is 41 feet above base of Fairview Formation.

Holotype: Illustrated as fig. 6, Pl. IV, deposited at Orton Museum, The Ohio State University, Columbus, Ohio, No. 74MM-193.2-3, 102.3, 3.7. OSU #33881.

Distribution: Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky.
Leiosphaeridia tenuissima Eisenack, 1958
Pl. IV, fig. 5.

1958 Leiosphaeridia tenuissima Esienack, p.391, 392, Pl. 1, fig. 2, 3.

Description: Vesicle single-walled, probably spherical, always compressed; outline nearly circular; wall thin with compressional folds that may be concentric and curved, but are usually linear and sometimes intereseecting or overlapping; no pylome observed.

Remarks: This form is compressed morphotype. It is distinguished by its thin wall and its size.

Discussion: It is most likely that Leiosphaeridia tenuissima is closely related to Leiosphaeridia tenuissima forma A and to Leiosphaeridia baltica; indeed, all three forms may be different preservational artifacts of the same entity. Nevertheless, morphological distinction of the three morphotypes has been maintained here until either biometric analysis or other techniques can justify their reference to a single species. Rarely are all three morphotypes found in the same lithotype, while specimens of either Leiosphaeridia tenuissima or Leiosphaeridia baltica may occur in high relative abundances in nearly monospecific acritarch assemblages.

Occurrences of large numbers of these three morphotypes seem to reflect a relatively shallow-water facies. In such an environment, chemical action, either depositional, post-depositional, lithificational
or diagenetic, could have been the agent that produced the dominant form by altering the morphology of representatives of one species to give it the appearance of that of another.

At Maysville, Kentucky, *Leiosphaeridia tenuissima* is restricted to shales or siltstones except for one bed of biomicritic limestone. It has not been found in biosparites or in other lithologies which in places bear uncompressed acritarchs. The size range of *L. tenuissima* appears constant through the sequence studied.

The excystment opening in this form resembles the spindle-form opening described by Eisenack (1958a, 1958b, 1963, 1974, 1976) with a slit and overlapping folds of the cyst wall opening outward producing a lip-like appearance, or a triangular opening with the wall folded over itself along each of the three sides of the triangle. This is nearly identical to the appearance of the openings in *L. baltica*.

**Dimensions:** 73 specimens. Vesicle diameter 88 (151) 245μ. More than 90 percent of my measured specimens of *Leiosphaeridia tenuissima* have a vesicle diameter between 100 and 200μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville, Covington, Newport, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Lexington Ls., Middle Ordovician [Shermanian], Clay's Ferry, Kentucky; Clays Ferry Fm., Middle–Upper Ordovician [Shermanian and Edenian], Clay's Ferry, Kentucky; Garrard Siltstone, Upper Ordovician [Edenian], Clay's Ferry Kentucky.
Previously reported occurrences: Ostseekalke, Upper Ordovician, Sweden (Eisenack, 1958b).
Description: Vesicle single-walled, spherical to subspherical; outline circular to oval, wall thin; sculpture absent; subconcentric and radial linear folding. Color from yellow-brown to reddish brown, darker than other acritarchs in the same assemblage.

Remarks: This form is recognized by its outline, size, characteristic pattern of folds, and particularly its color. It is distinguished from *L. tenuissima* and placed in a separate subspecies on color alone.

Discussion: This very characteristic form has intersecting linear folds, which often follow the outer circular outline of the vesicle and form concentric folds. At high magnification the outer irregular edge of this acritarch suggests a spongy vesicle surface.

The color varies from yellow-brown to a dark reddish brown and is always darker than that of all other acritarchs in the same sample. It is possible that this dark color may be simply an artifact of preservation.

Although only twenty specimens were measured, a definite increase in relative size is apparent from the Kope Formation up into the overlying Fairview Formation at Maysville, Kentucky. The fifteen specimens from the Kope Formation have a diameter measured as 96 (123) 149 \( \mu \), whereas the diameter of five specimens from the Fairview Formation measured 140 (173) 210 \( \mu \). This is very different from the values for
Leiosphaeridia baltica and Leiosphaeridia tenuissima from the same part of the section at Maysville, Kentucky.

**Dimensions:** 20 specimens. Vesicle diameter 91 (133) 210 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio.
Leiosphaeridia cf. tubulosa Eisenack, 1963
Pl. IV, fig. 8-10.

1963 Leiosphaeridia tubulosa Eisenack, p. 213, Pl. 20, fig. 6, 7.

Description: Vesicle single-walled, spherical to oval, smooth; tubular extension of vesicle wall projects directly from the vesicle wall. Multiple chambered vesicle sometimes occurs with chambers arranged linearly.

Remarks: The vesicle shape and tubular extension are characteristic features of this form. The presence of a single wall layer with its tubular extension distinguished this form from Leiosphaeridia extratubulata. The variation in vesicle shape, its single wall, and the small number of specimens available (3) prevent certain placement of this variable form in Leiosphaeridia tubulosa Eisenack, 1963.

Discussion: Unusual specimens placed in this species are single-walled forms with one or more bulbous, but not always spherical, chambers. Where multiple chambers occur there is complete communication between the chambers. The tubular extension of the vesicle wall in multiple-chambered forms occurs only on a terminal chamber.
Slide number and coordinates | Vesicle length | Vesicle width | Tube length | Tube width
--- | --- | --- | --- | ---
74MM-193.2-1 102.6, 12.8 | 100μ | 55μ | 20μ | 11μ
" " 101.6, 13.8 | 20 | 55 | 7 | 8
102.1, 13.8 | 60 | 24 | 53 | 65 | 38 | 10

**Distribution:** Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky.

**Previously reported occurrences:** Jewéschen Stufe, Middle Ordovician, Estonia (Eisenack, 1963); Ostseekalke, Upper Ordovician, Gotland, Sweden (Eisenack, 1965b).
Leiosphaeridia wenlockia Downie, 1959
Pl. IV, fig. 7

1959 Leiosphaeridia wenlockia Downie, p. 65, Pl. 12, fig. 2-4.

Description: Vesicle single-walled, spherical; outline circular to subcircular and sometimes folded to produce a fusiform appearance; wall smooth to finely ornamented; circular pylome present, sometimes with a raised rim.

Remarks: The small size, general lack of sculpture, and presence of a pylome distinguish this species.

Discussion: In the original diagnosis of L. wenlockia, Downie (1959) stated that the walls were "yellow, 1 μ thick, smooth, waxy". Combaz and Peniguel (1972, p. 128) described a form as L. cf. wenlockia, using open nomenclature to include the scabrate forms found in what were reported as Lower and Middle Ordovician rocks of the Canning Basin, Australia. A wider species definition is used here as the scabrate texture is either a preservational artifact or similar enough to the texture in the holotype in all other ways to justify the inclusion of this character in the definition of the species. It may be difficult to separate specimens of L. wenlockia from small specimens of Dicommopalla macadamii Loeblich, 1970, that have the outer wall layer removed.

Leiosphaeridia wenlockia can easily be separated from species of Schismatosphaeridium Staplin et al., 1965, which have lenticular vesicles
and a cleft opposite the pylome.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Covington, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky.

**Previously reported occurrences:** Wenlock Shale, Middle Silurian [Wenlockian], England (Downie, 1959).
**Genus Leiovalia Eisenack, 1965**

Type species: *Leiovalia ovalis* (Eisenack, 1938)

**Description:** Vesicle single-walled, prolately spheroidal to longitudinally flattened-bacilliform; outline oval to subrectangular with rounded corners; wall thin; sculpture absent or very fine.

**Remarks:** *Leiovalia* is characterized by its oval to elongate vesicle. It differs from *Navifusa* Combaz et al., 1967, by its shorter long axis and from *Leiosphaeridia* Eisenack, 1969, by being oval rather than spherical.

**Discussion:** Because no numerical values have been proposed to distinguish precisely between *Leiovalia* and *Navifusa*, there is some question as to what may constitute a reliable difference between these genera. In a recent paper Playford (1977, p. 29) referred some forms to *Navifusa bacillum* (Deunff, 1955), the shorter of which appear identical to specimens of *Leiovalia similis* Eisenack, 1965.
Leiovalia similis Eisenack, 1965
Pl. III, fig. 9, 10.

1965 Leiovalia similis Eisenack, p. 139, 140, Pl. 12, fig. 5, 6.
1965 Leiofusa brasiliensis lingula Brito and Santos, p. 16, Pl. I, fig. 1, Pl. II, fig. 2.
1972 Leiovalia similis Combaz and Peniguel, p. 131, Pl. 1, fig. 22, 24.
1975 Leiovalia aff. navicula Tynni, p. 23, fig. 23.
1975 Leiovalia similis Tynni, p. 23, 24, Pl. III:1
1975 Leiovalia similis forma rugosa Tynni, p. 24, Pl. III:2
1977 Navifusa bacillum (Deunff, 1955) Playford (pars), p. 29, 30, Pl. 12, fig. 5, 6, non Pl. 12, fig. 1-4, 7-9.

Description: Vesicle single-walled, bacilliform and flattened in long dimension; outline bilaterally symmetrical, rectangular with rounded corners; wall thin; sculpture absent to microgranulate; vesicle length usually twice to three times the width, rarely greater or less.

Remarks: This species is recognized by its characteristic shape, size, length to width ratio, and microtexture. It is not cylindrical but rather flattened, and almost pillow-shaped. The microgranulate ornament is minute and usually unrecognizable with transmitted light microscopy.

Discussion: The original types of Leiovalia similis have length and width values and length to width ratios (ca. 2 to 1, 3 to 1) very similar to the forms found in rocks from the Cincinnati Region. Some other forms have been described as different species which exhibit values that completely, or in part, fall within the same range of variation as
those in *Leiovalia similis* as recognized in this study. These forms are listed below.

Table 4. Measurements of specimens similar to *Leiovalia similis*.

<table>
<thead>
<tr>
<th>Species</th>
<th>Length</th>
<th>Width</th>
<th>Length:width ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Leiofusa navicula</em> Eisenack, 1951</td>
<td>210µ</td>
<td>50µ</td>
<td>4.2</td>
</tr>
<tr>
<td><em>Leiofusa bacillum</em> Deunff, 1955</td>
<td>100-150</td>
<td>12-20</td>
<td>7.5-8</td>
</tr>
<tr>
<td><em>Leiofusa minuta</em> Deunff, 1955</td>
<td>94</td>
<td>25</td>
<td>3.8</td>
</tr>
<tr>
<td><em>Leiofusa cf. navicula</em> Hedlund, 1960</td>
<td>127.5</td>
<td>42.5</td>
<td>ca. 2-3</td>
</tr>
<tr>
<td></td>
<td>162.5</td>
<td>77.5</td>
<td></td>
</tr>
<tr>
<td><em>Leiovalia similis</em> Eisenack, 1965</td>
<td>124</td>
<td>54</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>149</td>
<td>70</td>
<td>2.1</td>
</tr>
<tr>
<td><em>Leiofusa brasiliensis</em> Brito and Santos, 1965</td>
<td>130-250</td>
<td>30-60</td>
<td>3.3-5.5</td>
</tr>
<tr>
<td><em>Leiofusa brasiliensis lingula</em> Brito and Santos, 1965</td>
<td>90-190</td>
<td>35-75</td>
<td>1.7-3.3</td>
</tr>
<tr>
<td><em>Navifusa teretis</em> Loeblich, 1970</td>
<td>183-376</td>
<td>68-112</td>
<td>2.7-3.5</td>
</tr>
<tr>
<td><em>Leiovalia similis</em> Combaz and Peniguel, 1972</td>
<td>150</td>
<td>60</td>
<td>2.5</td>
</tr>
<tr>
<td><em>Quisquilites widderensis</em> Legault, 1973</td>
<td>140-186</td>
<td>31-41</td>
<td>ca. 5</td>
</tr>
<tr>
<td><em>Navifusa drosera</em> Wicander, 1974</td>
<td>116-135</td>
<td>27-35</td>
<td>ca. 4</td>
</tr>
<tr>
<td><em>Leiovalia aff. navicula</em> Tynni, 1975</td>
<td>100-150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><em>L. similis</em> Tynni, 1975</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>L. similis forma rugosa</em> Tynni, 1975</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Navifusa bacillum</em> (Deunff, 1955) Playford, 1977</td>
<td>63(174)300</td>
<td>25(39)55</td>
<td>4.5</td>
</tr>
<tr>
<td><em>Leiovalia similis</em> THIS STUDY</td>
<td>79(116)162</td>
<td>35(49)61</td>
<td>1.5(2.4)3.3</td>
</tr>
</tbody>
</table>
Navifusa teretis Loeblich, 1970, from the Middle Ordovician of Oklahoma, although much larger than Leiovalia similis, has a similar length to width ratio as the latter form and may have some relationship to it. Leiofusa minuta Deunff, 1955, and L. bacillum Deunff, 1955, from the Devonian of Canada, are more narrow. Leiofusa cf. navicula Hedlund, 1960, Leiofusa brasiliensis lingula Brito and Santos, 1965, and probably part of the described population of Navifusa bacillum (Deunff, 1955), all fall within the circumscription of Leiovalia similis used here.

Navifusa drosera Wicander, 1974, and Quisquilites widderensis Legault, 1973, from the Devonian of Ohio and Canada, respectively, were considered by Playford (1977) to be synonymous with his concept of Navifusa bacillum. Both forms seem related to Leiovalia similis although they have a greater length to width ratio.

Specimens of Leiovalia similis reported by Combaz and Peniguel (1972) from the Llandeilian of Australia have length and width values that fall within the circumscription of Leiovalia similis as used here. Likewise, three forms reported by Tynni (1975) seem to conspecific with Leiovalia similis.

**Dimensions:** 21 specimens. Vesicle length 79 (116) 162 µ; vesicle width 35 (49) 61 µ; length to width ratio 1.5 (2.4) 3.3.

**Distribution:** Lexington Limestone, Middle Ordovician [Shermanian], Clay's Ferry, Kentucky; Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky, and Cincinnati, Ohio; Clays Ferry Fm., Middle
and Upper Ordovician [Shermanian and Edenian], Clay's Ferry, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky, and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky, Cincinnati, Ohio.

Previously reported occurrences: Ostseekalke, Upper Ordovician, Gotland (Eisenack, 1965b); Goldwyr Fm., Middle Ordovician [Llanvirnian-Llandeilian], Canning Basin, Australia (Combaz and Peniguel, 1972); Bothnian Sea, Middle Ordovician, Finland (Tynni, 1975); Lower Picos Fm., Lower Devonian, Brazil (Brito and Santos, 1965); Stoopin River Fm., Kwataboahegan Fm., Murray Island Fm., Williams Island Fm., Lower to Middle Devonian [Emsian-Givetian] Ontario, Canada (Playford, 1977).
Genus Lophosphaeridium Timofeev ex Downie, 1963

Types species: Lophosphaeridium rarum Timofeev ex Downie, 1963 = L. rarum Timofeev, 1959 p. 29, Pl. 2, fig. 5; Pl. 24, fig. 2.

1959 Lophosphaeridium Timofeev, p. 29 (nomen nudum)
1963 Lophosphaeridium Downie, p. 630.
1970 Lophosphaeridium Lister, p. 61

Description: Vesicle single-walled, spherical; outline circular to subcircular; wall sculpture of solid tubercles, usually rounded, excystment usually by rupture.

Remarks: This spherical form is characterized by its sculpture, which consists only of solid tubercles of various profiles but which are usually round in plan view.

Discussion: When Timofeev (1959) described Lophosphaeridium, he included in the genus two species, L. rarum Timofeev, 1959, and L. plicatum Timofeev, 1959, neither of which was designated a type species. The complete generic description was "vesicle thick, tuberculose". Downie (1963) designated L. rarum as the type species and tentatively included spherical forms with variously shaped solid tubercles in the genus.

Lister (1970, p. 61), in a footnote, offered an emended diagnosis, eliminating vesicle thickness as a general character. His diagnosis reads: "vesicle hollow, single-walled with ornament of solid tubercles. Excystment is by cryptosuture."
Recent workers (Loeblich and Tappan, 1976; Playford, 1977) have noted that the genus is imprecisely defined. Loeblich and Wicander (1976, p. 16) consider Lophosphaeridium "a granulose leiosphere... and we would restrict the genus to include only species with low rounded grana-like tubercles." Playford (1977, p. 26) considered Lophosphaeridium as including vesicles "bearing collectively a variety of process types, all relatively inconspicuous and... solid grana, verrucae, bacula ". Lophosphaeridium Timofeev ex Downie, 1963 is distinguished from Leiosphaeridia Eisenack, 1958 by having solid tubercles, and from Buedingiisphaeridium Schaarschmidt, 1963, emended Lister, 1970, which has conical, always partially hollow, tubercles, that communicate with the vesicle interior. Protosphaeridium Timofeev, 1966, the description of which reads, "envelope spherical, diameter from five to 50-60 μ, single-layered, smooth or slightly sculptured (shagreen-like, tuberculate, pitted)," is similar to Lophosphaeridium but Timofeev (1966, p. 24) stated "Protosphaeridium differs from most of the genera... in having a smooth or slightly sculptured surface of the envelope and in having no internal nucleus." It appears that the description of Lophosphaeridium Timofeev, 1959 ex Downie, 1963 significantly overlaps, in terms of morphological characteristics, that of Protosphaeridium Timofeev, 1966.

The definition of Lophosphaeridium followed here is nearly identical to that of Lister (1970).
Lophosphaeridium sp. A
Pl. V, fig. 4-6.

Description: Vesicle single-walled, spherical; outline circular; sculpture granulate; rounded grana about one micron wide with bases nearly touching each other.

Remarks: Much confusion surrounds determination of species of Lophosphaeridium. Because comparative material is not always well-preserved or well-illustrated, the species A designation has been used here. This species is recognized by the size and shape of the grana and their spacing. Lophosphaeridium sp. A is distinguished from Lophosphaeridium sp. B by the spacing of the grana.

Dimensions: 16 specimens. Vesicle diameter 25 (47) 56 μ.

Distribution: Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Grant Lake Ls., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky.
Lophosphaeridium sp. B
Pl. V, fig. 1-3.

Description: Vesicle single-walled, spherical; outline circular; sculpture granulate; rounded grana about one micron wide, evenly spaced and more than one micron apart.

Remarks: This species is recognized by the shape of the grana and their spacing. It is distinguished from Lophosphaeridium sp. A by the spacing of the grana. Lophosphaeridium sp. A has grana with bases nearly touching each other and Lophosphaeridium sp. B has grana separated from each other more than one micron.


Distribution: Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky and Cincinnati, Ohio; Grant Lake Ls., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
Genus *Micrhystridium* Deflandre, 1937

Type species: *Micrhystridium inconspicuum* Deflandre, 1937.

**Description:** Vesicle single-walled, spherical to subspherical to polyhedral; outline circular to polygonal. Processes few to many, simple, homomorphic, solid to hollow; tips closed, acuminate; contact with vesicle angular to curved; septations between processes and vesicle cavity present or absent; sculpture fine to absent. Vesicle less than 20 μ in diameter.

**Remarks:** The distinguishing characters of species of *Micrhystridium* are the simple processes, the presence of little vesicle sculpture, and most important, a vesicle diameter less than 20 μ.

**Discussion:** That *Micrhystridium* may represent a heterogeneous group of microfossils has not been challenged seriously. Deflandre (1937) introduced the genus to include "globular organisms ornamented with various appendages, and whose size, generally less than 20 μ, can be as little as 8 to 10 μ."

Staplin (1961) restricted *Micrhystridium* to include forms with simple processes and removed the size restriction. He considered *Baltisphaeridium* Eisenack, 1958 to be a junior synonym of this genus. Most authors, however, retained *Baltisphaeridium* for forms with simple processes with no communication to the vesicle cavity and a diameter greater than 20 μ. Staplin et al. (1965) accepted the use of the generic
designation Baltisphaeridium Eisenack, 1958 for forms with processes communicating freely with the vesicle.

Polygonium Vavrdova, 1966 [=Goniosphaeridium Eisenack, 1969] is characterized by free communication between vesicle and processes. Micrhystridium is retained, as circumscribed by Downie and Sarjeant (1963, p. 92), that is, "Hystrichospheres [acritarchs] with spherical to oval shells not divided into fields or plates, bearing processes with closed tips, most often simple, rarely branched or ramifying, without distal connections of any kind. The processes are generally of one type only. Mean and modal diameter of shell less than 20 \mu."

Therefore, in this study, Micrhystridium is separated from other groups (e.g., Baltisphaeridium, Polygonium, Veryhachium). It is realized, however, that some of the species included in Micrhystridium here may belong in one of the latter genera in a biological sense.

Loeblich (1970a, p. 707) stated that "the sacredness of [vesicle diameter] of 20 \mu or less for Micrhystridium Deflandre, 1937, is ridiculous when one considers the variation within modern phytoplankton species that can be observed in clonal culture with no possible doubt that only one true species is involved. An examination of illustrations in a work on the genus Micrhystridium Deflandre sensu lato (Deflandre and Deflandre, 1965b), clearly shows the heterogeneous nature of forms considered to be congeneric." When one considers "phytoplankton species in clonal culture" or the illustrations of Deflandre and Deflandre (1965b) there is no problem to agree with Loeblich's opinion. Nevertheless, Deflandre and Deflandre (1965a) were careful to point out that Micrhystridium Deflandre, 1937 was not a name devised for biological
entities, but rather, for a group of "parataxa" described only on cyst morphology and more importantly "provisionally".

From the introduction of the neologism "acritarch" (Evitt, 1963, p. 300), the designation has been used for the "residue of forms of unknown affinities for which the name Hystrichosphaeridia is no longer appropriate." "Wherever the biological affinities of individual acritarch general can be established with sufficient precision, these genera should forthwith cease to be referred to as acritarchs and should be assigned to their proper places in the taxonomic hierarchy under the appropriate nomenclatural code" (Evitt, 1963, p. 300). This statement could be taken to imply that acritarch genera have been proposed for natural taxa. However, in the base of Micrhystridium and other genera, this may not be true. At least some living phytoplankton, for example, species of Echinum Meunier, 1910 from recent Arctic plankton, noted by Deflandre and Deflandre (1965a, p. 87) and illustrated (Deflandre and Deflandre, 1965b, fig. 2511-2518), have the morphology, including small size (4—5μ) that, if they were found as fossils, would place them in the genus Micrhystridium. The living forms of Echinum, however, can be studied as living organisms and classified within the Code of Botanical Nomenclature as taxa and not as "parataxa" or form taxa.

Deflandre and Deflandre (1965a, 1965b) recognized the possibility that all fossils classified as Micrhystridium species may not be congeneric with Echinum Meunier. In fact, the polyphyletic nature of Micrhystridium was suggested (Deflandre and Deflandre, 1965a).

Loeblich (1970a, p. 706) preceded his discussion of Micrhystridium by pointing out problems in published systematics. For example, he
mentioned incomplete descriptions, inadequate figures, lack of attention to detail of wall character, low magnification of figures specimens, poor preparation and the inability to obtain comparative material, as reasons for taxa being "merely named". Palynomorph study, however, is fraught with such problems and more importantly, it is sometimes impossible, even after the most careful and exhaustive examination, to produce wholly adequate circumscriptions for microfossil taxa. Despite this obvious barrier to scientific progress, many poorly preserved, poorly prepared, and even poorly figured specimens classified as incertae sedis have great value to the student of fossil microplankton. There is no reason to reject taxonomic descriptions that are useful until improved taxonomy can be offered.

Although other authors have approached the problem of the status and characteristics of Micrhystridium in a variety of ways, Eisenack (1962c, as translated in Norris and Sarjeant, 1965) sums up the interpretation used here, that "one can disagree with the limits of diameter and also whether a genus can be defined on the size of its representatives, one can finally doubt its validity, but one can scarcely alter its sense...Micrhystridium is, at least, defined as a practical genus... I see Micrhystridium as a collective genus for all very small forms so long as renewed studies and wider knowledge on the ordering do not isolate them."

There are, in addition, numerous species of Micrhystridium. Many species are similar, or nearly identical, and unreeved species have been reported from both Lower Paleozoic and Jurassic rocks. Many circumscriptions are overlapping and, for this reason, the designation cf.
and *Micrhystidium* sp. A and *M.* sp. B have been used below in order to simply record occurrences of forms referable to this genus.
**Micrhystridium cf. acum** Martin, 1968  
Pl. V, fig. 7-10.

cf. 1968 **Micrhystridium acum** Martin, p. 68, Pl. VI, fig. 273, text-fig. 21.

**Description:** Vesicle single-walled, spherical; outline circular; processes homomorphic, cylindrical, solid (?), regularly and radially arranged; tips capitate; angular process contact with vesicle. Vesicle and process sculpture absent.

**Remarks:** This species is characterized by its vesicle size and capitate, radially arranged, cylindrical processes.

**Discussion:** This form is rare in Middle Ordovician rocks from New York State and was reported as "very rare = <1%" by Martin (1968b) in Wenlockian and Ludlovian rocks from Belgium. The nature of preservation and the small size of the North American forms are such that the actual nature of the capitate tips is difficult to examine with light microscopy. Likewise, the photograph published by Martin is very small and although the text-figure (Martin, 1968b, p. 68) shows some resemblance to forms from New York, uncertainty of identity justifies the cf. designation.

Because of the rarity of this form in both Belgium and New York, its range is of questionable value stratigraphically at the present time.
**Dimensions:** 6 specimens. Vesicle diameter 10 (14) 18μ; process length 2 (3) 4μ.

**Distribution:** Denley Fm., Upper Ordovician [Edenian], Trenton Falls and Martinsburg, New York; Sugar River Fm., Middle Ordovician [Shermanian], Martinsburg and Kings Falls, New York.

**Previously reported occurrences:** Jonquoi and Thimensart beds, Middle and Upper Silurian [Wenlockian and Ludlovian], Belgium (Martin, 1968b).
Micrhystridium sp. A
Pl. V, fig. 12.

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to subcircular. Processes shorter than the vesicle diameter, homomorphic, thin, conical, hollow to solid, regularly arranged radially; tips simple, acuminate; curved process contact with vesicle. Sculpture absent.

**Remarks:** The diagnostic features used to recognize this form are the vesicle size, the regular arrangement of the processes (which may have their tips broken off), and the process contact with the vesicle.

**Discussion:** This form is similar to some published illustrations of several species and dissimilar to other forms of the same species. It is not too common, nor well-preserved, but this long-ranging simple and small form can possibly be of increased biostratigraphic value if studied in the future with SEM since surface microtexture might hold the key to taxonomic assignment.

**Dimension:** 24 specimens. Vesicle diameter 7 (14) 18 μ; process length 2 (4) 7 μ.

**Distribution:** Kings Falls Fm., Middle Ordovician [Kirkfieldian], Martinsburg, New York; Sugar River Fm., Middle Ordovician [Shermanian], Martinsburg, Deer River, New York; Denley Fm., Middle–Upper Ordovician [Shermanian and Edenian], Trenton Falls, Deer River, and Martinsburg,
New York; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls and Deer River, New York.
Description: Vesicle single-walled, spherical to subspherical; outline circular to subcircular. Processes shorter than vesicle diameter, homomorphic, thin, cylindrical, solid, regularly arranged radially; tips simple and acuminate; angular process contact with the vesicle; sculpture absent.

Remarks: The size and nature of the processes and their contact with the vesicle were used to recognize this form.

Discussion: As is the case with some other species of *Micrhystridium*, the similarity of this form to some previously published illustrations and circumscriptions is recognized, but the preservation of the material is not good enough to separate artifacts of preservation from specific characters in previously described forms, as well as in the specimens from New York State. Therefore, *M*. sp. B has been referred to in open nomenclature at the time being.

Dimensions: Vesicle diameter 12 (14) 18 μm; process length 2 (4) 5 μm.

Distribution: Kings Falls Fm., Middle Ordovician [Kirkfieldian] Martinsburg, New York; Sugar River Fm., Middle Ordovician [Shermanian], Martinsburg, New York; Denley Fm., Middle–Upper Ordovician [Shermanian and Edenian], Trenton Falls, New York; Hillier Fm., Upper Ordovician [Edenian], Martinsburg, Deer River and Trenton Falls, New York.
Genus *Multiplicisphaeridium* Staplin, 1961, restricted Staplin et al., 1965

Type species: *Multiplicisphaeridium ramispinosum* Staplin, 1961.

1961 *Cymatiogalea* Deunff (pars), p. 41.
1970 *Ammonidium* Lister, pp. 48, 49.
1970 *Visbysphaera* Lister, p. 98.

**Description:** Vesicle single-walled, spherical to subspherical, rarely polyhedral; outline circular to polygonal; processes hollow, more or less homomorphic, regularly distributed; tips closed distally, multifurcate, acuminate; contact with vesicle usually angular; no septations between processes and vesicle cavity; vesicle sculpture fine to absent, usually agrees with process sculpture.

**Remarks:** The branching of the processes in a single specimen, or within a species, may vary in complexity, but the tip morphology and formula of branching are consistent.

**Discussion:** The presence of free communication between vesicle and processes, a characteristic omitted from the original diagnosis by
Staplin (1961), was added later (Staplin et al., 1965). Eisenack (1969) suggested an emendation, not followed here, which included in the genus forms with an obstruction between the vesicle and processes. In another paper, Eisenack and Cramer (1973) placed many genera in synonymy by accepting within the concept of the present genus broad variations in surface sculpture, vesicle polygonality and wall layers. This last interpretation is not followed here as it is considered too general.

The usually smooth wall sculpture of Multiplicisphaeridium can be distinguished from that of Diexallophasis Loeblich, 1970, which is coarser. Diaphorochroa Wicander, 1974, was proposed for forms with variable sculpture from vesicle to process. Ammonidium Lister, 1970 was introduced for forms with single branching of the processes. This feature is not considered a generic character in this study. Piliferosphaera, Loeblich, 1970, was proposed for forms that had vesicle sculpture only. Here, it is considered more valuable to retain such species within Multiplicisphaeridium in order to more easily recognize morphological relationships between otherwise similar species. Visbysphaera Lister, 1970, was defined to include forms with an internal wall; this character is here considered a consequence of environmental conditions which is not useful for generic differentiation.
Multiplicisphaeridium bifurcatum Staplin et al., 1965
Pl. V, fig. 13.

1965 Multiplicisphaeridium bifurcatum, Staplin et al., p. 182,
Pl. 18, fig. 13.

1973 Filisphaeridium bifurcatum Thusu, p. 814, Pl. 195, fig. 8,12.


Description: Vesicle single-walled, spherical; outline circular;
processes numerous, hollow, homomorphic, conical; tips bifurcate,
acuminate; process contact with vesicle curved; free communication be-
tween process and vesicle cavities; vesicle and process sculpture absent.

Remarks: This Multiplicisphaeridium species is characterized by its
fairly small vesicle diameter and its conical processes with bifurcate
tips.

Discussion: Well-preserved specimens of Multiplicisphaeridium bifurca-
tum, like the ones from the Cincinnati Region, are very easily recogniz-
ed. However, specimens from New York State are less certainly assigned
to this species. The specimens from New York are thermally altered to
the extent that they rarely have complete process tips preserved.
Nevertheless, the small vesicle diameter, the length of the conical,
bifurcate processes and the absence of sculpture seem sufficient
criteria for assigning these specimens to M. bifurcatum. Because this
is somewhat tentative, the dimensions of the specimens from the two
regions have been reported separately below.
The description, as well as the illustrations, of Filisphaeridium bifurcatum Thusu, 1973, from the Middle Silurian Rochester Shale of Southern Ontario, Canada, appear to agree closely with the forms from the Cincinnati Region. This prompted Eisenack and Cramer (1976, p. 449) to transfer F. bifurcatum to Multiplicisphaeridium. The dimensions of F. bifurcatum Thusu were reported as "size of the vesicle 27–36μ (range 25–38μ); length of the process 3–5μ (range 3–5μ)." Thusu's specimens have a slightly larger vesicle and slightly shorter process length than the Ordovician forms studied here. The type material of the present species, from Middle Ordovician rocks of Anticosti Island, Nova Scotia (Staplin, et al., 1965), had a vesicle size (25–35μ) nearly identical to Thusu's specimens, although the process length (ca. 25μ) was considerably larger than that in either Thusu's forms or those studied here. Also, the furca length in specimens of the type material exceeds that of those described by Thusu. Nevertheless, the specific assignment of the specimens from the Cincinnati Region and New York State seems justified.

It is possible that the forms from New York, when complete, might more closely resemble M. irregulare Staplin et al., 1965 than M. bifurcatum. The former species has numerous simple processes, and some bifurcate and occasionally trifurcate processes. The rocks, in which specimens of M. irregulare occur, are the same as those reported on by Staplin et al. (1965).

Vesicle diameter 14 (16) 18 μ; process length 5 (8) 12 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Covington, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Sugar River Fm., Middle Ordovician [Shermanian], Deer River, New York; Denley Fm., Upper Ordovician [Edenian], Deer River, Trenton Falls, and Martinsburg, New York; Steuben Fm., Upper Ordovician [Edenian], Deer River and Trenton Falls, New York.

**Previously reported occurrences:** Subsurface, Middle Ordovician, Anticosti Island, Quebec, Canada (Staplin et al., 1965); subsurface, Lower Ordovician [Arenigian-Llanvirnian], Kent, England (Lister and et al., 1969); Rochester Fm., Middle Silurian, Ontario, Canada (Thusu, 1973).
**Multiplicisphaeridium cf. fisherii** (Cramer, 1968)

Pl. V, fig. 16, 17.

cf. 1968 **Baltisphaeridium fisherii**, Cramer, p. 65, Pl. 1, fig. 1.

cf. 1970 **Multiplicisphaeridium fisherii**, Lister, p. 89, Pl. 10, fig. 18; Pl. 11, fig. 3.

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to subcircular; processes numerous (10-20), hollow, heteromorphic, cylindrical; tips branched, acuminate; branching usually in bifurcate patterns, sometimes branching at midpoint of process, sometimes nearer the distal end; process contact with vesicle angular; vesicle and process sculpture absent.

**Remarks:** Dimensions and process branching patterns most closely resemble those in *M. fisherii* (Cramer, 1968). Only six compressed specimens have been found and their process contact with the vesicle is angular. Cramer (1970a, p. 130) stated that "the processes are pillar-shaped with a square basal angle", but his specimens appear to have a curved process contact with the vesicle in his illustrations (Cramer, 1970a, Pl. VII, fig. 116, 117, 118, 122; Pl. VIII, fig. 138, Pl. IX, fig. 143, 144; Pl. X, fig. 156, text-figure 39d). For this reason the cf. designation has been used.

**Discussion:** If this species is related to *M. fisherii* (Cramer, 1968), it is probably a genetically related precursor of this species, which was described by Cramer (1968, 1970a) from the Silurian.
Dimensions: 6 specimens. Vesicle diameter 48 (59) 87 μ; process length 21 (25) 31 μ; process number 10-20; process width about 3 μ.

Distribution: Kope Fm., Upper Ordovician [Edenian], Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, New York.
**Multiplicisphaeridium** sp. A  
*Pl. V, fig. 14*

1971a **Multiplicisphaeridium corallinum** Kjellström, p. 47, 48,  
*Pl. 3, fig. 8*

1971a **Multiplicisphaeridium digitatum** Kjellström, p. 48, 49,  
*Pl. 3, fig. 9.*

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to subcircular; processes hollow, conical, homomorphic, regularly arranged; tips with several orders of bifurcations, acuminate; contact between process and vesicle slightly curved; free communication between hollow process and the vesicle cavity; vesicle sculpture absent; processes possibly microgranulate.

**Remarks:** This species is nearly identical to *Ordovicidium groetlingboensis* (Kjellström, 1971a) except for the absence of an inner wall. *Multiplicisphaeridium* sp. A is not formally named because it is believed to be a variant of *O. groetlingboensis*.

**Discussion:** *Multiplicisphaeridium* sp. A is placed in this genus because it displays a hollow, multifurcate process with free communication to the vesicle cavity. However, the specimens found in the Cincinnati Region are most likely closely related to *Ordovicidium groetlingboensis*. The generic description of *O. groetlingboensis* suggests that the processes do not have a cavity continuous with the vesicle. Because of the biostratigraphic position of the relatively few specimens found in the Cincinnati Region, a tentative separation of these forms from *O.*
**groetlingboensis** is considered biostratigraphically potentially valuable.

The presence of a thicker wall, or more likely, an internal cyst in **groetlingboensis** is probably a reflection of changes in environmental conditions, and therefore, **M. sp. A** may be best viewed as an environmental variant of the species.

The species appears very similar to specimens identified as **M. corallinum** (Eisenack, 1959) and **M. digitatum** (Eisenack, 1938) by Kjellström (1971a). Eisenack and Cramer (1973, p. 574) feel that **M. corallinum** (as recognized by Kjellström, 1971a) is not synonymous with **M. corallinum** as originally intended. Further, they question Kjellström's recognition of **M. digitatum** (Eisenack and Cramer, 1973, p. 608). Despite the nomenclatural problem here, Kjellström's photographs and descriptions are so clear that there is no doubt that his specimens are identical to those studied here.

**Dimensions:** 2 specimens. Vesicle diameter 42, 42 μ; process length 22–28 μ; process width 8 μ.

**Distribution:** Grant Lake Ls., Upper Ordovician [Maysvillian], Maysville Kentucky.

**Previously reported occurrences:** Subsurface, Middle Ordovician [Lower Viruan], Gotland, Sweden.
Genus **Ordovicidium** Tappan and Loeblich, 1971

Type species: **Peteinosphaeridium groetlingboensis** Kjellström, 1971a.

1937 **Hystrichosphaeridium** Deflandre (pars), pp. 51-103.

1958 **Baltisphaeridium** Eisenack (pars), p. 398

1969 **Peteinosphaeridium** (Staplin et al., 1965) Eisenack (pars), p. 252-254.

1971 **Ordovicidium** Tappan and Loeblich, p. 398.

**Description:** Vesicle double-walled, spherical to subspherical; outline circular to subcircular. Processes arising from outer wall, radially arranged, cylindrical to slightly conical, mostly hollow, homomorphic to heteromorphic; tips closed, acuminate; branching of processes usually bifurcate; contact of process to vesicle angular; septations between processes and vesicle cavity. Vesicle and process sculpture absent to granulate. No pylome has been found.

**Remarks:** The hollow, cylindrical, usually bifurcate nature of the processes without communication between process and vesicle cavities is diagnostic. Several orders of bifurcation of process tips are common. Also the lack of a pylome appears to be characteristic.

**Discussion:** The introduction of the genus **Ordovicidium** by Tappan and Loeblich (1971) offers a solution to a complex taxonomic and nomenclatural problem. As early as 1938, Eisenack described specimens that
today might properly be included in *Ordovicidium*. At that time all acritarchs with branching closed processes and no crests on the vesicle were included in the genus *Hystrichosphaeridium* Deflandre, 1937. Eisenack (1938) proposed *H. trifurcatum* to include several forms, which he later (Eisenack, 1958) placed in *Baltisphaeridium* Eisenack, 1958. *Baltisphaeridium* Eisenack was proposed to include non-tabulate acritarchs with well-spaced, branched or unbranched, hollow, homomorphic appendages. *Baltisphaeridium trifurcatum* Eisenack, 1958, was later split into several subspecies, some having veils or fins on their processes and others lacking veils. One of these subspecies, *B. trifurcatum* ssp. *nudum* (Eisenack, 1959), lacks veils on the processes and may be referable to *Ordovicidium*.

Staplin et al. (1965) proposed the genus *Peteinosphaeridium* to include forms with thin-walled veils along the entire length of the branching processes. Eisenack (1969) emended *Peteinosphaeridium* (Staplin et al., 1965) and stated that the development of veils was a variable character; such structures might occur along the entire length or along only a part of the process, or be absent altogether. Eisenack and Cramer (1973) included in *Peteinosphaeridium* (Staplin et al., 1965) Eisenack, 1969 numerous veiled forms as well as forms without veils, such as *Baltisphaeridium nudum* (Eisenack, 1959), *B. breviradiatum* (Eisenack, 1959), *Peteinosphaeridium aequifurcatum* Kjellström, 1971, *P. heteromorphicum* Kjellström, 1971, *P. groetlingboensis* Kjellström, 1971, *P. majorfurcatum* Kjellström, 1971, and *P. majorvesiculum* Kjellström, 1971.
Tappan and Loeblich (1971) proposed *Ordovicidium* to include unveiled forms. In their discussion of this genus, they omitted any reference to *Peteinosphaeridium* but the forms they described appear to be congeneric with many of the unveiled forms of *Peteinosphaeridium* mentioned above.


The processes of specimens of *Ordovicidium* are cylindrical to conical and hollow with communication to the interior of the vesicle obstructed by a thin membrane. Tappan and Loeblich (1971) described this membrane as one layer of a two-layered wall. Few tips of the processes are simple (Fig. 17a), and most bifurcate at least once (Fig. 17b), and sometimes twice or more (Fig. 17c-e). The tips themselves are acuminate, and especially well-preserved specimens have an ultra-fine thread at the process tip which is visible only in the SEM (Tappan and Loeblich, 1971). In some specimens the bifurcation may be irregular, which produces the appearance of a trifurcate tip (Fig. 17e). Processes with these characters have been recognized in the holotype of *P. groetlingboensis* Kjellström, 1971, as well as in other specimens examined in this study.
Well-preserved processes of *Peteinosphaeridium trifurcatum* are veiled along the entire length. They vary in construction from solid strands formed by the junction of the veils along the same line (Fig. 18a) to hollow prismatic processes formed by the intersection of veils (Fig. 18b). When well-preserved, the hollow processes are covered distally by a membrane. Proximally there is no communication between the processes and the interior of the vesicle.

Because of the characteristic process morphology, *Peteinosphaeridium* Staplin et al., 1965 is retained here for species with veiled processes, following the original diagnosis. *Peteinosphaeridium* is considered distinct from *Ordovicidium* Tappan and Loeblich, 1971, which is taken to include species characterized by conical to cylindrical processes with bifurcate tips.

Eisenack (1959) illustrated a specimen of *Baltisphaeridium trifurcatum* ssp. nudum (Pl. 17, fig. 4) which might now be placed in *Ordovicidium*. This is the only illustrated example of a circular pylome in a form that might be placed in this genus. Otherwise, no pylomes have been reported in specimens of *Ordovicidium*. Pylomes are, however, commonly reported in specimens of *Peteinosphaeridium*.

The type species of *Ordovicidium* is here designated by combination as *O. groetlingboensis* (Kjellström, 1971a). Originally the species was proposed as *Peteinosphaeridium groetlingboensis* Kjellström, 1971, and the paper in which it is described was distributed in March 1971. Publication of the paper in which the genus *Ordovicidium* Tappan and Loeblich, 1971 was proposed was not until March 3, 1972, although it is dated October, 1971. The type species designated for *Ordovicidium* in the original publication of this genus was *Ordovicidium elegantulum* Tappan and Loeblich.
Fig. 17 - Process morphology in specimens of *Ordovicidium groetlingboensis*. a, simple; b, bifurcate; c-e multiple bifurcate.
Fig. 18 - Process morphology in *Peteinosphaeridium intermedium*. 

a, solid strand formed by the junction of the veils along the same line; b, hollow prismatic processes formed by the intersection of veils.
1971. However, *O. elegantulum* is here considered conspecific with *Peteinosphaeridium groetlingboensis* Kjellström, 1971 on the basis of examination of the holotype of *Peteinosphaeridium groetlingboensis* and specimens of *Ordovicidium elegantulum* Tappan and Loeblich from Kentucky. According to the law of priority, the name *P. groetlingboensis* Kjellström must be used, *O. elegantulum* Tappan and Loeblich being the junior synonym. Nevertheless, *Ordovicidium* Tappan and Loeblich, 1971 is validly published and is here considered a valuable new genus. Because *O. elegantulum* was the type species for this genus and the species in a junior synonym of *Peteinosphaeridium groetlingboensis*, a new combination, *Ordovicidium groetlingboensis* (Kjellström, 1971a) is proposed.

The following species have features diagnostic of *Ordovicidium* and should therefore be transferred to this genus:

*Peteinosphaeridium aequifurcatum* Kjellström, 1971a, p. 51, 52, Pl. 3, fig. 12.

*P. asperum* Kjellström, 1971b, p. 32, fig. 21.

*P. heteromorphicum* Kjellström, 1971a, p. 53, Pl. 3, fig. 2.

*P. majorfurcatum* Kjellström, 1971a, p. 54, Pl. 3, fig. 3.

*P. majorvesiculum* Kjellström, 1971a, p. 54, 55, Pl. 4, fig. 4.

*P. nanofurcatum* Kjellström, 1971a, p. 55, Pl. 4, fig. 5.

*Baltisphaeridium trifurcatum nudum* Eisenack, 1959, p. 203, Pl. 17, fig. 4-6.

*B. trifurcatum paucifurcatum* Eisenack, 1959, p. 203, Pl. 17, fig. 8-10.

It is probable that *Peteinosphaeridium breviradiatum* (Eisenack, 1959), at least in part, should be transferred to *Ordovicidium* but further evidence is needed to support this suggestion.
**Ordovicidium groetlingboensis** (Kjellström, 1971a) comb. nov.
Pl. V, fig. 15; Pl. VI, fig. 1-3, 5, 6, 9, 11.

1971 **Peteinosphaeridium groetlingboensis** Kjellström, p. 52, 53, Pl. 4, fig. 1. (Distribution date, March 1971)

1972 **Ordovicidium elegantulum** Tappan and Loeblich, p. 398, 400, Pl. 7, fig. 1-7 (Distribution date, March 3, 1972)

**Description:** Vesicle double-walled, spherical; outline circular; processes made of outer wall, numerous (usually 15-25), hollow, usually heteromorphic, conical to cylindrical; tips acuminate, multifurcate (rarely simple) with up to four orders of bifurcations; angular process contact with vesicle; inner wall forming a barrier to communication between vesicle cavity and process cavity. Vesicle sculpture of outer wall somewhat microgranulate, processes more granulate with densest sculpture at process tips.

**Remarks:** This species is distinguished from **Ordovicidium nudum** (Eisenack, 1959) by the granulate sculpture on the vesicle and processes. Eisenack (1959, Pl. 17, fig. 4) figured a specimen of **Baltisphaeridium nudum** with a pylome. No such structure has been recognized in **O. groetlingboensis**.

**Discussion:** The specimens from New York State and the Cincinnati Region have been measured, and vesicle size, process length and process number demonstrate a normal distribution (Fig. 19-23). The distribution of dimensions overlaps Kjellström's (1971a) measurements of specimens of **O. heteromorphicum** (Kjellström, 1971a), **O. majorfurcatum** (Kjellström, 1971a), and **O. nudum** (Eisenack, 1959). **O. aequifurcatum** is characterized
Fig. 19 - Relative frequency of different vesicle diameters in specimens of **Orthocelatum**. **Prorotalbus**.
Fig. 20 - Relative frequency of different process lengths in specimens of *Ordovicidium groetlingboensis*.

Fig. 21 - Relative frequency of different vesicle diameter/process length ratios in specimens of *Ordovicidium groetlingboensis*. 
Fig. 22 - Relative frequency of process length/number of processes ratios in specimens of *Ordovicidium groetlingboensis*.

Fig. 23 - Relative frequency of vesicle diameter/number of processes ratios in specimens of *Ordovicidium groetlingboensis*. 
(Kjellström, 1971a, p. 52) by "equal-size furcae and broadening portion of the process stem". I feel that the former characteristic is part of a variable characteristic. In measurements of 104 specimens from the Cincinnati Region, bifurcation on a specimen varied from no bifurcations to three or four orders of bifurcations. Rarely (in 2 of 104 specimens) all the processes on a single specimen showed a single order of bifurcation. The "broadening portion" of the process stem may be a consequence of compaction.

Ordovicidium groetlingboensis was not originally described as having granulate sculpture, however, the holotype does, in fact, display such sculpture. For this reason synonomy with O. elegantulum Tappan and Loeblich, 1971 is recognized. Again, the dimensions reported by Kjellström (1971a, 1976) fall within the measurements of the forms from Cincinnati Region and New York State.

Ordovicidium heteromorphicum (Kjellström, 1971a) was distinguished by the presence of simple as well as bifurcate processes. Both the figured specimens of O. elegantulum (=O. groetlingboensis) in Tappan and Loeblich (1971, Pl. 7, fig. 1-3, 6, 7) and 40 of 104 specimens from the Cincinnati Region demonstrate heteromorphic processes.

Ordovicidium majorfurcatum (Kjellström, 1971a) was originally described as having thick vesicle wall and thereby distinguished from Ordovicidium nudum (Eisenack, 1959). Unfortunately, measurements of wall thickness were not reported. It is here considered to be a variable character. No granulate sculpture was reported in O. majorfurcatum but the scale of the illustration by Kjellström (1971a) is too small to recognize grana. If grana are present, all the features and dimensions
of this species would fall within the range of those for *O. groetlingboensis*.

*Ordovicidium majorvesiculum* (Kjellström, 1971a) was distinguished by its large vesicle size and short, broad processes. The vesicle diameter is about 50% greater than that of species now attributable to *O. groetlingboensis*. However, granulate sculpture is present in the holotype and *O. majorvesiculum* might represent a closely related form.

**Dimensions:** 144 specimens. Vesicle diameter 37 (53) 77 µ; process length 9 (18) 30 µ; process width 2 (5) 9 µ; number of processes 9–33.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Grant Lake Limestone, Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Middle-Upper Ordovician [Shermanian and Edenian], Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky. Kings Falls Fm., Middle Ordovician [Kirkfieldian], City Brook, New York; Denley Fm., Middle-Upper Ordovician [Shermanian and Edenian], Martinsburg, Deer River, Trenton Falls, New York; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, Deer River, New York.

**Previously reported occurrences:** subsurface, Middle Ordovician [Lower Viruan], Gotland, Sweden (Kjellström, 1971a); subsurface, Middle
Ordovician [Lower Viruan], Öland, Sweden (Kjellström, 1972); subsurface, Middle Ordovician [Lower Viruan], Östergötland, Sweden (Kjellström, 1976); Bromide Formation, Middle Ordovician, Oklahoma (Tappan and Loeblich, 1971).
**Ordovicidium sp. A**  
Pl. VI, fig. 4.

**Description**: Vesicle apparently single-walled; outline circular; processes numerous (>30 on circumference), hollow, homomorphic, conical, regularly arranged radially; tips usually bifurcate (rarely simple or trifurcate), usually with one order of bifurcation only, acuminate; process contact with vesicle angular, septations between processes and vesicle cavity; vesicle and process sculpture absent. No excystment structure recognized.

**Remarks**: This rare form is easily recognized by its numerous short processes which most commonly have only a single order of bifurcation on each process. The hollow processes are separated from the vesicle cavity.

**Discussion**: This species has been found only as flattened specimens and may be shaped more like a circular pillow than a sphere. The flattened specimens have sometimes been found folded over themselves. 

**Ordovicidium** sp. A is easily distinguished from *O. groetlingboensis* (Kjellström, 1971) by the more numerous short processes, apparent lack of granulate process sculpture, and lack of higher order of process bifurcation.

The species is also easily distinguished from *O. nanofurcatum* (Kjellström, 1971a, p. 55) which has fewer "lambda-shaped" processes, which "bifurcate with bulbous furca-tips", and from *Peteinosphaeridium breviradiatum* (Eisenack, 1959), which has trifurcate processes that in poor illustrations (Eisenack, 1959, Pl. 17, fig. 7; Kjellström, 1971b,
p. 33, fig. 22) resemble those of *Peteinosphaeridium* species.

**Dimensions:** 4 specimens. Vesicle diameter 77, 70, 55, 44 μ; process length 7, 5, 6, 6μ; process width 1-2, 1, 1, 1μ; number of processes on circumference 58, 70, 33, 32; order of bifurcations 0°-2°.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Sugar River Fm., Middle Ordovician [Shermanian], Deer River, New York.
Genus *Petaloferidium* gen. nov.

Type species: *Petaloferidium stigii* sp. nov.

**Origin of generic name:** *Petalo-* Gr. petalon - leaf, + *feridium* L. fero - to bear.

**Description:** Vesicle single-walled, spherical to subspherical; outline circular to subcircular to subpolygonal; processes conical, hollow; free communication between process and vesicle cavity; process contact with vesicle curved; process tips thickened and rounded or with rounded petaloid lobes arranged palmately.

**Remarks:** This genus is distinguished by the process shape and the thickened, often petaloid, process terminations.

**Discussion:** This new genus includes at least one previously described species, *Petaloferidium florigera* (Vavrdova, 1977) nov. comb., formerly *Evittia florigera* Vavrdova, 1977. The morphology of the process is considered the diagnostic feature of this genus and the petaloid or lobulate process tips of *P. florigera* are nearly identical to those of *P. stigii*.

The process tips diagnostic of this genus are thickened, darker and vary from rounded (Figure 24a) to bulbous (Figure 24b), and inverted bulbous (Figure 24c).

Regardless if one accepts the original concept of the genus *Evittia* Brito, 1967, the restriction of it by Loeblich (1970a), the emendation
Fig. 24 - Process morphology of species of Petaloferidium. a, b, c, and d, process tips of Petaloferidium stigii sp. nov.; e, f, same P. florigera (Vavrdova); a - rounded; b - bulbous; c - inverted bulbous; d, e - petaloid; f - discoidal lobulate.
offered by Lister (1970a), or its synonomy with *Multiplicisphaeridium*

suggested by Cramer (1970a) and Eisenack and Cramer (1973), *Petaloferidium*
is quite different from *Evittia* in appearance of the petaloid
process tips which are not similar to the ramifying processes in most
species of *Evittia*.

*Florisphaeridium* Lister, 1970 has complexly petaloid, but open,
processes which are probably unrelated to those of *Petaloferidium*. Some
species attributed to *Multiplicisphaeridium* [e.g. ?*M. toyetae* (Cramer,
1964)] that have "roset-like structures" at the process tips, are com-
plexly petaloid to digitate and may be distantly related to species of
*Petaloferidium*. 
**Petaloferidium stigii** sp. nov.  
Pl. VI, fig. 7, 8, 10.

**Origin of specific epithet:** This species is named for paleontologist and stratigrapher Stig M. Bergström.

**Description:** Vesicle single-walled, subspherical; outline subcircular to polygonal; processes conical, hollow; free communication between hollow process and vesicle cavity; process contact with vesicle curved; process tips homomorphic to heteromorphic; homomorphic tips always thickened with bulbous terminations, heteromorphic tips include both bulbous tips and tips with rounded petaloid lobes arranged palmately with about three or four petals per tip; vesicle and process surface microgranulate with micrograna tightly packed and nearly touching each other.

**Remarks:** This species is distinguished by its homomorphic thickened, rounded bulbous process tips or heteromorphic processes with both bulbous tips and thickened, roundly petaloid tips. The micro-granulate surface (<1 μ according to the terminology of Tappan and Loeblich, 1971) is also diagnostic of the species.

**Discussion:** This species is distinguished from *Petaloferidium florigera* (Vavrdova, 1977, p. 116, Pl. 11, fig. 1-10, text-fig. 6a, 6b) by the more common bulbous tips, its diagnostic microgranulate sculpture and its larger size.
**Dimensions:** 6 specimens. Vesicle diameter 49, 49, 53, 68, 68, 70 μ; process length 11 (18) 25 μ; number of processes 6-10; process width at bases 5 (6.6) 11 μ; distance between processes 18 (29) 40 μ; petal length about 2 μ.

**Type locality and formation:** Clays Ferry Formation, Upper Ordovician [Edenian], Clay's Ferry, Kentucky. Sample CF-10 is 67 feet above base of Clays Ferry Formation.

**Holotype:** Illustrated in Pl.VI, fig. 8, deposited at the Orton Museum, The Ohio State University, Columbus, Ohio, U.S.A., Slide No. Cf-10-1, 102.1, 11.0. OSU #33909.

**Distribution:** Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
Genus *Peteinosphaeridium* Staplin et al., 1965

Type species: *Peteinosphaeridium trifurcatum* (ex bergstromii) Eisenack, 1931.

Description: Vesicle single-walled, spherical; outline circular to subcircular. Processes numerous, homomorphic, hollow or solid, multifurcate, radially arranged; processes with longitudinal veils (fins or lists). Vesicle sculpture absent, granulate, or microreticulate; pylome often present, with or without an everted lip.

Remarks: Diagnostic features of *Peteinosphaeridium* are the longitudinally veiled multifurcate processes and the spherical vesicle form.

Discussion: *Peteinosphaeridium* Staplin et al., 1965, was introduced to include forms with veiled processes, which had previously been referred to *Baltisphaeridium* Eisenack, 1958. Staplin et al. (1965) stated that "some of the subspecies or formae of *Peteinosphaeridium trifurcatum*, however, are described as lacking fins and should be maintained in *Baltisphaeridium*.

Eisenack (1969) proposed emendation of *Peteinosphaeridium* Staplin et al., 1965, because of the fact that the original diagnosis was too narrow and that many specimens referred to the genus lacked veils along the entire margin of a process.

In this study, the concept of the more narrowly defined *Peteinosphaeridium* Staplin et al., 1965, is followed. In specimens from the eastern Midcontinent of the United States, the processes of
all specimens of *Peteinosphaeridium* are veiled. The forms grouped under *Peteinosphaeridium* (Staplin et al., 1965) emended Eisenack, 1969 by Eisenack and Cramer (1973) have been referred to other genera; those with veiled processes are included in *Peteinosphaeridium* Staplin et al., 1965; those with unveiled simple processes in *Baltisphaeridium* Eisenack, 1958; and those with unveiled cylindrical multifurcate processes lacking communication with the vesicle interior in *Ordovicidium* Tappan and Loeblich, 1971. Forms with veiled multifurcate processes with communication with the vesicle interior are placed in *Multiplicisphaeridium* Staplin 1961, restricted Staplin, et al., 1965.

For a more complete discussion of the morphological differences between *Ordovicidium* and *Peteinosphaeridium*, see the remarks and discussion under *Ordovicidium* (See P. 184-188).

Species of *Polyancistrodorus* Loeblich and Tappan, 1969 and *Axisphaeridium* Eisenack, 1967 both with processes similar to those of species of *Peteinosphaeridium*, were separated from this genus on the basis of their possession of an antapical pseudopylome.
Peteinosphaeridium hypertrophicum Eisenack, 1976
Pl. VII, fig. 1, 3.

1976 Peteinosphaeridium trifurcatum hypertrophicum Eisenack,
p. 195, Pl. 4, fig. 4-7.

Description: Vesicle single-walled, spherical; outline circular to
subcircular. Processes numerous, homomorphic, radially arranged, hollow
or solid, multifurcate; process contact with vesicle angular; process
with smooth, thin longitudinal veils. Process larger than \( \frac{1}{2} \) vesicle
diameter. Vesicle sculpture absent.

Remarks: The diagnostic features of Peteinosphaeridium hypertrophicum
is its smooth vesicle and process length.

Discussion: Peteinosphaeridium trifurcatum hypertrophicum Eisenack was
proposed as a subspecies in a continuous intergrading complex of forms
(Eisenack, 1976, p. 196) of Peteinosphaeridium. This complex, which in-
cludes taxa with similar multifurcate processes having veils along their
entire length, comprises a series of forms from that with the longest
processes, P. trifurcatum hypertrophicum Eisenack, 1976, to an inter-
mediate form, P. trifurcatum intermedium Eisenack, 1976, to a form with
short processes, P. breviradiatum (Eisenack, 1959). The original
diagnosis of Baltisphaeridium trifurcatum by Eisenack (1938) included
forms now assignable to P. breviradiatum. Later, Eisenack (1959) de-
scribed B. trifurcatum forma breviradiatum and illustrated a form de-
scribed as having "a process length less than the radius." The
illustrated form (Eisenack, 1959) shows processes approximately 1/10 as long as the vesicle diameter. A similar form illustrated by Eisenack (1965b) and designated _P. trifurcatum_ ssp. _brefiradiatum_ has approximately the same ratio of process length to vesicle diameter.

Similarly, Kjellström (1971b) after elevating _P. trifurcatum_ ssp. _breviradiatum_ to species rank and placing it in the genus _Peteinosphaeridium_, described specimens with similar characteristics. The sequence of forms dealt with by Eisenack (1959) included two other forms. Forms with processes about \( \frac{1}{2} \) as long as the vesicle diameter were referred to as _B. trifurcatum_ forma _typica_ and forms with processes longer than \( \frac{1}{2} \) the vesicle diameter were called _B. trifurcatum_ forma _longiradiata_. However, these three forms (_B. trifurcatum_ forma _breviradiatum_, forma _typica_ and forma _longiradiata_) were distinguished on other criteria than simply process length (e.g., incomplete vs. complete veils on the processes, presence or absence of pylomes, etc.). Finally, Eisenack (1976) added consistency to the interrelated complex and used the designation _Peteinosphaeridium trifurcatum hypertrophicum_ for forms with processes between 3/4 and 4/5 as long as the vesicle diameter and the designation _P. trifurcatum intermedium_ for forms with a process length of about \( \frac{1}{2} \) or slightly less of the vesicle diameter. Unfortunately, the measured specimens of _P. trifurcatum hypertrophicum_ reported by Eisenack (1976, p. 195) have a ratio of process length to vesicle diameter of less than 3/4 to 4/5. Nevertheless, Eisenack's stated ratios are accepted here as useful taxonomic distinctions and the two subspecies introduced by Eisenack (1976) are elevated to species rank. Three species are therefore recognized, with all intergradations
between them, namely *P. hypertrophicum*, *P. intermedium*, and *P. breviradiatum*. The characteristics recognized as similar in species of this complex are the process construction and the vesicle sculpture, whereas the diagnostic feature for each species is the process length/vesicle diameter ratio. Although there is reason to question on biological grounds the value of recognizing in classification distinctions like process length, such distinctions can and should be recorded in this way, particularly when dealing with groups *incertae sedis*, such as acritarchs that are classified only on morphology. Hopefully, the accumulation of such morphological detail will retain detailed observations in the literature and in so doing add more complete understanding of the taxa, leading, perhaps, to their removal from *incertae sedis*.

*Peteinosphaeridium micranthum* (Eisenack, 1959) has relatively shorter processes than *P. breviradiatum*, the length of the processes being about 1/20 of the vesicle diameter. It is likely that *P. hymenoferum* (Eisenack, 1938) is closely related to *P. hypertrophicum* and that *P. dissimilis* Gorka, 1969 (based on a single, slightly damaged specimen) is synonymous with *P. intermedium*. It is difficult to recognize species characters from the original illustrations of either of these taxa.

**Dimensions:** 2 specimens. Vesicle diameter, 60 μ; 63 μ; process length 23–33 μ.

**Distribution:** Garrard Siltstone, Upper Ordovician [Edenian]; Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky.
Previously reported occurrences: Middle Ordovician, Öland, Sweden
(Staplin et al., 1965); Vaginatumkalk, Sweden (Eisenack, 1976).
Peteinosphaeridium intermedium Eisenack, 1976
Pl. VI, fig. 4-10.

1976 Peteinosphaeridium trifurcatum intermedium Eisenack, p. 196, Pl. 4, fig. 8-11.

Description: Vesicle single-walled, spherical; outline circular to sub-circular; processes numerous, homomorphic, radially arranged, hollow or solid, multifurcate, usually quadrafurcate; processes with smooth, thin, longitudinal veils (fins or lists); process contact with vesicle angular; processes about \( \frac{1}{2} \) of vesicle diameter or less; vesicle sculpture absent; pylome with everted lip.

Remarks: The diagnostic features of Peteinosphaeridium intermedium are the smooth vesicle and the process length.

Discussion: Peteinosphaeridium trifurcatum intermedium Eisenack, was proposed as a subspecies separate from P. trifurcatum hypertrophicum Eisenack, 1976. The distinction between these two subspecies was based primarily on process length which is here considered a specific character. In assemblages from the Cincinnati Region specimens of P. intermedium are commonly present but P. hypertrophicum occurs in only one sample.

Peteinosphaeridium intermedium resembles Peteinosphaeridium velatum Kjellström, 1971 although the processes of P. velatum are somewhat shorter. Judging from the illustration of P. velatum, each of the "three stems, filiform, homomorphic, trifurcate" found on each of the
processes and described by Kjellström (1971a, p. 58) appears to represent the junction line of two veils on each process. It is likely that *P. velatum* Kjellström, 1971 is a junior synonym of *Peteinosphaeridium* *trifurcatum* (Eisenack, 1931) and might be within the circumscription of *P. intermedium* Eisenack, 1976. Unfortunately, the holotype of *P. velatum* has been lost (written communication, Kjellström, 1977).

The specimen of *P. trifurcatum* (Eisenack, 1931) illustrated by Kjellström (1971a) may represent a species that should be referred to *Ordovicidium* Tappan and Loeblich, 1971.

**Dimensions:** 10 specimens. Vesicle diameter 46 (57) 71 μ; process length 7-14 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian] Maysville, Covington and Newport, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Grant Lake Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Lexington Ls., Middle Ordovician [Shermanian] Clay's Ferry, Kentucky; Clays Ferry Fm., Middle-Upper Ordovician [Shermanian and Edenian], Clay's Ferry Kentucky; Garrard Siltstone, Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky; Kings Falls Fm., Middle Ordovician [Kirkfieldian], Deer River, City Brook and Martinsburg, New York; Sugar River Fm., Middle Ordovician [Shermanian], Deer River, City Brook and Martinsburg, New York; Denley Fm., Middle-Upper Ordovician
[Shermanian and Edenian], City Brook, Trenton Falls, Deer River and Martinsburg, New York; Steuben Fm., Upper Ordovician [Edenian] Trenton Falls, Martinsburg and Deer River, New York.

Previously reported occurrences: Borehole, Lower Ordovician [Upper Arenigian], Poland (Gorka, 1969); borehole, Middle Ordovician [Lower Viruan], Gotland, Sweden (Kjellström, 1971a); borehole, Middle Ordovician [Lower Viruan], Öland, Sweden (Kjellström, 1972); borehole, Lower Ordovician [Arenigian] Montagne Noire, France (Rauscher, 1973); dredging, Middle Ordovician, Bothnian Sea, Finland (Tynni, 1975); Vaginatumkalk, Middle Ordovician, Sweden (Eisenack, 1976); borehole, Middle Ordovician [Lower Viruan], Östergötland, Sweden (Kjellström, 1976).
Peteinosphaeridium intermedium ssp. A
Pl. VII, fig. 2.

Description: Vesicle single-walled, spherical; outline circular to sub-circular. Processes numerous, homomorphic, radially arranged, hollow or solid, multifurcate, usually quadrafurcate; processes with smooth thin longitudinal veils (fins or lists). Processes of about $\frac{1}{2}$ as long as the vesicle diameter. Process contact with vesicle angular. Antapical pseudopylome present as thickening in vesicle wall. Pseudopylome may have conical, blunt-tipped processes associated with thickening.

Remarks: This taxon is distinguished from Peteinosphaeridium intermedium by the presence of an antapical pseudopylome.

Discussion: The genus Polyancistrodorus Loeblich and Tappan, 1969 is nearly identical to Peteinosphaeridium Staplin et al., 1965 and differs mainly by having a "thickened antapical pseudopylome."

It seems to me that the genus Peteinosphaeridium shows very close affinities to Polyancistrodorus and that the presence of an antapical pseudopylome may not necessarily be of generic significance. In the generic description of Polyancistrodorus (Loeblich and Tappan, 1969, p. 51) is stated that "at antapical end of vesicle and slightly excentric in position, the wall may [note the implied absence in some specimens] bulge out into a pseudopylome, a thickened knob, with terminal notch and apparent central canal[neither the notch nor the canal was illustrated]." However, because form taxa should be recognized on distinct morphological criteria, it seems preferable not to consider
the presence of an antapical pseudopylome as a taxonomic distinction until such time as sufficient biometric and biostratigraphic data have been accumulated to provide us with a better understanding of these structures. For this reason, I will use the designation *Peteinosphaeridium intermedium* ssp. A for the specimens described here. It should also be noted that these specimens differ from specimens of *Polyancistrodorus* Loeblich and Tappan, 1969 in not having serrate edges on the veils.

Loeblich and Tappan (1969) distinguished *Polyancistrodorus columbariferus* from *Peteinosphaeridium bergstromii* by the "less circular vesicle outline, prominent lip around pylome, more numerous processes and in having an antapical pseudopylome," and the same species from *Peteinosphaeridium trifurcatum* "in being smaller in size, in having a more prominent lip, but a pylome of smaller size, 7-11.5 vs. 23 in *Peteinosphaeridium trifurcatum*." It has been noted by Eisenack and Cramer (1973) that *Peteinosphaeridium bergstromii* is a junior synonym of *Peteinosphaeridium trifurcatum*.

The specimens from the Cincinnati Region resemble most closely *Peteinosphaeridium trifurcatum* ssp. *intermedium* of Eisenack (1976) but differ by the presence of the antapical pseudopylome.

**Dimensions:** 6 specimens. Vesicle diameter 49 (58 ) 67 μ; process length 7-14 μ.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian],
Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
**Peteinosphaeridium jimschopfi** sp. nov.

Pl. VIII, fig. 3, 5, 6, 8, 9.

**Origin of specific epithet:** this species is named to honor the paleobotanist James M. Schopf.

**Description:** Vesicle single-walled, spherical; outline circular to subcircular. Processes numerous, homomorphic, solid, multifurcate, usually trifurcate, radially arranged; process contact with vesicle angular; processes with longitudinal veils (fins or lists) occasionally connecting one process to an adjacent process. Process length about 1/6 vesicle diameter. Microreticulate sculpture on vesicle.

**Remarks:** This species is characterized by the microreticulate vesicle sculpture and by the fact that adjacent processes are sometimes connected by longitudinal veils.

**Discussion:** This species is best recognized with SEM, but microreticulate surface can be seen with oil immersion in transmitted light microscopy.

**Dimensions:** 3 specimens. Vesicle diameter 60, 60, 60 μ; process length 9=12 μ.

**Type locality and formation:** Kope Fm., Upper Ordovician [Edenian], Maysville, Kentucky. Sample 74MM-o is 152 feet below the top of the Kope Formation.
Holotype: Illustrated as fig. 3, 5, 6, 8, 9 of Pl. VIII, deposited at the Orton Museum, The Ohio State University, Columbus, Ohio, U.S.A., Slide No. 74MM0-1, 106.8, 8.3. OSU #33921.

Distribution: Kope Fm., Upper Ordovician [Edenian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
Peteinosphaeridium sp. A
Pl. VIII, fig. 11, 12.

Description: Vesicle single-walled, spherical; outline circular to subcircular. Processes numerous, homomorphic, solid, multifurcate, usually trifurcate, radially arranged; process contact with vesicle angular; processes with veils that follow contour of single strand of process including the furcate tips. Outer margin of veils serrate and curved even where process is angular. No sculpture on vesicle. Pylome present with raised collar.

Remarks: The diagnostic feature of this species is the serrate nature of the veils.

Discussion: Polyancistrodorus columbariferum Loeblich and Tappan, 1969 is similar to this species in that it also has an everted pylome and serrated veils. However, Peteinosphaeridium sp. A has no antapical pseudopylome and the outer margins of the veil are curved. Only a single specimen of this species was found using SEM.

Dimensions: 1 specimen. Vesicle diameter 40 μ; process length 18 μ.

Distribution: Kope Fm., Upper Ordovician [Edenian], Covington, Kentucky.
Genus Polygonium Vavrdova, 1966

Type species: Polygonium gracilis Vavrdova, 1966.

1966 Polygonium Vavrdova, p. 412, 413.
1971 Goniosphaeridium Kjellström, p. 43.

Description: Vesicle single-walled, polyhedral to nearly spherical; outline polygonal to nearly circular. Processes relatively few (about 15); hollow, homomorphic, simple, regularly arranged; process tips closed, usually acuminate or slightly blunt; contact with vesicle usually curved; free communication between vesicle and process. Sculpture finely granulate to absent; vesicle diameter usually exceeds 20 μ.

Remarks: The distinguishing features of Polygonium are its polyhedral (polygonal in outline) vesicle, the free communication between vesicle and processes, the simple process tips, and the lack of coarse sculpture.

Discussion: The original diagnosis of Polygonium Vavrdova, 1966 is essentially the same as that of Goniosphaeridium Eisenack, 1969, which is here regarded as a synonym of Polygonium. Since Polygonium gracilis Vavrdova, 1966, the type species of Polygonium, was originally described as having a diameter of 20 - 35 μ, it is thought appropriate to refer forms with a vesicle diameter greater than 20 μ to Polygonium.
Kjellström (1971a, p. 43) emended Eisenack's diagnosis of *Goniosphaeridium* to include specimens with vesicle size greater than 20 \( \mu \). thereby clearly distinguishing *Goniosphaeridium* from *Micrhystridium*. Eisenack and Cramer (1976, p. 629) state "there are no objective means to distinguish *Polygonium* from *Micrhystridium*; hence *Polygonium* must be placed in synonymy with *Micrhystridium*. Taxa originally listed as *Polygonium* are now placed in *Micrhystridium." *Polygonium* Vavrdova, 1966 has priority over *Goniosphaeridium* Eisenack, 1969, and the emendation of Kjellström (1971a) for *Goniosphaeridium*, "vesicle diameter usually exceeds 20 \( \mu \), is here incorporated into the concept of *Polygonium*.

*Polygonium* differs from *Veryhachium* Deunff ex Downie, 1959, which has fewer processes, from *Micrhystridium* Deflandre, 1937, which has a vesicle diameter less than 20 \( \mu \), and from *Multiplicisphaeridium* (Staplin) Staplin et al., 1965, which has branched processes.
Polygonium nanum (Deflandre, 1945) comb. nov.  
Pl. VIII, fig. 1, Fig. 25a

1942 *Hystrichosphaeridium brevispinosum nanum* Deflandre, p. 476, fig. 1, 16 (nomen nudum)

1945 *Hystrichosphaeridium brevispinosum nanum* Deflandre, p. 62, 63, Pl. 1, fig. 5-7, 17, 18.

1959 *Baltisphaeridium brevispinosum nanum* Downie, p. 59, Pl. 10, fig. 9.

non 1965 *Baltisphaeridium nanum* Cookson, p. 89, Pl. 10, fig. 5-8.

1965 *Baltisphaeridium nanum* Martin, p. 2, 3, Pl. 1, fig. 10.

1973 ?*Baltisphaeridium nanum* Eisenack and Cramer, p. 159-161, text-fig. on p. 159.

**Description:** Vesicle single-walled, polyhedral; outline polygonal to subcircular; processes hollow, conical, homomorphic; tips simple, acuminate; process contact with vesicle curved. Free communication between process and vesicle. Vesicle and process sculpture apparently absent.

**Remarks:** This species was first described by Deflandre (1945, p. 62, 63) as a small variety of *Hystrichosphaeridium brevispinosum*, "the type measuring 27 μ in diameter and 45 μ with the spines". The distinguishing characters visible in the illustrations by Deflandre (1945, Pl. 1, fig. 5-7 and 17, 18) are the polyhedral body, curved process-vesicle contact, free communication between process and vesicle, and apparent lack of sculpture.
Discussion: The specimens on which the species was proposed are poorly preserved. The description, however, is clear enough to have lasting value. The specimens found in the Cincinnati Region are very well preserved and show little more morphologically than those specimens used in the original description of the species.

Martin (1968b) reported specimens of Baltisphaeridium nanum with a vesicle diameter of 17-35 μ from the Ordovician of Belgium. Her specific determination was doubted by Eisenack and Cramer (1973, p. 159) in their consideration of ?Baltisphaeridium nanum.

Kjellström (1971a, p. 36) described B. nanum specimens with a vesicle diameter of 41-52 μ and a "faintly defined separation of the interior of the process from the vesicle cavity". I was unable to recognize this separation on specimens from the Cincinnati Region or on the specimen that Kjellström (1971a, Pl. 2, fig. 7) photographed for illustration.

Polygonium gracilis Vavrdova, 1966, the type species, is nearly identical to Polygonium nanum (Deflandre, 1945) comb. nov., being distinguished only by the "process formula" described for P. gracilis. Since "process formula" is not often used in determination of acritarch species there has been a lack of reported occurrences of P. gracilis. The circumscription of P. nanum used here probably includes P. gracilis.

Forms from the Cincinnati Region with relatively few processes resemble specimens of Goniosphaeridium connectum Kjellström, 1971a, although the vesicle diameter of G. connectum has been reported as 40-45 μ (Kjellström, 1971a), which is to be compared with the 19-35 μ diameter for specimens studied here.
Two specimens found at Maysville, Kentucky, display the bilateral symmetry usually associated with species of *Acanthodiacrondium*. They have not been separated taxonomically here because it is believed that they are morphologic variants of *Polygonium nanum*. Their dimensions have not been included below.

Specimens showing granulate sculpture on the processes have been placed in *Polygonium polyacanthum* (Eisenack, 1965) comb. nov.

**Dimensions**: 56 specimens. Vesicle diameter 18 (24) 35μ; process length 7 (14) 23μ; number of processes 8 (16) 27.

**Distribution**: Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky, Cincinnati, Ohio; Clays Ferry Fm., Middle–Upper Ordovician [Shermanian and Edenian], Clay's Ferry, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Calloway Creek Fm., Upper Ordovician [Maysvillian], Clay's Ferry, Kentucky; Kings Falls Limestone, Middle Ordovician [Kirkfieldian], Martinsburg, New York; Denley Limestone, Upper Ordovician [Edenian], Trenton Falls and Deer River, New York.

**Previously reported occurrences**: Montagne Noire, Upper Ordovician – Middle Silurian [Ashgillian – Wenlockian], France (Deflandre, 1942, 1945); Wenlock Shales, Middle Silurian [Wenlockian], England (Downie, 1958, 1963); Lower Ordovician to Lower Silurian [Arenigian – Llandoveryian], Belgium (Martín, 1965, 1968); Elton Beds, Upper Silurian [Ludlovian],
Shropshire, England (Lister, 1970); possibly Middle Devonian [Upper Couvinian], Brittany, France (Deunff, 1954b).
Fig. 25 - Morphology of *Polygonium nanum* (a) and *Polygonium polyacanthum* (b). Sculpture absent in *Polygonium nanum*. Processes granululate in *Polygonium polyacanthum*. 
**Polygonium polyacanthum** (Eisenack, 1965) comb. nov.
Pl. VIII, fig. 2; Fig. 25b.

1931 *Ovum hispidum polygonale* Eisenack (pars), p. 113, Pl. 4, fig. 16, 18, 20
1938 *Hystrichosphaeridium polygonale* Eisenack (pars), p. 12. Pl. 4, fig. 1, 2.
1959 *Baltisphaeridium polygonale* Eisenack (pars), pp. 199, 200, Pl. 16, fig. 6.
1962 *Baltisphaeridium polygonale* Eisenack, p. 359
1963 *Beryhachium polygonale* Eisenack, p. 209, Pl. 19, fig. 2.
1965 *Baltisphaeridium polygonale* forma *polyacantha* Eisenack (pars), p. 136, 137, Pl. 13, fig. 3, 4.
1968 *Baltisphaeridium polygonale* forma *polyacantha* Eisenack (pars), p. 91, Pl. 24, fig. 9.
1969 *Baltisphaeridium polygonale* polyacantha Gorka, p. 27, 28, Pl. 2, fig. 3, 4, 7, text-fig. 6.

**Description:** Vesicle single-walled, polyhedral; outline polygonal to subcircular; processes hollow, homorphic, conical; tips simple, acuminate; curved process contact with vesicle; free communication between process and vesicle. Vesicle sculpture absent; processes granulate, usually with grana concentrated on the distal parts.

**Remarks:** This species is characterized by the small grana usually found only on the distal parts of the processes. The form is considered sufficiently distinct to be raised to the specific level.
Discussion: This form is usually more rare than Polygonium nanum (Deflandre, 1945). The processes of P. polyacanthum are relatively longer and fewer than in the former species.

Polygonium polyacanthum differs from P. gracilis Vavrdova, 1966 in vesicle sculpture although some authors (Gorka, 1969; Eisenack and Cramer, 1973) have considered the two species synonymous.

The sculpture of P. polyacanthum varies from discretely echinate to microgranulate. This sculpture is probably intergradational from essentially absent in P. nanum to microgranulate - echinate in P. polyacanthum to more coarsely echinate in P. uncinatum (Martin, 1968b) comb. nov. It will be useful to carefully examine the stratigraphic ranges of these three species as they all seem to range through most of the Ordovician and at least through most of the Silurian.

In distinguishing P. polyacanthum from P. nanum it is noted that acanthodiacrodid forms are found only with smooth processes and are therefore included in P. nanum.

It is important to note the general absence of granulate forms in samples from New York State. This may be in part a consequence of the state of preservation of the microfossils in New York. Usually the degree of thermal alteration in these rocks in sufficient to at least partially corrode the outermost portion of the vesicle wall, especially at the distal end of the processes. Nevertheless, at least two specimens from New York State are probably attributable to P. polyacanthum.

Dimensions: 38 specimens. Vesicle diameter 19 (28) 44 μ; process length 9 (23) 30 μ; process number 6 (14) 23.
**Distribution**: Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Maysville and Newport, Kentucky and Cincinnati, Ohio; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Grant Lake Limestone, Upper Ordovician [Maysvillian], Maysville, Kentucky; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, New York.

**Previously reported occurrences**: Erratics, Ordovician and Silurian, Baltic Region (Eisenack, 1931, 1938, 1959, 1963, 1965b, 1968b); subsurface and erratics, Lower Ordovician [Arenigian], Poland (Gorka, 1969).
Polygonium cf. polygonale (Eisenack, 1931) comb. nov.
Pl. VIII, fig. 10.

cf. 1931 Ovum hispidum polygonale Eisenack, p. 113, Pl. 4, fig. 16-20, Pl. 5, fig. 18.

cf. 1938 Hystichosphaeridium polygonale Eisenack, p. 12, 22, Pl. 4, fig. 1.

cf. 1959 Baltisphaeridium polygonale Eisenack, p. 199, 200, Pl. 16, fig. 6-9.

cf. 1964 Veryhachium polygonale Deflandre and Deflandre, No. 392, fiche 2061.


cf. 1969 P. polygonale Lister, Cocks and Rushton, p. 602 (P. obviously misprint of B. [=Baltisphaeridium].


Description: Vesicle single-walled, polyhedral to subspherical; outline polygonal to subcircular; processes numerous, conical, very wide-based, homomorphic, regularly arranged radially; tips simple, slightly rounded to acuminate; process contact with vesicle curved; process in communication with vesicle cavity; vesicle and process sculpture microgranulate.

Remarks: The diagnostic features of P. polygonale are the wide process bases, the size, the less polygonal body shape than P. nanum, and the lack of coarse sculpture. The cf. designation is used because my specimens are not as large as most others referred to the present species and they exhibit microgranulate sculpture.
Discussion: This species was reported as having a vesicle diameter of "up to 250 \mu\text{m}" (Eisenack, 1959). The forms from New York State and the Cincinnati Region are only 42-70 \mu. There is some doubt concerning how closely these forms are related to those previously described. The previously reported occurrences ranging from Middle Ordovician to Silurian age are listed in Eisenack and Cramer (1973, p. 499-500) and are not listed here.

A smaller subspecies with echinate process sculpture, *Polygonium polygonale polyacanthum* (Eisenack, 1965), is elevated to species rank in this study and it is possible that it is not as closely related to *P. polygonale* as previously thought.

Dimensions: 6 specimens. Vesicle diameter 42 (51) 70 \mu\text{m}; process length 16 (19) 22 \mu; process number 12+ (17+) 23.

Distribution: Kope Fm., Upper Ordovician [Edenian], Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Newport, Kentucky; Steuben Fm., Upper Ordovician [Edenian], Trenton Falls, New York.
Genus **Rhopaliophora** Tappan and Loeblich, 1971

Type species: **Rhopaliophora folatilis** Tappan and Loeblich, 1971.

**Description:** Vesicle apparently double-walled, spherical; outline circular to subcircular; inner wall thicker, spherical, apparently unsculptured; outer wall thinner and forms processes; processes numerous, hollow, heteromorphic to homomorphic, usually conical, short, usually less than one-tenth the vesicle diameter; tips variable, simple or multifurcate, blunt, rounded, rarely acuminate; process contact with vesicle curved to angular; no apparent communication between process and vesicle cavity; sculpture on process and vesicle varies from microcostate to absent. Circular pylome with operculum and elevated rim common.

**Remarks:** This genus is characterized by the two wall layers, the outer layer forming short stout processes which are usually rounded and heteromorphic. The circular pylome is often present.

Representative of this genus can easily be mistaken for specimens of *Peteinosphaeridium* Staplin et al., 1965 when examined with transmitted light.

**Discussion:** *Rhopaliophora* has thin-walled processes that easily fold or compress and when examined with transmitted light they can be confused with multifurcate processes as in *Peteinosphaeridium* or the warty processes in some species of *Lophosphaeridium*. 
Rhopaliophora folatilis Tappan and Loeblich, 1971
Pl. VIII, fig. 7.

1971 Rhopaliophora folatilis Tappan and Loeblich, p. 404-406,
Pl. 9, fig. 1-6.

Description: Vesicle double-walled, spherical; outline circular to sub-
circular; processes numerous, hollow, homomorphic, short, stout, conical
variable in size; tips bluntly rounded, easily collapsed, simple;
process contact with vesicle curved; vesicle and process sculpture
absent as seen in transmitted light. Circular pylome sometimes present.

Remarks: The diagnostic feature of this species is the nature of the
processes. Tappan and Loeblich (1971, p. 406) described this form as
having a "strongly pinnate alignment of many tiny costae about 0.05 μ
in width".

Discussion: All the features except the microcostae mentioned by
Tappan and Loeblich (1971) are visible in the few specimens examined in
this study. However, because only two specimens were found, SEM study
to determine if microcostae are present was impractical.

Dimensions: 2 specimens. Vesicle diameter 56, 53μ; process length
2-4 μ.

Distribution: Fairview Fm., Upper Ordovician [Maysvillian], Maysville,
Kentucky and Cincinnati, Ohio.
Previously reported occurrences: Eden Fm. [= Kope Fm.], Upper Ordovician [Edenian], Indiana (Tappan and Loeblich, 1971).
Description: Vesicle double-walled, spherical; outline circular; processes numerous, conical, hollow, heteromorphic; tips simple to multifurcate, rounded; process contact with vesicle angular; furcae or projections of process tips few to as many as 14, sometimes equal to length of process; vesicle and process sculpture absent as seen in transmitted light. Circular pylome with elevated rim present.

Remarks: The diagnostic features of this species are the number and variability of the short processes. Tappan and Loeblich (1971) recognized a microrugulate surface sculpture with SEM.

Discussion: As is the case with Rhopaliophora folatilis, Rhopaliophora impexa was so rare in the assemblages studied here that SEM studies were impractical. It is possible that the microtexture described by Tappan and Loeblich (1971) is present on the specimens found here. All other features and dimensions are similar.

Distribution: Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio.

Previously reported occurrences: Eden Fm. [= Kope Fm.], Upper Ordovician [Edenian], Indiana (Tappan and Loeblich, 1971).
Genus *Veryhachium* Deunff ex Downie, 1959

Type species: *Veryhachium trisulcum* (Deunff, 1951) Denuff, 1959.

1954 *Veryhachium* Deunff, p. 306 (nomen nudum)
1959 *Veryhachium* Downie, p. 62.
1966 *Hystrichotriangulum* Andreeva, p. 132.

**Description:** Vesicle single-walled, pillow-shaped to polyhedral; outline triangular to polygonal; processes three to eight in number; processes simple, hollow, homomorphic, symmetrically arranged at corners; processes tips closed, acuminate or slightly blunt; contact between processes and vesicle straight to curved; free communication between vesicle and process. Sculpture usually uniform, varying from granular to absent, sometimes restricted to processes; excystment may be by epitychal flaps.

**Remarks:** Since *Veryhachium* was originally described (Deunff, 1954a) without designation of a type species, Downie (1959) selected *Veryhachium trisulcum* as genotype.

**Discussion:** Many genera have been distinguished previously by a combination of such characteristics as vesicle shape, morphology and arrangement of processes, and more recently, by the type of surface
sculpture. Loeblich and Tappan (1976) have proposed subdivision of Veryhachium into several genera on the basis of surface texture. Hence, they recognize excystment opening as characteristic of Impulviculus Loeblich and Tappan, 1969, the striated wall sculpture as characteristic of Arkonia Burmann, 1970, and the spinose ornamentation as characteristic of Villosacapsula Loeblich and Tappan, 1976. Veryhachium is here distinguished from Micrhystridium and Polygonium by its number of processes, and from Frankea Burmann, 1970 [= Dateriocradus Tappan and Loeblich, 1970] by the presence of multifurcate processes in the latter genus.
**Veryhachium lairdii** (Deflandre, 1946) Deunff, 1954
Pl. IX, fig. 1, Fig. 26g.

Selected list of synonyms:

1862 *Xanthidium* sp. White, p. 386, fig. 3.

1942 *Hystrichosphaeridium staurasteroides* Deflandre (pers), p. 476, fig. 10.

1946 *Hystrichosphaeridium lairdii*, Deflandre, card 1112.

1954 *Veryhachium lairdii* Deunff, p. 306.

1958 *Veryhachium minutum* Downie, p. 344, p. 17, fig. 4, text-fig. 3c.

1964 *Veryhachium valiente* Cramer, p. 34 (nomen nudum)

1964 *Veryhachium valiente* Cramer, p. 311, Pl. XII, fig. 3, 4, Text-fig. 28, fig. 7, 8, 9.

**Description:** Vesicle single-walled, pillow-shaped; outline square to rectangular; processes four in number, in the same plane on the vesicle, hollow, conical, homomorphic, rigid to flexible; process tips simple, acuminate; no septation between vesicle and processes; processes emerge from corners of vesicle and usually exceed vesicle diameter in length; vesicle and process sculpture absent. Vesicle usually less than 20 microns in diameter.

**Remarks:** This species resembles *Neovervachium carminae* (Cramer, 1964b) and *Veryhachium strictum* Deunff, 1966, in general shape, but is smaller, lacks the periderm and the striate sculpture of the former species, and shows little concavity of the vesicle.
Veryhachium lairdii (Deflandre, 1946) Deunff, 1954 was described as having a square to rectangular central body, and side length of 8-40 \( \mu \), generally 20-25 \( \mu \). The ratio of the long side to the short side has been determined to be 1-1.7 (Martin, 1968b). Four appendages are in the same plane as central body, with a length comprising between 2/3 and 2 times that of the sides. The processes are conical with simple pointed tips.

Veryhachium minutum Downie, 1958 was described as "test small, about 3-15 \( \mu \), formed by united bases of the processes; test wall thin, colourless, transparent, processes conical; length 80-200% of the test diameter, but difficult to distinguish test from processes; number 4 or 6."

Veryhachium valiente Cramer, 1964 was defined as "central body rectangular to square with straight sides. Four appendages at each corner, situated in the same plane. Occasionally a fifth appendage, situated near the center of the central body, is present. The processes end in a sharp tip. The wall is psilate at 1200X magnification, moderately thick and moderately transparent."

The \( V. \) minutum-\( V. \) lairdii-\( V. \) valiente complex includes small veryhachids, usually with four processes in the same plane and no sculpture. Cramer (1964b, p. 311) suggested that the difference between \( V. \) valiente and \( V. \) lairdii is the straight sides of the former and the concave sides of the latter. Statistical treatment of measurements of 80 specimens of these two taxa suggests they "belong to one and the same species" (Kalvacheva and Chobanova, 1973, p. 20). Kalvacheva and Chobanova also examined \( V. \) minutum and suggested that it is a
separate species with a length of 4-11 μ (3-5 μ in Downie's original diagnosis) for the 20 specimens they measured, and that the size is the diagnostic features of the species.

Despite the apparent possibility to segregate V. minutum from the V. lairdii-V. valiente group, the specimens from the Cincinnati Region seem to represent variations of a single morphotype. Veryhachium lairdii is used as a specific designation because, although the specimens from the Cincinnati Region are smaller on the average than those recognized elsewhere, they do fit within the circumscription suggested by Deflandre (1946).

Veryhachium staurasteroides (Deflandre, 1942) was described as having a quadrangular vesicle with long recurved processes. Moreau-Benoit (1974) has measured the vesicle and found it to be 12-20 μ and the processes to be 12-30 μ. This definition includes the dimensions of specimens considered and V. lairdii from the Cincinnati Region. The recurved processes of the specimens from the United States are thought here to be artifacts of preservation and/or preparation techniques.

Quality of preservation, preparation techniques, and simple mechanical torsion on individual specimens during deposition or lithification or during preparation for study can affect the size and shape of specimens to widen the variation of a single morphologic entity. It is for this reason the synonymy above has been used.

Small forms of V. europaeum Stockmans and Williere, 1960 have four processes arranged tetrahedrally rather than in the same plane. The fact that the morphology characteristics of many forms intergrade and overlap has been pointed out previously (Cramer, 1970, p. 96). No
adequate taxonomic revision of the rectangular to square, unsculptured veryhachids with four processes has been carried out to clearly define species in this group.

In Algeria, Jardine et al. (1974, fig. 3) record the presence of *Veryhachium longispinosum* Jardiné et al. 1974 in the "Ashgill? Caradoc." Their form is morphologically identical to *Veryhachium lairdii* from the Cincinnati Region except that *V. longispinosum* is larger, having a vesicle with a length of 25–40 μ and processes that are 50–65 μ in length.

*Veryhachium wenlockia* (Downie, 1959) Downie and Sarjeant, 1963 from the Silurian (Downie, 1959) and the Arenigian (Vavrdova, 1974) is similar in size (vesicle 6 to 27 μ; processes 100–500% vesicle length) to specimens from the Cincinnati Region but has a tetrahedral rather than a pillow-shaped vesicle shape.

**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky; Fairview Fm., Upper Ordovician [Maysvillian], Kentucky and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky; Garrard Siltstone, Upper Ordovician [Edenian] Clay's Ferry, Kentucky.

*Previously reported occurrences of V. lairdii:* Upper Ordovician Caradocian, Brittany, France (Deunff, 1959); Silurian [=Middle Ordovician], New York (White, 1862); Silurian, New York (Fisher, 1953); Silurian, Ontario, Canada (Laird, 1935); Upper Silurian and Lower
Devonian, Spain (Cramer, 1964a, 1964b); Devonian, Tunisia (Deunff, 1966; Lower Ordovician [Arenigian] and Silurian, Belgium (Martin, 1965, 1968b); Lower Ordovician [Tremadocian], England (Downie, 1958); Middle Ordovician [Llanvirnian-Llandeiliian], Iskur Gorge, Bulgaria (Kalvacheva and Chobanova, 1973); Middle Ordovician [Llanvirnian], Brittany, France (Henry, 1969); Middle Ordovician [Llanvirnian-Llandeiliian], USSR (Piskun, 1974); Middle Ordovician, Bothnian Sea, Finland (Tynni, 1975); Lower and Middle Ordovician [Arenigian and Llanvirnian], England (Lister and Holliday, 1970); Silurian [Torronian], Belgium (Stockmans and Williere, 1963; Upper Ordovician [Ashgillian], Bohemia, Czechoslovakia (Kanzalova-Manzacova, 1969); Silurian and Devonian, Brazil (Brito, 1967); Upper Ordovician-Silurian, Massif Armoricain, France (Moreau-Benoit, 1974);

As V. valiente Cramer, 1964:
Silurian, Spain (Cramer, 1964a, 1964b, 1970a); Silurian [Tarronian], Belgium (Martin, 1965); Maplewood Shale [Llandovery-Wenlockian], New York (Cramer, 1968); Tuscarora and Rose Hill Fm., Lower Silurian [Llandovery], Pennsylvania (Cramer, 1967); Ross Brook Fm., Silurian [Llandovery-Wenlockian], Nova Scotia, Canada (Cramer, 1970c); Silurian-Devonian, France (Moreau-Benoit, 1974);

As V. staurasteroides (Deflandre, 1942)
Silurian, France (Deflandre, 1942); Silurian, France (Moreau-Benoit, 1974).
Veryhachium trispinosum (Eisenack, 1938) Deunff, 1954
Pl. IX, fig. 2-21, Pl. X, fig. 1, 3, 6-9, Fig. 26a-e.

1938  Hystrichosphaeridium trispinosum Eisenack, p. 16, fig. 2

The listing of a complete synonymy is beyond the scope of this study. Cramer (1970, pp. 95-104) published a list of 44 species of Veryhachium and Micrhystridium that he considered conspecific. Although this study cannot confirm the synonymy of all the species listed by Cramer, his taxonomic philosophy is accepted in most cases.

Description: Vesicle single-walled, triangular to pillow-shaped; outline triangular; processes at corners, usually three, rarely four, hollow, homomorphic, conical and in the same plane; tips simple, acuminate; contact between processes and vesicle straight; free communication between vesicle and processes; sculpture microgranular with micrograna usually more densely packed on processes; length of vesicle wall along a side usually exceeds 25 μ; process length usually less than the vesicle wall length.

Remarks: Veryhachium trispinosum is characterized by having three processes in the same plane. Variety in degree of compression accounts for some variation in concavity and convexity in plan view. The processes are continuous with the vesicle and in most specimens, no clear demarcation between the process and vesicle is evident. Although in
some cases the processes are longer than the vesicle wall, measurement of forms from the Cincinnati Region shows that the processes are usually shorter than the length of the vesicle wall.

Microgranum are visible in SEM and, in most cases, can be seen also at about 400 X magnification with transmitted light. Weakly formed striae similar to the striae that are more definitely developed in species of Arkonia are visible in SEM photographs (Pl. IX, fig. 9; Pl. X, figs. 7, 9).

Discussion: Veryhachium trispinosum was simply defined as a form with three processes, which are shorter than the diameter of the vesicle (Henry, 1969). The complexity of the synonymy has been discussed (Martin, 1968a, Cramer, 1970b) and the differences between the present species and similar forms will not be discussed here. The present species is, however, distinguished from V. lairdii (Deflandre, 1946) by size, and from V. sp. A by the vesicle/process ratio and the fine sculpture. Veryhachium trispinosum is common and fairly uniform morphologically in my collection.

Dimensions: 93 specimens. Vesicle diameter 26 (37) 53 μ; process length 11 (15) 21 μ.

Distribution: Kope Fm., Upper Ordovician [Edenian] Maysville, Covington and Newport, Kentucky and Cincinnati, Ohio; Fairview Fm., Upper Ordovician [Maysvillian], Maysville, Kentucky and Cincinnati, Ohio; Miamitown Shale, Upper Ordovician [Maysvillian], Cincinnati, Ohio; Grant Lake Ls., Upper Ordovician [Maysvillian], Maysville, Kentucky; Lexington
Previously reported occurrences: Numerous occurrences in Ordovician, Silurian and Devonian rocks. Several pages of references are given for occurrences reported before 1968 in Cramer (1970a, pp. 94-114).
**Veryhachium sp. A**

*Pl. X, fig. 4, 5.*

**Description:** Vesicle single-walled, triangularly pillow-shaped to nearly ovoid; outline triangular to subcircular, with relatively long processes at corners; in some cases the processes exceed the vesicle diameter; three processes, hollow, homomorphic, conical and in the same plane; process tips simple, acuminate; contact between processes straight to curved; free communication between vesicle and processes; sculpture microrugulate, with densely packed ornaments uniformly distributed on vesicle and processes.

**Remarks:** *Veryhachium* sp. A is characterized by vesicle sides which are shorter than the processes. The vesicle is sometimes inflated. The microrugulate ornament is best observed with SEM.

**Discussion:** This relatively rare element in the population of Veryhachids in the Cincinnati Region is similar to *Veryhachium irroratum* Loeblich and Tappan, 1969, and distinguished from it by the microrugulate sculpture as opposed to the "grana on processes tending to develop into small prickles" (Loeblich and Tappan, 1969, p. 56). It differs from species of *Villosacapsula* Loeblich and Tappan, 1976, which have spines rather than grana.

**Dimensions:** 7 specimens. Vesicle diameter 18 (22) 26 μ; process length 28 (32) 42 μ.
**Distribution:** Kope Fm., Upper Ordovician [Edenian], Maysville and Covington, Kentucky and Cincinnati, Ohio; Grant Lake Ls., Upper Ordovician [Maysvillian], Maysville, Kentucky; Clays Ferry Fm., Upper Ordovician [Edenian], Clay's Ferry, Kentucky.
Fig. 26 - Morphology of species of *Veryhachium*. a–c, *V. trispinosum*. Note finely granulate vesicle and the presence of three processes; d, *V. trispinosum*. Note finely granulate vesicle and the presence of four processes; e, *B. trispinosum*. Note long processes and absence of sculpture; f, *V. sp. A*. Note microrugulate sculpture on vesicle and the presence of three processes; g, *V. lairdii*. Note unsculptured vesicle and the presence of four processes.
LIST OF REFERENCES

Achab, A., 1976, Les acritarches de la Formation d'Awantjish (Llando- 
verian supérieur) du sondage Val Brilliant, Vallée de la 

Andreeva, E. M., 1966, Complexes ordoviciens de spores et autres 
microfossiles végétaux en URSS. Trudy Vses. nauch issledov. 
geol. inst. 2(141):24-30.

Bassler, R. S., 1906, A study of the James types of Ordovician and 

Bastin, E. S., 1908, Description of the Rockland quadrangle, Me. 

Boldor, C. and Visarion, A., 1972, Asupra Prezentei Ordovicianului in 
Regiunea Fenes (Carpatii Meridionali-Banatul de Est). Romania, 

Brito, I. M., 1967, Silurian and Devonian acritarcha from the Maranhão 

Brito, I. M., 1969, Un nouveau sous-groupe d'Acritarche. Inst. Geo-

Brito, I. M. and Santos, A. S., 1965, Contribuição ao conhecimento dos 
microfósseis Silurianos e Devonianos da Bacia do Maranhão. Notas 

2:639-652.

Burmann, G., 1970, Weitere organische Mikrofossilien aus dem unteren 

Burmann, G., 1973, Das Ordovizium der nordlichen Phyllitzone. Teil I: 

Campbell, M. R., 1898, Description of the Richmond quadrangle 
4 maps.

247


Eaton, A., 1824, A geological and agricultural survey of the district adjoining the Erie Canal, 163 p.


Eisenack, A., 1934, Neue Mikrofossilien des baltischen Silurs. III. und neue Mikrofossilien des böhmischen Silurs I. Paläont. Z., 16:52-76.


Eisenack, A., 1948, Mikrofossilien aus Kieselknollen des böhmischen Ordoviziums. Senckenbergiana, 28(4-6):105-117.


Graham, R., 1933, Preparation of palaeobotanical sections by the peel method, Stain Technology, 18(2):65-68.


Sweet, W. C., in press, Conodonts and Conodont Biostratigraphy of the Post-Tyrone Ordovician Rocks of Cincinnati Region. U. S. Geol. Surv., Prof. Paper 1066-D.


APPENDIX A
SAMPLE DESCRIPTIONS

The samples studied are described and listed in descending stratigraphic order. Sample numbers and formational boundaries are given for reference.

The sample numbers are of two types. One numbering system follows the method used in the Micropaleontology Laboratory at The Ohio State University. Samples with this numbering code are filed at The Ohio State University.

Numbers for the Ohio State samples have a number, a letter code and another number. A sample number such as 75MB12 indicate that the sample was collected in 1975 and was 12 feet above the base of the section.

A second numbering system has been used for some samples. These samples are not filed at the Ohio State University. A sample number such as CF-12 indicates that the sample was the twelfth sample collected at the Clay's Ferry section and for samples with this numbering code the stratigraphic elevation is given from some stratigraphic reference level at the sampled locality.

Maysville Section, Maysville, Kentucky

Thirty-five samples were examined from the 344 feet (195 m) section described by Carpenter and Ory (1961) along U.S. Rt. 62-68 about 1 mile south of Maysville, Kentucky. The upper part of Kope Formation
(74MM220-74MM344) are exposed at this locality. At this locality sample descriptions are after Miller (1976, p. 212) and are from hand specimen analysis. The samples were collected by Merrell Miller.

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>74MM344</td>
<td>Biosparite with limey intraclasts</td>
</tr>
<tr>
<td>74MM334</td>
<td>Brachiopod biosparite with micrite</td>
</tr>
<tr>
<td>74MM332</td>
<td>Gastropod biomicrite</td>
</tr>
<tr>
<td>74MM326</td>
<td>Sparse brachiopod biomicrite</td>
</tr>
<tr>
<td>74MM314.5</td>
<td>Bryozoan trilobite biosparite</td>
</tr>
<tr>
<td>74MM306.8</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>74MM297.3</td>
<td>Bivalve-brachiopod biomicrite</td>
</tr>
<tr>
<td>74MM294.3</td>
<td>Brachiopod biomicrite</td>
</tr>
<tr>
<td>74MM280.3</td>
<td>Dark blue-gray laminated biosparite</td>
</tr>
<tr>
<td>74MM274.8</td>
<td>Brachiopod biomicite with bryozoans and -rilobites</td>
</tr>
<tr>
<td>74MM268.4</td>
<td>Sparse brachiopod-bivalve biomicrite</td>
</tr>
<tr>
<td>74MM249.9</td>
<td>Sparse brachiopod biomicite</td>
</tr>
<tr>
<td>74MM241.8</td>
<td>Laminated calcareous siltstone</td>
</tr>
<tr>
<td>74MM237.3</td>
<td>Sparse brachiopod biosparite</td>
</tr>
<tr>
<td>74MM207.6</td>
<td>Light-gray calcareous siltstone</td>
</tr>
<tr>
<td>74MM193.2</td>
<td>Trilobite brachiopod biomicite</td>
</tr>
<tr>
<td>74MM189.8</td>
<td>Sparse biomicite</td>
</tr>
<tr>
<td>74MM179.4</td>
<td>Dark blue-gray calcareous siltstone</td>
</tr>
<tr>
<td>74MM174.6</td>
<td>Brachiopod biosparite</td>
</tr>
<tr>
<td>74MM166.3</td>
<td>Packed bryozoan biomicite</td>
</tr>
<tr>
<td>74MM161.5</td>
<td>Calcareous siltstone</td>
</tr>
<tr>
<td>74MM152.3</td>
<td>Brachiopod biosparite</td>
</tr>
<tr>
<td>74MM143.3a</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>74MM119</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>74MM107.2</td>
<td>Packed brachiopod biomicite</td>
</tr>
<tr>
<td>74MM95a</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>74MM95</td>
<td>Biosparite</td>
</tr>
<tr>
<td>74MM87.3</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>74MM80</td>
<td>Sparse brachiopod shaly biomicite</td>
</tr>
<tr>
<td>74MM31.8</td>
<td>Sparse fossiliferous biomicite with silty bed</td>
</tr>
<tr>
<td>74MM26.5</td>
<td>Brachiopod biomicite</td>
</tr>
<tr>
<td>74MM22.2</td>
<td>Fossiliferous biosparite</td>
</tr>
<tr>
<td>74MM16.4</td>
<td>Reddish-brown shaly siltstone</td>
</tr>
<tr>
<td>74MM9.8</td>
<td>Brachiopod biomicite</td>
</tr>
<tr>
<td>74MM0</td>
<td>Brachiopod biomicite with trilobite fragments</td>
</tr>
</tbody>
</table>

Cincinnati Composite Section, area near Cincinnati, Ohio

Twenty-two samples were examined from a 308 feet (94.2 m) composite section compiled from exposures in three areas within a few miles of each other in and adjacent to Cincinnati, Ohio. The stratigraphically
highest seven samples (75MB0, 75MB12, 75MB47.5, 75MB60, 75MB100.5, 75MB114.5, 75MB135) were collected by Merrell Miller from the upper Kope Formation (75MB0), the Fairview Formation (75MB12-75MB100.5), the Miamitown shale (75MB114.5) and the lower part of the Grant Lake limestone (75MB135) along Clifton Avenue in Cincinnati (see Miller, 1976, p. 213). The Edenian-Maysvillian stadial boundary has been recognized as the formational contact of the Kope and Fairview Formations at this section.

Clifton Avenue, Cincinnati

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>75MB135</td>
<td>Brachiopod biomicrite</td>
</tr>
<tr>
<td>75MB114.5</td>
<td>Blue-gray calcareous shale</td>
</tr>
<tr>
<td>75MB100.5</td>
<td>Brachiopod biomicrite</td>
</tr>
<tr>
<td>75MB60</td>
<td>Brachiopod biosparite</td>
</tr>
<tr>
<td>75MB47.5</td>
<td>Brachiopod biomicrite</td>
</tr>
<tr>
<td>75MB12</td>
<td>Bryozoan biomicrite</td>
</tr>
<tr>
<td>75MB0</td>
<td>Brachiopod, bryozoan biomicrite</td>
</tr>
</tbody>
</table>

Four samples near the Kope-Fairview formational contact were collected at the exposure behind the Newport Shopping Center at Newport, Kentucky from the Kope Formation (NSC-2, 4) and the Fairview Formation (NSC-1, 2).

Newport (Ky.) Shopping Center

<table>
<thead>
<tr>
<th>Sample</th>
<th>Description</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSC-1</td>
<td>Brachiopod biomicrite</td>
<td>25 feet above base of Fairview Fm.</td>
</tr>
<tr>
<td>NSC-2</td>
<td>Yellow-gray shaly mudstone with brachiopods</td>
<td>24 feet above Fairview Fm.</td>
</tr>
<tr>
<td>NSC-3</td>
<td>Bryozoan biosparite</td>
<td>20 feet below top of Kope Fm.</td>
</tr>
<tr>
<td>NSC-4</td>
<td>Blue-gray shaly calcareous mudstone</td>
<td>21 feet below top of Kope Fm.</td>
</tr>
</tbody>
</table>

Eleven samples from the Kope Formation (Cov 1-Cov 11) were collected from the roadcut along the eastern side of I-75 in Covington, Kentucky about 4 miles south of the bridge across the Ohio River.
Covington, Ky.

<table>
<thead>
<tr>
<th>Cov-11</th>
<th>Bryozoan biosparite</th>
<th>Kope Fm., 144 feet above base of outcrop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cov-10</td>
<td>Blue-gray calcareous shaly mudstone</td>
<td>Kope Fm., 119 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-8</td>
<td>Blue-gray shaly calcareous mudstone</td>
<td>Kope Fm., 79 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-7</td>
<td>Sparse brachiopod biosparite</td>
<td>Kope Fm., 78 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-6</td>
<td>Medium-gray shaly calcareous mudstone</td>
<td>Kope Fm., 58 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-5</td>
<td>Sparse brachiopod biosparite</td>
<td>Kope Fm., 53 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-4</td>
<td>Medium-gray shaly calcareous mudstone</td>
<td>Kope Fm., 28 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-3</td>
<td>Crinoid biosparite limestone</td>
<td>Kope Fm., 27 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-2</td>
<td>Medium-gray shaly calcareous mudstone</td>
<td>Kope Fm., 21 feet above base of outcrop.</td>
</tr>
<tr>
<td>Cov-1</td>
<td>Sparse brachiopod biosparite with micrite</td>
<td>Kope Fm., 20 feet above base of outcrop.</td>
</tr>
</tbody>
</table>

Clay's Ferry Section, Clay's Ferry, Kentucky

Twenty samples were examined from the 243 feet (74 m) section along Clay's Ferry Road and I-75 described by Weir and Greene (1965) and Weir, Greene and Simmons (1965). The upper part of the Lexington Limestone (CF1, CF2), the Clays Ferry Formation (CF3-CF12, CF18-CF13), the Garrard Siltstone (CF13), and the lower part of the Calloway Creek Formation (SA0, SA25) are exposed at this locality. Samples 73SA-0 and 73SA-25 were collected by Walter Sweet.

<table>
<thead>
<tr>
<th>73SA-25</th>
<th>Brachiopod biosparite</th>
<th>25 feet above base of Calloway Creek Fm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>73SA-0</td>
<td>Biosparite with micrite</td>
<td>base of Calloway Creek Fm.</td>
</tr>
<tr>
<td>CF-13</td>
<td>Limy siltstone</td>
<td>6 feet above base of Garrard Siltstone</td>
</tr>
<tr>
<td>CF-14</td>
<td>Silty limestone</td>
<td>2 feet below top of Clays Ferry Fm.</td>
</tr>
<tr>
<td>CF-15</td>
<td>Shaly siltstone</td>
<td>162 feet above base of Clays Ferry Fm.</td>
</tr>
<tr>
<td>CF-16</td>
<td>Unfossiliferous micrite</td>
<td>160 feet above base of Clays Ferry Fm.</td>
</tr>
</tbody>
</table>
Sixty-one samples were examined from five stratigraphic sections in New York State. These sections are at City Brook (62B-CB-1-62B-CB-60), Trenton Falls (62BTR-53-62BTR-250), Martinsburg, Roaring Brook (62BMRB-5, 62BMRB-287), Deer River, Kings Falls (62BKDR-2-62BKDR-148), and Deer River, High Falls (62BDR-3-62BDR-284). Measured sections can be found for City Brook in Kay, 1953; for Trenton Falls in Prosser & Cumings, 1897; Kay, 1943, 1953; and Ross, 1964; for Martinsburg, Roaring Brook in Ross, 1964; for Deer River, Kings Falls in Ross, 1964; and for Deer River, High Falls in Kay 1933, 1937. My samples are the same as those collected and used for conodont study by Schopf (1966).
The composite has been compiled on the basis of conodont data from Sweet (pers. comm., 1977) and elevations used in the composite are seen in fig.

Samples of Utica Shale collected from Rathbun Brook, Nowadaga Creek, Gulf Stream and at Copenhagen and Holland Patent, New York were barren.

### City Brook between Newport and Middleville, N.Y. (Kay, 1953)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>62B-CB60</td>
<td>Crinoid biosparite</td>
<td>Sugar River Formation</td>
</tr>
<tr>
<td>62B-CB50</td>
<td>Brachiopod-crinoid biosparite</td>
<td>Sugar River Formation</td>
</tr>
<tr>
<td>62B-CB39</td>
<td>Brachiopod biosparite</td>
<td>Sugar River Formation</td>
</tr>
<tr>
<td>62B-CB30</td>
<td>Crinoid-brachiopod biosparite</td>
<td>Kings Falls Formation</td>
</tr>
<tr>
<td>62B-CB20</td>
<td>Brachiopod biosparite</td>
<td>Kings Falls Formation</td>
</tr>
<tr>
<td>62B-CB10</td>
<td>Brachiopod biosparite</td>
<td>Kings Falls Formation</td>
</tr>
<tr>
<td>62B-CB1</td>
<td>Brachiopod biosparite</td>
<td>Kings Falls Formation</td>
</tr>
</tbody>
</table>

### Martinsburg, Roaring Brook, between Martinsburg and N.Y. highway 12 (Ross, 1964)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>62BMRB-287</td>
<td>Brachiopod biosparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BMRB-251</td>
<td>Sparse brachiopod biosparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BMRB-224</td>
<td>Cinoid-brachiopod biomicrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BMRB-199</td>
<td>Brachiopod biosparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BMRB-179</td>
<td>Brachiopod biomicrite with sparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BMRB-156</td>
<td>Crinoid biosparite</td>
<td>Sugar River Fm.</td>
</tr>
<tr>
<td>62BMRB-128</td>
<td>Fossiliferous biosparite with micrite</td>
<td>Sugar River Fm.</td>
</tr>
<tr>
<td>62BMRB-98</td>
<td>Crinoid-brachiopod biomicrite with sparite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BMRB-73</td>
<td>Sparse brachiopod biomicite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BMRB-46</td>
<td>Brachiopod-crinoid biomicrite with sparite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BMRB-5</td>
<td>Brachiopod biomicrite with sparite</td>
<td>Napanee Fm.</td>
</tr>
</tbody>
</table>

### Deer River, Kings Falls near Copenhagen, N.Y. (Ross, 1964)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>62BKDR-148</td>
<td>Brachiopod biosparite</td>
<td>Sugar River Fm.</td>
</tr>
<tr>
<td>62BKDR-132</td>
<td>Brachiopod biomicrite with sparite</td>
<td>Sugar River Fm.</td>
</tr>
<tr>
<td>62BKDR-111</td>
<td>Brachiopod biomicrite with sparite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
<td>Formation</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>62BMKDR-77</td>
<td>Brachiopod biosparite with micrite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BKDR-58</td>
<td>Crinoid biosparite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BKDR-40</td>
<td>Brachiopod biomicrite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BKDR-22</td>
<td>Brachiopod biomicrite</td>
<td>Kings Falls Fm.</td>
</tr>
<tr>
<td>62BKDR-2</td>
<td>Brachiopod biomicrite</td>
<td>Rockland Fm.</td>
</tr>
</tbody>
</table>

Deer River, High Falls near Copenhagen, N.Y. (Kay 1933, 1937)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>62BDR-284</td>
<td>Biosparite</td>
<td>Hillier Fm.</td>
</tr>
<tr>
<td>62BDR-249</td>
<td>Brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-230</td>
<td>Crinoid-brachiopod biomicrite with sparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-210</td>
<td>Crinoid-brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-181</td>
<td>Brachiopod biomicrite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-166</td>
<td>Biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-147</td>
<td>Brachiopod-crinoid biomicrite with sparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-123</td>
<td>Biosparite with micrite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-100</td>
<td>Sparse brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-84</td>
<td>Crinoid biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BDR-64</td>
<td>Brachiopod biosparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BDR-43</td>
<td>Brachiopod biomicrite with sparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BDR-23</td>
<td>Brachiopod biomicite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BDR-3</td>
<td>Brachiopod biomicite</td>
<td>Denley Fm.</td>
</tr>
</tbody>
</table>

Trenton Falls, West Canada Creek (Proser & Cumings 1897; Kay 1943, 1953; Ross 1964)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>62BTR-250</td>
<td>Brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-244</td>
<td>Brachiopod-crinoid biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-235</td>
<td>Brachiopod-crinoid biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-220</td>
<td>Brachiopod biomicrite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-212</td>
<td>Brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-179</td>
<td>Brachiopod biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-170</td>
<td>Brachiopod-crinoid biosparite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-159</td>
<td>Brachiopod biomicite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-141</td>
<td>Brachiopod biomicite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-127</td>
<td>Micrite</td>
<td>Steuben Ls.</td>
</tr>
<tr>
<td>62BTR-115</td>
<td>Micrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-109</td>
<td>Sparite with micrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-103</td>
<td>Sparite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-95</td>
<td>Micrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-80</td>
<td>Sparse crinoid biomicrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-65</td>
<td>Micrite</td>
<td>Denley Fm.</td>
</tr>
<tr>
<td>62BTR-53</td>
<td>Sparse brachiopod biomicrite</td>
<td>Denley Fm.</td>
</tr>
</tbody>
</table>
### APPENDIX B

**TABLES OF ACRITARCH OCCURRENCES**

<table>
<thead>
<tr>
<th>Species</th>
<th>0</th>
<th>1</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>36</th>
<th>36</th>
<th>39</th>
<th>41</th>
<th>48</th>
<th>55</th>
<th>58</th>
<th>65</th>
<th>77</th>
<th>78</th>
<th>88</th>
<th>89</th>
<th>96</th>
<th>97</th>
<th>98</th>
<th>110</th>
<th>129</th>
<th>126</th>
<th>146</th>
<th>147</th>
<th>166</th>
<th>167</th>
<th>176</th>
<th>176</th>
<th>217</th>
<th>218</th>
<th>219</th>
<th>238</th>
<th>250</th>
<th>252</th>
<th>264</th>
<th>282</th>
<th>284</th>
<th>291</th>
<th>302</th>
<th>323</th>
<th>335</th>
<th>358</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sphenocapsidium tripartitum</em></td>
<td>57</td>
<td>27</td>
<td>12</td>
<td>9</td>
<td>64</td>
<td>4</td>
<td>93</td>
<td>4</td>
<td>41</td>
<td>37</td>
<td>78</td>
<td>4</td>
<td>18</td>
<td>83</td>
<td>1</td>
<td>13</td>
<td>40</td>
<td>50</td>
<td>56</td>
<td>67</td>
<td>165</td>
<td>60</td>
<td>5</td>
<td>42</td>
<td>175</td>
<td>13</td>
<td>546</td>
<td>63</td>
<td>174</td>
<td>74</td>
<td>61</td>
<td>109</td>
<td>21</td>
<td>97</td>
<td>470</td>
<td>75</td>
<td>82</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ptiloderma trilobatum</em></td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>21</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>14</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>103</td>
<td>5</td>
<td>18</td>
<td>13</td>
<td>17</td>
<td>21</td>
<td>57</td>
<td>20</td>
<td>11</td>
<td>21</td>
<td>15</td>
<td>45</td>
<td>19</td>
<td>74</td>
<td>31</td>
<td>32</td>
<td>33</td>
<td>23</td>
<td>10</td>
<td>30</td>
<td>46</td>
<td>20</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Nothosphaeridiopsis simplex</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>24</td>
<td>7</td>
<td>15</td>
<td>1</td>
<td>22</td>
<td>19</td>
<td>37</td>
<td>9</td>
<td>33</td>
<td>9</td>
<td>13</td>
<td>5</td>
<td>71</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heterocapsa sp.</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>24</td>
<td>7</td>
<td>15</td>
<td>1</td>
<td>22</td>
<td>19</td>
<td>37</td>
<td>9</td>
<td>33</td>
<td>9</td>
<td>13</td>
<td>5</td>
<td>71</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heterocapsa sp.</em></td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>16</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>9</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Paracyclus geinitzii</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>25</td>
<td>3</td>
<td>39</td>
<td>11</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Acrinocapsa elegans</em></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>25</td>
<td>3</td>
<td>39</td>
<td>11</td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heterocapsa sp.</em></td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heterocapsa sp.</em></td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 5. Acritarch Occurrences in Samples Used in New York State Composite Section**
Table 6. Acritarch Occurrences in Samples at Maysville, Kentucky.

| Sample Numbers | 0    | 9.8  | 16.4 | 22.2 | 26.3 | 31.6 | 60   | 87.3 | 95   | 143.3 | 161.5 | 166.3 | 174.6 | 182.8 | 183.2 | 207.6 | 237.3 | 241.8 | 249.9 | 268.4 | 274.8 | 280.3 | 294.3 | 297.3 | 306.8 | 314.5 | 326  | 332  | 334  | 344  |
|----------------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Verphilium trispinosum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Poterinosphaeridium intermedium* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Leiosphaeridia haitica* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Dicompsa macrodactyl* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Mastospheridium annelaroe* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Polygonium namum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Mastospheridium cf. galatum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Leiosphaeridina tenella* spp. A |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Arermicium squarrosum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Verphilium haitidi* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Leiosphaeridia similis* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Ordoviciidium grottingianum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Poterinosphaeridium intermedium* spp. A |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Poterinosphaeridium fincheyi* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Posphahcria* sp. A |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Leiosphaeridia? asp. polygonum* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Mastospheridium ap. A* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora laticeps* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| *Anomalopora longa* |      |      |      |      |      |      |      |      |      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
Table 7. Acritarch Occurrences in Samples Used in Cincinnati Composite Section

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample Numbers</th>
<th>COV 1</th>
<th>COV 2</th>
<th>COV 3</th>
<th>COV 4</th>
<th>COV 5</th>
<th>COV 6</th>
<th>NSC 4</th>
<th>MB 12</th>
<th>MB 47.5</th>
<th>MB 60</th>
<th>MB 100.5</th>
<th>MB 114.5</th>
<th>MB 135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veryhachium trispinosum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroinosphaeridium intermedium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lophosphaeridium sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium hirsutolides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polygonium nanum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium cf. psilatum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lelosphaeridium baltica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordovicianum groenlingboenii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dicommopalla macadamii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veryhachium lairdii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplicisphaeridium bifurcatum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liovalia similis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium annellicae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polygonium polyacanthum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veryhachium sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lioosphaeridium tenerissima ssp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lioafusa cf. fusiformis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lioosphaeridium tenerissima</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lioosphaeridium tenerissima</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acromarianum squarrosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordovicidium sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polypanium cf. polyomato</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Petroinosphaeridium intermedium ssp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lophosphaeridium sp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplicisphaeridium cf. fisherii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium latiradiatum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lioafusa cf. parvitas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhopaliophora folatilis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhopaliophora impexa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multisphaeridium ingersae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8. Acritarch Occurrences in Samples at Clay's Ferry, Kentucky

<table>
<thead>
<tr>
<th>Species</th>
<th>Sample Numbers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verybachium trispinosum</td>
<td></td>
<td>20</td>
<td>17</td>
<td>37</td>
<td>1</td>
<td>2</td>
<td>59</td>
<td>44</td>
<td>73</td>
<td>21</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peteinosphaeridium intermedium</td>
<td></td>
<td>17</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td>8</td>
<td>38</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiosphaeridia tenuissima</td>
<td></td>
<td>59</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiovalia similis</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplicisphaeridium sp. A</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>14</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ordovicidium groenlingboensis</td>
<td></td>
<td>3</td>
<td>3</td>
<td>25</td>
<td>9</td>
<td>12</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polygonium nanum</td>
<td></td>
<td>1</td>
<td>14</td>
<td>16</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiosphaeridia baltica</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verybachium sp. A</td>
<td></td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anomaloplasium lumariacupis</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium cf. psilatum</td>
<td></td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium annolecce</td>
<td></td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium hirsutoides</td>
<td></td>
<td>3</td>
<td>5</td>
<td>30</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lophosphaeridium sp. B</td>
<td></td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verybachium lairdii</td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplicisphaeridium cf. fisharill</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dicommopalla macadamii</td>
<td></td>
<td>1</td>
<td>3</td>
<td>29</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium cf. klavavensa</td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiosphaeridia venlockia</td>
<td></td>
<td>7</td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peteinosphaeridium intermedium ssp. A</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium sp. A</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baltisphaeridium ingereae</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplicisphaeridium bifurcatum</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peteinosphaeridium jimschopfii</td>
<td></td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lophosphaeridium sp. A</td>
<td></td>
<td>+</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peteinosphaeridium stigii</td>
<td></td>
<td>1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peteinosphaeridium hypertrophicum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiofusa cf. fusiformis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leiosphaeridia tenuissima ssp. A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

275
APPENDIX C

PLATES

EXPLANATION OF PLATE I

All specimens 600 x. Slide coordinates within parentheses.

Fig. 1 - Baltisphaeridium annelieae Kjellström. Sample Cov-5-3 (100.0, 12.4). OSU 33851.

Fig. 2 - Baltisphaeridium cf. klabavense. Sample 62BCB-1B (112.9, 20.9). OSU 33852. Note granulate ornament on both process and vesicle and darkened thickening at process contact with vesicle.

Fig. 3 - Baltisphaeridium sp. B. Sample 62BDR-3-2 (99.4, 10.0). OSU 33853.

Fig. 4 - Baltisphaeridium ingerae Kjellström. Sample 75MB-100.5-1 (112.5, 19.8). OSU 33854. Note granulate vesicle and processes.

Fig. 5 - Baltisphaeridium latiradiatum (Eisenack). Sample 75MB-0-1 (115.2, 17.2). OSU 33855.

Fig. 6 - Anomaloplaisium lumariacuspis Tappan and Loeblich. Sample 74MM-314.5B (102.4, 20.5). OSU 33856.

Fig. 7 - Baltisphaeridium cf. psilatum. Sample Cov-2-1 (99.0, 5.7). OSU 33857.

Fig. 8 - Aremoricanium squarrosum Loeblich and MacAdam. Sample Cov-6-1 (98.1, 11.0). OSU 33858.

Fig. 9 - Baltisphaeridium hirsutoides (Eisenack). Sample 75MB-0-1 (109.5, 9.2). OSU 33859.

Fig. 10 - Baltisphaeridium hirsutoides (Eisenack). Sample Cov-6SEM. Note smooth vesicle and processes on compressed specimens. OSU 33860.
EXPLANATION OF PLATE II

All specimens 600x except Fig. 8-1200x, Fig. 10-1950x and Fig. 11-7000x. Slide coordinates within parentheses.

Fig. 1 - Baltisphaeridium sp. A. Sample SEM-Cov-8. OSU 33861. Gold-coated specimen preserved as peel mounted in glass microslide. This is the same specimen illustrated in Fig. 2, Fig. 3.

Fig. 2 - Baltisphaeridium sp. A. Sample Cov-8. Temporary water mount permanently preserved after gold coating. See Fig. 1.

Fig. 3 - Baltisphaeridium sp. A. Sample Cov-8. SEM mount, subsequently peeled and preserved. See Fig. 1.

Fig. 4 - Dicommopalla macadamii Loeblich. Sample 74MM-334-1 (101.7, 14.9). OSU 33862. Note single pylome with thickened rim and frayed outer layer.

Fig. 5 - Dicommopalla macadamii Loeblich. Sample 75MB-47.5 (108.5, 14.8) OSU 33863. Note two pylomes with thickened rim at approximately 180° to each other.

Fig. 6 - Dicommopalla macadamii Loeblich. Sample SEM 74MMO-B. OSU 33864. Uncompressed specimen with two pylomes, one pylome visible. See also Fig. 9, 10.

Fig. 7 - Dicommopalla macadamii Loeblich. SEM 74MMO-B. OSU 33865. SEM view of pylome on uncompressed specimen. See also Fig. 8, 11.

Fig. 8 - Dicommopalla macadamii Loeblich. Sample SEM74MMO-B. OSU 33865. Detail of pylome of specimen in Fig. 7.
Fig. 9 - *Dicommopalla macadamii* Loeblich. Sample SEM 74MM0-B. OSU 33864. Second pylome in same specimen in Fig. 6. Note outer wall covering pylome.

Fig. 10 - *Dicommopalla macadamii* Loeblich. Sample SEM 74MM0-B. OSU 33864. Detail of same specimen in Fig. 6, 9. Note outer wall covering pylome.

Fig. 11 - *Dicommopalla macadamii* Loeblich. Sample SEM 74MM0-B. OSU 33865. Detail of same specimen in Fig. 7, 8. Note tear in thin outer wall showing inner wall.
EXPLANATION OF PLATE III

All specimens 400x except Figs. 9 and 10 which are 600x. Slide co­ordinates within parentheses.

Fig. 1 - *Leiosphaeridia baltica* Eisenack. Uncompressed cyst showing triangular opening. Sample 74MM-294-2 (100.6, 15.1). OSU 33866.

Fig. 2 - *Leiosphaeridia baltica* Eisenack. Uncompressed cyst showing triangular opening. Sample 74MM 294-2 (100.6, 11.9). OSU 33867.

Fig. 3 - *Leiosphaeridia baltica* Eisenack. Uncompressed cyst showing elongate polygonal opening with incipient flattening of vesicle flaps. Sample 74MM 294-2 (106.6, 17.6). OSU 33868.

Fig. 4 - *Leiosphaeridia baltica* Eisenack. Uncompressed cyst showing elongate opening with overlapping flaps of vesicle wall. Sample 74MM 294-2 (106.4, 19.8). OSU 33869.

Fig. 5 - *Leiosphaeridia baltica* Eisenack. Partially compressed cyst showing elongate opening with overlapping flaps of vesicle wall. Sample 74MM-294-2 (104.0, 6.9). OSU 33870.

Fig. 6 - *Leiosphaeridia baltica* Eisenack. Uncompressed cyst showing elongate opening with overlapping flaps of vesicle wall. Sample 74MM 294-2 (104.6, 18.8). OSU 33871.

Fig. 7 - *Leiosphaeridia baltica* Eisenack. Compressed cyst showing elongate opening with multiple overlapping flaps of vesicle wall. Sample 74MM 294-2 (105.1, 18.0). OSU 33872.
Fig. 8 - \textit{Leiosphaeridia baltica} Eisenack. Detailed overlapping flaps of vesicle wall superficially resembling specimens of species of \textit{Leiofusa}. Sample 74MM-87.3-A (98.0, 12.6). OSU 33873.

Fig. 9 - \textit{Leiovalia similis} Eisenack. Bacilliform cyst with impressions of dissolved pyrite crystals. Sample CF-10-3 (104.5, 13.6). OSU 33874.

Fig. 10 - \textit{Leiovalia similis} Eisenack. Bacilliform cyst. Sample Cov-5-3 (104.3, 10.1). OSU 33875.
EXPLANATION OF PLATE IV

All specimens 600x except Fig. 6 which is 400x. Slide coordinates within parentheses.

Fig. 1 - Leiofusa cf. fusiformis. Large fusiform cyst. Sample 75MB-12-1 (111.9, 18.6). OSU 33876.

Fig. 2 - Leiofusa cf. fusiformis. Fusiform cyst with processes of different lengths resembling Leiofusa algerensis Cramer. Sample 74MM-95-1 (103.1, 9.7). OSU 33877.

Fig. 3 - Leiofusa cf. parvitatis. Sample 75 MB-0-1. (103.2, 20.2). OSU 33878.

Fig. 4 - Leiosphaeridia tenuissima ssp. A. Cyst with compressional folds and darkened vesicle wall. Sample CF-13-3 (98.9, 20.2). OSU 33879.

Fig. 5 - Leiosphaeridia tenuissima. Cyst with compressional folds. Sample CF-18-1 (108.7, 15.0). OSU 33880.

Fig. 6 - Leiosphaeridia extratubulata. Sp. nov., holotype. Spherical vesicle with thin-walled tube arising from outer wall. Sample 74MM-193.2 (97.0, 18.4). OSU 33881.

Fig. 7 - Leiosphaeridia wenlockia Downie. Circular pylome visible on lower left portion of vesicle. Sample CF-10-3 (98.0, 8.2). OSU 33882.

Fig. 8 - Leiosphaeridia cf. tubulosa. Subspherical vesicle with tube arising from thick dark inner wall and covered by a thinner outer wall. Sample 74MM-193.2-1 (102.1, 13.8). OSU 33883.
Fig. 9 - *Leiosphaeridia* cf. *tubulosa*. Reniform vesicle with tube arising from thick inner wall and extending into thin wall. Sample 74MM-193.2-1 (102.6, 12.8). OSU 33884.

Fig. 10 - *Leiosphaeridia* cf. *tubulosa*. Vesicle of three interconnected subspheres with tube arising from thick inner wall and extending into thin wall. Sample 74MM-193.2-1 (101.6, 13.8). OSU 33885.
EXPLANATION OF PLATE V

All specimens 600x except Fig. 7 and 10 which are 1500x. Slide co­ordinates within parentheses.

Fig. 1 - *Lophosphaeridium* sp. B. Granulate vesicle with medial split. Basis of grana not touching each other. Sample CF-8-3 (99.3, 7.0). OSU 33886.

Fig. 2 - *Lophosphaeridium* sp. B. Granulate vesicle with medial split. Bases of grana not touching each other. Sample CF-9-1 (112.1, 13.1). OSU 33887.

Fig. 3 - *Lophosphaeridium* sp. B. Granulate vesicle with medial split. Bases of grana not touching each other. Sample 73SA-0-1 (109.1, 19.6). OSU 33888.

Fig. 4 - *Lophosphaeridium* sp. A. Granulate vesicle with bases of grana touching each other. Sample 74MM-268.4-3 (107.1, 5.2). OSU 33889.

Fig. 5 - *Lophosphaeridium* sp. A. Granulate vesicle with bases of grana touching each other. Sample 74MM-249.7-1 (98.5, 14.7). OSU 33890.

Fig. 6 - *Lophosphoeridium* sp. A. Granulate vesicle with bases of grana touching each other. Sample 74MM-249.7-1 (106.1, 9.7). OSU 33891.

Fig. 7 - *Micrhystridium* cf. acum. Detail of vesicle with fine bulb-tipped processes. Sample 62BMRB-98-4 (95.7, 18.7). OSU 33892.

Fig. 8 - *Micrhystridium* cf. acum. Vesicle with fine bulb-tipped processes. Sample 62BMRB-98-2 (95.7, 18.7). OSU 33892.
Fig. 9 - *Micrhystridium* cf. *acum*. Vesicle with fine bulb-tipped processes. Sample 62BMKDR-119B (104.4, 3.7). OSU 33893.

Fig. 10 - *Micrhystridium* cf. *acum*. Detail of vesicle with fine bulb-tipped processes. Sample 62BKDR-119B (104.4, 3.7). OSU 33894.

Fig. 11 - *Micrhystridium* sp. B. Vesicle with angular process contact. Sample 62BMRB-98-4 (95.3, 10.5). OSU 33895.

Fig. 12 - *Micrhystridium* sp. A. Vesicle with curved process contact. Sample 62BMRF-98-4 (95.5, 16.3). OSU 33896.

Fig. 13 - *Multiplicisphaeridium bifurcatum* Staplin et al. Vesicle with bifurcate and rarely simple processes. Sample Cov-1-3 (110.8, 13.6). OSU 33897.

Fig. 14 - *Multiplicisphaeridium* sp. A. Single-walled vesicle with numerous impressions of dissolved pyrite crystals. Sample 74MM-306-1 (111.4, 17.1). OSU 33898.

Fig. 15 - *Ordovicidium groetlingboensis* (Kjellström). Sample CF-12-1 (115.7, 11.6). OSU 33899.

Fig. 16 - *Multiplicisphaeridium* cf. *fisherii*. Multifurcate process tips. Sample 75MB-0-1 (117.9, 14.5). OSU 33900.

Fig. 17 - *Multiplicisphaeridium* cf. *fisherii*. Multifurcate process tips. Sample CF-8-1 (106.4, 14.0). OSU 33901.
EXPLANATION OF PLATE VI

All specimens 600x except Fig. 9 which is 1600x and Fig. 11 which is 600x. Slide coordinates within parentheses.

Fig. 1 - *Ordovicidium groetlingboensis* (Kjellström). Sample CF-12-1 (115.7, 11.7). OSU 33902.

Fig. 2 - *Ordovicidium groetlingboensis* (Kjellström). Darkened vesicle with some broken processes on thermally altered cyst. Sample 62MRB-287-1 (103.0, 17.6). OSU 33902.

Fig. 3 - *Ordovicidium groetlingboensis* (Kjellström). Darkened vesicle and granular processes on thermally altered cyst. Sample 62B-TR-220-1 (110.0, 15.6). OSU 33904.

Fig. 4 - *Ordovicidium* sp. A. Numerous bifurcate processes on compressed and folded vesicle. Sample Cov-6-1 (96.4, 13.7). OSU 33905.

Fig. 5 - *Ordovicidium groetlingboensis* (Kjellström). Compressed vesicle. Sample SEM Cov-8. OSU 33906.

Fig. 6 - *Ordovicidium groetlingboensis* (Kjellström). Partially compressed vesicle. Sample SEM74MM-9.8. OSU 33907.

Fig. 7 - *Petaloferidium stigii* sp. nov. Heterogeneous process tips. Sample CF-10-1 (115.1, 16.2). OSU 33908.

Fig. 8 - *Petaloferidium stigii* sp. nov., holotype. Heterogeneous process tips showing petaloid, inverted bulbous tips. Sample CF-10-1 (102.1, 11.0). OSU 33909.

Fig. 9 - *Ordovicidium groetlingboensis* (Kjellström). Detail of specimen showing granulate bifurcate process tip. Sample SEM74MM-9.8.
Fig. 10 - *Petalofeirdium stigii* sp. nov. Heterogeneous process tips.
Sample CF-10-1 (112.3, 8.3). OSU 33910.

Fig. 11 - *Ordovicidium groetlingboensis* (Kjellström). Detail of grana on bifurcate process tip. Sample SEM74MM-9.8. OSU 33907.
EXPLANATION OF PLATE VII

All specimens 600x except Fig. 10 which is 2000x. Slide coordinates within parentheses.

Fig. 1 - *Peteinosphaeridium hypertrophicum* Eisenack. Note long, veiled process on compressed vesicle. Sample 73SA-0-1 (114.5, 21.5). OSU 33911.

Fig. 2 - *Peteinosphaeridium intermedium* ssp. A. Uncompressed spherical vesicle with apical pylome opening and antapical pseudopylome. Sample 74MM-0-1 (110.8, 11.8). OSU 33912.

Fig. 3 - *Peteinosphaeridium hypertrophicum* Eisenack. Long, veiled process on compressed vesicle. Sample 73SA-25-1 (108.5, 10.8). OSU 33913.

Fig. 4 - *Peteinosphaeridium intermedium* Eisenack. Darkened thermally altered vesicle with intersecting veils at junction of processes that appear as darkened threads. Sample 62BDR-123-1 (106.8, 18.5). OSU 33914.

Fig. 5 - *Peteinosphaeridium intermedium* Eisenack. Corroded vesicle and processes. Sample SEM62BDR-123. OSU 33915.

Fig. 6 - *Peteinosphaeridium intermedium* Eisenack. Equatorial focus of compressed vesicle with pylome. Sample CF-18-2 (107.4, 5.9). OSU 33916.

Fig. 7 - *Peteinosphaeridium intermedium* Eisenack. Surface focus of compressed vesicle showing triradiate veil arrangement on processes. Sample CF-18-2 (107.4, 5.9). OSU 33916.
Fig. 8 - *Peteinosphaeridium intermedium* Eisenack. Smooth-walled uncompressed vesicle with no corrosion. Sample SEM72MM-0-B. OSU 33917.

Fig. 9 - *Peteinosphaeridium intermedium* Eisenack. Uncompressed vesicle with processes of joined veils. Sample SEM CF-18. OSU 33918.
EXPLANATION OF PLATE VIII

All specimens 600x except Fig. 8 which is 3100x, Fig. 9 which is 6500x, and Fig. 12 which is 3000x. Slide coordinates within parentheses.

Fig. 1 - *Polygonium nanum* (Deflandre). Uncompressed vesicle with smooth processes. Sample 74MM-107.2-3 (100.6, 8.8). OSU 33919.

Fig. 2 - *Polygonium polyacanthum* (Eisenack) comb. nov. Uncompressed vesicle with granulate simple processes. Sample 74MM-31.8-1 (101.6, 10.4). OSU 33920.

Fig. 3 - *Peteinosphaeridium jimschopfii* sp. nov., holotype. Finely reticulate vesicle with circular pylome. Sample 74MM-0-1 (106.8, 8.3). OSU 33921.

Fig. 4 - *Rhopaliophora impexa* Tappan and Loeblich. Sample 74MM-306-2 (110.2, 20.9). OSU 33922.

Fig. 5 - *Peteinosphaeridium jimschopfii* sp. nov. Sample SEM 74MM-0-1. OSU 33923.

Fig. 6 - *Peteinosphaeridium jimschopfii* sp. nov. Sample SEM 74MM-0-B. OSU 33924.

Fig. 7 - *Rhopaliophora folatilis* Tappan and Loeblich. Sample 75MB-12-1 (117.9, 18.2). OSU 33925.

Fig. 8 - *Peteinosphaeridium jimschopfii* sp. nov. Detail of same specimen as in Fig. 5. Note reticulate vesicle wall. Sample SEM 74MM-0-1. OSU 33923.

Fig. 9 - *Peteinosphaeridium jimschopfii* sp. nov. Detail of same specimen as in Fig. 6. Note reticulate vesicle wall and veiled process. Sample SEM 74 MM-0-B. OSU 33924.
Fig. 10 - Polygonium cf. polygonale. Thermally altered and corroded vesicle. Sample 62BTR-141-B (101.8, 7.9). OSU 33925.

Fig. 11 - Peteinosphaeridium sp. A. Cyst with interconnected trifurcate process tips and circular pylome. Sample SEM Cov-5. OSU 33926.

Fig. 12 - Peteinosphaeridium sp. A. Detail of vesicle with serrate veils on trifurcate process. Sample SEM Cov-5. OSU 33926.
EXPLANATION OF PLATE IX

All specimens 600x except Fig. 8 and 9 which are 1750x, Fig. 11 which is 4700x, and Fig. 12 which is 6000x. Slide coordinates within parentheses.

Fig. 1 - *Veryhachium lairdii* (Deflandre). Vesicle with four processes and internal pyrite crystal. Sample 74MM0-1 (95.8, 8.6). OSU 33927.

Fig. 2 - *Veryhachium trispinosum* (Eisenack). Note granulate vesicle. Sample CF-2-1 (98.1, 12.2). OSU 33928.

Fig. 3 - *Veryhachium trispinosum* (Eisenack). Note long processes. Sample CF-18-1 (110.2, 11.9). OSU 33929.

Fig. 4 - *Veryhachium trispinosum* (Eisenack). Vesicle with triradiate fold. Sample CF-18-1 (97.0, 9.5). OSU 33930.

Fig. 5 - *Veryhachium trispinosum* (Eisenack). Vesicle with impressions from dissolved pyrite crystals. Sample 74MM-143.3a-A (107.8, 12.2). OSU 33931.

Fig. 6 - *Veryhachium trispinosum* (Eisenack). Vesicle with granulate process tips and epitychal opening. Sample SEM Cov-5. OSU 33932.

Fig. 7 - *Veryhachium trispinosum* (Eisenack). Partially collapsed vesicle with granular surface. Sample SEM Cov-5A. OSU 33933.

Fig. 8 - *Veryhachium trispinosum* (Eisenack). Detail of granulate process. Sample SEM Cov-5A. OSU 33933.

Fig. 9 - *Veryhachium trispinosum* (Eisenack). Detail of granulate vesicle with faintly striate ornament. Sample SEM Cov-5. OSU 33933.
Fig. 10 - *Veryhachium trispinosum* (Eisenack). Vesicle with triradiate fold and rigid processes. Sample SEM 74MM0-B. OSU 33934.

Fig. 11 - *Veryhachium trispinosum* (Eisenack). Detail showing granulate process tip. Sample SEM 74MM0-B. OSU 33934.

Fig. 12 - *Veryhachium trispinosum* (Eisenack). Detail showing granulate vesicle wall. Sample SEM 74MM0-B. OSU 33934.
EXPLANATION OF PLATE X

All specimens 600x except Fig. 4 and 5 which are 2000x, Fig. 7 which is 750x, and Fig. 9 which is 7500x. Slide coordinates within parentheses.

Fig. 1 - *Veryhachium trispinosum* (Eisenack). Darkened, thermally altered granulate vesicle. Sample 62B-MRB-199-3 (115.4, 9.8). OSU 33935.

Fig. 2 - *Veryhachium* sp. A. Note microrugulate surface ornament. Sample SEM-Cov-8. OSU 33936.

Fig. 3 - *Veryhachium trispinosum* (Eisenack). Darkened thermally altered vesicle. Sample 62BMRB-287-4 (105.8, 14.6). OSU 33937.

Fig. 4 - *Veryhachium* sp. A. Detail of microrugulate ornament on process. Sample SEM Cov-8. OSU 33936.

Fig. 5 - *Veryhachium* sp. A. Detail of vesicle with microrugulate ornament. Sample SEM Cov-8. OSU 33936.

Fig. 6 - *Veryhachium trispinosum* (Eisenack). Darkened, thermally altered, granulate vesicle. Sample 62BTR-200-8 (103.0, 20.1). OSU 33937.

Fig. 7 - *Veryhachium trispinosum* (Eisenack). Granulate vesicle with faintly striate pattern on vesicle wall. Sample SEM 74MM0-1. OSU 33938.

Fig. 8 - *Veryhachium trispinosum* (Eisenack). Darkened, thermally altered, rigid vesicle. Sample 62BMRB-199-4 (120.2, 712). OSU 33939.

Fig. 9 - *Veryhachium trispinosum* (Eisenack). Detail of faintly striate vesicle ornament. Sample SEM 74MM0-1. OSU 33938.