

PALYNOLOGY OF THE HANNIBAL FORMATION (LOWER MISSISSIPPIAN)
OF NORTHEAST MISSOURI AND WESTERN ILLINOIS

A Dissertation
Presented to
the Faculty of the Graduate School
University of Missouri

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Dwight Delon Brown
September 1968

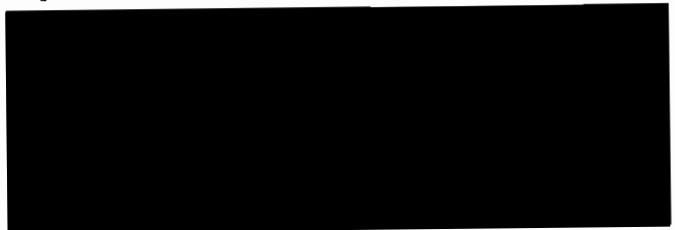
The undersigned, appointed by the Dean of the Graduate Faculty, have examined a thesis entitled

PALYNOLOGY OF THE HANNIBAL FORMATION
(LOWER MISSISSIPPIAN) OF
NORTHEAST MISSOURI AND WESTERN ILLINOIS

presented by Dwight Deion Brown

a candidate for the degree of Doctor of Philosophy

and hereby certify that in their opinion it is worthy of acceptance.



ACKNOWLEDGMENTS

The author wishes to thank Dr. J. M. Wood for his sincere interest in, and direction of the project; for his corrections and helpful suggestions to the improvement of the manuscript; for his advice, confidence, constant encouragement, and friendship throughout the author's graduate tenure.

To Dr. D. B. Dunn the author expresses appreciation for his encouragement, valuable advice, and helpful corrections to the dissertation.

The author most appreciatively thanks his wife, Karen, for accompanying him to the collecting localities, assisting with the laboratory work, for preparing the slides, for assisting with the darkroom procedure, for preparing the charts, figures, and plates in final form, for typing the manuscript, and for her devotion, encouragement, and tolerance throughout this project.

The author also wishes to thank C. Collinson of the Illinois Geological Survey for providing him with subsurface samples of the Nutwood Member of the Hannibal Formation.

The author wishes to express his appreciation for the support he received through the National Defense Education Act Fellowship.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
II. REVIEW OF THE LITERATURE	6
General Statement.	6
Previous Work on Mississippian Miospores	7
Previous Work on Mississippian Acritarchs.	24
Discussion of Literature on the Hannibal Formation.	29
III. MATERIALS AND METHODS.	35
General Statement.	35
Collecting Procedure	35
Coding of Localities and Samples	36
Collecting Localities.	37
Northeastern Missouri.	37
Western Illinois	40
Southwest Missouri	41
Laboratory Procedure	42
Maceration of samples.	56
Preparation of floatation solution	58
Floatation technique	58
Slide preparation.	60
Micrography and Photomicrography	62
IV. SYSTEMATIC STUDY OF THE MIOSPORES, ACRITARCHS, AND <u>TASMANITES</u>	63

CHAPTER	PAGE
Miospores.	63
Spore morphology and classification.	63
Systematic description of miospores.	68
Acritarcha	125
Introductory statement	125
Classification and affinity.	126
Geological importance.	128
Systematic description of acritarchs	130
<u>Tasmanites</u>	157
General statement.	157
Systematic description of <u>Tasmanites</u>	159
V. DISCUSSION AND CONCLUSIONS	174
Introductory Statement	174
Composition of the Assemblage.	175
The miospore assemblage.	176
The acritarch assemblage	187
The <u>Tasmanites</u> assemblage.	191
Comparison with other Assemblages.	192
Comparison of miospore assemblage.	192
Comparison of acritarch assemblage	198
Comparison of <u>Tasmanites</u> assemblage.	200
Age of the Hannibal assemblages.	201
Paleoecology	203
Physical criteria.	203

CHAPTER	PAGE
Fossil criteria.	206
Kinderhookian paleolatitudes	211
SUMMARY.	216
LITERATURE CITED	220
VITA	282

LIST OF ILLUSTRATIONS

FIGURE	PAGE
1. Portion of Quadrangle Map showing Locality Ha-1	43
2. Portion of Quadrangle Map showing Locality Ha-2	43
3. Columnar Section at Collecting Locality Ha-1	44
4. Columnar Section at Collecting Locality Ha-2	45
5. Portion of Quadrangle Map showing Locality Ha-3 and Locality Cu-2.	46
6. Portion of Quadrangle Map showing Locality Cu-1 and Locality Cu-3.	46
7. Columnar Section of Collecting Locality Ha-3	47
8. Columnar Section of Collecting Locality Cu-1	48
9. Columnar Section of Collecting Locality Cu-2	49
10. Columnar Section of Collecting Locality Cu-3	50
11. Portion of Quadrangle Map showing Locality Ha-4	51
12. Portion of Quadrangle Map showing Locality Nu-1	51
13. Columnar Section at Collecting Locality Ha-4	52
14. Columnar Section at Collecting Locality Nu-1	53
15. Portion of Quadrangle Map showing Locality Nu-2	54

FIGURE	PAGE
16. Portion of Quadrangle Map showing First Locality of Northview Formation and Second Locality of Northview Formation	54
17. Columnar Section at Collecting Locality Nu-2 (and Ha-5).	55
 CHART	
I. Vertical Distribution and Comparison of Miospore Assemblage	166
II. Vertical Distribution and Comparison of Acritarcha Assemblage	168
III. Vertical Distribution and Comparison of Tasmanites Assemblage	170
IV. Relative Abundance of Miospore Assemblage . . .	171
V. Relative Abundance of Acritarcha Assemblage . .	172
VI. Relative Abundance of <u>Tasmanites</u> Assemblage . .	173
 PLATE	
I. Miospores	251
II. Miospores	254
III. Miospores	257
IV. Miospores	260
V. Genera Indeterminate.	263
VI. Acritarcha.	266
VII. Acritarcha.	269

PLATE	PAGE
VIII. Acritarcha	272
IX. Acritarcha	275
X. <u>Tasmanites</u>	277
XI. <u>Tasmanites</u>	279
XII. <u>Tasmanites</u>	281

CHAPTER I

INTRODUCTION

The purpose of this study is to describe and illustrate the miospore, acritarch, and Tasmanites assemblages which are present in the Lower Mississippian Hannibal Formation of northeast Missouri and western Illinois, and to determine the botanical, stratigraphical, and paleoecological significance of the assemblages.

This research project was initiated in the summer of 1964 under the direction of Dr. J. M. Wood who foresaw the need to fill the void in palynological information regarding the occurrence of Mississippian miospores in Missouri sediments.

The present study is the first report on the Lower Mississippian miospores of Missouri and Illinois. The one other report concerned with Lower Mississippian miospores in the United States is that of Winslow (1962). An abundant acritarch assemblage is reported here for the first time from the Lower Mississippian strata of North America.

The Hannibal Formation was chosen for a number of reasons. 1) The Hannibal Formation is located in the standard section for the Mississippian Period in North America. 2) It was felt that a study of the spores of

the Hannibal Formation could help clarify the confusion regarding the Mississippian-Devonian boundary in northeast Missouri. 3) A colleague of the author, S. Gupta, was carrying out a miospore investigation of the Upper Devonian Grassy Creek and Saverton Formations in northeast Missouri. The miospore assemblage contained in these formation was reported by Gupta in 1965 (unpublished Ph.D dissertation, University of Missouri). By comparing the miospore assemblages of the formation involved, it was believed that not only could a Mississippian-Devonian boundary be established, but more importantly the author felt that a comparison could establish the presence or absence of a "floral gap" between the two systems. This latter interest was prompted by a statement made by the late Dr. M. G. Mehl which was based on conodont information from the Devonian and Mississippian formations in northeast Missouri. Mehl (1961) believed that a great hiatus existed between the two systems. 4) There was disagreement regarding the stratigraphic relationship between the Hannibal Formation of northeast Missouri and the Northview Formation of southwest Missouri. Some paleontologists (ie., Conkin and Conkin, 1965) had advocated a time equivalence for these two formations.

Interest in Mississippian miospores has steadily increased since 1955, which is evidenced by the increased

number of publications dealing with miospores of this age. This increased interest is due in part to botanical and academic reasons on the part of the researchers who recognized the need for information regarding the geological history and evolutionary development of vascular plants. Another reason for the increased interest in the Mississippian miospores is the fact that miospores have become very useful tools in stratigraphic correlation. Oil companies especially have taken advantage of the usefulness of miospores in alleviating stratigraphic problems. Their usefulness to stratigraphic geologists and the advantage they have over other fossil types is due to their mode of dispersal (wind and water), their resistance to destruction during fossilization, their independence of environmental factors which control the distribution of marine life (ie., temperature, salinity, depth, etc.), and to the fact that like other organic life they are subject to evolutionary forces. However, the author hastens to point out that the use of miospores has been pursued as an end in itself since the plant sources of these spores has been of limited use or concern. Moreover, the Mississippian spore suites from some other states are under study, but there have been no previous studies made on the Lower Mississippian miospores of Missouri sediments.

Recently there has been interest in determining the existence of latitudinal climatically controlled paleofloral provinces based on miospore data (Sullivan, 1965 and 1967).

When used in conjunction with other fossil data such as that supplied by the acritarchs, miospores are helpful in paleoecological interpretations. For example, ancient shorelines have been determined on the basis of the inverse abundance of miospores and acritarchs contained in marine sediments. This is due to the fact that the number of miospores gradually diminishes as the distance from their source (land) increases, while acritarch abundance increases.

The large number of known Lower Mississippian miospore species indicates that a varied flora consisting of numerous plants existed at the beginning of the Mississippian Period. However, the presently known plant microfossils, such as stems, leaves, and sporangia, from Lower Mississippian deposits of the United States are not numerous. For this reason the botanical affinities of Mississippian miospores are difficult to determine at this time. Future work by paleobotanists, such as that by Taylor and Eggert who are now interested in Upper Mississippian plant macrofossils, may stimulate interest and extension of the study into the Lower Mississippian

so that the plants that existed during the Lower Mississippian in the mid continent region of the United States will be investigated. When such studies have been undertaken it is the author's hope that the plant sources of the miospore suites encountered in this study can be of value in evolutionary, paleoecological, and geobotanical studies.

Published reports on Lower Mississippian acritarchs are extremely rare at present. However, interest in these marine organisms is increasing due to their potential value in solving stratigraphic problems.

CHAPTER II

REVIEW OF THE LITERATURE

General statement

The early work in palynology was concerned primarily with Pleistocene peat deposits and Recent bog and marsh deposits. The interest in this aspect of palynology was initiated by Von Post in 1916. Von Post, using pollen diagrams, successfully established the previous floral and glacial history of southern Sweden.

Beginning in 1920, Thiessen and his coworkers proved that Pennsylvanian coal seams could be identified and correlated on the basis of spores contained therein. As a result, spores became valuable stratigraphic tools to geologists and during the 1930's and 1940's many spore publications appeared, most of which dealt with the spores contained in Pennsylvanian coal beds.

In the latter part of the 1940's petroleum companies became interested in palynology as a means of solving stratigraphic problems and thus gave impetus to the additional development of the science of palynology.

Activity in palynology increased approximately ten fold during the 1950's resulting in more publications during that decade than the total publications in this area of all previous decades.

Interest in palynology has steadily increased during the 1960's as is witnessed by the increased number of publications each year over the previous year. The majority of these publications deal with Cretaceous or Cenozoic spores and pollen; however, interest in Mississippian spores has increased steadily since 1955.

Previous work on Mississippian Miospores

The first publication dealing with Mississippian spores (which also included Pennsylvanian spores) was that of Reinsch in 1884, in which he illustrated Carboniferous spores from the Moscow coal basin. This publication, in which he illustrated both microspores and megaspores, is considered to be the most outstanding early spore publication.

Shortly thereafter, Bennie and Kidston (1886) published a paper on the spores present in the Carboniferous of Scotland.

In 1937, Berry published a paper on the miospore content of the Pennington Coal of Tennessee which is Upper Mississippian in age.

Although most of Naumova's spore publications are concerned with the Devonian spores of Russia, in 1937 she described miospores from the Lower Carboniferous of the Moscow coal basin. One year later (1938) two Russian workers, Lubert and Waltz, published the first of their

two important papers describing the Lower Carboniferous miospores of Russia. Unfortunately, neither of their two publications (1938 and 1941) was available. However, Playford reports their findings in his 1962 publication (pp. 565-566). The 1938 publication dealt primarily with the Tournaisian coals and Visean coals in part. In the five districts they sampled in European Russia (Moscow, Kizel, Borovichi, Selizharovo, and Voronezh) they found the Tournaisian to be characterized by cingulate spores, whereas the Asiatic Russia district (Karaganda Basin) was characterized by azonate spores with spines or tubercules. Luber and Waltz's 1941 publication was wider in scope, ranging in age from the Devonian to the Permian. In this publication they described 262 species of microspores and pollen grains.

The results of Playford's investigation of the Lower Carboniferous of Spitsbergen will be discussed later in this chapter, but it is noted here that he found much similarity between the Spitsbergen assemblage and the European Russia spore assemblage described by Luber and Waltz.

Raistrick (1938) and Knox (1948) illustrated microspores from the coals of the Lower Carboniferous Limestone Group of Scotland and Northumberland. These authors did not formally describe genera and species, but grouped the

spores into types. Such a system of classification served its purpose since Raistrick was concerned only with correlating coal seams.

In 1950, Schemel described a number of new species and two new genera from an Upper Mississippian coal from Utah. The two genera which are characteristic of the Upper Mississippian are Rotaspora and Tripartites; however, the most abundant genus in the Utah material was Densosporites.

Beginning in 1955 there was a marked increase in the number of publications dealing with Mississippian microspores. However, many of these publications were concerned with Upper rather than Lower Mississippian formations.

Hoffmeister, Staplin, and Malloy (1955) published a major work on the Upper Mississippian Hardinsburg Formation of Illinois and Kentucky in which they described nineteen genera (three new) and fifty-nine species (thirty-seven new). The three new genera they described were Auroraspora, Convolutispora, and Grandispora. The most abundant genera present in the coals and shales of the Hardinsburg Formation and representing ninety-five per cent of the total spore assemblages were Cirratiradites, Punctatisporites, Densosporites, Granulatisporites and Schulzospora. These authors further reported that

Cirratriradites constituted forty to fifty-five per cent of the total spore population in both coal and shale samples.

In 1956 and 1958 Ishchenko investigated the spore content of the Russian Lower Carboniferous in the Donetz Basin. He found many species which had a limited vertical distribution thus permitting zonations. According to Ishchenko each of the three stages of the Lower Carboniferous of the Donetz Basin (Tournaisian, Visean, and Namurian A) were characterized by a distinct microfloral suite.

The first important and significant contribution to the knowledge of Lower Mississippian (Kinderhookian) miospores in North America was that of Hacquebard in 1957. Hacquebard found an abundant and varied spore flora in the coal of the Horton Group of Nova Scotia. The Horton Group consists of a non marine sequence of shales, sandstone and conglomerates with a few thin layers of coal. The Horton Group is subdivided into the Horton Bluff Formation (oldest) and the Cheverie Formation (youngest). Hacquebard's assemblage was based on two coal samples from the Horton Bluff Formation, and consisted of nineteen genera (four new) and fifty species (thirty new species and fourteen new types).

The four new genera described by Hacquebard were the

result of a re-evaluation of Naumova's broad groups. His reclassification and emendation was based on Potonié and Kremp's morphographic system of fossil spore taxonomy. The four new genera were Vallatisporites (p. 312, pl. 2, figs. 12-15), Leiozonotriletes (p. 314, pl. 3, figs. 1-5), Spinozonotriletes (p. 314, pl. 3, figs. 6-10), and Lepidozonotriletes (p. 316, pl. 2, figs. 11-12). Moreover, Hacquebard emended the genus Stenozonotriletes (Naumova, 1937) Hacquebard, 1957, pp. 313-314, pl. 2, figs. 16-22.

Naumova's "sub-groups" are broadly defined and for that reason one subgroup usually includes two or more genera as they are delimited by Potonié and Kremp's system. For example, Hymenozonotriletes Naumova, 1937 includes all spores with a membranous margin. This would include several flange or perispore genera such as Cirratriradites and Endosporites. Vallatisporites conforms to the broad confines of Hymenozonotriletes Naumova, 1937.

The distinguishing characteristics of Vallatisporites Hacquebard, 1957, are the groove or rampart-like area between the central body and the equatorial portion, and the single row of pits located near the inner margin of the perispores. In some species these two diagnostic characteristics (grooves and pits) separate this genus.

from superficially similar genera such as Densosporites.

The subgroup Archaeozonotriletes Naumova, 1937, included the genus Leiozonotriletes Hacquebard, 1957, and the genus Spinozonotriletes, Hacquebard, 1957. The former genus is characterized by a thick perispore in the form of a dense flange. In the latter, the thick perispore possesses spines. Hacquebard mentions (p. 314) that Archaeozonotriletes could feasibly undergo further subdivision. The other new genus described by Hacquebard was Lepidozonotriletes. This genus has a thick perispore "with rows of imbricating, plate-like, scalloped units, extending beyond the body margin in the form of a pseudoflange." (p. 316)

Stenozonotriletes (Naumova, 1937) Hacquebard, pp. 313-314, pl. 2, figs. 16-22, has a rounded narrow rim which "surrounds the central area like a tire around a wheel." (Hacquebard, 1957, p. 313) Hacquebard emended this subgroup because Naumova's description included some species of Lycospora.

Because of the general resemblance between the microflora of the Horton Group and Upper Devonian microflora described by Naumova (1953), Hacquebard suggested that the Basal Mississippian flora was not far removed from the Devonian flora, and, therefore, a large floral gap between the two systems did not exist.

The work on the Lower Mississippian of Nova Scotia by Hacquebard was followed by a more comprehensive survey of the Horton Group by Playford in 1964.

Playford's study was based on thirteen collecting localities and included samples from the entire Horton Group sequence. This sequence included the Horton Bluff Formation, "Undifferentiated" Horton Group and the Upper Tournaisian Cheverie Formation. The lithology of the samples varied from coal, siltstone, shaly siltstone, black shale, and gray micaceous shale.

Playford described twenty-eight genera (none new) and fifty-three species, twenty-one of which were new.

Playford discovered that two miospore assemblages existed in the Horton Group. One assemblage corresponded to the Horton Bluff (Lower Tournaisian) and the other belonged to the Cheverie Formation (Upper Tournaisian). This study again indicates the importance of miospores in alleviating stratigraphic problems.

Because Playford sampled more thoroughly than did Hacquebard, Playford found several species not described by Hacquebard (1957). Playford's results will be discussed more fully in later chapters (comparisons with other assemblages), however, it is noted here that there is much similarity between the Hannibal assemblage and that described by Playford from Nova Scotia.

Playford reiterated what Hacquebard has previously noted regarding comparisons with other regions. Playford (1963, pp. 41-42) made the following statement, "The Horton Bluff assemblage appears to show more general affinity to Upper Devonian microfloras, chiefly those described by Naumova (1953) from the Russian platform, than to known Lower Carboniferous assemblages."

In 1960 Staplin described the miospore content of the Golata Formation (Upper Mississippian) of Alberta, Canada. The age of this formation is considered by Staplin to be Lower Chesterian. The Upper Mississippian coal investigated by Hacquebard and Barss (1957) from the South Nahannie River area of Canada is younger than the Golata Formation.

Kedo published several papers on the Devonian and Mississippian of Russia (Pripyat Depression). In his 1957, 1962, and 1963 publications he discussed the stratigraphic importance of two species. One of these species was Hymenozonotriletes pusillites Kedo, 1957 (p. 22), which was structurally similar to Vallatisporites (Hacquebard, 1957) Sullivan, 1964. Kedo considered the presence of this species to be indicative of the Lower Tournaisian (index species). The other species to which he attached stratigraphic importance was Hymenozonotriletes lepidophytus Kedo, 1957 (p. 24). This species

is characteristically present in the Upper Famennian of the Pripyat area of Russia. The stratigraphic importance of this species is discussed in detail by Owens and Streeel (1967) and is discussed in the final chapter of the present study.

Prior to 1961, the only published report on the Carboniferous spores of Spitsbergen was that of Luber (1935). Since 1961, several papers have appeared which deal with the dispersed miospores of this now frozen area. The first of these publications was an investigation of the Lower Carboniferous (Tournaisian and Visean) of central Vestspitsbergen by Hughes and Playford (1961). This preliminary investigation was based on "three representative rock samples from the Billefjorden sandstones," (p. 27) which included a carbonaceous sandstone, a carbonaceous siltstone and a coal. Their purpose was to report and describe the more important microflora from this area. They described one new genus Velosporites, and thirteen new species. They recorded no monolete spores.

In 1962 and 1963 Playford, in his two part publication, described a total of 115 species, thirty-nine new species, and one new genus Radialetes.

Playford's samples were taken from the Culm sequence of central Vestspitsbergen. This sequence of strata consisted mostly of sandstones, with less prevalent

carbonaceous shales and siltstone layers and minor coal seams. The lower part of this sequence was Tournaisian in age (Kinderhook) and the upper part was Upper Visean or Lower Namurian (early or middle Chester).

Playford recognized two distinct suites of spores which he called the Rarituberculatus Assemblage and the Aurita Assemblage. The Rarituberculatus Assemblage was characterized by the miospores Lophozonotriletes rari-
tuberculatus (Luber) Kedo, 1957, and was Tournaisian in age. The Aurita Assemblage belonged to the Visean Stage and was characterized by the presence of Murospora aurita (Waltz) Playford, 1962. This was the first comprehensive analysis of the Lower Carboniferous spores of Spitsbergen and was significant in two respects. First, the assemblage was remarkably similar to those described by Luber and Waltz (1938 and 1941) from the Lower Carboniferous of the U.S.S.R., and by Ishchenko (1956 and 1958) from the Lower Carboniferous of the U.S.S.R. (Donetz Basin). Secondly, the assemblage described by Playford showed very little similarity to the Lower Carboniferous assemblages of North America described by Hacquebard, 1957, Winslow, 1962, Playford, 1963, nor did it show similarity to the known Lower Carboniferous European assemblages (Sullivan, 1964, and Butterworth, 1967).

Regional differences in the Lower Carboniferous flora

which are exemplified by Playford's work have been extensively studied by Sullivan. In his 1966 and 1967 analysis of the known Carboniferous microflora assemblages, Sullivan showed that at least two distinct floral suites (provinces) existed in the Lower Carboniferous.

Sullivan (1965 and 1967) also discussed three suites which existed during the Upper Mississippian. These suites were the Grandispora suite, the Monilospora suite, and the Kazakhstan suite. It should be pointed out that two of these area provinces were in existence during Lower Mississippian time. In areal extent, the Upper Mississippian Grandispora suite corresponds to the Lower Mississippian Vallatisporites suite and likewise the Upper Mississippian Monilospora suite corresponds to the Lophozonotriletes suite. Sullivan reported (p. 188) that the Kazakhstan suite has a more limited geographical distribution since it is, at present, known only from Kazakhstan in eastern Russia (Luber, 1955).

Sullivan attributed the geographic distribution of these provinces (suites) to climatic zones which existed during the Mississippian Period. Using palaeomagnetic data he found that, "If...palaeolatitudes are superimposed on the map showing the distribution of the three spore suites (fig. 1), it will be noted that spore floras of a similar composition occupy the same latitudinal belt.

Thus, the Grandispora suite occupies a zone astride the equator between 20° N and 20° S. The Monilospora suite in the northern hemisphere extends approximately from 20° N to 40° N. The Kazakhstan suite generally lies to the north of the zone characterized by the Monilospora suite." (1967, p. 190)

In 1962 Bhararwaj and Venkatachala described a spore assemblage from the Lower Carboniferous of Spitsbergen. These authors found an abundance of the cingulate genus Cristatisporites Potonie and Kremp, 1954, which had an abundance of sixty per cent. However, Butterworth (1966, p. 19) noted that some of the species of Cristatisporites they described belonged to Densosporites.

Marcia Winslow (1962) made a comprehensive survey of the microfossil assemblage contained in the Upper Devonian and Lower Mississippian Formations of Ohio. She described twenty megaspore and microspore genera (four new), five species of Tasmanites, and three species of Hystrichospheres. The total biota consisted of twenty-four genera and eighty species (including unnamed forms) of which thirty-one were new species.

Winslow's rock samples were taken from ten localities east of the Cincinnati arch. The Devonian formations included (in ascending order) the Olentangy shale, Ohio shale (Huron and Cleveland members), and the Chagrin shale.

The Basal Mississippian formations Winslow sampled are (in ascending order), the Bedford shale, Berea sandstone, Sunbury shale, Cuyahoga formation, Black Hand formation, and Logan formation. The microfossils consisted of microspores, megaspores, Tasmanites, Hystriosphærids, and Foerstian remains. The Foerstian remains are, according to Winslow (1962, p. 1), "represented by small black onate or elongate, sometimes bifurcating, thalli that may be allied with the brown algae." She found them to be restricted to the lower part of the Ohio shale (Devonian). These structures were not found in the Hannibal Formation, but Gupta (1965) reported their presence in the Grassy Creek Formation of Missouri.

Butterworth and Spinner, in a recent publication (1967) on the Lower Carboniferous spores of northeast England, described the megaspore and microspore assemblages present in the coal and shales of the Cementstone group (Tournaisian) and the Calciferous Sandstone Series overlying the Cementstone group. Butterworth described sixteen genera and forty-three species (six new) of miospores. Some of the species reported by Butterworth were: Retusosporites incohatus Sullivan, 1964, Punctatisporites debilis Hacquebard, 1957, Cyclogranisporites commodus Playford, 1963, Apiculiretusisporites multisetata (Luber) Butterworth, 1967, Perotriletes

perinatus Hughes and Playford, 1961, and Convultispora cf. finis Love, 1960.

Sullivan (1964a) has been very active in Lower Carboniferous miospore research. His first publication dealing with Tournaisian spores was in 1964. This investigation, which is the first record of Tournaisian spores from Europe, was concerned with the Lower Limestone Shales of the Forest of Dean Basin in England. The miospores were recovered from two shale samples and consisted of twelve genera and fifteen species (two new species and two new combinations). The two most abundant species present in these shales were Retusotriletes incohatus (Sullivan, 1964), and Punctatisporites irrasus (Hacquebard, 1957). In one shale sample (Plump Hill) the former species had an abundance of eighty-four per cent and in the other shale sample (Puddlebrook) Punctatisporites irrasus comprised eighty-eight per cent of the total assemblage.

Sullivan noted (1964, p. 1256) that, "the assemblages provide an interesting admixture of Devonian and Carboniferous elements." Hacquebard (1957) and Playford (1963) came to a similar conclusion from their study of Tournaisian spores. Of notable absence was the species Lophozonotriletes rarituberculatus (Luber) Kedo, 1957, which was very abundant in the same age material in

Spitsbergen (Playford, 1962).

In 1964 Sullivan described miospores from the Drybrook Sandstone of the Forest of Dean Basin which is younger (Visean) than the lower limestone shales of the same area. In 1966 Sullivan and Marshall described a spore assemblage from Scotland which was also Visean in age.

The latest publication by Sullivan (1968) is a report on the Tournaisian spore assemblage from the Cementstone Group of Ayrshire, Scotland.

Sullivan described twelve genera and twenty-two species (eight new species). At least eight of the species are known to be characteristic of (restricted to) Tournaisian age sediments. These eight species were: Pustulatisporites gibberosus Playford, 1963, Raistrickia clavata (Hacquebard, 1957) Playford, 1963, Vallatisporites vallatus Hacquebard, 1957, Lycospora torulosa Hacquebard, 1957, Retusotriletes incohatus Sullivan, 1964, Raistrickia corynoges Sullivan, 1968, (Raistrickia sp. A Sullivan, 1964), Baculatisporites fusticulus Sullivan, 1968, and Knoxisporites pristinus, Sullivan, 1968. Other species reported by Sullivan which were common in (but not restricted to) the Vallatisporites suite (Sullivan, 1967) were: Punctatisporites irrasus (Hacquebard, 1957), Punctatisporites viriosus (Hacquebard, 1957), Endosporites

micromanifestus (Hacquebard, 1957), and Grandispora echinata (Hacquebard, 1957). The three species of Punctatisporites; Punctatisporites irrasus, Punctatisporites planus, and Punctatisporites viriosus, all described initially by Hacquebard (1957), were the dominant species in the Scottish assemblage.

Streel (1966) in his examination of the Lower Tournaisian of the Dinant Basin of Belgium found an abundance of Hymenozonotriletes lepidophytus Kedo, 1957, which permitted him to propose a series of seven zones within the Tn1a and Tn1b deposits based on distinctive population of this species.

Other important species reported by Streel were: Punctatisporites irrasus Hacquebard, 1957, Retusotriletes incohatus Sullivan, 1964, cf. Dicrospora multifurcata Winslow, 1962, and Lophozonotriletes rarituberculatus (Luber) Kedo, 1957. The presence of the latter species was significant because it was the first record of its presence in Europe. It had previously been reported from Spitsbergen (Playford, 1963), Russia (Kedo, 1957), and Canada (McGregor and Owens, 1966).

The only report on the Lower Carboniferous microfossil flora of the southern hemisphere is that of Balme (1960). In this publication he described twenty-one miospore genera from three bore cores from the Fitzroy

Basin in western Australia. According to Sullivan (1968, p. 128) the following species described by Balme were of significance and were characteristic of the Tournaisian Vallatisporites suite. The taxon in parenthesis is Sullivan's interpretation of the taxonomic position of the species Balme described. Cingulati gen. et sp. nov. (Vallatisporites), Retusotriletes sp. (Retusotriletes incohatus, Sullivan, 1964), Punctatisporites sp. B (Punctatisporites irrasus Hacquebard, 1957), Apiculatisporis sp. (Raistrickia abtrusa, Playford, 1963), and Grandispora cf. G. spinosa Hoffmeister, Staplin, and Malloy, 1955 (Grandispora echinata, Hacquebard, 1957). Balme reported that "small spinose hystrichosphaerids," (p. 26) were common in one of the samples examined (Laurel Beds).

One unpublished Ph.D dissertation and one Master's thesis, both of which dealt with Upper Devonian spores are discussed below because of their geographic and stratigraphic proximity to the Hannibal Formation.

A Master's thesis (University of Oklahoma) was prepared by Urban in 1960. In this study on the Upper Devonian Woodford shale of Oklahoma, Urban described ten genera and twenty-one species of miospores, six genera and nineteen species of hystrichospheres (Acritarchs), six species of Tasmanites, and seven incertae sedis.

A comparison of Urban's assemblages to the Hannibal assemblage is discussed in a later chapter. Several species of both miospores and acritarchs appear to be conspecific with those in the Hannibal material at hand.

In 1964 Gupta prepared a Ph.D dissertation on the miospore content of the Upper Devonian Grassy Creek and Saverton Formations. Gupta collected samples of these dark shales from outcrops in northeastern Missouri. In this area these formations are separated from the Hannibal Formation by the Louisiana Formation. Gupta described twenty-five miospore genera, eight species of Tasmanites, two species of Leiosphaeridia, and two species of hystri-chospheres. In comparing the Grassy Creek and Saverton miospore assemblages with previously described assemblages Gupta made the following statement (p. 169), "the assemblages studied have very few species in common with other Upper Devonian assemblages of North America and outside."

Previous work on Mississippian Acritarchs

Ehrenberg (1838, 1843, and 1856) first discovered hystri-chospheres in his thin section study of Mesozoic flints and cherts. He considered these spherical bodies with processes to be silicified zygo spores of Xanthidium which is a fresh water desmid.

The first reported occurrence of these spiny

structures from paleozoic rock was in 1862. White (1862) described them from an Upper Silurian limestone of New York.

Because no living representatives were known, the affinity of these spiny cysts presented a problem to early workers. In 1845 Mantell suggested that these spheres were composed of organic substances rather than silica as proposed by Ehrenberg. Although Mantell has since been proven to be correct in his interpretation of the organic nature of cysts, the view of Ehrenberg was upheld until the early part of the Twentieth Century.

In 1932 and 1933 Wetzel proposed the Family Hystri-chospheridae (unspecified systematic position) with four genera, to accommodate all previously described species of the spiny spherical structures.

Deflandre (1934) published the first of his papers on Cretaceous hystrichospheres. In 1937 he proposed the genus Hystrichosphaeridium for forms having tube-like processes. Micrhystridium (Deflandre, 1937) included all hystrichospheres with an average diameter of less than twenty microns.

Eisenack (1938) in his study of assemblages in the Baltic Silurian showed that there was no difference between the hystrichospheres and those forms having no spines. Therefore, he erected the genus Leiosphaera to

accommodate forms having a smooth, granular or punctate surface but possessing no spines. He included the forms having rod-like shapes in the genus Leiofusa. Leiosphaera later had to be emended (Eisenack, 1958) because it included some forms of the genus Tasmanites Newton, 1875. As a result, Eisenack abandoned the genus Leiosphaera and established the genus Leiosphaeridia (1958) for forms which could not be included within the genus Tasmanites.

According to Manten, Reinsch (1905) was the first to consider the hystrichospheres to be dinoflagellate cysts. Deflandre (1947) supported this view concerning the affinity and planktonic nature of the hystrichospheres. This affinity was substantiated by Evitt (1963). Manten made the following comment regarding the affinity of the hystrichospheres, "It is very ironic that both the genera Hystrichosphaera and Hystrichosphaeridium, from which the group name of the hystrichosphaerids was derived, happened to be based on fossil dinoflagellates." (Manten, 1967, p. 296) This has resulted in some confusion between fossil dinoflagellates and "hystrichosphaerids." Forms previously referred to as hystrichospheres are now called acritarchs (as proposed by Evitt, 1963). The nomenclature and taxonomic problems of the acritarchs are discussed in greater detail in a separate section.

The only known publication directly concerned with

Lower Mississippian acritarchs are those of Stockmans and Williere (1966 and 1967). In their 1966 publication on the Tournaisian acritarchs of Belgium they described five genera (one new) and eighteen species (six new). The genera present in the Tournaisian of Belgium were:

Veryhachium Deunff, 1954, Baltisphaeridium Eisenack, 1958, Micrhystridium Deflandre, 1937, Cymantiosphaera Wetzel, 1933, and Tornacia Stockmans and Williere, 1966.

In 1967, Hemer and Nygreen published a paper on the microfossils from the Lower Carboniferous of Saudi Arabia. They reported eight species of algae, seven new genera and fifteen species (fourteen new) of acritarchs, and two incertae sedis species.

In 1961, Staplin published a paper on an acritarch assemblage from an Upper Devonian reef deposit in Alberta, Canada. He described ten species of the genus Protoleiosphaeridium Timofieve, 1959, ten species of Micrhystridium (Deflandre) Staplin, 1961, three species of Multiplicisphaeridium Staplin, 1961, eight species of Veryhachium Deunff, 1954, three species of Cymatiosphaera Wetzel, 1933, two species of Dictyotidium (Eisenack, 1955) Staplin, 1961, and one new genus Duvernaysphaera Staplin, 1961.

Many of the species described by Staplin have been transferred to other genera by Downie and Sarjeant (1963). For example, these authors considered the genus

Protoleiosphaeridium invalid and transferred all species of this genus to the genus Leiosphaeridia Eisenack, 1958. This emendation and others by Downie and Sarjeant will be discussed in greater detail in a later chapter.

The other investigation on Upper Devonian acritarchs was that of Urban, 1960. He described nine species of Cymatiosphaera Wetzel, 1933, one species of Veryhachium Deunff, 1954, one species of Leiosphaera and one species Leiosphaeridia, six species of Tasmanites and seven species of incertae sedis. Urban did not give specific names to the species, referring to them only as types.

The genus Tasmanites, which is synonymous with many "Sporangites" was first described by Newton (1875) and employed by him to designate punctate disc-like bodies he found in Tasmanite marine "coal" (Permian) from Tasmania, an island near southeastern Australia.

Most publications on Tasmanites result from investigations of Devonian material rather than Lower Mississippian. Representations of the genus Tasmanites are most abundant in Upper Devonian sediments; however, they have been found in sediments ranging in age from Middle Silurian to Recent.

One of the most active workers on Tasmanites is Sommer. Since 1953, Sommer has described several species of Tasmanites from the Upper Devonian shales in Brazil.

In 1967 Sommer and his coworker Van Boekel gave a synopsis of Brazilian Tasmanites described to date. They have described eleven species of Tasmanites and have divided them into groups according to the following characteristics. Group one, with four species, is characterized by a conspicuous outer ring. Group two, with three species, is characterized by conspicuous punctae or pores, without an outer ring. Group three, with two species, is characterized by conspicuous folds. Group four, with two species, is characterized by an oval to spindle shape.

Discussion of the literature on the Hannibal Formation

The formation which occupies a stratigraphic position above the Louisiana Formation and below the Choteau Formation and which outcrops in northeastern Missouri was originally called the "Vermicular Shales and Sandstones" by Swallow in 1855 (p. 103). In 1892, (pp. 289-290) Keyes proposed and applied the name Hannibal to these silty shales and argillaceous siltstones which outcrop (type section) along the Mississippi River bluff at Hannibal, Missouri. At this locality the Hannibal Formation rests upon the Louisiana Formation and is overlain by the Burlington Formation.

Moore (1928), in his description of the section at Kinderhook, Illinois (from where the Series name

Kinderhookian is derived) applied the name Hannibal to all sediment below the Choteau Formation (or Burlington where Choteau is absent) and above the Louisiana Formation. At some localities the Hannibal rests upon an oolitic silty limestone referred to as either "Glen Park" or "Hamburg." At some localities in western Illinois the Louisiana and the oolitic limestone units are both absent; there the Hannibal rests directly upon the Saverton Formation. Moreover, Moore considered the McCraney Limestone, which outcrops in NW Illinois and SE Iowa, the English River Sandstone, which outcrops in SE Iowa, and the Maple Mill Shale, which outcrops in SE Iowa, all to be members of the Hannibal Formation.

Workman and Gillette (1956) considered the "Glen Park", the Maple Mill Shale, and the English River Siltstone to be formations within the "Hannibal Group." Their "Hannibal Group" occurred above the Louisiana Limestone and below the Choteau Limestone. The Nutwood, which they designated as a member of the Maple Mill, will be discussed in greater detail later in this chapter.

Many of the Basal Mississippian formations, which outcrop in the type area for the Mississippian System, contain only a meager macrofauna. This has resulted in an uncertain stratigraphic position for those formations. Much of the confusion concerning the relationship between

the Basal Mississippian Formations (as well as Upper Devonian Formations) has been alleviated by recent conodont work by Collinson (1961b and 1961c), Collinson et al. (1962), and Canis (1967).

Collinson (1961b) considered the English River Formation to be a facies of the Hannibal Formation. He placed these formations at the base of the Kinderhookian Series. Thus, the McCraney Formation is considered to be younger than the English River and Hannibal Formations. According to Collinson (p. 100, figs. 1 to 3), the Maple Mill Formation (SE Iowa) is actually Upper Devonian and is a facies of the Saverton and Grassy Creek Formations, both of which are known to be Upper Devonian in age.

The conodont content of the Louisiana Formation, which has an unconformable contact with the overlying Hannibal Formation, indicates an age equivalence to the upper part of the Saverton Formation and also correlates with the Upper Devonian Wocklumeria Stufe of western Germany.

The "Glen Park" ("Hamburg") which sometimes intervenes between the Louisiana and Hannibal is, according to Collinson (p. 105), "probably the oldest Mississippian Formation in the Mississippi Valley and correlates with the lower Gattendorfia Stufe (cu I) of Europe."

According to Collinson (p. 106) the abundant conodont

faunas of the Hannibal Formation indicated Basal Kinderhook age and correlated with the European Gattendorfia Stufe.

Canis (1967) in his conodont study of the Kinderhookian of Missouri also found that the Hannibal Formation (basal part) correlated with the Gattendorfia Stufe and made the following statement (p. 44) regarding the base of the Hannibal Formation, "The oldest Mississippian rocks in Missouri are located in northeast Missouri. During earliest Early Mississippian the Hannibal shale was deposited."

In parts of Missouri (other than NE) the earliest Mississippian Formation is the Bachelor Formation. This is a sandstone which Canis considered to be the initial deposit of the "Kinderhookian transgression." On the basis of the conodont assemblages in the Bachelor and in the Upper Hannibal, Canis made the following statement (p. 44), "This (Kinderhookian) transgression took place while the Upper Hannibal was being deposited in northeastern Missouri."

The Hannibal Formation is exposed in the Upper Mississippi Valley and reaches a maximum thickness of 100+ feet in Pike County, Missouri, and Pike County, Illinois. Eastward across Illinois the formation thins and grades into the upper portion of the New Albany

Formation. The formation consists of shale, shaly siltstone, and siltstone. The color varies from olive green or bluish green to gray to buff. The upper portion is a siltstone. The lower portion of the formation varies from silty shale to shaly siltstone. At some localities a dark brown to black shale facies occurs at the base of the Hannibal Formation. This dark, fissile shale is known as the Cuivre Member in Missouri; and in Illinois, where it is much more extensive, the Member name Nutwood is applied.

In 1961 Mehl proposed the name Cuivre to designate a shale unit between the Hannibal shale and the Louisiana limestone in Pike County, Missouri. The type locality for this unit is located in SE 1/4 NE 1/4 SE 1/4 Sec. 35, T.54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri.

The Nutwood Member of the Hannibal Formation was named by Workman and Gillette in 1956 for the dark brown to black facies of the Maple Mill Formation. The type locality for this facies is in Jersey County, Illinois SE 1/4 NW 1/4 Sec. 34, T.8 N., R.13 W. It is exposed along a creek that flows through "The Narrow" 1.1 miles NE of Nutwood, Illinois.

According to Collinson (1961b, p. 106), the formation which Workman and Gillette referred to as the Maple Mill

is actually the Hannibal Formation. The Nutwood, therefore, is a black shale facies of the Hannibal Formation. The Nutwood is a silty noncalcareous, dark brown to black, fissile shale. Workman and Gillette noted that this shale is sometimes difficult to distinguish from the dark fissile Grassy Creek shale. These authors showed that in the subsurface of western Illinois the Nutwood reached a maximum thickness of forty feet. In geographical area the unit is restricted to the following counties in Illinois: Calhoun, Jersey, Green Macoupin, Madison, St. Clair, Bond, Montgomery, Sangamon, Christian, Shelby, and Fayette.

CHAPTER III

MATERIALS AND METHODS

General statement

Samples of the Hannibal Formation were obtained from outcrops located in northeastern Missouri in Marion and Pike Counties and in western Illinois in Pike, Calhoun, and Jersey Counties.

The collections were made in the fall of 1965 and the summer and fall of 1966. The samples were then processed in the Palynology Laboratory, Botany Department, University of Missouri. All samples were washed thoroughly prior to maceration. Prior to and between use all laboratory equipment and utensils were cleaned with detergent and rinsed in distilled water. No other spore or pollen samples were being processed in the Palynology Laboratory while the Hannibal material was being macerated.

Collecting procedure

Consecutive channel samples were obtained from the lower black shale portion of the Hannibal Formation. The samples were collected from benches which varied in thickness from six inches to two feet; however, most of the benches were one foot in thickness. Fresh, unweathered samples were collected in new paper bags and labeled in the field. The basal black shale is called the Cuivre

Member in Missouri and in Illinois it is known as the Nutwood Member. This black shale, when present, varies in thickness from four to twenty feet and reaches a maximum thickness of forty feet subsurface in Illinois. The majority of spores described in this study came from the lower black shale.

The remainder of the Hannibal Formation consists of silty gray to green shales and gray, greenish to buff siltstones. Preliminary investigations of samples from the silty shales and siltstones revealed few spores and many samples were barren of spores. Therefore, detailed consecutive samples were not collected from this upper portion of the Hannibal Formation. This portion was sampled at vertical intervals of five to ten feet.

Coding of localities and samples

The usual way of identifying localities is by simply numbering the localities such as Locality 1, Locality 2, and so forth. This procedure was followed; however, each locality received, in addition to the number and preceding the number, a two letter abbreviation of the formation or member collected there. For example, Cu represents the Cuivre Member, Nu represents the Nutwood Member, and the Hannibal proper was coded Ha. Collections were made from three Cuivre outcrops. These localities were coded Cu-1, Cu-2, and Cu-3. Likewise the two localities of the

Nutwood Member were coded Nu-1 and Nu-2. The localities where these two members are not present were coded Ha-1, Ha-2, Ha-3, and Ha-4. At each locality the lowermost sample collected was given the letter A. Sample B represents a horizon above A, as does C above B and so forth. By example, the code Nu-1-A represents the lowermost sample collected at the first locality where the Nutwood Member was collected. In each instance the first locality, Nu-1, Cu-1, and Ha-1, represents the type locality for that member or formation.

Collecting localities

A total of nine outcrops of the Hannibal Formation were sampled. Six of these outcrops were located in Missouri and three were located in Illinois. Two subsurface samples of the Nutwood Member were obtained from the Illinois Geological Survey.

Northeastern Missouri. Locality Ha-1, samples A through E; SE 1/4 SE 1/4 Sec. 28, T.57 N., R.4 W., Hannibal Quadrangle, Marion County, Missouri. The geographical location is shown in Figure 1. A columnar section is shown in Figure 3 (Modified from Koenig and Martion, 1961, Fig. 29). This is the type section for the Hannibal Formation. The section is located in the southern part of the city of Hannibal on Route AA

along the Mississippi River bluff. The bluff is very steep and is known locally as Lovers Leap.

Locality Ha-2, samples A through G; NE 1/4 SW 1/4 Sec. 12, T.55 N., R.3 W., Barry Quadrangle, Pike County, Missouri. The geographical location is shown in Figure 2. A columnar section is shown in Figure 4 (Modified from Koenig and Martin, 1961, fig. 23). This outcrop is located in a roadcut on Missouri Highway 79 approximately one-half mile north of the junction of Missouri Highway 79 and State Road TT. Twenty-eight feet of the Hannibal Formation are exposed here just below the Burlington Limestone.

Locality Ha-3, samples A through H; NE 1/4 SE 1/4 Sec. 27, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri. The geographical location is shown in Figure 5. A columnar section is shown in Figure 7. This outcrop is located one-half mile northwest of the Bethany Cemetery. In the Hannibal Formation there is an abundance of cast and molds of "caudi galli" (Taonurus), commonly known as rooster tail, which has an unknown affinity but may represent a bottom phenomenon.

Locality Cu-1, samples A through D; SE 1/4 NE 1/4 SE 1/4 Sec. 35, T.54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri. The geographical location is shown in Figure 6. A columnar section is shown in

Figure 8. This outcrop of the Cuivre is located approximately 4.5 miles north of Bowling Green, Missouri on one of the head branches of Grassy Creek. There are four feet of the Cuivre exposed here in the stream bank. Some of the thin lenses of sandstone show current ripple marks. Botryoidal pyrite, up to an inch in thickness, is associated with some of the sandstone lenses. This locality, along with locality Cu-3, which was collected downstream 0.2-0.3 mile, represents the type locality for the Cuivre as it was designated by Mehl (1960, pp. 98-100).

Locality Cu-2, samples A through E; SE 1/4 NE 1/4 SW 1/4 Sec. 25, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri. The geographical location is shown in Figure 5. A columnar section is shown in Figure 9 (Modified from Koenig and Martin, 1961, fig. 18). This outcrop is just west of Louisiana in a roadcut on Route NN, 0.5 mile south of U. S. Highway 54. Mehl (1960, p. 27) identified and assigned the lower four to six feet of the Hannibal outcrop to the Cuivre.

Locality Cu-3, samples A through H; SW 1/4 NW 1/4 Sec. 36, T. 54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri. The geographical location is shown in Figure 6. A columnar section is shown in Figure 10. This outcrop of the Cuivre occurs 0.2-0.3 mile downstream from locality Cu-1. Both of these

outcrops occur at the type locality for the Cuivre as designated by Mehl (1960, pp. 98-100). Twelve feet of the Cuivre are exposed at this locality.

Western Illinois. Locality Ha-4, samples A through G; SE 1/4 Sec. 35, T.6 S., R.5 W., Nebo Quadrangle, Pike County, Illinois. The geographical location is shown in Figure 11. A columnar section is shown in Figure 13 (Modified from Collinson, 1961, fig. 12). This outcrop occurs on the east side of State Highway 96, 1.8 miles south of Atlas, Illinois. The basal black shale of the Hannibal Formation is absent at this locality.

Locality Nu-1, samples A through F; SE 1/4 NW 1/4 Sec. 34, T.8 N., R.13 W., Hardin Quadrangle, Jersey County, Illinois. The geographical location is shown in Figure 12. A columnar section is shown in Figure 14. This outcrop was designated as the type section for the Nutwood by Workman and Gillette (1956, p. 27). Thirteen feet of the Nutwood are exposed here along the creek which flows through "The Narrow" 1.1 miles northeast of Nutwood, Illinois.

Locality Nu-2, samples A through F; NW 1/4 NE 1/4 Sec. 35, T.9 N., R.3 W., Hardin Quadrangle, Calhoun County, Illinois. The geographical location is shown in Figure 15. A columnar section is shown in Figure 17 (Modified from Collinson, 1961, fig. 7). This outcrop is

located in the lower part of the bluff which occurs at the northern edge of Hamburg, Illinois. At the time of collection the greenish shale, was not thought to be a part of the Nutwood and therefore was not labeled as Nutwood. Samples of this green shale were labeled as Hannibal (Ha-5, samples A through D).

The two subsurface samples of the Nutwood were coded as follows: Nu-3, sample A; Sec. 15, T.14 N., R.3 W., depth 1610-1650 feet, Christian County, Illinois, and Nu-4, sample A, Sec. 23, T.7 N., R.3 W., depth 2080-2110 feet, Montgomery County, Illinois.

Workman and Gillette (1956, p. 20) mentioned that a good exposure (twenty feet) of the Nutwood occurred in Mason's Hollow, about one mile north of Grafton, Illinois, NE 1/4 SE 1/4 Sec. 4, T.6 N., R.12 W, Grafton Quadrangle, Jersey County, Illinois. The outcrop occurred on the eastern bank of the stream that runs through Mason's Hollow. At the time the Nutwood was being collected (fall, 1966) road construction along the creek had covered the outcrop and samples could not be collected.

Southwest Missouri. Two outcrops of the Northview Formation were sampled in order to determine its stratigraphic position in relation to the Hannibal Formation. However, the samples were barren of spores and correlation was not possible. The geographical

locations are shown in Figure 16.

Six samples were collected in a road cut on the west fork of County Road B, 1 mile northwest of Northview, Missouri. SW 1/4 SW 1/4 Sec. 23, T.30 N., R.19 W., Niangua Quadrangle, Webster County, Missouri. This is the type locality for the Northview. Approximately 20 feet of olive green shale are exposed here.

Seven samples of the Northview were collected in a roadcut on the east side of County Road B approximately one half mile north of Northview, Missouri. NE 1/4 SW 1/4 Sec. 26, T.30 N., R.19 W., Niangua Quadrangle, Webster County, Missouri. Approximately 35 feet of the Northview Formation are exposed here. At this locality the formation consisted of greenish gray to bluish gray shales and gray brown to buff siltstones.

Wayne Canis (oral communication) also found very few conodonts in the Northview. However, he was able to determine that the Northview was not a time equivalent of the Hannibal. Stratigraphically, he places the Northview as Upper Kinderhookian, whereas the Hannibal is lowermost Kinderhookian. (Canis, 1968)

Laboratory procedure

In carrying out the laboratory procedure, the cadmium iodide and potassium iodide flotation technique was used to separate the microfossils from the matrix. Brown

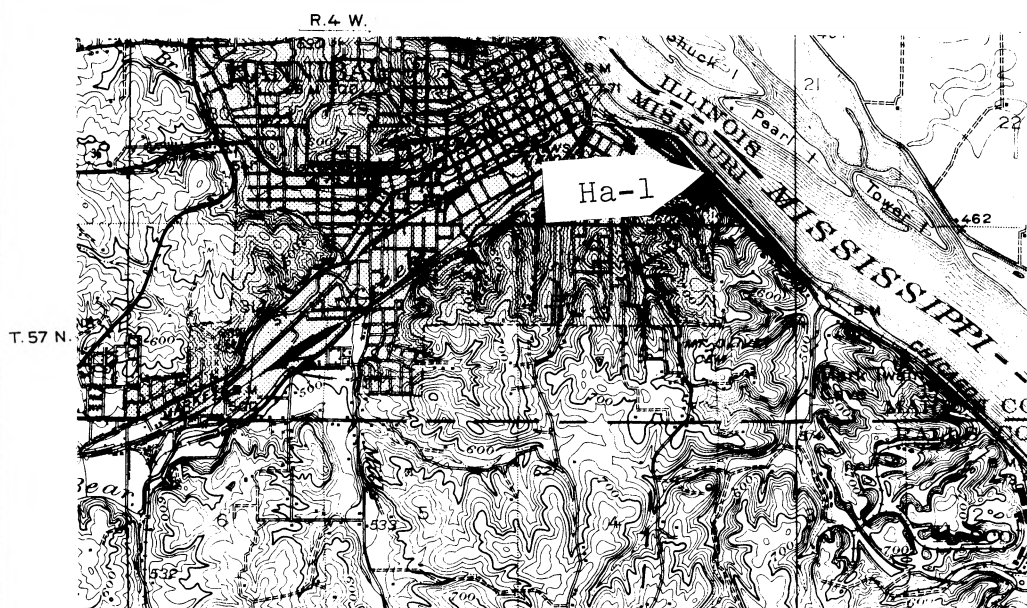


Figure 1. Locality Ha-1; Se 1/4 SE 1/4 Sec. 28, T.57 N., R.4 W., Hannibal Quadrangle, Marion County, Missouri.

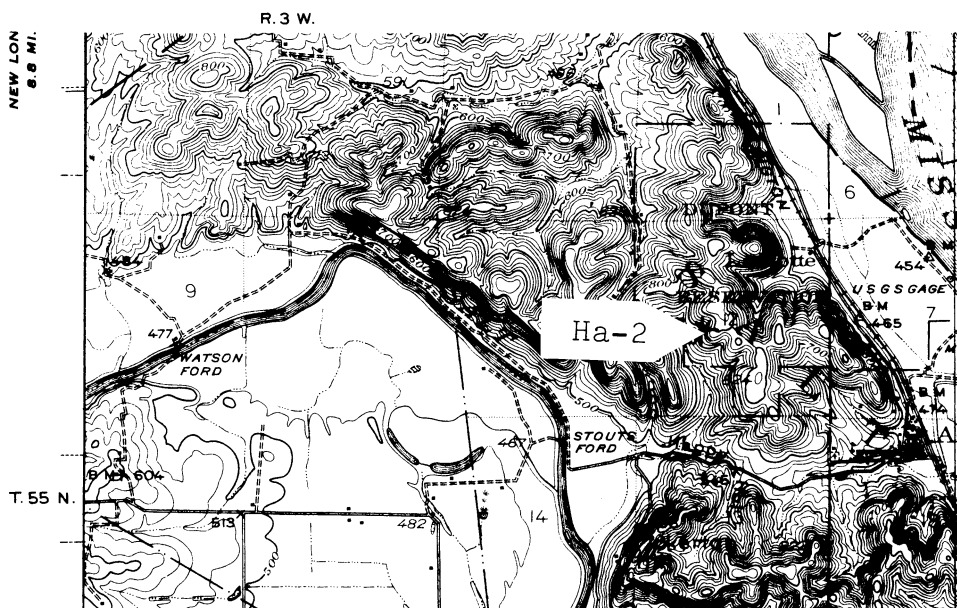


Figure 2. Locality Ha-2; NE 1/4 SW 1/4 Sec. 12, T.55 N., R.3 W., Barry Quadrangle, Pike County, Missouri.

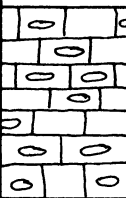
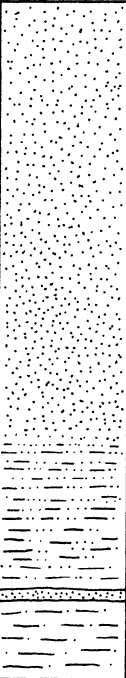

SYSTEM	SERIES	FORMATION	SAMPLE	DESCRIPTION
MISSISSIPPIAN	OSAGIAN	BURLINGTON		Limestone, thick bedded, coarsely crystalline, crinoidal, gray to buff. 80 to 90 ft.
	KINDERHOOKIAN	HANNIBAL		Siltstone, buff to gray. 30 ft. Siltstone, shaly, and silty shale, blue gray to olive gray. 25 ft.
DEVONIAN	UPPER DEVONIAN	LOUISIANA		Limestone, dolomitic, thin bedded, brown to buff. 34 ft. exposed.

Figure 3. Columnar section at collecting locality Ha-1; SE 1/4 SE 1/4 Sec. 28, T.57 N., R.4 W., Hannibal Quadrangle, Marion County, Missouri. (Modified from Martin and Koenig, 1961, Fig. 29)

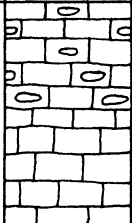
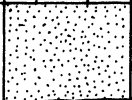
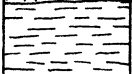
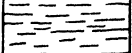

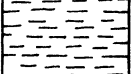
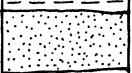

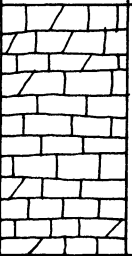
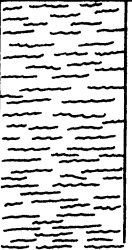
SYSTEM	SERIES	FORMATION		SAMPLE	DESCRIPTION
MISSISSIPPIAN	OSAGIAN	BURLINGTON			Limestone, gray to buff, coarsely crystalline, crinoidal, bands and nodules of chert in upper portion. 60 ft.
	KINDERHOOKIAN	HANNIBAL		G	Siltstone, yellowish green. 5 ft. 6 in.
				F	Shale, olive green, silty in upper 2 ft. 6 ft. 6 in.
				E	
				D	Siltstone, yellowish green. 3 ft. 6 in.
				C	Shale, olive green. 5 ft.
				B	Siltstone, yellowish green. 2 ft. 6 in.
			A	Shale, yellowish green. 4 ft. 6 in. Covered. 83 ft.	
DEVONIAN	UPPER DEVONIAN	LOUISIANA			Limestone, tan to gray, lithographic. 33 ft.
	UPPER DEVONIAN	SAVERTON-GRASSY CREEK			Shale, dark gray, fissile, light green clay at base. 36 ft.

Figure 4. Columnar section at collecting locality Ha-2; NE 1/4 SW 1/4 Sec. 12, T.55 N., R.3 W., Barry Quadrangle, Pike County, Missouri. (Modified from Martin and Koenig, 1961, Fig. 23)

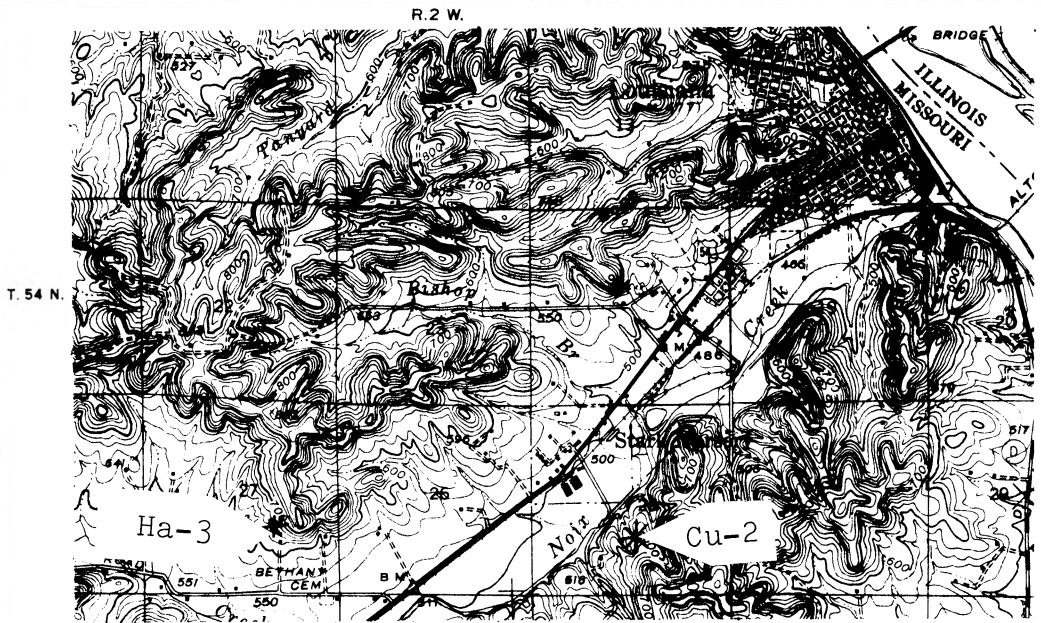


Figure 5. Locality Ha-3; NE 1/4 SE 1/4 Sec. 27, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri.
 Locality Cu-2; SE 1/4 NE 1/4 SW 1/4 Sec. 25, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri

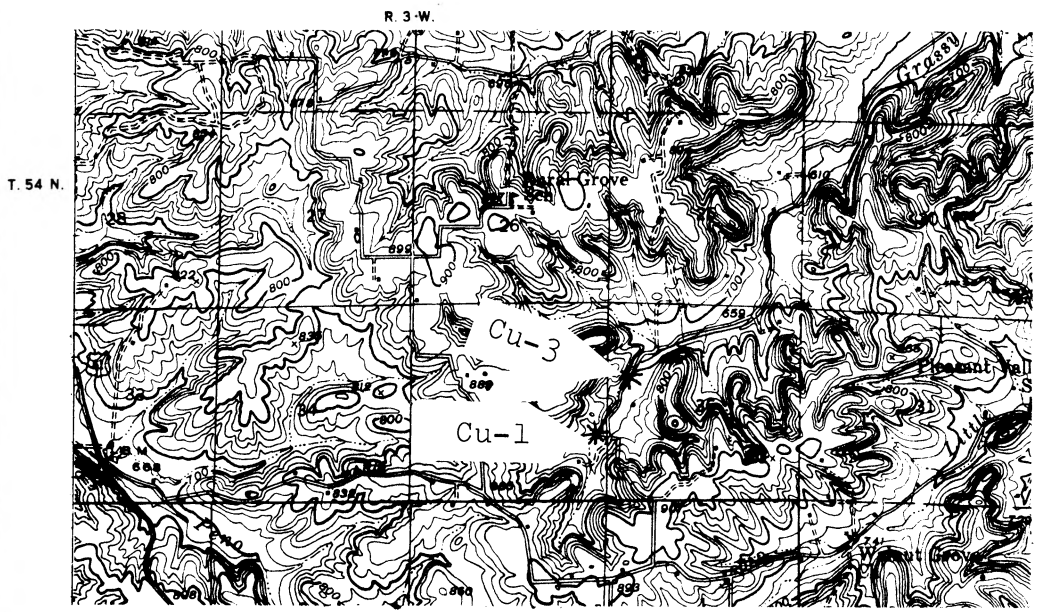


Figure 6. Locality Cu-1; SE 1/4 NE 1/4 SE 1/4 Sec. 35, T.54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri.
 Locality Cu-3; SW 1/4 NW 1/4 Sec. 36, T. 54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri.

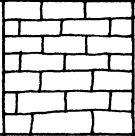
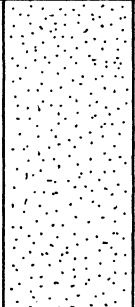
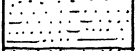
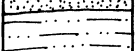
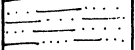

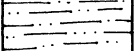
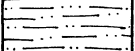
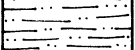
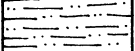
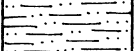
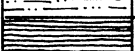
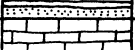
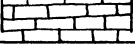
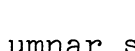
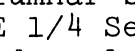
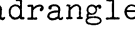







SYSTEM	SERIES	FORMATION		SAMPLE
MISSISSIPPIAN	OSAGIAN	BUR-LINGTON		Limestone, yellowish brown to buff, coarsely crystalline, crinoidal. 20 ft.
	KINDERHOOKIAN	HANNIBAL	                     	I Siltstone, gray to buff. 60 ft. H G F E
			DEV.	LA.
DEV.	U. DEV.			Limestone, buff, lithographic. 5 ft. exposed.

Figure 7. Columnar section at collecting locality Ha-3; NE 1/4 SE 1/4 Sec. 27, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri.

SYSTEM	SERIES	FORMATION		SAMPLE	DESCRIPTION
MISSISSIPPIAN	KINDERHOOKIAN	HANNIBAL		<p>D</p> <p>C</p> <p>B</p> <p>A</p>	<p>CUIVRE MEMBER</p> <p>Shale, dark brown to black, fissile; ripple marked sandstone lenses with botryoidal pyrite. 4 ft.</p>

Figure 8. Columnar section at collecting locality Cu-1; SE 1/4 NE 1/4 SE 1/4 Sec. 35, T.54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri.


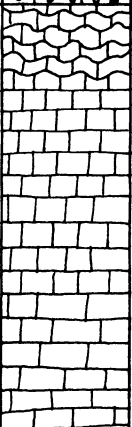
SYSTEM	SERIES	FORMATION	SAMPLE	DESCRIPTION
				LOESS COVER
MISSISSIPPIAN	KINDERHOOKIAN	HANNIBAL	F	Shale, silty, greenish gray. 20 ft.
			E	
			D	CUIVRE MEMBER
			C	
B				
A	"HAMBURG OOLITE" 1 ft. 10 in.			
DEVONIAN	UPPER DEVONIAN	LOUISIANA		Limestone, buff to gray; contains calcite nodules; wavy bedded in upper portion. 28 ft. exposed.

Figure 9. Columnar section at collecting locality Cu-2; SE 1/4 NE 1/4 SW 1/4 Sec. 25, T.54 N., R.2 W., Bowling Green Quadrangle, Pike County, Missouri. (Modified from Martin and Koenig, 1961, Fig. 18)


SYSTEM	SERIES	FORMATION		SAMPLE	DESCRIPTION
MISSISSIPPIAN	KINDERHOOKIAN	HANNIBAL			<p style="text-align: right;">50</p> <p>Shale, silty, gray to greenish gray. 10 ft.</p>
				H G F E D C	<p>CUIVRE MEMBER</p> <p>Shale, dark brown to black, fissile; ripple marked sandstone lenses with botryoidal pyrite. 10 ft.</p>
				B A	<p>Siltstone, dark gray. 2 ft.</p>

Figure 10. Columnar section at collecting locality Cu-3; SW 1/4 NW 1/4 Sec. 36, T.54 N., R.3 W., Bowling Green Quadrangle, Pike County, Missouri.

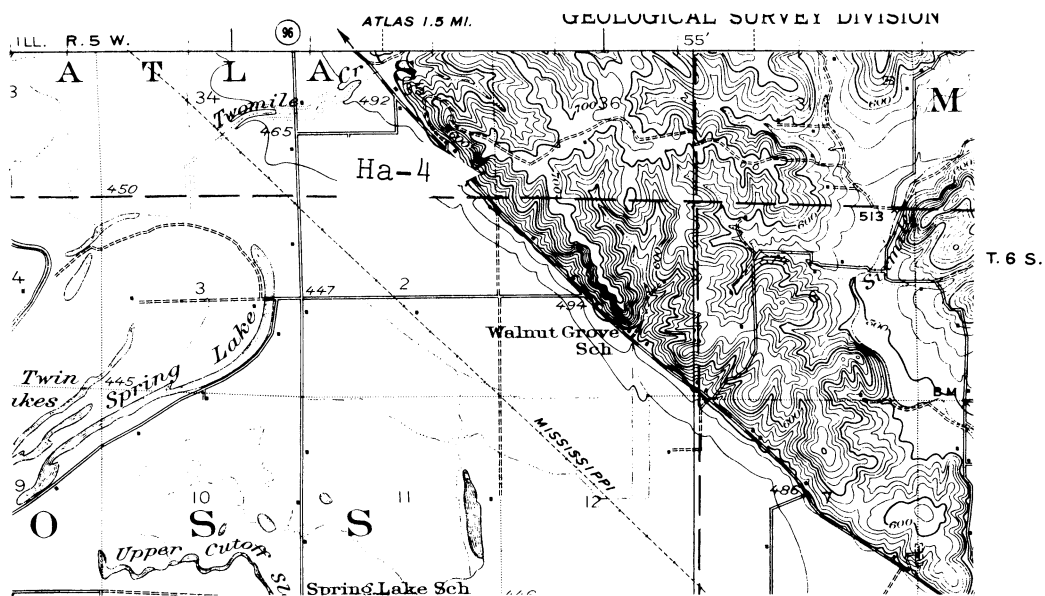


Figure 11. Locality Ha-4; SE 1/4 Sec. 35, T.6 S.,
R.5 W., Nebo Quadrangle, Pike County, Illinois.

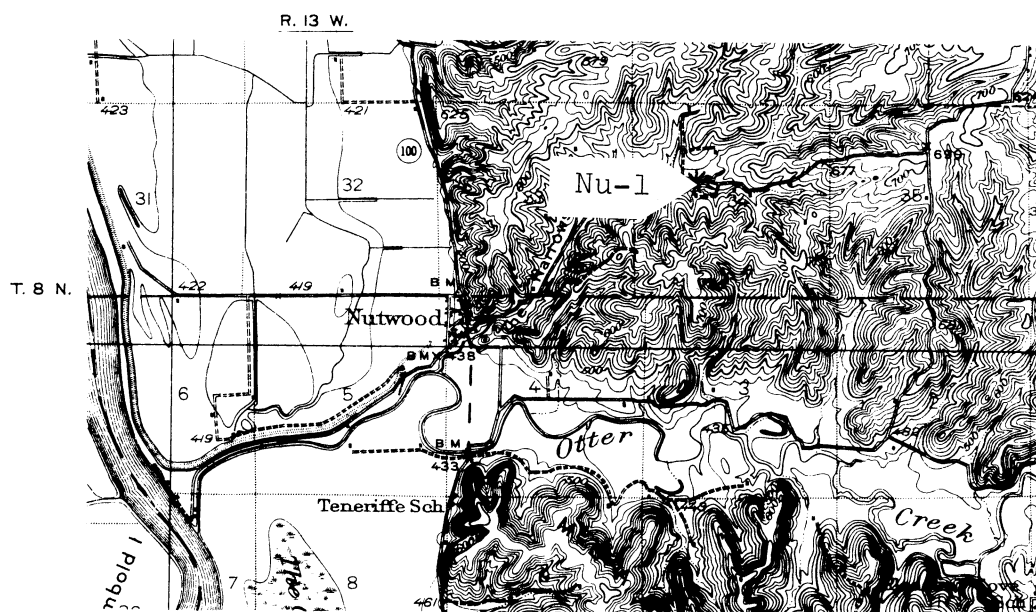


Figure 12. Locality Nu-1; SE 1/4 NW 1/4 Sec. 34,
T.8 N., R.13 W., Hardin Quadrangle, Jersey
County, Illinois.

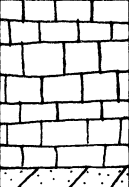
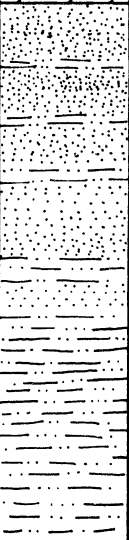
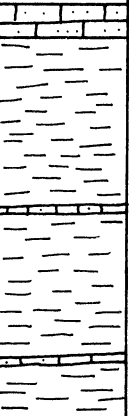

SYSTEM	SERIES	FORMATION	SAMPLE	DESCRIPTION	
MISSISSIPPIAN	OSAGIAN	BURLINGTON		Limestone, buff, crinoidal. 20 ft.	
	KINDERHOOKIAN	HANNIBAL	H		Siltstone, buff to gray, shaly in parts. 30 ft.
			G		
			F		
			E		
D					
C	Shale, silty, gray to greenish gray. 25 ft.				
B					
A					
				"GLEN PARK" Limestone. 3 ft.	
DEVONIAN	UPPER DEVONIAN	SAVERTON		Shale, greenish gray, with thin silty limestone beds. 40 ft.	
				GRASSY CREEK Shale, dark. 5 ft.	

Figure 13. Columnar section at collecting locality Ha-4; SE 1/4 Sec. 35, T.6 S., R.5 W., Nebo Quadrangle, Pike County, Illinois. (Modified from Collinson, 1961, Fig. 12)

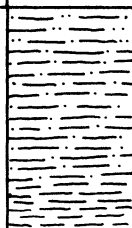
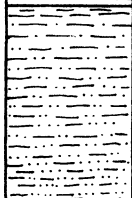
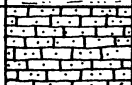

SYSTEM	SERIES	FORMATION		SAMPLE	DESCRIPTION
MISSISSIPPIAN	KINDERHOOKIAN	HANNIBAL		F	Shale, silty, greenish gray. 12 ft.
				E	NUTWOOD MEMBER
			D	Shale, dark brown to black, fissile. 13 ft.	
			C		
				B	Shale, silty, gray. 10 ft.
GLEN PARK		A		Limestone, gray, thin bedded, ripple marked. 4 ft.	
DEV.	U. DEV.	LA.			Limestone, gray, sublithographic. 1 ft. exposed.

Figure 14. Columnar section at collecting locality Nu-1; SE 1/4 NW 1/4 Sec. 34, T.8 N., R.13 W., Hardin Quadrangle, Jersey County, Illinois.

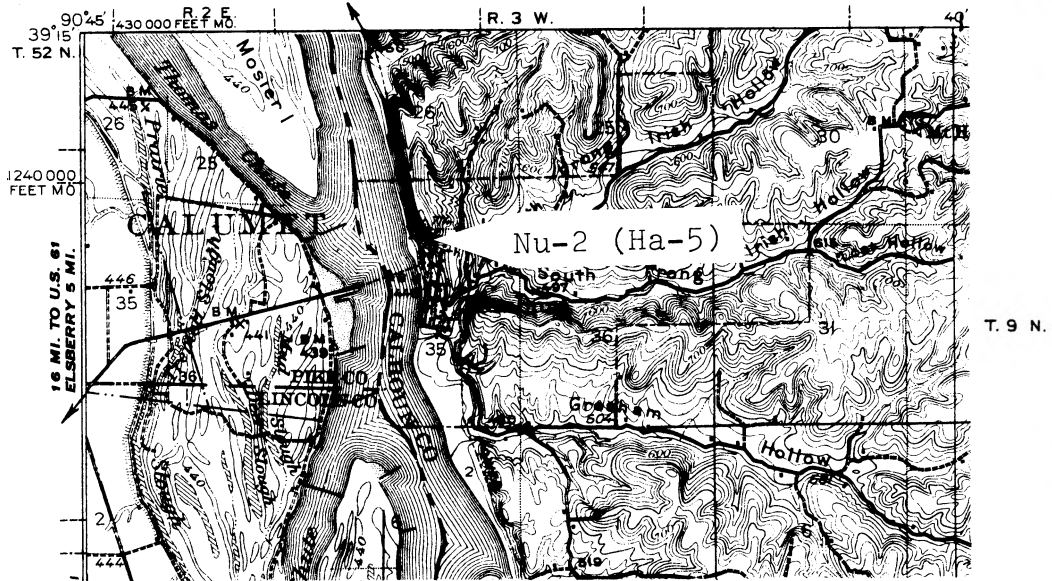


Figure 15. Locality Nu-2 (and Ha-5); NW 1/4 NE 1/4 Sec. 35, T.9 N., R.3 W., Hardin Quadrangle, Calhoun County, Illinois.

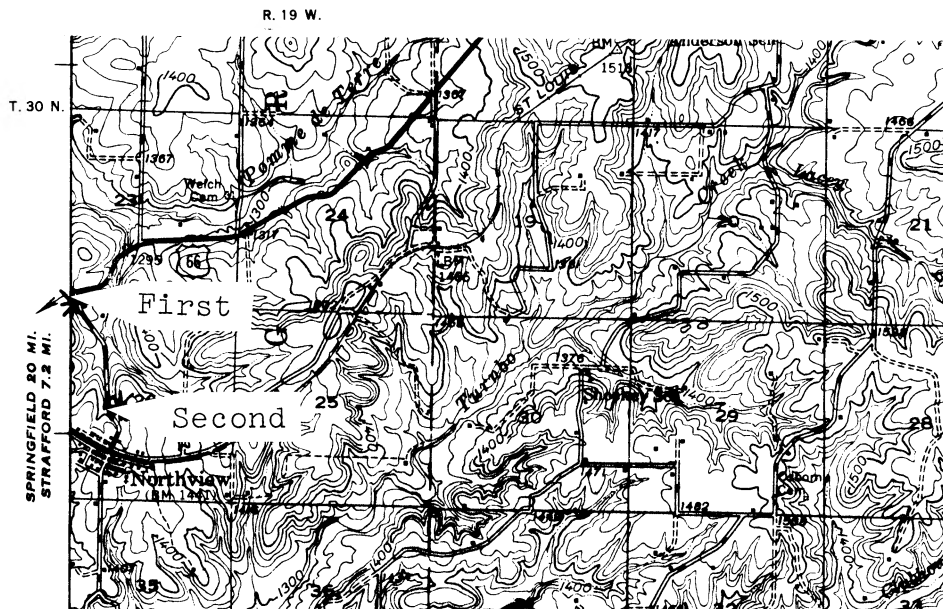


Figure 16. First locality of Northview Formation (Type section); SW 1/4 SE 1/4 Sec. 23, T.30 N., R.19 W., Niangua Quadrangle, Webster County, Missouri.

Second locality of Northview Formation NE 1/4 SW 1/4 Sec. 26, T.30 N., R.19 W., Niangua Quadrangle, Webster County, Missouri.

SYSTEM	SERIES	FORMATION		SAMPLE	DESCRIPTION
MISSISSIPPIAN	OSAGIAN	BURLINGTON			Limestone, buff, crinoidal. 10 ft.
	KINDERHOOKIAN	CHOUTEAU			Limestone, gray to buff, calcite geodes in lower portion. 20 ft.
		HANNIBAL			Covered. 70 ft. Shale, silty, greenish to gray. 10 ft.
					Siltstone, buff to gray. 6 ft.
				A-F	NUTWOOD MEMBER Shale, dark brown, fissile. 6 ft.
			D C	Shale, greenish gray. 3 ft. Covered. 10 ft.	
			B A	Shale, greenish to blue gray. 3 ft. Covered.	

Figure 17. Columnar section at collecting locality Nu-2 (and Ha-5); NW 1/4 NE 1/4 Sec. 35, T.9 N., R.3 W., Hardin Quadrangle, Calhoun County, Illinois. (Modified from Collinson, 1961, Fig. 7)

(1960, p. 46) does not give relative proportions of cadmium iodide and potassium iodide used, nor does he give the procedure for the flotation process. However, the optimum proportions were determined through experimentation. This phase of the laboratory work is discussed in detail on page 58. The advantage of using the cadmium iodide and potassium iodide solution is, as Brown pointed out (p. 46), "Non-corrosive to skin, filter paper, or plant tissue. It is non-volatile at ordinary temperatures and, under ordinary conditions, non-toxic." He reported that this technique gave very good results as it did in this investigation.

It was hoped that the hydrofluoric acid treatment could be eliminated by using the cadmium iodide and potassium iodide flotation technique. However, if the samples were floated after the hydrochloric acid treatment very few spores were recovered in the float. Therefore, in order to liberate the spores, the hydrofluoric acid treatment was necessary.

Maceration of samples

1. The shale samples were washed thoroughly to remove any possible contamination.
2. After drying, the samples were crushed with a Denver Fire Clay crusher. The crusher was cleaned thoroughly between samples.

3. The crushed samples were divided (riffle sample splitter) in order to have a statistical representation of each bench in each sample macerated.
4. Seventy-five grams of each sample were macerated in a 1,00 ml pyrex beaker. The remainder of each sample was stored in a new paper bag and labeled.
5. A ten per cent solution of hydrochloric acid was added to the sample and was allowed to react with the carbonates for a period of twenty-four hours with periodic stirring.
6. To assure complete removal of the carbonates fresh hydrochloric acid was added and the sample was warmed.
7. The dilute hydrochloric acid was then decanted and the sample was washed with distilled water.
8. The sample was transferred to a polyethylene beaker.
9. A fifty-two per cent hydrofluoric acid solution was added and allowed to react under the hood for two days with periodic stirring.

10. Fresh hydrofluoric acid was added and the sample was then heated in a water bath in order to permit more complete solution removal of the silica.
11. The hydrofluoric acid was diluted with distilled water. This reduced the specific gravity and allowed the spores to sink. The dilute hydrofluoric acid solution was allowed to stand and then was decanted.
12. The sample was washed four to five times with distilled water to assure complete removal of the hydrofluoric acid.

Preparation of floatation solution. One hundred fifty grams each of potassium iodide and cadmium iodide was added to 100 grams of warm distilled water. The resulting solution, which is in a 3:1 ratio (three parts Ki-CdI to one part water), had a specific gravity of 2.2. This specific gravity allowed most of the inorganic material to sink, including silica (SiO_2) which has a specific gravity of 2.6, while the lighter organic spore material, with a specific gravity of 1:1 to 1.2, remained in the solution.

Floatation technique. The cadmium iodide and potassium iodide floatation technique was necessary for

this particular study because the ratio of inorganic material to organic material was quite large. In such a situation removal of all the inorganic material would have been virtually impossible because even after treatment of the original seventy-five grams with hydrochloric acid and hydrofluoric acid there was approximately one-half of the original sample remaining.

1. After the samples had been treated with hydrochloric acid and hydrofluoric acid and washed well, half of the sample was centrifuged to remove excess water and the other half was stored in 20 ml storage bottles.
2. The centrifugation was carried out using 50 ml tubes.
3. Five to ten ml of the cadmium iodide and potassium iodide solution was added to the sample in the centrifuge tube.
4. The contents were stirred well to make sure the spores were free and allowed to float.
5. The mixture was then centrifuged. The speed of centrifugation was slow at first to prevent the spores from being pulled down with the larger particles. The speed was gradually increased until separation of the

spore material from the inorganic material was complete.

6. The float was then decanted into a clean 250 ml beaker.
7. At this point a temporary slide was made to determine the spore content. If spores were present the process was continued.
8. The float was diluted with 200 ml of distilled water. This reduced the specific gravity and allowed the spore material to sink.
9. The dilute float solution was transferred to clean 50 ml centrifuge tubes and centrifuged at high speed.
10. The dilute potassium iodide and cadmium iodide solution was decanted. The spore material was concentrated at the bottom of the centrifuge tube.
11. The concentrated spore material was washed with distilled water to remove any potassium iodide and cadmium iodide.
12. The aqueous spore concentrate was decanted into 10 ml storage bottles and labeled.

Slide preparation

1. The slides and cover slips were cleaned with ethyl alcohol to remove any grease and

- dust, and dried with cheesecloth.
2. One drop of Clearcol and one drop of aqueous spore solution were mixed thoroughly on a cover slip and then allowed to dry.
 3. One drop of Diaphane was used to adhere the cover slip to the slide.
 4. The slides were labeled and the Diaphane allowed to dry three to four days on a warming plate kept at 37° centigrade.
 5. The slides were stored in a microscope slide box and were kept at room temperature.
 6. No staining was used in this procedure.
 7. Ten to fifteen slides were made from each sample collected.
 8. The final number on the slide label indicates the slide number. The slide number is preceded by the bench, locality, and formation designations respectively. For example, Ha-3-D-2 is slide number "2" of bench "D" at the Hannibal collecting locality number "3."
 9. The slides containing the figured spores described herein are deposited in the Paleobotanical Collections, Department of Botany, University of Missouri, Columbia,

Missouri.

Micrography and Photomicrography

A Labolux microscope was used in the identification of the specimens. The graduated scales on the mechanical stage of the microscope were used to record the position of the specimens. The positions were indicated by an "east-west" coordinate followed by a "north-south" coordinate. The coordinates of each specimen was recorded in a standard laboratory notebook and was accompanied by a sketch of the specimen.

The photomicrography was done at the Biology Department, Sam Houston State College, Huntsville, Texas. Negatives were made on Kodak Plus-X panchromatic film. The prints were made on Kodak polycontrast photographic paper.

CHAPTER IV
SYSTEMATIC STUDY OF THE MIOSPORES,
ACRITARCHS AND TASMANITES

Miospores

Spore Morphography and Classification. Vascular plant spores are produced from reproductive tissue in a structure called a sporangium which is produced by the diploid sporophyte plant. The reproductive tissue initially produces a diploid spore mother cell. This cell undergoes meiosis to produce four haploid spores. Functionally, a spore is the initial phase of the gametophyte generation in the plant life cycle. Upon maturation the spore consists of a single haploid cell; the protoplasmic content of which is enclosed by a cell wall (sporoderm). The protoplasm is lost during fossilization; however, since the wall is composed of resistant organic substances (cellulose and cutin) it is commonly preserved in ancient sediments.

During the development of the four spores from the spore mother cell, a characteristic mark develops on the wall of each spore due to the close contact with the other three spores. If the four spores are in a tetrahedral arrangement each spore will have radial symmetry and will have three marks 120° apart which converge to a

common point (proximal pole) marking the center of the tetrad. This portion of the spore is called the "proximal" side, while that portion furthest from the center is called the "distal" side. The three marks are referred to as the "trilete mark" or "laesurae." Some spores have a bilateral symmetry and one contact mark (monolete). Winslow (1962, p. 9) made the following comment regarding spore symmetry:

If spore wall formation takes place following the two free nuclear divisions of the spore mother cell nucleus, the spores will be arranged tetrahedrally and each will possess fundamentally a radial symmetry. On the other hand, if the spore walls form after each of the two nuclear divisions, the spores will be arranged in either a tetragonal or a sectorial pattern, and each spore will show bilateral symmetry.

During its development the spore assumes a characteristic shape and the spore wall frequently develops ornaments of various shapes and forms. These ornaments and the spore shapes are important in the classification of spores. For example, those with similar ornamentation are frequently grouped as one taxon. Although similar features usually show genetic relationships (one plant species produces one spore type), it has been shown (Schopf, 1964) that distantly related plants can produce morphographically similar spores. In this respect, Bhararwaj comments (1967, p. 343), "It is scientifically wrong to presume affinities between one morphographic

feature and another without concrete evidence from in situ spores." Therefore, because spores are dispersed from the mother plant, genetic relationships between plant and spore or between spore and spore cannot be proved in the fossil record unless the spores are found within a sporangium of known affinity (in situ).

Consequently, the system of classification used in spore taxonomy and based upon morphographic characters is artificial. Spore taxa are for this reason treated under the International Code of Botanical Nomenclature as "form" genera or "form" species. According to the code (Stafleu, 1967, p. 20), "a form genus is a genus of fossil plants of which only relatively small but comparable parts are known (ie., spores, pollen grains, fruits, leaf impressions)." A form genus, as opposed to an organ genus, is a genus unassignable to a family and is therefore by definition artificial. The higher categories (above the generic level) of spore taxonomy proposed by Potonié are also artificial categories (ie., infraturma, subturma, turma, and anteturma).

"Morphography is our only universal means of defining a genus for spora dispersa." (Bhararwaj, 1967, p. 341) Each genus is characterized by a "type" species ("genotype") which best exemplifies the genus. Stafleu, speaking as a taxonomist and as a non-palynologist, commented that

although the palynological species is a "morphospecies, typological rather than biological, non-dimensional rather than finite" the concept is not far removed from that used by taxonomists dealing with herbarium specimens which are, in a sense, "man-made fossils." In this respect he made the following statement (1967, p. 17), "most present day work in taxonomic neobotany has the 'morphospecies' of necessity as its basic concept."

Bhararwaj (1957, p. 341) points out the advantage of using the "genotype" concept in spore taxonomy.

If done faithfully, such a spore genus should be a phylogenetically homogeneous taxon representing one evolutionary tendency, corresponding in all probability to a part or whole of an organ genus of the palaeobotanical nomenclature.

In regard to significant criteria used in spore classification, Bhararwaj (1967) suggests that spore genera should be separated from each other on the basis of qualitative morphographic character differences while spore species should be separated on the basis of quantitative morphographic differences. The qualitative morphographic features noted by Bhararwaj are the shape, nature of ornamentation, nature of tetrad mark, presence or absence of saccus, attachment of saccus, orientation and nature of ornamentation on central body, shape of sculptural elements, and organization in three dimensions (appearance of spore prior to fossilization). Some of

the important quantitatively variable morphographical features noted by Bhararwaj are overall size, size of sculptural elements, number of sculptural elements in a unit area, and size of other measurable features.

The system of spore classification initiated by Potonié and Kremp (1954, 1955, and 1956) is a morphographic system based upon the factors outlined above, and centered around the type species concept. Potonié and Kremp's system was used in this study and although the system is artificial under the International Code of Botanical Nomenclature, recent work such as that of Balbach exemplifies the previous statement made by Bhararwaj regarding the phylogenetic significance of the genotype. Balbach (1967), in her study of spores in situ (Lycospora in lycopod sporangia), found that some morphographic characters used in spore classification were constant for spores within a single sporangium (or sporangia belonging to a single organ species). She found that size, shape, and ornamentation were constant. In regard to spore size, the taxonomic value of which has been questioned by some palynologists, Balbach found that the average standard deviation for all specimens equals only 5.5 to 7.0 per cent of the mean diameter and the range 25 to 30 per cent of the mean diameter. She also found that there were no growth stages of the spores within a sporangium (ie., no

classes of mature or immature spores). However, she did report the presence of "abortive" spores in the same sporangium with "normal" spores. These abortive spores were different from the normal spores in size (slightly smaller) and ornamentation (coarser). As spora dispersae these abortive spores would undoubtedly be classified as a separate species, which again points out the artificial nature of spora dispersae classification. Therefore, spore classification has limitations both in regard to the unknown sources of the spores and the unknown relationships which the spores (and other entities) bear to one another. However, with these limitations in mind, the author is of the opinion that Potonié and Kremp's morphographic system is the most logical construct presently available. Consequently, the classification system erected by Potonié and Kremp is followed in this study.

Anteturma SPORITES H. Potonié 1893

Turma TRILETES (Reinsch) Potonié and Kremp 1954

Infraturma LAEVIGATI (Benn. & Kid.) Pot. & Kr. 1954

Genus LEIOTRILETES (Naumova) Pot. & Kr. 1954

Type species: Leiotriletes sphaerotriangulus (Loose)
Potonié and Kremp, 1954. (Reference Potonié and Kremp,
1955, p. 41, pl. 11, figs. 107-109)

Description: Miospores radial, trilete; amb triangular or subtriangular. Surface laevigate, sometimes infra-punctate or infragranulate. Length of laesurae usually more than one half spore radius. Proximal apical pyramid often present.

Remarks: The triangular amb of Leiotriletes differentiates it from laevigate species of Punctatisporites. Many of these triangular, laevigate spores are non-diagnostic and are not restricted to a particular time interval. Such spores do not seem to very important in correlation.

Stratigraphic range: Lower Devonian (Richardson et coll., 1964) to Permian (Hoff. et al., 1955a).

Affinity: Miospores belonging to the genus Leiotriletes were reported by W. & R. Remy (1957, p. 58) to be in the following fern fructifications: Oligocarpia gutbieri Goppert, Oligocarpia cliveri H. Potonie, Renaultia sp., Discopteris schumanni Stur. Playford (1962, p. 674) commented that morphologically simple spores such as Leiotriletes (as well as Calamospora and Punctatisporites) are known from numerous plant groups such as Bryophyta, Psilophytales, Equisetales, and Filicales.

Leiotriletes inermis (Waltz) Ishchenko

Plate I, fig. 1

1938 Azonotriletes inermis Waltz in Luber and Waltz, p. 11, pl. 1, fig. 3, pl. 5, fig. 48, and pl. A,

fig. 2.

1952 Leiotriletes inermis (Waltz) Ishchenko, p. 9,
pl. 1, figs. 2, 3.

1955 Asterocalamotriletes inermis (Waltz) Lubert,
p. 40, pl. 1, figs. 2, 3.

1955 Leiotriletes inermis (Waltz) Potonié and Kremp,
p. 37.

1961 Leiotriletes inermis (Waltz) Potonié and Kremp,
in Hughes and Playford, p. 30, pl. 1, fig. 1.

1962 Leiotriletes inermis (Waltz) Potonié and Kremp,
in Playford, p. 574, pl. 78, figs. 3, 4.

Description: Miospores radial, trilete; amb subtriangular with convex sides and rounded corners. Laesurae straight, two thirds to four fifths spore radius, exine laevigate, 1 to 2 microns thick; margin smooth.

Dimensions: 32 to 50 microns.

Abundance: Twenty-five specimens.

Occurrence: Samples Nu-1-B, D; Nu-2-A, E, F; Ha-1-D; Ha-3-B, C, D; and Ha-5-A, B, C.

Remarks: This species has been previously recorded from the Lower Mississippian of Spitsbergen (Playford, 1962), and Upper Devonian of Missouri (Gupta, 1965).

Leiotriletes ornatus Ishchenko

Plate I, figs. 2, 3

1956 Leiotriletes ornatus Ishchenko, p. 22, pl. 2,

figs. 18-21.

1960 Spore type 1 of Love, p. 122, pl. 2, fig. 9 and text-fig. 12.

1962 Leiotriletes ornatus Ishchenko in Playford, p. 575, pl. 78, figs. 7, 8.

1964 Leiotriletes ornatus Ishchenko in Sullivan, p. 1251, pl. 1, fig. 1.

Description: Miospores radial, trilete; amb subtriangular with convex sides. Laesurae straight and extending almost to spore margin. Lips prominent, dark; individually two to four microns in width. Exine laevigate, about 2 microns thick.

Dimensions: 24 to 40 microns.

Abundance: Twenty-five specimens.

Occurrence: Samples Nu-1-D; Nu-2-A, E; Cu-3-B; Ha-3-B, C, D; and Ha-5-B, C.

Remarks: Sullivan reported this species from the Lower Limestone Shale (Tournaisian) of England. The specimens in this study are slightly smaller than those reported by Sullivan (1964) and Playford (1963). Scott and Doherty (1967) in their study of the Nation River Formation (Upper Devonian) of East Central Alaska recorded Leiotriletes sp., p. 48, fig. 3-h, which shows similarity to Leiotriletes ornatus in having thick lips. Scott and Doherty's species was not described.

Genus PUNCTATISPORITES (Ibrahim) Potonié and Kremp

Type species: Punctatisporites punctatus Ibrahim, 1933.
(Reference Potonié and Kremp, 1955, p. 44, pl. 11, figs. 122, 123)

Description: Miospores radial, trilete; amb circular to subcircular. Laesurae length more than one half spore radius. Exine punctate, infragranulate or laevigate.

Remarks: Species of the genus Calamospora have distinct contact areas which are usually darker than the rest of the spore. The laesurae are also shorter in Calamospora than in Punctatisporites, usually one half or less of the spore radius.

Stratigraphic range: Lower Devonian (McGregor and Owens, 1966) to Permian (Hoffmeister et al., 1955a).

Affinity: Potonié (1962) reported that the genus Punctatisporites has been recorded from fructifications of Psilopsida (pp. 37, 40) and from eight different species of Filices.

Punctatisporites debilis Hacquebard

Plate I, figs. 4, 5

1957 Punctatisporites debilis Hacquebard, p. 309
pl. 1, figs. 5, 6.

1963b Punctatisporites debilis Hacquebard in
Playford, p. 7, pl. 1, fig. 6.

1967 Punctatisporites debilis Hacquebard in

Butterworth, p. 2, pl. 1, figs. 5, 6.

Description: Miospores radial, trilete; amb circular to subcircular. Laesurae one-half to two-thirds spore radius, trilete area sometimes split open. Exine about one micron, laevigate to finely infragranulate; compression folds common.

Dimensions: 28 to 59 microns.

Abundance: Fifty specimens.

Occurrence: Samples Nu-1-D; Nu-2-E; Ha-3-B, C, D; Ha-5-A, B; and Cu-3-E.

Remarks: Punctatisporites irrasus Hacquebard 1957, p. 308, pl. 1, figs. 5, 6 is similar but is larger (67 to 83 microns) and has a slightly thicker wall (2 microns).

Punctatisporites debilis was one of the more abundant species in the present study.

Punctatisporites glaber (Naumova) Playford

Plate I, fig. 6

1938 Azonotriletes glaber (Naumova) Waltz in Luber and Waltz, p. 8, pl. 1, fig. 2, pl. A, fig. 3.

1952 Leiotriletes glaber (Waltz) Ischenko, p. 13, pl. 2, figs. 15, 16.

1955 Calamospora glaber (Naumova) Potonie and Kremp, p. 47.

1955 Punctatisporites nitidus Hoffmeister, Staplin,

- and Malloy, pp. 393, 394, pl. 36, fig. 4.
- 1955 Punctatisporites? callosus Hoffmeister, Staplin, and Malloy, p. 393, pl. 39, fig. 7.
- 1956 Leiotriletes glaber Naumova in Ishchenko, pp. 18, 19, pl. 1, fig. 7, 8.
- 1957 Punctatisporites planus Hacquebard, p. 308, pl. 1, fig. 12.
- 1958 Punctatisporites cf. nitidus Hoffmeister, Staplin, and Malloy in Butterworth and Williams, p. 361, pl. 1, figs. 7, 8.
- 1960 Punctatisporites curviradiatus Staplin, p. 7, pl. 1, figs. 17, 20.
- 1962 Punctatisporites glaber (Naumova) Playford, p. 576, pl. 78, figs. 15, 16.

Description: Miospores radial, trilete; amb circular to subcircular. Laesurae simple, two-thirds to three-fourths spore radius. Exine laevigate, 1 to 2 microns thick.

Dimensions: 40 to 50 microns.

Abundance: Twenty specimens.

Occurrence: Samples Nu-2-A, C, E; Ha-1-E; Ha-3-B, C, D; and Ha-5-C.

Remarks: Since this species has a wide vertical distribution which ranges from the Devonian (Ishchenko, 1958) to the Upper Carboniferous (Playford, 1962), it has limited stratigraphic value.

In his discussion of Punctatisporites glaber, Playford (1962, p. 577) points out that this species probably includes spores from several different plants.

Punctatisporites solidus Hacquebard

Plate I, figs. 7, 8

1957 Punctatisporites solidus Hacquebard, p. 308, pl. 1, fig. 13.

1963 Punctatisporites solidus Hacquebard in Playford, pp. 7, 8, pl. 1, fig. 12.

Description: Miospores radial, trilete; amb roundly subtriangular. Laesurae distinct, sometimes unequal in length, two-thirds to three-fourths radius; lips irregularly developed. Exine laevigate to finely infra-punctate; 2 to 4 microns thick, appearing as a limbus-like margin.

Dimensions: 40 to 60 microns.

Abundance: Six specimens.

Occurrence: Samples Nu-2-E; and Ha-3-C, D.

Remarks: A similar species, Punctatisporites sp. cf.

Punctatisporites solidus, was recorded by Balme and Hassell (1962, p. 5, pl. 1, fig. 4) from the Upper Devonian of Australia. Punctatisporites limbatus Hacquebard (1957, p. 308, pl. 1, figs. 9-11) is large (111 to 206 microns) and the marginal limbus has a width of 4 to 8 microns.

Genus RETUSOTRILETES (Naumova) Streel

Type species: Retusotriletes simplex Naumova, 1953, p. 29, pl. 2, fig. 9. (Streel, 1964, pp. 238, 239)

Description: Miospores radial, trilete; amb circular to subtriangular. Contact areas delimited by curvaturae. Exine laevigate.

Remarks: Potonié (1958, pp. 13, 14) designated the type species for this genus. The type is laevigate but subsequent authors have included ornamented forms within this genus, using the curvaturae and contact areas as the diagnostic characteristics of the genus. Streel (1964) suggests that, in order to be consistent with the type species, only laevigate species should be included within the genus. For spores having ornamentation (ie., grana, coni, and/or spines) as well as curvaturae, Streel has instituted a new genus, Apiculiretusispora Streel. This distinction is more desirable under the morphographic system of nomenclature. Playford (1963, p. 9) suggested that the separation should be at the suprageneric level "to incorporate such azonate miospores, in which the most salient common feature is curvaturate development." However, Streel's emendation leaves Retusotriletes status quo within the Infraturma Laevigati, as it was originally designated by Potonié (1958). Streel includes Apiculiretusispora within the Infraturma Apiculati on the basis

of its exine sculpture.

Stratigraphic range: Miospores belonging to the genus Retusotriletes occur throughout the Devonian (Chaloner, p. 85). They are present, but not as abundant, in Lower Mississippian strata (Playford, 1963a, p. 10).

Affinity: Uncertain. However, McGregor notes (1964a, p. 11) that the spores of Protopteridium minutum (Halle, 1936) resemble some specimens of Retusotriletes semi-zonalis (McGregor, 1964). The spores of Protopteridium minutum (Halle, 1936) figured and described by Potonie (1962, p. 89, pl. 8, fig. 204) shows curvaturae and appeared to be conformable with the genus Retusotriletes.

Retusotriletes incohatus Sullivan

Plate I, figs. 9, 10

1964 Retusotriletes incohatus Sullivan, pp. 1251, 1252, pl. 1, figs. 5, 6, 7.

1966 Retusotriletes incohatus Sullivan in Streeel, p. 82, pl. 2, figs. 22, 23

1967 Retusotriletes incohatus Sullivan in Butterworth, p. 3, pl. 1, figs. 12, 13.

Description: Miospores radial, trilete; amb circular to subcircular. Contact areas not always clearly defined; therefore, curvaturae is complete to imperfectae. Exine laevigate to infragranulate, about 2 microns thick.

Dimensions: 35 to 55 microns.

Abundance: Fifty specimens

Occurrence: Samples Nu-1-E; Nu-2-C, E; Ha-1-E; Ha-3-B, C, D; and Ha-5-A, C, D.

Remarks: Sullivan initially described this species from the lower limestone shales in the Forest of Dean in which he found an admixture of Devonian and Carboniferous spores. Sullivan reported that Retusotriletes incohatus comprised over one-half (58 to 65 per cent) the total spore population. It has also been recorded from the Lower Carboniferous rocks of northwest England (Butterworth, 1967) and from the Tn2a deposits (Basal Carboniferous) of the Dinant Basin of Belgium (Streel, 1966).

Retusotriletes sp. cf. R. semizonalis McGregor

Plate I, figs. 11, 12

1964 Retusotriletes semizonalis McGregor, p. 10,
pl. 2, figs. 1 to 5, and 7, 8.

1967 Retusotriletes semizonalis McGregor in Streel,
p. 23, pl. 1, figs. 12, 13.

Description: Miospores radial, trilete; amb subcircular. Laesurae accompanied by slightly elevated narrow lips; curvaturae well developed. Exine about 1 micron thick, very finely granulate; grana less than 0.5 microns in height and width.

Dimensions: 30 to 45 microns.

Abundance: Ten specimens.

Occurrence: Samples Ha-3-C, D.

Remarks: McGregor's specimens are ornamented with very small coni which he says can be seen under oil immersion. Streel's specimens are infrapunctate. The specimens in this study have a thinner wall than Retusotriletes incohatus Sullivan, 1964.

Infraturma APICULATI (Benn. & Kid.) Potonié' and Kremp

Subinfraturma GRANULATI Dybova and Jachowicz

Genus GRANULATISPORITES (Ibrahim) Potonié' and Kremp

Type species: Granulatisporites granulatus Ibrahim, 1933.

(Reference: Potonié' and Kremp, 1955, p. 58, pl. 12, figs. 157 to 160).

Description: Miospores radial, trilete; amb. triangular.

Exine sculptured with grana.

Remarks: The triangular shape of Granulatisporites distinguishes it from Cyclogranisporites.

Stratigraphic range: Lower Devonian (Allen, 1965, p. 693) to Permian (Hoffmeister, et al., 1955a).

Affinity: Potonié' (1962) reported that spores of the genus Granulatisporites have been found with the following fossil

Filices: Todites recurvatus Harris 1931, Lygodium skottsbergii Halle 1940, and some fructifications of Crossotheca.

Granulatisporites crenulatus Playford

Plate I, fig. 13; Plate II, fig. 14

1963 Granulatisporites crenulatus Playford, p. 11
pl. 2, figs. 8 to 10.

Description: Miospores radial, trilete; amb subtriangular with rounded apices and convex sides. Laesurae simple, straight, about four-fifths spore radius. Exine sculptured with closely spaced grana (0.5 to 1 micron in basal diameter and 0.5 micron, or less, in height) which are separated by a negative microreticulum; exine thickness 2 to 3 microns.

Dimensions: 24 to 45 microns.

Abundance: Forty-five specimens.

Occurrence: Present in most all samples.

Remarks: Some of these specimens are smaller than those reported by Playford (36 to 45 microns). Granulatisporites crenulatus seems to have been a wide ranging species since it occurred in most samples.

Genus CYCLOGRANISPORITES Potonié and Kremp

Type species: Cyclogranisporites leopoldi (Kremp, 1952) Potonié and Kremp, 1954. (Reference: Potonié and Kremp, 1955, p. 62, pl. 13, figs. 174 to 178)

Description: Miospores radial, trilete; amb circular. Exine sculpture consists of grana.

Remarks: The only difference between Cyclogranisporites and Granulatisporites is the shape. The sculpture consists of grana in both genera.

Stratigraphic range: Upper Devonian to Upper Pennsylvanian (Hoffmeister, et al., 1955a)

Affinity: According to Potonié (1962) the affinity of Cyclogranisporites is with Psilopsida, Noeggerathiopsida, and Filices. He lists fifteen known fructifications which contain spores of the genus Cyclogranisporites. Eleven of these are Filices.

Cyclogranisporites commodus Playford

Plate II, fig. 15

1963 Cyclogranisporites commodus Playford, p. 12, pl. 2, figs. 3 to 5.

Description: Miospores radial, trilete; amb circular. Laesurae simple, about two-thirds spore radius. Exine thin, approximately 1 micron; folding common. Sculpture consists of closely spaced grana.

Dimensions: 29 to 46 microns.

Abundance: Eighteen specimens.

Occurrence: Samples Nu-2-A, E, F; Ha-3-A, B; and Ha-5-B.

Remarks: This species has been previously recorded from the Lower Mississippian of Nova Scotia (Playford, 1963) and from the Lower Carboniferous of England (Butterworth and Spinner, 1967).

Subinfraturma VERRUCATI Dybova and Jachowicz

Genus VERRUCOSISPORITES (Ibrahim) Potonié and Kremp

Type species: Verrucosisporites verrucosus Ibrahim, 1933.

(Reference: Potonié and Kremp, 1955, pl. 13, fig. 195)

Description: Miospores radial, trilete; amb circular to subcircular. Exine ornamented with verrucae.

Remarks: The basal outline of the verrucae are usually reflected in the form of a negative reticulum or microreticulum.

Stratigraphic range: Middle Devonian (Hacquebard, 1957, p. 305) to Upper Permian (Hoffmeister, et al., 1955a)

Affinity: According to Potonie (1962) the following fossil fructifications contain spores of the genus

Verrucosisporites: Sporangiostrombus rugosus Bode 1929, three species of the genus Zygopteris Corda 1845, and Waldenburgia corynepteroides Gothan 1950.

Verrucosisporites nitidus Playford

Plate II, fig. 16

1953 Lophotriletes grumosus Naumova, p. 57, pl. 7, fig. 14, 15 (Non Verrucosisporites grumosus Ibrahim, 1933).

1956 Lophotriletes aff. grumosus Naumova in Ishchenko, p. 40, pl. 7, fig. 74.

1963 Verrucosisporites nitidus Playford, pp. 13, 14,

pl. 3, figs. 3 to 6 (Nom. nov. for Lophotriletes grumosus Naumova).

Description: Miospores radial, trilete; amb circular to roundly subtriangular. Projections consist of rounded verrucae which are separated by a negative reticulum. Verrucae are 1 to 4 microns in height and 3 to 6 microns in basal diameter. Laesurae simple, straight; length of laesurae two-thirds to four-fifths spore radius.

Dimensions: 32 to 40 microns.

Abundance: Nine specimens.

Occurrence: Samples Nu-2-C, E; and Ha-5-A, B, D.

Remarks: Lophotriletes is characterized by a triangular or subtriangular shape and by conate sculpture. Therefore, Playford reclassified Lophotriletes grumosus Naumova, 1953, which does not possess the above attributes, and included it within the genus Verrucosisporites in accordance with Potonié and Kremp's system of classification. Normally this would have resulted in the species having the name Verrucosisporites grumosus, but this combination of genus and species names had been used and published by Ibrahim in 1933. Therefore, Playford proposed nitidus in lieu of grumosus.

Genus CONVERRUCOSISPORITES Potonié and Kremp

Type species: Converrucosisporites triquetrus (Ibrahim)

Potonié and Kremp, 1954. (Reference: Potonié and Kremp, 1955, p. 63, pl. 3, fig. 191)

Description: Miospores radial, trilete; amb triangular to subtriangular. Exine sculpture with verrucae.

Remarks: Converrucosisporites is never completely circular in outline and differs from Verrucosisporites in this respect.

Stratigraphic range: Upper Devonian (McGregor and Owens, 1966) to Permian (Shaffer, 1964).

Affinity: Converrucosisporites is possibly allied to the Filicales (Potonié and Kremp, 1955, p. 63).

Converrucosisporites parvinodosus Playford

Plate II, figs. 17, 18

1963 Converrucosisporites parvinodosus Playford,
p. 15, pl. 3, figs. 7 to 9.

Description: Miospores radial, trilete; amb subtriangular with convex sides. Exine sculpture consist of numerous, smooth, rounded verrucae which are separated by a negative microreticulum reflecting the bases of the verrucae which are subcircular to irregular in outline. Verrucae 0.5 to 1.5 microns in height and 0.5 to 4 microns in basal diameter. Exine thickness 2 to 3 microns.

Dimensions: 29 to 45 microns.

Abundance: Twenty-five specimens.

Occurrence: Samples Nu-1-D; Nu-2-A, B, E, F; Ha-1-E;

Ha-3-B, C, D; and Ha-5-B, C.

Remarks: This species is similar to Granulatisporites crenulatus Playford, 1963, p. 11, pl. 2, figs. 8 to 10. The only difference is in the size of the sculpturing elements.

Subinfraturma NODATI Dyboval and Jachowicz
Genus ANAPICULATISPORITES Potonié and Kremp

Type species: Anapiculatisporites isselburgensis Potonié and Kremp, 1954, p. 130.

Description: Miospores radial, trilete; amb circular to roundly subtriangular. Exine of proximal surface laevigate; distal surface sculptured with coni, apiculi, or spines.

Remarks: Schopfites Kosanke, 1950, also has a smooth proximal surface, but differs from Anapiculatisporites in the type of sculpturing elements on the distal surface.

Stratigraphic range: Middle Devonian (Chaloner, 1967) to Upper Pennsylvanian (Winslow, 1962).

Affinity: According to Potonié and Kremp (1955, p. 81) Anapiculatisporites may have an affinity with the Filices.

Anapiculatisporites ampullaceus (Hacquebard) Playford

Plate II, fig. 19

1957 Raistrickia ampullacea Hacquebard, p. 310,
pl. 1, figs. 21, 22.

1957 Raistrickia sp. A Hacquebard, p. 311, pl. 2
fig. 3.

1963 Anapiculatisporites ampullaceus (Hacquebard,
1957) Playford, p. 16, pl. 3, figs. 6, 7

Description: Miospores radial, trilete; amb subtriangular to subcircular. Exine of proximal surface laevigate to finely granulate; distal surface sculptured with broad-based spines. When the upper portions of these spines are broken they have the appearance of baculae. The projections are discrete, with subcircular bases, 2 to 4 microns in diameter and 1 to 10 microns apart; length varies up to 5 microns. Laesurae simple, two-thirds to four-fifths spore radius. Exine thickness about 2 microns.

Dimensions: 35 to 45 microns.

Abundance: Ten specimens.

Occurrence: Samples Nu-1-F; Nu-2-A; Ha-3-B; and Ha-5-A.

Remarks: Playford reassigned these spores to the genus Anapiculatisporites after determining that the projections were spines rather than baculae.

Genus PUSTULATISPORITES (Pot. & Kr.) Imgrund

Type species: Pustulatisporites pustulatus Potonié and Kremp, 1954. (Reference: Potonié and Kremp, 1955, pp. 82, 83)

Description: Miospores radial, trilete; amb subtriangular to subcircular. Exine sculptured with both verrucae and blunt coni which are not closely spaced.

Remarks: The more widely spaced sculpturing elements of Pustulatisporites distinguishes it from the more closely spaced verrucae of Verrucosisporites and Converrucosporites.

Stratigraphic range: Basal Mississippian (Playford, 1963) to Lower Permian (Imgrund, 1960).

Affinity: Unknown

Pustulatisporites gibberosus (Hacquebard) Playford

Plate II, figs. 20, 21

1957 Raistricka? gibberosa Hacquebard, p. 310,
pl. 2, fig. 1.

1963 Pustulatisporites gibberosus (Hacquebard)
Playford, pp. 18, 19, pl. 3, figs. 18 to 20.

Description: Miospores radial, trilete; amb subtriangular to subcircular. Exine, with the exception of the contact areas, ornamented with smooth verrucae and blunt coni. Basal outline of the projections, circular to slightly elongated; basal diameter of 1 to 5 microns; height 1 to 6 microns. Laesurae simple, two-thirds to four-fifths spore radius. Exine thickness 2 to 3 microns.

Dimensions: 37 to 58 microns.

Abundance: Twenty-two specimens.

Occurrence: Samples Nu-1-D; Ha-3-B, C, D; Ha-5-A, B, C; and Cu-3-B.

Remarks: Playford notes that Pustulatisporites gibberosus is very similar to Azonotriletes rarituberculatus Sadkova, (in Luber and Waltz, 1941, p. 56, pl. 11, fig. 191), which was recorded from the Lower Carboniferous of Russia. However, the latter is larger and has a circular amb (Playford, 1963b, p. 19).

Genus APICULIRETUSISPORA Streel

Type species: Apiculiretusispora brandtii Streel, 1964, pp. 240 to 242, pl. 1, figs. 6, 10, text-fig. 2.

Description: Miospores radial, trilete; amb circular to subtriangular. Curvaturae at the terminal end of the trilete rays. Contact areas (proximal) smooth or ornamentation reduced. The remainder of the exine sculptured with grani, coni, and/or spinae.

Remarks: This genus differs from Cyclogranisporites Potonié and Kremp, and Planisporites (Knox) Potonié and Kremp, in possessing curvaturae and a smooth or reduced sculpture in the contact areas. Retusotriletes (Naumova, 1953) Streel, 1964 (pp. 238, 239) has a smooth exine. Naumova's original description of Retusotriletes was based mainly on the presence of contact areas and curvaturae at the extremities of the trilete mark, and

included smooth forms as well as forms possessing exinal projections.

Stratigraphic range: Middle Devonian (Chaloner, 1967) to Lower Carboniferous (Streel, 1966).

Affinity: Unknown.

Apiculiretusispora multisetata (Luber) Butterworth

Plate II, figs. 22, 23

1938 Azonotriletes multisetus Luber in Luber and Waltz, p. 32, pl. 5, fig. 61.

1955 Filicitriletes multisetus (Luber) Luber, pp. 55, 56, pl. 3, fig. 52.

1955 Acanthotriletes multisetosus (Luber) Potonié and Kremp, p. 84.

1967 Apiculiretusispora multisetata (Luber) Butterworth in Butterworth and Spinner, pp. 5, 6, pl. 2, figs. 13, 18.

Description: Miospores radial, trilete; amb circular.

Laesurae simple, two-thirds to three-fourths spore radius, with curvaturae usually joining the laesurae extremities.

Sculpture consisting of spines or baculae less than 1 micron wide and up to 2 microns in length. Sculpturing elements less prominent (sometimes absent) in the contact areas. Exine thin, approximately 1 micron.

Dimensions: 36 to 45 microns.

Abundance: Twelve specimens.

Occurrence: Samples Ha-3-C, D; and Ha-5-B.

Remarks: Butterworth's transferral of this species to Apiculiretusispora Streel, was based on the presence of curvaturae (although not always clearly defined) and the reduced ornamentation on the contact areas. Acanthotriletes raptus Allen, 1965, p. 678, pl. 94, figs. 19, 20, may be conspecific. Although Allen reports larger spines (1.5 microns in length and 0.5 to 2.5 microns wide) the contact areas are laevigate.

Genus GRANDISPORA Hoffmeister, Staplin, and Malloy

Type species: Grandispora spinosa Hoffmeister, Staplin, and Malloy, 1955, p. 388, pl. 39, figs. 10, 14.

Description: Miospores radial, trilete; exine differentiated into an exoexine enclosing an intexinal central body (mesosporoid). Exoexine ornamented on distal and equatorial surfaces with prominent scattered spines or cones. Amb of both mesosporoid and exoexine subcircular.

Remarks: The diagnostic feature of this genus is spinoseconate sculpture and differs from Endosporites in this respect.

Stratigraphic range: Basal Mississippian (Hacquebard, 1957) to Upper Mississippian (Hoffmeister, Staplin, and Malloy, 1955).

Affinity: Unknown.

Grandispora echinata Hacquebard

Plate II, fig. 24

1957 Grandispora echinata Hacquebard, p. 317, pl. 3,
fig. 17.

Description: Miospores radial, trilete; amb subcircular to subtriangular. Laesurae indistinct and accompanied by folds which extend almost to spore equator. Distal and equatorial surface of exoexine ornamented with small cones which are 1.5 to 2 microns high, 1 to 1.5 microns in basal diameter, and spaced 3 to 5 microns apart; thickness of exoexine 1 to 2 microns; mesosporoid not always clearly defined.

Dimensions: 55 to 70 microns.

Abundance: Four specimens.

Occurrence: Samples Nu-2-B; and Ha-5-A, C.

Remarks: This species was first recorded from Basal Mississippian strata of Nova Scotia (Horton Group) by Hacquebard (1957), and subsequently by Playford (1964). Recently (1966) Sullivan and Marshall reported it from Visean (Mississippian) rocks of Scotland. In Grandispora spinosa Hoffmeister, Staplin, and Malloy (1955b, p. 388, pl. 39, figs. 10, 14) the spines are longer (up to 8 microns in length). Urban's Hymenozonotriletes sp. 2 (1960, pp. 12, 13, pl. 1, fig. 7) probably belongs to Grandispora echinata. He reports (p. 13), "perispore

ornamented with coarse grana about one micron high and 1 to 2 microns wide." The diameter of his specimens was 52 to 60 microns.

Infraturma MURORNATI Potonié and Kremp

Genus CONVOLUTISPORA Hoffmeister, Staplin, and Malloy

Type species: Convolutispora florida Hoffmeister, Staplin, and Malloy, 1955, p. 384, pl. 38, figs. 5, 6.

Description: Miospores radial, trilete; amb circular to subcircular. Ornamentation consists of closely packed anastomosing ridges (muri). Laesurae usually simple, often obscured.

Remarks: The depressed areas between the anastomosing ridges vary from small lacunae to irregular radiating depressions.

Stratigraphic range: Lower Devonian (McGregor and Owens, 1966) to Lower Pennsylvania (Felix and Burbridge, 1967).

Affinity: Smith (1962) in his description of three fructifications from the Lower Carboniferous of Scotland reported that the genus Convolutispora was present in the sporangia of the pteridosperm genus Staphylotheca. "As spora dispersa type B spores would probably have been placed in the genus Convolutispora Hoffmeister, Staplin, and Malloy." (Smith, 1962, p. 235)

Convolutispora sp. cf. C. ampla Hoff., Stap., & Mall.

Plate II, fig. 25, Plate III, fig. 26

1955 Convolutispora ampla Hoffmesiter, Staplin, and Malloy, p. 384, pl. 38, fig. 12.

Description: Miospores radial, trilete; amb circular.

Sculpture consists of anastomosing muri, which are 1 to 2 microns in height and width. Shape of lumina irregular, varying from circular to subcircular (1 to 3 microns in diameter) to elongate and sinuous. Laesurae simple, two-thirds to three-fourths spore radius. Exine 2 to 3 microns thick.

Dimensions: 55 to 75 microns.

Abundance: Six specimens.

Occurrence: Samples Nu-4-A; and Ha-3-B, C.

Remarks: The above description agrees fairly closely with Hoffmeister, Staplin, and Malloy's species.

Convolutispora sp. cf. C. ampla was not abundant and four of the six specimens were found in one sample.

Genus EMPHANISPORITES McGregor

Type species: Emphanisporites rotatus McGregor, 1961, p. 3, pl. 1, figs. 1 to 4.

Synonym

Genus RADFORTHIA Winslow, 1962. Type species:

Radforthia radiata Winslow, 1962, p. 72, pl. 16,

figs. 15, 15a, pl. 22, fig. 17.

Description: Miospores radial, trilete; amb subtriangular to subcircular. Exine ornamented on proximal side with radial ridges which extend almost to equator.

Remarks: These miospores with radial ridges (ribs) on their proximal faces were discovered by McGregor in the Gaspé region of Canada. McGregor published his description of this genus which he called Emphanisporites in 1961, describing six spore forms within the complex. In 1962, Winslow published the results of her comprehensive spore study of the Upper Devonian and Lower Mississippian rocks of Ohio in which she described the genus Radforthia. This genus was also characterized by having proximal radial ridges; however, because McGregor's publication was prior to that of Winslow's the valid name for this genus is Emphanisporites.

The genus Radiaspora, Hoffmeister, Staplin, and Malloy, 1955a ex Balme, 1961 is also characterized by radial ribs; however, McGregor (1961, p. 3) states that the ribs are distal rather than proximal in the case of Radiaspora.

Stratigraphic range: Lower Devonian (Richardson, 1967) to Lower Mississippian (Winslow, 1962).

Affinity: Unknown.

Emphanisporites rotatus McGregor

Plate III, fig. 27

1961 Emphanisporites rotatus McGregor, p. 3, pl. 1,
figs. 1 to 4.

Description: Miospores radial, trilete; amb subtriangular. Radial ribs on proximal side; 4 to 6 ribs per sector (between laesurae). Exine otherwise laevigate, 2 microns thick.

Dimensions: 57 microns.

Abundance: One specimen

Occurrence: Sample Ha-1-D.

Remarks: This species and other species of the genus Emphanisporites occur throughout the Devonian. Emphanisporites is a Devonian genus and is rare in Lower Mississippian strata. It is for this reason that the one specimen is reported in this study. The extinction of this spore type plus other typically Devonian spore types will be discussed in a later chapter.

Subturma PERINOTRILETES Erdtman

Genus PEROTRILETES Erdtman ex Couper

Type species: Perotriletes granulatus Couper, pp. 31, 32, pl. 3, figs. 28, 29.

Synonym:

Genus DIAPHANOSPORA Balme and Hassell, 1962. Type

species: Diaphanospora riciniata Balme and Hassell, 1962, p. 20, pl. 4, figs. 1 to 4, text-fig. 5.

Description: Miospores radial, trilete; amb of spore body circular to triangular. Body enclosed by a thin, translucent, loosely fitting perine which is usually wrinkled or folded.

Remarks: In 1962 Balme and Hassell, in their report on the Upper Devonian spores of Australia, described a new genus which they called Diaphanospora. Their generic description of this spore type coincided with the description of the genus Perotriletes, which was a genus Couper (1951) recorded from the Upper Jurassic of New Zealand. Balme and Hassel recognized the morphographic similarity of their new genus to that of Perotriletes; however, they justified the new epithet on the basis of the following statement (p. 20). "No spores with perispores have ever been found in Permian or Triassic sediments in Australia, and for this reason it is considered that a distinct genus is necessary for the Upper Devonian species."

Such reasoning has no basis in the presently accepted method of miospore taxonomy. It may be that these two genera have diverse affinities, but until such diversity is shown in situ and until a natural classification of spore taxonomy is formulated, two names for the same spore

(in a morphographic sense) has no meaning and is in fact confusing. The author of the present study is in agreement with Playford who made the following statement (1963, p. 601) in regard to the Australian forms described by Balme and Hassell. "The apparent absence of such perinate forms in the Permian and Triassic of Australia is not considered sufficient justification for their assignment to a form genus other than Perotriletes." Furthermore, in his discussion of problems involved in classification and stratigraphic applications of plant microfossils, Schopf (1964, p. 51) pointed out that

Generic ranges usually span a considerable interval of geologic time. Range charts...tend to be generalized. At best, they represent a progress report on what is known at a given time about the occurrence and stratigraphic distribution of fossils.

Stratigraphic range: Lower Devonian (Richardson et coll., 1964) to Jurassic (Couper, 1953).

Affinity: Potonie (1962) did not report any affinity for Perotriletes. However, Playford (1962, p. 601) makes the following statement. "Spores of the Recent Selaginella sibirica group figured by Knox (1950, pl. 11, figs. 76 to 82) appear conformable with Perotriletes."

Perotriletes perinatus Hughes and Playford

Plate III, figs. 28, 29

1961 Perotriletes perinatus Hughes and Playford,
p. 33, pl. 2, figs. 7 to 10.

1963 Perotriletes perinatus Hughes and Playford in
Playford, p. 33, pl. 10, fig. 5.

1967 Perotriletes perinatus Hughes and Playford in
Butterworth and Spinner, p. 11, pl. 1, figs. 14,
17.

Description: Miospores radial, trilete; amb of spore
body (exine) subtriangular to circular, laevigate, about
2 microns thick. Perine thin, translucent, laevigate to
finely granulate, usually wrinkled. Extension beyond
body is usually irregular due to folding. Laesurae length
two-thirds to four-fifths body radius.

Dimensions: 35 to 65 microns.

Abundance. Ten specimens.

Occurrence: Samples Nu-2-A, E; Ha-3-B, C, D; and Ha-5-A,
B, C.

Remarks: Hughes and Playford (1961) broadly define this
species in regard to the amb. They include circular
spores (pl. 2, fig. 10), triangular spores with concave
sides (pl. 2, fig. 9), and subtriangular spores with
convex sides (pl. 2, figs. 7, 8). In many genera such
extreme differences in the amb are considered to be
justification for the institution of different species.
Urban (1960) described four species of a genus (Genus A,
pp. 21 to 24, pl. 2, figs. 8 to 16, pl. 3, figs. 1 to 3)
from the Woodford shale which, in the opinion of the author

probably belongs (at least in part) to Perotriletes.

Perotriletes spherotriangulatus sp. nov.

Plate III, figs. 30, 31

Description: Miospores radial, trilete; amb of spore body circular to subcircular. Spore body laevigate. Spore body has an equatorial "rim" 3 to 4 microns wide. Laesurae distinct, extending to "rim." Perine, when present, has a triangular amb extending about 10 to 15 microns beyond spore body opposite the laesurae and about 5 microns beyond spore body in the interradian area.

Holotype: Hannibal Formation, sample Ha-3-D, slide number 2, co-ordinates 67.3 X 103.1. Plate III, fig. 30. Deposited in the Paleobotanical Collections, Department of Botany, University of Missouri, Columbia, Missouri.

Dimensions: Spore body 40 to 60 microns.

Abundance: Six specimens.

Occurrence: Samples Ha-3-C, D; and Ha-5-A.

Remarks: Hymenozonotriletes speciosus Naumova, 1953, p. 65, pl. 9, fig. 1, appears to be similar. In her specimens the amb of the perisporium is triangular and the circular to rounded triangular body has a thickened margin. However, the perisporium is slightly apiculate and the trilete rays almost reach the amb. Urban's Genus A, sp. 4 (1960, p. 23, pl. 2, fig. 15) appears to be identical to Perotriletes spherotriangulatus sp. nov.

Hymenozonotriletes pseudoreticulatus Menendez and de Baldis 1967, from the Devonian of Paraguay is superficially similar to Perotriletes spherotriangulatus; however, the central body of their species is ornamented with "lobate ridges" and the "equatorial flange" has small projections (cones).

Turma ZONALES (Bennie & Kidston) R. Potonié'

Subturma ZONOTRILETES Waltz

Infraturma CINGULATI Potonié' and Klaus

Genus LOPHOZONOTRILETES (Naumova) Potonié'

Type species: Lophozonotriletes lebediansis Naumova, 1953, p. 119, pl. 17, fig. 42.

Description: Miospores radial, trilete; amb subcircular to subtriangular. Spore differentiated into a cingulum and a spore body, both of which may be ornamented with large coni, spines, or verrucae. Projections less prominent on proximal side (contact area).

Remarks: Hughes and Playford (1961) in their discussion (pp. 35, 36) of the Lower Carboniferous, Spitsbergen species Lophozonotriletes rarituberculatus and Lophozonotriletes dentatus, pointed out that neither of these fit comfortably within the confines of Lophozonotriletes as emended by Potonié' (1958, p. 28). In this respect they make the following statement (p. 35): "We believe,

however, that these two species are close to some of those described by Naumova (1953) when she instituted this genus." Until a more detailed study of the materials can be made, the author used the generic determination in the sense that Hughes and Playford use it.

Stratigraphic range: Middle Devonian (Richardson et coll., 1964) to Upper Mississippian (Richardson et coll., 1964).

Affinity: Unknown.

Lophozonotriletes dentatus Hughes and Playford

Plate III, figs. 32, 33

1961 Lophozonotriletes dentatus Hughes and Playford, pp. 36, 37, pl. 3, figs. 8 to 10.

1963a Lophozonotriletes dentatus Hughes and Playford in Playford, p. 639, pl. 91, fig. 5.

Description: Miospores radial, trilete; amb subtriangular. Laesurae simple and straight, extending almost to body margin. Projections (verruculae) irregularly distributed on distal side and on the margin of the cingulum which extends 5 to 10 microns beyond spore body margin. Exine otherwise laevigate.

Dimensions: Diameter, including projections, 34 to 52 microns.

Abundance: Ten specimens.

Occurrence: Samples Nu-1-D, F; Nu-2-B, F; Ha-3-D; Ha-5-C; and Cu-3-B.

Remarks: The lower size limit of Playford's specimens was 42 microns. McGregor and Owens (1967, p. 58, pl. 26, fig. 35) also recorded Lophozonotriletes dentatus from the Famennian deposits (Griper Bay Formations) of northern Canada. Lophozonotriletes sp. 1, (pl. 2, figs. 1, 3, 5) described by Urban (1960) from the Woodford shale (Upper Devonian) of Oklahoma appears to belong to Lophozonotriletes dentatus. Urban's specimens had a size range of 35 to 57 microns. The author intends to pursue the study of this group of entities at a later date.

Lophozonotriletes rarituberculatus (Luber) Kedo

Plate IV, figs. 34, 35

1941 Zonotriletes rarituberculatus Luber in Luber and Waltz, pp. 10, 30, pl. 1, fig. 5, and pl. 5, fig. 76.

1956 Euryzonotriletes rarituberculatus (Luber) Ishchenko var. triangulatus Ishchenko, p. 51, pl. 8, fig. 104.

1957 Lophozonotriletes rarituberculatus (Luber) Kedo, p. 1166.

1961 Lophozonotriletes triangulatus Hughes and Playford, pp. 35, 36, pl. 3, figs. 3 to 7.

1963 Lophozonotriletes rarituberculatus (Luber) Kedo in Playford, p. 638, pl. 91, figs. 8, 9, text-fig. 96.

1966 Lophozonotriletes rarituberculatus (Luber) Kedo
in Streel, p. 85, pl. 2, figs. 16, 17.

Description: Miospores radial, trilete; amb rounded triangular. Cingulum of similar density to spore body with a smooth to serrate margin. Oval to rounded verrucae, 5 to 10 microns in basal diameter, on distal side of central body; exine otherwise laevigate to granulate. Laesurae simple, extending nearly to body margin.

Dimensions: Overall diameter 37 to 45 microns, cingulum 4 to 9 microns.

Abundance: Eleven specimens

Occurrence: Samples Nu-1-D, E, F; Nu-2-A; Ha-3-D; and Ha-5-C.

Remarks: The specimens in this study are somewhat smaller than those reported by Playford (1963): Playford's specimens ranged from 50 to 80 microns. However, those specimens reported by Streel (1966) from the Dinant Basin of Belgium have a size range of 40 to 45 microns, which is essentially the same size range as the specimens in this study (37 to 45 microns).

Genus LYCOSPORA (S., W. & B.) Potonie and Kremp

Type species: Lycospora micropapillata (Wilson and Coe, 1940) Schopf, Wilson, and Bentall, 1944, p. 54, pl. 3, fig. 9.

Description: Miospores radial, trilete; amb of cingulum (flange) circular to subtriangular, usually conformable with spore body outline. Laesurae usually distinct and frequently accompanied by lip development.

Remarks: Staplin (1960, p. 20) and Playford (1963, p. 636) believe that differences in states of preservation is the reason for a large number of recorded species within the genus Lycospora. This has resulted in different names being applied to the same species. This situation is exemplified by Staplin's list of synonyms for Lycospora uber (1960, p. 20, pl. 4, figs. 13, 17, 18, and 20). In 1958, Potonié emended Stenozonotriletes Naumova, 1937 and transferred several species to the genus Lycospora. Hacquebard (1957, p. 313) also pointed out that several of Naumova's species recorded as Stenozonotriletes probably belonged to the genus Lycospora. It is the author's opinion that, according to Potonié and Kremp's morphographic system of spore taxonomy, emendations of Naumova's broadly defined groups are justified.

Stratigraphic range: Middle Devonian (Richardson et coll., 1964) to Middle Permian (Shaffer, 1964).

Affinity: The affinity of spores belonging to the genus Lycospora seems to be well established with arborescent lycopods. Potonié (1962) lists numerous lycopsid fructifications which are known to have produced species of

Lycospora. Winslow (1962, p. 40) in her discussion of the affinity of Lycospora states that, "All the cone studies suggest that Lycospora is authentically identified with the Lepidodendrales." The cone genus which commonly produced Lycospora is known to be Lepidostrobus which was found in organic connection with the vegetative genus Lepidodendron.

Lycospora pseudoannulata Kosanke

Plate IV, fig. 36

1950 Lycospora pseudoannulata Kosanke, p. 45, pl. 10, fig. 7.

1955 Cirratriradites pseudoannulatus (Kosanke)

Hoffmeister, Staplin, and Malloy, p. 383, pl. 36, fig. 25.

Description: Miospores radial, trilete; amb subtriangular with rounded (sometimes pointed) apices. Laesurae distinct, extending to spore body margin accompanied by thin, elevated lips; proximal apex raised. Spore body laevigate, sometimes finely granulate. Cingulum is laevigate, small perforations are present on weathered specimens. Width of cingulum 2 to 4 microns. A narrow crassitudo is visible on some specimens.

Dimensions: 27 to 32 microns.

Abundance: Sixty specimens.

Occurrence: Samples Nu-2-D; Nu-4-A; and Ha-3-D.

Remarks: The specimens recorded by Kosanke and Hoffmeister et al. ranged from 30 to 40 microns, which is somewhat larger than those in the Hannibal material. Kosanke (1950) initially described and recorded Lycospora pseudoannulata from the Pennsylvanian deposits of Illinois. Hoffmeister et al. (1955) transferred this species to the genus Cirratriradites because they considered the cingulum to be a flange. Moreover, they reported a common occurrence of this species from the Hardinsburg Formation (Upper Mississippian) of Illinois and Kentucky. However, the specimens observed in this study, with the exception of the weathered specimens, showed a well developed cingulum. Therefore, on the basis of the cingulum the author refers these specimens to Lycospora pseudoannulata. This species was most abundant in one subsurface sample (courtesy of the Illinois Geological Survey) of the Nutwood from Montgomery County, Illinois, Sec. 23, T.7 N., R.3 W., at a depth of 2080 to 2110 feet. Its presence in the Hannibal material represents the earliest record of its occurrence. Evidentially Lycospora pseudoannulata persisted as part of the "Illinois" flora for over fifty million years (from Lower Mississippian to Lower Pennsylvanian).

Anteturma POLLENITES R. Potonié

Turma SACCITES Erdtman

Subturma MONOSACCITES (Chitaley) Potonié and Kremp

Infraturma TRILETESACCITI Leschik

Subinfraturma INTRORNATI Butterworth and Williams

Genue ENDOSPORITES Wilson and Coe

Type species: Endosporites ornatus Wilson and Coe, 1940, p. 184, fig. 2. (By designation of Schopf, Wilson, and Bentall, 1944, p. 45)

Description: Miospores radial, trilete; amb circular to subtriangular. The bladder (exoexine) is membranous, translucent, laevigate to granulate, punctate, or infra-recticulate. Laesurae commonly extend to the spore body (intexine) margin, sometimes accompanied by raised lips.

Remarks: It is sometimes difficult to distinguish species of this genus from those of other monosaccate genera due to what appears to be non-agreement among palynologists as to what generic characteristics are diagnostic.

Several workers, notably Potonié and Kremp 1954, Bhararwaj 1957, and Richardson 1960, regard the limbus (an equatorial thickening of the bladder) as an important diagnostic characteristic of the genus Endosporites.

However, the original description, (Wilson and Coe, 1940) which is still accepted unemended, makes no mention of a limbus. Moreover, as Playford pointed out (1963a, p. 651), there are at present several species within the genus Endosporites which do not possess a limbus. Playford

suggests (p. 651) that to alleviate this confusion, "a complete reappraisal of the type species of this (Endosporites) and other related monosaccate genera (particularly Auroraspora) would seem advisable." A similar confusing situation developed in the genus Densosporites (and related cingulate genera). However, recently Butterworth (1964) and nine of his colleagues reviewed and reappraised this group. A similar study needs to be undertaken with the bladder spore group and until such time the author prefers (as did Playford, 1963, and Sullivan and Marshall, 1966) to retain the species described here as Endosporites micromanifestus within the genus to which it was originally assigned by Hacquebard (1957).

Stratigraphic range: Middle Devonian (Richardson, 1960) to Permian (Hoffmeister, et al., 1955a)

Affinity: Potonié (1962, pp. 71, 72, pl. 6, fig. 141) reported that the lycopod cone Polysporia mirabilis Newberry, 1872 (synonym Lepidostrobus zea Chaloner, 1953) contained microspores belonging to the genus Endosporites. Chaloner (1967, p. 91) noted that the presence of a saccus has been considered by some workers as a criterion for recognizing pollen. However, the saccate spores belonging to the genus Endosporites are known to be microspores having an affinity with the lycopods.

Endosporites micromanifestus Hacquebard

Plate IV, figs. 37, 38

1956 Hymenozonotriletes aff. variabilis Naumova in
Ishchenko, p. 62, pl. 11, figs. 129, 130.

1957 Endosporites micromanifestus Hacquebard, p. 317,
pl. 3, fig. 16.

1960 Auroraspora micromanifestus (Hacquebard)
Richardson, p. 51, pl. 14, fig. 2.

1963 Endosporites micromanifestus Hacquebard in
Playford, p. 652, pl. 93, figs. 17, 18.

1966 Endosporites micromanifestus Hacquebard in
Sullivan and Marshall, p. 278, pl. 3, fig. 18.

Description: Miospores radial, trilete; amb convexly subtriangular. Laesurae distinct, accompanied by bladder folds which extend almost to spore equator. Intexine thin, outline conformable with amb. Exoexine (bladder) thin and infragranulate.

Dimensions: Central body 30 to 52 microns, overall size 45 to 76 microns.

Abundance: Ten specimens.

Occurrence: Samples Nu-2-F; Nu-4-A; Ha-1-E; Ha-3-D; and Ha-5-C.

Remarks: The overall size of previously described specimens of Endosporites micromanifestus is 42 to 100 microns. It differs from Endosporites macromanifestus Hacquebard,

1957 (p. 317, pl. 3, figs. 14, 15) only in size, the latter being over 110 microns. This species seems to be rather widespread in Mississippian and also in some Devonian sediments. Previous occurrences are from the Lower Mississippian (Kinderhook) of Nova Scotia (Hacquebard, 1957), Scottish Visean (Upper Lower Carboniferous Love, 1960), and Lower Carboniferous of Spitsbergen (Hughes and Playford, 1961, and Playford, 1963). Ishchenko (1956) reported its occurrence throughout the Mississippian in the Donetz Basin of Russia, while Butterworth and Spinner (1967) reported this taxon from the Lower Carboniferous (Mississippian) rocks of England. It is the author's opinion that Hymenozonotriletes sp. 1, described by Urban (1960, pl. 1, figs. 5, 6) from the Upper Devonian of Oklahoma probably belongs to Endosporites micromanifestus.

In 1960, Richardson emended Endosporites micromanifestus and its larger counterpart Endosporites macromanifestus (pp. 49 to 51, pl. 14, figs. 1, 2) and transferred each to the genus Auroraspora Hoffmeister, Staplin, and Malloy, 1955. He believes that because neither of these two species has a limbus, which is, in his opinion, a characteristic of Endosporites, both belong in the genus Auroraspora. However, the type species for the genus Endosporites (E. ornatus) does not possess a limbus.

Auroraspora has a delicate transparent bladder, which is not present in Endosporites micromanifestus. Therefore, this species does not fit comfortably within the confines of Auroraspora. In this report the species in question has been retained within its originally assigned genus (Hacquebard, 1957) for reason which have been discussed previously (Remarks: Endosporites).

Genus AURORASPORA Hoffmeister, Staplin, and Malloy

Type species: Auroraspora solisortus Hoffmeister, Staplin, and Malloy, 1955, p. 381, pl. 37, fig. 3.

Description: Miospores radial, trilete; amb circular to subtriangular. Spore body (intexine) usually conformable with amb, laevigate to granulate and thicker than the bladder. Exoexine (bladder) thin, laevigate to granulate, commonly folded.

Remarks: The central body and the bladder of Endosporites Wilson and Coe, are approximately equal in thickness. Potonié and Kremp (1954, pp. 171 to 173, pl. 18, figs. 80, 81) in their diagnosis of Endosporites note that a marginal limbus is present on the bladder. In Auroraspora the bladder is thinner than the central body wall and does not possess a limbus.

Stratigraphic range: Lower Devonian (Chaloner, 1967) to Lower Pennsylvanian (Felix and Burbridge, 1967).

Affinity: Unknown.

Auroraspora minutigranulata sp. nov.

Plate IV, figs. 39, 40, 41, 42

Description: Miospores radial, trilete; amb circular to subtriangular, frequently irregular due to folding of exoexine. Exoexine thin, 1 micron or less, densely covered with very small grana (less than 0.5 micron in height and diameter). Spore body (intexine) outline usually conformable with amb, denser than exoexine, 1 to 2 microns thick and laevigate. Laesurae extending to spore body margin and accompanied by raised lips. Lips darker and 2 to 3 microns wide.

Holotype: Hannibal Formation, Nutwood Member, sample Nu-2-F, slide number 1, co-ordinates 54.8 X 107.9.

Plate IV, figs. 39, 40, 41, 42. Deposited in the Paleobotanist Collections, Department of Botany, University of Missouri, Columbia, Missouri.

Dimensions: Overall size 24 to 35 microns. Body 22 to 30 microns.

Abundance: Eighty-five specimens.

Occurrence: Present in almost all samples.

Remarks: This new species may be similar to Naumova's (1953) Archaeozonotriletes parvimammatus. Her specimens ranged in size from 25 to 30 microns and she states (p. 117) that the "perisporium is densely covered with

small warts." In 1957, Kedo transferred Naumova's species to the genus Hymenozonotriletes. A translation of Kedo's work was not available. McGregor and Owens (1967, pl. 27, figs. 13, 14) figured, but did not describe specimens of Hymenozonotriletes parvinammatus (Naumova) Kedo, 1957.

Furthermore, Naumova's description is brief, and therefore, until further information is made available concerning the relationship between the intexine and exoexine, the author prefers to distinguish Auroraspora minutigranulata from Hymenozonotriletes parvimammatus.

Sullivan (1967) described and figured specimens of Auroraspora macra Sullivan, 1967 (p. 124, pl. 27, figs. 6, 7) from the Lower Carboniferous (Tournaisian) Cementstone Group of Scotland. This species is similar in appearance to Auroraspora minutigranulata. However, the former species is larger (48 to 68 microns) and the exoexine is laevigate (usually pitted or torn). The exoexine of Auroraspora minutigranulata, upon preliminary examination, appeared also to be punctate; however, after critically examining numerous specimens it was concluded that the exoexine was finely granulate rather than punctate.

Genus HYMENOZONOTRILETES Naumova

Type species: Hymenozonotriletes polyacanthus Naumova, 1953, p. 41, pl. 4, figs. 11, 12. (By designation of Potonie, 1958, p. 29)

Description: Miospores radial, trilete; amb rounded triangular. Exine composed of two layered; the intexine forms an inner body which is surrounded by an exoexine. Exoexine ornamented with spines.

Remarks: The species described below as Hymenozonotriletes lepidophytus Kedo, 1957, needs to be transferred to another genus, since the presence of spines is not always a diagnostic feature of this species. A forthcoming publication by Owens and Streel will deal with the taxonomic position of this species. The same two authors, in their 1967 publication dealing with this species, spoke of the Hymenozonotriletes lepidophytus "complex" which indicated considerable variation within the species. Because the complex is stratigraphically limited (mostly Upper Devonian) and because it is unique in its possession of a camerate exoexine, the complex may be deserving of a new generic category. Because of its similarity to the genus Endosporites (ie., the relationship between the exoexine and intexine) the complex is tentatively assigned to the same subturma.

Affinity: Unknown.

Hymenozonotriletes lepidophytus Kedo

Plate IV, fig. 43

1957 Hymenozonotriletes lepidophytus Kedo, 1957a,

p. 24.

1962 Leiozonotriletes naumovae Balme and Hassell,
p. 18, pl. 4, figs. 10 to 12, text-fig. 4.

1962 Endosporites lacunosus Winslow, p. 44, pl. 16,
figs. 1 to 5, text-fig. 4.

1966 Hymenozonotriletes lepidophytus Kedo in Streel,
pp. 69, 70, pl. 1, figs. 1 to 12.

1967 Hymenozonotriletes lepidophytus Kedo in Owens
and Streel, pp. 141 to 149, pl. 1, figs. A to G.

Description: Miospores radial, trilete; camerate, amb rounded triangular. Exine two layered; exoexine (bladder) has circular to subcircular lumina, 2 to 10 microns in diameter; otherwise finely punctate. A marginal limbus (1.5 microns wide) is present on some specimens. Intexine (inner body) appears laevigate, up to 2 microns thick, outline conformable with amb. Laesurae frequently accompanied and obscured by folds of the exoexine which continue beyond body margin.

Dimensions: Overall size range 50 to 110 microns.

Diameter of central body 40 to 70 microns.

Abundance: Five specimens.

Occurrence: Samples Nu-2-A, B; Ha-3-D; and Ha-5-C.

Remarks: Owens and Streel (1967) gave an excellent discussion of the Hymenozonotriletes lepidophytus complex. They commented on the stratigraphic value of the complex, which seems to be restricted to Upper Famennian (Upper

Upper Devonian) and Lower Tournaisian (Basal Mississippian) deposits. The species has been recorded from Upper Devonian (Famennian) strata of western Australia (Balme), northern Africa (Wray), Alaska (Scott and Doher), and northern Canada (McGregor and Owens, 1967, p. 64, pl. 24, figs. 6, 7, 8). Winslow recorded Endosporites lacunosus as being most abundant in the Bedford Shale (Lower Mississippian) of Ohio and the uppermost part of the Cleveland Member of the Ohio shale (Upper Devonian). According to Owens and Streel, the Tnlb (rather than the Tnla) represents the base of the Carboniferous system (Gattendorfia zone) which would, therefore, by necessity include the Tnla with the Devonian system. Owens and Streel believe that the Hymenozonotriletes lepidophytus complex is restricted to the Devonian Period, and that its occurrence in the Lower Mississippian of Ohio (Winslow, 1962) is "anomalous." These authors suggest that an incorrectly designated boundary between the Mississippian-Devonian systems could account for the "anomaly." Hymenozonotriletes lepidophytus was not abundant in the Hannibal material. However, its occurrence indicates that the plant which produced this spore did persist into the Lower Mississippian.

GENERA INDETERMINATE

Genus SECARISPORITES Neves

Type species: Secarisporites lobatus Neves, 1961, p. 260.

?Secarisporites sp.

Plate V, fig. 44

Description: Miospores radial, trilete; amb subtriangular. Appears to have a central body and peripheral lobes characteristic of Secarisporites; lobes extend as much as 12 microns beyond body. Body approximately 29 microns in diameter.

Dimensions: Maximum diameter, including projections, 53.7 microns.

Abundance: One specimen.

Occurrence: Sample Nu-2-C.

Remarks: If this spore, represented here by only one specimen, does belong to the genus Secarisporites, it would represent the earliest record of its occurrence. It has been previously recorded from the Visean (Sullivan and Marshall, 1966) Namurian (Neves, 1961), and Lower Pennsylvanian (Felix and Burbridge, 1967). Winslow's Convolutispora tuberosa (1962, p. 71, pl. 17, figs. 20 to 22) appears similar in construction.

Genus CIRRATRIRADITES Wilson and Coe

Type species: Cirratriradites maculatus Wilson and Coe,

1940, p. 183, fig. 7. (By designation of Schopf, Wilson, and Bentall, 1944, p. 43).

?Cirratriradites sp.

Plate V, fig. 45

Description: Miospores radial, trilete; amb subtriangular; central body appears triangular (37 microns). Flange is thin and has radial striations and the laesurae seem to continue onto the flange; flange extends approximately 20 microns beyond body margin.

Dimensions: Maximum diameter 58.0 microns.

Abundance: One specimen.

Occurrence: Sample Ha-3-B.

Remarks: Only one specimen was found; however, the description conforms closely to the generic description of Cirratriradites, Wilson and Coe, 1940.

Genus LOPHOZONOTRILETES (Naumova) Potonié¹

Type species: Lophozonotriletes lebediansis Naumova, 1953, p. 119, pl. 17, fig. 42.

?Lophozonotriletes cristifer (Luber) Kedo

Plate V, fig. 46

Description: Miospores trilete. The distal side, which is sculptured with irregular protuberances, 2 to 4 microns in length, appears extended. The proximal side is

laevigate, laesurae barely discernible.

Dimensions: Maximum diameter 46.4 microns.

Abundance: Two specimens.

Occurrence: Samples Nu-1-F; and Nu-2-F.

Remarks: McGregor and Owens recorded Lophozonotriletes cristifer (Luber) Kedo, 1957, from Famennian deposits of northern Canada (1967, p. 60, pl. 6, 7). Cyrtospora clavigera Winslow, 1962, p. 67, pl. 22, figs. 18 to 20, has similar ornamentation and the distal side is extended. Schopfites augustus Playford, 1963, p. 26, pl. 8, figs. 2 to 7, is similar in construction (projections on distal side) however, the distal side is not extended.

Genus DENSOSPORITES (Berry) Butterworth, et al.

Type species: Densosporites covensis Berry, 1937, p. 157, fig. 11.

?Densosporites sp.

Plate V, fig. 47

Description: Miospores radial, trilete; amb subtriangular. Cingulum appears to extend approximately 11 to 12 microns beyond spore body and has an inner thickened zone 5 to 6 microns wide. Outer portion of cingulum is perforated (proximal). Central body appears granulate. Laesurae simple, straight, and extends to body margin.

Dimensions: Maximum diameter 63.8 microns.

Abundance: One specimen.

Occurrence: Sample Nu-2-E.

Remarks: Only one specimen was found; therefore, identification was not positive. Hacquebard (1957) and Playford (1963b) did not report any Densosporites from the Horton Group. However, this genus has been recorded from the Lower Carboniferous of Spitsbergen (Hughes and Playford, 1962, and Playford, 1963a).

Genus VALLATISPORITES (Hacquebard) Sullivan

Type species: Vallatisporites vallatus Hacquebard, 1957, p. 312, pl. 2, fig. 12.

?Vallatisporites sp.

Plate V, figs. 48, 49

Description: Miospores radial, trilete; amb subtriangular with convex sides. Pits, slightly elongated radially, are present on the inner portion of the equatorial zone. At junction of equatorial zone and "spore cavity" the narrow characteristic "groove" seems to be present. Laesurae appear to be elevated and extend onto equatorial zone (fig. 49).

Dimensions: Maximum diameter 58.0 microns.

Abundance: One specimen.

Occurrence: Sample Nu-1-D.

Remarks: The genus Vallatisporites was erected by

Hacquebard (1957) and separated from Naumova's subgroup Hymenozonotriletes. Its distinguishing characteristic is the "groove or rampart-like area" which separates the central body from the equatorial zone. Sullivan emended this genus in 1964, and applied the term cuniculus to the "groove." "The cuniculus is located at the equator of the spore cavity and probably represents the space between the margins of the spore cavity and the inner surface of the equatorially expanded exoexine." (Sullivan, p. 370) It is significant that only one specimen, which appears to belong to Vallatisporites, was found in the Hannibal material because the genus is typically present in Lower Mississippian sediment. This anomaly is discussed in greater detail on page 186. Hacquebard described four species from the Horton material; Playford had a total of seventy specimens (two species) from the same formation. Vallatisporites was also abundant in the microflora of the Woodford Shale of Oklahoma (1960, Urban). Urban described four species of Vallatisporites from this Upper Devonian formation. Tholisporites foveolatus Hughes and Playford, 1961, p. 38, pl. 4, figs. 1 to 7 (especially fig. 6), appears similar to the specimen here identified as ?Vallatisporites sp.

Genus SPINOZONOTRILETES Hacquebard

Type species: Spinozonotriletes uncatatus Hacquebard, 1957, p. 316, pl. 3, figs. 8 to 10.

?Spinozonotriletes sp.

Plate V, figs. 50, 51

Description: Miospores radial, trilete; amb subtriangular with convex sides. Laesurae raised, sinuous and extend to central body ("mesosporid") margin. Exoexine thicker than central body and sculptured on equatorial and distal side with spinae which have broad bases and pointed apices, 1 to 3 microns in length.

Dimensions: Maximum diameter 60.9 microns.

Abundance: One specimen.

Occurrence: Sample Nu-2-F.

Remarks: Sullivan (1964), in describing specimens of Spinozonotriletes balteatus Playford, 1963a, remarks (p. 1256) that, "In the Forest of Dean examples, the equatorial thickening is marked by a darkening of the colour of the exine, but there is frequently no well defined inner margin." The one specimen in the present study shows the darker color (fig. 51); moreover, the spine dimensions are also similar to those described by Sullivan.

Genus LOPHOTRILETES (Naumova) Potonié¹ and Kremp

Type species: Lophotriletes gibbosus (Ibrahim) Potonié¹

and Kremp, 1954.

?Lophotriletes plicatus

Plate V, fig. 52

1967 Lophotriletes plicatus Butterworth in Butterworth
and Spinner, p. 5, pl. 1, figs. 10, 11.

Description: Miospores radial, trilete; amb subtriangular with convex (sometimes straight) sides. Exine densely ornamented with spines and bacula, 2 to 3 microns in length and 1 to 2 microns in basal diameter. Laesurae approximately two-thirds spore radius.

Dimensions: 35 to 40 microns.

Abundance: Five specimens.

Occurrence: Sample Nu-1-F; and Nu-2-E, F.

Remarks: The specimens in question are smaller than those reported by Butterworth. There seems to be a reduction in the size of the projections in the contact areas; therefore, it is possible that these specimens belong to the genus Apiculretusisporites Streel, 1964.

Genus RETUSOTRILETES (Naumova) Streel

Type species: Retusotriletes simplex Naumova, 1953,
p. 29, pl. 2, fig. 9.

?Retusotriletes sp.

Plate V, fig. 53

Description: Miospores radial, trilete; amb subcircular. Exine laevigate, 2.5 microns thick, and somewhat darker at apex. Laesurae slightly raised with curvaturae at terminal end of laesurae.

Dimensions: Maximum diameter 78.3 microns.

Abundance: One specimen.

Occurrence: Sample Nu-2-F.

Remarks: This specimen seems to belong to Retusotriletes (Naumova) Streel, 1964, because of the curvaturae.

ACRITARCHA

Introductory statements

The group name "Acritarcha" was derived from the two Greek roots akritos and arche, and means "of unknown origin." The term was proposed by Evitt (1963) and was applied to microplanktonic fossils of unknown affinity and treated under the International Code of Botanical Nomenclature as Incertae Sedis.

These "acritarchs" are unicellular structures, variously shaped (ie., spherical to elongate or polygonal) having an organic wall which encloses a central cavity. The wall may be laevigate or ornamented with punctae, grana, spines, or other processes. The central portion, from which projections commonly arise, is called the

"test." The diameter of the "test" normally varies between 10 to 100 microns.

Classification and Affinity

Prior to Evitt's proposal, all paleomicroplankton had been referred to as "hystrichospheres" ("spiny balls"), regardless of known affinity. The latter term was introduced in the 1930's when interest in these spherical spinose bodies was initiated. The general term "hystrichosphere" was derived from two dinoflagellate genera described by two European paleontologists. These genera are Hystrichosphaera Wetzel, 1933, and Hystrichosphaeridium Deflandre, 1934.

The affinity of the acritarchs is, as the name implies, questionable and most likely polyphyletic. They may be eggs of various marine organisms, or spores of higher plants. However, Downie, Evitt, and Sarjeant commented that, "the acritarch probably comprise for the most part, various stages in the life cycle of unicellular algae, cysts, spore cysts, vegetative stages, etc." (1963, p. 7)

Some fossil microplankton referred to as hystrichospheres were known to be related to the dinoflagellates due to their morphological similarity to living forms. Evitt proposed that these fossil microplankton of known

affinity should be separated from the remainder of the "spiny balls" of unknown origin. The former class includes the fossil genera Hystriosphera Wetzel, and Hystriospheridium Deflandre. Therefore, Evitt suggested the latter term "hystriosphere" should be applied to "spiny balls" of known dinoflagellate affinity, while the term "acritarch" should be applied to "spiny balls" which cannot be identified as dinoflagellates. This distinction has been readily accepted by most palynologists. Those characteristics which demonstrate dinoflagellate affinity have been outlined by Evitt.

1. Presence of a transverse furrow, with or without a longitudinal furrow.
2. Evidence of tabulation by alignment or grouping of ridges or processes according to the plate arrangement of typical thecate dinoflagellates.
3. Presence of an archeopyle (an opening...)
4. Overall shape; an extreme peridinioid outline is indicative of dinoflagellate affinities, but it should not be considered conclusive without supporting evidence.

Downie, Evitt, and Sarjeant (1963) proposed thirteen subgroups to accommodate forms included within the group Acritarcha. Each subgroup name is based on a characteristic morphological feature common to the subgroup. The subgroups commonly present in Paleozoic material are: Sphaeromorphitae (sphaira = ball); Herkomorphitae (herkos = wall or fence); Polygonomorphitae (poly + gonia = many + angle); and Acanthormorphitae (akantha = thorn).

In regard to the genera within the subgroups, Downie, Evitt, and Sarjeant did not designate "types" nor are the subgroups based on generic names. Their reason for not doing this was to avoid future modification of names and circumscription of the subgroups in case the affinity of the "type" was determined. Downie, Evitt, and Sarjeant commented (1963, p. 6):

In the future, as the systematic relationships of individual genera of acritarchs are established, these genera should be removed from the group and attributed to appropriate families, orders, etc.

In 1963, Downie and Sarjeant reviewed and redefined several commonly occurring acritarch genera in an attempt to eliminate confusion regarding the circumscription of those genera. The taxonomic proposals of these authors, which are adhered to in this study, are accepted by most authors (with the exception of Staplin, et al., 1965). Downie and Sarjeant's generic emendations are discussed individually in the systematic description section (generic "Remarks") of this chapter.

Geological importance

In regard to the fossil record, fossil dinoflagellates are known from the Jurassic (Evitt, 1963) to Recent; whereas the acritarchs are known from the Pre-Cambrian to Recent. Therefore, the stratigraphic value of the dinoflagellates is primarily limited to the Mesozoic and

Cenozoic. On the other hand, acritarchs are important tools for the correlation of Paleozoic deposits. Not only are the acritarchs important in geological correlation, they are also used effectively in paleoecological interpretations. They are characteristically marine organisms, and have a widespread occurrence in most types of marine sediments. When acritarch data is used in conjunction with fossil miospore data much important paleoecological information can be obtained (ie., ancient shorelines). This aspect is discussed more fully in a separate chapter under the section heading "Paleoecology."

The most common acritarch genera encountered in Paleozoic strata are: Leiosphaeridia (Eisenack) Downie and Sarjeant, 1963; Lophosphaeridium (Timofiev) Downie, 1963; Leiofusa Eisenack, 1938; Cymatiosphaera (Wetzel) Deflandre, 1954; Microhystridium (Deflandre) Downie and Sarjeant, 1963; Baltisphaeridium (Eisenack) Downie and Sarjeant, 1963; and Veryhachium (Deunff) Downie and Sarjeant, 1963.

The Ordovician, Cambrian, and Pre-Cambrian forms are small and morphologically simple, belonging for the most part to Leiosphaeridium and Lophosphaeridium. More varied and larger forms, which are present in Upper Devonian and Mississippian sediments, first begin to appear in the Silurian. Some species have a short

stratigraphic range and are therefore useful stratigraphic tools. However, some species have a very long geological history such as Veryhachium rhomboidium Downie, 1959, which has been recorded from the Silurian (Downie, 1959) to the Permian (Wall and Downie, 1963).

SYSTEMATIC DESCRIPTION

Group ACRITARCHA Evitt

Subgroup SPHAEROMORPHITAE Downie, Evitt, and Sarjeant

Description: "Acritarchs having a spherical to ellipsoidal shell lacking an inner body. Surface granular, smooth, punctate or perforate, but not otherwise ornamented. Without observed opening, with a simple circular pylome, or opening by splitting." (Downie, Evitt, and Sarjeant, 1963, p. 8)

Genus LEIOSPHAERIDIA (Eisenack) Downie and Sarjeant

Synonyms

Leiosphaeridium Timofiev 1959 ex Staplin, 1961,
p. 407.

Protoleiosphaeridium Timofiev 1959 ex Staplin, 1961
p. 405.

Type species: Leiosphaeridia baltica Eisenack, 1958,
p. 8, pl. 2, fig. 5.

Description: Spherical to ellipsoidal bodies without

processes, often collapsed and folded with or without pylomes. Walls thin, laevigate, granular or punctate.

Remarks: Downie and Sarjeant (1963) rejected the two genera Leiosphaeridium and Protoleiosphaeridium and reattributed species of these genera to the genus Leiosphaeridia. Their reasons for the rejections and reattributions are as follows (1963, pp. 87, 88):

The name Leiosphaeridium was proposed as an amendment of Leiosphaera and presumably Timofiev regarded L. solida as its type species; Leiosphaeridium is thus a junior synonym of Leiosphaera and hence of Tasmanites. If the single species attributed to Leiosphaeridium by Timofiev were considered as its type, its characters are such as to render it attributed to Leiosphaeridia of which the genus then becomes a junior synonym. Whichever viewpoint taken, the name Leiosphaeridium must be abandoned. Protoleiosphaeridium might be retained as a subgenus of Leiosphaeridia and restricted to thin-walled forms having a diameter less than 50 microns. The type of Eisenack's genus has a size range 80-140 microns; however, the total range size of all species attributed to this genus is 23-150 microns and there is no indication of any division into size modes. We feel that Protoleiosphaeridium should be treated as a synonym of Leiosphaeridia and rejected, and that its species should be reattributed to the latter genus.

Staplin, who has been in bitter disagreement with Downie and Sarjeant (and Evitt and Eisenack), has taken issue with the latter on the above statements involving the genus Protoleiosphaeridium. Staplin commented (Staplin, et al., 1965, p. 175):

There is little merit in Downie and Sarjeant's suggestion that it be degraded to a subgenus of Leiosphaeridia. Their rejection of it, based on

the feeling that it is synonymous with Leiosphaeridia is personal and does not invalidate the genus under the International Code of Botanical Nomenclature.

After reading both sides of the argument, the author is in agreement with Downie and Sarjeant due to the overlapping diagnosis of Protoleiosphaeridium with Leiosphaeridia. If these genera were retained as separate taxa, then the basis of differentiation would be size alone, and Staplin himself pointed out (Staplin, et al., 1965, p. 176) that, "size alone is not a rewarding criterion for generic differentiation."

Stratigraphic range: This is a wide ranging genus and has been reported from the Pre-Cambrian of the U.S.S.R. (Timofiev, 1959) to the Lower Cretaceous of Germany (Eisenack, 1958).

Leiosphaeridia orbiculata (Staplin) Downie and Sarjeant

Plate VI, figs. 54, 55

1961 Protoleiosphaeridium orbiculatum Staplin,
p. 405, pl. 48, fig. 12.

1963 Leiosphaeridia orbiculata (Staplin, 1961)
Downie and Sarjeant, p. 95.

Description: Vesicle circular, laevigate; usually folded; wall thickness 1 to 2 microns (usually 1.5 to 2 microns).

Dimensions: Test diameter 23 to 50 microns.

Abundance: Twenty-five per cent of acritarch assemblage.

Occurrence: Present in almost all samples.

Remarks: This morphologically simple form is quite common in the Hannibal material. Staplin, in his description, does not give the wall thickness of the species and stated simply that the wall was relatively thick. He further noted that the wall was thicker than the wall of Leiosphaeridia wenlockia Downie (1959), which was recorded from the Baltic Silurian. The size range of Downie's species was 20 to 30 microns with a wall thickness of 1 micron. Downie (1963) expressed doubt about the validity of Leiosphaeridia orbiculata. It is difficult to distinguish morphologically simple forms such as these; however, the author agrees with Staplin in that the wall of Leiosphaeridia orbiculata is thicker than that of Leiosphaeridia wenlockia. Gupta (1965) reported a new species of Leiosphaeridia (Leiosphaeridia devonicus, pp. 148, 149, pl. 10, fig. 78) from the Upper Devonian of Missouri, which in the opinion of the author, belongs to Leiosphaeridia orbiculata. Gupta's species had a size range of 32 to 45 microns and a wall thickness of 1.2 to 2 microns, and was spherical in shape. Gupta reported a common occurrence of this species throughout the Grassy Creek and Saverton shales.

Leiosphaeridia triangulata sp. nov.

Plate VI, fig. 56

Description: Test outline triangular, surface laevigate; folds are frequently present; wall thickness 1 to 2 microns.

Holotype: Hannibal Formation, Nutwood Member; sample Nu-2-D, slide number 2, co-ordinates 59.0 X 103.8.

Deposited in the Paleobotanical Collections, Department of Botany, University of Missouri, Columbia, Missouri.

Dimensions: Test diameter 25 to 35 microns.

Abundance: Two per cent of acritarch assemblage.

Occurrence: Samples Nu-2-D, E.

Remarks: The possibility of this form being a spore belonging to the triangular laevigate genus Leiotriletes was considered. However, in all specimens observed, no trace of a trilete ray was seen. Hence, it has been allocated to the acritarch genus Leiosphaeridia.

Leiosphaeridia sp. A

Plate VI, figs. 57, 58

Description: 'Nest' of approximately fifty spherical tests, wall appears laevigate; wall thickness 2.5 microns.

Dimensions: Test diameter 20 to 21 microns.

Abundance: One nest of approximately thirty specimens.

Occurrence: Sample Ha-5-B.

Remarks: Combaz (1967) found such masses of leiospheres in Lower Paleozoic rocks of Libya, the Sahara, and

Australia. He believes that such group associations lend support to the idea that the leiospheres have algal affinity. Leiosphaeridia sp. A differs from Leiosphaeridia orbiculata in having a smaller test diameter and a thicker wall. As with the other unnamed species of acritarchs, the author intends to apply names after further investigation regarding the occurrence of acritarchs in Lower Mississippian strata.

Leiosphaeridia major (Staplin) Downie and Sarjeant

Plate VI, fig. 59

1961 Protoleiosphaeridium major Staplin, p. 406,
pl. 48, fig. 6.

1963 Leiosphaeridia major (Staplin) Downie and
Sarjeant, p. 95.

Description: Vesicle circular, laevigate, frequently folded; wall thickness 1.5 to 2 microns.

Dimensions: Test diameter 60 to 100 microns.

Abundance: Two per cent of acritarch assemblage.

Occurrence: Samples Nu-2-B, C, D; Ha-3-B, C; and Ha-5-A, D.

Remarks: This species is morphologically simple like Leiosphaeridia orbiculata, but is larger and differs only in this respect. Downie (1959) reported a species of Leiosphaeridia (Leiosphaeridia cf. microcystis Eisenack) from the Baltic Silurian which may be similar to

Leiosphaeridia major. Downie did not report the wall thickness. However, his specimens had a size range of 57 to 72 microns. The size of Leiosphaeridia major is within the lower size range of Tasmanites sinuosus Winslow (1962, p. 83, pl. 20, figs. 1, 2, 3). The latter species has a size range of 50 to 425 microns and a wall thickness of 2 to 13 microns; however, the wall is punctate and differs from Leiosphaeridia major in this respect.

Leiosphaeridia fastigatirugosum (Staplin)

Downie and Sarjeant

Plate VI, fig. 60

1961 Leiosphaeridium fastigatirugosum Staplin, p. 408,
pl. 50, fig. 9.

1963 Leiosphaeridia fastigatirugosum (Staplin) Downie
and Sarjeant, p. 95.

Description: Test spherical, surface laevigate; wall thin, approximately 1 to 1.5 microns thick and folded.

Dimensions: Test diameter 150 to 255 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Samples Nu-2-E, F; and Ha-3-D.

Remarks: These specimens are larger than Leiosphaeridia major and the wall is thinner. Staplin reported a size range of 120 to 150 microns for this species, "and perhaps a little larger." (1961, p. 408) Some of the

specimens in the present study have a rough surface which, in the opinion of the author, is due to weathering.

Leiosphaeridia microgranifera (Staplin)

Downie and Sarjeant

Plate VI, fig. 61

1961 Protoleiosphaeridium microgranifer Staplin,
p. 405, pl. 48, fig. 4.

1963 Leiosphaeridia microgranifera (Staplin) Downie
and Sarjeant, p. 95.

Description: Test spherical, usually folded; wall densely covered with small grana which are 0.5 micron or less in height and width, wall thickness 1 micron.

Dimensions: Test diameter 30 to 35 microns.

Abundance: Five per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, B, C.

Remarks: Protoleiosphaeridia granulosum Staplin (1961, p. 406, pl. 48, fig. 1) has larger grana (more than 0.5) and is smaller (16 to 28 microns).

Leiosphaeridia sp. B

Plate VI, fig. 62

Description: Test triangular in outline, surface densely covered with small grana which are less than 0.5 micron in height and width. Wall approximately 1 micron thick and commonly folded.

Dimensions: Test diameter 29 to 32 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Sample Nu-2-D.

Remarks: Only five specimens were found and these occurred in one sample. No trilete ray was observed and therefore these specimens are included within the acritarch group.

Genus LOPHOSPHAERIDIUM Timofiev

Type species: Lophosphaeridium rarum Timofiev, 1959, p. 29, pl. 2, fig. 5. (Designated by Downie, 1963, p. 630)

Description: Spherical to ellipsoidal bodies ornamented with solid spines and tubercles which are short in relation to the body size.

Remarks: Because this genus is ornamented with spines and tubercles it does not appear to conform to the subgroup Sphaeromorphitae (Downie, Evitt, and Sarjeant, 1963).

However, it is included within this subgroup in accordance with its original allocation (Downie, Evitt, and Sarjeant, 1963, p. 8). Downie (1963, p. 629) also included Lophosphaeridium within the subgroup Sphaeromorphitae.

Stratigraphic range: This genus has been recorded from the Lower Ordovician of Russia (Timofiev, 1959), Middle Silurian of England (Downie, 1963), and Upper Devonian of Canada (Staplin, 1961).

Lophosphaeridium papillatum (Staplin) new. comb.

Plate VII, fig. 63

1961 Protoleiosphaeridium papillatum Staplin, p. 406,
pl. 48, figs. 10, 11.

Description: Test circular, sometimes folded; densely covered with short, solid spines, 1 to 1.5 microns in length.

Dimensions: Test diameter, not including projections, 32 to 40 microns.

Abundance: Two to three per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, F; Ha-3-A, B; and Ha-5-A, B.

Remarks: This species is transferred to the genus Lophosphaeridium on the basis of the short, solid spines. Downie (1963, p. 631) inferred that Protoleiosphaeridium papillatum belonged to the genus Lophosphaeridium; however, he did not officially reclassify the species.

Staplin (1961, p. 407) noted that Baltisphaeridium microspinosum (Eisenack) Downie, 1959, is larger. Downie reported a size range of 48 to 69 microns and a spine length of 1.5 microns (1963, p. 60). He has since transferred Baltisphaeridium microspinosum from the genus Baltisphaeridium to the genus Lophosphaeridium (1963, p. 632, pl. 92, fig. 11) on the basis of the short, solid spines. Achauer's unidentified form (1959, p. 46, pl. 3, fig. f) which has "papillate?" ornamentation and

a diameter of 39 microns may belong to Lophosphaeridium papillatum.

Lophosphaeridium microsaetosum (Staplin) new. comb.

Plate VII, fig. 64

Description: Test circular, ornamented with short, solid spines 2 to 4 microns in length, simple and closed at tips.

Dimensions: Test diameter, not including projections, 30 to 40 microns.

Abundance: One per cent of acritarch assemblage.

Remarks: As with Lophosphaeridium papillatum this species is transferred to the genus Lophosphaeridium on the basis of the short, solid spines. Downie (1963, p. 631) inferred that Protoleiosphaeridium microsaetosum belonged to the genus Lophosphaeridium; however, he did not officially reclassify the species.

Lophosphaeridium microsaetosum differs from Lophosphaeridium papillatum in having longer spines. Lophosphaeridium critrinum Downie (1963, pp. 630, 631, pl. 92, fig. 3) has pylomes and differs from Lophosphaeridium microsaetosum in this respect.

Subgroup HERKOMORPHITAE Downie, Evitt, and Sarjeant

Description: "Acritarchs having a spherical to ellipsoidal or subpolygonal test without an inner body. Surface of

test subdivided by crests into polygonal fields or regular or irregular form: surface within these fields smooth, punctate or tuberculate. No median girdle present.

Rod-like supports or projecting spines present in some at crest junctions. No observed opening or a simple, circular pylome." (Downie, Evitt, and Sarjeant, 1963, p. 10)

Genus CYMATIOSPHAERA (Wetzel) Deflandre

Type species: Cymatiosphaera radiata O. Wetzel, 1933, p. 27, pl. 4, fig. 8.

Description: Test spherical, ellipsoidal, or lenticular, often with radial ribs; vesicle surface divided into polygonal fields by membranes perpendicular to the surface.

Remarks: This genus was not abundant in the Hannibal material; however, it is reported here because it is the first record of its occurrence in the Lower Mississippian material of North America.

Stratigraphic range: This genus has been recorded from Lower Ordovician (Deunff, 1961) to Upper Cretaceous (O. Wetzel, 1933).

Cymatiosphaera sp.

Plate VII, fig. 65

Description: Test circular in outline, surface divided into polygonal areas which are variable in size and outline, surface otherwise laevigate.

Dimensions: Test diameter 55 to 60 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A; and Ha-1-E.

Remarks: Not enough specimens were found to determine a species assignment. However, the author plans to conduct further investigation of Lower Mississippian strata and this species may prove to be more abundant than is indicated by this study.

Genus DICTYOTIDIUM (Eisenack) Staplin

Type species: Dictyotidium (al. Leiosphaera) dictyotum (Eisenack, 1938b, p. 27, pl. 3, figs. 8a, b, c) Eisenack, 1955. (Reference: Norris and Sarjeant, 1967, p. 24)

Description: Vesicle spherical; surface reticulate, delimiting polygonal lacunar areas; small apiculae or spines may arise from the ridge.

Remarks: Staplin emended this genus to include those forms with short spines or apiculae on the ridges. Staplin also noted that the size of two lacunae may be smaller than the others. These lacunae are opposite and are located at "poles."

Stratigraphic range: This genus has been reported from

the Baltic Silurian (Eisenack, 1955) and from the Upper Devonian of Canada (Staplin, 1961).

Dictyotidium sp. A

Plate VII, fig. 66

Description: Test spherical, having a surface with smooth, sinuous muri approximately 1 micron in height and width; muri usually arranged concentrically and anastomosing to form irregular lacunae.

Dimensions: Test diameter 28 to 40 microns.

Abundance: Two to three per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, B, E; and Ha-5-B, C.

Remarks: Staplin reported two species of Dictyotidium from the Upper Devonian of Canada. Dictyotidium polosymmetrium Staplin (1961, p. 417, pl. 49, fig. 13) differs from Dictyotidium sp. A in having large polygonal areas (10 to 12 microns wide). Dictyotidium polygonium Staplin (1961, p. 417, pl. 49, fig. 14) differs in having a raised grana in the center of each polygon.

Dictyotidium sp. B

Plate VII, figs. 67, 68

Description: Test spherical, surface having sinuous muri approximately 1 micron in height and width; spines arising from muri, spines 4 to 10 microns in length.

Dimensions: Test diameter 24 to 32 microns.

Abundance: Two to three per cent of acritarch assemblage.

Occurrence: Samples Ha-3-A, B, C; and Ha-5-B, C, D.

Remarks: In regard to the test size and nature of muri, this species is similar to Dictyotidium sp. A. However, it differs in having spines arising from the muri.

Subgroup POLYGONOMORPHITAE Downie, Evitt, and Sarjeant

Description: "Acritarchs having a pronouncedly polygonal test, without an inner body and without crests. Processes isolate or fusing at the base, few in number, normally simple, rarely branching." (Downie, Evitt, and Sarjeant, 1963, p. 8)

Genus VERYHACHIUM (Deunff) Downie and Sarjeant

Type species: Veryhachium (al. Hystrichosphaeridium) trioulcum Deunff, 1951, p. 323, fig. 2. (Reference: Norris and Sarjeant, 1967, p. 62)

Description: Shape of test polygonal or subpolygonal having 3 to 8 hollow pointed spines with closed tips. Shape frequently determined by the number of spines present. Size of tests 10 to 40 microns.

Remarks: According to Downie and Sarjeant (1963, p. 93) the distinguishing characteristics of this genus are the shape of the test and the number of spines. Any form with more than eight spines belongs either to Micrhy-

stridium or to Baltisphaeridium.

Stratigraphic range: This genus has been recorded from Lower Ordovician (Downie, 1958) to Upper Cretaceous (O. Wetzel, 1933).

Veryhachium downiei Stockmans and Williere

Plate VII, fig. 69

1961 Veryhachium reductum (Deunff) forme trispinosoides De Jekhowsky, p. 212, pl. 2, figs. 22 to 32.

1962 Veryhachium downiei Stockmans and Williere, p. 47, pl. 2, figs. 20, 21, 22.

1966 Veryhachium trispinosoides Stockmans and Williere, p. 465, pl. 1, figs. 6 to 0.

Description: Vesicle triangular in shape with convex sides which meet to form spines at three apices. Surface laevigate; spine length 8 to 18 microns.

Dimensions: Test diameter 9 to 23 microns.

Abundance: Fifteen per cent of acritarch assemblage.

Occurrence: Present in almost all samples.

Remarks: This species has been reported from the Upper Devonian and Lower Carboniferous of Belgium by Stockmans and Williere. These authors differentiate this species from Veryhachium trispinosum (Eisenack) Downie and Sarjeant, 1963, on the basis of size. The latter species is larger and the holotype measures 65 microns from the base of the triangle to the tip of the opposite spines.

Staplin reported Veryhachium downiei (as Veryhachium sp. cf. H. trispinosum Eisenack) from the Upper Devonian of Canada (1961, p. 13, pl. 49, figs. 2, 5). In the author's opinion, some of the specimens of Hystrichosphaeridium trispinosum Eisenack, which were reported from the Upper Devonian and Lower Mississippian of Ohio by Winslow (1962, p. 75, pl. 22, figs. 1 to 4) belong, in part, to Veryhachium downiei.

Veryhachium brevitrispinum Staplin

Plate VII, fig. 70

1961 Veryhachium brevitrispinum Staplin, 1961, p. 92, pl. 49, fig. 70.

Description: Vesicle triangular in shape with convex sides and with short spines at each of the three apices. Surface very finely granulate; spines short, 5 to 6 microns.

Dimensions: Test diameter 30 to 35 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Samples Ha-3-A; and Ha-5-B.

Remarks: This species differs from Veryhachium downiei in having a granulate surface.

Veryhachium europaeum Stockmans and Williere

Plate VII, fig. 71

1960 Veryhachium europaeum Stockmans and Williere, p. 3, pl. 2, fig. 25.

Description: Test tetrahedral, four equal spines; surface laevigate; spine length 8 to 12 microns.

Dimensions: Test diameter 20 to 25 microns.

Abundance: Two per cent of acritarch assemblage.

Occurrence: Samples Nu-2-C; Ha-3-A; Ha-5-A, B; and Cu-3-E.

Remarks: Stockmans and Williere originally described this species from the Devonian of Belgium. In 1963, Wall and Downie (p. 782, pl. 14, figs. 4 to 6) reported its occurrence in the Permian of Britain. This is the first recorded occurrence of Veryhachium europaeum from Mississippian strata of North America.

Veryhachium rhomboidium Downie

Plate VII, figs. 72, 73, 74

1959 Veryhachium rhomboidium Downie, p. 62, pl. 12, fig. 10.

Description: Test rhomboidal in outline with four apical spines. Up to five additional spines may be present; however, it still retains its rhomboidal outline; test surface laevigate; spine length 8 to 15 microns.

Dimensions: Test diameter 10 to 25 microns.

Abundance: Ten per cent of acritarch assemblage.

Occurrence: Present in almost all samples.

Remarks: Wall and Downie recorded this species from the Permian of Britain (1963, p. 781, pl. 114, figs. 1, 2, 3).

These authors suggested that Veryhachium minor Staplin (1961, p. 414, pl. 49, fig. 9) based on Devonian material belongs to Veryhachium rhomboidium. This species is reported here for the first time from Mississippian sediment of North America.

Veryhachium formosum Stockmans and Williere

Plate VIII, fig. 75

1960 Veryhachium formosum Stockmans and Williere
p. 2, pl. 2, fig. 28.

Description: Test tetrahedral with four apical spines, 1 to 5 supplementary processes ornamenting the faces; spine length 6 to 18 microns.

Dimensions: Test diameter 15 to 25 microns.

Abundance: Four per cent of acritarch assemblage.

Occurrence: Samples Ha-3-A; and Ha-5-A, B.

Remarks: This species differs from Veryhachium europaeum Stockmans and Williere, in having more than four spines. It differs from Veryhachium rhomboidium Downie, in having a triangular outline.

Veryhachium sp. A

Plate VIII, figs. 76, 77

Description: Test pentagonal in outline with five prominent spines; 2 to 4 additional processes usually present. Test surface laevigate, spine length 8 to 17

microns.

Dimensions: Test diameter 25 to 30 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Samples Ha-3-B; and Ha-5-A, B.

Remarks: This species differs from Veryhachium rhomboidium Downie, in having a pentagonal outline.

Veryhachium sp. B

Plate VIII, fig. 78

Description: Test pentagonal in outline with five appendages which taper to a blunt point. Lines (folds?) radiating from central part of test to the tips of the appendages. Spine length 15 to 16 microns.

Dimensions: Test diameter 30 to 32 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Sample Ha-1-E.

Remarks: This species differs from Veryhachium sp. A in having only five appendages and in having blunt, pointed spines. Veryhachium octoaster Staplin (1961, p. 413, pl. 49, figs. 3, 4) has radiating lines as in Veryhachium sp. B; however, the former species has eight spines.

Subgroup ACANTHOMORPHITAE Downie, Evitt, and Sarjeant

Description: "Acritarchs having a spherical or ellipsoidal test, without an inner body and without crests. Processes

isolate, simple, or branching, solid or hollow, distributed arbitrarily or regularly. Without observed opening or with a simple circular pylome." (Downie, Evitt, and Sarjeant, p. 7)

Genus BALTISPHAERIDIUM (Eisenack) Downie and Sarjeant

Type species: Baltisphaeridium (al. Ovum hispidum) longispinosum (Eisenack, 1931, p. 110, pl. 5, figs. 6 to 17) Eisenack, 1958. (Reference: Norris and Sarjeant, 1967, p. 13)

Description: Test spherical to oval with numerous processes. Processes are always closed at tips and simple; may be branching and hollow to solid. Diameter of shell greater than 20 microns.

Remarks: The principal difference between this genus (Baltisphaeridium) and the genus Micrhystridium is size. The size of the tests in the former genus is greater than 20 microns, whereas the latter genus has a test size less than 20 microns. Staplin proposed that Baltisphaeridium should be treated as a synonym of Micrhystridium and he abandoned the former genus. Staplin was criticized by Eisenack (1962, p. 96) and by Downie and Sarjeant (1963, p. 92) for this emendation. The latter authors believing that the size boundary between Micrhystridium and Baltisphaeridium was significant and

represented two natural size modes advocated the retention of both genera. The author believes that Staplin's suggestion has merit since there does seem to be overlapping beyond the 20 micron demarcation line in both genera. The upper size range of some species of Micrhystridium extends above 20 microns and the lower size range in some species of Baltisphaeridium extends below 20 microns. However, until there is more universal agreement among acritarch workers and additional information about the degree of variability in size of these entities is published, the author has accepted the opinions of Downie, Sarjeant, and Eisenack.

Baltisphaeridium sp. B

Plate VIII, figs. 79, 80

Description: Test subspherical; surface ornamented with short (hollow) spines which have broad, bulbous bases (1 to 3 microns). Spines 1.5 to 3 microns in length and are spaced 1 to 4 microns apart.

Dimensions: Test diameter 35 to 45 microns.

Abundance: Four per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, D, E, F; and Ha-3-B.

Remarks: This species, which was quite abundant in some samples, appears to be similar to Hystrichosphaera sp. 2 Urban (1960, p. 26, pl. 3, figs. 6, 7) and to sp. 5 Urban (1960, p. 28, pl. 3, fig. 11).

Baltisphaeridium sp. B

Plate VIII, fig. 81

Description: Test subspherical, ornamented with large hollow spines which are 3 to 4 microns in basal diameter and 15 to 20 microns in length. Spines taper to a simple point.

Dimensions: Test diameter 60 to 65 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Samples Ha-5-A, B.

Remarks: This species differs from Baltisphaeridium sp. C in having fewer spines and longer spines and wider based spines. The diameters of these specimens are greater than those of Baltisphaeridium sp. A.

Baltisphaeridium sp. C

Plate IX, fig. 82

Description: Test spherical, ornamented with hollow spines which are 5 to 10 microns in length and 2 microns in basal diameter. Some spines bifurcate at these tips.

Dimensions: Test diameter 50 to 60 microns.

Abundance: Less than 1 per cent of acritarch assemblage.

Occurrence: Sample Ha-5-B.

Remarks: This is the only acritarch species in the Hannibal material having spines which furcated at their tips.

Baltisphaeridium lucidum (Deunff) Downie and Sarjeant

Plate IX, fig. 83

1959 Hystrichosphaeridium lucidum Deunff, p. 25,
pl. 9, fig. 82.

1963 Baltisphaeridium lucidum (Deunff) Downie and
Sarjeant, p. 90.

1966 Baltisphaeridium lucidum (Deunff) Downie and
Sarjeant in Stockmans and Williere, p. 467, pl. 1,
fig. 16.

Description: Test polygonal with hollow spines 20 to 30
microns in length which taper to a simple point. Number
of spines per specimen varies from ten to fifteen.

Dimensions: Test diameter 15 to 25 microns.

Abundance: Four per cent of acritarch assemblage.

Occurrence: Samples Nu-2-B, D, E; Ha-3-A; and Ha-5-B, C.

Remarks: This species resembles Baltisphaeridium octo-
spinosum (Staplin, 1961) Downie and Sarjeant, 1963, which
Staplin recorded from the Upper Devonian of Canada (p. 410,
pl. 48, fig. 18). However, Staplin reported that the
number of spines (eight) was constant.

Baltisphaeridium sp. cf. B. debilispinum

Wall and Downie

Plate IX, fig. 84

1963 Baltisphaeridium debilispinum Wall and Downie,
p. 777, pl. 112, figs. 1, 2, text-figs. 3a, b.

Description: Test spherical, laevigate, ornamented with fifteen to twenty-five spines. Length of spines 10 to 20 microns.

Dimensions: Test diameter 18 to 25 microns.

Abundance: Two per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, D; Ha-3-A; and Ha-5-A, B.

Remarks: This species is similar to Baltisphaeridium debilispinum Wall and Downie. However, the spine length in the latter is not greater than 50 per cent of the diameter.

Genus MICRHYSTRIDIUM (Deflandre) Downie and Sarjeant

Type species: Micrhystridium (al. Hystrichosphaera) inconspicuum (Deflandre, 1935, p. 233, pl. 9, figs. 11, 12) Deflandre, 1937. (Reference: Norris and Sarjeant, 1967, pp. 40, 41)

Description: Tests spherical to oval; processes simple, rarely branching, hollow or solid but with closed tips. Mean and modal diameter of test less than 20 microns.

Remarks: The size relationship of Micrhystridium to that of Baltisphaeridium has previously been discussed (p. 149).

Stratigraphic range: According to Downie and Sarjeant (1964) this genus has been recorded from the Lower Ordovician (Downie, 1958) to the Eocene (Pastiels, 1948).

Micrhystridium lunatum Stockmans and Williere

Plate IX, figs. 85, 86

1966 Micrhystridium lunatum Stockmans and Williere,
p. 237, pl. 1, fig. 16, text-fig. 2.

Description: "Test is described as having proximal and distal orientation. The proximal region is ornamented with spines which are 8 to 17 microns in length. The distal region is characterized by two larger spines which are 12 to 20 microns in length and which form what is best described as "les extremités d'un croissant de lune."
(Stockmans and Williere, 1966, p. 237)

Dimensions: Test diameter 15 to 25 microns.

Abundance: Four per cent of acritarch assemblage.

Occurrence: Samples Ha-3-A, B; and Ha-5-A, B, D.

Remarks: The shape of this species is unique and somewhat difficult to describe, but very easy to recognize since the two larger spines form the shape of a quarter moon. The only previously reported occurrence of Micrhystridium lunatum is from the Lower Tournaisian (Lower Mississippian) rocks of Belgium (Stockmans and Williere, 1966). Since it is not known from any other geological horizon, Micrhystridium lunatum may prove to be an important index fossil for the Lower Mississippian.

Micrhystridium bistchoensis Staplin

Plate IX, fig. 87

1961 Micrhystridium bistchoensis Staplin, p. 409,
pl. 48, fig. 15.

Description: Test spherical to subspherical, ornamented with spines which are 4 to 10 microns in length. Spines (fourteen to eighteen in number) are hollow with pointed tips.

Dimensions: Test diameter 15 to 20 microns.

Abundance: Four per cent of acritarch assemblage.

Occurrence: Samples Nu-2-A, B, C, D, E; Ha-3-A; and Ha-5-A.

Remarks: In some specimens the tips of the spines were broken, thus appearing less pointed than those described by Staplin (p. 48, fig. 15).

Micrhystridium sp. cf. Baltisphaeridium triangulare

Stockmans and Williere

Plate IX, figs. 88, 89

1962 Micrhystridium sp. cf. B. triangulare Stockmans
and Williere, p. 59, pl. 1, fig. 11 text-fig. 16.

Description: Test subtriangular with straight to convex sides and rounded apices. Test ornamented with ten to twenty-five spines which are 10 to 18 microns in length.

Dimensions: Test diameter 15 to 22 microns.

Abundance: Six per cent of acritarch assemblage.

Occurrence: Samples Ha-5-A, B, D; Ha-3-A, B; and Nu-2-D.

Remarks: This species is characterized by the triangular shape of the test. The only difference between this species and Baltisphaeridium triangulare is the size. The latter species, which Stockmans and Williere described from the Upper Devonian of Belgium, has a test size of 22 to 25 microns. Because the Upper Devonian specimens were over 20 microns in test diameter, Stockmans and Williere allocated them to the genus Baltisphaeridium in accordance with Downie and Sarjeant's classification (1963, p. 84). For the same reason the specimens in this study, which are less than 20 microns in test diameter are, therefore, included within the genus Micrhystridium. The reason for the retention of both genera in this study has been discussed previously (p. 149). However, the author believes that the separation on the basis of size of the species described here from the Upper Devonian species (B. triangulare) is purely artificial. It is a situation comparable to that faced Staplin who preferred to remove the 20 micron "arbitrary limit" between the genera Baltisphaeridium and Micrhystridium.

If size is to be used as a criterion it should be identified as a purely artificial construct except in those cases where the size ranges of the extinct entities are fairly well established. At this point in time we are not permitted the latter option, but should continue

to amass data to clarify this situation.

TASMANITES

General statement

The name Tasmanites, which is synonymous with many "sporangites", was first used by Newton (1875) and employed by him to designate punctate, disc-like bodies he found in a marine coal (Permian) from an island near southeastern Australia known as Tasmania.

Newton noted the absence of a triradiate mark, but rejected an algal affinity. It is now generally accepted that Tasmanites are not of terrestrial plant origin. Until recently most workers designated Tasmanites as "relationship unknown." In 1962, Wall demonstrated the similarity between the fossil genus Tasmanites and the modern marine, green alga Pachysphaera pelagica Ostenfeld. Wall noted that the size, shape, and wall thickness of this green alga closely resembled several species of Tasmanites. Even more significant was the presence of punctations and pores in the wall of Pachysphaera pelagica which is also characteristic of Tasmanites. Furthermore, Wall stated (1962, p. 358) that "microchemical test on Pachysphaera gave the same results as those obtained by Eisenack on Tasmanites." As a result

of this investigation by Wall, most workers now include Tasmanites within the Chlorophyceae. Wall did not speculate as to whether his specimens of Pachysphaera represented a vegetative or encysted stage since its reproductive cycle was unknown at the time Wall published his paper. To the author's knowledge, Wall has not published any subsequent articles dealing with Pachysphaera pelagica.

Tasmanites occur throughout the geological column beginning with the Ordovician Period (Eisenack, 1962). They are common and frequently abundant in the Upper Devonian and Lower Mississippian black shales. Winslow pointed out (1962, p. 78) that their abundance may be due to a favorable environment of preservation (oxygen deficient environment) which is usually associated with black shale deposition.

Class CHLOROPHYCEAE

Order TASMANALES Sommer

Family TASMANACEAE (Sommer) Sommer and van Boekel

Genus TASMANITES Newton emend.

Schopf, Wilson, and Bentall

Type species: Tasmanites punctatus Newton, 1875, p. 341, pl. 10, figs. 2, 8. (Reference: Norris and Sarjeant, 1967, p. 57)

Description: Spherical or ellipsoidal bodies which are usually flattened into discs by compression during fossilization which commonly results in folds; 25 to 800 microns in diameter. No haptotypic structures present; surface smooth or rugose; wall single or multilayered, completely or partially penetrated by radial pores (punctae) which vary in size and distribution.

Remarks: Although there are some differences of opinions in regard to the affinity of Tasmanites, the author has used the systematics proposed by Sommer and van Boekel (1967, p. 643). These authors, who have done more work with Tasmanites than any other authors, consider these structures to be algal in origin. These spherical structures, which have previously been included with incertae sedis and still are by some authors (ie., Staplin, et al., 1965), have, according to Wall (1962), living representatives. Wall commented (1962, p. 359):

...the genus Tasmanites is to be regarded as a fossil green alga with close biological affinities to the present marine organisms Pachysphaera pelagica Ostenfeld and other "species" of Pachysphaera. In fact, Pachysphaera is regarded as a living representative of the fossil genus Tasmanites.

Stratigraphic range: Lower Ordovician (Eisenack, 1962) to Recent (Wall, 1962)

Tasmanites sinuosus Winslow

Plate X, figs. 90, 91

1962 Tasmanites sinuosus Winslow, p. 83, pl. 20,
figs. 1 to 3, text-figs. 90, 91.

Description: Spherical; surface smooth to rugose; wall finely punctate, folded, and 2 to 6 microns thick.

Dimensions: 60 to 317 microns.

Abundance: Forty-one per cent of Tasmanites assemblage.

Occurrence: Samples Nu-1-D, F; Nu-2-A, B, C, E, F; Ha-3-B, C, D; and Ha-5-A, D.

Remarks: This species was the most abundant species of Tasmanites in the Hannibal material. Tasmanites sinuosus has previously been reported from the Upper Devonian and Lower Mississippian of Ohio (Winslow, 1962), the Upper Devonian of Missouri (Gupta, 1965), and from the Upper Devonian of Michigan, Ontario, and northern Ohio (Boneham, 1967). In 1956, Sommer reported an occurrence of three specimens of Tasmanites salustiano (Sommer, 1953) from the Middle Devonian of Brazil which appear to be similar to Tasmanites sinuosus. Winslow noted this similarity; however, she stated that, "since geographic separation is great and Sommer's material is older than that described here, it seems best for the present to treat them as distinct." (1962, p. 83)

Geographical and stratigraphic separation are not good bases for distinguishing species and there is good reason to suspect future work may show that Tasmanites

sinuosus and Tasmanites salustianoï are synonymous.

However, the specimens in this study more closely conform to Winslow's diagnosis of Tasmanites sinuosus than to Sommer's diagnosis (which was based on three specimens) and therefore Tasmanites sinuosus is applied here.

Tasmanites huronensis (Dawson) Winslow

Plate X, fig. 92

1871 Sporangites huronensis Dawson, p. 257, text-figs. 1 to 3.

1944 Tasmanites huronensis (Dawson) Schopf, Wilson, and Bentall, pp. 11 to 18.

1962 Tasmanites huronensis (Dawson) Winslow, p. 81, pl. 21, fig. 1a, text-figs. 10, 11.

Description: Spherical; wall smooth, 6 to 11 microns thick with numerous, straight, radial punctae which are up to 1 micron in diameter.

Dimensions: 239 to 265 microns.

Abundance: Nine per cent of Tasmanites assemblage.

Occurrence: Samples Nu-1-D; Ha-3-B, C, D; and Ha-5-D.

Remarks: The specimens of Tasmanites huronensis reported by Winslow from the Upper Devonian of Ohio had a diameter of 200 to 450 microns and a wall thickness of 12 to 35 microns. This species was also reported by Gupta (1965, p. 140, pl. 9, figs. 69, 70, 71) from the Upper Devonian of Missouri.

Tasmanites sp. A

Plate X, fig. 93, Plate XI, fig. 94

Description: Spherical; surface smooth; wall 2 to 7 microns thick with numerous, minute punctae not always easily visible. Infrareticulations delimiting polygonal, circular, or subcircular areas which are 2 to 5 microns in width.

Dimensions: 70 to 100 microns.

Abundance: Twenty-one per cent of Tasmanites assemblage.

Occurrence: Samples Nu-2-C, E, F; Ha-3-C, D; and Ha-5-C.

Remarks: This species is distinguished from other known species of Tasmanites in having an infrareticulate wall. An unidentified form showing "reticulate ornamentation" and having a diameter of 96 microns, described by Achauer (1959, pl. 4, fig. b) from the Upper Devonian of Montana, appears to be similar to the specimens in this study.

Tasmanites sp. B

Plate XI, fig. 95

Description: Spherical; wall reticulate resulting in large lacunae which are circular to subcircular in outline and 5 to 15 microns in diameter.

Dimensions: 95 to 105 microns.

Abundance: Three per cent of Tasmanites assemblage.

Occurrence: Sample Nu-2-E.

Remarks: No punctae were observed in the wall of these

specimens. Tasmanites sp. B differs from Tasmanites sp. A in having larger lacunae.

Tasmanites sp. C

Plate XI, fig. 96

Description: Spherical; wall multilayered and 8 to 12 microns thick. Central area reticulate; lacunae 1 to 7 microns in diameter, polygonal.

Dimensions: 75 to 110 microns.

Abundance: Twelve per cent of Tasmanites assemblage.

Occurrence: Sample Nu-2-E.

Remarks: This species was found in only one sample and is unlike any previously described form of Tasmanites known to the author. Urban's Tasmanites sp. 1 (1960, pl. 6, figs. 9 to 12) is reticulate; however, in his specimens a "pore" was located in the center of each polygon.

Tasmanites sp. D

Plate XII, figs. 97, 98

Description: Spherical; surface smooth; wall finely and densely punctate, 5 to 8 microns thick. One characteristic fold centrally located.

Dimensions: 87 to 109 microns.

Abundance: Eight per cent of Tasmanites assemblage.

Occurrence: Samples Nu-1-D; Nu-2-C; and Ha-3-B, C, D.

Remarks: These specimens appear to represent a discrete

taxonomic entity. They have a small range in wall thickness and in diameter. In the present study specimens of Tasmanites sinuosus having a diameter equivalent to Tasmanites sp. D (87 to 109 microns) have a wall thickness of only 2 to 3 microns.

?Tasmanites sp.

Plate XII, fig. 99

Description: Rhombohedral form with a wall thickness of 10 to 12 microns; wall finely and densely punctate.

Dimensions: Maximum diameter 218 microns.

Abundance: One specimen.

Occurrence: Sample Ha-5-D.

Remarks: Only one specimen was found in the Hannibal material and it may or may not be a type of Tasmanites. This form may belong to Tetraporina which is a rhombohedral shaped genus now assigned to Chlorophyta. Hemer and Nygreen (1967, pp. 183, 184, pl. 1, figs. 5 to 10) reported the occurrence of Tetraporina from the Lower Carboniferous of Saudi Arabia; however, their specimens had a maximum diameter of 67 microns.

Tasmanites sp. cf. euzebioi Sommer

Plate XII, fig. 100

1956 Tasmanites euzebioi Sommer, p. 179, pl. 1,
fig. 8, pl. 2, fig. 4.

Description: Oval; surface smooth; wall 1 to 3 microns thick; very few punctae.

Dimensions: Major diameter 180 to 306 microns.

Abundance: Six per cent of Tasmanites assemblage.

Occurrence: Samples Nu-2-E; and Ha-3-A, C, D.

Remarks: Sommer's specimens had a size range of 370 to 520 microns, which is larger than those in this study. However, the shape and the rarity of punctae are characteristics common to both.

CHART I
VERTICAL DISTRIBUTION AND COMPARISON OF MIOSPORE ASSEMBLAGE
(x indicates presence of species)

	Ha-5 (Hamburg, Ill.)				Nu-2 (Louisiana, Mo.)				Ha-3 (Louisiana, Mo.)			
	A	B	C	D	A	B	C	D	A	B	C	D
1. Leiotriletes												
L. inermis	x	x	x	x	x	x	x	x	x	x	x	x
L. ornatus	x	x	x	x	x	x	x	x	x	x	x	x
2. Punctatisporites												
P. debilis	x	x	x	x	x	x	x	x	x	x	x	x
P. glaber	x	x	x	x	x	x	x	x	x	x	x	x
P. solidus	x	x	x	x	x	x	x	x	x	x	x	x
3. Retusotriletes												
R. incohatius	x	x	x	x	x	x	x	x	x	x	x	x
R. sp. cf. C. semizonalis												
4. Granulatisporites												
G. crenulatus	x	x	x	x	x	x	x	x	x	x	x	x
5. Cyclogranisporites												
C. commodus	x	x	x	x	x	x	x	x	x	x	x	x
6. Verrucosisporites												
V. nitidus	x	x	x	x	x	x	x	x	x	x	x	x
7. Converrucosisporites												
C. parvinodosus	x	x	x	x	x	x	x	x	x	x	x	x
8. Anapiculatisporites												
A. ampullaceus	x	x	x	x	x	x	x	x	x	x	x	x
9. Pustulatisporites												
P. gibberosus	x	x	x	x	x	x	x	x	x	x	x	x
10. Apiculiretusispora												
A. multisetata	x	x	x	x	x	x	x	x	x	x	x	x
11. Grandispora												
G. echinata	x	x	x	x	x	x	x	x	x	x	x	x

CHART I (contd.)

	(Hamburg, Ill.)					(Louisiana, Mo.)								
	Ha-5	Nu-2				Ha-3	Ha-3							
	A	B	C	D	A	B	C	D	E	F	A	B	C	D
12. Convolutispora														
C. sp. cf. C. ampla.														x x
13. Emphanisporites														
E. rotatus														
14. Perotriletes														
(Occurred in sample Ha-1-D)														
P. perinatus	x	x	x	x										x x x
P. spherotriangulatus sp. nov. x														x x
15. Lophozonotriletes														
L. dentatus	x													
L. rarituberculatus														
Lycospora														
L. pseudoannulata	x													
17. Endosporites														
E. micromanifestus														
18. Auroraspora														
A. minutigranulata sp. nov.	x	x	x	x	x	x	x	x	x	x				x x
19. Hymenozonotriletes														
H. lepidophytus														
?Secarisporites sp.														
?Cirratriaradites sp.														
?Lophozonotriletes sp.														
?Densosporites sp.														
?Vallatisporites sp.														
?Spinozonotriletes sp.														
?Lophotriletes plicatus														
?Retusotriletes sp.														
(Occurred in sample Nu-1-D)														

CHART II (contd.)

	(Hamburg, Ill.)					(Louisiana, Mo.)												
	Ha-5					Nu-2					Ha-3							
	A	B	C	D	A	B	C	D	E	F	A	B	C	D	A	B	C	D
B. sp. C.				x														
B. lucidum.				x					x									
B. sp. cf. B. debilispinum.				x					x									
7. <i>Microhystridium</i>																		
M. lunatum.								x										
M. bistchoensis																		
M. sp. cf. B. triangulare								x										

CHART III
 VERTICAL DISTRIBUTION AND COMPARISON OF TASMANITES ASSEMBLAGE
 (Hamburg, Ill.) (Louisiana, Mo.)
 Ha-5 Nu-2 Ha-3
 A B C D A B C D E F A B C D

1. Tasmanites																				
T. sinuosus	x			x	x	x	x													
T. huronensis				x																
T. sp. A.			x																	
T. sp. B.																				
T. sp. C.																				
T. sp. D.																				
?Tasmanites sp.																				
T. sp. cf. euzebioi																				

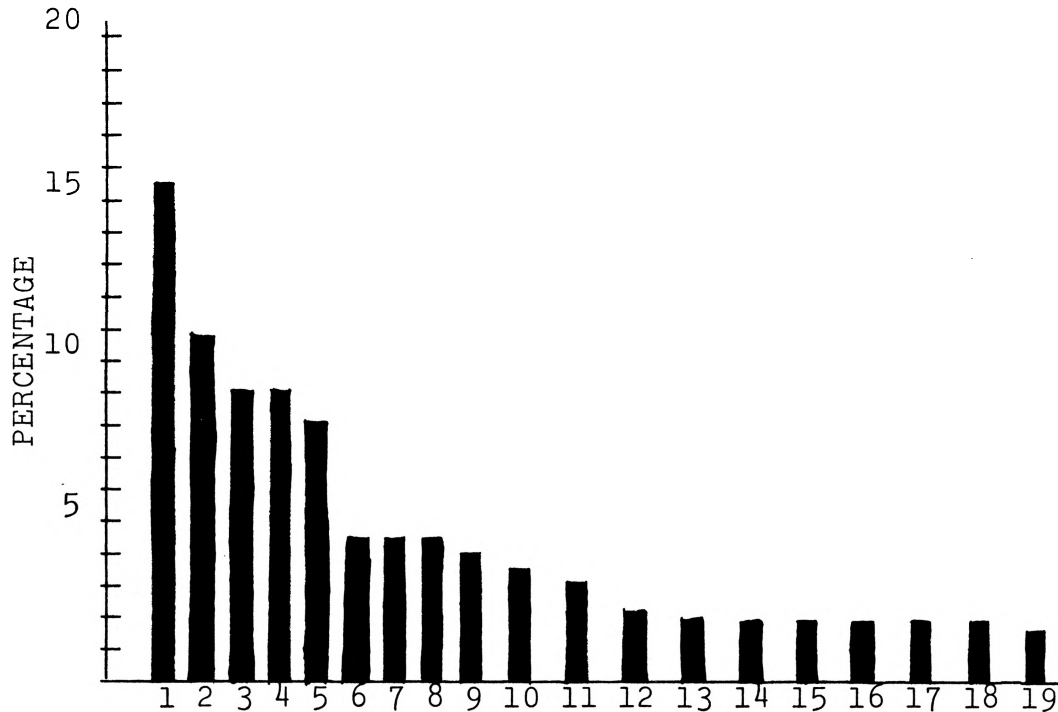


CHART IV
RELATIVE ABUNDANCE OF MIOSPORE ASSEMBLAGE

- 1 = *Auroraspora minutigranulata* sp. nov. (15.4%)
 2 = *Lycospora pseudoannulata* (10.8%)
 3 = *Punctatisporites debilis* (9.0%)
 4 = *Retusotriletes incohatus* (9.0%)
 5 = *Granulatisporites crenulatus* (8.1%)
 6 = *Leiotriletes inermis* (4.5%)
 7 = *Leiotriletes ornatus* (4.5%)
 8 = *Converrucosisporites parvinodosus* (4.5%)
 9 = *Pustulatisporites gibberosus* (4.0%)
 10 = *Punctatisporites glaber* (3.6%)
 11 = *Cyclogranisporites commodus* (3.2%)
 12 = *Apiculiretusispora multiseta* (2.1%)
 13 = *Lophozonotriletes rarituberculatus* (1.9%)
 14 = *Retusotriletes* sp. cf. *R. semizonalis* (1.8%)
 15 = *Anapiculatisporites ampullaceus* (1.8%)
 16 = *Perotriletes perinatus* (1.8%)
 17 = *Lophozonotriletes dentatus* (1.8%)
 18 = *Endosporites micromanifestus* (1.8%)
 19 = *Verrucosisporites nitidus* (1.6%)

Those species having a relative abundance of less than 1% are: *Punctatisporites solidus*, *Grandispora echinata*, *Convolutispora* sp. cf. *C. ampla*, *Emphanisporites rotatus*, *Perotriletes spherotriangulatus* sp. nov., *Hymenozonotriletes lepidophytus*, and the eight genera indeterminate.

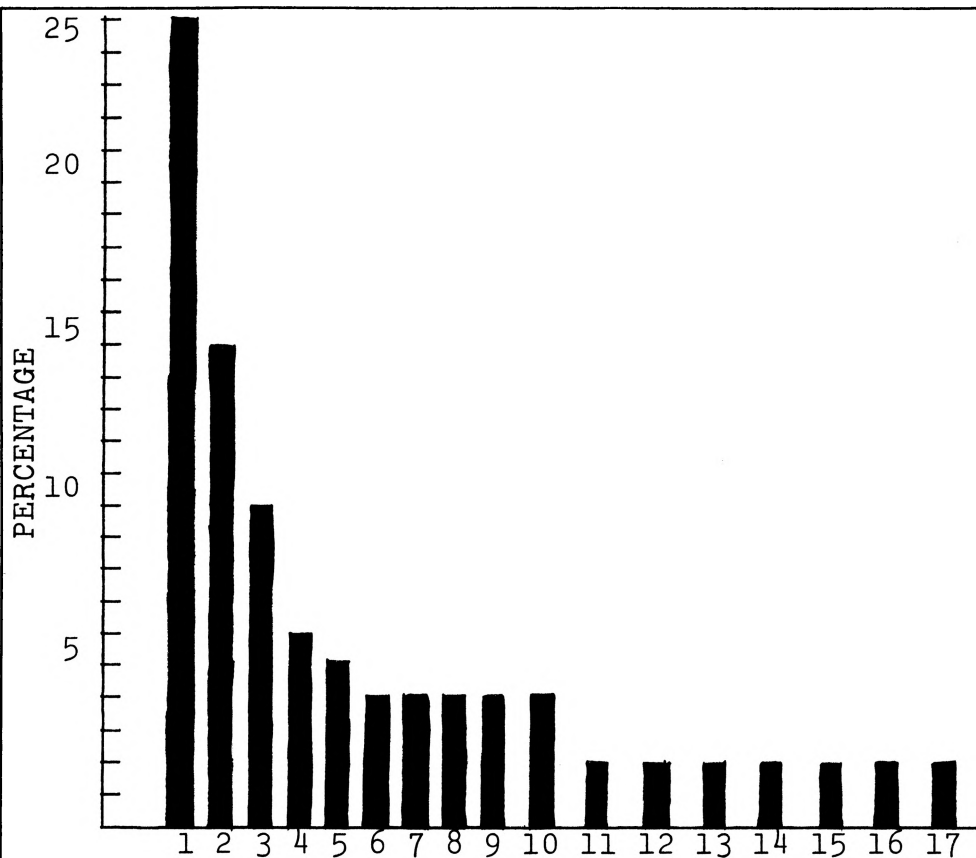


CHART V
RELATIVE ABUNDANCE OF ACRITARCHA ASSEMBLAGE

- 1 = *Leiosphaeridia orbiculata* (25%)
- 2 = *Veryhachium downiei* (15%)
- 3 = *Veryhachium rhomboidium* (10%)
- 4 = *Micrhystridium* sp. cf. *B. triangulare* (6%)
- 5 = *Leiosphaeridia microgranifera* (5%)
- 6 = *Veryhachium formosum* (4%)
- 7 = *Baltisphaeridium* sp. A (4%)
- 8 = *Baltisphaeridium lucidum* (4%)
- 9 = *Micrhystridium lunatum* (4%)
- 10 = *Micrhystridium bistchoensis* (4%)
- 11 = *Leiosphaeridia triangulata* sp. nov. (2%)
- 12 = *Leiosphaeridia major* (2%)
- 13 = *Lophosphaeridium papillatum* (2%)
- 14 = *Dictyotidium* sp. A (2%)
- 15 = *Dictyotidium* sp. B (2%)
- 16 = *Veryhachium europaeum* (2%)
- 17 = *Baltisphaeridium* sp. cf. *B. debilispinum* (2%)

Those species having a relative abundance of less than 1% are: *Leiosphaeridia* sp. A; *L. fastigatirugosum*; *L. sp. B*; *Lophosphaeridium microsaeetosum*; *Cymatisphaera* sp.; *Veryhachium brevitrispinum*; *V. sp. A*; *V. sp. B*; *Baltisphaeridium* sp. A, and *B. sp. C*.

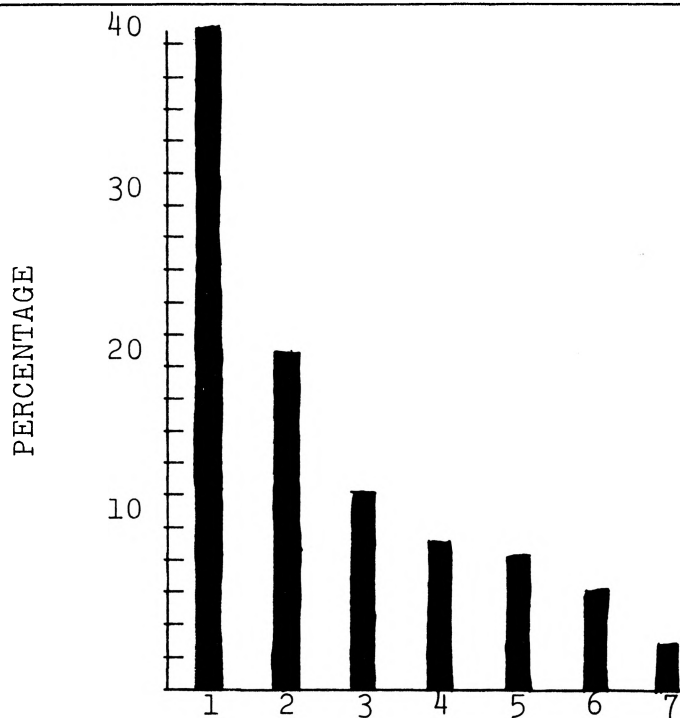


CHART VI
RELATIVE ABUNDANCE OF TASMANITES ASSEMBLAGE

- 1 = *Tasmanites sinuosus* (41%)
- 2 = *Tasmanites* sp. A (21%)
- 3 = *Tasmanites* sp. C (12%)
- 4 = *Tasmanites huronensis* (9%)
- 5 = *Tasmanites* sp. D (8%)
- 6 = *Tasmanites* sp. cf. *euzebioi* (6%)
- 7 = *Tasmanites* sp. B (3%)

Only one specimen of ?*Tasmanites* sp. was present.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Introductory statement

Before discussing and comparing the Hannibal microflora assemblage with other assemblages, it should be pointed out that variation in assemblages can result from human error during the collection and processing of samples. In reviewing some of the pitfalls of palynology, Cross (1964, p. 12) made the following statement:

One of the most significant weaknesses in modern palynologic studies is the difference in results derived from the study of the same samples or similar samples by different laboratories. Many of the differences are the result of processing the samples in different ways. Many are the result of operator error or competence. Some are the result of improper sampling or contamination. Ineffective or careless laboratory technique and poorly collected samples together, have imposed great limitations on the quality and results of many studies.

Throughout this investigation the author has been keenly aware of and on guard against the possibility of bias introduction. Extreme care was taken in the collection and processing, as described in the section on Materials and Methods, of all samples used. Consequently, the author is of the opinion that the fossils described herein constitute an accurate record of the microflora preserved in that portion of the Hannibal Formation taken into account in this study.

Composition of the Assemblage

The majority of the miospores described in this study were recovered from the lower black shale unit of the Hannibal Formation. The samples collected from the upper portion of the formation, which is predominantly siltstone, had a very low miospore content and in some instances were devoid of miospores. According to Cross (1964) approximately fifty per cent of siltstone samples contain a miospore assemblage adequate for study.

Conditions which can influence the presence or absence of miospores are (Cross, 1964, p. 7):

rate of accumulation of sediment; distance from life environment or source; mode of transportation; and resistance to destruction by alternate wetting and drying, oxidation, biochemical or bacterial action or other processes of fossilization.

All outcrops produced at least a few miospores with the exception of locality Ha-2. The Hannibal at this locality (see figs. 2, 4), which was collected just below the Burlington Limestone, was completely devoid of miospores. The outcrops which were most prolific in miospore, acritarch, and Tasmanites content were locality Ha-3 (figs. 5, 7) and locality Nu-2 (figs. 15, 17). It is for this reason that these outcrops are used for the charts (Charts I and II) which show the occurrence and vertical distribution of the miospores.

The Miospore Assemblage. The Hannibal miospore assemblage consisted of twenty-five genera and thirty-three species. Five species were new, two of which the author named, and there were eight types of genera indeterminate.

The most prevalent miospore type in the Hannibal Formation was the azonate ornamented forms (grana, warts, spines, etc.) which constituted approximately 26 per cent of the total miospore assemblage. These azonate ornamented forms were represented in this study by the following genera: Cyclogranisporites, Convolutispora, Converrucosisporites, Verrucosisporites, Granulatisporites, Pustulatisporites, Anapiculatisporites, and Apiculiretusispora. Playford noted (1963, p. 674) that kinds of miospores such as these were most likely produced by fern-like plants.

The simple laevigate genera Leiotriletes, Retusotriletes, and Punctatisporites, which according to Playford (1963, p. 674) belong to either the Bryophyta, Psilophytales, Equisetales, or the Filicales, were present in an abundance of 32 per cent.

The saccate spores, such as Auroraspora and Endosporites indicate the presence of lycopods, (Chaloner, 1967). These genera represented 21 per cent of the miospore assemblage.

The cingulate spore genus Lycospora has a lycopod affinity (Balbach, 1966) and the genus Lophozonotriletes may also have a lycopod affinity (Playford, 1963). These two genera represented 17 per cent of the total miospore assemblage.

Therefore, on the basis of the frequency and the known affinities of the above miospore types it would appear that the flora which produced the miospores preserved in the Hannibal Formation consisted primarily of ferns and lycopods.

The nine genera which were most abundant in the Hannibal Formation and which constituted approximately 80 per cent of the total assemblage are: Auroraspora (one species) 15.4 per cent, Punctatisporites (three species) 12.6 per cent, Retusotriletes (two species) 10.8 per cent, Lycospora (one species) 10.8 per cent, Leiotriletes (two species) 9 per cent, Granulatisporites (one species) 8.1 per cent, Converrucosisporites (one species) 4.5 per cent, Pustulatisporites (one species) 4.0 per cent, and Lophozonotriletes (two species) 3.7 per cent.

The most abundant species (see Chart IV) in the Hannibal material was Auroraspora minutigranulata sp. nov. This species had a relative abundance of 15.4 per cent. No similar species has been described from the Lower

Mississippian of North America; however, Auroraspora macra Sullivan (1968, p. 124, pl. 27, figs. 6-10) which was recorded from the Lower Tournaisian of Scotland, is similar to Auroraspora minutigranulata sp. nov. One major difference between these two species is size. The Hannibal species has a diameter of 24 to 35 microns, whereas Sullivan's species had a size range of 48 to 68 microns. However, as discussed on page 113, the erection of the new species was founded on wall ornamentation and not especially on size difference.

The second most abundant species was Lycospora pseudoannulata Kosanke, 1950. The majority of these specimens were recovered from one subsurface sample of the Nutwood. However, additional specimens occurred at localities Ha-5, Nu-2, and Ha-3. This species represented 10.8 per cent of the total miospore assemblage. The presence of this species in the Lower Mississippian material is significant because this is the earliest record of its occurrence. It has been previously recorded from the Pennsylvanian of Illinois (Kosanki, 1950) and from the Upper Mississippian of Kentucky (Hoffmeister, et al., 1955). The presence of this species also indicates that the arborescent lycopod genus Lepidodendron was most surely present since species of Lycospora have repeatedly been recovered from the cones of Lepidodendron (Playford,

1963).

The third most abundant species was Retusotriletes incohatus Sullivan, 1964, while Punctatisporites debilis Hacquebard, had the same relative abundance of 9.0 per cent. The presence of the former species is significant because Retusotriletes is typically a Devonian genus (Playford, 1963, p. 10). However, this species occurred abundantly in the Lower Carboniferous of Britain (Sullivan, 1964). Its presence in the Lower Mississippian probably represents a remnant or holdover of a Devonian flora. Punctatisporites debilis, on the basis of presently available reports, appears to be a typically Lower Mississippian species and has been recorded elsewhere from Nova Scotia (Hacquebard, 1957 and Playford, 1963), and from the Lower Carboniferous of England (Butterworth, 1967).

One other species of Retusotriletes was recorded from the Hannibal; however, it is a minor element representing only 1.8 per cent of the total miospore assemblage. The species Retusotriletes sp. cf. semizonalis McGregor, occurred in only two samples.

Two other species of Punctatisporites were present in the Hannibal material. Punctatisporites glaber (Naumova) Playford, occurred in several samples and had a relative abundance of 3.6 per cent. However, the presence of Punctatisporites glaber is not significant. Its

geological record dates from the Upper Devonian (Gupta, 1965) and it occurs throughout the Lower Carboniferous (Playford, 1963). Punctatisporites solidus Hacquebard, was rare in the Hannibal material at hand (less than 1 per cent of miospore assemblage) and was present in only three samples. Hacquebard recorded this species originally from the Lower Mississippian of Canada. It has recently been recorded from the Upper Mississippian of Oklahoma (Felix and Burbridge, 1967).

Granulatisporites crenulatus Playford, had a relative abundance of 8.1 per cent. Although this species is fourth in order of abundance, it was the most widely occurring species since it was present in most all samples examined in this study. Playford reported that Granulatisporites crenulatus was abundant in one sample and rare in three other samples of the Lower Mississippian Horton Group (Nova Scotia).

The two species of Leiotriletes (Leiotriletes inermis (Waltz) Ishchenko and Leiotriletes ornatus Ishchenko) were equally represented, both having a relative abundance of 4.5 per cent. Both of these species have been recorded from the Lower Carboniferous materials of Spitsbergen (Playford, 1961), while Leiotriletes ornatus has also been reported from the Lower Carboniferous materials of Britain (Sullivan, 1964).

Converrucosisporites parvinodosus Playford, also had an abundance of 4.5 per cent. Playford reported a rare occurrence of this species in five samples of the Horton Group of Nova Scotia (Lower Mississippian).

Pustulatisporites gibberosus Playford, which is believed to be restricted to the Lower Mississippian (Sullivan, 1968, p. 127) represented 4.0 per cent of the total Hannibal Miospore assemblage reported here.

Perotriletes spherotriangulatus sp. nov. had an abundance of less than 1 per cent. Urban described specimens (Genus A, sp. 4, 1960) which, in the author's opinion, belong to this species. The true distribution and occurrence of this species may be difficult to determine because in some specimens the delicate exoexine is torn. Urban noted that in some specimens the exoexine was missing completely. This would probably result in the spore being classified within another genus. The other species of Perotriletes present in the Hannibal Formation was Perotriletes perinatus Hughes and Playford, which had a relative abundance of 1.8 per cent. This species had a wider occurrence than Perotriletes spherotriangulatus sp. nov. since it was present in eight samples. Although Perotriletes perinatus was originally recorded from the Lower Mississippian (Hughes and Playford, 1962), it is not restricted to the Lower Mississippian

strata, and has since been recorded from the Visean (Upper Mississippian) of Scotland (Sullivan and Marshall, 1960) and from the Upper Mississippian of Oklahoma (Felix and Burbridge, 1967).

The presence of Lophozonotriletes rarituberculatus (Luber) Kedo in this Hannibal material is significant since it was thought to be restricted geographically to Spitsbergen and Russia (Sullivan, 1967). This is the first reported occurrence of this species from the Lower Mississippian of North America. However, Streel (1966) has recently recorded Lophozonotriletes rarituberculatus from the Tournaisian of Belgium. This species was not abundant in the Hannibal material (1.9 per cent); however, it occurred in six different samples. One other species of Lophozonotriletes was present in the Hannibal Formation. Lophozonotriletes dentatus Hughes and Playford, occurred in seven samples and with approximately the same frequency (1.8 per cent) as Lophozonotriletes rarituberculatus (1.9 per cent). As with Lophozonotriletes rarituberculatus, Lophozonotriletes dentatus is also known from the Lower Carboniferous of Spitsbergen (Playford, 1962), and the Upper Devonian of Canada (McGregor and Owens, 1966).

Cyclogranisporites commodus Playford, had a relative abundance of 3.2 per cent and is known from the Lower

Mississippian of Canada (Playford, 1963) and from the Lower Carboniferous of England (Butterworth, 1967).

Grandispora echinata Hacquebard, and Endosporites micromanifestus Hacquebard, were first recorded from the Lower Mississippian of Canada by Hacquebard (1957).

Since that time the known stratigraphic and geographic ranges of these two taxa have widened. For example, both have been reported from the Upper Mississippian of the British Visean (Sullivan and Marshall, 1960) and from the Upper Mississippian of Oklahoma (Burbridge and Felix, 1967). Endosporites micromanifestus has been recorded from the Devonian of Britain (Richardson, 1967), and Grandispora echinata is known from the Upper Devonian of Australia. In the Hannibal material Endosporites micromanifestus occurred in five samples and had a relative abundance of 1.8 per cent. Grandispora echinata was present in only three samples and constituted less than 1 per cent of the total miospore assemblage.

Hymenozonotriletes lepidophytus Kedo had a rare occurrence in the Hannibal material (less than 1 per cent). Owens and Streel (1967) consider the occurrence of this species, which was originally recorded from the Upper Devonian of Russia (Kedo, 1957), to be significant. These authors believe it is an important index species having a restricted occurrence in the Upper Devonian.

Geographically, the species is widely dispersed and has been recorded from the Upper Devonian of Russia (Kedo, 1957), Belgium (Streel, 1966), Britain (Neves and Dolby, 1967), Australia (Balme and Hassell, 1962 as Leiozonotriletes naumovae), Ohio (Winslow, 1962 as Endosporites lacunosus), Libya (Wray, 1964), and Canada (McGregor and Owens, 1966). In regard to the occurrence of Hymenozonotriletes lepidophytus in the Lower Mississippian and Upper Devonian of Ohio (Winslow, 1962), Owens and Streel made the following comment (1967, p. 147):

The occurrence of this complex in both the Upper Devonian and Lower Mississippian rocks of Ohio is anomalous when compared with its restricted distribution in the Upper Famennian or Strunian in other parts of the world.

Furthermore, they suggested that Winslow was working with Upper Devonian rocks only and that the boundary between the Devonian and Mississippian systems did not occur where it was designated by Winslow. If Owens and Streel are correct, then this would perhaps explain the absence of similarity in the miospores from Ohio and those of this study from the Lower Mississippian Hannibal Formation.

Verrucosisporites nitidus Playford, was also rare (1.6 per cent) in the Hannibal material and occurred in five samples. Sullivan also recorded this species from the Lower Carboniferous of Britain (1964) as Verrucosisporites grumosus.

Anapiculatisporites ampullaceus (Hacquebard)

Playford, which was recorded from the Lower Mississippian rocks of Canada (Playford, 1963), occurred in only four Hannibal samples and had a relative abundance of 1.8 per cent.

Apiculiretusispora multisetata (Luber) Butterworth, occurred in three samples and had a relative abundance of 2.1 per cent. Its previous record is from the Lower Carboniferous of Russia (Luber and Waltz, 1939), the Lower Carboniferous of Spitsbergen (Playford, 1962), and from the Lower Carboniferous of Britain (Butterworth, 1967).

There were eight types of miospores, each having only one or two representatives, which the author questionably allocated to eight genera (genera indeterminate). These types were: ?Secarisporites sp., ?Cirratriadites sp., ?Lophozonotriletes cristifer, ?Densosporites sp., ?Vallatisporites sp., ?Spinozonotriletes sp., ?Lophotriletes plicatus, and ?Retusotriletes sp.

The presence of a questionable type referable to the genus Vallatisporites is significant in two respects. First, one species of this genus (Vallatisporites vallatus) is listed by Sullivan (1967) as an important index species (Basal Mississippian). Secondly, it is significant that this genus was abundant in the Upper

Devonian of Oklahoma but rare in the materials studied here. Urban (1960) recorded four species from this Upper Devonian strata (Woodford shale). Gupta, however, recorded only one species of Vallatisporites from the Upper Devonian of Missouri. This species, Vallatisporites missouriensis Gupta (1965, p. 130), occurred in only one sample of the Saverton Formation material he used.

The presence of this genus in the Upper Devonian of the mid-continent of the United States (Oklahoma and Missouri), the absence of the genus from the Lower Mississippian of the same area (Missouri), and its presence in the Lower Mississippian of Nova Scotia and Britain is a perplexing problem. One possible explanation is that the plants that produced Vallatisporites existed in the mid-continent area of the United States during the latter part of the Devonian Period. Then, due to some geological event occurring between the Devonian and Mississippian periods (perhaps a climatic or topographic change), they were forced to migrate to those areas where they persisted and contributed spores which are now reported as abundant in Lower Mississippian strata. Those area (northeast North America and Europe) may have represented newly created provinces conducive to occupancy by the Vallatisporites spore producing plants.

The above explanation of the absence of this taxon

from the Lower Mississippian materials at hand is conjecture, but the author is convinced that the genus Vallatisporites is not an important part of the Lower Mississippian Hannibal miospore assembly, and that its absence is not due to "ineffective or careless" collecting or laboratory technique.

The Acritarch Assemblage. The Hannibal material studied contained a large number and variety of acritarchs. The assemblage consisted of seven genera and twenty-seven species. Twelve species are new, one of which was named here. The author plans to continue investigating the Lower Mississippian acritarchs; therefore, new names will be applied at a later date.

The most abundant genus was Leiosphaeridia. This genus was represented by seven species and constituted 35 per cent of the total acritarch assemblage.

The genus Veryhachium had seven species and represented 33 per cent of the total acritarch assemblage. It is significant to note that these two genera (Leiosphaeridia and Veryhachium) composed 68 per cent of the total acritarch assemblage.

The genus Micrhystridium was the third most abundant, having three species and a relative abundance of 14 per cent.

There were five species of the genus Baltisphaeridium;

however, they represented only 11 per cent of the total assemblage.

The three least prevalent genera were Lophosphaeridium, Dictyotidium, and Cymatiosphaera. Lophosphaeridium had two species and constituted 2 per cent of the assemblage. Dictyotidium also had two species; however, it constituted 4 per cent of the assemblage. Cymatiosphaera had only one species and was not significant numerically, constituting less than 1 per cent of the total assemblage.

The most abundant and widely occurring species (see Chart I and V) was Leiosphaeridia orbiculata (Staplin) Downie and Sarjeant, which represented 25 per cent of the total acritarch assemblage. This species was originally described from the Upper Devonian of Canada (Staplin, 1961). The next most abundant species of this genus was Leiosphaeridia microgranifera (Staplin) Downie and Sarjeant, which represented 5 per cent of the total assemblage. Leiosphaeridia major (Staplin) Downie and Sarjeant, occurred in several samples, but was not abundant in any one sample and constituted only 2 per cent of the total assemblage. Leiosphaeridia triangulata sp. nov. occurred in only two samples, but was abundant in those samples and represented approximately 2 per cent of the total assemblage. Leiosphaeridia sp. A,

Leiosphaeridia sp. B, and Leiosphaeridia fastigatirugosum (Staplin) Downie and Sarjeant did not occur widely and each represented less than 1 per cent of the total assemblage.

Of the seven species of the genus Veryhachium recorded here, Veryhachium downiei Stockmans and Williere, and Veryhachium rhomboidium Downie, both had a wide ranging occurrence vertically and horizontally. The former had a relative abundance of 15 per cent while Veryhachium rhomboidium had a relative abundance of 10 per cent. These two species have a long geological history and have been recorded from the Silurian to the Permian Period (Wall and Downie, 1963); consequently, their appearance here cannot be considered important stratigraphically. Veryhachium brevitrispinum Staplin is similar to Veryhachium downiei in shape and form; however, the surface is finely granulate. Veryhachium brevitrispinum was not abundant (less than 1 per cent) and occurred in only two samples. The remaining species of Veryhachium were not abundant or widely occurring. Veryhachium europaeum Stockmans and Williere occurred in four samples and constituted 2 per cent of the total assemblage. Veryhachium formosum Stockmans and Williere was more prevalent and represented 4 per cent of the total assemblage. Veryhachium sp. A, and Veryhachium

sp. B were minor elements constituting less than 1 per cent of the total assemblage.

Micrhystridium lunatum Stockmans and Williere, which occurred in several samples and had a relative abundance of 4 per cent is an easily recognized form due to its unique shape. This species may be a potential Lower Mississippian index species. Its occurrence in the Hannibal Formation material studied here, and in the Lower Tournaisian (Mississippian) of Belgium (Stockmans and Williere, 1960) are the only known occurrences to date. The other two species of Micrhystridium occurred in several samples. Micrhystridium bistchoensis Staplin, had a relative abundance of 4 per cent and Micrhystridium sp. cf. Baltisphaeridium triangulare Stockmans and Williere represented 6 per cent of the total assemblage.

There were five species of Baltisphaeridium in the Hannibal material. Baltisphaeridium sp. A and Baltisphaeridium lucidum (Deunff) Downie and Sarjeant, were the most widely occurring and abundant species of this genus; each having a relative abundance of 4 per cent. Baltisphaeridium sp. cf. B. debilispinum Wall and Downie was less prevalent and constituted only 2 per cent of the total assemblage. Baltisphaeridium sp. B, and Baltisphaeridium sp. C were restricted to two samples,

and represented less than 1 per cent of the acritarch assemblage.

The genus Lophosphaeridium was represented by two species. Lophosphaeridium microsaetosum Staplin new. comb. had a restricted occurrence (three samples) and a relative abundance of less than 1 per cent. Lophosphaeridium papillatum Staplin new. comb. was more abundant (2 per cent) than was Lophosphaeridium microsaetosum and also occurred in more samples (6 versus 3).

The two species of Dictyotidium were equally represented in the Hannibal material; each having a relative abundance of 2 per cent. Dictyotidium sp. A occurred in five samples and Dictyotidium sp. B occurred in six samples.

The Tasmanites Assemblage. The occurrence of the genus Tasmanites in the Hannibal Formation under study here was restricted to the lower black shale. Tasmanites sinuosus Winslow, was the most prevalent and widely occurring species (see Charts III and VI) and represented 41 per cent of the total Tasmanites assemblage.

Tasmanites sp. A was the next most abundant species constituting 21 per cent of the assemblage. The species was present in five samples.

Tasmanites sp. C, the third most abundant species, was present in only one sample. However, it constituted

12 per cent of the total assemblage.

Tasmanites huronensis (Dawson) Winslow was recorded from only four samples and represented 9 per cent of the total assemblage.

Tasmanites sp. D had a relative abundance of 8 per cent and was found in five samples.

Tasmanites sp. cf. T. euzebioi Sommer occurred in four samples and represented 6 per cent of the total assemblage.

Tasmanites sp. B occurred in one sample and was not abundant (3 per cent).

?Tasmanites sp. was represented by one specimen.

Comparison with other Assemblages

Comparison of Miospore Assemblage. In comparing this Hannibal miospore assemblage with previously described assemblages, the greatest degree of similarity was found to be with the assemblage of the Lower Mississippian Horton Group of eastern Canada (Nova Scotia). Hacquebard (1957) was the first to describe and illustrate the miospores present in this non-marine sequence of strata. Hacquebard's assemblage, based on two coal samples, consisted of nineteen genera and fifty species of miospores. Of the fifty species described by Hacquebard, the following six are also in the Hannibal material:

Punctatisporites debilis Hacquebard, Punctatisporites

solidus Hacquebard, Anapiculatisporites ampullaceus (Hacquebard) Playford, Pustulatisporites gibberosus (Hacquebard) Playford, Endosporites micromanifestus Hacquebard, and Grandispora echinata Hacquebard.

In 1963, Playford reported an assemblage of miospores from the Horton Group. Playford's investigation was more thorough than Hacquebard's since it was based on samples from the entire sequence of strata in the group rather than on just two coal samples. Consequently, Playford reported twenty-eight genera and fifty-three species of miospores. Eleven of these fifty-three species of miospores were also present in this study of the Hannibal Formation. They were as follows: Punctatisporites debilis Hacquebard, Punctatisporites solidus Hacquebard, Granulatisporites crenulatus Playford, Cyclogranisporites commodus Playford, Verrucosisporites nitidus Playford, Converrucosisporites parvinodosus Playford, Anapiculatisporites ampullaceus (Hacquebard) Playford, Pustulatisporites gibberosus Playford, Grandispora echinata Hacquebard, Perotriletes perinatus Playford and Hughes, and Endosporites micromanifestus Hacquebard.

Butterworth (1967) described twenty-seven genera and forty-three species of miospores from the Lower Carboniferous rocks of northwest England. There were six species common to both this Hannibal assemblage and

Butterworth's assemblage. These species are: Punctatisporites debilis Hacquebard, Retusotriletes incohatus Sullivan, Cyclogranisporites commodus Playford, Apiculiretusispora multisetata (Luber) Butterworth, Endosporites micromanifestus Hacquebard, and Perotriletes perinatus Hughes and Playford.

In Playford's two part publication dealing with the Lower Carboniferous miospores of Spitsbergen, 115 species were recorded. Eight of these were also present in the Hannibal Formation. These species are: Leiotriletes inermis (Waltz) Ishchenko, Leiotriletes ornatus Ishchenko, Punctatisporites glaber (Naumova) Playford, Apiculiretusispora multisetata (Luber) Butterworth (recorded by Playford as Acanthotriletes multisetus (Luber) Potonie and Kremp), Perotriletes perinatus Hughes and Playford, Endosporites micromanifestus Hacquebard, Lophozonotriletes rarituberculatus (Luber) Kedo, and Lophozonotriletes dentatus Hughes and Playford.

Recently (1968) Sullivan described an assemblage of miospores from the Lower Tournaisian (Lower Mississippian) Cementstone Group of Scotland. Sullivan noted that at some localities the Cementstone Group occurred just above the Upper Old Red Sandstone (Devonian) separated by an unconformity. Of the twenty-two species (eight new) reported by Sullivan, four were also present

in this report of the spores of the Hannibal. These four are: Pustulatisporites gibberosus (Hacquebard) Playford, Grandispora echinata Hacquebard, Retusotriletes incohatus Sullivan, and Endosporites micromanifestus Hacquebard. Auroraspora macra Sullivan is similar, but larger than Auroraspora minutigranulata sp. nov.

Sullivan's 1964 publication on the miospores of the Lower Carboniferous (Lower Mississippian) shales from the Forest of Dean Basin (England) was the first publication describing Tournaisian miospores from Europe. Sullivan found that the assemblage was dominated by circular laevigate spores belonging to the genera Retusotriletes and Punctatisporites. He described fifteen species of miospores, three of which were also present in the Hannibal material. These three are: Leiotriletes ornatus Ishchenko, Retusotriletes incohatus Sullivan, and Verrucosisporites nitidus (Naumova) Playford (recorded by Sullivan as Verrucosisporites grumosus (Naumova) Sullivan). Sullivan also recorded an abundance of Punctatisporites irrasus Hacquebard, which differs from Punctatisporites debilis Hacquebard in having a larger diameter.

Streel (1966) reported a miospore assemblage from the Lower Tournaisian (Lower Mississippian) of Belgium. The lower part of this strata is now believed to be Upper

Devonian (Owens and Streel, 1967). Those species recorded by Streel which are also present in the Hannibal Formation are: Retusotriletes incohatus Sullivan, Lophozonotriletes rarituberculatus (Luber) Kedo, and Hymenozonotriletes lepidophytus Kedo.

Only two species of the miospore assemblage described by Winslow (1962) from the Upper Devonian and Lower Mississippian of Ohio were present in the Hannibal Formation. These two species are: Hymenozonotriletes lepidophytus Kedo (recorded by Winslow as Endosporites lacunosus Winslow), and Emphanisporites rotatus McGregor (recorded by Winslow as Radforthia radiata Winslow). This non-similarity is anomalous in light of the similarity between the Lower Mississippian Missouri - Illinois miospore assemblage and the Lower Mississippian Nova Scotia miospore assemblage. In light of Sullivan's paleolatitudes, which are discussed in greater detail on page 211, Missouri and Ohio occupied the same Kinderhookian paleolatitude and should have supported somewhat similar vegetation. Tschudy (1964, p. 21) suggested that differences in spore assemblage such as that between the Lower Mississippian Ohio assemblage and the Lower Mississippian Missouri - Illinois assemblage could be due to different drainage systems, and

thus, two different miospore source areas. The example he cited to support this contention was the Ohio River system draining a deciduous forest area versus the Red River and Arkansas River systems draining the southwest plain areas. If these two drainage systems flowed into different basins, the sediment in each basin, though contemporary, would contain a vastly different pollen assemblage. Perhaps this best explains the absence of similarity in the Lower Mississippian of Ohio and Missouri - Illinois miospore assemblage.

In comparing the Hannibal assemblage with the two known Upper Devonian miospore investigations from Missouri (Gupta, 1965) and Oklahoma (Urban, 1960) there appears to be greater similarity with the Upper Devonian of Oklahoma than with the Upper Devonian of Missouri. There were two species recorded by Gupta which are also present in the Hannibal Formation. These species are:

Punctatisporites glaber (Naumova) Playford, and Leio-triletes inermis (Waltz) Ishchenko. In the author's opinion there are five species common to both the Hannibal Formation and the Upper Devonian of Oklahoma. These species are: Endosporites micromanifestus Hacquebard (recorded by Urban as Hymenozonotriletes sp. 1), Grandispora echinata Hacquebard (recorded by Urban as

Hymenozonotriletes sp. 2), Lophozonotriletes dentatus Hughes and Playford (recorded by Urban as Lophozonotriletes sp. 1), Perotriletes perinatus Hughes and Playford (recorded by Urban as Genus A, sp. 1), and Perotriletes spherotriangulatus sp. nov. (recorded by Urban as Genus A, sp. 4).

Comparison of Acritarch Assemblage. The greatest degree of similarity between this Hannibal acritarch assemblage and previously described assemblages was with the one described by Staplin (1961) from the Upper Devonian of Canada. The following ten species were common to both assemblages: Leiosphaeridia orbiculata (Staplin) Downie and Sarjeant, Leiosphaeridia microgranifera (Staplin) Downie and Sarjeant, Veryhachium downiei Stockmans and Williere (recorded by Staplin as Veryhachium sp. cf. H. trispinosum Eisenack), Leiosphaeridia major (Staplin) Downie and Sarjeant, Leiosphaeridia fastigatirugosum (Staplin) Downie and Sarjeant, Lophosphaeridium microsaetosum Staplin new. comb., Micrhystridium bistchoensis Staplin, Veryhachium rhomboidium Downie (recorded by Staplin as Veryhachium minor Staplin), and Veryhachium brevitrispinum Staplin.

Stockmans and Williere (1965 and 1966) described the acritarchs present in the Lower Tournaisian (Lower

Mississippian) of Belgium. They have reported thirty-three species belonging for the most part to the genera Veryhachium, Micrhystridium, and Baltisphaeridium. Three of the thirty-three species are also present in the Hannibal. These species are: Veryhachium downiei Stockmans and Williere, Baltisphaeridium lucidum Stockmans and Williere, and Micrhystridium sp. cf. B. triangulare Stockmans and Williere.

Stockmans and Williere in previous publications on Upper Devonian acritarchs of Belgium have described numerous specimens. Three of their Upper Devonian acritarch species are present in the Hannibal Formation. These species are: Veryhachium downiei Stockmans and Williere, Veryhachium formosum Stockmans and Williere, and Veryhachium europaeum Stockmans and Williere.

There was no similarity between the Hannibal acritarch assemblage and that described by Hemer and Nygreen from the Lower Carboniferous of Saudia Arabia with the exception of the one species Leiosphaeridia orbiculata (Staplin) Downie and Sarjeant. This was also the only acritarch species common to both the Hannibal and the Upper Devonian of the Grassy Creek and Saverton Formations of Missouri (Gupta, 1965). Gupta reported this species as Leiosphaeridia glaber Gupta.

Two species present in the Upper Devonian and Lower

Mississippian of Ohio (Winslow, 1962) were also present in the Hannibal Formation. These two species are:

Veryhachium downiei Stockmans and Williere (recorded by Winslow as Hystrichosphaeridium trispinosum Eisenack) and Micrhystridium bistchoensis Staplin (recorded by Winslow as Micrhystridium sp. A).

The acritarch species which appear to be common to both the Hannibal and the Woodford (Upper Devonian of Oklahoma) assemblages are: Cymatiosphaera sp. (similar to Cymatiosphaera sp. 3 Urban), Baltisphaeridium lucidum Stockmans and Williere (similar to Hystrichosphaeridium sp. 9 Urban), Baltisphaeridium sp. A (similar to Hystrichosphaeridium sp. 1 Urban), and Baltisphaeridium sp. B (similar to Hystrichosphaeridium sp. 6 Urban).

Comparison of Tasmanites Assemblage. In comparing this Hannibal Tasmanites assemblage with other assemblages only two species have previously been described.

Tasmanites sinuous Winslow and Tasmanites huronensis (Dawson) Winslow, have been recorded from the Upper Devonian and Lower Mississippian of Ohio (Winslow, 1962), Upper Devonian of Missouri (Gupta, 1965), and from the Upper Devonian of Michigan, Ontario, and northern Ohio (Boneham, 1967). Tasmanites sp. cf. T. euzebioi Sommer appears to be similar to the species described by Sommer from Brazil. However, Tasmanites euzebioi is larger than

the specimens in the Hannibal Formation. It is uncertain at this time; however, it appears that the other five species of Tasmanites present in the Hannibal may be restricted to the Mississippian Period since they are unlike known Upper Devonian forms.

Age of the Hannibal Assemblages. The miospore assemblage present in the Hannibal indicates that the age of the Hannibal is very Early Mississippian. In addition to the presence and dominance of typically Lower Mississippian miospores, which indicate that age for the Hannibal Formation, the rare occurrence of a few typically Upper Devonian miospore species and the similarity between the Hannibal acritarch assemblage and the Upper Devonian acritarch assemblage of Canada are indicative of a time proximity to the Devonian Period.

The miospore species which are normally restricted to Devonian sediment, but which are present in the Hannibal are: Hymenozonotriletes lepidophytus Kedo, Emphanisporites rotatus McGregor, plus the genus Retusotriletes. Although Retusotriletes is normally characteristic of and restricted to the Devonian Period, one species belonging to this genus, Retusotriletes incohatus, is a typically Lower Mississippian species and has been recorded from numerous sediments of that age. The species which are known as of now to be

restricted to the Lower Mississippian Period and which are present in the Hannibal material are: Punctatisporites debilis Hacquebard, Retusotriletes incohatus Sullivan, Pustulatisporites gibberosus (Hacquebard) Playford, Auroraspora minutigranulata sp. nov., Granulatisporites crenulatus Playford, Converrucosisporites parvinodosus Playford, and Cyclogranisporites commodus Playford.

Species present in the Hannibal material which are known to be common in, but not restricted to, Lower Mississippian strata are: Endosporites micromanifestus Hacquebard, Grandispora echinata Hacquebard, Lophozonotriletes dentatus Hughes and Playford, Perotriletes perinatus Hughes and Playford, and Leiotriletes ornatus Ishchenko.

Due to the sparsity of publications concerned with Lower Mississippian acritarchs, the author was unable to make any concrete conclusions concerning the stratigraphic importance of this Hannibal acritarch assemblage. The author plans to continue investigating the occurrence and stratigraphic distribution of Lower Mississippian and Upper Devonian acritarchs and hopes to establish the presence of key species which could be used in geological correlations.

The Early Mississippian age for the Hannibal Formation based on the miospore assemblage is in

agreement with previous conclusions arrived at by Mehl (1961), Collinson (1961), and Canis (1967), and based on conodont data.

Paleoecology

Physical criteria. The Nutwood and Cuivre Members of the Hannibal Formation, from which the majority of the microfossils described herein were derived, are "black shales." Black shales are usually barren of fossils except for spores, acritarchs, Tasmanites, and conodonts due to the lack of oxygen in the environment of deposition (reducing environment). The actual environment of sedimentation which results in dark shales, such as those in this study, has long been a controversial subject. Some of the suggested environments are: near shore shallow lagoons (Grabou, 1917), deep stagnant basins (Clark, 1904), abyssal depths of a geosyncline (Ruedemann, 1934), and deep stagnant water below wave base (Rich, 1951).

In areas of contemporary black mud accumulation, it is evident that more than one kind of environment is involved. For example, black mud rich in organic matter and hydrogen sulfide is accumulating at the present time in the Black Sea. However, black mud is also accumulating in the Norwegian fjords. In the fjords, water density

stratification prevents free circulation of the bottom waters and few organisms can survive there. These two examples indicate that there is no one set of environmental conditions conducive to black shale deposition. Dunbar and Rodgers (1958), in their discussion of black shales (Chapter 11), also infer that no one theory can be applied to all black shales.

The dark color is due either to a high organic content or to a high content of iron sulfide (pyrite, FeS_2) or to both. The latter is an indication of the presence of H_2S in the depositional environment. The toxic environment created by the presence of H_2S is also used to explain the absence or rarities of marine fossils in the black shales.

Pyrite is present in the lower member (Cuivre) of the Hannibal Formation and is either disseminated in the shale or is in the form of botryoidal pyrite forming layers up to an inch in thickness (locality Cu-1 and Cu-3). Therefore, in the author's opinion, the dark color of the Nutwood (Cuivre) is due in part to iron sulfide and in part to organic matter since some samples have a very high organic content.

Workman and Gillette (1956), in their subsurface study of the Kinderhook Formations of Illinois show (fig. 11) the thickness and aerial extent of the Nutwood. In aerial extent the black shale occupies a limited area

covering approximately counties and part of six additional counties (5,000 to 6,000 square miles). Their isopach map shows that the Nutwood has a maximum thickness of forty feet. Considering the geographical configuration and extent as depicted by Workman and Gillette, it would appear feasible that the area now occupied by the black pyritic shale once represented a bay or lagoon rich in H_2S , having a sediment source (stream) primarily from the west (Missouri). Such an interpretation is substantiated by the ripple marked sandstone lenses (asymmetrical ripples) which occur within the black shale in Missouri indicating the presence of an ancient stream, and by the fact that the ripple marked discontinuous sandstone lenses exist in a 'tongue' of the unit which points toward the west extending into eastern Missouri. This tongue, with its sandstone lenses, could represent the mouth of an ancient stream which dumped sediment into the eastward extending marine basin. The presence of ripple marked sandstone also indicates that the unit was deposited near shore. Of the proposed environments regarding black shale deposition, Grabau's near shore shallow lagoon theory seems to best approach what the author believes was the depositional environment of the Nutwood (Cuivre) shale. Since megaspores are normally deposited close to their source, one argument against a

near shore environment is the absence of megaspores in the Nutwood (Cuivre) shales.

Fossil criteria. It has been known for some time that there is an inverse relationship in the relative abundance of miospores versus marine organisms such as acritarchs and Tasmanites in regard to distance from shore (Winslow, 1962, p. 3). This is true of contemporary sedimentation and has been shown to be true of ancient sedimentation (Williams and Sarjeant, 1967, p. 395). As the distance from shore increases it follows that the abundance of miospores decreases: spores are wind disseminated. Those spores with greater mass will be carried a lesser distance by the wind; therefore, the occurrence of megaspores or large miospores will be indicative of a near shore environment while the predominant occurrence of lighter spores, carried far greater distances (up to 100 km according to Faegri and Iversen, 1964), would indicate a site of deposition some distance from shore. Miospores are also transported by way of water and in this respect Tschudy (1964, p. 20) states that, "I am convinced that wind transport has been overemphasized and water transport underestimated." Stanley (1965) in studying the abundance of pollen and spores in marine sediment off the east coast of the United States found that the greatest concentration of those

derived from rivers occurred at a distance of 20 to 180 miles from the shoreline (Reference: Williams and Sarjeant, 1967). In the author's opinion, wind and water are equally important in contributing spores and pollen to sediment.

Regardless of transportation mode Williams and Sarjeant (1967, p. 394) point out that pollen and spores are the hydraulic equivalent of medium and finer sized silt (less than 1/32 mm) and therefore "the greatest concentration of pollen and spores in marine sediment theoretically should occur where sediments predominantly of medium and finer size (clay) occur."

As the distance from shore increases there will be a corresponding increase in the number of marine acritarchs present in the sediment. On the basis of inverse abundance of miospores and acritarchs present in sediment, old shorelines have been postulated.

The presence of acritarchs and Tasmanites in the Hannibal Formation material considered here indicates that the lower black shale portion of this formation is marine in origin since their occurrence is restricted to marine sediments (Williams and Sarjeant, 1967). While the occurrence of Tasmanites is restricted to the lower black shale, the acritarchs are also more abundant in lower black shales; however, a few acritarch species occur

throughout the formation.

The occurrence of miospores is restricted almost exclusively to the lower black shale with a few small miospores (ie., Punctatisporites debilis) occurring in the upper portions of the Hannibal. The abundance of miospores indicates a relative proximity to a land mass; however, land plants apparently did not grow in the immediate vicinity of the Nutwood environment as evidenced by the absence of megaspores. Because of their larger size megaspores are not as widely dispersed as are the smaller miospores.

The absence of miospores in the upper portion of the Hannibal Formation, with the exception of the small types which can be carried by wind greater distances, coupled with the presence of acritarchs in that portion of the formation, indicates that the Kinderhookian seashore was some distance away during the deposition of the upper portion of the Hannibal Formation in northeast Missouri and western Illinois. This agrees with the conclusions made by Canis in his study of Kinderhookian conodonts of Missouri (1967). Furthermore, Canis concluded that at the time the upper portion of the Hannibal Formation was being deposited in northeast Missouri, the transgressing Kinderhookian Sea was initially depositing a thin sandstone (Bachelor Formation) in the central parts of

Missouri. This means that the nearest land mass where plants could grow was more than 100 miles away, thus accounting for the low number of miospores in the upper portion of the Hannibal Formation in northeast Missouri and western Illinois. This microflora study lends support to Canis' conclusions.

In their discussion of the importance and potential importance of organic-walled microfossils in paleoecological interpretations, Williams and Sarjeant (1967) reviewed some of the recent contributions in this area. One which appears significant to the present study is that of Wall (1965). Wall was studying the paleoecological relationships of acritarchs in the Lower Jurassic sediment of Britain wherein he found that short spined forms of acritarchs were associated with turbulent water conditions; whereas the longer spined forms favored tranquil water environments. Applying this information to the Hannibal acritarch assemblage the water must have been turbulent during the initial deposition of the dark shale. Chart II shows that the types of acritarchs present in the lowermost sample (A) at both localities (Ha-3 and Ha-5) are predominantly the short spined types (ie., Lophosphaeridium and Micrhystridium). If the water was turbulent then there should also be fewer miospores present since the turbulent water would prevent them from

settling and being deposited. Moreover, in such an oxygen rich environment the fungi could have access to this carbohydrate source. Chart I (Miospores) supports this contention since few miospores were found in the lowermost sample (A) especially Ha-3-A. Although locality Cu-1 is not represented on the occurrence charts, the author noted that ripple marked sandstone lenses, a turbulent water indicator, were present within the shale at this locality. Of significance is the fact that at this locality (Cu-1) short spined forms acritarchs occur throughout the shale and sandstone sequence; whereas most miospores are rare. This agrees with and further confirms Wall's interpretation concerning acritarch occurrence relative to the depositional environment.

In regard to the occurrence of Tasmanites, Chart III shows that these organisms do not occur in the lowermost sample and are restricted almost exclusively to the upper portion of the black shale. Past studies have indicated that Tasmanites become more numerous as the distance from shore increases. Therefore, their occurrence in the upper portion of the shale would indicate that the shore distance had increased at the time that portion of the shale was deposited, accompanied by an increase in water depth and a decrease in turbulence.

Kinderhookian Paleolatitudes

In recent years, paleontologists have become more interested in the ecological interpretation of fossil faunas and floras. This has resulted in a discipline in geology, which is now known as paleoecology, that has been in existence for approximately ten years.

Another new aspect of geology from which paleoecology has derived valuable information is the study of paleomagnetism. The latter involves the study of iron particle orientation in ancient sediments. Here the principal assumption is that iron particles, as they are deposited, will orientate themselves in a north-south relationship due to the magnetic forces which are assumed to have been in existence for millions of years. The upshot of paleomagnetic data is that the iron particles in ancient sediments are not in an orientation which corresponds to the present north-south poles; evidently indicating that the poles have "wandered" in the geological past.

Sullivan (1966 and 1967) has applied Mississippian paleomagnetic data to the known distribution of Mississippian miospores and has proposed an interesting theory regarding climatically controlled, latitudinal provinces of paleofloras. The known distribution of Kinderhookian miospores indicates that at least two floral provinces existed on the earth at that time. Sullivan calls these

miospore provinces the Vallatisporites suite and the Lophozonotriletes suite. Each suite is characterized by a distinct miospore assemblage. Sullivan plotted the occurrence of each suite and found that the Vallatisporites suite existed in Canada (Hacquebard, 1957 and Playford, 1963), Ohio (Winslow, 1962), Britain (Sullivan, 1964), Belgium (Streel, 1966), and northwestern Australia (Balme, 1960); whereas the Lophozonotriletes suite occurred in Spitsbergen (Playford, 1962 and 1963), and western Russia (Luber and Waltz, 1938 and Ishchenko, 1956 and 1958).

Superimposing the Mississippian paleolatitudes derived from paleomagnetic data, Sullivan (1967, figs. 1, 2) found that the Vallatisporites suite occupied an equatorial belt approximately 0-15° north-south; whereas the Lophozonotriletes suite was in a latitudinal belt approximately 20-40° north. On this map, Missouri and Illinois are located approximately 15° south, which is also the latitude of Nova Scotia; whereas Britain and Belgium, which are also within the Vallatisporites province, are located 10-15° north. The similarity between the Kinderhookian miospore assemblage of northeast Missouri and Nova Scotia has been discussed previously; however, in this light it is interesting to note that these two areas occupied the same paleolatitude which could account for the similarity. Thus, the data

amassed by this study of the Hannibal materials appears to lend support for Sullivan's study.

The six key species listed by Sullivan (1967, pp. 188, 189) which are characteristic of the Vallatisporites suite are: Punctatisporites irrasus Hacquebard, Retusotriletes incohatus Sullivan, Pustulatisporites pretiosus Playford, Pustulatisporites gibberosus (Hacquebard) Playford, Raistrickia clavata Hacquebard, and Vallatisporites vallatus Hacquebard. Of these six key species, two are present in the Hannibal material. These are Retusotriletes incohatus Sullivan, which was the third most abundant species in the Hannibal (9 per cent of total), and Pustulatisporites gibberosus (Hacquebard) Playford, which had a relative abundance of 4 per cent. Punctatisporites debilis Hacquebard, 1957, which had a relative abundance of 9 per cent in the Hannibal material, is not listed as a key species by Sullivan. However, this species is very similar to Punctatisporites irrasus Hacquebard, which Sullivan did list. The only difference between the two species is size; Punctatisporites debilis has a diameter of 28 to 59 microns, whereas Punctatisporites irrasus has a size range of 67 to 83 microns. The weakness of this basis for specific separation has already suffered sufficient abuse in this report.

In the author's opinion the Hannibal assemblage

belongs to the Vallatisporites suite. However, it is interesting to note that one key species of the more northerly located Lophozonotriletes suite (20 - 40° north) does occur in the Hannibal Formation. This species is Lophozonotriletes rarituberculatus which is present in a relative abundance of 1.9 per cent. Its presence here is the first record of its occurrence in the Lower Mississippian sediment of North America, and is also the southernmost occurrence (15° south).

In the faunas and floras that exist today, the tropical regions of the earth are rich in numbers of species and these numbers decrease poleward. Just the opposite is true of the population size within a species. The number of individuals within a species is greater in the poleward areas, whereas the number of species present in the same area is smaller. Differences in population size due to difference in latitude and based on miospore frequency cannot be tested in the fossil record. This is due to the fact that the number of spores per sporangium varies greatly in different species. In addition to variation in biogenetic production, miospore frequency is subject to many physical variables such as proximity to spore source, type of rock - different lithologies produce different spore frequencies - (Schopf, 1962, p. 32), and depositional environment (oxydizing versus

reducing). (Cross, 1964, p. 10)

Applying the Principle of Uniformitarianism to the number of species relative to latitude, the fossil miospore assemblages present in the Lower Carboniferous should, in light of Sullivan's paleolatitudes, have a greater abundance of miospore species in paleoequatorial-ward areas of the mid United States, northeastern Canada, and mid European countries (ie., England, France, Belgium, and Germany) than in the more northern areas of Spitsbergen and western Russia which occupied paleolatitudes of 20-40° north. Proof of the above will entail extensive miospore investigations of all Kinderhookian sediment now included within the zones proposed by Sullivan. Such a study would add another supporting plank to Sullivan's platform. This is an intriguing area of possibility and deserves further investigation: the author intends to pursue this lead.

SUMMARY

The Hannibal Formation contained miospores, acritarchs, and Tasmanites. Samples of the Hannibal Formation were collected from six outcrops in Missouri and three outcrops in Illinois. In addition to these samples, two subsurface samples of the Nutwood Member of the Hannibal Formation were obtained from the Illinois Geological Survey. Samples from two outcrops were collected and processed from the Northview Formation and found to be barren of miospores and acritarchs.

There were twenty-five genera and thirty-three species of miospores, seven genera and twenty-seven species of acritarchs, and eight species of Tasmanites, making a total microflora of thirty-three genera and sixty-eight species in the Hannibal Formation.

The majority of miospores, acritarchs, and Tasmanites described in this study were recovered from the lower black shale (Nutwood - Cuivre) of the Hannibal Formation.

The nine numerically important genera present in the Hannibal Formation were Auroraspora, Punctatisporites, Retusotriletes, Lycospora, Leiotriletes, Granulatisporites, Converrucosisporites, Pustulatisporites, and Lophozonotriletes.

The seven genera of acritarchs present in the Hannibal Formation were Leiosphaeridia, Veryhachium,

Micrhystridium, Baltisphaeridium, Lophosphaeridium,
Dictyotidium, and Cymatiosphaera.

On the basis of the microflora contained in the Hannibal Formation, the following statements can be made.

The Hannibal miospore assemblage is indicative of an Early Mississippian age.

The presence of acritarchs and Tasmanites in the Hannibal indicates that the formation is marine in origin.

The Nutwood and Cuivre shales are time equivalent, and are in fact the same unit. Consequently, if a name for this unit (facies) is to be retained, Nutwood (Workman and Gillette, 1956) should take precedence and be applied in lieu of Cuivre (Mehl, 1961).

The presence of miospores in the lower shale member (Nutwood) of the Hannibal Formation indicates a near shore environment during its deposition; however, no megaspores were found.

The probable depositional environment of the Nutwood (Cuivre) was an inshore marine basin high in H₂S content.

The absence or rarity of miospores in the upper portion of the Hannibal Formation indicates that the transgressing Kinderhookian Seashore where land plants could have existed must have been a great distance away when the upper portion of the Hannibal Formation was deposited.

The similarity between the Hannibal miospore assemblage and the Lower Mississippian miospore assemblage of the Horton Group of Nova Scotia (Hacquebard, 1957 and Playford, 1963) would seem to indicate that the two areas supported a similar type of vegetation during the Lower Mississippian Period. The similarity between the assemblages also indicates that the Horton Group and the Hannibal Formation are time equivalent. The Horton Group is a non-marine sequence of strata and therefore is void of acritarchs.

Although containing only two key species of the five listed by Sullivan (1967), the Hannibal assemblage belongs to the Vallatisporites suite which existed in a paleoequatorial province.

There is essentially no similarity between the Lower Mississippian assemblage of Ohio (Winslow, 1962) and the Lower Mississippian assemblage of Missouri.

Based on a comparison of the miospore assemblage described by Gupta (1965) from the Upper Devonian Grassy Creek and Saverton Formations of northeastern Missouri and the miospore assemblage present in the Hannibal Formation of the same area, there is a very significant "floral gap" between the two systems (Devonian and Mississippian). Only two species were common to both miospore assemblages.

There is a greater similarity between the miospore

assemblage described by Urban (1960) from the Upper Devonian (Woodford Formation) of Oklahoma and the Hannibal assemblage than there is between the miospore assemblage from the Upper Devonian of Missouri (Gupta, 1965) and the Hannibal miospore assemblage. There appeared to be five species common to the Oklahoma and Hannibal assemblages.

Mehl (1961) noted that more localities of the basal dark shale may be discovered in the future. In this respect the basal 4 to 5 feet of dark shale at locality Ha-3 (figs. 5, 7) should henceforth be referred to as the Nutwood Member (or facies) of the Hannibal Formation.

LITERATURE CITED

- Achauer, C. W. 1959. Stratigraphy and microfossils of the Sappington Formation in southwestern Montana. In: Billings Geol. Soc. 10th Anniversary Ann. Field Conf., pp. 41-49.
- Allen, K. C. 1965. Lower and Middle Devonian spores of north and central Vestspitsbergen. *Palaeontology*, 8(4):687-748.
- Ames, H. T. 1961. Catalogue of fossil spores and pollen. Pennsylvania State University, Univ. Park, Pa., 1:131 (translations).
- Arnold, C. A. 1937. Devonian and Mississippian plant-bearing formations in eastern America. Second Congr. Avan. Etudes Stratigraph. Geol. Carbonifere, *Compt. Rend.*, (1935), 1:47-62.
- _____, 1948. The Mississippian flora. *Jour. Geol.*, 56(4):367-372.
- Balbach, M. J. 1966. Microspores variation in Lepidostro-
lus and comparison with Lycospora. *Micropaleontology*, 12(3):334-342.
- Balme, B. E. 1960a. Notes on some carboniferous microfloras from western Australia. Fourth Congr. Avan. Etudes Stratigraph. Geol. Carbonifere, *Compt. Rend.*, Heerlen, 1958, 1:25-31.

- _____, 1960b. The Upper Devonian (Frasnian) spores from the Carnarvon Basin, western Australia. *Palaeobotanist*, 9(1-2):1-10.
- _____, and Hassell, C. W. 1962. Upper Devonian spores from the Canning Basin, western Australia. *Micro-paleontology*, 8(1):28.
- Bell, A. H. 1943. Subsurface structure of the base of the Kinderhook - New Albany shale in central and southern Illinois. *Ill. State Geol. Surv., Rept. of Inv. 92*, 13 pp.
- Bell, W. A. 1965. Carboniferous plants of eastern Canada. *Geol. Surv. Canada, Paper no. 66-11*, 76 pp.
- Bennie, J. and Kidston, R. 1886. On the occurrence of spores in the Carboniferous Formation of Scotland. *Royal Phys. Soc. Edinburgh Proc.*, 9:82-117.
- Berry, W. 1937. Spores from the Pennington coal, Rhea County, Tennessee, *Am. Midland Naturalist*, 18(1): 155-160.
- Bhararwaj, D. C. 1957a. The palynological investigations of the Sarr coals. (Part 1, Morphographie of Sporae dispersae). *Paleontographica, Abt. B*, 101:73-125.
- _____, 1957b. The spore flora of Velener Schichten (Lower Westpahlia D) in the Ruhr Coal Measures. *Palaeontographica, Abt. B*, 102:110-138.
- _____, 1967. A scientific basis for the circumscription

- of species and genera in sporal dispersae. Rev. Palaeobotan. Palynol., 3(1-4):333-345.
- _____, and Venkatachala, B. S. 1962. Spore assemblage out of a Lower Carboniferous shale from Spitsbergen. Palaeobotanist, 10(1-2):18-47.
- Boneham, R. F. 1967. Devonian Tasmanites from Michigan, Ontario, and northern Ohio. Papers of the Michigan Academy of Science, Arts, and Letters, 52:163-173.
- Branson, E. B. 1938. Stratigraphy and paleontology of the Lower Mississippian of Missouri. Part 1, Univ. of Missouri Studies, 13(3):208.
- Brown, C. A. 1960. Palynological techniques. C. A. Brown, Baton Rouge, La. 188 pp.
- Butterworth, M. A. 1966. The distribution of Densospores. Palaeobotanist, 15(1-2):16-28.
- _____, and Williams, R. W. 1958. The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. Trans. R. Soc. Edinburg, Part 2, 63(7):353-392.
- _____, and Spinner, E. 1967. Lower Carboniferous spores from northwest England. Palaeontology, Part 1, 10:24.
- Byvsheva, T. 1957. Spore-pollen characteristics of the Clastic rocks of the Lower Carboniferous in the

- Melekess and Buzuluk exploratory drill holes.
Doklady Akad. Nauk U.S.S.R., 116(6):1009-1011.
- Campbell, G. 1946. New Albany shale. Geol. Soc. Am. Bull., 57:829-908.
- Canis, W. 1968. Conodonts and biostratigraphy of the Lower Mississippian of Missouri. Journal of Paleontology, 42(2):525-555.
- Chaloner, W. G. 1957. Recent advances in science: Botany. Palaeozoic spores and pollen. Sci. Prog., Part 179, 45:158-525
- _____, 1967. Spores and land plant evolution. Rev. Palaeobotan. Palynol., 1:83-93.
- Collinson, C. 1961a. Road log. Second day of field conference: Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook. Missouri Div. Geol. Surv. and Water Resources Rept. Inv. 27, pp. 49-74.
- _____, 1961b. The Kinderhookian Series in the Mississippi Valley: Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook. Missouri Div. Geol. Surv. and Water Resources Rept. Inv. 27, pp. 100-109.
- _____, 1961c. Conodonts Faunas from the Louisiana and McCraney Formation of Illinois, Iowa, and Missouri. Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook. Missouri Div. Geol. Surv. and Water Resources Rept. Inv. 27, pp. 110-141.

- _____, Scott, A. J., and Rexroad, C. B. 1962. Six charts showing biostratigraphic zones, and correlations based on conodonts from the Devonian and Mississippian rocks of the Upper Mississippi Valley. Ill. Geol. Surv. Circ. 328, 32 pp.
- Combaz, A. 1966. Sur les niveaux a Tasmanacees du paleozoique Saharien. *The Palaeobotanist*, 15(1-2):29-34.
- _____, A. 1967. Leiosphaeridaceae Eisenack, 1954, et Protoleiosphaeridae Timofiev, 1959-Leurs affinites, leur role sedimentologique et geologique. *Rev. Palaeobotan. Palynol.*, 1(1-4):309-321.
- _____, Lange, F. W., and Pansart, J. 1967. Les Leiofusidae Eisenack, 1938. *Rev. Palaeobotan. Palynol.*, 1(1-4):291-307.
- Conkin, J. E. and Conkin, B. M. 1964a. Devonian foraminifera, Part 1, The Louisiana Limestone of Missouri and Illinois. *Bull. Am. Pal.*, 47(213):53-105.
- _____, 1964b. Mississippian foraminifera of the United States, Part 1, The Northview Formation of Missouri. *Micropaleontology*, 10(1):19-49.
- _____, and Pike, J. W. 1965. Mississippian foraminifera of the United States, Part 2, Hannibal Formation of northeastern Missouri and western Illinois. *Micropaleontology*, 11(3):335-360.

- Cross, A. T. 1964. Plant microfossils and geology. In:
A. T. Cross (editor) Palynology in Oil Exploration-
Soc. Econ. Paleontologists Mineralogists, Spec.
Publ. no. 11, pp. 3-13.
- _____, and Hoskins, 1952. The Devonian-Mississippian
transition flora of east-central United States.
Third Congr. Avan. Etudes Stratigraph. Geol.
Carbonifere, Compt. Rend., (1951), 1:113-122.
- Deflandre, G. 1935. Considerations biologiques sur les
organismes d'origine planctonique conserves dans les
silex de la craie. Bull. Biol. Fr. Belg., 69:213-
244.
- _____, 1937. Microfossiles des silex cretaces.
Flagelles incertae sedis. Hystrichosphaeridees.
Sarcodines. Organismes divers. Ann. Paleont.,
26:51-103.
- _____, 1946. Radiolaires et Hystrichospherides du
Carbonifere de la Montagne Noire, Acad. Sci. Paris,
C. R., 223:515-517.
- _____, and Deflandre-Rigaud, M. 1962. Nomenclature et
systematique des Hystrichospheres (s. l.). Obser-
vations et rectifications. Rev. Micropaleont.,
4(4):190-196.
- Dettmann, M. E. 1963. Upper Mesozoic microfloras from
southeastern Australia. Proc. R. Soc. Vict.,

77:148.

Deunff, J. 1954a. Micro-organismes planctonique (Hystrichospheres) dans le Devonien du Massif armoricain. Soc. Geol. Fr., C. R. Somm., (11):239-242.

_____, 1954b. Veryhachium, genre nouveau d'Hystrichospheres du Primaire. Soc. Geol. Fr., C. R. Somm., (13):305-306.

_____, 1954c. Sur un microplancton du Devonien du Canada recelant des types nouveaux d'Hystrichospherides. Acad. Sci. Paris, C. R., 239:1064-1066.

_____, 1955. Un microplancton fossile devonien a Hystrichospheres du Continent Nord-Americain. Bull. Microsc. Applique, Ser. 2, 5(11-12):138-147.

Downie, C. 1959. Hystrichospheres from the Silurian Wenlock Shale of England. Palaeontology, Part 1, 2:56-71.

_____, 1963. Hystrichospheres (acritarchs) and spores of the Wenlock Shales (Silurian) of Wenlock, England. Palaeontology, Part 4, 6:625-652.

_____, 1967. The geological history of the microplankton. Rev. Palaeobotan. Palynol., 1:269-281.

_____, Williams, G. L. and Sarjeant, W. A. S. 1961. Classification of fossil microplankton. Nature, 192(4801):471.

_____, and Sarjeant, W. A. S. 1963. On the interpretation

and status of some Hystrichosphere genera. *Palaeontology*, 6(1):83-96.

_____, Evitt, W. R. and Sarjeant, W. A. S. 1963. Dinoflagellates, hystrichospheres and the classification of the acritarchs. *Stanford Univ. Publ. Geol. Sci.*, 7(3):1-16.

Dunbar, C. O. and Rodgers, J. 1957. *Principles of stratigraphy*. John Wiley & Sons, Inc., New York, 356 pp.

Dybova, S. and Jachowicz, A. 1957. Microspores of the Upper Silesian coal measures. *Poland Inst. Geol. Prace*, 23:1-328.

Ehrenberg, C. G. 1854. *Mikrogeologie. Das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbstständigen Lebens auf der Erde*. Voss, Leipzig, 374 pp.

Eisenack, A. 1931. Neue Mikrofossilien des baltischen Silurs I. *Palaont. A*, 13(1-2):74-118.

_____, 1938. Hystrichosphaerideen und Verwandte Formen im Baltischen Silur. *Z. Geschiebeforsch*, 14:60-61.

_____, 1956. Probleme der Vermehrung und des Lebensraumes bei der Gattung Leiosphaera (Hystrichosphaeridea). *Neu. Jb. Geol. Pal., Abh.*, 102(3): 402-408.

_____, 1958. Tasmanites Newton 1875 und Leiosphaeridia n.g. als Gattungen der Hystrichosphaeridea. *Palaeon-*

- tographica, Ser. A, 110:1-19.
- _____, 1962. Mitteilungen über Leiosphären und über das Pylom bei Hystriosphären. New Jb. Geol. Palaont. Abh., Part 1, 114:58-80.
- _____, 1963a. Hystriosphären. Biol. Reviews, 38(1): 107-139.
- _____, 1963b. Über einige Arten der Gattung Tasmanites Newton 1875. Grana Palynologica, Part 2, 4:204-216.
- Erdtman, G. 1947. Suggestions for the classification of fossil and recent pollen grains and spores. Svensk. Bot. Tidskr., 41(1):104-114.
- _____, 1954. Some remarks on terms, diagnosis, classification, and methods in palynology. Svensk. Bot. Tidskr., 48(1-4):471-484.
- Evitt, W. R. 1963a. A discussion and proposal concerning fossil dinoflagellates, hystriospheres, and acritarchs. Nat. Acad. Sci., Proc., 49(2):158-164.
- _____, 1963b. A discussion and proposal concerning fossil dinoflagellates, hystriospheres, and acritarchs. Nat. Acad. Sci., Proc., 49(3):298-302.
- _____, 1967. Five complications of the literature on organic-walled fossil microplankton. Micropaleontology, 13(1):111-114.
- Felix, J. F. and Burbridge, P. P. 1967. Palynology of the Springer Formation of southern Oklahoma.

- Palaeontology, Part 3, 10:349-425.
- Guennel, G. K. 1952. Fossil spores of the Alleghenian coals in Indiana. Ind. Dept. of Conservation, Geol. Surv. Rept. of Progress, no. 4, 40 pp.
- _____, 1963. Devonian spores in a Middle Silurian Reef. *Grana Palynologica*, 4(2):1-40.
- Gupta, S. 1965. Palynology of Grassy Creek and Saverton Shales of Missouri. Unpublished Ph. D dissertation, University of Missouri (Botany), 248 pp.
- Hacquebard, P. A. 1957. Plant spores in coal from the Horton Group (Miss.) of Nova Scotia. *Micropaleontology*, 3:301-324.
- _____, and Barss, M. S. 1957. A Carboniferous spore assemblage in coal from the South Nahanni River area, Northwest territories. *Geol. Surv. Canada, Bull. no. 40*, 63 pp.
- Hass, W. H. 1956. Age and correlation of the Chattanooga shale and the Maury Formation. U. S. Geol. Surv. Prof. Paper 286, 47 pp.
- Hemer, D. O. and Hygreen, D. W. 1967. Algae, acritarchs, and other microfossils incertae sedis from the Lower Carboniferous of Saudi Arabia. *Micropaleontology*, 13(2):183-194.
- Høeg, O. A. 1937. The Devonian floras and their bearing upon the origin of vascular plants. *Bot. Review*,

3:563-592.

- Hoffmeister, W. S., Staplin, F. L., and Malloy, R. E.
1955a. Geologic range of Paleozoic plant spores in
North America. *Micropaleontology*, 1(1):9-27.
- _____, 1955b. Mississippian plant spores from the
Hardinsburg Formation of Illinois and Kentucky.
Jour. Paleontology, 29(3):372-399.
- Hoskins, J. H. and Cross, A. T. 1952. The petrification
flora of the Devonian-Mississippian black shale.
Palaeobotanist, 1:215-238.
- Hughes, N. F. and Playford, G. 1961. Palynological
reconnaissance of the Lower Carboniferous of
Spitsbergen. *Micropaleontology*, 7(1):27-44.
- Ibrahim, A. C. 1932. Beschreibung von Sporenformen aus
Floz Agir. In: Potonié, Robert, Sporenformen aus
den Flozen Agir und Bismarck des Ruhregebietes.
Neus Jahrb., Beilage-Band 67, Abt. B, pp. 447-449.
- Ishchenko, A. M. 1956. Spores and pollen in Lower
Carboniferous coal deposits in the western extension
of the Donetz Basin and their stratigraphic signi-
ficance. *Akad. Nauk Ukrain. U.S.S.R. Inst. Geol.*
Nauk Trudy, Ser. Strat. Pal., 11:1-184, (in Russian).
- _____, 1958. Sporo-pollen analysis of the Lower Carboni-
ferous sediments of the Dnieper-Donetz Basin. *Akad.*
Nauk Ukrainisan U.S.S.R., Tr. Inst. Geol. Nauk.

Ser. Strat. Paleont. 17:1-188, (in Russian)

Jodry, R. L. and Campau, D. E. 1961. Small pseudo-chitinous and resinous microfossils: new tools for the subsurface geologists. Amer. Assoc. Petrol. Geol., Bull., Part 2, 45(8):1378-1391.

Jongmans, W. J. 1937. Contribution of a comparison between the Carboniferous floras of the United States and of western Europe. Second Congr. Avan. Etudes Stratigraph. Geol. Carbonifere, Compt. Rend., 1:363-387.

Kent, D. M. 1963. The stratigraphy of the Upper Devonian Saskatchewan Group of southwestern Saskatchewan. Saskatch. Dep. Min. Res., Rept. no. 73, 51 pp.

Kedo, G. I. 1957. Spores from the supra Salt Devonian deposits of the Pripyat Depression and their stratigraphic significance. Tr. Inst. Geol. Nauk Akad. Nauk Belorussk. U.S.S.R., Ser. Stratigraph. Paleontol. 2:3-43, (in Russian)

_____, 1962. Spore assemblages of Upper Famennian and Tournaisian deposits and the Pripyat Depressions. Trans. Society Palynologist, Acad. Sci. Moscow, pp. 73-79.

_____, 1963. Spores of the Tournaisian stage of the Pripyat Depressions and their stratigraphical significance. In: Palaeontology and Stratigraphy

of the U.S.S.R., Symposium IV. Nauka i Tekhuika, Minsk, pp. 3-121 (in Russian).

Keyes, C. R. 1892. The principal Mississippian section. Bull. Geol. Soc. Am., 3:283-300.

Knox, E. M. 1948. The microspores in coals of the Limestone Coal Group in Scotland. Inst. Min. Eng. Trans., Part 3, 107:155-163.

Kosanke, R. M. 1943. The characteristic plant microfossils of the Pittsburg and Pomeroy coals of Ohio. Amer. Midland Nat., Part 1, 29:119-132.

_____, 1950. Pennsylvanian spores of Illinois and their use in correlation. Ill. Geol. Surv. Bull. 74, 128 pp.

_____, 1959. Late paleozoic small spore floras of United States. Resumé Congrès. Internat. Bot., 2:200.

_____, 1964. Applied paleozoic palynology. In: A. T. Cross (editor) Palynology in Oil Exploration-Soc. Econ. Paleontologists Mineralogists, Spec. Publ. no. 11, pp. 75-89.

Kräusel, R. 1939. Sind die paläozoischen Hystrichosphaerideen Einzeller or Planzenspores? Senckenbergiana, 21:358-368.

Kremp, G. O. W. 1965. Morphologic Encyclopedia of Palynology. University of Arizona, 185 pp.

- _____, 1967. Tetrad markings of Pteridophytic spores and their evolutionary significance. *Rev. Palaeobotan. Palynol.*, 3:311-323.
- _____, Ames, H. T., and Kouar, A. J. 1960a. Catalogue of fossil, pollen, and spores: Devonian spores, Pennsylvania State Univ., Univ. Park, Pa., 11:1-157.
- _____, Ames, H. T., and Kouar, A. J. 1960b. Catalogue of fossil, pollen, and spores: Devonian spores, Pennsylvania State Univ., Univ. Park, Pa., 12:1-154.
- Love, L. G. 1960. Assemblages of small spores from the Lower Oil-Shale Group of Scotland. *Roy. Soc. Edinburg, Proc.*, Sec. B, Part 2, 67:99-126.
- _____, and Neves, R. 1963. Palynological evidence on the age of the Carboniferous of Inninmore. *Geol. Soc. Glasgow, Trans.*, Part 1, 25:61-71.
- Luber, A. A. 1955. Atlas of spores and pollen from the Palaeozoic deposits of Kazakhstan. Alma-Ata. Akad. Nauk Kazakh. U.S.S.R., 125 pp.
- _____, and Waltz, I. E. 1938. Classification and stratigraphical value of spores of some Carboniferous coal deposits in the U.S.S.R. *Tsen. Nauch.-Issled. Geol.-Razved. Inst.*, Trudy, 105:1-46, (in Russian).
- _____, 1941. Atlas of microspores and pollen grains of the Paleozoic of the U.S.S.R. *Vses. Nauch.-Issled, Geol. Inst.*, Trudy, 139:1-108, (in Russian).

- McGregor, D. C. 1960. Devonian spores from Melville Island Canadian Arctic archipelago. *Paleont.*, Part 1, 3:1-44.
- _____, 1961. Spores with proximal radial pattern from the Devonian of Canada. *Geol. Surv. Canada, Bull.* 76, 11 pp.
- _____, 1964a. Devonian miospores from the Ghost River Formation, Alberta. *Geol. Surv. Canada, Bull.* 109, 31 pp.
- _____, 1964b. Devonian plants of western Canada. *Geol. Surv. Canada, Paper no.* 62-4, 34 pp.
- _____, 1967. Composition and range of some Devonian spore assemblages of Canada. *Rev. Palaeobotan. Palynol.*, 1:173-183.
- _____, and Owens, B. 1966. Devonian spores of eastern and northern Canada. *Canada Geol. Surv. Paper no.* 66, Part 30, 66 pp.
- Manten, A. A. 1966a. Half a century of modern palynology. *Earth-Science Reviews*, 2(4):277-316.
- _____, 1966b. Some current trends in palynology. *Earth-Science Reviews*, 2(4):317-343.
- Martin, J. A. and Koenig, J. W. 1961. Road log. Second day of field conference: *Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook*, Missouri Div. Geol. Surv. and Water Resources Rept. Inv. 27, pp. 9-48.

- Mehl, M. G. 1960. The relationships of the base of Mississippian systems of Missouri. J. Scientific Lab., Dension Univ., Part 5, 45:57-107.
- _____, and Shaffer, B. 1961. Sporangites as "horizon markers." In: Kansas Geol. Surv. 26th Field Conf. Guidebook, Missouri Div. Geol. Surv. and Water Resources Rept Inv. 27, pp. 95-99.
- Moore, R. C. 1928. Early Mississippian formations in Missouri. Missouri Div. Geol. and Mines, sec. ser., 21:1-238.
- _____, 1935. The Mississippian system in the Upper Mississippian Valley region. In: Kansas Geol. Soc. 9th Ann. Field Conf. Guidebook, Missouri Div. Geol. Surv. and Water Resources Rept. Inv. 27, pp. 239-245.
- Naumova, S. N. 1937. Spores and pollen of the coals of the U.S.S.R., Int. Geol. Congr., Absts., 17:60-61.
- _____, 1938. Microspores from the coals of the Moscow Basin (Latin diagnosis, English summary), In: Petrography of coals and limestones of the Moscow Basin-Symposium. Trans. All-Union Sci. Inst. Econ. Mineralogy, fasc. 119, pp. 21-31.
- _____, 1953. Spore-pollen complexes of the Upper Devonian of the Russian platform, and their stratigraphic significance. Akad. Nauk U.S.S.R. Inst. Geol. Nauk Trudy, no. 143, ser. no. 60, 200 pp,

Moscow (in Russian).

- _____, 1960. Spore-pollen complexes of Upper Devonian of the Russian platform (translated by Ivan Madirrzaaz). *Inter. Geol. Frev.*, Part 8, 2:688-704.
- Neves, R. 1961. Namurian plant spores from the southern Pennines, England. *Palaeontology*, Part 2, 4:247-279.
- Newton, E. T. 1875. On Tasmanites and Australian "white coal." *Geol. Mag.*, ser. 2, part. 2, pp. 337-342.
- Niewoehner, W. B. 1955. Devonian-Mississippian boundary formations, Missouri. (Unpublished Master's thesis, University of Missouri (Geology)).
- Norris, G. and Sarjeant, W. A. S. 1967. A descriptive index of genera of fossil Dinophyceae and Acritarcha. *New Zeal. Dept. and Res. Paleontol.*, Bull. no. 40, 71 pp.
- Owens, B. and Burgess, I. C. 1965. The stratigraphy and palynology of the Upper Carboniferous outlier of Stainmore, Westmorland. Great Britain, *Geol. Surv.*, Bull. no. 23, pp. 17-44.
- _____, and Streel, M. 1967. Hymenozonotriletes lepidophytus Kedo, its distribution and significance in relation to the Devonian-Carboniferous boundary. *Rev. Palaeobotan. Palynol.*, 1:141-150.
- Pettitt, J. M. 1965. Two heterosporous plants from the Upper Devonian of North America. *Bull. Brit. Mus.*

(Nat'l. Hist.), Geol. 10(3):83-92.

Playford, G. 1962. Lower Carboniferous microfloras of Spitsbergen. Part One. Palaeontology, Part 3, 5:550-618.

_____, 1963a. Lower Carboniferous microfloras of Spitsbergen. Part Two. Palaeontology, Part 4, 5:619-678.

_____, 1963b. Miospores from the Mississippian Horton Group, eastern Canada. Canada, Geol. Surv., Bull. no. 107, 11 pp.

_____, and Barss, M. S. 1963. Upper Mississippian microflora from Axel Heiberg Island, District of Franklin. Canada, Geol. Surv., Paper no. 62-36, 5 pp.

Potonié, R. 1952. Zur morphologie and morphologischen nomenklatur der sporites H. Potonié 1893. Palaeont. Zeitschr., 25(3-4):143-154.

_____, 1954. Stellung der paläozoischen sporengattungen in naturlichen system. Palaeont. Zeitschr., 28(3-4): 103-139.

_____, 1956. Synopsis der Gattungen der sporae dispersae. I Teil. Sporites, Beih. Geol. Jahrb., 23:1-103.

_____, 1958. Synopsis der Gattungen der sporae dispersae. II Teil. Sporites (Nächtrage), Saccites, Aletes, Praecolpate, polyplicates, monocolpates. Beih. Geol. Jahrb., 31:1-114.

- _____, 1960. Synopsis der Gattungen der sporaee dispersae. III Teil. "Nächtrage sporites, fortsetzung pollenites, nit. Generalregister zu Teil I-III, Beih. Geol. Jahrb., 39:1-189.
- _____, 1962. Synopsis der sporaee in situ. Beih. Geol. Jahrb., 52:1-204.
- _____, 1967. New phylogenetic facts on fossil spores. Rev. Palaeobotan. Palynol., 1:75-82.
- _____, and Kremp, G. 1954. Die Gattunge der paläozoischen sporaee dispersae und ihre stratigraphie. Geol. Jahrb., 69:11-194.
- _____, 1955. Die sporaee dispersae des Ruhrkarbons, ihre morphographie und stratigraphie mit Ausblicken auf Arten anderen gebiete und Zeitabschnitte Teil I. Palaeontographica, Abt. B, 98:1-136.
- _____, 1956. Die sporaee dispersae des Ruhrkarbons, ihre morphographie und stratigraphie mit Ausblicken auf Arten anderen gebiete und Zeitabschnitte Teil II. Palaeontographica, Abt. B, 99:85-191.
- Radforth, N. W. and McGregor, D. C. 1954. Some plant microfossils important to Pre-Carboniferous stratigraphy and contributing to our knowledge of the early floras. Canadian Jour. Bot., 32:601-621.
- Raistrick, A. 1938. The microspore content of some Lower Carboniferous coals. Leeds Geol. Assoc. Trans.,

5(4):221-226.

- Read, C. B. 1955. Floras of the Pocono Formation and Price Sandstone in parts of Pennsylvania, Maryland, West Virginia, and Virginia. U. S. Geol. Surv. Prof. Paper 263, 32 pp.
- _____, and Campbell, G. 1939. Preliminary account of the New Albany shale flora. Am. Midland Naturalist, 21(2):435-453.
- Reinsch, P. F. 1884a. Micro-Palaeophytologia formationis carboniferae. Continens Trileteas et Stelideas, Erlangae, Germania, Teho. Krische, 1:1-80.
- _____, 1884b. Micro-Palaeophytologia formationis carboniferae. Continens Discieas, Spaherocladiteas, etc., Erlangae, Germania, Teho. Krische, 2:1-55.
- Remy, R. and Remy, W. 1955. Mittelungen über sporen, die aus inkohlten Fruktifaktionen von echten Farnen des Karbon gewonnen wurden. Abh. Deutsch Akad. Wiss. Berlin, Jg., 1:41-47.
- Remy, W. 1957. Durch Mazeration fertiler Farne des Paläozoikums gewonnene Sporen. Palaeont. Z., 31:55-65.
- Rich, J. L. 1951. Probable fondo origin of Marcellus, Ohio, New Albany, Chattanooga bituminous shales. Amer. Assoc. Petrol. Geol. Bull., 35:2017-2040.
- Richardson, J. B. 1960. Spores from the Middle Old Red

Sandstone of Cromartz, Scotland. *Paleont.*, Part 1, 3:45-63.

_____, 1965. Middle Old Red Sandstone spore assemblages from the Orcadian Basin, northeast Scotland. *Palaeontology*, Part 3, 7:559-605.

_____, 1967. Some British Lower Devonian spore assemblages and their stratigraphic significance. *Rev. Palaeobotan. Palynol.*, 1(1-4):111-129.

_____, et coll., 1964. Stratigraphical distribution of some Devonian and Lower Carboniferous spores. *Congr. Avan. Etudes Stratigraph. Geol. Carbonifere*, *Compt. Rend.*, Paris (1963), pp. 1111-1114.

Sarjeant, W. A. S. 1961. The Hystriospheres; a review and discussion. *Grana Palynologica*, Part 3, 2:102-111.

Schemel, M. P. 1950. Carboniferous plant spores from Daggett County, Utah. *Jour. Paleontology*, 24(2): 232-244.

Schopf, J. M. 1957. Spores and problematic plants commonly regarded as marine. In: Ladd, H. S. (editor) *Treatise on marine ecology and paleoecology*, *Paleoecology*, *Geol. Soc. America Mem.* 67, 2:709-718.

_____, 1963. Nomenclature for fossil plants. *Taxon.*, 12(8):279-282.

_____, 1964a. Practical problems and principles in study

of plant microfossils. In: A. T. Cross (editor)
Palynology in Oil Exploration-Soc. Econ. Paleontolo-
gists Mineralogists, Spec, Publ. no. 11, pp. 29-55.

_____, 1964b. Russian palynology today; literature and
application to exploration. In: A. T. Cross
(Editor) Palynology in Oil Exploration-Soc. Econ.
Paleontologists Mineralotists, Spec. Publ. no. 11,
pp. 181-200.

_____, Wilson, L. R. and Bentall, R. 1944. An annotated
synopsis of Paleozoic fossil spores and the definition
of generic groups. Ill. Geol. Surv. Rept. Inv. 91,
72 pp.

Scott, R. A. and Doher, I. 1967. Palynological evidence
for Devonian age of the Nation River Formation,
east-central Alaska. U. S. Geol. Surv. Prof.
Paper no. 575-B, pp. B45-B49.

Shaffer, B. 1964. Stratigraphic and paleoecologic
significance of plant microflossils in Permian
evaporites of Kansas. In: A. T. Cross (editor)
Palynology in Oil Exploration-Soc. Econ. Paleontolo-
gists Mineralogists Spec. Publ. no. 11, pp. 97-115.

Smith, A. H. V. and Butterworth, M. A. 1967. Miospores
in the coal seams of the Carboniferous of Great
Britain. Spec. Paper Palaeont. no 1, 324 pp.

Smith, D. L. 1962. Three fructifications from the

Scottish Lower Carboniferous. *Palaeontology*, Part 2, 5:225-237.

Sommer, F. W. 1953. Os esporomorfos do Folhelo de Barreirinha. Brazil, Div. Geol. Mineralotia, 140:1-49.

_____, 1956. South American paleozoic sporomorphae without haptotypic structures. *Micropaleont.*, 2(2):175-181.

_____, 1967. Brazilian Palaeozoic Algomycetes and Tasmanaceae. *Palaeontology*, Part 4, 10:640-646.

Stafleu, F. A. 1967. Palynology, nomenclature and terminology. *Rev. Palaeobotan. Palynol.*, 3(1-4):15-26.

Staplin, F. L. 1960. Upper Mississippian plant spores from the Golata Formation, Alberta, Canada. *Palaeontographica*, Abt. B, 107(1-3):1-40.

_____, 1961. Reef-controlled distribution of Devonian microplankton in Alberta. *Palaeontology*, Part 3, 4:392-424.

_____, Jansonius, J. and Pocock, S. 1965. Evaluation of some Acritarchous Hystrichosphere genera. *N. Jb. Geol. Palaeont. Abh.*, 123:167-201.

Stockmans, F. and Willière, Y. 1962a. Hystrichospheres du Devonien belge (sondage de l'asile d'alienes a Tournai). *Bull. Soc. Beolg. de Géol., de Paléont. et d'Hydrolog.*, 71:41-77.

- _____, 1962b. Hystrichospheres du Devonien belge (sondage de Wepion). Bull. Soc. Belg. de Géol., de Paléont. et d'Hydrol., 71:83-99.
- _____, 1965. Les acritarches du Dinantien du sondage de l'asile d'aliènes a Tournai (Belgique). Bull. Soc. Belg. de Géol., de Paléont. et d'Hydrol., 74:462-477.
- _____, 1966. Les acritarches du Dinantien de sondage de Vieux Leuze a Leuze (Hainaut, Belgique). Bull. Soc. Belge de Geol., Pal. et Hydrologie, 75:223-241.
- Streel, M. 1964a. Une association de spores de la Vesdre a Goe (Belgique). Ann. Soc. Geol. de Belgique, T. 87, Bull. 7, 30 pp.
- _____, 1964b. Etude palynologique de Devonien de sondage de Booischt (Belgique). Bull. Belg. Geol. Soc., 73(2):172-185.
- _____, 1966. Criteres palynologiques pour une stratigraphie detaille du Tnla dans les bassins ardenno-rhenans. Ann. Soc. Geol. Belg., Bull. 89, pp. 65-96.
- _____, 1967. Associations de spores du Devonien inferieur belge et leur signification stratigraphique. Ann. Soc. Geol. Belg., Bull., 90:12-54.
- Sullivan, H. J. 1964a. Miospores from the Lower Limestone Shales (Tournaisian) of the Forest of Dean Basin, Gloucestershire. Congr. Avan. Etudes Stratigraph,

- Geol. Carbonifere, Compt. Rend., 5, Paris (1963),
3:1249-1258.
- _____, 1964b. Miospores from the Drybrook Sandstone and associated measures in the Forest of Dean Basin, Gloucestershire. Palaeontology, Part 3, 7:351-392.
- _____, 1966. Palynological evidence concerning the regional differentiation of Upper Mississippian floras. Pollen et Spores, 7(3):539-563.
- _____, 1967. Regional differences in Mississippian spore assemblages. Rev. Palaeobotan. Palynol., 1(1-4):185-192.
- _____, 1968. A Tournaisian spore flora from the Cementstone Group of Ayrshire, Scotland. Palaeontology, Part 1, 11:116-140.
- _____, and Marshall, A. E. 1966. Visean spores from Scotland. Micropaleontology, 12(3):265-285.
- Swallow, G. C. 1885. Geology of Missouri. Missouri Geol. Surv. Second Ann. Rept., Chapter 1, pp. 59-135.
- Thiessen, R. 1921. Origin and composition of certain oil shales. Econ. Geol., 16:289-300.
- Timofiev, B. V. 1959. The ancient flora of the Pre-Baltic and its stratigraphic significance. Mem. Trud. Vses. Neft. Nauc.-Issled. Geol.-Razv. Inst. 129:1-319.
- Thomas, L. A. 1949. Devonian-Mississippian Formations of southern Iowa. Geol. Soc. Am. Bull. 66, pp.

403-438.

- Tschudy, R. H. 1964. Palynology and time stratigraphic determination. In: A. T. Cross (editor) Palynology in Oil Exploration-Soc. Econ. Paleontologists Mineralogists, Spec. Publ. no. 11, pp. 18-28.
- Upshaw, C. F. and Creath, W. B. 1965. Pennsylvanian miospores from a cave deposit in Devonian limestone, Calloway County, Missouri. *Micropaleontology*, 11(4):431-448.
- Urban, J. B. 1960. Microfossils of the Woodford shale (Devonian) of Oklahoma. Unpublished Master's thesis, University of Oklahoma, 78 pp.
- Valentine, J. W. 1968. Climatic regulation of species diversification and extinction. *Geol. Soc. Am. Bull.* 79:273-276.
- Venkatachala, B. S. 1964. Lower Carboniferous miospores from Boneport Gulf Basin, Australia. *Palaeobotanist.* 12:109-114.
- Virgan, J. O. 1964. Spores from Devonian deposits, Minerdalen, Spitsbergen. *Norsk Polarinstitut, Skr.* no. 132, 32 pp.
- Von Post, L. 1916. Om skogstradpollen i sydsvenska torfmosselager foljder. *Geol. Foren. Stockholm Forh.* 38:384-390, 392-393.
- Wall, D. 1962. Evidence from recent plankton regarding

- Tulsa Geol. Soc. Digest, 27:166-171.
- _____, 1963. A geological history of Oklahoma's vegetation. Shale Shaker, 13(9):4-20.
- _____, and Coe, E. A. 1940. Descriptions of some unassigned plant microfossils from the Des Moines Series of Iowa. Amer. Midland Nat., 23(1):182-186.
- _____, and Hoffmeister, W. S. 1956. Plant microfossils of the Croweburg coal. Okla. Geol. Surv. Circular 32, 57 pp.
- _____, and Hedlund, R. W. 1960. Two techniques for staining Hystrichosphaerids. Okla. Geol. Notes, 20(4):101-102.
- Winslow, M. R. 1959. Upper Mississippian and Pennsylvanian megaspores and other plant microfossils from Illinois. Ill. State Geol. Surv., Bull. 89, 100 pp.
- _____, 1962. Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio. U. S. Geol. Surv. Prof. Paper no. 364, 93 pp.
- Workman, L. W. and Gillette, T. 1956. Subsurface stratigraphy of the Kinderhook series in Illinois. Ill. Geol. Surv. Rept. Inv. no. 189, 46 pp.
- Wray, J. L. 1964. Paleozoic palynomorphs from Libya. In: A. T. Cross (editor) Palynology in Oil Exploration-Soc. Econ. Paleontologists Mineralogists,

Spec. Publ. no. 11, pp. 90-96.

PLATES I - XII

The specimens figured are on permanent slides which are deposited in the Paleobotanical Collections, Department of Botany, University of Missouri at Columbia, Missouri. Each specimen is referred to by a sample and slide number. This number is followed by east-west and north-south microscope stage co-ordinate numbers which designate the location of the specimen in question on the slide indicated. All figures are X690 unless otherwise indicated and are from unretouched negatives.

PLATE I

- Figure 1 Leiotriletes inermis (Waltz) Ishchenko 1952.
Maximum diameter 31.9 microns; sample
Ha-3-D, slide number 1, co-ordinates
63.7 X 96.4. (Page 69)
- Figures 2, 3 Leiotriletes ornatus Ishchenko 1956. Fig. 2,
maximum diameter 23.5 microns; sample
Nu-2-E, slide number 2, co-ordinates
61.2 X 99.1. Fig. 3, maximum diameter
27.5 microns; sample Ha-3-B, slide number
3, co-ordinates 59.3 X 96.0. (Page 70)
- Figures 4, 5 Punctatisporites debilis Hacquebard 1957.
Fig. 4, maximum diameter 33.4 microns;
sample Ha-5-A, slide number 2, co-ordinates
54.0 X 94.1. Fig. 5, maximum diameter
50.8 microns; sample Ha-3-C, slide number
7, co-ordinates 65.0 X 96.7. (Page 72)
- Figure 6 Punctatisporites glaber (Naumova) Playford
1962. Maximum diameter 42.0 microns;
sample Ha-3-B, slide number 7, co-ordinates
53.4 X 109.6. (Page 73)
- Figures 7, 8 Punctatisporites solidus Hacquebard 1957.
Fig. 7, maximum diameter 84.1 microns;
sample Ha-3-D, slide number 9, co-ordinates
64.7 X 94.2. Fig. 8, maximum diameter

40.6 microns; sample Nu-2-E, slide number 4, co-ordinates 55.4 X 95.0.

(Page 75)

Figures 9, 10 Retusotriletes incohatatus Sullivan 1964.

Fig. 9, maximum diameter 55.1 microns; sample Ha-3-D, slide number 7, co-ordinates 52.5 X 105.4. Fig. 10, maximum diameter 34.8 microns; sample Ha-3-D, slide number 7, co-ordinates 56.8 X 101.5. (Page 77)

Figures 11, 12 Retusotriletes sp. cf. R. semizonalis

McGregor 1964. Fig. 11, maximum diameter 39.1 microns; sample Ha-3-C, slide number 9, co-ordinates 68.0 X 102.9. Fig. 12, maximum diameter 37.7 microns; sample Ha-3-C, slide number 1, co-ordinates 60.9 X 106.0. (Page 78)

Figure 13 Granulatisporites crenulatus Playford 1963.

Maximum diameter 34.0 microns; sample Nu-2-C, slide number 7, co-ordinates 62.0 X 106.0. (Page 80)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

PLATE I

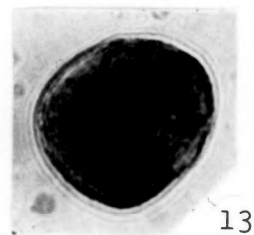
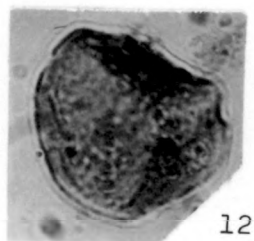
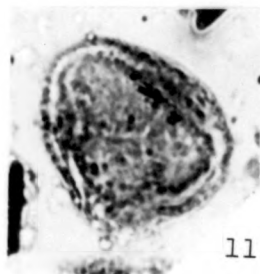
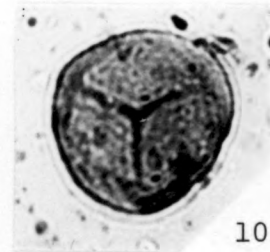
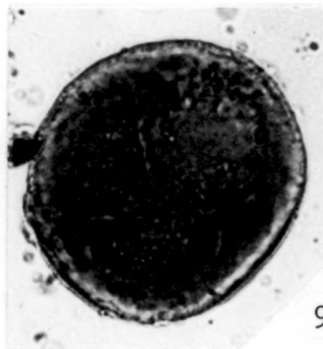
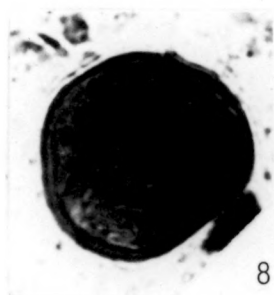
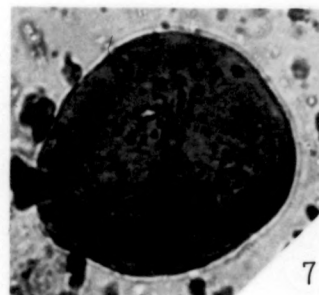
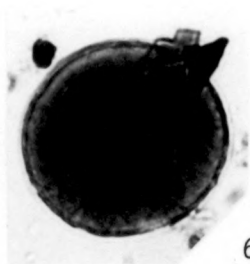
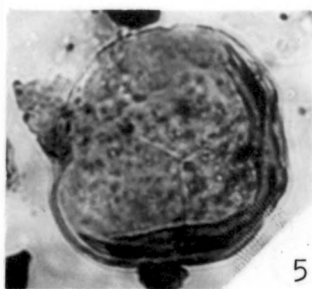
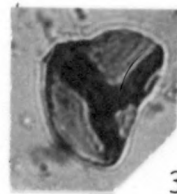
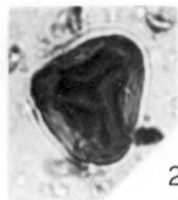
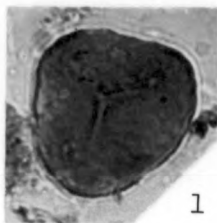


Plate II

- Figure 14 Granulatisporites crenulatus Playford
1963. Maximum diameter 27.6 microns;
sample Nu-2-B, slide number 1,
co-ordinates 60.1 X 112.2. (Page 80)
- Figure 15 Cyclogranisporites commodus Playford 1963.
Maximum diameter 45.0 microns; sample
Ha-5-B, slide number 8, co-ordinates
54.8 X 99.2. (Page 81)
- Figure 16 Verrucosisporites nitidus (Naumova)
Playford 1963. Maximum diameter 40.6
microns; sample Ha-5-A, slide number 8,
co-ordinates 63.2 X 96.7. (Page 82)
- Figures 17, 18 Converrucosisporites parvinodosus Playford
1963. Fig. 17, maximum diameter 33.6
microns; sample Ha-3-C, slide number 6,
co-ordinates 68.8 X 101.2. Fig. 18,
maximum diameter 29.5 microns; sample
Nu-2-E, slide number 7, co-ordinates
67.9 X 98.9. (Page 84)
- Figure 19 Anapiculatisporites ampullaceus
(Hacquebard) Playford 1963. Maximum
diameter, including projections, 52.2
microns; sample Ha-3-B, slide number 1,
co-ordinates 53.8 X 95.0. (Page 85)

Figures 20, 21 Pustulatisporites gibberosus Playford 1963.

Fig. 20, maximum diameter, including projections, 40.0 microns; sample Nu-2-E, slide number 3, co-ordinates 68.0 X 109.3. Fig. 21, maximum diameter, including projections, 46.4 microns; sample Ha-5-A, slide number 4, co-ordinates 61.4 X 100.3. (Page 87)

Figures 22, 23 Apiculiretusispora multiseta (Luber)

Butterworth, 1967. Fig. 22, maximum diameter, including projections, 42.1 microns; sample Ha-3-D, slide number 9, co-ordinates 60.8 X 107.0. Fig. 23, same spore showing proximal view. (Page 89)

Figure 24 Grandispora echinata Hacquebard 1957.

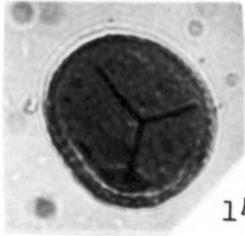
Maximum diameter 69.6 microns; sample Nu-2-B, slide number 10, co-ordinates 68.4 X 100.7. (Page 91)

Figure 25 Convolutispora sp. cf. C. ampla Hoff-

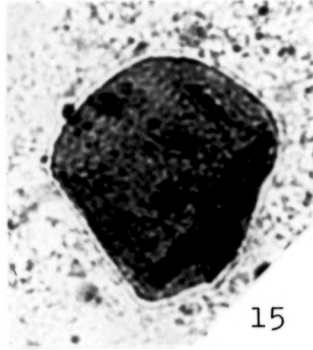
meister, Staplin, and Malloy 1955. Maximum diameter 55.1 microns; sample Nu-4-A, slide number 1, co-ordinates 67.7 X 105.2. (Page 93)

Palynology of the Hannibal Fm. NE Mo. and W. Ill.

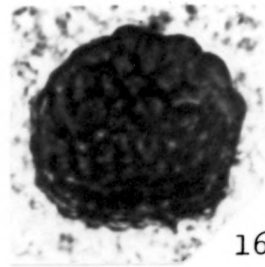
PLATE II



14



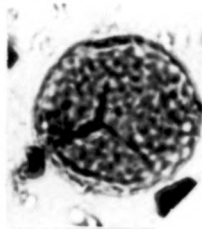
15



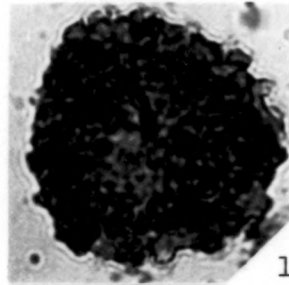
16



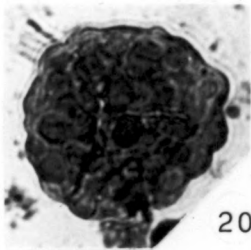
17



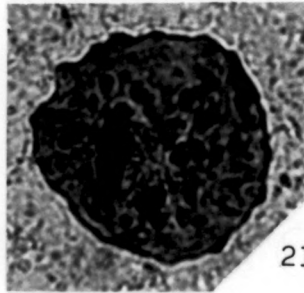
18



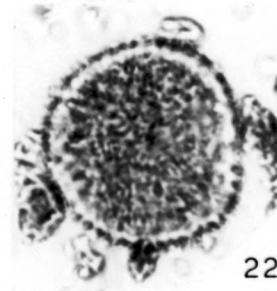
19



20



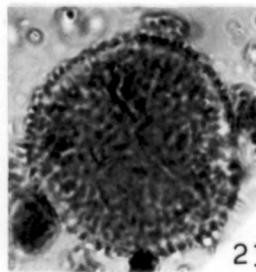
21



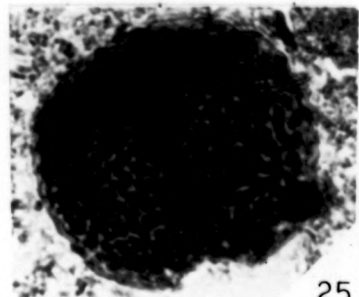
22



24



23



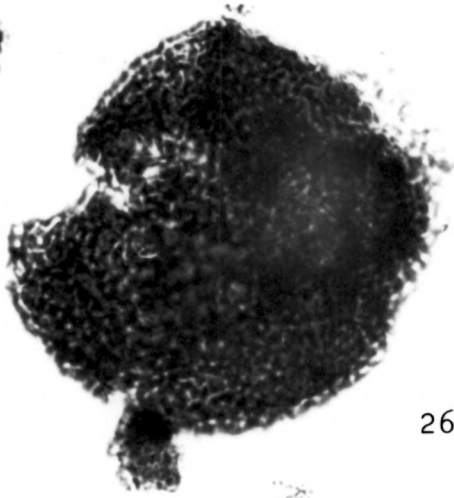
25

PLATE III

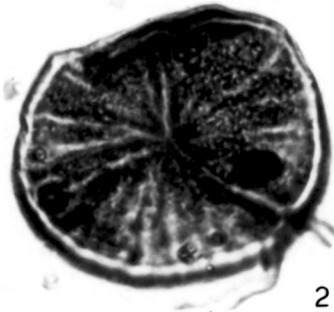
- Figure 26 Convolutispora sp. cf. C. ampla
Hoffmeister, Staplin, and Malloy 1955.
Maximum diameter 75.4 microns; sample
Ha-3-B, slide number 7, co-ordinates
52.8 X 109.2. (Page 93)
- Figure 27 Emphanisporites rotatus McGregor 1961.
Maximum diameter 58.0 microns; sample
Ha-1-D, slide number 1, co-ordinates
54.4 X 105.5. (Page 95)
- Figures 28, 29 Perotriletes perinatus Hughes and Playford
1962. Fig. 28, maximum diameter 58.0
microns, sample Ha-3-D, slide number 9,
co-ordinates 62.0 X 109.9. Fig. 29,
maximum diameter 63.8 microns; sample
Ha-3-C, slide number 6, co-ordinates
56.1 X 110.8. (Page 97)
- Figures 30, 31 Perotriletes spherotriangulatus sp. nov.
Fig. 30, Holotype, diameter of central
body 43.5 microns; sample Ha-3-D, slide
number 2, co-ordinates 67.3 X 103.1.
Fig. 31, maximum diameter 58.0 microns;
sample Ha-5-A, slide number 3,
co-ordinates 63.2 X 96.6. (Page 99)

Figures 32, 33 Lophozonotriletes dentatus Hughes and Playford 1961. Fig. 32, maximum diameter, including projections, 46.4 microns; sample Cu-3-B, slide number 1, co-ordinates 56.4 X 107.4. Fig. 33, maximum diameter, including projections, 43.5 microns; sample Ha-5-C, slide number 3, co-ordinates 61.9 X 102.9.
(Page 101)

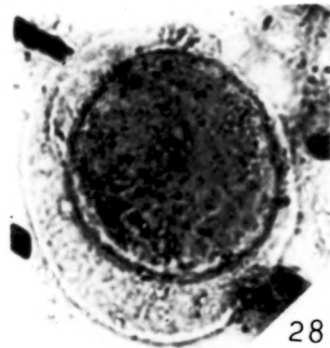
Palynology of the Hannibal Fm. NE. Mo. and W. Ill.
PLATE III



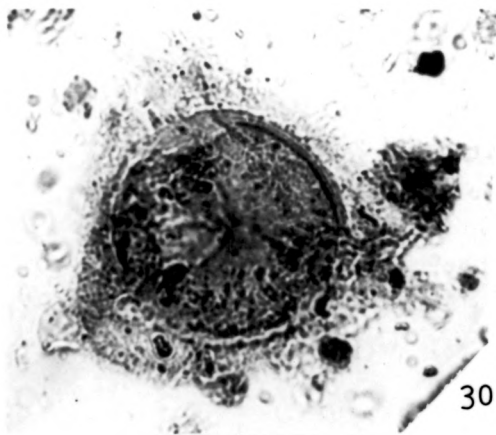
26



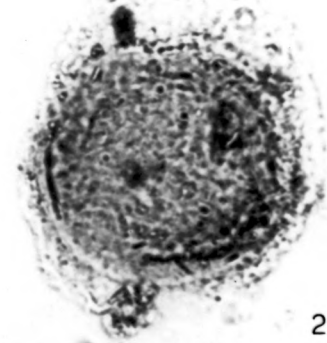
27



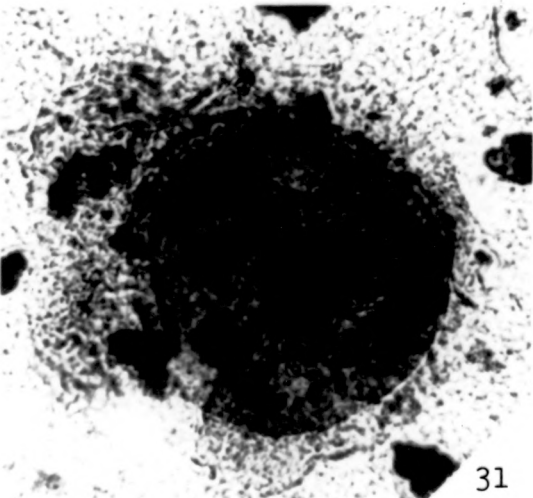
28



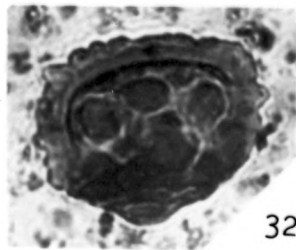
30



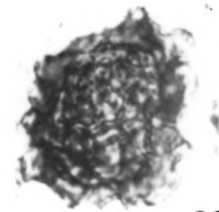
29



31



32



33

PLATE IV

- Figures 34, 35 Lophozonotriletes rarituberculatus (Luber)
Kedo 1957. Fig. 34, proximal view.
Fig. 35, distal view showing verrucae.
Maximum diameter 40.6 microns; sample
Nu-2-A, slide number 2, co-ordinates
59.3 X 97.6. (Page 102)
- Figure 36 Lycospora pseudoannulata Kosanke 1950.
Maximum diameter 33.4 microns; sample
Nu-4-A, slide number 4, co-ordinates
70.0 X 111.5. (Page 105)
- Figures 37, 38 Endosporites micromanifestus Hacquebard
1957. Fig. 37, maximum diameter 59.5
microns; sample Nu-2-F, slide number 3,
co-ordinates 60.0 X 104.5. Fig. 38,
maximum diameter 43.5 microns; sample
Ha-1-E, slide number 10, co-ordinates
56.0 X 98.7. (Page 109)
- Figures 39-42 Auroraspora minutigranulata sp. nov.
Figs. 39 and 42 (X1570). Proximal and
distal view respectively, showing
relationship between exoexine and
intexine. Maximum diameter 36.3 microns;
sample Nu-2-F, slide number 1,
co-ordinates 54.8 X 107.9. Fig. 40,

maximum diameter 37.1 microns; sample Nu-2-A, slide number 2, co-ordinates 60.1 X 101.5. Fig. 41, maximum diameter 27.5 microns; sample Nu-2-A, slide number 3, co-ordinates 51.0 X 110.9. (Page 112)

Figure 43

Hymenozonotriletes lepidophytus Kedo 1957.

Distal view showing lacunae. Maximum diameter 92.8 microns; sample Ha-3-D, slide number 2, co-ordinates 60.3 X 104.0. (Page 114)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

PLATE IV

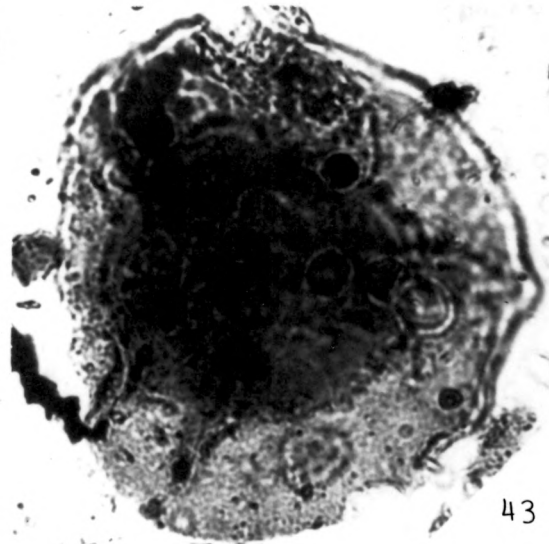
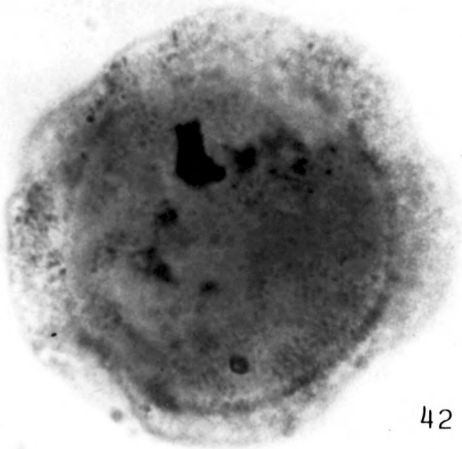
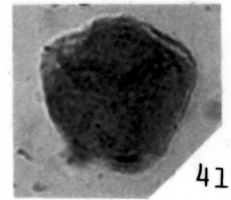
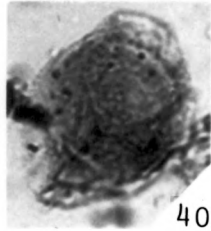
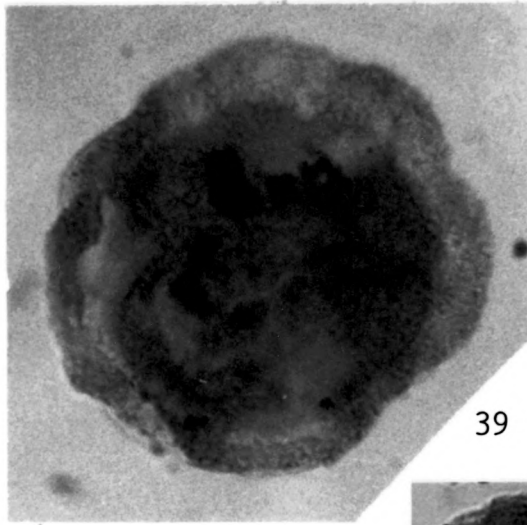
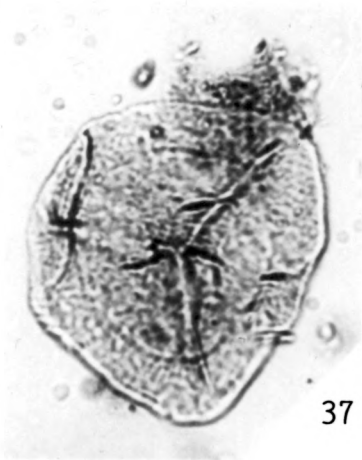
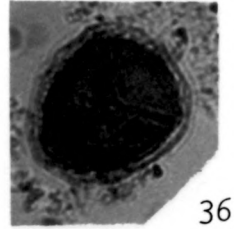
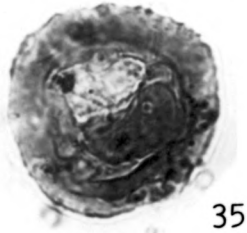


PLATE V

- Figure 44 ?Secarisporites sp. Maximum diameter, including projections, 53.7 microns; sample Nu-2-C, slide number 7, co-ordinates 68.6 X 100.0. (Page 117)
- Figure 45 ?Cirratriradites sp. Maximum diameter 58.0 microns; sample Ha-3-B, slide number 1, co-ordinates 54.0 X 109.0. (Page 118)
- Figure 46 ?Lophozonotriletes cristifer (Luber) Kedo 1957. Maximum diameter 46.4 microns; sample Nu-1-F, slide number 2, co-ordinates 63.0 X 96.0. (Page 118)
- Figure 47 ?Densosporites sp. Maximum diameter 63.8 microns; sample Nu-2-E, slide number 2, co-ordinates 54.4 X 105.0. (Page 119)
- Figures 48, 49 ?Vallatisporites sp. Fig. 48 showing perforations along inner margin of cingulum. Fig. 49 showing laesurae development. Maximum diameter 58.0 microns; sample Nu-1-D, slide number 13, co-ordinates 64.5 X 93.9. (Page 120)
- Figures 50, 51 ?Spinozonotriletes sp. Fig. 50 distal view. Fig. 51 showing zona. Maximum

diameter 60.9 microns; sample Nu-2-F,
slide number 10, co-ordinates 62.7 X
106.6. (Page 122)

Figure 52

?Cf. Lophotriletes plicatus Butterworth
1967. Maximum diameter, including
projections, 42.0 microns; sample Ha-3-D,
slide number 14, co-ordinates 57.7 X
104.2. (Page 124)

Figure 53

?Retusotriletes sp. Maximum diameter
78.3 microns; sample Nu-2-F, slide
number 5, co-ordinates 59.6 X 100.5.
(Page 124)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.
PLATE V

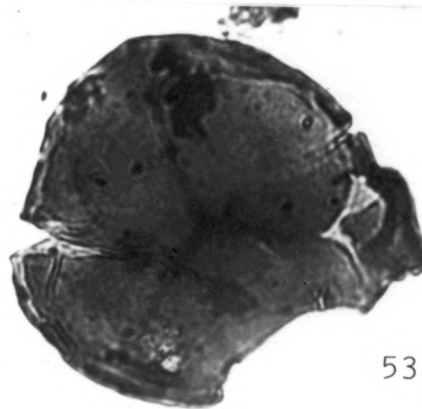
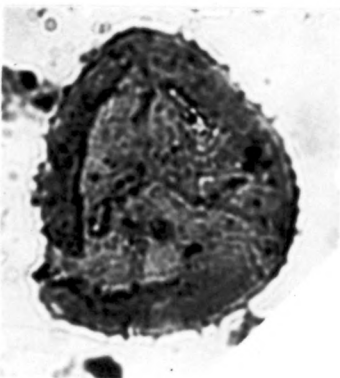
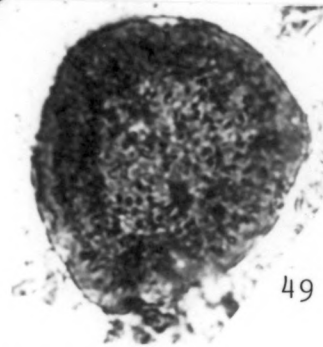
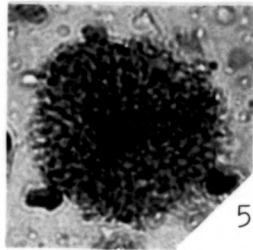
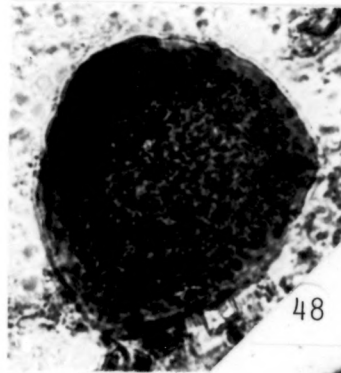
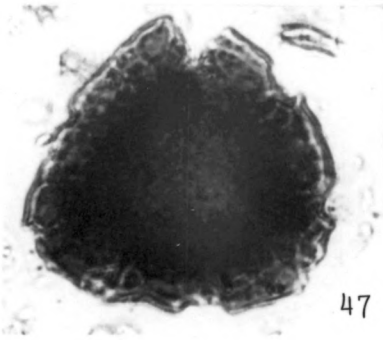
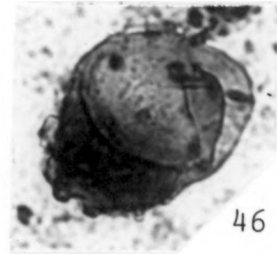
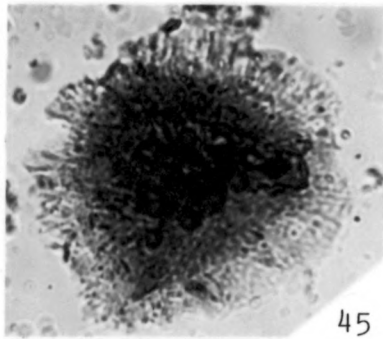
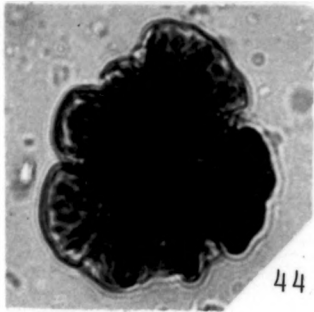


PLATE VI

- Figures 54, 55 Leiosphaeridia orbiculatum (Staplin)
Downie and Sarjeant 1963. Fig. 54,
maximum test diameter 46.4 microns;
sample Nu-2-A, slide number 1,
co-ordinates 55.2 X 105.3. Fig. 55,
maximum test diameter 49.3 microns;
sample Nu-2-C, slide number 5,
co-ordinates 56.7 X 105.3. (Page 132)
- Figure 56 Leiosphaeridia triangulata sp. nov.
Maximum test diameter 31.2 microns;
sample Nu-2-D, slide number 2,
co-ordinates 59.0 X 103.8. (Page 133)
- Figures 57, 58 Leiosphaeridia sp. A. Fig. 57, maximum
test diameter 20.7 microns; sample
Ha-5-B, slide number 9, co-ordinates
64.4 X 105.8. Fig. 58, an enlargement
of the right side of Fig. 57. (Page 134)
- Figure 59 Leiosphaeridia major (Staplin) Downie and
Sarjeant 1963. Fig. 59, maximum test
diameter 66.6 microns; sample Nu-2-B,
slide number 2, co-ordinates 66.9 X
100.3. (Page 135)
- Figure 60 Leiosphaeridia fastigatirugosum (Staplin)
Downie and Sarjeant 1963. Maximum test

diameter 255.0 microns; sample Ha-3-D,
slide number 11, co-ordinates 52.0 X
96.7. (Page 136)

Figure 61

Leiosphaeridia microgranifera (Staplin)

Downie and Sarjeant 1963. Maximum
test diameter 34.8 microns; sample
Nu-2-A, slide number 1, co-ordinates
58.5 X 96.4. (Page 137)

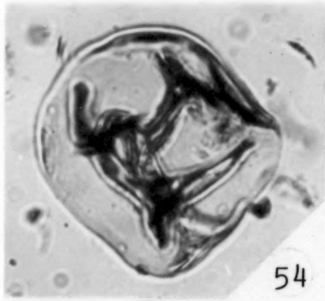
Figure 62

Leiosphaeridia sp. B. Maximum test

diameter 31.9 microns; sample Nu-2-D,
slide number 2, co-ordinates 55.0 X
95.5. (Page 137)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

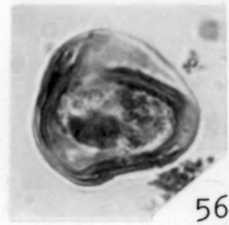
PLATE VI



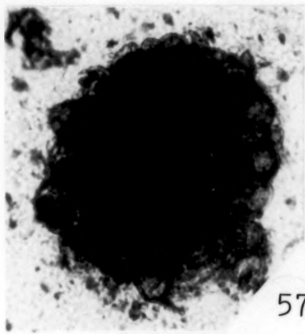
54



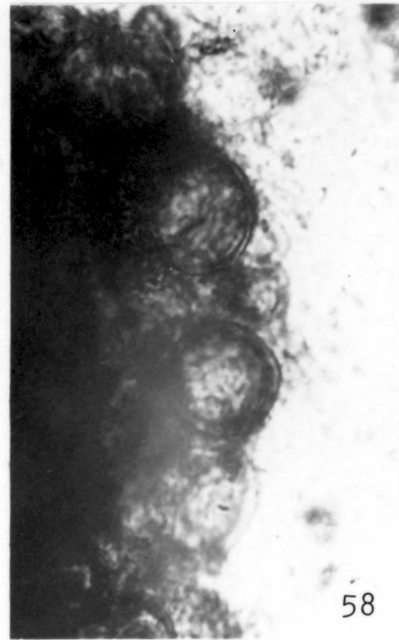
55



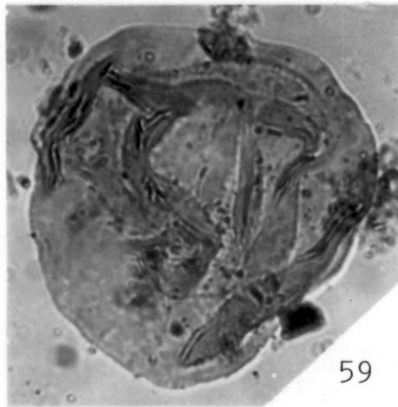
56



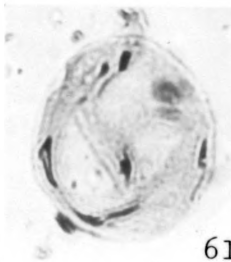
57



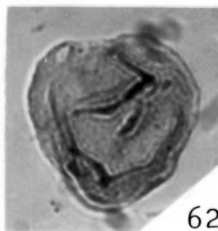
58



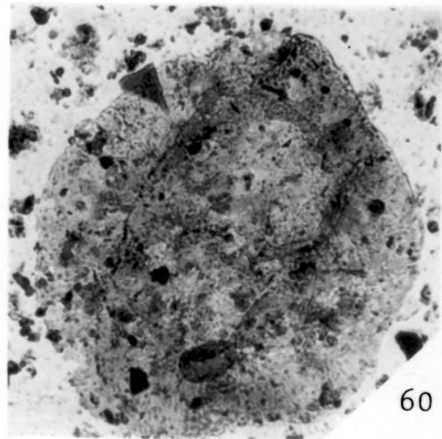
59



61



62



60

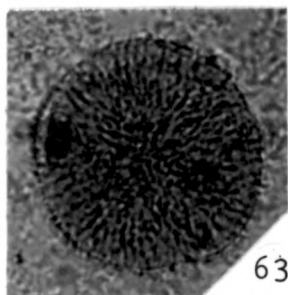
PLATE VII

- Figure 63 Lophosphaeridium papillatum (Staplin)
new. comb. Maximum test diameter 43.5
microns; sample Ha-5-A, slide number
4, co-ordinates 61.2 X 99.1. (Page 138)
- Figure 64 Lophosphaeridium microsaeosum (Staplin)
new. comb. Maximum test diameter 32.5
microns; sample Ha-1-E, slide number 6,
co-ordinates 53.5 X 97.0. (Page 139)
- Figure 65 Cymatiosphaera sp. Maximum diameter 60.5
microns; sample Nu-2-A, slide number 2,
co-ordinates 63.0 X 109.2. (Page 141)
- Figure 66 Dictyotidium sp. A. Maximum diameter
36.2 microns; sample Ha-5-C, slide
number 10, co-ordinates 64.1 X 101.6.
(Page 142)
- Figures 67, 68 Dictyotidium sp. B. Maximum test diameter
24.0 microns, spine length 5 to 10
microns; sample Ha-5-C, slide number 9,
co-ordinates 71.6 X 105.6. (Page 143)
- Figure 69 Veryhachium downiei Stockmans and Williere
1962. Maximum diameter from tip of
spine to opposite side 31.9 microns;
sample Ha-3-A, slide number 4,
co-ordinates 58.6 X 107.7. (Page 145)

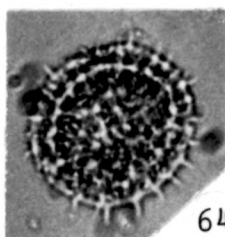
- Figure 70 Veryhachium brevitrispinum Staplin 1961.
Maximum diameter from tip of spine to
opposite side 34.8 microns; sample
Ha-3-A, slide number 4, co-ordinates
58.6 X 101.2. (Page 146)
- Figure 71 Veryhachium europaeum Stockmans and
Williere 1960. Maximum diameter from
tip of spine to opposite side 33.5
microns; sample Cu-3-E, slide number 2,
co-ordinates 63.0 X 112.0. (Page 146)
- Figures 72-74 Veryhachium rhomboidium Downie 1959.
Fig. 72, maximum test diameter 21
microns, spine length 8 to 10 microns;
sample Ha-3-A, slide number 10,
co-ordinates 61.1 X 107.0. Fig. 73,
maximum test diameter 23.0 microns,
spine length 15.0 microns; sample
Ha-3-A, slide number 5, co-ordinates
61.3 X 97.2. Fig. 74, maximum test
diameter 22.4 microns, spine length
14 to 17 microns; sample Nu-2-B, slide
number 2, co-ordinates 67.3 X 102.1.
(Page 147)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

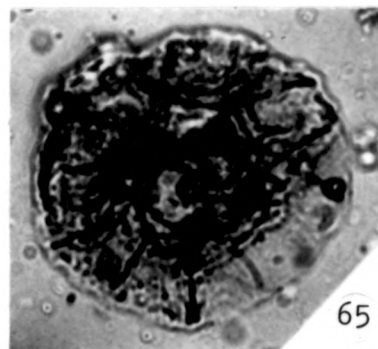
PLATE VII



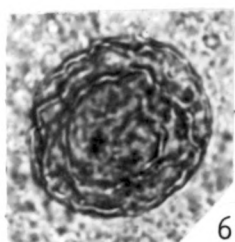
63



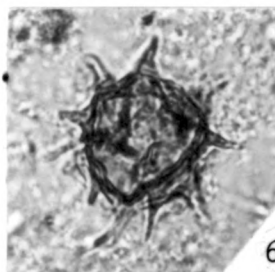
64



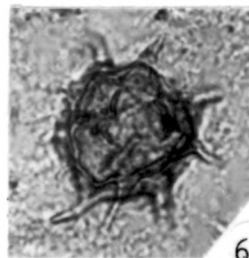
65



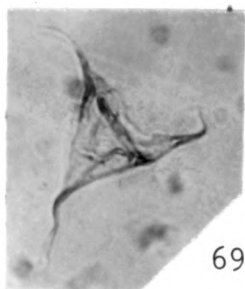
66



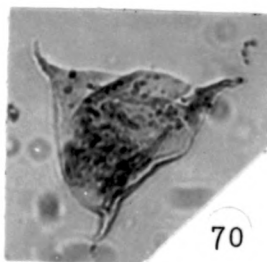
67



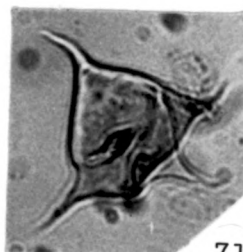
68



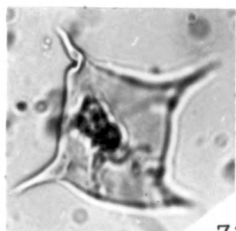
69



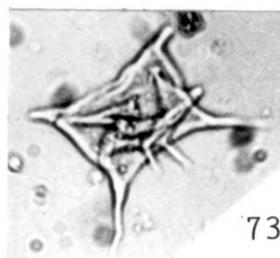
70



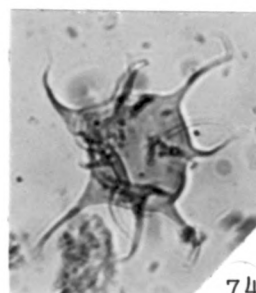
71



72



73



74

PLATE VIII

- Figure 75 Veryhachium formosum Stockmans and Williere
1960. Maximum test diameter 22.5
microns, spine length 17.0 microns;
sample Ha-3-A, slide number 2,
co-ordinates 69.5 X 101.3. (Page 148)
- Figures 76, 77 Veryhachium sp. A. Fig. 76, maximum test
diameter 29.0 microns, spine length 14.0
microns; sample Ha-5-A, slide number 9,
co-ordinates 54.5 X 96.0. Fig. 77,
maximum test diameter 29.0 microns,
spine length 8 to 9 microns; sample
Ha-3-B, slide number 4, co-ordinates
65.4 X 102.7. (Page 148)
- Figure 78 Veryhachium sp. B. Maximum test diameter
30.0 microns, spine length 16.0 microns;
sample Ha-1-E, slide number 4,
co-ordinates 65.5 X 99.0. (Page 149)
- Figures 79, 80 Baltisphaeridium sp. A. Maximum test
diameter 43.5 microns, spine length 3.0
microns; sample Nu-2-D, slide number 2,
co-ordinates 55.2 X 105.2. Fig. 80,
maximum test diameter 45.0 microns,
spine length 2.0 microns; sample Nu-2-A,
slide number 1, co-ordinates 58.5 X 96.4.

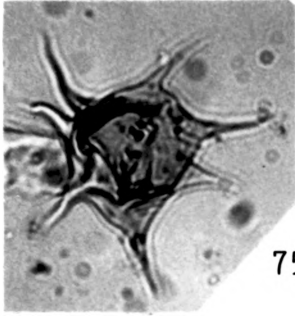
(Page 151)

Figure 81

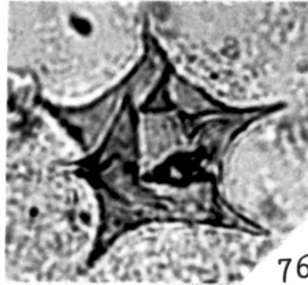
Baltisphaeridium sp. B. Maximum test
diameter 63.5 microns, spine length
17 to 20 microns; sample Ha-5-A, slide
number 3, co-ordinates 56.5 X 96.4.

(Page 151)

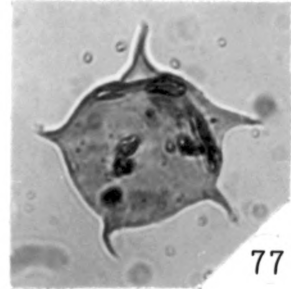
Palynology of the Hannibal Fm. NE. Mo. and W. Ill.
PLATE VIII



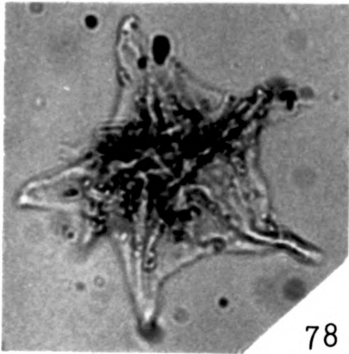
75



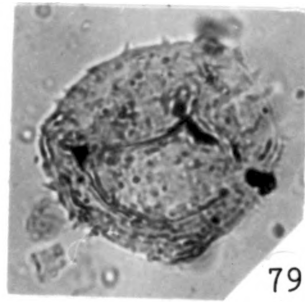
76



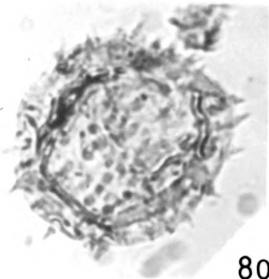
77



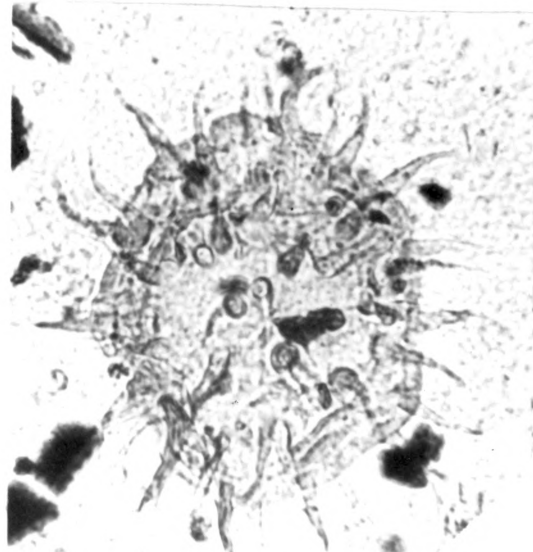
78



79



80



81

Plate IX

- Figure 82 Baltisphaeridium sp. C. Maximum test diameter 58.0 microns, spine length 12 to 15 microns; sample Ha-5-B, slide number 4, co-ordinates 54.2 X 98.1. (Page 152)
- Figure 83 Baltisphaeridium lucidum (Deunff) Downie and Sarjeant 1963. Maximum test diameter 26.0 microns, spine length 26 to 29 microns; sample Ha-3-A, slide number 8, co-ordinates 61.5 X 105.1. (Page 152)
- Figure 84 Baltisphaeridium sp. cf. B. debilispinum Wall and Downie 1963. Maximum test diameter 23.0 microns, spine length 15 to 20 microns; sample Ha-3-A, slide number 8, co-ordinates 66.0 X 103.1. (Page 153)
- Figures 85, 86 Micrhystridium lunatum Stockmans and Williere 1966. Fig. 85, maximum test diameter 18.5 microns, spine length 10 to 17 microns; sample Ha-3-A, slide number 10, co-ordinates 58.5 X 105.2. Fig. 86, maximum test diameter 24.3 microns, spine length 14 to 18 microns; sample

Ha-3-A, slide number 8, co-ordinates
64.3 X 105.3. (Page 154)

Figure 87

Micrhystridium bistchoensis Staplin 1961.

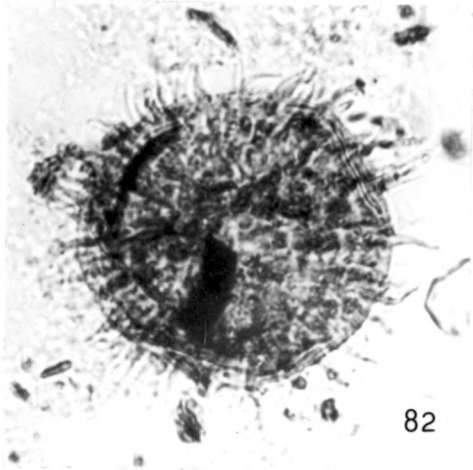
Maximum test diameter 18.5 microns,
spine length 4 to 8 microns; sample
Ha-5-B, slide number 8, co-ordinates
51.8 X 98.9. (Page 155)

Figures 88, 89

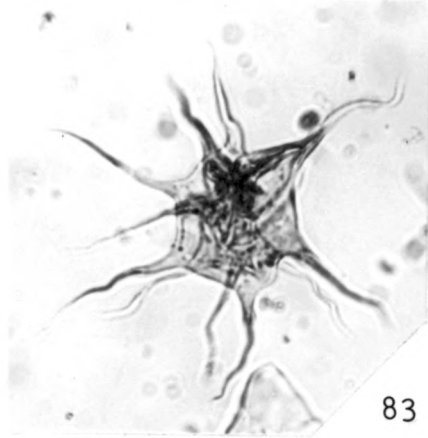
Micrhystridium sp. cf. Baltisphaeridium
triangulare Stockmans and Williere 1962.

Fig. 88, maximum test diameter 20.8
microns, spine length 12 to 16 microns;
sample Ha-3-A, slide number 10,
co-ordinates 59.0 X 106.0. Fig. 89,
maximum test diameter 20.3 microns,
spine length 10 to 12 microns; sample
Ha-3-A, slide number 8, co-ordinates
65.9 X 107.6. (Page 156)

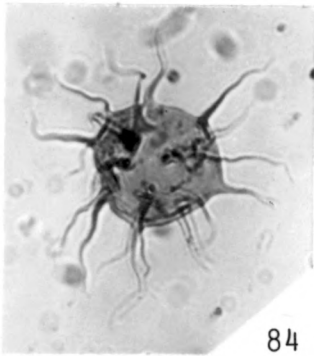
Palynology of the Hannibal Fm. NE. Mo. and W. Ill.
PLATE IX



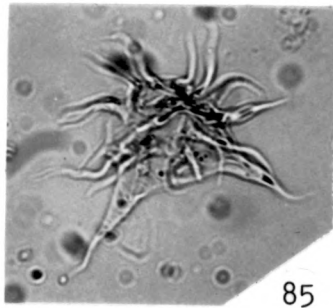
82



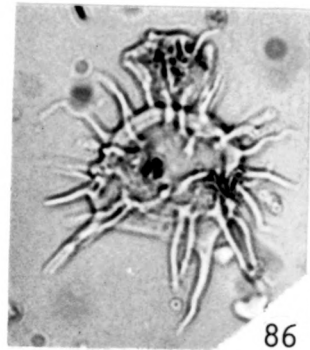
83



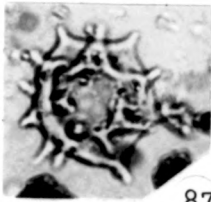
84



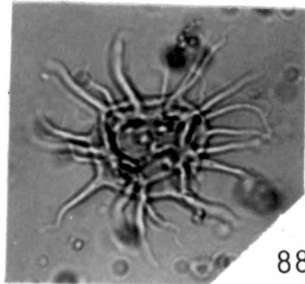
85



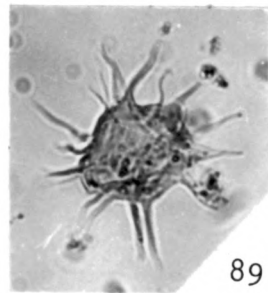
86



87



88



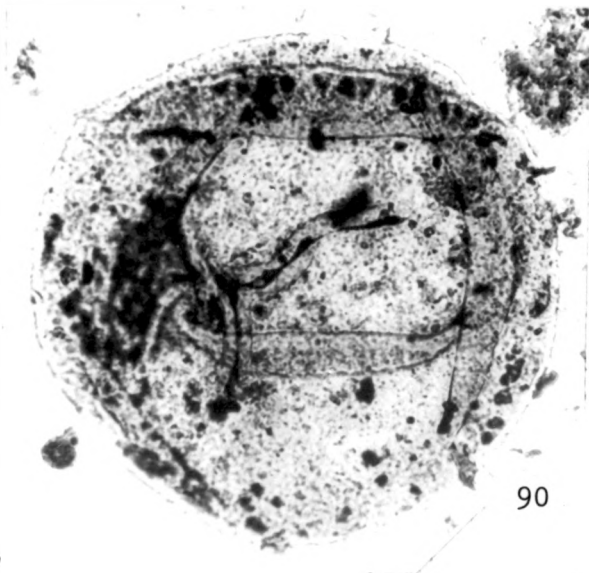
89

PLATE X

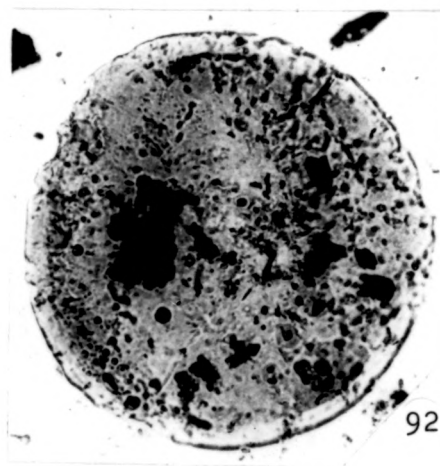
- Figures 90, 91 Tasmanites sinuosus Winslow 1962. Fig. 90 (X235). Maximum diameter 317.0 microns; sample Ha-3-D, slide number 14, co-ordinates 68.7 X 102.8. Fig. 91, maximum diameter 96.0 microns; sample Ha-3-B, slide number 9, co-ordinates 58.7 X 104.7. (Page 160)
- Figure 92 Tasmanites huronensis (Dawson) Winslow 1962. Fig. 92 (X235). Maximum diameter 250.0 microns; sample Ha-3-B, slide number 6, co-ordinates 61.3 X 96.8. (Page 161)
- Figure 93 Tasmanites sp. A. Maximum diameter 100.0 microns; sample Ha-3-D, slide number 10, co-ordinates 53.6 X 99.3. (Page 162)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

PLATE X



90



92



91



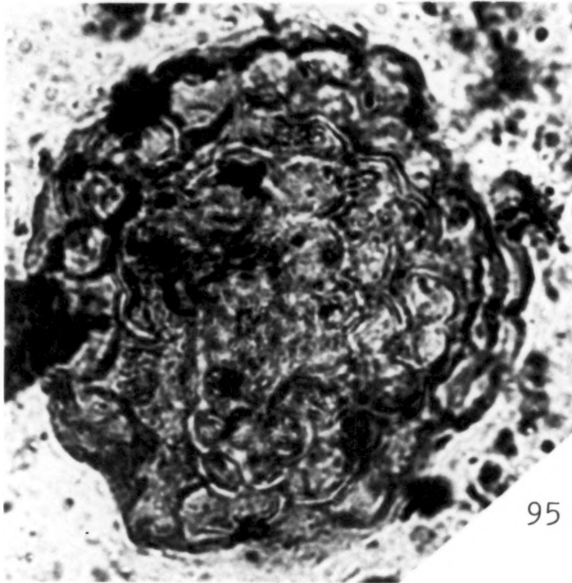
93

PLATE XI

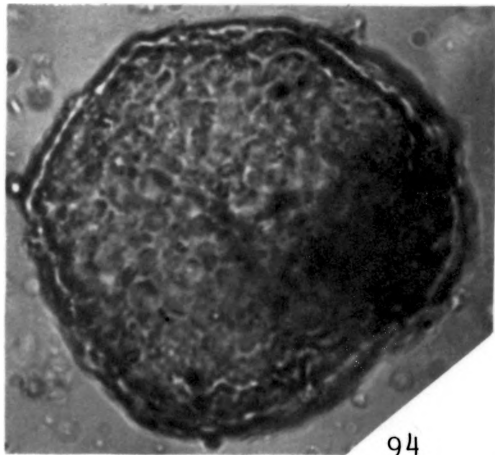
- Figure 94 Tasmanites sp. A. Maximum diameter 105.0
microns; sample Nu-2-E, slide number 10,
co-ordinates 50.7 X 101.0. (Page 162)
- Figure 95 Tasmanites sp. B. Maximum diameter 81.0
microns; sample Nu-2-F, slide number 10,
co-ordinates 55.4 X 98.0. (Page 163)
- Figure 96 Tasmanites sp. C. Maximum diameter 105.0
microns; sample Nu-2-E, slide number 5,
co-ordinates 54.0 X 93.2. (Page 163)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

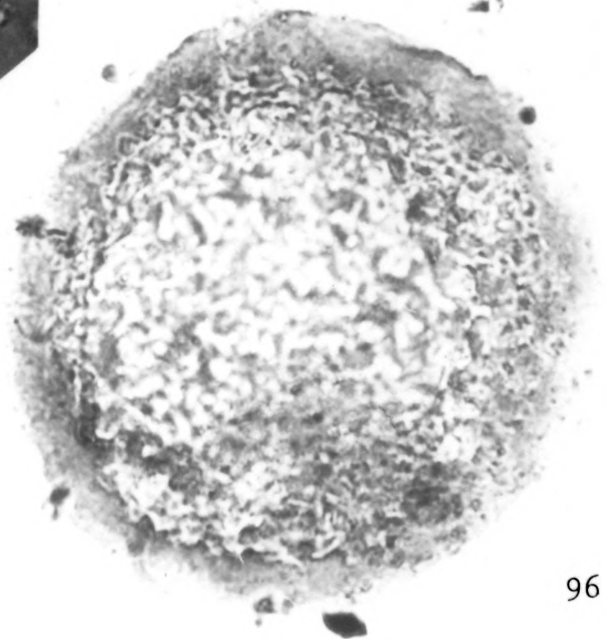
PLATE XI



95



94



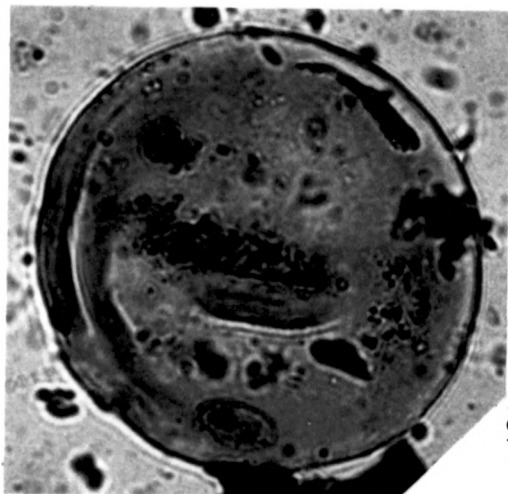
96

PLATE XII

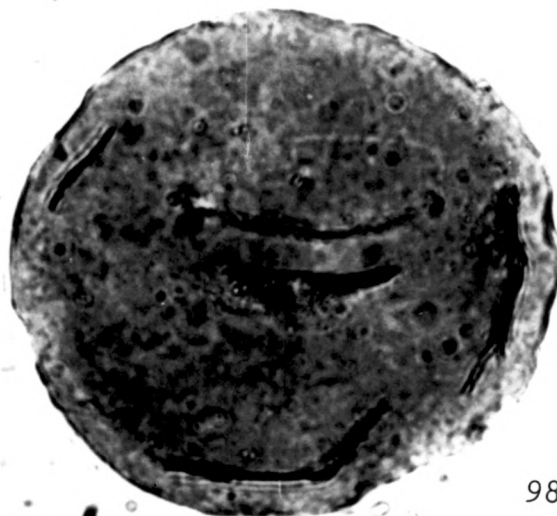
- Figures 97, 98 Tasmanites sp. D. Fig. 97, maximum diameter 87.0 microns; sample Ha-3-D, slide number 3, co-ordinates 65.5 X 100.1. Fig. 98, maximum diameter 109.0 microns; sample Nu-2-C, co-ordinates 52.3 X 105.0. (Page 164)
- Figure 99 ?Tasmanites sp. Fig. 99 (X235). Maximum diameter 218.0 microns; sample Ha-5-D, slide number 3, co-ordinates 62.7 X 96.4. (Page 164)
- Figure 100 Tasmanites sp. cf. T. euzebioi Sommer 1956. Fig. 100 (X235). Maximum diameter 306.0 microns; sample Nu-2-E, slide number 9, co-ordinates 58.5 X 105.9. (Page 165)

Palynology of the Hannibal Fm. NE. Mo. and W. Ill.

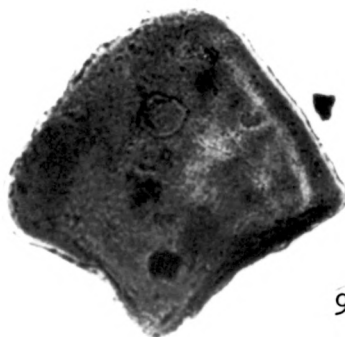
PLATE XII



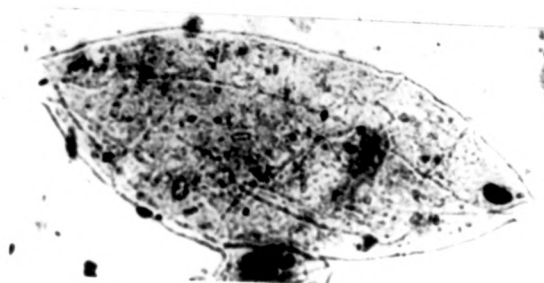
97



98



99



100

VITA

Dwight Delon Brown was born on [REDACTED], in Hamden, Chariton County, Missouri. He attended Keytesville High School, Ketyesville, Missouri, and graduated from that school in 1955. In the fall of September, 1956, he enrolled in the University of Missouri, Columbia, Missouri. He received a Bachelor of Arts degree in Geology from that institution in 1962. In the summer of 1962, he enrolled in graduate school in the Department of Botany, University of Missouri, Columbia, Missouri, and was awarded an NDEA fellowship at that time to support research in Palynology.

He has been employed as an Assistant Professor of Biology at Sam Houston State College, Huntsville, Texas, since June, 1967.

University Libraries
University of Missouri

Digitization Information Page

Local identifier Brown1968

Source information

Format Book
Content type Text with images
Source ID Gift copy from department; not added to MU collection
Notes Microscope slide images are dark and can be hard to discern.

Capture information

Date captured 07/16/2025
Scanner manufacturer Fujitsu
Scanner model fi-7460
Scanning system software ScandAll Pro v. 2.1.5 Premium
Optical resolution 600 dpi
Color settings 8 bit grayscale
File types tiff
Notes N/A

Derivatives - Access copy

Compression Tiff: LZW compression
Editing software Adobe Photoshop 2025
Resolution 600 dpi
Color grayscale
File types tiff, combined into pdf
Notes Images cropped, straightened, and brightened to best ability.