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ABSTRACT

PALYNOMORPHS OF THE WOODFORD SHALE OF
SOUTH CENTRAL OKLAHOMA WITH OBSERVATIONS
ON THEIR SIGNIFICANCE IN ZONATION
AND PALEOECOLOGY

by William F. von Almen

This study was made to describe the palynomorphs of the Woodford Formation of south central Oklahoma, establish environmental zones, correlate these environmental zones, determine the geologic age of the formation and make a logical interpretation of the environment of deposition of the formation.

Fifty-five outcrop and core chip samples were processed and organic residue slides were utilized to identify palynomorphs, make counts and compare the types of palynomorphs observed to establish environmental zones, compare individual significant palynomorph species to identify the age of the formation and, based on a lithologic examination and the types of palynomorphs and organic detritus (not assignable to known palynomorphs or whole organisms) present in the residues, postulate a logical environment of deposition for the formation.

Ninety-seven palynomorphs are described and/or discussed, of which 59 are microspores, 34 are acritarchs, 2 are scolecodonts and 2 are of uncertain affinity. Two of these palynomorphs are described as new genera and three are described as new species. Three palynomorph zones, that illustrate cycles of marine transgression and regression, are present in the formation, although these zones are not definitely correlative from one section to another. Leiosphere zones are also present and in some cases correlative, although their environmental significance is not known.

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Data pertaining to the occurrence of palynomorphs of different groups together, separately, and in stratigraphic units of the same lithology, illustrate that acritarchs possessing processes or membranes are significant in environmental interpretation. They are more abundant in sediments deposited where microspores occur and land-derived nutrients are abundant, than in sediments deposited where leiospheres are the most abundant type of palynomorph, and in cases where they occur in the same lithologic unit they are apparently facies controlled.

Microspore species obtained from the "Woodford (?) Brown Carbonate" are significant in identifying the age of this basal, subjacent unit of the Woodford Formation in the Texas Company #1 Gipson well in Marshall County, Oklahoma as Middle Devonian (Erian). Microspore species obtained from the 333-foot section of the Woodford Formation at Hickory Creek are 1) significant in identifying the basal 10 feet of the formation as probable Upper Devonian (Senecan) in age, 2) inconclusive in identifying the age of the succeeding 298 feet of the formation and 3) significant in identifying the top 25 feet of the formation as Lower Mississippian (Kinderhookian) in age. Microspore species recovered in the Woodford Formation residues of this study are not conspecific with those reported from Devonian-Mississippian black shales in other parts of the United States.

The lithologic similarity of the formation throughout the area of study and the presence of well-preserved organic material in all samples are significant because they support a locus of deposition where reducing conditions were present. Land-derived palynomorphs are not significant in determining water depths in the area although the presence of microspores and acritarchs possessing processes or membranes, and the constant abundance of leiospheres in all samples is suggestive of a relatively constant water depth.

PALYNOMORPHS OF THE WOODFORD SHALE OF SOUTH CENTRAL OKLAHOMA WITH OBSERVATIONS ON THEIR SIGNIFICANCE IN ZONATION AND PALEOECOLOGY

By

rederick
William F. von Almen

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Geology

1970

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ACKNOWLEDGEMENTS

I deeply appreciate the guidance and encouragement of Professor Aureal T. Cross, who served as my advisor and whose knowledge of the Devonian-Mississippian flora was an invaluable asset in the course of this research. Constructive criticism of the manuscript and corrective suggestions from Dr. C. E. Prouty, Dr. J. H. Fisher, Dr. R. E. Erlich and Dr. J. E. Smith were most helpful in organization of all biostratigraphic material included in the dissertation.

I sincerely thank Paul W. Nygreen and O. B. Bourn, Chevron Oil Company, Oklahoma City, Oklahoma whose assistance in sample collecting and discussions of palynomorph assemblages were an invaluable aid. Thanks are due J. D. Wooten and M. W. Thompson, Chevron Oil Company, Oklahoma City, Oklahoma for preparation of some of the residues and slides.

Chevron Oil Company, Oklahoma City, Oklahoma provided equipment for field work and sample collecting, and laboratory space and equipment for some sample processing and slide preparation.

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3 Upper Wood
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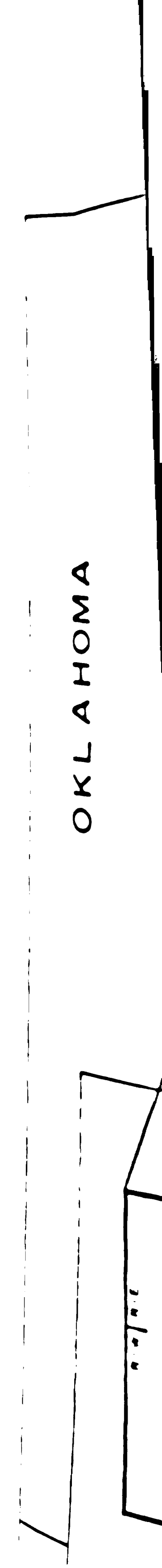
INTRODUCTION

The Woodford Chert (Taff, 1902) of Oklahoma, Texas and New Mexico is a lateral lithologic equivalent of an extensive black shale and chert deposit known as the Chattanooga Shale, Middle Arkansas Novaculite, Ellsworth-Antrim Shale, New Albany Shale, and Ohio Black Shale in the central United States (Cross and Hoskins, 1951a, 1951b; Hoskins and Cross, 1952; Campbell, 1946; Fisher, 1953); Huron Black Shale and Kettle Point Shale in eastern Canada (Cross and Hoskins, 1951a); and the Exshaw Shale and Baaken Shale in western Canada (ibid.; Clark and Stearns, 1959). These formations occupy roughly similar stratigraphic positions though not all time equivalent (synchronous), and are enigmatic in respect to their age and environment of deposition.

The Woodford Chert of southern Oklahoma contains abundant acid resistant organic matter, including palynomorphs. An investigation of these forms was started in 1965 in anticipation of determining the age and environment of deposition of the Woodford. Specifically, the main objectives of this study are to: 1) describe palynomorphs from the formation; 2) establish environmental zones, utilizing palynomorphs, in the relatively lithologically homogeneous formation from a completely exposed surface section in Hickory Creek, Carter County, Oklahoma (Figure 1, Locality 1, page 2); 3) correlate the Hickory Creek section, utilizing the environmental zones, with the Woodford Chert from 4 wells in Carter, Garvin and Marshall Counties, Oklahoma, from which core chips were obtained and analyzed from parts of the formation (Figure 1, Localities 4, 5, 6, 7, page 2); 4) determine the geologic age of the Woodford Chert by comparison of its palynological assemblages with those published assemblages of known age, including the Ohio Black Shale of Ohio (Winslow, 1962)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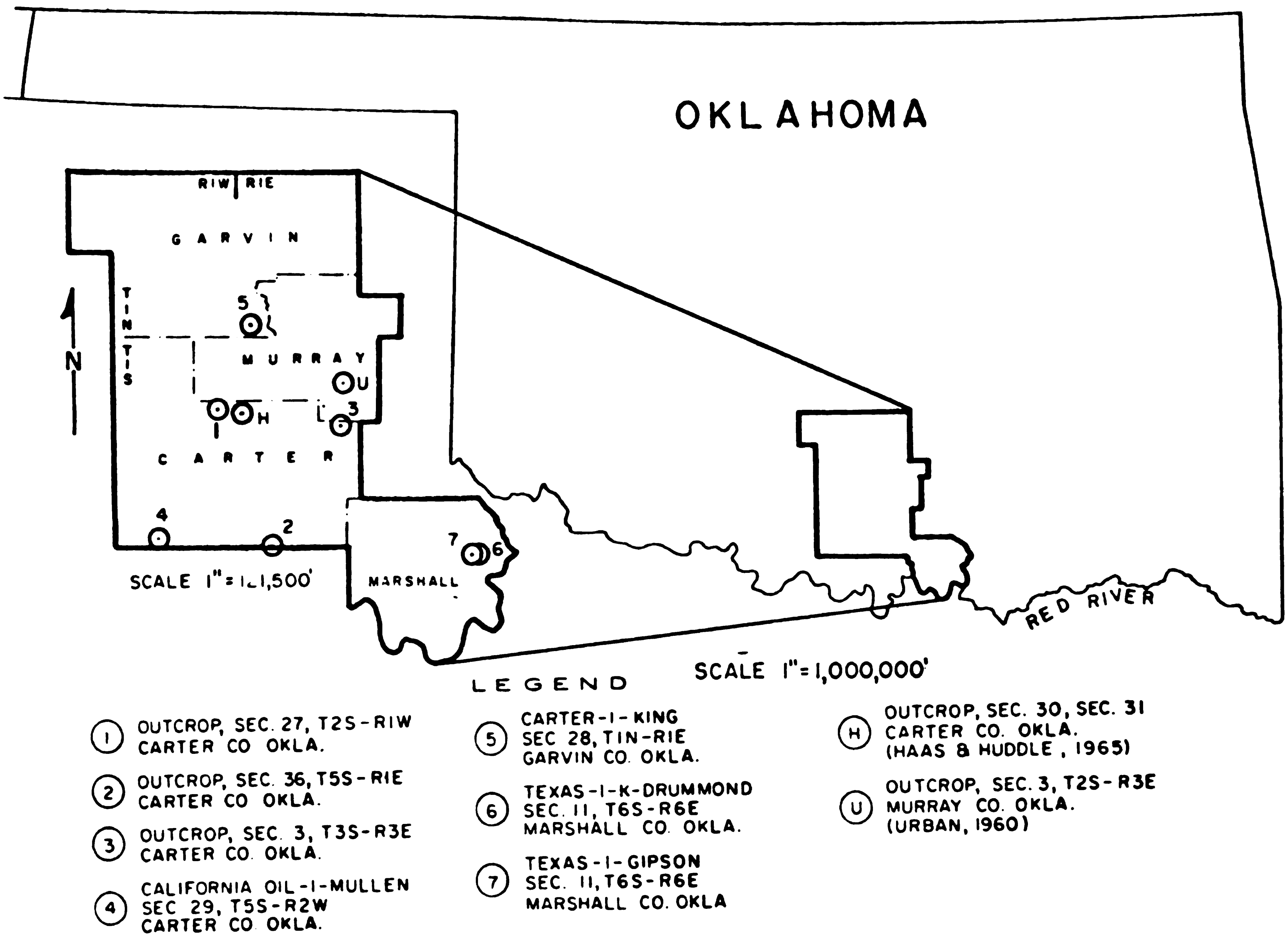

Figure 1--Map of collecting localities.

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and the Kettle Point Formation of Ontario, Canada (McGregor and Owens, 1966); and 5) make a logical interpretation of the environment of deposition of the formation utilizing lithology and all types of entities in the acid-resistant organic residues.

Locations of collections (Figure 1, page 2) of the Woodford Chert for palynological analysis in this study are:

1. Outcrop Section:

   Hickory Creek, N½ sec. 27, T.2S., R.1W., Carter County, Oklahoma

2. Well Cores:

   California Oil Company #1 Mullen, center SE¼SE¼ sec. 29, T.5S., R.2W., Carter County, Oklahoma

   Carter #1 King, SW¼NW¼NW¼ sec. 28, T.1N., R.1E., Garvin County, Oklahoma

   Texas Company #1-K Drummond, center SE¼NE¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma

   Texas Company #1 Gipson, NE¼NE¼NW¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma

GEOLOGY

General Statement

The Woodford Chert was named by Taff in 1902 for black, siliceous shale interbedded with black, fissile shale that crops out about one-fourth mile north of Woodford, Oklahoma, on the south flank of the Arbuckle Mountains. The Woodford Chert subsequently here is called the Woodford Formation because no samples collected or observed while making this study are chert <u>sensu</u> <u>strictu</u>.

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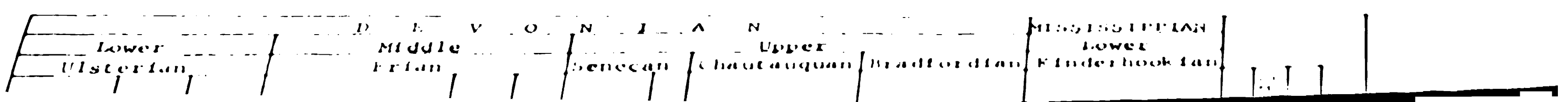
Stratigraphy

The Woodford Formation of southern Oklahoma is a transitional Devonian-Mississippian formation (Cross and Hoskins, 1951a) and unconformably overlies strata of ages ranging from Precambrian to Early Devonian (Tarr, Jordan and Rowland, 1965) (Figure 2, page 5).

In the area north of Woodford, Oklahoma, the Woodford Formation unconformably overlies the Bois d'Arc Limestone, a formation of Early Devonian (Ulsterian) age in the Silurian-Devonian Hunton Group, and is overlain by the Sycamore Formation of Early Mississippian (Kinderhookian) age.

In the Texas Company #1 Gipson well, Marshall County, Oklahoma, the stratigraphic unit underlying the Woodford is a brown, fine-grained, dolomitic, glauconitic siltstone which has orthoquartzite stringers and chert pebbles in the basal part. This rock unit was assigned to the "Misener (?)" (Walters, 1958), and the "basal Woodford Carbonate" (Maxwell, 1959). Amsden (1960), in his work with the Hunton Group of Oklahoma, described sections of rock exposed in Oil Creek (NW¼NE¼ sec. 20, T.3S., R.4E., Johnston County, Oklahoma) and Turkey Creek (NW¼NE¼SE¼ sec. 34, T.4S., R.4E., Marshall County, Oklahoma). Portions of these sections are yellow-brown to brown dolomite and dolomitic siltstone at the base of the Woodford Formation. Amsden (1960) assigned this unit to what he calls the "Woodford (?) Brown Carbonate." Shannon (1962) concluded that this dolomitic unit exposed in Johnston and Marshall Counties, and the dolomitic unit in the Texas Company #1 Gipson well, Marshall County were the same, and he named the unit the Mannsville Dolomite. Amsden, Klapper and Ormiston (1968) discuss these surface and subsurface sections, restrict the Mannsville Dolomite to the dolomite unit at Oil Creek in Marshall



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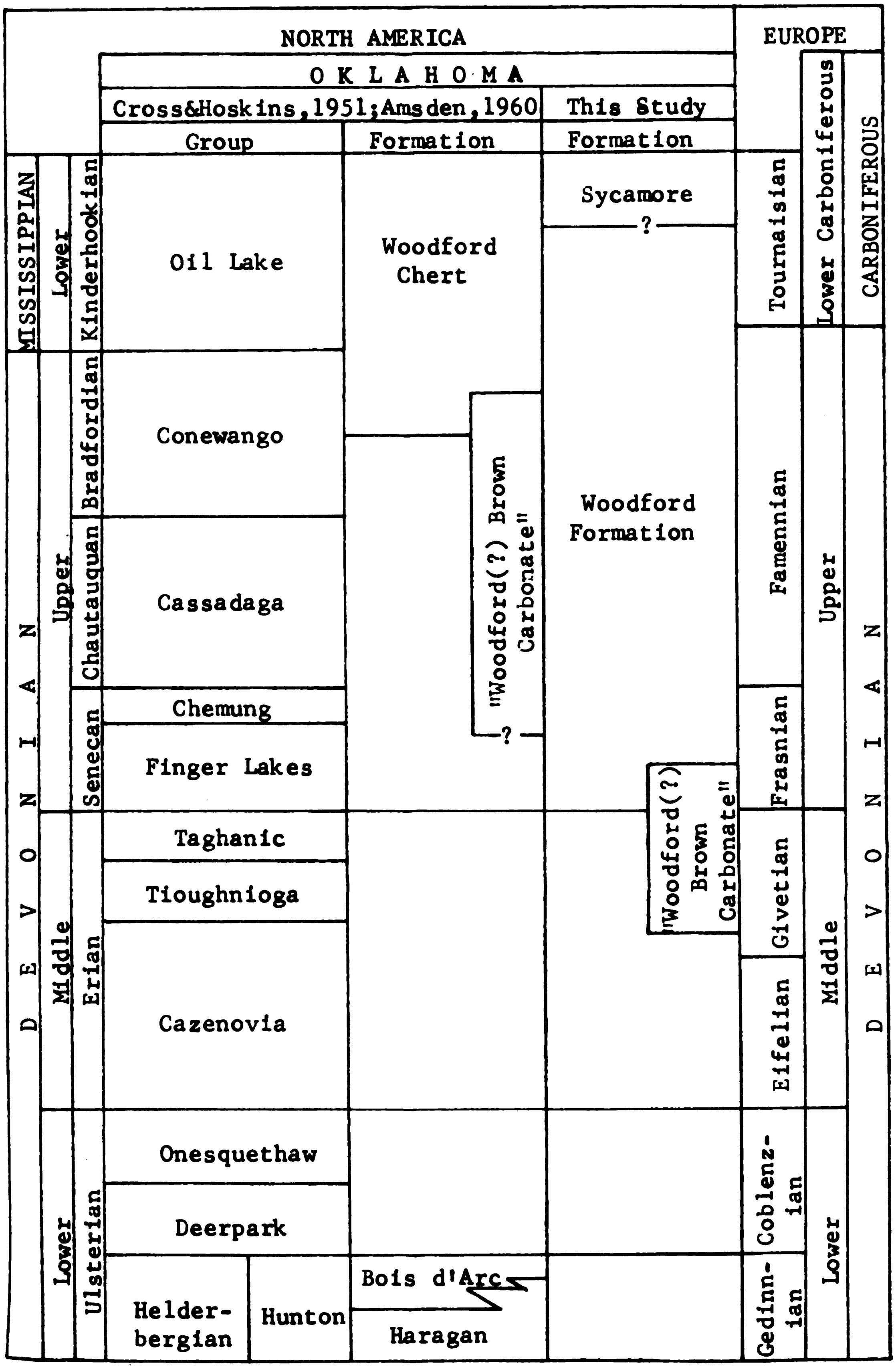

Figure 2--Correlation of Woodford Formation of Oklahoma with North American and European Series.

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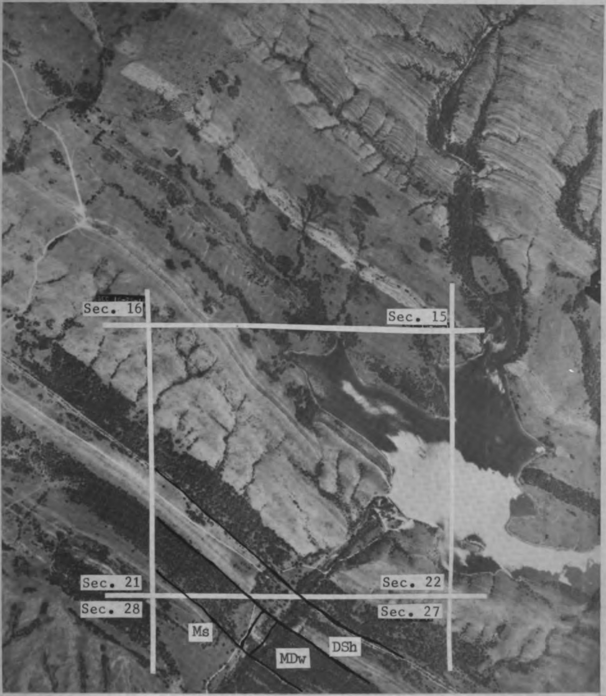
County because of the presence of Early Silurian conodonts, and state that the dolomitic siltstone exposed at Turkey Creek and in the Texas Company #1 Gipson well is probably "correlative with rocks which in the subsurface have been called Misener, and approximately correlative with the Sycamore Sandstone Member (of the Chattanooga Shale) of northeastern Oklahoma (Amsden, Klapper and Ormiston, 1968). The suggestion is also made that the dolomitic siltstone is Late Devonian in age (ibid.). Core chips of the siltstone unit were taken from the #1 Gipson and have been analyzed in this study.

The outcrop section collected for this study is exposed, predominantly subaqueously, in Hickory Creek in the N½ sec. 27, T.2S., R.1W., Carter County, Oklahoma (Figure 3, page 7) and is, or is near the type section of the Woodford Formation. The formation at this outcrop is 333 feet thick and is black to brown, siliceous, organic-rich, blocky shale with two 6-inch stringers of sandy, glauconitic clay in the basal 2 feet of the section. The upper 71 feet of the section is composed of black to brown, organic rich, fissile shale units up to 3 inches in thickness, interbedded with siliceous blocky shale. Phosphatic concretions up to 2 inches in diameter are common to abundant in the upper 71 feet of the section. The entire section contains disseminated pyrite, and microscopic cubes of pyrite concentrated along the shale laminae. The Woodford Formation was observed in several other areas during the course of this study in order to determine the occurrence of any lithologic variations. At 2 other localities (Figure 1, Localities 2 and 3, page 2) phosphatic concretions are also common to abundant in the upper part of the formation and rare to absent in the lower part; and at Locality 2 (Figure 1, page 2) portions of silicified logs of *Callixylon* were found, parallel to the



LEGEND

Ms-Mississippian Sycamore Formation
MDw-Devonian-Mississippian Woodford Formation
DSh-Devonian Bois d'Arc Limestone

Woodford Formation outcrop

Figure 3--Aerial photograph of Hickory Creek outcrop.

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bedding, in the lower part of the formation. The total length of these silicified logs was not measurable as pieces up to 2 feet in length were the longest ones removed from the outcrop. The largest of these logs measures 1.5 feet in diameter.

PROCEDURES

Sample Collection

Eighteen samples, collected from the outcrop, were analyzed in this study. These samples consist of 17 samples of the Woodford Formation, collected at 20-foot to 30-foot intervals, and 1 sample of the Sycamore Formation collected within 10 feet of the top of the Woodford Formation (Figure 4, page 9). The Sycamore sample contained no palynomorphs.

Core chips of the Woodford Formation were taken from 4 wells, the "Woodford (?) Brown Carbonate" from 1 well and the Bois d'Arc Limestone from 1 well. The wells, formations and sampled intervals are as follows:

California Oil Company #1 Mullen, Carter County, Oklahoma

Woodford Formation, top part

8978' - 8987' (-8030' - -8039' below sea level)

9010' - 9023' (-8062' - -8075' below sea level)

Seven chips were taken at 3-foot intervals; all samples were utilized in this study (Figure 5, page 10).

Carter #1 King, Garvin County, Oklahoma

Woodford Formation, basal part

12,166' - 12,242' (-11,318' - -11,400' below sea level)

Bois d'Arc Limestone

12,242' - 12,265' (-11,400' - -11,417' below sea level)

One Bois d'Arc Limestone sample and 7 Woodford Formation samples utilized in this study (Figure 6, page 12).

D E V O N I A N					MISSISSIPPIAN	System
Gedinnian	Frasnian		Famennian		Tournaisian	Europe
Ulsterian	Senecan	Chautauquan		Bradfordian	Kinderhookian	U. S.
Bois d'Arc	W o o d f o r d				Sycamore	Formation

Figure 4.--

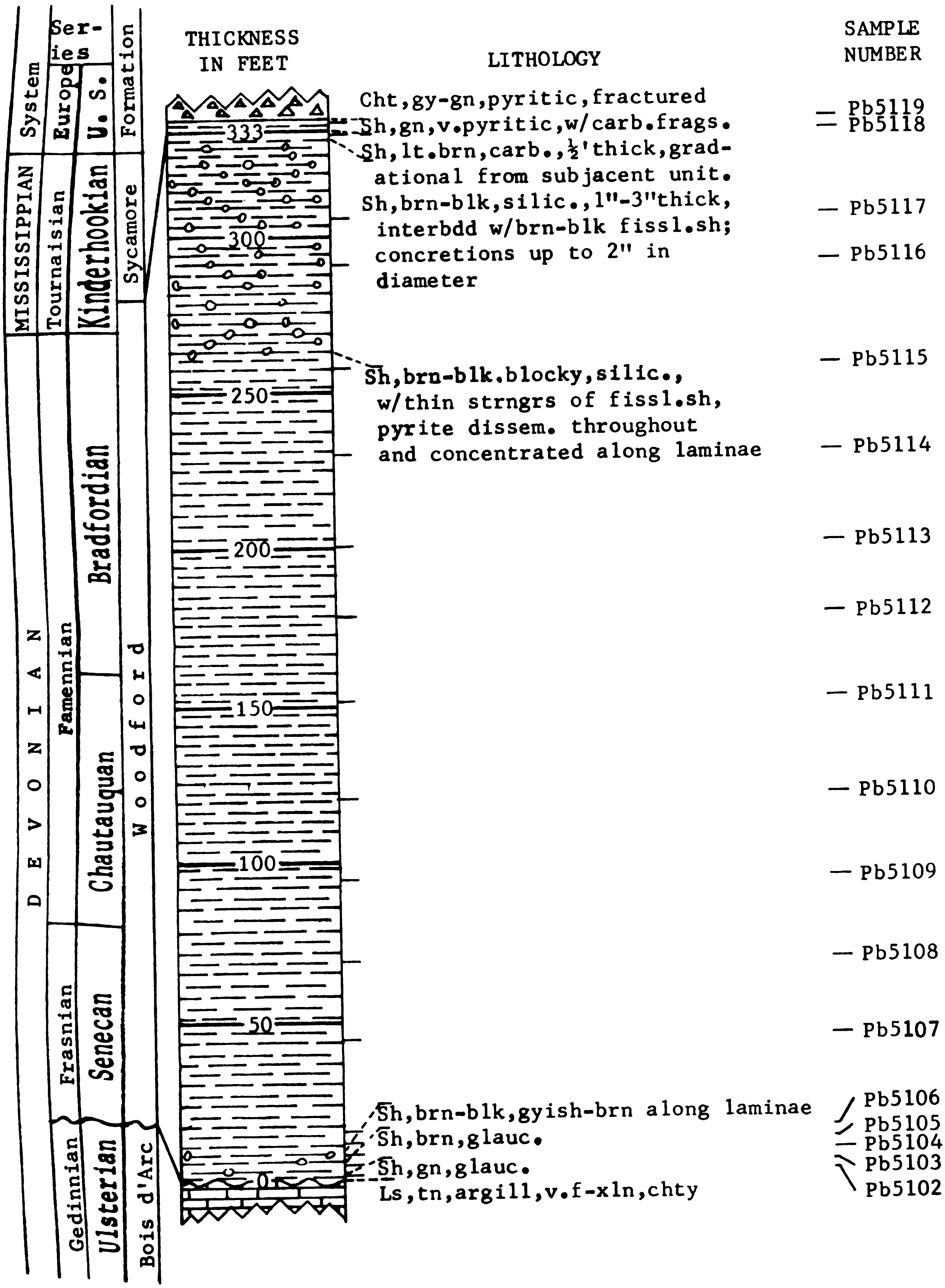
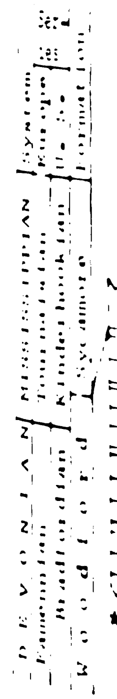


Figure 4--Lithology and sample sequence, Woodford Formation, Hickory Creek outcrop, N½ sec. 27, T.2S., R.1W., Carter County, Oklahoma



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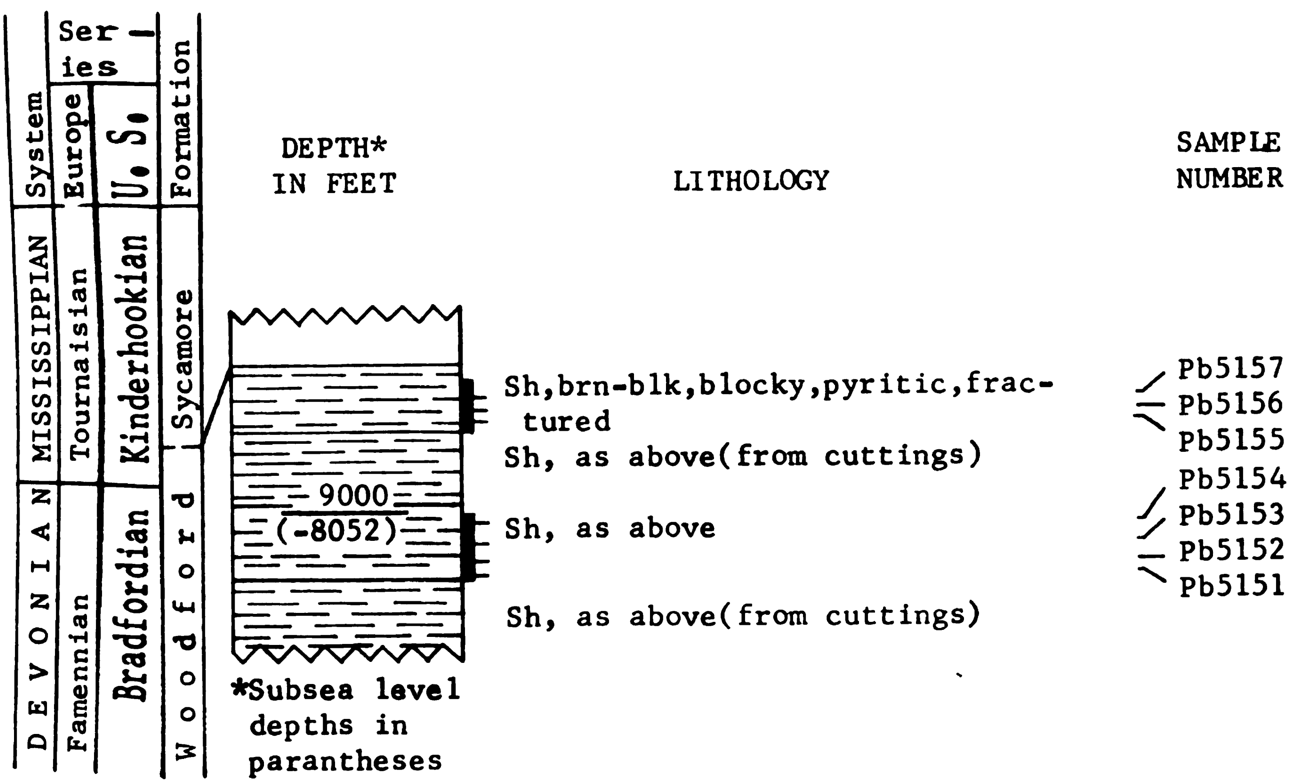

Figure 5--Lithology and sample sequence, Woodford Formation, California Oil Company #1 Mullen well, center SE¼SE¼ sec. 29, T.5S., R.2W., Carter County, Oklahoma

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Texas Company #1 Gipson, Marshall County, Oklahoma

Woodford Formation, basal part

4020' - 4043' (-3311' - -3334' below sea level)

"Woodford (?) Brown Carbonate"

4046' - 4121' (-3337' - -3412' below sea level)

Fourteen "Woodford (?) Brown Carbonate" samples and 5 Woodford Formation samples utilized in this study (Figure 7, page 13).

Texas Company #1-K Drummond, Marshall County, Oklahoma

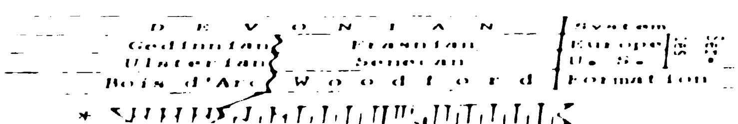
Woodford Formation, top part

3050' - 3075' (-2331' - -2356' below sea level)

Three chips taken at 5-foot intervals; all samples utilized in this study (Figure 8, page 14).

Preparation

Five grams of each sample were crushed and subjected to an 18% Hydrochloric acid treatment and a subsequent 70% Hydrofluoric acid treatment for 12 to 24 hours each to remove calcareous and siliceous minerals, respectively. Some of the consolidated portions of the samples did not disaggregate in the chemical treatment and were examined with a binocular microscope. These consolidated portions of the sample were masses of organic detritus. They were subjected to repeated treatments of a hot Clorox (.25% sodium hypochlorite) solution and were then placed in an ultrasonic vibrator for 20 seconds (the ultrasonic treatment apparently was not severe enough to destroy palynomorphs which is sometimes the case, because fragile perisporate and spinose palynomorphs were recovered from every sample treated in this manner). All residue was retained, and treated with a 5% solution of Calgon (sodium phosphate, soda ash and other sodium carbonates). The residue was then mixed with water in a 90 ml. centrifuge tube and allowed to settle 4 to 6 times at the rate of 2



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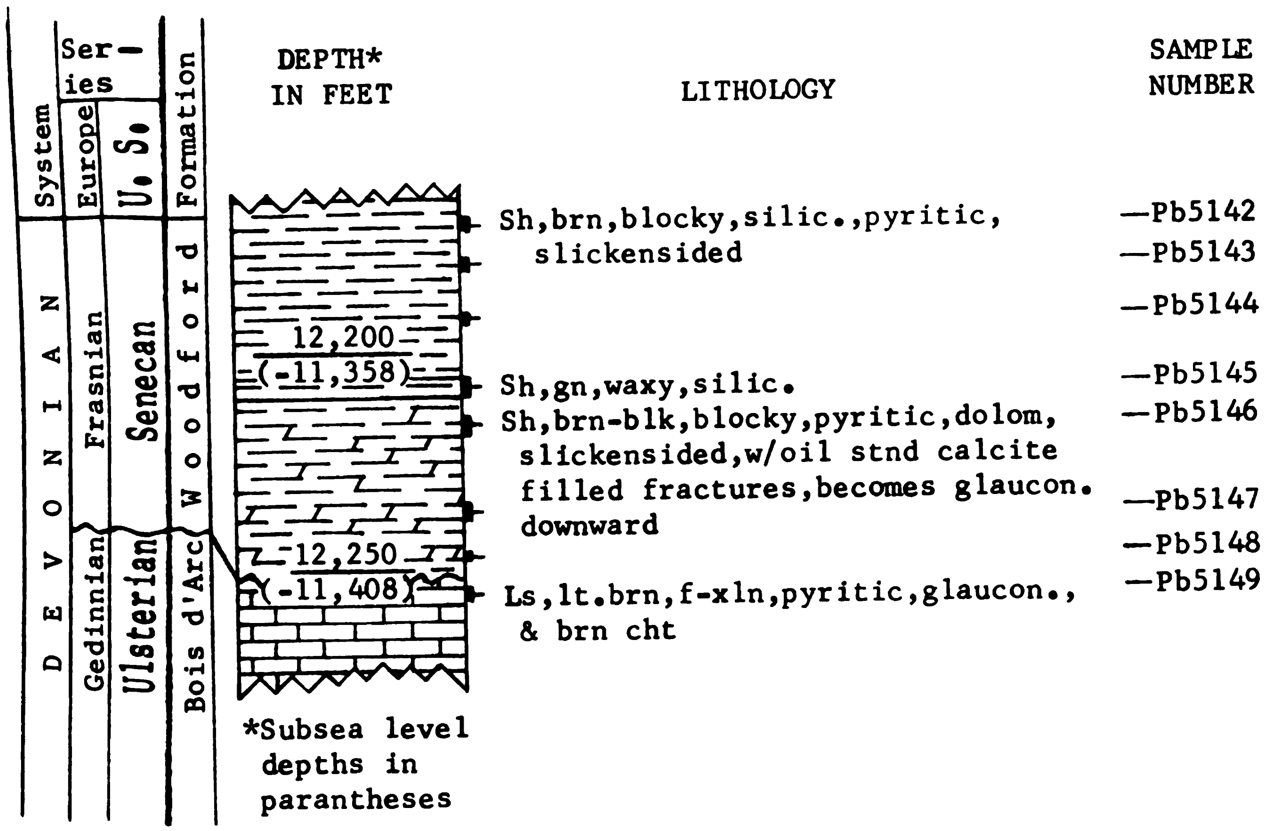
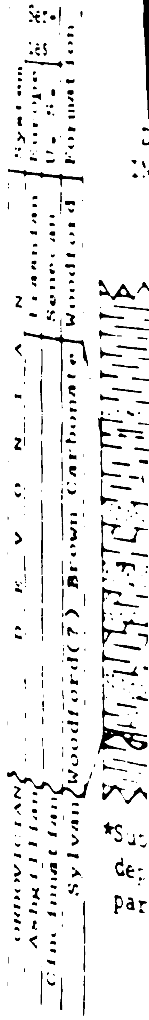


Figure 6--Lithology and sample sequence, Woodford Formation, Carter #1 King well, SW¼NW¼NW¼, sec. 28, T.1N., R.1E., Garvin County, Oklahoma



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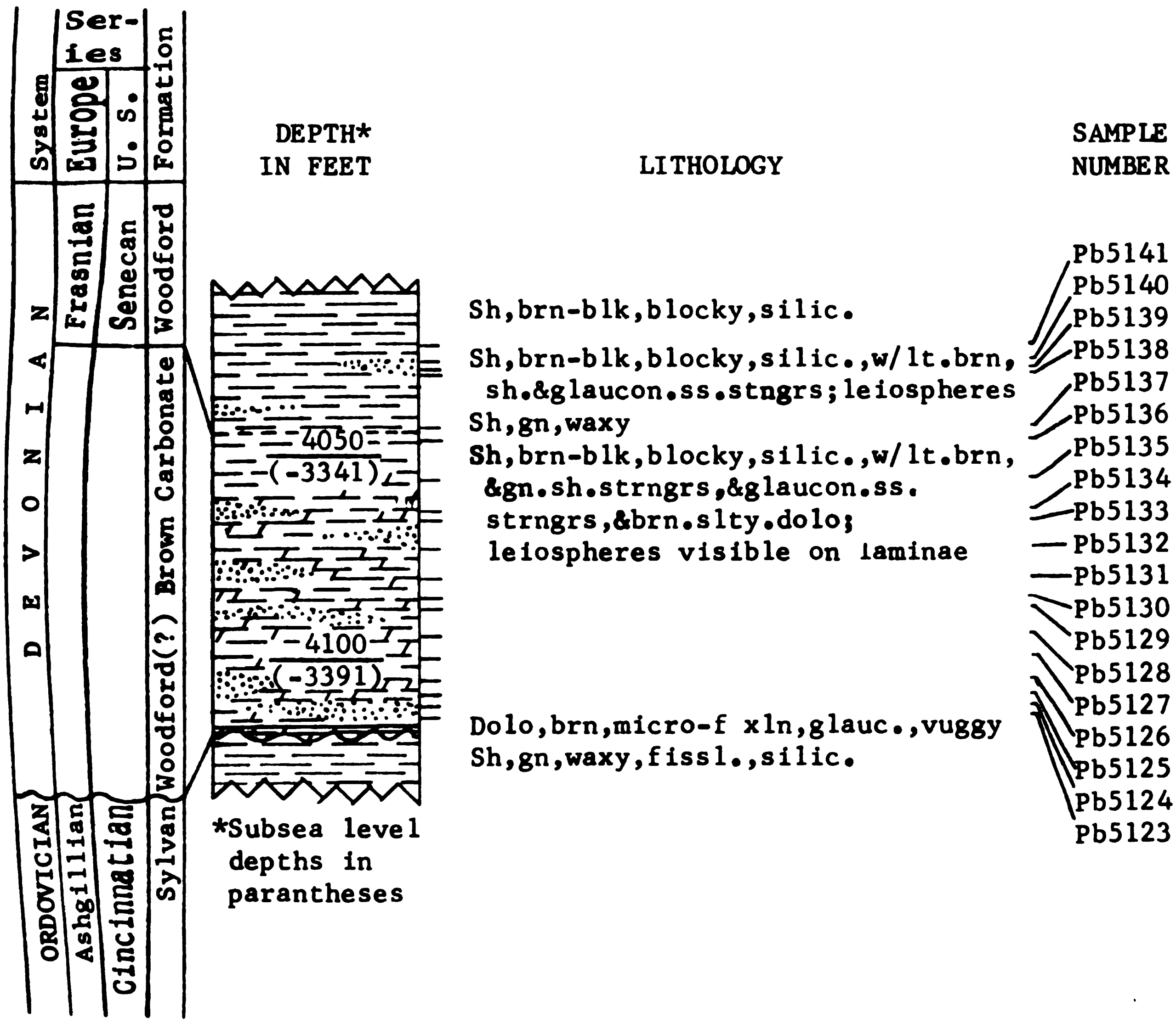
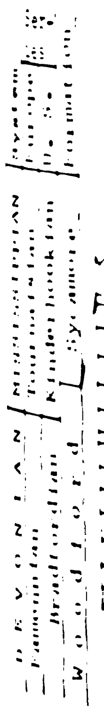


Figure 7--Lithology and sample sequence, Woodford Formation and "Woodford(?) Brown Carbonate", Texas Company #1 Gipson well, NE¼NE¼NW¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma



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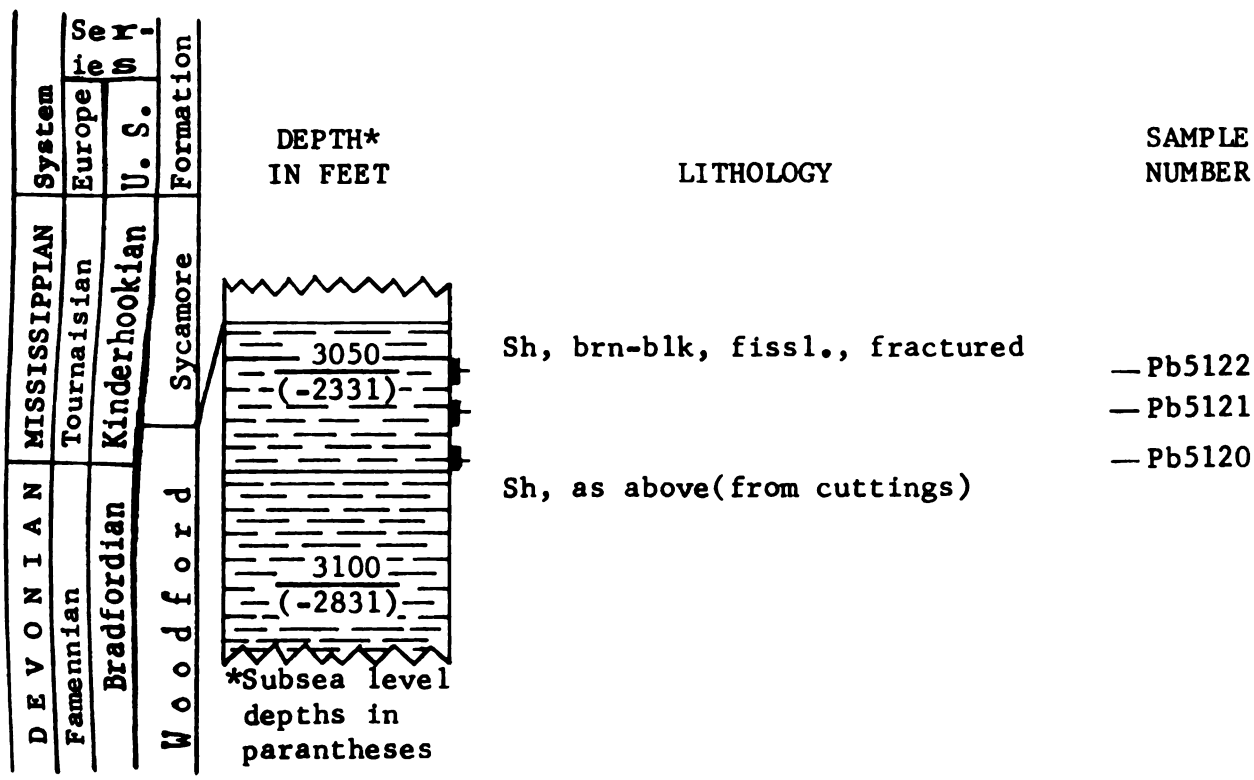

Figure 8--Lithology and sample sequence, Woodford Formation, Texas Company #1-K Drummond, center SE¼NW¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma

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hours the first time and 1.5 hours for each subsequent time to remove all fine disseminated organic matter. After the settling procedure was completed, the residue was swirled to remove all heavy minerals (Funkhouser and Evitt, 1959, p. 373). Residues were then stored in 2-dram vials in water containing a drop of formalin as a preservative.

Four or more slides of each residue were made. The residues were mounted on a 22mm. x 40 mm. coverslip in Clearcol, allowed to dry, then inverted and mounted on microscope slides with Harleco (Synthetic resin) as a mounting medium. At least four slides of each sample were examined thoroughly with a Leitz Ortholux Microscope and a Zeiss Photomicroscope. All palynomorphs, except those which were abundant, possessed the same morphological features and were assigned to the same species, were recorded by coordinates for detailed study, comparison, description and photography. Coordinates for location of palynomorphs illustrated on the plates are in millimeters from an "x" scribed on the underside of the slide. This "x" is located in the center of the slide. The palynomorph is then located in number of millimeters left or right of the "x" on the horizontal scale, and up or down from the "x" on the vertical scale. The first coordinate for each illustrated palynomorph is preceded by an L for left, or an R for right and is the number of millimeters that the palynomorph is in that direction from the "x". The second coordinate is preceded by a U for up, or a D for down and is the number of millimeters that the palynomorph is in that direction from the "x". All residue slides, and residues, have been placed in the Michigan State University Palynology Laboratory, Department of Geology, Michigan State University, East Lansing, Michigan 48823, and are numbered in accordance with the numbering system of that laboratory.

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PALEONTOLOGY

The systematic classification of the Sporae Dispersae used in this study is that of Potonie and Kremp (1954), emended by Potonie (1956, 1958 and 1960) and partially emended by Neves and Owens (1966).

The systematic classification of the acritarchs used in this study is the classification established by Downie, Evitt and Sarjeant (1963). Included in the acritarch classification are some restrictions proposed by Staplin, Jansonius and Pocock (1965) and the addition of the Subgroup SCUTELLOMORPHITAE Brito, 1967.

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Turma TRILETES (Reinsch, 1891) Potonie & Kremp, 1954

Suprasubturma ACAMERATITRILETES Neves & Owens, 1966

Subturma AZONOTRILETES Luber, 1935

Infraturma LAEVIGATI (Bennie & Kidston, 1886) R. Potonie, 1956

Genus LEIOTRILETES (Naumova 1937?, 1939) Potonie & Kremp, 1954

Type species. L. sphaerotriangulus (Loose, 1932) Potonie & Kremp, 1954, p. 41, pl. 11, figs. 107-109

LEIOTRILETES SIMPLEX Naumova, 1953

Plate 1, Figure 1

Discussion: The species, as described by Naumova (1953), varies in size (20u to 35u), shape (round-triangular to triangular), wall thickness (thin to thick) and occurs in strata of Givetian and Frasnian age on the Russian Platform. The specimens examined in this study are thick walled and have a convexo-triangular outline.

Occurrence: Devonian to Tertiary (Naumova, 1953)

Samples: Pb 5111?, Pb 5137

LEIOTRILETES CONFERTUS McGregor, 1960

Plate 1, Figure 2

Description: Spores radial, trilete; diameter 55u; outline broadly triangular; exine one micron to 2u in thickness; ornamentation levigate, shagreen to minutely granulose; trilete mark straight, simple; laesura extend nearly to equator, trilete mark nearly obscure when laesura are closed.

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Occurrence: Frasnian:-Famennian? (McGregor, 1960)

Samples: Pb 5102, Pb 5105, Pb 5111?, Pb 5118?, Pb 5141?

Genus PUNCTATISPORITES (Ibrahim, 1933) Potonie & Kremp, 1954

Type species. P. punctatus (Ibrahim, 1932) Ibrahim, 1933, p. 21, pl. 2, fig. 18

PUNCTATISPORITES GLABER (Naumova, 1937?) Playford, 1963

Plate 1, Figure 3

Discussion: This species and its occurrence is discussed thoroughly by Playford (1963). P. glaber, as presently described, is of little stratigraphic value and because of its simple form probably includes more than one species common to the Devonian and Carboniferous Systems.

Occurrence: Devonian to Lower Carboniferous (Luber, 1941; Ishchenko, 1958; Hoffmeister, Staplin & Malloy, 1955; Playford, 1963

Samples: Pb 5105, Pb 5111, Pb5112

Genus RETUSOTRILETES (Naumova, 1937?, 1953) Streel, 1964

Type species. R. simplex Naumova, 1953, p. 29, pl. II, fig. 9

RETUSOTRILETES cf. NIGRITELLUS (Luber, 1941, 1955) Streel, 1967

Plate 1, Figures 4, 7

Description: Spores radial, trilete, diameter 39u to 57u; wall thickness one micron to 2u; outline circular to convexo-triangular, ornamentation levigate to slightly roughened, darkened triangular area at apex of proximal hemisphere and surrounding trilete mark; laesura short, simple, length 2/3 to 3/4 spore radius with extremities te

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tremities terminating proximally from equator and forming a poorly developed area of curvaturae.

Discussion: These specimens are placed in the genus Retusotriletes as recommended by Streel (1967). Imperfectly developed areas of curvaturae are visible. There appears to be slight differences between the illustrated specimens and R. nigritellus as the darkened area surrounding the trilete mark is triangular and not circular as described and illustrated by Luber and Waltz (1941) and Luber (1955) and the maximum diameter of the described specimens is 57u instead of 40u (Luber and Waltz, 1941).

Occurrence: Lower Carboniferous to Visean (Luber, 1955)

Samples: Pb 5105, Pb5126, Pb 5136

RETUSOTRILETES (al. PHYLLOTHECOTRILETES) MICROGRANULATUS

(Vigran, 1964) Streel, 1967

Plate 1, Figure 6

Discussion: The illustrated species conforms with Streel's (1967) description except for the size which falls within the size range of Vigran's (1964) original description.

Occurrence: Givetian to Frasnian (Vigran, 1964)

Emsian (Streel, 1967)

Sample: Pb 5126

RETUSOTRILETES TENERIMEDIUM Chibrikova, 1959

Plate 1, Figures 5, 8

Discussion: The figured specimen is the only one observed in this study. This specimen displays the same features as Chibrikova (1959, p. 52) described and illustrated (1959, pl. 5, figs. 9, 10; 1962, pl. 14, fig. 82). The only other occurrence of R. tenerimedium is reported by

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reported by de Jersey (1966) from the Middle Devonian Etonvale Formation of the Adavale Basin, Western Queensland, Australia.

Occurrence: Upper Eifelian to Lower Givetian (Chibrikova, 1959, 1962)

Middle Devonian (de Jersey, 1966)

Sample: Pb 5129

RETUSOTRILETES PARVIMAMMATUS Naumova, 1953

Plate 1, Figure 9

Discussion: The illustrated specimen conforms with R. parvimammatus Naumova, 1953, in that it is finely granulate under oil immersion objective, has a thickened margin, a well expressed contact area (area of curvaturae) and simple laesurae.

Occurrence: Middle and Upper Devonian (Naumova, 1953)

Samples: Pb 5126, Pb 5130?

RETUSOTRILETES TRIANGULATUS (Streel, 1964) Streel, 1967

Plate 1, Figure 10

Description: Spores radial, trilete; diameter 63u; outline circular; wall thickness about 3u; area of curvaturae distinct (except where corroded), proximal hemisphere (inside area of curvaturae) levigate with darkened triangular area surrounding junction of laesurae at apex, proximal hemisphere (outside area of curvaturae), equatorial margin and distal hemisphere finely granulose; laesura straight, simple, length 2/3 spore radius, rays terminate at inner points of area of curvaturae.

Discussion: These specimens are placed in R. triangulatus (Streel, 1964) Streel, 1967, although the exine of the illustrated specimens is less folded than those described and illustrated by Streel (1964, pl. I, figs. 3, 4,

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figs. 3, 4, 5). R. communis Naumova, 1953, appears to be similar except it doesn't have a darkened triangular apical area and is externally shagreen rather than finely granulose as are the illustrated specimens. R. raisae Chibrikova, 1962, may actually be conspecific with R. triangulatus as the proximal darkened triangular apical area and the smooth to shagreen thin exine exhibiting folds are also included in the description of R. raisae.

Occurrence: Siegenian-Eifelian (Streel, 1967)

Samples: Pb 5129, Pb 5130

RETUSOTRILETES ROTUNDUS (Streel, 1964) Streel, 1967

Plate 1, Figures 11, 12

Discussion: This species, described by Streel (1964), has been reported only by Streel (1964, 1967) prior to the present occurrence. Undoubtedly the species is similar to some of the trilete retusoid spores described by Russian palynologists although difficulty arises in interpreting some of their generalized specific descriptions and line drawings.

Occurrence: Lower Emsian-Lower Givetian (Streel, 1964, 1967)

Samples: Pb 5124?, Pb 5126, Pb 5127, Pb 5130, Pb 5136

RETUSOTRILETES DUBIUS (Eisenack, 1944) Richardson, 1965

Plate 2, Figure 1

Discussion: The illustrated specimen possesses the characteristics of R. dubius, even to the contorted minute radial wrinkles in the area of curvaturae on the proximal hemisphere, but does not have a triangular darkened contact area (Richardson, 1965).

Occurrence: Eifelian-Givetian (Richardson, 1965)

Sample: Pb 5136

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RETUSOTRILETES INCOHATUS? Sullivan, 1964

Plate 2, Figure 2, 3

Description: Spores radial, trilete; diameter 48u; outline circular; ornamentation levigate (slightly pitted because of corrosion); laesura straight, distinct, length about 3/4 spore radius, bordered by labra 3u wide. Contact areas shallowly depressed and defined by curvaturae imperfectae.

Discussion: This specimen is questionably assigned to R. incohatus Sullivan, 1964, because only one specimen and one questionably assigned specimen were observed and they appear to be slightly corroded. The illustrated spore (Plate 2, Figure 2) does appear to conform with the description of R. incohatus and seems to be preserved as well as some specimens illustrated by Sullivan (1964a, pl. I, fig. 5).

Occurrence: Tournaisian (Sullivan, 1964a)

Samples: Pb 5110?, Pb 5118

RETUSOTRILETES COMMUNIS Naumova, 1953

Plate 2, Figures 4, 5

Discussion: Naumova (1953, p. 97) does not mention that R. communis has labra along the rays of the trilete mark, although labra are apparently present as de Jersey (1966, p. 7), after personal communication with Dr. Chibrikova concerning some species of Retusotriletes from the Devonian of Australia, describes R. simplex Naumova, 1954, with labra and states that its levigate exine distinguishes it from R. communis.

Occurrence: Middle and Upper Devonian (Naumova, 1953; Chibrikova, 1962)

Samples: Pb 5110, Pb 5120?, Pb 5145

cf. RETUSOTRILETES NIGRATUS (Naumova, 1953) Streel, 1967

Plate 2, Figure 6

Description: Spores radial, trilete; diameter 73u; exine approximately 2u thick; outline circular; ornamentation levigate to slightly roughened; trilete rays straight to slightly curved, simple, laesura length less than ½ spore radius; dark triangular area at apex of proximal hemisphere surrounding trilete mark.

Discussion: Leiotriletes nigratus was described by Naumova (1953) from the Middle and Upper Devonian strata of the Russian Platform and was again described by Ishchenko (1958) as a new species from the Upper Devonian and Tournaisian Stage of the Lower Carboniferous. These specimens may be homonymous as Naumova (1953, p. 23) states that the exine of her species is thick and the illustrated specimen (op. cit. pl. I, fig. 9) shows two minor peripheral folds, while Ishchenko (1958, pp. 34-35) states, "A remarkable feature of this spore is the presence of a thickening of the exine 'at the apex of the spore' (author) which has the shape of an equilateral triangle within which the aperture is located," and shows numerous peripheral folds on the illustrated specimen (op. cit., pl. I, fig. 4), which seems to be indicative of a thin exine. Allen (1965, p. 693) places both species in the genus Calamospora Schopf, Wilson and Bentall, 1944, and Streel (1967, p. 27) suggests assigning the species to Retusotriletes (Naumova, 1953) Streel, 1964. The illustrated spore may be conspecific with Retusotriletes nigratus sensu Naumova, 1953, as the smooth, thick exine, short trilete mark and darkened contact area at the apex are the major features of both the illustrated species and R. nigratus sensu Naumova (1953).

Occurrence: Samples: Pb 5103, Pb 5118?

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Plate 2, Figure 7

Description: Spores radial, trilete; diameter 48u; outline circular to oval (may be due to compression); distal hemisphere, equator and proximal hemisphere outside area of curvaturae levigate, proximal hemisphere inside area of curvaturae contorted into very fine wrinkles that radiate from the apex; trilete rays straight, simple; laesura bordered by labra about 2u in height and width, rays extend nearly to spore equator; area of curvaturae more distinct when observed with 100X oil immersion objective than at lower magnification.

Discussion: The illustrated species is quite similar to *Retusotriletes dubius* (Eisenack, 1944) Richardson, 1965, from the Middle Old Red Sandstone of England although the minimum diameter of *R. dubius* is 8u larger than the diameter of the illustrated specimen. *R. translaticus* Chibrikova, 1959, from the Upper Eifelian and Lower Givetian of Russia is also similar, but smaller.

Occurrence: Samples: Pb 5109?, Pb 5111

Infraturma APICULATI (Bennie & Kidston, 1886) R. Potonie, 1956

Genus CYCLOGRANISPORITES Potonie & Kremp, 1954

Type species. *C. leopoldi* (Kremp, 1952) Potonie & Kremp, 1954, pp. 126, 129; pl. 4, fig. 8; pl. 20, fig. 103

CYCLOGRANISPORITES cf. AZONOTRILETES PUNCTATUS var. MINUTUS Waltz, 1941

Plate 2, Figure 8

Description: Spores radial, trilete; diameter 57u; outline circular; ornamentation very finely granulose; exine thin; trilete rays straig

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straight, simple; laesura length nearly equal to spore radius; exine folded along all three rays of trilete mark.

Discussion: Azonotriletes punctatus Waltz, 1941, is described as having "fine-grained or punctate" ornamentation and that "the thickness of the exine increases from small forms to coarser ones." Although the diameter of the observed specimens of the illustrated variety are larger (by 12u) than originally stated in the varietal description by Luber and Waltz in 1941 (diameter 25u to 45u), other varietal features are satisfied (i. e., very thin, finely granulose, folded exine with simple laesura having a length of at least 2/3 the radius of the spore).

Occurrence: Lower Carboniferous (Luber & Waltz, 1941)

Samples: Pb 5103, Pb 5109, Pb 5135?

CYCLOGRANISPORITES LASIUS (Waltz, 1938) Playford, 1962

Plate 2, Figure 9

Discussion: C. lasius (Waltz, 1938) Playford, 1962, first described by Waltz, was separated into two varieties, C. lasius var. majus (90u to 120u in diameter) and C. lasius var. giganteus (70u to 95u in diameter). Neither Luber and Waltz (1941) nor Playford (1962) mention a varietal name for those specimens having a diameter of less than 70u. Therefore, the illustrated specimen, which is less than 70u in diameter, is not assigned to either variety.

Occurrence: Lower Carboniferous (Luber & Waltz, 1938, 1941; Luber, 1955; Playford, 1962)

Samples: Pb 5103, Pb 5116?, Pb 5117?

CYCLOGRANISPORITES cf. COMMODUS Playford, 1963

Plate 2, Figure 11

Description: Spores radial, trilete; diameter 44u; exine one micron thick; outline subcircular; ornamentation composed of fine dense grana; trilete rays straight, simple, length nearly equal to spore radius.

Discussion: *C. commodus* Playford, 1963, is quite similar to the described species except that the laesura of *C. commodus* are shorter than the laesura of the described specimen.

Occurrence: Samples: Pb 5103, Pb 5103

CYCLOGRANISPORITES SP. A

Plate 2, Figure 10

Description: Spores radial, trilete; diameter 49u; wall thickness one micron to 2u; outline originally circular; ornamentation finely granulose; trilete rays straight, simple; laesura length nearly equal to spore radius.

Discussion: The illustrated spore appears to be conspecific with those species of *Cyclogranisporites* illustrated by Kerr, McGregor and McLaren (1965, pl. 3, fig. 13) and McGregor and Owens (1966, pl. XXVI, fig. 3) from the Griper Bay Formation from Helena and Bathurst Islands of northern Canada. A detailed comparison with these species is not possible as descriptions were not given in the cited publication.

Occurrence: Samples: Pb 5105, Pb 5106, Pb 5111, Pb 5110?

CYCLOGRANISPORITES SP. B

Plate 2, Figure 12

Description: Spores radial, trilete; diameter 54u; exine 2u to 3u thick; outline circular; distal and equatorial ornamentation coarsely granulose, proximal ornamentation finely granulose; distinct broad folds, of varying patterns, across distal hemisphere; these folds terminate into folds coincident with the equator; wall thickness appears as an indistince zona. Laesura straight, bordered by labra 2u to 3u in height and width that decrease equatorward, laesura length nearly equal to spore radius.

Discussion: The illustrated specimen may be encompassed by Lophotriletes Naumova, 1937?, and specifically with Lophotriletes rugosus Naumova, 1950; but these publications are not available, thus detailed comparison is not possible and assignment to the genus is not made. Archaeozonotriletes notatus Naumova, 1953, also appears to be similar to the illustrated species, if the wall thickness of A. notatus has been mistaken for a perisporium. Several species of Archaeozonotriletes Naumova, 1953, are granulose and conate and have various types of folds across the distal hemisphere. These folds do not terminate abruptly at the spore equator, but spread and extend around the equator thereby forming a fold that blends into the wall that is presumed to be the effect of compression (flattening) of the spore during sedimentation and lithification. This feature actually appears to be an indistinct zona. Naumova, 1953, speciates these types of spores on the types of distal folds combined with the type of ornamentation. Many spores of this type are present in the dolomitic siltstone at the base of the Woodford but no two specimens have exactly the same pattern of distal folding. Examination of these spores under the 100X oil immersion objective shows quite clearly that the indistinct equatorial zona is actually exine thickness; therefore, this species has been assigned to Cyclogranisporites Potonie and Kremp, 1954.

Occurrence: Samples: Pb 5133, Pb 5135, Pb 5136, Pb 5137, Pb 5105, Pb 5103, Pb 5102

Genus ANAPICULATISPORITES Potonie & Kremp, 1954

Type species. A. isselburgensis Potonie & Kremp, 1954, p. 133, pl. 20, fig. 97

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ANAPICULATISPORITES cf. A. AMPULLACEUS (Hacquebard, 1957) Playford, 1963

Plate 3, Figures 1, 2

Description: Spores radial, trilete; diameter 50u; outline convexo-triangular to oval; proximal hemisphere finely wrinkled, distal hemisphere and equator ornamented with triform elements consisting of pustules (3u x 3u), flask-shaped projections (5u long x 3u wide) and pila (3u x 3u) sometimes bearing a short spine at the apex of the caput (swollen head of the pila); trilete rays straight to sinuous, length at least 2/3 spore radius. At terminus of laesura, half-circular depressions (apea of Naumova, 1953) are developed, thus forming an imperfect area of curvaturae.

Discussion: The illustrated specimens are quite similar to A. ampullaceus (Hacquebard, 1957) Playford, 1963, and actually may be conspecific, except that A. ampullaceus is not reported to be retusoid. Retusotriletes famenensis Naumova, 1953, a species from the Lower Famennian of the Russian Platform appears to be similar to the illustrated specimen. Naumova (1953, p. 111) describes the sculptural elements of R. famenensis as rounded protuberences rather than triform elements.

Occurrence: Samples: Pb 5111, Pb 5110, Pb 5109, Pb 5108?

ANAPICULATISPORITES SP. A

Plate 3, Figures 3, 4

Description: Spores radial, trilete; diameter 45u; outline convexo-triangular; exine of distal hemisphere and equator ornamented with cones 2u long and approximately 5u apart, exine on proximal hemisphere levigate and finely wrinkled; trilete rays straight to slightly sinuous, simple, length 1/2 to 2/3 spore radius.

Discussion: Acanthotriletes paucispinus Naumova, 1953, is similar to th

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to the illustrated specimens in size, shape and type of ornamentation, although Naumova (1953, p. 107) states that the exine (apparently both proximal and distal hemispheres) is ornamented with spines and the rays of the aperture are equal to the radius of the spore body. These specimens are probably related to Anapiculatisporites cf. ampullaceus as they occur in the same sample.

Occurrence: Samples: Pb 5114, Pb 5111, Pb 5110, Pb 5109

Genus APICULIRETUSISPORA (Streel, 1964) Streel, 1967

Type species. A. brandtii Streel, 1964, p. 7, pl. I, figs. 6, 7, 8, 9, 10, p. 8, text fig. 2

APICULIRETUSISPORA GREGGSI (McGregor, 1964) var. MINUTUS comb. nov.

Plate 3, Figures 5, 6, 7, 8

Description: Spores radial, trilete, retusoid; diameter 43u to 50u; outline circular to subcircular; distal hemisphere, equatorial margin and proximal hemisphere (not enclosed by area of curvaturae) ornamented with closely packed coni .5u to one micron long and slightly less in basal diameter. These ornaments appear to be grana and are not distinct except when observed under the oil immersion objective. Contact area, inside area of curvaturae levigate; trilete rays straight to slightly curved on some specimens, laesura often thickened or folded, length nearly equal to spore radius. Rays terminate slightly proximal to equator to form incomplete area of curvaturae. Arcuate thickenings dark to slightly discernible.

Discussion: Trilete retusoid spores possessing ornamentation less than one micron in height were removed from Retusotriletes (Naumova,1937?, 1953) Streel, 1964 and reassigned to the genus Apiculiretusispora (Streel)

1964) Streel, 1967. Retusotriletes verrucosus (Naumova in litt.) Kedo, 1955, appears similar to the illustrated specimens except that R. verrucosus is larger and is ornamented with very fine, rounded tubercules (grana?). Retusotriletes punctatus Chibrikova, 1959, may be granulose and may actually be conspecific with the illustrated species, but Chibrikova is not specific regarding ornamentation; also, the darkened arcuate thickenings at the equatorial termini of the rays are not as pronounced as on R. punctatus. Retusotriletes greggsi McGregor, 1964 is morphologically the same as the described specimens except that R. greggsi is larger; thus, this species is considered to be a variation of R. greggsi at the present time, and with further investigation the size gap may be eliminated and R. greggsi emended to include the described variation.

Occurrence: Samples: Pb 5133, Pb 5137, Pb 5138, Pb 5139, Pb 5144?, Pb 5149?

APICULIRETUSISPORA PLICATA (Allen, 1965) Streel, 1967

1965 Cyclogranisporites plicatus Allen, p. 695, pl. 94, figs. 6-9

Plate 3, Figures 9, 10

Discussion: These specimens are assigned to A. plicata (Allen, 1965) Streel, 1967, as they possess all features described by Allen (1965, p. 695) except for a slightly thicker exine of approximately 2u in thickness. The ornamentation consists of grana that are less than one micron in height and diameter, although some are smaller. Streel (1967, p. B33) emended the species and stated that the ornamentation is dominantly grana and small cones (obvious in Streel, 1967, pl. II, figs. 32, 33); also, that some specimens have a 2-layered exine and actually may be perisporate (op. cit., p. B33 and pl. II, figs. 33, 34). The illustrated specimen is definitely retusoid, levigate in the area of curvaturae and granulose on the distal hemisphere, equatorial margin and proximal hemisphere outside of the area of curvaturae. The specimens are probably conspecific with A. plicata as emended by Streel (1967, p. B33) although his emendation may actually encompass more than one species. The illustrated specimen is assigned in the strict sense of the original description by Allen (1965, p. 695).

Occurrence: Gedinnian to Givetian (Allen, 1965)

Lower Siegenian to Lower Couvinien (Streel, 1967)

Sample: Pb 5135

APICULIRETUSISPORA SP. A

Plate 3, Figures 11, 12, 13, 14; Plate 4, Figures 1, 2, 3

Description: Spores radial, trilete, retusoid; diameter 50u to 68u; outline oval to convexo-triangular; proximal hemisphere (inside area of curvaturae) levigate, distal hemisphere, equatorial margin and proximal hemisphere (outside area of curvaturae) spinose or conate; ornaments predominantly spines that are distinct, closely packed and less than one micron in length; area of curvaturae encloses part to all of the proximal hemisphere; trilete rays straight to sinuous, rays distinct either as straight to sinuous ridges 2u to 5u wide or as straight lines of commissure, length of rays nearly equal to spore radius with extremities terminating to form poor to well developed area of curvaturae.

Discussion: Retusotriletes Naumova, 1937?, 1953 probably encompasses the described specimens, although Naumova (1953) describes all sculptural elements of the genus as grana or protuberences. Retusotriletes spp. described by Kedo (1955) have levigate, granulose or coarsely partic

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granulose exines and are in the same size range of the illustrated specimens or have a minimum diameter at least 15u larger, and have ornaments at least 4u longer than the illustrated specimens. Apiculiretusispora (Streel, 1964) Streel, 1967, encompasses all retusoid spores with ornamentation less than one micron in length. The described specimens are in that category, although their shape and ornamentation are considered to be diagnostic of a new species, because no species of Apiculiretusispora similar to these have been noted in the literature.

Occurrence: Samples: Pb 5102, Pb 5103, Pb 5104, Pb 5105, Pb 5110?, Pb 5145, Pb 5146, Pb 5147, Pb 5148, Pb 5149, Pb 5130, Pb 5133, Pb 5134, Pb 5135, Pb 5136, Pb 5137, Pb 5138, Pb 5139, Pb 5141

Genus PUSTULATISPORITES (Potonie & Kremp, 1954) Imgrund, 1960

Type species. P. pustulatus Potonie & Kremp, 1954, p. 134, pl. 20, fig. 93; text, p. 21, pl. 6, fig. 17

PUSTULATISPORITES GIBBEROSUS (Hacquebard, 1957)
Playford, 1963
Plate 4, Figure 4

Discussion: Playford (1963, p. 19) discussed the similarities of this species with the Middle and Upper Carboniferous species Azonotriletes rarituberculatus Sadkova, 1941 (in Luber and Waltz, 1941, p. 56, pl. XII (not pl. II as stated by Playford), fig. 191), subsequently described from the Lower Carboniferous sediments of the Donetz Basin of Russia by Ishchenko (1956, p. 41, pl. VI, fig. 78) as Lophotriletes rarituberculatus (Sadkova, 1941) Naumova (1953, p. 109, pl. XVI, figs.

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37, 38) described and illustrated *Lophotriletes salebrosus* var. *famenensis*, from the Famennian of the Russian Platform, that closely resembles the illustrated specimen.

Occurrence: Upper Devonian to Lower Mississippian (Hacquebard, 1957; Playford, 1963)

Samples: Pb 5118

Genus BULLATISPORITES Allen, 1965

Type species. *B. bullatus* Allen, 1965, pp. 702-703, pl. 96, figs. 5, 6, 7

BULLATISPORITES BULLATUS Allen, 1965

Plate 4, Figures 5, 6

Discussion: The illustrated specimen, although considerably folded, possesses equatorial and distal pila that frequently support a minute spine at the apex of the caput. Curvaturae is present (observed under the oil immersion objective) on the proximal surface and the contact areas are essentially levigate. The diameter of the illustrated specimen is 4u smaller than those Allen (1965, p. 703) reported, but the smaller size is not believed significant enough for the creation of a new species.

Occurrence: Siegenian - Eifelian (Allen, 1965)

Samples: Pb 5124?, Pb 5125?, Pb 5127, Pb 5129

Genus DIBOLISPORITES Richardson, 1965

Type species. *D. echinaceus* (Eisenack, 1944) Richardson, 1965, p. 568-569, pl. 89, figs. 5, 6 cf.

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cf. DIBOLISPORITES ECHINACEUS (Eisenack, 1944) Richardson, 1965

Plate 4, Figures 7, 8, 9

Discussion: The illustrated specimen is placed in affinity with *D. echinaceus* because of its biform ornaments, thin exoexine, area of curvaturae, size and elevated labra which are nearly equal in length to the spore radius. The difference between the illustrated specimen and *Dibolisporites echinaceus* is that the exine of the illustrated spore exhibits two distinct layers (see pl. 4, fig. 7), a feature not exhibited by the specimens described by Richardson (1965, p. 568-570). *D.* cf. *D. echinaceus* (Eisenack, 1944) Richardson, 1965, illustrated but not described by McGregor and Owens (1966, p. 16, pl. V, figs. 11, 12) appears to have an exine composed of more than one layer (fig. 11) and identical ornaments (fig. 12).

The exine composed of more than one layer, is here considered a major morphologic difference, therefore, a definite generic assignment of the illustrated spore is not made at this time.

Occurrence: Sample: Pb 5129

? DIBOLISPORITES SP.

Plate 5, Figures 1, 2, 3

Description: Spores radial, trilete, retusoid; total diameter 63u to 107u, diameter of intexine 59u to 107u; outline convexo-triangular; intexine levigate, exoexine of distal hemisphere and equatorial margin ornamented with biform elements composed of coni, spines and pila with spinose tips; distal exoexine between sculptural elements infragranulose, proximal exoexine finely granulose. Trilete rays straight, bounded by labra about one micron wide, ray length nearly equal to spore radius.

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Occurrence:

Genus DICTY

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Discussion: The described specimens are similar to species of Dibolisporites (Eisenack, 1944) Richardson, 1965, except for the presence of an intexine and an exoexine in the described specimens. Cyclogranisporites sp. McGregor and Owens, 1966 (p. 10, pl. II, figs. 7, 17, 18, 19) is similar except for the granulose ornamentation.

Occurrence: Samples: Pb 5129, Pb 5130

Infraturma MURONATI Potonie & Kremp, 1954

Genus DICTYOTRILETES (Naumova, 1937) Potonie & Kremp, 1954

Type species. D. mediareticulatus (Ibrahim, 1933)
Potonie & Kremp, 1954, p. 144, pl. 20, fig. 98;
text pl. 8, figs. 29, 30

DICTYOTRILETES SP.

Plate 5, Figures 4, 5

Description: Spores radial, trilete; total diameter 41u; outline convexo-triangular; ornamentation coarsely reticulate on distal hemisphere and extending to equatorial margin, proximal hemisphere levigate. Trilete rays straight, simple, ray length equal to 3/4 spore radius.

Discussion: The figured specimen is the only one observed in this study. This spore definitely possesses the generic features of Dictyotriletes as amended by Potonie and Kremp (1954). D. devonicus Naumova, 1953, is similar although difficulty is encountered with this comparison as Naumova (1953, p. 59) does not state that the reticulate ornamentation is restricted to the distal hemisphere as it is on the specimen here illustrated. Dictyotriletes spp. as illustrated by McGregor and Owens (1966, p. 12, pl. III, fig. 13; p. 14, pl. IV, figs. 4, 6, 9, and

p. 50, pl. XXII, figs. 19, 20) do not appear to be significantly similar to the illustrated spore for specific comparison.

Occurrence: Sample: Pb 5109

Genus EMPHANISPORITES McGregor, 1961

Type species. *E. rotatus*, McGregor, 1961, p. 3, pl. I, figs. 1, 2, 3, 4

EMPHANISPORITES ROTATUS McGregor, 1961

Plate 5, Figures 6, 7

Discussion: Only four specimens definitely assignable to *E. rotatus* were observed in the residues examined for this study.

Occurrence: Lower Devonian-Middle Devonian (McGregor, 1961)

Siegenian-Lower Eifelian (Allen, 1965)

Samples: Pb 5128, Pb 5129

EMPHANISPORITES NEGLECTUS Vigran, 1964

Plate 5, Figure 10

Discussion: The illustrated specimens (two of a tetrad) are the only representatives of this species observed in the residues examined for this study. These specimens also possess all features listed in the specific, and actually expanded description of Allen (1965, p. 708).

Occurrence: Upper Givetian (Vigran, 1964)

Siegenian, Emsian (Allen, 1965)

Sample: Pb 5127

EMPHANISPORITES ANNULATUS McGregor, 1961

Plate 5, Figures 8, 9

Discussion: These spores are conspecific with *E. annulatus* although the illustrated specimens are somewhat corroded. Other spores, including o

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including other specimens of _E. annulatus_, in this sample are also corroded. The corrosion is probably caused by oxidation, due to heat and pressure at depth, and not maceration.

Occurrence: Lower Devonian-Middle Devonian (McGregor, 1961)

Samples: Pb 5124?, Pb 5150

EMPHANISPORITES ROBUSTUS McGregor, 1961

Plate 5, Figures 11, 12

Discussion: These spores are the most common occurring _Emphanisporites spp_. observed in this study.

Occurrence: Lower Devonian-Middle Devonian (McGregor, 1961)

Samples: Pb 5124, Pb 5126, Pb 5128, Pb 5129, Pb 5131

Subturma PERINOTRILITES (Erdtman, 1947) Dettman, 1963

Infraturma PERINOTRILITI (Erdtman, 1947) Dettman, 1963

Genus PEROTRILITES (Erdtman, 1947) ex Couper, 1953

Type species. _P. granulatus_ Couper, 1953, p. 31, pl. 3, figs. 28, 29

Discussion: The spores assigned to the genus _Perotrilites_ Couper, 1953, in this study may well be assignable to the genus _Diaphanospora_ Balme and Hassell, 1960. Basically, the two genera are not different in morphological organization. Balme and Hassell (1960, p. 20) state their reason for the establishment of the genus _Diaphanospora_ is because _Perotrilites_ Couper, 1953, was described from rocks deposited during the Jurassic Period and "No spores with perispores have ever been found in Permian or Triassic sediments." In the utilization of a morphological classification, this reasoning for the establishment of a new genus is considered invalid; therefore, the genus _Perotrilites_

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(Erdtman, 1947) ex Couper, 1953, is used in this study since it has priority over Diaphanospora which is believed to be synonomous with Perotrilites.

PEROTRILITES PERINATUS (Hughes & Playford, 1961) emend.

Plate 6, Figures 8, 9

Description: Spores radial, trilete, perisporate; total diameter 41u to 46u; central body diameter 37u to 44u; perispore width 2u to 3u and less than one micron in thickness; overall outline subcircular in proximal view; central body levigate; laesura simple, straight, length slightly less than central body radius, often obscured due to ridge-like folding of perispore on proximal hemisphere that is coincident with the laesura. Perispore transparent, finely-to medium granulose on distal hemisphere, levigate on proximal hemisphere, attached to central body along laesura to form slightly sinuous ridges up to 3u in width and at laesura terminus perispore forms "wadded" raised areas that extend to the equatorial edge of the perispore; perispore fits close to the central body on the proximal hemisphere and is loose and finely wrinkled into a reticulate-like pattern on the distal hemisphere.

Discussion: This species is emended to 1) include perisporate spores with a smaller central body than was described by Hughes and Playford (1961, p. 33) and 2) define in more detail the perispore ornament and attachment to the central body.

Occurrence: Lower Carboniferous, (Hughes & Playford, 1961; Playford, 1962)

Mississippian, (Playford, 1963)

Lower Carboniferous (Visean) (Barss, 1967)

Samples: Pb 5109, Pb 5110, Pb 5117, Pb 5118, Pb 5120?

PEROTRILITES LUTEOLUS (Naumova, 1953) comb. nov.

1953 *Archaeozonotriletes luteolus* Naumova, p. 128-129, pl. XIX, figs. 6, 7

1957 *Hymenozonotriletes luteolus* (Naumova) Kedo, p. 51-52, pl. II, figs. 14, 15

Plate 7, Figure 7

Description: Spores radial, trilete, perisporate; total diameter 32u to 37u; central body diameter 27u to 29u; perispore width 3u to 7u; overall equatorial outline circular to subcircular, central body circular; central body levigate to finely granulose; laesura simple, straight, length equal to radius of central body, obscured on some specimens by proximal labra-like folds of perispore that are coincident with the laesura. Perispore transluscent, ornamented on the distal hemisphere and equatorial margin of well-preserved specimens with coarse grana or pustules approximately one micron in diameter. Between these elements the perispore is microreticulate.

Discussion: The described specimens are conspecific with *Hymenozonotriletes luteolus* (Naumova) Kedo, 1957 (p. 51-52), but are assigned to the genus *Perotrilites* Couper, 1953, because of the classification used in this study.

Occurrence: Upper Famennian (Naumova, 1953)

Famennian (Kedo, 1957)

Samples: Pb 5117, Pb 5118

PEROTRILITES EVANIDUS (Kedo, 1957) comb. nov.

1957 Hymenozonotriletes evanidus (Kedo, 1957), p. 51, pl. II, fig. 13

Plate 7, Figures 8, 9

Description: Spores radial, trilete, perisporate; total diameter 43u to 47u; central body diameter 33u to 36u; perispore width 6u to 7u; overall equatorial outline and central body equatorial outline subcircular to convexo-triangular; central body levigate to very finely granulose; laesura simple, straight, length equal to radius of central body, obscured on most specimens by proximal labra-like folding of perispore that is coincident with laesura and extends to the equatorial margin of the perispore. Perispore translucent, equatorial margin uneven, microreticulate on distal hemisphere and equatorial margin with ornamentation becoming much finer on the proximal hemisphere.

Discussion: The described specimen possesses the specific morphologic features of Hymenozonotriletes evanidus Kedo, 1957. The minor difference in total diameter (the described species measures 3u to 7u less than H. evanidus) is here considered an insufficient amount for the creation of a new species. Kedo (1957, p. 51) also states that the perispore of H. evanidus is "covered with very fine warts or it is coarsely shagreen." The vagueness of the description of the perispore ornamentation makes comparison difficult, but the description complimented with the line drawing of H. evanidus Kedo (1957, pl. II, fig. 13) conforms quite well with the described specimen.

H. truncatus (Naumova, 1953) Kedo, 1957, is also similar to the described specimen but Kedo (1957, p. 53) describes the perispore ornaments to be fine tubercles, closely adjacent to one another and the

perispore of the illustrated specimen is definitely not tuberculate.

Occurrence: Famennian (Kedo, 1957)

Samples: Pb 5110, Pb 5117, Pb 5118

PEROTRILITES SPINOSUS SP. NOV.

Plate 6, Figures 10, 11; Plate 7, Figures 1, 2, 3, 6

Description: Spores radial, trilete, perisporate; total diameter 60u to 90u; central body diameter 50u to 63u; perispore width 9u to 33u; equatorial outline including perispore subcircular to oval; central body thick, levigate, appears foveate with irregularly shaped and spaced pits (probably formed by bacterial action); laesura simple, straight; laesura length slightly less than central body radius. Perispore transparent, levigate on proximal hemisphere, ornamented along equatorial margin and distal hemisphere with widely spaced spines up to 5u in length and one micron in diameter, finely microreticulate between spines.

Discussion: *Hymenozonotriletes spinosus* Naumova, 1953, is consistently smaller and possesses a narrow equatorial central body zone. *H. spinosus* Naumova, 1953, as described by Chibrikova (1959, p. 77; pl. XIII, fig. 4) does not possess the equatorial central body zone. No other spores studied in the present literature are similar to the described specimens, and the distinctly spinose perispore is significantly diagnostic for the creation of a new species.

Occurrence: Samples: Pb 5133, Pb 5136

PEROTRILITES SP. A.

Plate 6, Figures 1, 2, 3, 6

Description: Spores radial, trilete, perisporate; total diameter 55u to 63u, central body diameter 51u to 58u; maximum perispore width 5u; central body wall thickness 2u to 3u; overall equatorial outline and central body outline circular to subcircular; central body levigate; perispore finely granulose, some specimens ornamented with widely spaced coarse granules on the distal hemisphere which become finer on the proximal hemisphere. Trilete mark simple, straight, length nearly equal to central body radius, commissure distinct on some specimens. Perispore thin, transparent, less than one micron in thickness, fits closely to both proximal and distal hemispheres of central body and is sometimes folded or "curled up" around the equator of the central body; perispore is attached to the proximal hemisphere approximately 2u equatorward from the trilete rays.

Discussion: These specimens, although similar to *Diaphanospora spp.* described by Balme and Hassell (1960, p. 20-22) and Guennel (1963, pp. 257-259), differ from these previously described species in the following ways:

D. reciniata Balme & Hassell, 1960--has levigate perispore

D. perplexa Balme & Hassell, 1960--has granulose central body

D. sp. Balme & Hassell, 1960--has rugulose perispore

D. apiculata Guennel, 1963--has distally apiculate central body

D. cingulata Guennel, 1963--has cingulate granulose central body

D. reticulata Guennel, 1963--has zona plus perispore

Hymenozonotriletes Naumova, 1937, probably encompasses the described specimens and more specifically *H. commutatus* Naumova, 1937, which may be conspecific with the described specimens. The difference between *H. commutatus* and these spores is that the minimum diameter of the Woodford specimens is greater than 50u while Naumova's maximum diameter for

H. commutatus is 50u.

Occurrence: Samples Pb 5117, Pb 5118, Pb 5128, Pb 5129, Pb 5135 Pb 5137, Pb 5139, Pb 5141

PEROTRILITES SP. B

Plate 6, Figures 4, 5, 7

Description: Spores radial, trilete, perisporate; total diameter 51u to 76u, central body diameter 48u to 58u, thickness 2u to 3u; perispore width 3u to 13u, thickness less than one micron; central body subcircular (differentiated into discernable to distinct mesospore that is observable in some specimens only under oil immersion phase contrast objective), levigate on proximal hemisphere, levigate to finely granulose on distal hemisphere, cingulum-like thickened area up to 11u wide parallels equator of central body. Laesura simple, straight, length nearly equal to diameter of central body but obscured on some specimens by ridge-like folds of perispore up to 2u in width that widen to 4u at the equatorial margin of the central body; these ridge-like folds are coincident with the laesura and extend to the equatorial margin of the perispore. Perispore transparent, finely granulose to conate (coni less than .5u in length and basal diameter), wrinkled into a very fine reticulate pattern on the distal hemisphere of some specimens.

Discussion: The illustrated specimens are similar to and may be conspecific with Diaphanospora perplexa Balme and Hassell, 1960. Balme and Hassell (1960, p. 22) do not state that D. perplexa possesses the cingulum-like equatorial thickening of the central body as does the illustrated specimens. D. reticulata Guennel, 1963, is also quite similar although Guennel (1963, p. 258-259) does not mention the presence of a mesospore in any of his specimens. Auroraspora sp. Balme,

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1960 (p. 29, pl. 4, figs. 18, 19), also appears to be quite similar to the illustrated specimens although Balme (1960, p. 29) does not define any perispore ornamentation.

Occurrence: Samples: Pb 5102?, Pb 5103, Pb 5105, Pb 5108, Pb 5109, Pb 5110, Pb 5112?, Pb 5116?, Pb 5118, Pb 5120?, Pb 5121?, Pb 5122?, Pb 5127, Pb 5133?, Pb 5144, Pb 5145, Pb 5148?, Pb 5152?

PEROTRILITES SP. C.

Plate 7, Figures 4, 5

Description: Spores radial, trilete, perisporate; total diameter 150u; central body diameter 92u; maximum perispore width, including processes, 37u; maximum process length 10u; equatorial outline including perispore convexo-triangular, equatorial outline of central body circular to subcircular; central body thick, levigate; laesura obscured by slightly sinuous proximal folds of perispore that are coincident with the laesura and extend to the equatorial margin of the perispore. Perispore transparent, levigate on proximal hemisphere, equatorial margin and distal hemisphere ornamented with widely spaced spines with wide bases and gradually tapering points. The spines possess abrupt transverse annular expansions approximately 5u from their base; the expansions are 2u in length, thus these elements ornamenting the equatorial margin and distal hemisphere of the perispore appear to be cross-shaped or cruciform.

Discussion: The illustrated specimen is the only one observed in this study. The species is assigned to the genus Perotrilites Couper, 1955, becaus

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1953, because the membrane is levigate (except for the cruciform processes), thin, transparent and thus quite distinct from other large spores possessing thick and finely wrinkled exoexines, i.e., Ancyrospora (Richardson, 1960) Richardson, 1962, that have been reported from rocks of Devonian age.

Occurrence: Sample: Pb 5126

PEROTRILITES SP. D

Plate 7, Figures 10, 11

Description: Spores radial, trilete, perisporate; total diameter 43u to 46u; central body diameter 38u to 42u; exine thickness one micron or less; perispore thickness approximately 2u; outline circular; central body levigate, distal hemisphere randomly folded; laesura simple, straight, length equal to central body radius. Perispore translucent to transparent, microreticulate on distal hemisphere becoming finely microreticulate on proximal hemisphere, fits tightly over proximal hemisphere and retains original spherical shape, without being folded, on distal hemisphere although corroded from an area on the distal hemisphere; thus, is structurally more stable than the central body which possesses random distal folds.

Discussion: Archaeozonotriletes Naumova, 1953, probably encompasses these specimens. No Archaeozonotriletes spp. described by Naumova or other Russian palynologists, or other spores studied in the present literature are similar enough to be compared with the described specimen. Specimens other than those illustrated are badly corroded but retain a spherical to slightly flattened shape, thus supporting the interpreted structural stability of the perispore.

Occurrence: Samples: Pb 5117, Pb 5120?, Pb 5121?, Pb 5122?

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PEROTRILITES SP. E

Plate 8, Figures 1, 2, 3, 4, 5, 6, 7

Description: Spores radial, trilete, perisporate; total diameter 71u to 85u, central body diameter 56u to 70u, perispore width 7u to 17u; overall outline and central body outline convexo-triangular; central body levigate on proximal hemisphere, conate at equator and on distal hemisphere (cones one micron or less in height and basal diameter). Trilete mark on central body obscured by distinct sinuous proximal triradiate folds of the perispore (up to 3u in width) that extend to the equator of the perispore. Perispore transparent, less than one micron thick, levigate proximally, ornamented around equator and on distal hemisphere with closely spaced cones approximately one micron in height and basal diameter, coni usually support a fine short spine at their tip (observable only under oil immersion objective). Other random sinuous perisporial folds are present on the proximal hemisphere. No distal perisporial folds observed as the perispore fits closely on the distal hemisphere of the central body. Several specimens noted with perispore partially ripped off and pulled away from proximal hemisphere.

Discussion: The described specimens differ from all other species of Perotrilites (Erdtman, 1947) ex Couper, 1953, in the possession of cones on the distal hemisphere of both the central body and perispore, plus the possession of a spine at the tip of the perisporial cones. P. conatus Richardson, 1965, is similar except that the central body is levigate and the perispore is apparently conate on both proximal and distal hemispheres (Richardson, 1965, p. 580).

Occurrence: Samples: Pb 5127, Pb 5128, Pb 5129, Pb 5130

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Turma ZONALES (Bennie & Kidston, 1886) R. Potonie, 1956

Subturma ZONOTRILETES Waltz, 1935

Infraturma CINGULATI (Pontonie & Klaus, 1954)

Dettman, 1963

Genus MUROSPORA Sommer, 1952

Type species. *M. Kosankei* Sommer, 1952, p. 20, fig. 13a

MUROSPORA SUBTERA (Waltz, 1941) comb. nov.

Plate 8, Figures 8, 11

Description: Spores radial, trilete, capsulate; total diameter 48u; central body diameter 38u; capsula surrounds central body and extends beyond the central body at the equator from 5u to 8u; overall equatorial outline irregularly subcircular, central body outline subcircular; central body and capsula levigate; laesura simple, straight, length equal to central body radius. Capsula thick at equator of central body but thins and fits closely to the distal and proximal hemispheres of the central body; capsula irregularly developed into six low discernable scallop-like equatorial thickenings at radial and interradial areas, partially cut by proximal slits coincident with and exposing portions of each laesura.

Discussion: This capsulate spore (Staplin, 1960, p. 28) possesses the same morphologic features as *Zonotriletes subterus* Waltz, 1941 (p. 54, pl. IV, fig. 59). Since the genus *Murospora* Sommer, 1952, was created for spores possessing such morphologic features, these spores are hereby assigned to that genus.

Occurrence: Lower Carboniferous (Luber & Waltz, 1941)

Sample: Pb 5118

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Genus LOPHOZONOTRILETES (Naumova, 1953) Potonie, 1958

Type species. L. lebedianensis Naumova, 1953, p. 132, pl. XIX, fig. 34

LOPHOZONOTRILETES DENTATUS Hughes & Playford, 1961

Plate 8, Figures 9, 10

Discussion: Although the illustrated specimen is smaller than Lophozonotriletes dentatus Hughes and Playford, 1961, by 6u, it possesses all other morphologic features of the species. The ornamentation of the Frasnian species L. gibberulus Naumova, 1953, and L. excisus Naumova, 1953, is also similar to that of the illustrated specimen, but the descriptions specify that the ornamentation of both species is on the proximal hemisphere.

Occurrence: Lower Carboniferous (Hughes & Playford, 1961, Playford, 1963)

Sample: Pb 5117

Infraturma PATINATI Butterworth & Williams, 1958

Genus CHELINOSPORA Allen, 1965

Type species. C. concinna Allen, 1965, pp. 728-729, pl. 101, figs. 12-20

CHELINOSPORA SP. A

Plate 9, Figures 1, 2

Description: Spores radial, trilete, patinate; total diameter 64u; central area diameter 45u; exine thickness including muri varies from 10u to 13u; central area convexo-triangular; exine on distal hemisphere and equatorial area ornamented with cone-like and flat-topped projections up to 4u high and 3u wide at the base. Projections are connected

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connected to each other with thin muri up to 3u high thus forming a reticulate patina up to 13u in thickness; patina thins over proximal hemisphere. Trilete mark distinct; laesura straight, length nearly equal to central body radius; laesura accompanied by labra 8u in height and 4u in width at junction of laesura, labra decrease abruptly at terminus of laesura.

Discussion: The illustrated specimen possesses a distal and equatorial patina that is reticulate. The diameter of this specimen and the lumina width is larger than those of the species described by Allen (1965, pp. 728-730). *Lophozonotriletes excisus* Naumova, 1953, from the Frasnian of the Russian Platform appears similar but does not possess labra.

Occurrence: Sample: Pb 5155

Suprasubturma CAMERATITRILETES Neves & Owens, 1966

Subturma MEMBRANATITRILETES Neves & Owens, 1966

Infraturma CINGULICAMERATI Neves & Owens, 1966

Genus CINGULIZONATES (Dybova & Jachowicz, 1957)
Butterworth, Jansonius, Smith and Staplin, 1964

Type species. *C. tuberosus* Dybova & Jachowicz, 1957, pp. 170-171

CINGULIZONATES SP. A

Plate 9, Figures 3, 6

Description: Spores radial, trilete, bizonate; total diameter 58u to 65u; central area diameter 30u to 39u; zona width 16u to 17u; cuesta width 8u to 10u; overall outline subcircular to convexo-triangular;

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central area levigate to finely granulose on proximal hemisphere; zona levigate to finely granulose on proximal hemisphere; equatorial margin serrate; distal portion of zona ornamented with blunt to sharp pointed coni up to 3.5u in diameter and 4.5u in length; distal portion of central area more finely ornamented and sometimes appearing scabrate. Trilete mark distinct, composed of straight to slightly curved sutural ridges 3u wide and 1.5u high that extend to the cuesta, laesura visible on some specimens (Plate 9, Figure 3) with length equal to 1/2 the central area radius.

Discussion: The illustrated specimens possess the morphologic features of *Cingulizonates* (Dybova and Jachowicz, 1957) Butterworth, Jansonius, Smith and Staplin, 1964 (pp. 99-100, 105). No other species of *Cingulizonates* possess such coarse sculptural elements on the distal portion of the zona.

Occurrence: Samples: Pb 5103, Pb 5132?, Pb 5135, Pb 5136, Pb 5145

CINGULIZONATES SP. B.

Plate 9, Figures 4, 5, 7, 8, 10

Description: Spores radial, trilete, bizonate; total diameter 60u to 85u; central area diameter 28u to 42u; zona width 16u to 23u; cuesta width 10u to 16u; overall outline convexo-triangular; proximal hemisphere levigate; equatorial margin ornamentation varies from serrate to bluntly conate to finely spinose; distal hemisphere ornamentation becomes finer from central area (convolute) to distal portion of cuesta (verrucae mixed with cristae of coni) to the equator (finely spinose); distal ornamentation on some specimens continues as cristae of coni nearly to equator where the coni are separate as distinct equatorial elements. Trilete mark distinct, composed of slightly sinuous sutural ridges from 2u to 3u in width

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width that extend to the cuesta, laesura not discernible.

Discussion: The distally convolute central area and cristae of coni on the distal portion of the cuesta separates these specimens from *Cingulizonates* *sp*. *A*. and from other described species of *Cingulizonates*.

Occurrence: Sample: Pb 5136

Infraturma CONTINUATI Neves & Owens, 1966

Genus DISCERNISPORITES (Neves, 1958)

Neves & Owens, 1966

Type species. *D*. *irregularis* (Neves, 1958) Neves & Owens, 1966 pp. 357-358

Discussion: The species assigned to this genus are specimens belonging to a plexus of monosaccate spores without a limbus that were originally described from Lower Carboniferous sediments of Canada and assigned to the genus *Endosporites* Wilson and Coe, 1940, by Hacquebard (1957, p. 317). The specimens were separated into two species because of the variation in total diameter. *E*. *micromanifestus* ranges from 58u to 100u in total diameter and *E*. *macromanifestus* ranges from 112u to 173u in total diameter. Also, the bladder of *E*. *micromanifestus* is "generally more distinctly granulose" (Hacquebard, 1957, p. 317) than that of *E*. *macromanifestus*. Neves (1958, pp. 4-5) described spores from the Upper Carboniferous of Northern England that are conspecific with *E*. *micromanifestus* Hacquebard, 1957 (Neves and Owens, 1966, p. 357) and assigned the spores to *Discernisporites* *concentricus*. Urban (1960) describes two species of *Hymenozonotriletes* Naumova, 1937, that appear to be very similar to *E*. *micromanifestus*. The two species are differentiated on the basis of one being minutely granulose and the other coarsely granulose (Urban, 1960, pp. 12-13). Richardson (1960, pp. 49-51) found spores in the Middle Old Red Sandstone of Cromarty, Scotland, that he believes are conspecific with _E. macromanifestus_. Neither the monosaccate specimens from the Middle Old Red Sandstone nor _E. macromanifestus_ possess a limbus. The monosaccate specimens from the Middle Old Red Sandstone also have both dark-and light-colored central bodies but are otherwise identical. _Auroraspora_ Hoffmeister, Staplin and Malloy, 1955, (p. 381) was described as possessing a "dark, subtriangular to subcircular central body and a delicate transparent bladder" (Hoffmeister, Staplin and Malloy, 1955, p. 381), and "the central body of _Endosporites_ approximates the bladder in thickness" (_ibid_). Neither detailed determinations of the central body thickness of _Auroraspora_ (here assumed not to be based on color) nor the presence or absence of a limbus was mentioned. Based on the presence of both dark-and light-colored central bodies in otherwise identical spores and the absence of the limboid feature in the Middle Old Red Sandstone specimens, Richardson (1960, pp. 49-51) assigned his monosaccate specimens to _Auroraspora_ and transferred both _E. macromanifestus_ and _E. micromanifestus_ to _Auroraspora_. Playford (1962), in a study of the Lower Carboniferous Microfloras of Spitsbergen, discussed the status of _Endosporites_ and _Auroraspora_ and stated that pending a complete reappraisal of the type species of _Endosporites_ and other related monosaccate genera (particularly _Auroraspora_) he preferred to retain the original generic assignment of the two species instituted by Hacquebard (1957) _E. micromanifestus_ and _E. macromanifestus_, which Richardson (1960) had transferred to _Auroraspora_. Sullivan (1964a), in a study of Tournaisian spores from Gloucestershire, describes and illustrates spores similar to both _Discernisporites irregularis_ Neves, 1958, and _D. concentricus_ Neves, 1958. Sullivan (1964a, p. 1255) further states "forms with an unornamented central area resemble specimens of *Endosporites micromanifestus* Hacquebard, 1957." Spores structurally similar to Devonian and Lower Carboniferous genera such as *Grandispora* Hoffmeister, Staplin and Malloy, 1955, and *Discernisporites* Neves, 1958, are reported from the Drybrook Sandstone of Lower Carboniferous Age from Gloucestershire (Sullivan, 1964b). These spores, possessing a two-layered exine with the exoexine possessing punctae and short sinuous channels, were assigned to the genus *Cribrosporites* by Sullivan (1964b). The genus is neither saccate nor zonate and the taxonomic position was delayed pending completion of a comprehensive project by the 'Commission Internationale de Microflore du Paleozoique' concerned with cavate spores (Sullivan, 1964b, pp. 379-380), although the species described by Sullivan appears to be more similar to *Hymenozonotriletes lepidophytus* Kedo, 1957, or *Endosporites lacunosus* Winslow, 1964, than to species of *Discernisporites*. Richardson (1965) again reports the occurrence of both *Auroraspora micromanifestus* and *A. macromanifestus* in the Middle Old Red Sandstone of the Orcadian Basin, Northwest Scotland, while Sullivan and Marshall (1966) report *Endosporites micromanifestus* in a Visean spore assemblage from Scotland. Barss (1967, pp. 24-25, pl. IV, figs. 4, 8; pp. 38-39, pl. XI, fig. 4; pp. 42-43, pl. XIII, figs. 27-29) illustrates *Endosporites micromanifestus*, *E. macromanifestus* and *Discernisporites concentricus* from Tournaisian, Visean and/or Namurian A sediments of Canada. Neves and Owens (1966), in a study of Namurian camerate spores from the English Pennines, discuss spore classifications and modify the generic diagnoses of some genera, including *Discernisporites*. *Discernisporites* is emended, assigned to Infraturma *Continuati* Neves and Owens, 1966, and the suggesti

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suggestion is made that the reinterpretation of the structure of _Discernisporites_ (as possessing a two-layered exine) "provides a suitable generic assignment for the two species _Endosporites macromanifestus_ Hacquebard and _Endosporites micromanifestus_ Hacquebard (_Discernisporites concentricus_ Neves)" Neves and Owens, 1966, p. 357).

The preceding discussion is not totally inclusive concerning the genus _Discernisporites_ (Neves, 1958) Neves and Owens, 1966, and the species _Auroraspora micromanifestus_ (Hacquebard, 1957) Richardson, 1960, and _Auroraspora macromanifestus_ (Hacquebard, 1957) Richardson, 1960; but from the discussion it is evident that a detailed study of the type species of _Endosporites_, _Auroraspora_ and _Grandispora_ is a necessity. The descriptions of these genera, particularly _Endosporites_ (_sensu_ Hacquebard, 1957; Playford, 1963; and Sullivan and Marshall, 1966), _Discernisporites_ (_sensu_ Sullivan, 1964a; Neves and Owens, 1966) and _Auroraspora_ (_sensu_ Richardson, 1960, 1965), are quite similar. There does appear to be a distinct difference in the ornamentation of the exoexines, when one compares the illustrations (assuming the ornamentation is not modified by maceration). The exoexines of those specimens reported from the Old Red Sandstone are distinctly less granulose-punctate than those illustrated specimens from the Carboniferous.

In the detailed study pertaining to the structure and ornamentation of these camerate spores, Neves and Owens (1966) recommend reassignment of both _Endosporites micromanifestus_ Hacquebard, 1957 and _E. macromanifestus_ Hacquebard, 1957 to the genus _Discernisporites_ (Neves, 1958) Neves and Owens, 1966, although they do not actually make the reassignment.

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Until such a time that a thorough comparison and reappraisal of the genera discussed in the preceding paragraphs can be made to determine which genera and/or species are valid, the species in this study are tentatively assigned to the genus Discernisporites (Neves, 1958) Neves and Owens, 1966.

DISCERNISPORITES IRREGULARIS (Neves, 1958) emend.

Plate 9, Figures 9, 11

Description: Spores radial, trilete, equatorially camerate; total diameter 60u; inner saccus diameter 40u; maximum width of exoexine (from equatorial edge of inner saccus to spore equator) 12u; overall outline and inner saccus outline subcircular; inner saccus levigate; proximal surface of exoexine levigate to finely granulose, surface of exoexine distal to inner saccus verrucose to coarsely granulose (boss-like projections) with the ornamentation becoming finer equatorward to distinctly granulose and bluntly conate along the equatorial margin; limbus absent; inner saccus outline distinct. Trilete mark distinct in the form of raised sinuous exoexine folds 3u wide, length of folds equal to inner saccus radius and equal to total spore radius in some cases, laesura obscured by folds.

Discussion: Discernisporites irregularis Neves, 1958 (p. 4), is described as having a proximal polar region that is ornamented with low warts and smooth elongate ridges that coalesce in places. Sullivan (1964a) states that the type material and additional specimens of D. irregularis was examined in collaboration with Dr. Neves and that the ornamentation originally described on the proximal polar region is actually on the distal surface. Neves and Owens (1966, pp. 357-378), in their emendation of the genus Discernisporites state that ornamentation or modification of the contact faces may be present, but not that the diamet

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ornamentation (particularly on the holotype *D. irregularis*) is external and on the distal hemisphere of the exoexine. *Cribrosporites cribellatus* Sullivan, 1964b, may be assignable to the genus *Discernisporites* but is not included with this species because the ornamentation, as described by Sullivan (1964b, pp. 380-381), is fragmenti-vermiculate and therefore definitely negative.

Occurrence: Upper Carboniferous (Neves, 1958)

Tournaisian (Sullivan, 1964a)

Sample: Pb 5118

DISCERNISPORITES CONCENTRICUS Neves, 1958

Plate 10, Figures 1, 2, 3

Description: Spores radial, trilete, equatorially camerate; total diameter 58u to 97u; inner saccus diameter 46u to 53u; maximum width of exoexine (from equatorial edge of inner saccus to spore equator) 10u to 26u; overall outline and inner saccus outline convexo-triangular; inner saccus levigate; exoexine granulose-punctate, limbus absent. Inner saccus outline discernible to distinct. Trilete mark distinct in the form of straight raised exoexine folds from 2u to 8u in width, length of folds greater than radius of inner saccus and extending to equatorial margin of exoexine in some cases, laesura obscured by folds.

Discussion: This species is the most common of all *Discernisporites spp.* observed in the samples analyzed in this study.

Occurrence: Tournaisian, Visean, Namurian (Ishchenko, 1956)

Mississippian (Hacquebard, 1957)

Upper Woodford (Urban, 1960)

Lower Carboniferous (Playford, 1963)

Visean (Sullivan, 1964a)

Tournaisian, Visean, Namurian A (Barss, 1967)

Samples: Pb 5117, Pb 5118

DISCERNISPORITES SP. A.

Plate 10, Figures 4, 5

Description: Spores radial, trilete, camerate; total diameter 63u to 98u; inner saccus diameter 40u to 53u; maximum exoexine width (from equatorial edge of inner saccus to spore equator) 13u to 25u; overall outline and inner saccus outline in proximal view convexo-triangular; inner saccus levigate; proximal and distal hemisphere of exoexine externally very finely granulose to granulose-punctate (distinct only when observed under oil immersion objective), limbus absent. Inner saccus outline distinct. Exoexine displays numerous minor folds plus three major triradiate distal folds. Trilete mark distinct in the form of raised sinuous exoexine folds along which the exoexine is intensely folded, length of folds equal to spore radius, laesura obscured by folds. The exoexine of the illustrated specimen has been detached from the distal part of the inner saccus.

Discussion: These spores are quite similar to and may be conspecific with *Discernisporites concentricus* Neves, 1958, but the exoexine of these specimens is much thinner and more finely granulose-punctate than *D. concentricus*.

Occurrence: Sample: Pb 5117

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DISCERNISPORITES SP. B.

Plate 10, Figure 6

Description: Spores radial, trilete, camerate; total diameter 50u to 60u; inner saccus diameter 41u to 57u; maximum width of exoexine (from equatorial edge of inner saccus to spore equator) 6u to 10u; overall outline and inner saccus outline oval to subcircular; inner saccus levigate; proximal and distal hemispheres of exoexine finely granulose-punctate, limbus absent. Inner saccus discernible to distinct. Trilete mark distinct in the form of raised uneven to sinuous exoexine folds 4u to 5u wide, length of folds equal or nearly equal to spore radius, laesura obscured by exoexine folds.

Discussion: These specimens possess many of the specific characteristics of *Discernisporites concentricus*, but are here separated because of the oval to subcircular outline and the narrowness of the exoexine in proximo-distal orientation. Some species of *Hymenozonotriletes* Naumova, 1937, described by Kedo (1957), appear to be similar, but the generalized descriptions plus the stylized drawings makes specific comparison difficult.

Occurrence: Sample: Pb 5118

Genus GEMINOSPORA Balme, 1960

Type species. *G. lemurata* Balme, 1960, pp. 4-5, pl. 1, figs. 5-10

Discussion: The genus *Geminospora* Balme, 1960, although discussed by Neves and Owens (1966, p. 340) as to its subturma assignment, was not assigned to an infraturma. Rather than create another infraturma, the genus is hereby placed in the Infraturma *Continuati*. The assignment is made because the cameration or line indicating the beginning of separation

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of the intexine and exoexine, although variable, is distinct and continuous around the equatorial edge of the intexine (inner saccus) when viewed under oil immersion or phase contrast objectives, and rigidity is present between the two exine layers even when separation increases and is more nearly complete.

This genus was discussed and compared with other similar spores from the Devonian of Russia that are in the literature (Balme, 1960, pp. 4-5).

GEMINOSPORA LEMURATA Balme, 1960

Plate 10, Figures 7, 8

Description: Spores radial, trilete, equatorially and distally camerate; total diameter 52u to 61u; inner saccus diameter 49u to 51u; maximum width of exoexine (from equatorial edge of inner saccus to spore equator) 6u; overall outline and inner saccus outline convexo-triangular to subcircular; inner saccus (mesosporoid of some authors) thin, levigate; proximal surface of exoexine faintly shagreen; distal hemisphere and equatorial margin ornamented with baculae .5u in height and less than .5u in diameter; inner saccus distinct. Trilete mark distinct, straight, bounded by labra one micron wide, laesura length nearly equal to spore radius.

Discussion: Since the establishment of the species by Balme (1960), it has been recorded (questionably) from the middle Frasnian of Canada (McGregor and Owens, 1966, p. 52, pl. XXIII, fig. 19) and from the upper Givetian of Australia (de Jersey, 1966, p. 17, pl. 10, figs. 1-3, 7, 8, 10 and 11) where it is abundant. Spores observed in residues from a thin coal within the middle Devonian Cedar Valley Formation of Iowa courtesy

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(courtesy of A. T. Cross palynology collection) are conspecific with *G. lemurata*, and other camerate spores exhibiting a high degree of variation of external ornamentation on the equatorial and distal portions of the exoexine are also present in the coal residues.

Occurrences: Frasnian (Balme, 1960)

Givetian (de Jersey, 1966)

Samples: Pb 5102, Pb 5103?, Pb 5105, Pb 5132, Pb 5147?, Pb 5148

GEMINOSPORA SP. A

Plate 10, Figures 9, 11, 12

Description: Spores radial, trilete, equatorially and distally camerate; total diameter 70u to 76u; inner saccus diameter 46u; maximum width of exoexine including transparent equatorial and distal membraneous extension (from equatorial edge of inner saccus to spore equator) 9u (interradial areas) to 17u (radial areas); overall outline and inner saccus outline circular to subcircular; inner saccus levigate with prolonged radial areas distinctly visible only under phase contrast objective; proximal surface levigate to slightly uneven; exoexine composed of an equatorial and distal thickened zone plus a transparent equatorial and distal membrane---the thickened zone is fine to coarsely conate to apiculate and these ornaments, one micron to 2u in length and one micron in basal diameter that are present along the equatorial margin and on the distal hemisphere, support the membrane. Trilete mark straight, simple, laesura length equal to inner saccus radius.

Discussion: No comparable camerate spores were found in published material. The thin transparent equatorial and distal membraneous extension of the exoexine exhibited by the illustrated specimens would effect their assignment to *Hymenozonotriletes* Naumova, 1937. Prolonged inner saccus radial areas are not exhibited by any of the species of *Hymenozonotriletes* Naumova, 1937, but are observable on *Archaeozonotriletes confusus* Naumova, 1953, and *A. singularis* Naumova, 1953, although these *Archaeozonotriletes spp.* do not possess a thin transparent membrane (hymen).

Occurrence: Samples: Pb 5103, Pb 5104, Pb 5135?

Subturma SOLUTITRILETES Neves & Owens, 1966

Infraturma PLANATI Neves & Owens, 1966

Genus REMYSPORITES Butterworth & Williams, 1958

Type species. *R. magnificus* (Horst, 1955) Butterworth & Williams, 1958, pp. 386-388, text fig. 6, pl. IV, fig. 7-9

REMYSPORITES? SP. A

Plate 10, Figure 10

Description: Spores radial, trilete; proximally, equatorially and distally camerate; total diameter 52u; inner saccus diameter 28u; maximum width of exoexine (from equatorial edge of inner saccus to spore equator) 16u; original overall outline and inner saccus outline circular; inner saccus levigate, exhibiting peripherial folds; exoexine transparent to translucent, granulose-punctate to microreticulate, irregularly folded. Trilete mark straight, simple, laesura length nearly equal to inner saccus radius and partially obscured by proximal folds of the exoexine that are coincident with laesura and extend to the equator of the exoexine.

Discussion: These specimens possess the general morphologic features of *Remysporites* Butterworth and Williams, 1958 (the exoexine is now known to completely cover the proximal surface of the central body as agreed upon by Butterworth and Playford (Playford, 1963, p. 653). All specimens observed are significantly smaller than any described species and the inner saccus is smaller in proportion to the overall diameter of the spore, although the inner saccus diameter was not given in the original description.

Occurrence: Samples: Pb 5112, Pb 5113, Pb 5117, Pb 5118?

Infraturma DECORATI Neves & Owens, 1966

Genus RHABDOSPORITES Richardson, 1960

Type species. *R. langi* (Eisenack, 1944) Richardson, 1960, p. 54 text fig. 4; pl. 14, figs. 9, 10

Discussion: *Rhabdosporites langi* (Eisenack, 1944) Richardson, 1960, was described to have a bladder that is usually strongly folded and to be externally ornamented with uniform densely packed rods. *R. scamnus* Allen, 1965, is different from *R. langi* by being smaller (in both maximum and minimum diameters) and by having an externally infragranulose exoexine. *R. scamnus* is in turn differentiated from *R. parvulus* Richardson, 1965, by possessing more exoexine folds than *R. parvulus*; also, the exoexine of *R. parvulus* is externally ornamented with fine rods and is usually folded. Speciation, pertaining to *R. langi*, *R. scamnus* and *R. parvulus* may be too detailed as immature specimens of *R. langi* are probably smaller and underdeveloped ornamentation may be granulose to conate.

RHABDOSPORITES LANGI (Eisenack, 1944) Richardson, 1960

Plate 11, Figures 1, 2

Discussion: The exoexine of the specimens is externally ornamented with rods less than one micron in length and the exoexine of some of the specimens exhibits broad random folds. The trilete mark on the illustrated specimens is obscured because of proximal folds of the exoexine that are parallel to and overlying the laesura.

Occurrence: Middle Devonian? (Eisenack, 1944)
Lower Givetian (Richardson, 1960)
Upper Eifelian-Givetian (Richardson, 1965)
Givetian? (McGregor & Owens, 1965)
Samples: Pb 5129, Pb 5130

RHABDOSPORITES SCAMNUS Allen, 1965

Plate 11, Figures 3, 6

Discussion: The exoexine of the illustrated specimen is externally ornamented on the distal hemisphere with minute grana (not infragranulose), and the proximal hemisphere possesses minute low sinuous ridges less than .5u in width and not greater than 2u in length. The ornamentation around the equatorial margin ranges from minute granules to cones.

Occurrence: Givetian (Allen, 1965)
Sample: Pb 5131

Turma MONOLETES Ibrahim, 1933

Subturma AZONOMONOLETES Luber, 1955

Infraturma SCULPTATOMONOLETI Dybova & Jachowicz, 1957

Genus APICULIRETUSOSPORA gen. nov.

Diagnosis: Spores monolete, outline oval, possesses a well-defined area of curvaturae. Distal, equatorial and proximal (equatorial to area of curvaturae) ornamentation composed of elements one micron or less in height. Ornamentation on proximal hemisphere within area of curvaturae levigate or reduced in respect to other ornamentation.

Remarks: Apiculiretusospora is hereby created for monolete spores possessing an area of curvaturae and ornaments one micron or less in height. The name has been modified from Apiculiretusispora (Streel, 1964) Streel, 1967, that was established for trilete spores possessing an area of curvaturae and ornaments one micron or less in height.

APICULIRETUSOSPORA SP.

Plate 11, Figures 4, 5, 7

Description: Spores monolete; maximum length 67u, maximum width 46u; outline oval; well defined area of curvaturae developed on proximal hemisphere on each side of monolete mark; distal, equatorial and proximal (equatorial to contact area or area of curvaturae) ornamentation granulose; proximal ornamentation inside area of curvaturae levigate. Monolete mark distinct, defined as ridge one micron to 2u in width, length slightly less than 3/4 spore length.

Discussion: The illustrated specimens (one tetrad and one individual spore) are the only ones observed in samples utilized in this study. The area of curvature, characteristic of Retusotriletes Naumova, 1937?, 1953, is well-defined and distinct on the illustrated specimen. Audretsch (1967) describes a monolete spore, Azonomonoletes sp., with an area of curvaturae and spinose ornamentation from the middle Devonian in

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Buffalo River Shales in the Great Slave Lake area, Northwest Territories; also, monolete spores with an area of curvaturae and various distal and equatorial ornamentation are present in Devonian sediments in Saudi Arabia (Nygreen, 1967, personal communication).

Occurrence: Sample: Pb 5136

INCERTAE SEDIS

Genus ANCYROSPORA (Richardson, 1960) Richardson, 1962

Type species. *A. grandispinosa* (Richardson, 1960) Richardson, 1962, pp. 175-176

ANCYROSPORA ANCYREA Richardson, 1962

Plate 11, Figure 8

Description: Spores radial, trilete; total diameter excluding spinose processes 130u to 150u; central body diameter 85u (one specimen); overall outline and central body outline roundly triangular; pseudoflange width around central body nearly equal; surface of exoexine minutely wrinkled where not corroded, ornamented with spinose processes 8u to 12u in length, which have wide conical bases, narrow slender stems and the majority exhibit a well marked bifurcation at their tips; central body levigate. Trilete mark distinct (when not covered with masses of pyrite) in the form of raised proximal exoexine folds, length approximately equal to central body radius.

Discussion: The majority of the specimens are either obliquely or equatorially compressed and the central body areas contain minute masses of pyrite compressed into the surface. The bifurcation of the spine extremities is observable only under oil immersion objective although

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broken spines are observable on the illustrated specimen. The observed specimens possess the morphologic features of A. ancyrea except where oxidation has caused decomposition and thus thinning of the equatorial portion of the pseudoflange.

Occurrence: Eifelian-Givetian (Richardson, 1960, 1962)
Emsian (to early Eifelian) (McGregor & Owens, 1966)
Samples: Pb 5125, Pb 5126, Pb 5128, Pb 5130,
Pb 5133

ANCYROSPORA cf. A. PARVA de Jersey, 1966

Plate 11, Figures 9, 10, 11; Plate 12, Figures 1, 2

Description: Spores radial, trilete; total diameter excluding spinose processes 65u to 95u; central body diameter 35u to 51u; overall outline and central body outline convexo-triangular to subrounded; pseudoflange width around central body unequal, 8u wide in interradial areas and 10u wide in radial areas (excluding spinose processes in both cases); surface of pseudoflange shagrenate to granulose-punctate, ornamented with spinose processes 5u to 15u in length that gradually widen toward their bases; spine tips roundly blunt to pointed, slightly expanded laterally to form flat-topped tips normal to the spine length, with two short-pointed lateral projections, rarely bifurcate and some corroded specimens from which the outer portion of the pseudoflange has been removed apparently have an infraexoexine supporting structure of rods with slender stems and flattened tips (Plate 11, Figure 10); central body levigate. Trilete mark distinct (when not covered with masses of pyrite) in the form of raised proximal exoexine folds that extend onto the pseudoflange, laesura length equal to central body radius.

Discussion: All of these specimens show evidence of slight oxidation that probably has altered the original appearance of the majority of the spine tips. Evidence supporting the spine tip alteration is the shagrenate appearance of the exoexine (and rounded to pointed processes) on parts of a specimen and on the same specimen levigate flattopped spines with two short-pointed lateral projections are present (Plate 11, Figures 9, 10); also, on some specimens the shagrenate outer portion of the exoexine is completely removed and the infraexoexine rods with slender stems and flattened tips are exposed (Plate 11, Figure 10). Details of the structure of the exoexine are not observable on well-preserved specimens of *Ancyrospora* that have been observed from other areas and such structures may be definitive on well-preserved specimens only with the electron microscope.

These specimens are comparable in overall diameter and central body diameter only with *Ancyrospora simplex* Guennel, 1963, and *A. parva* de Jersey, 1966. If exoexine ornamentation on well-preserved specimens of those illustrated is the same as the ornamentation on the less corroded portions, this species will probably be conspecific with *A. parva*, but not with *A. simplex* as the spine tips of *A. simplex* are definitely not bifurcate.

Occurrence: Sample: Pb 5133

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus MULTIPLICISPHAERIDIUM (Staplin, 1961) Staplin, Jansonius & Pocock, 1965

Type species. *M. ramispinosum* Staplin, 1961, p. 411, pl. 48, fig. 24

Discussion: This is a complicated acritarch genus that possesses "processes separate, proximally slender, distally multifurcate, expanded, dissected, or otherwise modified, with closed tips; processes on one vesicle all of one kind or variations of one type, not differentiated into more orders or kinds of processes; ----; no differentiation between vesicle wall and processes; spine cavity in open connection with vesicle interior" (Staplin, Jansonius and Pocock, 1965, p. 180).

Although there is a wide variety of complex spine types included in the genus, differentiation can definitely be made between at least two distinct forms, 1) those possessing processes that branch along the main process and the secondary branch divides once and/or more times such as *Multiplicisphaeridium ramispinosum* Staplin, 1961, and 2) those that furcate radially only at the distal tip of the process from one time such as *M. bifurcatum* Staplin, Jansonius and Pocock, 1965, to four times such as *M.? sprucegrovensis* Staplin, 1961, and even to six times as do some forms observed in this study. Also, those forms that furcate radially at the distal tip of the process have process cavities that not only open into the vesicle interior, in the majority of the processes of a specimen, but are also open at the distal tip.

The term furcate is used in this study to describe the type of process division that occurs in those forms where bi- to multiradial process division occurs only at the distal extremity of the process (i.e., Multiplicisphaeridium? sprucegrovensis) and branching is used to define other types of process division (i.e., M. ramispinosum).

Those forms having processes that furcate terminally once or in a radial manner, possess cavities that are open into the vesicle interior and are also open at the distal tip cannot be assigned to Hystrichosphaeridium (Deflandre, 1937) Eisenack, 1958b, because, although the processes expand at the distal tip, they furcate radially and are not funnel-like (Eisenack, 1958b, p. 399); they are reassigned to a new genus.

MULTIPLICISPHAERIDIUM RAMISPINOSUM Staplin, 1961

Plate 12, Figures 3, 4

Dimensions: Vesicle diameter 20u to 29u, process length 10u to 24u; 9 specimens measured.

Discussion: The specimens observed during this study possess all features of the species as described by Staplin (1961, p. 411). Small forms of Baltisphaeridium ramusculosum Deflandre, 1942, as illustrated by Cramer (1964, text fig. 4, p. 300; pl. III, figs. 8, 9) from the La Vid Shale member of the La Vid Formation (Siegenian to Middle Emsian age), Province of Leon, N. W. Spain, are of comparable size and have branched processes that are quite similar. A more detailed comparison cannot be made as no description is given by Cramer (1964, p. 301).

Occurrence: Upper Devonian (Staplin, 1961)

Samples: Pb 5128, Pb 5130, Pb 5135, Pb 5137, Pb 5143, Pb 5144, Pb 5145, Pb 5147, Pb 5156

Genus FURCASPHAERIDIUM gen. nov.

Type species. Multiplicisphaeridium? sprucegrovensis Staplin, 1961, p. 411; pl. 48, fig. 22; pl. 49, fig. 6; text fig. 9j, p. 415

Diagnosis: Vesicle ellipsoidal to spherical, psilate to finely granulose; processes separate, wide-to narrow based with those wide based processes becoming narrow toward the distal tip, distal tips expanded, radially bi- to multifurcate (at least six times) at distal tip; furcations do not divide a second time but may vary in number. Majority of processes have internal cavities that open into the vesicle interior and are also open at the distal tip.

FURCASPHAERIDIUM (MULTIPLICISPHAERIDIUM) SPRUCEGROVENSIS (Staplin, 1961) comb. nov.

Plate 12, Figures 5, 6, 8

Type species. Multiplicisphaeridium? sprucegrovensis Staplin, 1961, p. 411; pl. 48, fig. 22; pl. 49, fig. 6; text fig. 9j

Description: Vesicle circular, originally spherical, psilate to finely granulose, diameter 35u to 54u; processes psilate, slender, crowded, 10u to 17u in length, maximum basal diameter 3u but tapering distally to 2u and then enlarged at distal tip, majority of processes hollow throughout from vesicle interior to distal tip, distal tips radiially tetrafurcate to hexafurcate, furcations narrow and become cilia-like away from distal tip of process, length of furcations 2u to 8u.

Occurrence: Upper Devonian (Staplin, 1961)

Samples: Pb 5103, Pb 5126, Pb 5127, Pb 5136, Pb 5137, Pb 5141, Pb 5143?, Pb 5144, Pb 5145?, Pb 5155, Pb 5156?

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FURCASPHAERIDIUM SP.

Plate 12, Figures 7, 9

Description: Vesicle circular, originally spherical, finely granulose, diameter 62u; processes granulose, 9u to 10u in length, maximum basal diameter 6u but tapering distally to 2u and then enlarged at distal tip, majority of processes hollow throughout from vesicle interior to distal tip, distal tips radially tetrafurcate, furcations narrow and cilia-like, length of furcations 6u.

Discussion: The processes of the illustrated specimen are shorter and have a larger diameter than those of Furcasphaeridium sprucegrovensis (Staplin, 1961). The vesicle and processes are finely granulose whereas the processes of Furcasphaeridium sprucegrovensis are definitely psilate.

Occurrence: Sample: Pb 5141

Subgroup POLYGONOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus VERYHACHIUM (Deunff, 1954) ex Deunff, 1959

Type species. V. (al. Hystrichosphaeridium) trisulcum (Deunff, 1951, p. 323, fig. 3); Deunff, 1959, p. 27, pl. 1, figs. 4-13

VERYHACHIUM TRISPINOSUM Eisenack, 1938

Plate 12, Figures 10, 11

Dimensions: Vesicle diameter from center of one side to tip of opposing appendage 30u to 50u.

Occurrence: Ordovician to Recent (Several authors)

Samples: Pb 5126, Pb 5127, Pb 5128, Pb 5130, Pb 5131, Pb 5134, Pb 5135, Pb 5136, Pb 5137, Pb 5143, Pb 5144, Pb 5145, Pb 5147, Pb 5149

VERYHACHIUM TOLONTOLUM Cramer, 1964

Plate 13, Figures 1, 2

Dimensions: Maximum diameter from tip to tip 63u to 78u, maximum diameter of vesicle from side to side 22u to 30u; 6 specimens measured.

Discussion: The echinate ornamentation of these specimens is variable and on some specimens the ornamentation is cilia-like to absent.

Occurrence: Upper Ludlovian - Middle Siegenian (Cramer, 1964)

Samples: Pb 5103, Pb 5104, Pb 5117, Pb 5118, Pb 5120, Pb 5124, Pb 5125, Pb 5127, Pb 5128, Pb 5130, Pb 5132, Pb 5135, Pb 5137, Pb 5143, Pb 5145, Pb 5147, Pb 5149, Pb 5155

Subgroup SPHAEROMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus LEIOSPHAERIDIA (Eisenack, 1958a) Downie & Sarjeant, 1963

Type species. L. baltica Eisenack, 1958a, p. 8, pl. 2, fig. 5

LEIOSPHAERIDIA TENUISSIMA Eisenack, 1958

Plate 13, Figures 3, 4, 5, 6

Dimensions: Maximum diameter 66u to 320u; 11 specimens measured.

Discussion: Specimens assigned to this species vary greatly in diameter. Some specimens appear to be finely granulose which is probably the effect of minute wrinkling present in many specimens; other specimens display numerous deep folds and are commonly taper-pointed.

Occurrence: Ordovician (Eisenack, 1958a)

All samples

LEIOSPHAERIDIA SP. A

Plate 13, Figures 7, 8

Dimensions: Maximum diameter 78u to 190u; 6 specimens measured.

Descriptions: Vesicle circular in outline, shape originally spherical; wall thickness approximately 2u, aporate, without canals, externally granulose-punctate, minute to prominent folding of vesicle wall, taper-pointed specimens common.

Discussion: These specimens occur with *L. tenuissima* and always appear to be very badly corroded. They may be poorly preserved specimens of *L. tenuissima*, but are distinctly different in appearance and therefore are differentiated. *Trachysphaeridium* Timofeev, 1959, is finely granulose and may be similar to the illustrated specimens.

Occurrence: All Samples

Subgroup NETROMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus NAVIFUSA Combaz, Lange & Pansart, 1967

Type species. *Leiofusa* (al. *Ovum*) *hispidum* (*fusiformis*) Eisenack, 1934, p. 65, pl. 4, fig. 19

NAVIFUSA (LEIOFUSA) PROCERA (Deunff, 1966) Combaz, Lange & Pansart, 1967

Plate 13, Figure 9

Dimensions: Vesicle length 210u, diameter at center 30u and slightly less at extremities.

Discussion: The illustrated specimen, plus others present in the assemblage, is not punctate as are some of those described by Deunff (1966, p. 23); otherwise they possess all features of the species. These specimens appear similar to *Navifusa* (*Leiofusa*) *brasiliensis* (Brito and

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Santos, 1965) Combaz, Lange and Pansart, 1967, which is described to have a surface ornamentation of small warts (grana?) or to be psilate (Brito, 1967b, p. 474). These forms belong to an acritarch plexus of Lunulidia Eisenack, 1958---Navifusa Combaz, Lange and Pansart, 1967, and in the samples utilized in this study the forms range from psilate and very long, to granulose, short and quite similar to Quisquilites, Wilson and Urban, 1963, in shape and ornamentation.

Occurrence: Upper Devonian (Deunff, 1966)

Samples: Pb 5124, Pb 5125, Pb 5126, Pb 5127, Pb 5128, Pb 5129, Pb 5130, Pb 5131, Pb 5135, Pb 5136, Pb 5149

Genus QUISQUILITES Wilson & Urban, 1963

Type species. Q. buckhornensis Wilson & Urban, 1963, p. 18, pl. 1, figs. 1-12

QUISQUILITES BUCKHORNENSIS Wilson & Urban, 1963

Plate 14, Figures 1, 2, 3

Dimensions: Vesicle length 95u to 135u, diameter 38u to 74u, wall thickness 2u to 3u; 10 specimens measured.

Discussion: The illustrated specimens plus others observed during this study vary considerably in size and shape. The specimens possess the ornamentation and wall structure as described by Wilson and Skvarla (1967, p. 56) and discussed in the description of Quisquilites constrictus sp. nov., but not included in the generic or specific descriptions of Leiofusa Eisenack, 1934.

Occurrence: Upper Devonian (Wilson & Urban, 1963)

Samples: Pb 5102, Pb 5103, Pb 5104, Pb 5105, Pb 5121, Pb 5124, Pb 5125, Pb 5126, Pb 5127, Pb 5128, Pb 5129, Pb 5130, Pb 5131, Pb 5132, Pb 5133, Pb 5134, Pb 5135, Pb 5136, Pb 5137, Pb 5141, Pb 5143, Pb 5144, Pb 5145, Pb 5146, Pb 5147, Pb 5149

QUISQUILITES CONSTRICTUS SP. NOV.

Plate 13, Figures 10, 11

Description: Vesicle length 129u to 180u, vesicle diameter at widest point 40u to 42u, diameter at narrowest point 21u to 22u maximum wall thickness 3u; vesicle crescent-shaped with rounded extremities, diameter decreasing slightly over 2/3 the length of the vesicle to a minimum diameter of 32u, then becoming rapidly surpressed to a minimum diameter of 20u before the rounded extremity of the vesicle is reached. Number of layers comprising vesicle wall not determinable in well-preserved specimens although two layers are observable on corroded specimens. Surface very finely granulose with random coarser grana scattered sparsely over the surface; wall canals not observable under bright field illumination although examination under oil-immersion phase contrast objective reveals numerous black dots on the surface---these are probably the optical effect of canals reported to be present in the walls of Quisquilites buckhornensis Wilson and Urban, 1963, by Wilson and Skvarla (1967, pp. 54-63)--and indistinct canals are observable in the walls along portions of the periphery of some specimens.

Discussion: The illustrated specimens possess the morphologic features of the genus Quisquilites Wilson and Urban, 1963, except for the shape which is distinctly different and is hereby cited as one criterion for differentiation of the new species. Although Combaz, Lange and Pansart

(1967, pp. 306-307) believe that *Quisquilites* is closely related to *Pseudolunulida* Brito and Santos, 1965, the genus *Quisquilites* has priority.

Occurrence: Samples: Pb 5103, Pb 5136

Subgroup DIACROMORPHITAE Downie, Ervitt & Sarjeant, 1963

Genus LOPHODIACRODIUM (Timofeev, 1958) Deflandre & Deflandre - Riguad, 1962

Type species. *L. obtusum* Timofeev, 1958, p. 831, pl. 1, fig. 1, pl. 3, fig. 1

LOPHODIACRODIUM PEPINO Cramer, 1964

Plate 14, Figures 4, 5, 6, 7, 11

Dimensions: Vesicle length 15u to 38u, vesicle diameter 8u to 20u, spinose processes one micron or less in height and basal diameter; 6 specimens measured.

Discussion: The illustrated specimens possess the morphologic features as described by Cramer (1964, p. 330) from Ludlovian to Emsian strata of northwest Spain. The specimens photographed using the phase contrast objective (Plate 14, Figures 5, 7) illustrate the greater concentration of processes on the rounded extremities of the specimens.

Occurrence: Ludlovian-Emsian (Cramer, 1964)

Samples: Pb 5137, Pb 5145

Subgroup HERKOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus CYMATIOSPHAERA (O. Wetzel, 1933) Deflandre, 1954

Type species. *C. radiata* O. Wetzel, 1933, p. 27, pl. 4, fig. 8

CYMATIOSPHAERA CUBUS? Deunff, 1961

Plate 15, Figure 1

Description: Vesicle diameter 41u; membrane width 8u; vesicle subcircular to square with convex sides (square shape caused by folding), originally spherical to lenticular, ornamentation finely granulose; membrane transparent, psilate, less than one micron in thickness, possesses four to five major folds that extend across the vesicle to the equatorial margin of the membrane giving a general cubic aspect to the specimen.

Discussion: The vesicle of this species is not always spherical as is stated by Deunff as seen in the illustrated specimen. *C. octoplana* Downie, 1959, is also similar to the illustrated specimen in that the vesicle of each is finely granulose and the areas delimited by the folded membrane are sometimes the same in number, (8), as described by Downie (1959, p. 63). *C. octoplana* is associated with *C. cubus* (*ibid*.). The illustrated specimen plus other similar specimens observed in this study may be transitional between *C. octoplana* and *C. cubus*; however, based on the overall cubic aspect of the specimen, including the vesicle and membrane, and type of folding of the membrane the specimen is questionably assigned to *C. cubus* Deunff, 1961.

Occurrence: Middle Devonian (Deunff, 1954)

Samples: Pb 5102, Pb 5108, Pb 5109, Pb 5124, Pb 5125, Pb 5126, Pb 5129, Pb 5132, Pb 5135, Pb 5136, Pb 5137, Pb 5141, Pb 5143, Pb 5144, Pb 5145

CYMATIOSPHAERA CROSSI, SP. NOV.

Plate 14, Figures 12, 13, 14, 15

Description: Maximum vesicle diameter from corner to corner 42u and from side to side 33u; maximum membrane width 4u; vesicle thickness less than one micron at equator and becoming thicker toward the poles; vesicle outline subcircular to square with convex sides, originally lenticular as is indicated by the thinner equatorial portions of the vesicle and the equatorial extension of the membrane, ornamentation very finely granulose superposed on concentric ridges one micron or less in height and width that start at the poles of the vesicle and extend to its equator; membrane transparent, psilate, less than one micron in thickness, completely enclosing vesicle, four major folds radiate from each pole of the vesicle to the equatorial margin of the membrane with the fold widths at the poles being 2u to 3u then expanding to a maximum width of 10u at the vesicle equator and decreasing rapidly in width to a point at the membrane margin except along corroded edges.

Discussion: The membrane folds on the illustrated specimens are different from those observed on any other specimens of *Cymatiosphaera* in this study or described and/or illustrated in published literature. Since the patterns formed by the types of folding in the membrane have previously been considered a significant feature in the naming of species of *Cymatiosphaera* and those folds of the illustrated specimens form a unique cruciform pattern, the illustrated specimens are hereby assigned to *Cymatiosphaera crossi* sp. nov. in honor of Dr. A. T. Cross, director of this research.

Occurrence: Samples: Pb 5135, Pb 5143

CYMATIOSPHAERA SP. A

Plate 14, Figures 8, 9, 10

Description: Vesicle diameter 32u to 41u, membrane width 6u to 10u, 4 specimens measured; vesicle thickness approximately 3u; vesicle circular, originally spherical, ellipsoidal or lenticular, psilate;

membrane transparent, psilate, completely enclosing vesicle, five major membrane folds radiating from the poles of the vesicle and extending to the equatorial margin of the membrane giving rise to pentagonal symmetry and equatorial outline, circular membrane fold sometimes present on one side of vesicle (Plate 14, Figures 8, 9).

Discussion: The illustrated specimens possess a symmetry that is similar to Cymatiosphaera fagoni Deunff, 1954, and C. cf. fagoni Deunff, 1954, that were obtained from a specimen of Favosites turbinata Billings from Onondagon age rocks of Canada. Both of Deunff's species possess a general pentagonal symmetry but in the description of C. cf. fagoni Deunff (1954, p. 7) states, "One sees in effect here---the presence of multiple perforations which are less visible on the holotype." Neither the vesicle nor the membrane of the illustrated specimens are perforate. C. pentaster Staplin, 1961, also possesses pentagonal symmetry but is different from the illustrated specimens in the respect that the vesicle is at least 10u smaller and possesses spinose projections and ridges about 5u in length that are equatorial vesicle extensions to which the membrane connects (Staplin, 1961, p. 416).

Occurrence: Samples: Pb 5128, Pb 5130, Pb 5132, Pb 5137,
Pb 5144, Pb 5145

CYMATIOSPHAERA SP. B

Plate 15, Figures 2, 3

Description: Maximum vesicle diameter 55u, maximum membrane width 13u, 9 specimens measured; vesicle outline circular to oval, originally lenticular to elliptical shape, finely granulose; membrane transparent, psilate, less than one micron in thickness, possesses three major folds that extend across the vesicle to the equatorial edges of the membrane thus dividing each hemisphere into six equal segments and giving a

general hexagonal aspect to the specimen.

Discussion: No species of Cymatiosphaera noted in the literature have been described to possess a finely granulose vesicle and three major membrane folds. These features are hereby considered significant in differentiating the illustrated specimen from other species of the genus.

Occurrence: Samples: Pb 5126?, Pb 5127, Pb 5135, Pb 5136, Pb 5137, Pb 5141, Pb 5143, Pb 5144, Pb 5145, Pb 5156

CYMATIOSPHAERA SP. C

Plate 15, Figures 4, 5, 6

Description: Maximum vesicle diameter 59u, maximum membrane width 11u, 8 specimens measured; vesicle outline subcircular to oval, shape originally lenticular to elliptical, wall thickness 2u to 3u, ornamentation finely granulose; membrane transparent, psilate, less than one micron in thickness, possesses five major radiating folds that extend from the equatorial edges of the membrane poleward across one-third of the vesicle where each fold divides and joins a major fold around the pole of the vesicle forming a polar lacuna through the membrane to the surface of the vesicle. The radiating membrane folds divide each hemisphere into ten equal segments plus a subcircular to angular central lacuna.

Discussion: The membrane extending beyond the equatorial margin of the vesicle of these specimens is often partially torn off or folded onto the vesicle but the five folds, comprising the ten "spokes", are always observed to be present (Plate 15, Figure 6) and appear to be indicative of a type of membrane support or stiffening such as rods infolded in or under the membrane. The illustrated specimens have been compared with published Cymatiosphaera spp. from France, England and Canada but do not appear similar to any of the species because of the symmetry and polar lacuna present on the illustrated specimens.

Occurrence: Samples: Pb 5109, Pb 5110, Pb 5124, Pb 5126, Pb 5127, Pb 5128, Pb 5130, Pb 5133, Pb 5135, Pb 5137, Pb 5138, Pb 5141, Pb 5143, Pb 5144, Pb 5145, Pb 5146, Pb 5149, Pb 5156

Subgroup PTEROMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus DUVERNAYSPHAERA Staplin, 1961

Type species. *D. tenuicingulata* Staplin, 1961, p. 415, pl. 49, figs. 10, 11

DUVERNAYSPHAERA TESSELLA Deunff, 1964

1967 *Veliferites tenuimarginatus* Brito, p. 477, pl. 1, figs. 4, 5, 7

Plate 15, Figures 7, 8

Dimensions: Maximum vesicle diameter from tip to tip 54u (including processes), maximum vesicle diameter from side to side 32u, maximum membrane width 11u, 2 specimens measured.

Discussion: *Duvernaysphaera tessella* Deunff, 1964, was described from the Devonian of Tunisia. *D. wilsoni* Deunff, 1964, a species similar to *D. tessella* but with a pentagonal outline and possessing five processes instead of four, was also described at that time (Deunff, 1964). Other specimens of *Duvernaysphaera*, including *D. angelae*, were also observed by Deunff from the Devonian of Ohio (*ibid.*). Brito (1966, p. 78-79), apparently unaware of Deunff's 1964 publication, assigned both species to *Veliferites tenuimarginatus* in an abstract

(Brito, 1966) and then validated the species (Brito, 1967b, p. 477). Since Deunff's species has priority, Brito's species, illustrated on Plate 1, Figures 4, 5 and 7 (op. cit., p. 479), are hereby assigned to *D. tessella* and the species illustrated on Plate 1, Figures 6 and 8 (*ibid.*) are assigned to *D. wilsoni*.

Occurrence: Devonian (Deunff, 1964)

Lower Devonian (Brito, 1966, 1967b)

Samples: Pb 5128, Pb 5129, Pb 5130, Pb 5136, Pb 5141

DUVERNAYSPHAERA SP. A

Plate 15, Figures 9, 13

Description: Maximum vesicle diameter from tip to tip including processes 39u, maximum vesicle diameter from side to side 35u, vesicle wall 2u thick, maximum membrane width 5u; vesicle outline in polar view octagonal with vesicle extended at each corner of the octagon to form simple processes 5u in length, shape originally lenticular which is indicated by the presence of both processes and membrane only around the equatorial margin of the specimen, ornamentation rough, slit 6u in length extends across pole of vesicle; membrane transparent, psilate, less than one micron in thickness, attached to processes to form an equatorial flange 5u in width.

Discussion: The illustrated specimen is different from those *Duvernaysphaera spp.* described in published literature in its octagonal shape.

Occurrence: Samples: Pb 5128?, Pb 5129, Pb 5130, Pb 5131, Pb 5135

DUVERNAYSPHAERA SP. B

Plate 15, Figures 10, 11, 12

Description: Maximum vesicle diameter excluding processes 43u, maximum membrane width 9u, 18 specimens measured; vesicle wall thickness

2u to 3u; vesicle circular in polar view with vesicle extensions radiating from the equatorial margin to form twelve or more simple processes up to 9u in length and 2u or less in diameter, shape originally lenticular to ellipsoidal which is indicated by preferred orientation in a plane parallel to the equator plus the presence of processes and membrane only around the equatorial margin of the specimens; ornamentation rough to finely granulose with some specimens possessing broad subdued ridges that radiate from the poles to the equator, slit 5u in length extends across pole of vesicle of some specimens; membrane transparent, psilate, less than one micron in thickness, attached to processes to form an equatorial flange.

Discussion: The illustrated specimens appear similar to *Duvernaysphaera tenuicingulata* Staplin, 1961, although Staplin (*op. cit.*, pp. 415-416) states that the vesicle of *D. tenuicingulata* is levigate; also, the number of vesicle processes is not given in the description (*ibid.*) but appears to be less than twelve.

Occurrence: Samples: Pb 5102, Pb 5103, Pb 5105, Pb 5111, Pb 5112?, Pb 5127, Pb 5128, Pb 5129, Pb 5130, Pb 5132, Pb 5134, Pb 5135, Pb 5136, Pb 5137, Pb 5144, Pb 5145, Pb 5146, Pb 5151?, Pb 5155

Genus PTEROSPERMOPSIS W. Wetzel, 1952

Type species. *P. danica* W. Wetzel, 1952, p. 412, pl. A, fig. 16; text fig. 34

PTEROSPERMOPSIS cf. HARTI Sarjeant, 1960

Plate 16, Figures 1, 2

Description: Maximum total diameter 120u, minimum total diameter 61u; maximum vesicle diameter 62u, minimum vesicle diameter 39u; maximum membrane width 32u, minimum membrane width 15u, 11 specimens measured; overall equatorial outline and vesicle outline oval to circular, shape originally lenticular, vesicle wall thickness not determinable, vesicle psilate; membrane transparent, psilate, less than one micron thick, completely encloses vesicle, and fits closely on vesicle from poles to equator, extends an average of 24u outward from equatorial edge of vesicle; circular membrane thickening or fold on equatorial edge of vesicle with the thickening connected to thick "spokes" or folds up to 4u in width and twelve to fourteen in number that radiate from the equatorial edge of the vesicle to the outer edge of the membrane, one major membrane fold across vesicle is present on some specimens, indistinct thickened zone around outer edge of membrane.

Discussion: The broad thick radiating "membrane spokes or folds" that arise from and are connected to the circular membrane thickening or fold on the equatorial edge of the vesicle appear to lend support to, and strengthen the membrane. The membrane effects a differential orientation to the specimens as all specimens observed in this study are compressed in a plane parallel to the membrane or slightly oblique to it, but not in an equatorial orientation. The illustrated specimens are similar to and may be conspecific with P. harti Sarjeant, 1960. I saw no distinct rim at the outer edge of the membrane, as is depicted in the text-figure of P. harti (Sarjeant, 1960, text-fig. 3a. Sarjeant (op. cit., p. 402) was unable to differentiate this rim, except at low magnification.

Occurrence: Samples: Pb 5126, Pb 5127, Pb 5130, Pb 5132, Pb 5133, Pb 5136, Pb 5137, Pb 5145, Pb 5146, Pb 5147, Pb 5149, Pb 5152?, Pb 5155

Subgroup PRISMATOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus POLYEDRIXIUM (Deunff, 1954) Jansonius, 1962

Type species. *P. deflandri* Deunff, 1954, p. 1025, fig. 8

POLYEDRIXIUM? SP.

Plate 16, Figures 3, 4, 5, 6

Description: Maximum vesicle diameter from tip to tip 50u, maximum vesicle diameter from side to side 38u, 2 specimens measured; compressed vesicle outline stellate possessing six points, shape originally hexagonal; four points are oriented in one plane at angles of 90° to each other, the other two points extend in a plane normal to the plane of the other four points; each side triangular-shaped, arched inward but extending centrifugal to the center point of the vesicle and terminating in a point, distinct ridges 2u thick are present where triangular sides are joined together which apparently strengthened the vesicle; ornamentation slightly rough to indistinctly granulose.

Discussion: These illustrated specimens, in the compressed state are distinctly 6-pointed stellate shaped. They are similar to *Polyedrixium* (Deunff, 1954) Jansonius, 1962, in the respect that they are hollow, both the sides and the edges of the sides are arched inward or concave. The specimens are provisionally assigned to *Polyedrixium* because they possess no membrane on the ridges between the sides which is a major feature of *Polyedrixium*.

Occurrence: Sample: Pb 5145

Subgroup TASMANITITAE (Sommer, 1952) Staplin, Jansonius & Pocock, 1965

Genus TASMANITES Newton, 1875

Type species. *T. punctatus* Newton, 1875, p. 341, pl. 10, figs. 2, 8

TASMANITES cf. AVELINOI (Sommer, 1953) Sommer & Van Boekel, 1966

Plate 16, Figure 9

Description: Maximum total diameter 280u, 7 specimens measured; maximum wall thickness 15u, 6 specimens measured; outline circular, shape originally spherical, surface slightly rough to uneven on corroded specimens, distinct outer wall with sparse canals one micron or less in diameter that penetrate the entire wall thickness.

Discussion: The largest specimen in this group is 30u smaller than the smallest specimen measured by Sommer (1953, p. 41).

Occurrence: Samples: Pb 5103, Pb 5104, Pb 5115

TASMANITES HURONENSIS? (Dawson, 1871) Eisenack, 1963

Plate 17, Figures 5, 6

Dimensions: Total diameter 270u, wall thickness 12u, pylome diameter including distended "collar" thickness 39u.

Discussion: Eisenack (1963, p. 210, fig. 4) illustrated a specimen with a circular collar-like thickened area surrounding the pylome that he assigned to *T. huronensis*. The wall of the illustrated specimen does not contain as many canals as specimens of *T. huronensis* that have been described in available literature. The specimen does possess the other features of the species as described by Eisenack (1963, pp. 208-209; p. 210, fig. 4).

Occurrence: Upper Devonian (Dawson, 1886; Eisenack, 1963; Winslow, 1964)

Sample: Pb 5113

TASMANITES SP. A

Plate 16, Figures 7, 8, 10

Description: Maximum total diameter 210u, maximum total wall thickness 26u, inner wall thickness 15u, maximum outer wall thickness 10u, 3 specimens measured; outline circular, shape originally spherical, ornamentation psilate; wall composed of a distinct outer psilate layer and a distinct inner canalate layer; canals less than one micron in diameter, abundant, disseminated through the inner layer (Plate 16, Figure 10) and some are also grouped together to form circles of canals that extend to the outer surface of the inner wall layer (Plate 16, Figures 9, 10).

Discussion: The illustrated specimens appear to be conspecific with Tasmanites sp. 6 Urban, 1960 (pp. 43-44, pl. 7, fig. 8; pl. 8, figs. 1, 2) reported from the Lower Woodford of Buckhorn Creek, Murray County, Oklahoma, from sample residues from 15 feet to 55 feet above the base of the Woodford. Urban (ibid.) gives the diameter of the species from 80u to 500u. Some of the specimens included with the species do not appear to possess the same type of canals (ibid.) and if this is true the exclusion of these specimens would decrease the maximum diameter. Tasmanites tapajonensis (Sommer, 1953) Sommer and van Boekel, 1966, from the Devonian of Brazil is similar to the illustrated specimens although no canals grouped together to form circles are described or observable on the illustrations.

Occurrence: Lower Woodford (Urban, 1960)

Samples: Pb 5103, Pb 5106, Pb 5111

TASMANITES SP. B

Plate 17, Figures 7, 8

Description: Maximum total diameter 160u, maximum wall thickness 12u; outline circular, shape originally spherical; surface indistinctly reticulate; lacunae polygonal, measures 5u to 7u in width, reticulation not observed around periphery of specimen; canals 2u or less in diameter randomly arranged with some penetrating the entire thickness of the wall.

Discussion: The illustrated specimen, by being reticulate, possesses a feature not observed in other Tasmanites spp. described and/or illustrated in available literature. The specimens illustrated on Plate 18, Figures 1 through 7 appear similar although the lacunae are symmetrically arranged, distinct, smaller and contain what appears to be a papillate structure in the center that may be the optical effect of the wall canals that are located in the center of the lacunae. Urban (1960, p. 41, pl. 6, figs. 9, 10, 11, 12; p. 43, pl. 7, figs. 4, 5, 6) described and illustrated Tasmanites sp. 1 and T. sp. 5 respectively that are reticulate, but do not appear similar to the illustrated specimen.

Occurrence: Samples: Pb 5118, Pb 5136

TASMANITES SP. C

Plate 18, Figures 1, 2, 3, 4, 5, 6, 7

Description: Maximum saccus diameter 206u, 3 specimens measured, saccus wall thickness one micron or less; maximum vesicle diameter 132u, 8 specimens measured; maximum vesicle wall thickness 10u, 6 specimens measured; saccus outline circular to taper pointed, original shape probably spherical, surface psilate to granulose-punctate, leiosphere-like in appearance, saccus torn off some specimens; vesicle outline circular, shape originally spherical, diameter quite variable (51u to 132u), surface distinctly reticulate, lacuna polygonal but roughly hexagonal, maximum lacuna diameter 8u, 7 specimens measured; papilla 2u in diameter in center of each lacuna that may be the optical effect of wall canals (Plate 18, Figure 4) that penetrate entire thickness of vesicle wall.

Discussion: No externally reticulate Tasmanites spp.,with a papilla in each lacuna, enclosed in a thin leiosphere-like saccus have been observed in available literature. Some of the illustrated specimens are not enclosed in a saccus. One must assume that the reticulate canalate vesicles were enclosed in a saccus because the vesicles, when compared and studied in detail (compare Figures 2 and 5 with 3, 4 and 6 on Plate 18), possess the same morphological features. Canals aren't observable in the walls of all specimens but the shape of the lacuna, presence of papillae and shape of vesicles are the same. The reticulation is distinctly external and not built into the wall, as the reticulate network is definitely extended externally at the equator of the vesicle (see Plate 18, Figures 4, 6, 7). Urban (1960, p. 41, pl. 6, figs. 9, 10, 11, 12) described and illustrated Tasmanites sp. 1 as being reticulate and containing a "pore" approximately in the center of each polygon. The enlarged surface view (ibid., pl. 6, fig. 10) appears to be lo-focus with the lacunae and "pores" bearing the same relationship to each other; that is, both are actually positive features but are out-of-focus and the lacunal floor is in focus. Neither of these species (ibid., p. 41, p. 43) were reported to be contained in a saccus.

The illustrated specimens appear similar to or conspecific with some of Urban's (1960) species but this cannot be proven until specimen for specimen comparisons are made. The illustrated specimens are similar to <u>Leiosphaeridia carinthiaca</u> Bachman and Schmid, 1964, although <u>L. carinthiaca</u> Bachman and Schmid, 1964, does not have canalate walls or have a papilla in each lacuna. Species of <u>Pterosphaeridia</u> Madler, 1963, are all more coarsely reticulate than this species, do not possess a papilla in the lacuna and do not possess canalate walls.

<u>Occurrence</u>: Samples: Pb 5103, Pb 5118, Pb 5127, Pb 5128, Pb 5129, Pb 5131, Pb 5132, Pb 5133, Pb 5134, Pb 5135, Pb 5136, Pb 5137

TASMANITES? SP.

Plate 17, Figures 1, 2, 3, 4

<u>Description</u>: Maximum total diameter 270u, 2 specimens measured; maximum wall thickness 14u, 2 specimens measured; maximum wall plug diameter 102u, 2 specimens measured; outline circular, shape originally spherical, surface originally psilate (uneven to rough on corroded specimens), wall structure indistinct as specimens are slightly corroded; canals 2u or less in diameter are very scarce in the wall but are distinct and concentrated in the wall plug; canals penetrate entire thickness of plug.

<u>Discussion</u>: The wall thickness of the illustrated specimens is quite constant (10u to 14u) but the plug diameter is extremely variable (30u to 102u). A distinct feature common to these specimens is the circular wall plug where there is a concentration of canals 2u or less in diameter. The extreme variations in plug diameters may prove, with more detailed work, to be a diagnostic feature in the separation of these forms into different species. At the present time, these specimens

are placed in one group because of the similarity of total diameter, paucity of canals other than in the wall plugs and the canalate wall plugs where the canals are concentrated. These illustrated specimens differ from other *Tasmanites spp.* because of the presence of a canalate wall plug rather than a pylome.

Occurrence: Samples: Pb 5103, Pb 5107

Subgroup SCUTELLOMORPHITAE Brito, 1967

Genus MARANHITES Brito, 1965

Type species. *M. brasiliensis* Brito, 1965, Univ. Bahia, Escola Geol., Publ. Avulsa, no. 2, p. 2, pl. 1, fig. 1

MARANHITES BRASILIENSIS Brito, 1965

Plate 19, Figures 1, 2, 4

Dimensions: Maximum diameter 115u, 3 specimens measured; wall thickness not determinable.

Discussion: The specimens of *M. brasiliensis* present in the Lower Woodford are distinctly smaller than those reported from the Cabecas Formation of Brazil (Brito, 1965, pp. 1-4); otherwise, they possess the same morphologic features.

Occurrence: Middle-Upper Devonian (Brito, 1965, 1967a)

Samples: Pb 5135, Pb 5136, Pb 5138, Pb 5145

MARANHITES? SP

Plate 19, Figures 3, 5

Description: Total maximum diameter including processes 130u, maximum vesicle diameter 120u, maximum process length 26u, maximum process diameter 10u at base decreasing to 8u at terminal tip; outline circular, original shape interpreted to be lenticular because processes are present only in equatorial area; vesicle surface uneven to rough, processes attached in equatorial area and scallop-like depressions that are circular to oval in outline are present on vesicle where processes have been torn off (see Plate 19, Figure 3, right side); processes blunt, psilate.

Discussion: The illustrated specimen is the only one observed in this study. The specimen is described and illustrated because it appears similar to *Maranhites brasiliensis*, except that its processes are much larger than those on the specimens illustrated by Brito (1967a, pl. 1, fig. 3).

Occurrence: Sample: Pb 5145

Subgroup UNCERTAIN

Genus ONONDAGELLA Cramer, 1966

Type species. *Veryhachium asymmetrica* Deunff, 1954, figured in C. R. Acad. Sci., Paris, vol. 239, fig. 15, p. 1065; 1961 described in C. R. Seances Soc. Geol. France, vol. 8, pp. 216-218

Remarks: These acritarchs may belong to the Subgroup *Platymorphitae* Downie, Evitt and Sarjeant, 1963, but are not assigned to this subgroup because the shape of the darker "vesicle" does not coincide with the transparent outer layer that extends away from the vesicle and forms the "processes".

ONONDAGELLA DEUNFFI? Cramer, 1966

Plate 18, Figure 8

Dimensions: Maximum vesicle diameter from angular extremity to opposite side 78u, maximum process length 30u, 4 specimens measured.

Discussion: The material comprising the transparent processes is psilate and completely surrounds the darker vesicle. The ornamentation of the vesicle is granulose-punctate to slightly rough.

Occurrence: Ludlovian-Lower Gedinnian? (Cramer, 1966)

Samples: Pb 5127, Pb 5130, Pb 5131

ONONDAGELLA SP.

Plate 18, Figures 9, 10

Description: Maximum vesicle from angular extremity to opposite side 54u, maximum process length 15u; vesicle outline triangular with concave sides and rounded extremities, originally inflated, ornamentation finely granulose; material comprising the transparent process psilate and completely surrounding the darker psilate vesicle (see Plate 18, Figure 10).

Discussion: The illustrated specimens may be conspecific with *Onondagella sanpetrensis* Cramer, 1966, except that the total diameter of the illustrated specimen is larger by 18u than the total maximum diameter of *O. sanpetrensis* as described by Cramer (1966, p. 88).

Occurrence: Samples: Pb 5126, Pb 5127, Pb 5130

Genus RADISPHAERIDIUM gen. nov.

Type species. *R. radiatus* sp. nov.

Diagnosis: Acritarchs having a circular outline; original shape spherical or lenticular. External ornamentation composed of subdued radiating ridges, muri or thickenings that are prominent equatorward, extend and converge poleward, but diminish and in general completely disappear toward poles; surface other than muri psilate. Suture extending completely across test common to many specimens.

Comparison: The alete spore described and illustrated by Playford (1963, pp. 655-656 and pl. 95, figs. 7, 8, 9) as Radialetes costatus appears similar to the illustrated specimen. The radiating muri of R. costatus are much more prominent than those on the illustrated specimen. R. costatus also possesses major folds that extend across the specimens while folds observed on specimens grouped with the illustrated specimen are parallel to the equator. The types of folding may be the effect of different compressional forces during diagenesis but the presence of the suture extending across the pole to the equatorial edges on the illustrated specimen is distinct and is apparently not present on R. costatus (ibid.).

RADISPHAERIDIUM RADIATUS sp. nov.

Plate 18, Figure 11

Description: Total maximum diameter 38u, wall thickness 2u, 6 specimens measured; outline circular, original shape spherical or lenticular; surface ornamented with subdued radial muri or ridges that are prominent equatorward, extend and converge poleward but diminish and generally disappear toward poles, surface other than radiating ornaments psilate; maximum width of muri 2u; continuous fold 4u or less in width centripetal to and coincident with equator present on several specimens; suture extending completely across test commonly present.

Discussion: The illustrated specimen and others assigned to the species may be related to Radialetes costatus Playford, 1963, although the size variation of R. costatus is much greater than that of specimens observed in this assemblage.

Occurrence: Samples: Pb 5102, Pb 5103, Pb 5129, Pb 5130, Pb 5131, Pb 5132, Pb 5133, Pb 5134, Pb 5135, Pb 5136, Pb 5137, Pb 5139, Pb 5141, Pb 5144, Pb 5145

ACRITARCH GENUS A

Diagnosis: Vesicle originally spherical or lenticular, randomly folded; vesicle wall externally finely reticulate; lacuna polygonal, each lacuna separated by muri. This genus is similar to forms assigned to Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant, 1963, except for the absence of rodlike supports or projecting spines at muri junctions on all observed specimens.

ACRITARCH GENUS A, SP. A

Plate 19, Figures 6, 7, 11

Description: Maximum vesicle diameter 52u, 3 specimens measured; wall thickness one micron to 2u; outline oval to circular, shape originally spherical or lenticular; vesicle wall externally finely reticulate, lacuna polygonal, lacuna diameter one micron to 2u, muri separating lacuna one micron in height and width; random major and minor folds of vesicle wall present on all specimens.

Discussion: No acritarchs like the illustrated specimens are recorded in available literature. Some species of Symplassosphaeridium Timofeev, 1959, from the Cambrian of Russia appear similar to the illustrated specimens except that the spherical clusters and resulting lacunae are very coarse and one cannot make specific comparisons with these forms because of the generalized descriptions and drawings.

Occurrence: Samples: Pb 5132, Pb 5137, Pb 5145

ACRITARCH GENUS B

Diagnosis: Vesicle originally spherical, outline circular; vesicle externally ornamented with individual processes similar to the flared bell of a trumpet, each process contains a circular lacuna or depression in its center.

ACRITARCH GENUS B, SP. A

Plate 19, Figures 8, 9, 10

Description: Maximum vesicle diameter 63u, 3 specimens measured; wall thickness not determinable; outline circular, shape originally spherical; external vesicle ornamentation similar to the flared bell of a trumpet but thicker (Plate 19, Figure 9); height of ornaments one micron to 2u, outside diameter of flared portion of ornaments 3u to 6u, width of ornament wall 2u, lacuna or depression in center of ornament circular and one micron to 2u in depth and diameter.

Discussion: No acritarchs similar to the illustrated specimens are recorded in available literature. These specimens are distinct and may be valuable forms in age determination upon establishment of their geologic range.

Occurrence: Samples: Pb 5129, Pb 5130

Class PROTISTA

Subclass RADIOLARIA Muller, 1858

Order PORULOSIDA Haeckel, 1887

Suborder SPUMELLINA Ehrenberg, 1875

Division SPHAERELLARI Haeckel, 1882

Superfamily LIOSPHAERICAE Haeckel, 1882

Family CUBOSPHAERIDAE Haeckel, 1882

Discussion: Acid-resistant fragments possessing a distinctive form have been found in two sample residues utilized in this study. The fragments consist of individual detached processes (internal radial spine skeletons?) (Plate 20, Figures 2, 3, 4) and vesicles (internal central capsule skeletons?) with broken processes attached to them (Plate 20, Figure 1). The distinctive form of these fragments is suggestive of an internal acid-resistant skeleton of a radiolarian and therefore are provisionally assigned to the Subclass *Radiolaria* Muller, 1858.

RADIOLARIA? SP.

Plate 20, Figures 1, 2, 3, 4

Description: Maximum vesicle diameter 25u, wall thickness one micron or less, 2 specimens measured; vesicle transparent, outline circular, shape originally spherical, surface appears psilate but is corroded; 6 transparent major processes present, 4 in one plane extending normally from the vesicle surface at 90 degrees to each other. The other 2 major processes extend normally from opposite sides of the vesicle in a plane normal to the plane of the other 4 major processes; major processes cylindrical, hollow, flared outward at base where attached to vesicle, all major processes broken off 10u to 14u from base, one major process (Plate 20, Figure 1, lower right process) has 4 short simple spines 8u from the base of the process that extend laterally from the major process in a plane normal to the major process and at 90 degrees to each other, process wall thickness one micron or less, ornamentation psilate to very finely granulose. Detached processes transparent, wall thickness one micron or less, cylindrical, hollow with closed pointed extremities and outward flared bases, maximum length 134u (5 specimens measured), tapers rapidly from a maximum of 27u (4 specimens measured) at base to a maximum of 10u (5 specimens measured); 4 simple spines of 17u maximum length (4 specimens measured) extend laterally from major process in a plane normal to the major process and at 90 degrees to each other, simple spines arise at a maximum distance of 83u (5 specimens measured) from the base of the major process; ornamentation of both major processes and simple spines psilate to finely granulose.

Discussion: The illustrated vesicle plus one other are the only ones observed in this study. These forms are very fragile and can best be observed and photographed with the phase contrast objective. The shape and type of material comprising the broken processes of the illustrated vesicle appears to be the same (color, density, thickness, ornamentation) as that of the detached processes. Also, the presence of the short spines on one process of the illustrated vesicle (Plate 20, Figure 1, lower right process) is deemed a valid criterion for inclusion of the detached processes in the same genus with the illustrated vesicle. These specimens are distinct and different from any others observed in this study. Their presence in residues is difficult to determine because of their transparency. No acritarchs similar to the illustrated forms are recorded in available literature. Because of their symmetry and presence in palynological residues (after 80% HF and 15% HCl treatment), the postulation is hereby made that they are probably internal acid-resistant skeletons of radiolarians. Based on the vesicle (lattice shell?) and process symmetry, they are provisionally assigned to the Family Cubosphaeridae Haeckel, 1882, which is described as "Lattice shell single or concentrically multiple, with 6 main radial spines in two planes, meeting at right angles" (Campbell, 1954, p. D58).

Occurrence: Samples: Pb 5137, Pb 5143, Pb 5145

Phylum ANNELIDA Lamarck, 1809

Class POLYCHAETIA Grube, 1850

Order ERRANTIDA Andouin & Milne-Edwards, 1832

Family LEODICIDAE Treadwell, 1921

Genus ARABELLITES Hinde, 1879

Type species. A. hamatus Hinde, 1879

ARABELLITES SP.

Plate 21, Figure 5

Description: Right jaw of maxilla I, upper side; indistinct triangular shape; distinct large anterior fang separated from second denticle by broad concave portion of inner margin; second denticle approximately 2/3 the height of the large anterior fang; the 6 denticles posterior to the second denticle become progressively smaller toward the posterior end of the maxilla and also are recurved with the denticle tips pointing in a posterior direction. Denticles at posterior end of maxilla are fused together and are not distinguishable as individuals. A conspicuous thickened flange encircles the fossa.

Discussion: The illustrated specimen possesses the general morphologic features of some species of *Arabellites* Hinde, 1879, as interpreted by Sylvester (1959, p. 40), although it is much smaller than any described in available literature. The specimen would be classified as a member of the Family ATRAKTOPRIONIDAE Kielan-Jaworowska, 1966.

Occurrence: Samples: Pb 5129, Pb 5136

Family UNCERTAIN

SCOLECODONT GENUS A, SP. A

Plate 21, Figures 4, 6

Description: Elongated blade, 100u to 170u in length, concavely or convexly arched; one edge of blade covered with overlapping denticle-like segments up to 50 in number and decreasing from 6u in height at the anterior end of the blade fragment to less than one micron in height at posterior end of the blade where the segments are partially fused together; other edge of blade (opposite segments) thin, membranous and fragmented.

Discussion: No scolecodonts similar to the illustrated specimens have been described in available literature. The illustrated specimens are fragmented and are assumed to be parts of larger forms. These specimens are quite small in respect to some of the annelid worms described in the literature but they appear similar to and could be fragments of juvenile species of the genus *Protonympha* Clark, 1903 (Howell, 1962, p. W151) or *Palaeochaeta* Clark, 1903 (*ibid.*, p. W154).

Occurrence: Samples: Pb 5103, Pb 5110, Pb 5128, Pb 5131, Pb 5132, Pb 5135, Pb 5136, Pb 5137, Pb 5145, Pb 5146, Pb 5149

Group UNCERTAIN

Subgroup UNCERTAIN

GENUS A, SP. A

Plate 20, Figures 5, 6, 7, 8

Description: Maximum length from antero-basal tip of base to distal tip of cusp (extended interpretatively on specimen illustrated on Plate 20, Figure 7) 370u; maximum length of cusp from anterior tip of cusp to distal tip of cusp 375u, 7 specimens measured; cusp inclined and joined to base at an angle of 15 degrees to 20 degrees (Plate 20, Figures 8 and 7 respectively); basal cavity present on aboral surface of specimens where base is present, originally circular, not extending orally into cusp; ornamentation granulose-punctate.

Discussion: The illustrated specimens appear similar to some conodont genera that have been reported from Ordovician age rocks and more specifically Oistodus Pander, 1856 (M. C. Mound, 1968, personal communication). The probability of the illustrated specimens being conodonts and surviving palynological processing (70% HF, 18% HCl) seems unlikely unless they are a type of chitinous innerlining not previously reported. The suggestion has been made that these specimens may be conodonts reworked from Ordovician sediments, preserved in phosphate nodules and during processing the nodules were not completely dissolved until just prior to neutralization of the HCl. The occurrence of the specimens, both numerically (common) and areally (Marshall, Carter and

Garvin Counties) seems to refute the phosphate nodule mode of occurrence, particularly since phosphate nodules occur in much greater concentration in the upper part of the Woodford Formation than in the middle or lower part.

The illustrated specimens may also belong to the Phylum Annelida although no scolecodont genera similar to these specimens are recorded in available literature.

Occurrence: Samples: Pb 5102, Pb 5103, Pb 5129, Pb 5136, Pb 5137, Pb 5139, Pb 5143, Pb 5144, Pb 5145, Pb 5149

Phylum UNCERTAIN

Class UNCERTAIN

Order CHITINOZOA Eisenack, 1931

Family HOEGISPHAERIDAE Wilson & Dolly, 1964

Discussion: The Family HOEGISPHAERIDAE Wilson and Dolly, 1964, was established for the genus Hoegisphaera because of the distinctiveness of the genus. These forms are distinctly different from other chitinozoans because they are urn-shaped and apparently solitary. They are not chain forms. Evidence of their solitary form is the absence of the copula which is a membranous tube issuing from the aboral pole that is normally attached to the stoma of the lower individual in a chain form. Jansonius (1964, pp. 911-913) assigned Hoegisphaera to the Family DESMOCHITINIDAE Eisenack, 1931, a family of chain-forming chitinozoans, and the Commission Internationale de Microflore du Paleozoique (C. I. M. P.) (1964) discussed and/or established the Family ACOPULIDAE for acopulate forms. The assignment by Jansonius (1964, pp. 911-913) is considered invalid since _Hoegisphaera_ is a solitary form. The Family ACOPULIDAE seems to be appropriate for the genus, but the family's validity cannot be confirmed at the present time; therefore, the illustrated specimens are assigned to the Family HOEGISPHAERIDAE.

Genus HOEGISPHAERA (Staplin, 1961) Wilson & Dolly, 1964

Type species. _H. glabra_ Staplin, 1961, pp. 419-420, pl. 50, figs. 4, 5, 7

HOEGISPHAERA SCABIOSA (Wilson & Hedlund, 1964)

Wilson & Dolly, 1964

Plate 21, Figures 1, 2, 3

Discussion: The illustrated specimens, plus others observed in the residues that were utilized in this study are mainly test fragments with operculum present or detached opercula. The ornamentation of the specimens is mainly verrucose to vermiculate although some are psilate, granulose-punctate and even reticulate (see operculum, Plate 21, Figure 1). The illustrated specimens were compared with several _Hoegisphaera spp._ reported from Silurian-Devonian sediments of Leon Province, Spain, by Cramer (1966). The majority of the specimens (assumed to be the least altered by reworking) utilized in this study differ from those psilate to chagrinate species reported by Cramer (_ibid._) by being verrucose to vermiculate. The basis for the assignment of the illustrated specimens to _Hoegisphaera scabiosa_ is their size, diameter of operculum and ornamentation. _H. scabiosa_, previously reported from the Sylvan Shale (Hedlund, 1960; Wilson and Hedlund, 1964) probably does not range into the Devonian. This assumption is based on its absence in tens of slides of residues from Silurian-Devonian age rocks that were examined during the course of this study. The illustrated specimens and others observed in the residues utilized in this study are therefore assumed to be reworked. The variation in ornamentation may be the effect of processing, but is more likely alteration caused by oxidation during erosion, transportation, deposition and diagenesis of the Sylvan Shale as it was being reworked. The specimens possessing vermiculate ornamentation are assumed to be less altered than those possessing other types of ornamentation (based on observations by Wilson and Dolly, 1964, p. 227).

Other evidence that the specimens have been reworked is:

1. They were observed only in residues of the "Woodford (?) Brown Carbonate" and the basal part of the Woodford Formation.
2. Most of the specimens are fragmented.
3. The "Woodford (?) Brown Carbonate" that contains the majority of the specimens also contains acritarchs that are poorly preserved and cannot be identified with certainty, but appear to be similar to some of the acritarchs reported from the Sylvan Shale by Hedlund (1960).
4. The formation underlying the "Woodford (?) Brown Carbonate" in the Marshall County portion of the area of study is the Sylvan Shale which was probably the provenance for some of the sediments comprising the "Woodford (?) Brown Carbonate".
5. The formation underlying the Woodford Formation at the Carter County outcrop is the Bois d'Arc Limestone of Early Devonian Age, but the Sylvan Shale was probably exposed in the vicinity during Woodford deposition and was probably the provenance for some of the sediments comprising the basal Woodford Formation.

<u>Occurrence</u>: Sylvan Shale (Hedlund, 1960; Wilson & Hedlund, 1964)

Samples: Pb 5103, Pb 5125, Pb 5127, Pb 5128, Pb 5129, Pb 5130, Pb 5131, Pb 5135, Pb 5136, Pb 5137, Pb 5149

ENVIRONMENTAL ZONATION

General Statement

The environmental zonation of the Woodford Formation is based on a study of the land plant microspores, acritarchs, unidentifiable organic detritus and lithology. The presence of microspores in marine sediments is indicative of a land mass adjacent to the sea in which the microspores were deposited and preserved. The microspore abundance in the sediments is dependent on the nearness of the land mass to the locus of deposition (Upshaw, 1964). Acritarchs are considered to be marine microplankton (Staplin, 1961). In the subsequent discussion the acritarchs are subdivided into 2 groups: 1) leiospheres, a common name applied to genera of the Subgroup Sphaeromorphitae that are unornamented, vary in size (15 microns to 300 microns in diameter), possess walls of various thicknesses (one micron to 10 microns) and apparently were originally spherical in shape (Cross and Hoskins, 1951b; personal observation), and 2) acritarchs possessing processes or membranes which apply to genera of the Subgroups Acanthomorphitae, Herkomorphitae and Pteromorphitae. A study of the occurrence of acritarch genera of the preceding 4 subgroups, in respect to their occurrence in areas where high energy conditions prevailed (in reef areas and flanking reefs), and where energy conditions were lower (off-reef), was conducted by Staplin (1961). Staplin (ibid.) concluded that 1) simple, spherical microplankton such as Protoleiosphaeridium (Timofeev, 1959) Staplin, 1961 (leiospheres of this study) are found in shales interbedded with reef carbonates to off-reef areas and "their abundance and species variation increases away from reefs"; 2) thin-spined microplankton are seldom found within 1 mile of reefs but are otherwise widespread; and 3) thick-spined and polyhedral microplankton are present in off-reef strata and seldom occur within 4 miles of reefs. These conclusions will be considered in this study because of the profuse abundance, in some sample residues, of acritarch (microplankton) genera of the preceding subgroups. Some organic detritus observed in the residues utilized in this study cannot be assigned to known palynomorphs or whole organisms and is not similar to any type of land plant material observed in residues of other geologic ages. This detritus may be partially decayed marine algae, some of which may have passed through the alimentary canals of various organisms, and/or partially decayed organic remains of fauna that lived in the Woodford sea, although the only fossils assignable as fauna that were observed during lithologic and palynologic examinations of the Woodford are Lingula and scolecodonts. Conodonts are also present in the formation in the area of study (Hass and Huddle, 1965), although none were observed in the Woodford samples collected for this study.

Discussion

Microscopic examination of organic residues processed for this study revealed that the types of palynomorphs vary in abundance from sample to sample. Counts of 200 palynomorphs/sample were made. The palynomorphs were then classified as microspores or acritarchs, and the acritarchs then further subdivided as leiospheres or acritarchs possessing processes or membranes. Utilizing these palynomorph groups, ratios and percentage abundances were calculated. Ratio curves and percentage abundance curves were plotted and compared to establish the biofacies zones within the Woodford Formation. These biofacies zones are further evidence of the occurrence of minor transgressive-regressive marine cycles of sedimentation and periods of relative stability during deposition of the formation. Evidence which is indicative of periods of relative stability is the constant microspore/acritarch ratio in several successive samples in a section. Changes in the microspore/acritarch ratio may be indicative of minor transgressive and/or regressive marine cycles, such that an increase in the ratio is indicative of deposition nearer shore and a decrease in the ratio is indicative of deposition farther from shore. The calculations utilized to determine these transgressive-regressive marine cycles and periods of relative stability are 1) microspore/acritarch ratios, 2) microspore/leiosphere ratios, 3) percentage abundance of leiospheres less than 50 microns in diameter and leiospheres larger than 50 microns in diameter and 4) percentage abundance of leiospheres. Generally, although not always, those leiospheres larger than 50 microns in diameter are the predominant palynomorphs in residues in which there is a paucity of microspores and acritarchs possessing processes or membranes, which may indicate that the sediments containing an abundance of leiospheres larger than 50 microns in diameter were deposited farther from the source of the microspores (i.e., farther from shore) than those samples containing an abundance of leiospheres less than 50 microns in diameter. Dispersal of leiospheres in this marine formation is discussed on page 147 in the paleoecology section. Percentage abundance of acritarchs possessing processes or membranes has also been calculated. This criterion indicates that a relationship exists between these acritarchs and the microspores that previously has not been described, and may be of ecological significance. The relationship is that the acritarchs possessing processes or membranes are more abundant in sample residues that contain microspores and less than 80% leiospheres, and decrease in abundance in residues where microspores are very scarce to absent. Winslow (1962) reported that hystrichosphaerids are commonly associated with land-plant remains, although not where land-plant remains are the most abundant. Staplin's (1961) conclusions appear to be valid pertaining to the occurrence of the acritarchs possessing processes or membranes in the respect that they occur in sediments that were probably deposited 4 miles or farther offshore in quiet water where energy conditions were minimum. The profuse abundance of various types of leiospheres (in size and wall thickness) in samples where microspores and acritarchs possessing processes or membranes are rare to absent is suggestive that their abundance and variation increase away from areas of high energy conditions (ibid.), and is interpreted to be 10 miles or farther offshore.

Minor marine sedimentary cycles are not apparent in the Woodford Formation in the area of study. Therefore, the environmental zonation is based solely upon the results obtained from the ratio curves and percentage abundance curves that were calculated and constructed for the Woodford at each locality. Distance from shore of the deposition of sediments in the different environments is highly speculative, but is postulated based on the presence of the different types of acritarchs in the sample residues, as discussed in the preceding paragraph.

The formation is divisible into at least 3 environmental zones which are defined as:

Microspore-Acritarch Zone--palynomorph assemblage predominantly marine; microspore/acritarch ratio greater than .1 and/or acritarchs possessing processes or membranes constitute more than 10% of the assemblage; leiosphere abundance less than 95%, with those less than 50 microns in diameter being more abundant than, or nearly equal in abundance to, those larger than 50 microns in diameter; littoral-epineritic zone, 5 to 10 miles from shore and more nearly 10 miles when acritarchs possessing processes or membranes are more abundant than the microspores; most regressive zone in the area of study.

Microspore-Leiosphere Zone--palynomorph assemblage predominantly marine; microspore/acritarch ratio greater than .03, less than .1 and/or acritarchs possessing processes or membranes constitute more than 3%, but less than 10% of the assemblage; leiosphere abundance more than 90%, with those larger than 50 microns in diameter and those less than 50 microns in diameter varying in abundance; epi-infraneritic zone, about 10 miles from shore.

Leiosphere Zone--palynomorph assemblage predominantly marine; microspore/acritarch ratio less than .03; acritarchs possessing processes or membranes constitute less than 3% of the assemblage; leiosphere abundance more than 95%, with those larger than 50 microns in diameter constituting more than 70% of the leiospheres in the assemblage except in probable anomalous situations; epi-infraneritic zone, farther than 10 miles from shore; most transgressive zone in the area of study.

Environmental zone curves, constructed by graphing the preceding environmental zones, and transgression direction, based on the microspore/acritarch ratio and plotted on Tables 1-6 (pages 122, 123, 125, 127 and 129 respectively) are used in the following discussion.

Hickory Creek Outcrop Section

The following environmental zonation of the Woodford Formation at Hickory Creek, N½ sec. 22, T.2S., R.1W., Carter County, Oklahoma is the result of integrated palynomorph group analyses, which were utilized to define the environmental zones. The basal 9 feet of the Woodford were deposited as a transgressive marine unit which is indicated by the Microspore-Acritarch Zone (sample Pb5102), succeeded by the Microspore-Leiosphere Zone (sample Pb5103), and the Leiosphere Zone (sample Pb5104) (Table 1e, page 122). The occurrence of Lingula Grugiere, 1797 in these basal Woodford sediments is probably indicative of water depths of less than 100 feet, and the occurrence of logs (collected at this locality) and stumps of Callixylon up to 4½ feet in diameter (Miser, 1940) in the lower part of the Woodford is indicative that the locus of deposition was not too far from the habitat of Callixylon at this time, unless the Callixylon logs floated into the area from a distant land mass such as Ozarkia which is hundreds of miles to the north.

The succeeding 84 feet of sediments, consisting of samples Pb5105 through Pb5109, were deposited in the Leiosphere Zone, and are indicative of sediments deposited during a relatively stable period which is illustrated by the relatively constant microspore/acritarch ratio (Table 1a, page 122).

A very minor regressive cycle is illustrated by the Microspore-Leiosphere Zone in sample Pb5110 which was followed by transgression, and the succeeding 137 feet of sediments, consisting of samples Pb5111 through Pb5115, were deposited in the Leiosphere Zone (Table 1e, page 122). This sequence of sediments was probably deposited during a relatively stable period farther than 10 miles offshore which is supported by the constant microspore/acritarch ratio (Table 1a, page 122) and the constant occurrence of abundant leiospheres larger than 50 microns in diameter (Table 1d, page 122).

A regressive cycle, the maximum period of regression in the area, then occurred, and is denoted by the occurrence of the Microspore-Leiosphere Zone (sample Pb5116), followed by the Microspore-Acritarch Zone (sample Pb5117) (Table 1e, page 122). Evidence that a period of transgression followed is the presence of the Microspore-Leiosphere Zone in sample Pb5118 at the top of the formation (Table 1e, page 122).

The preceding transgressive-regressive marine cycles, defined by the environmental zones, are supported by the microspore/acritarch ratio curve, the microspore/leiosphere ratio curve and the percentage abundance of leiospheres (Table 1a, 1b and 1d respectively, page 122). The occurrence together of acritarchs possessing processes or membranes and microspores (compare Table 1a with 1c, page 122) is suggestive that a relationship exists between these acritarchs and the microspores (which is discussed on pages 146-147).

California Oil Company #1 Mullen

The environmental zone curve (Table 2e, page 123) illustrates that these samples were all deposited in the Leiosphere Zone.

The presence of the Leiosphere Zone in all samples analyzed from this well is supported by the microspore/leiosphere ratio curve (Table 2b, page 123). The percentage abundance of acritarchs possessing processes or membranes (Table 2c, page 123) does not support the suggested relationship of the occurrence of these acritarchs together with the microspores to the extent that their percentage abundance does in the Hickory Creek section (Table 1c, page 122). The high percentage of leiospheres larger than 50 microns in diameter (Table 2d, page 123) indicates that the locus of deposition was farther than 10 miles offshore at this time.

Texas Company #1-K Drummond

The environmental zone curve (Table 3e, page 125) illustrates that these samples were deposited in the Leiosphere Zone with the exception of a very minor regressive cycle which is distinguishable by the occurrence of the Microspore-Leiosphere Zone in sample Pb5121. This regressive cycle is supported by the microspore/leiosphere ratio curve and a decrease in the abundance of acritarchs possessing processes or membranes (Table 3b and 3c respectively, page 125). The high percentage of

Table 1--Woodford Formation, Hickory Creek, N½ sec. 22, T.2S., R.1W., Carter County, Oklahoma: a) microspore/acritarch ratio curve, b) microspore/leiosphere ratio curve, c) percentage abundance of acritarchs possessing processes or membranes, d) percentage abundance of leiospheres, and e) environmental zonation.

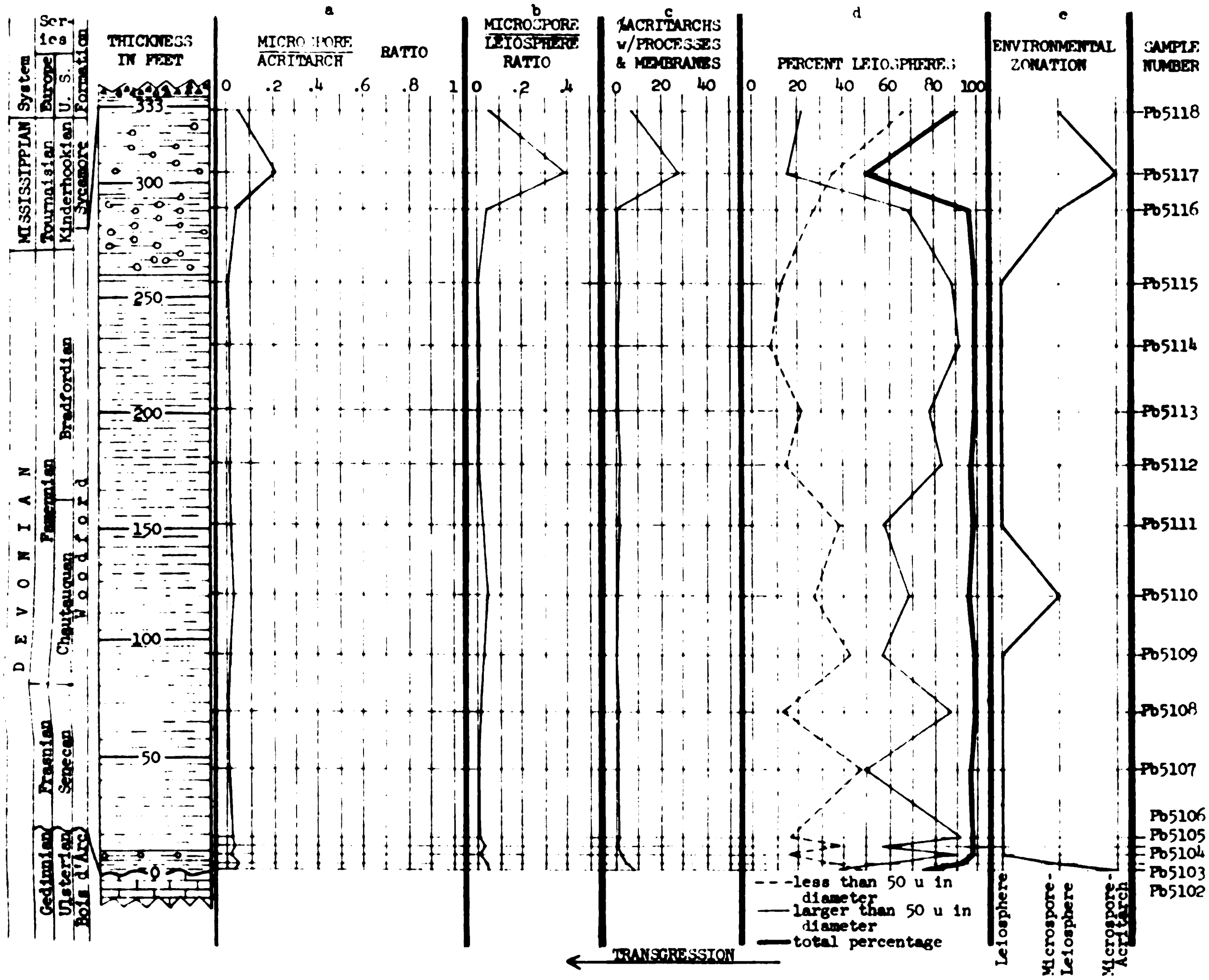
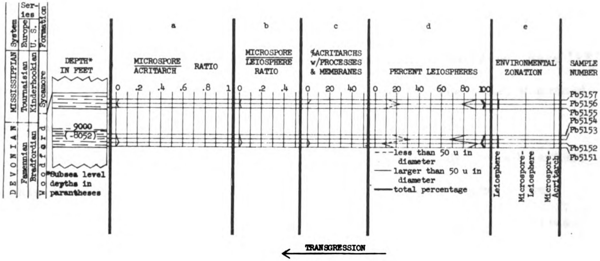


Table 2--Upper Woodford Formation, California Oil Company #1 Mullen well, center SE¼SE¼ sec. 29, T.5S., R.2W., Carter County, Oklahoma; a) microspore/acritarch ratio curve, b) microspore/leiosphere ratio curve, c) percentage abundance of acritarchs possessing processes or membranes, d) percentage abundance of leiospheres, and e) environmental zonation curve.



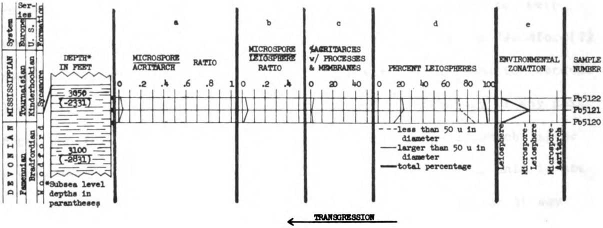
leiospheres in all 3 samples (Table 3d, page 125) is probably indicative of a locus of deposition 10 miles or farther offshore. The high percentage occurrence of leiospheres less than 50 microns in diameter is anomalous if these samples were deposited in the Leiosphere Zone, but can be accounted for if these organisms lived seaward of the area and if current action in the area was at a minimum. If such a situation existed, the smaller leiospheres would be washed into the area from a more seaward portion of the continental shelf and the majority of the larger leiospheres would remain behind. Another possibility is that these organisms lived in the area at the time this portion of the Woodford was deposited.

Carter #1 King

Interpretation of the environmental zone curve (Table 4e, page 127) resulted in the following environmental zonation of the basal Woodford sediments in this well.

The basal few feet of the Woodford was probably deposited farther than 10 miles offshore which is illustrated by the Leiosphere Zone in sample Pb5148, and a period of regression followed which is illustrated by the Microspore-Acritarch Zone in sample Pb5147 (Table 4e, page 127). Deposition continued in the Microspore-Acritarch Zone (sample Pb5146), although a decrease in the microspore/acritarch ratio (Table 4a, page 127) and an increase in the abundance of acritarchs possessing processes or membranes in sample Pb5146 (Table 4c, page 127) is suggestive that a period of transgression was beginning to occur in the area. This transgressive cycle is further supported by the occurrence of the Microspore-Leiosphere Zone in sample Pb5145 (Table 4e, page 127). A slight period of regression then occurred which is based on an increase in the abundance of acritarchs possessing processes or membranes and is

Table 3--Upper Woodford Formation, Texas Company #1-K Drummond well, center SE¼NW¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma; a) microspore/acritarch ratio curve, b) microspore/leiosphere ratio curve, c) percentage abundance of acritarchs possessing processes or membranes, d) percentage abundance of leiospheres, and e) environmental zonation curve.



illustrated by the Microspore-Acritarch Zone in sample Pb5144 (Table 4c, page 127). The presence of the Leiosphere Zone in the remaining samples (Pb5143 and Pb5142) (Table 4e, page 127) indicates that transgression then occurred in the area.

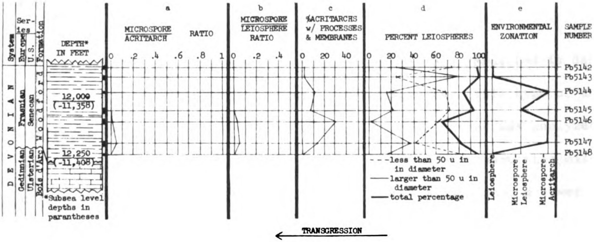
The microspore/leiosphere ratio curve and percentage abundance of leiospheres (Table 4b and 4d respectively, page 127) support the preceding zonation.

Texas Company #1 Gipson

Sample residues from only 3 core chips from the basal 23 feet of the Woodford Formation were analyzed from this well, although sample residues from 14 core chips of the "Woodford(?) Brown Carbonate" were examined during this study. These 14 sample residues of the "Woodford(?) Brown Carbonate" were not included in this environmental zonation because 1) the lithology of the unit is not similar to the lithology of any part of the Woodford Formation at Locality 1 (Figure 1, page 2) which is, or is very near to, the type locality; 2) the lithology of the unit is not similar to the lithology of any part of the Woodford Formation at any other locality where the Woodford was observed; 3) a thorough study of the 14 sample residues revealed that many palynomorphs present in the assemblage are conspecific with palynomorphs reported from Middle Devonian (Erian) age strata in other parts of the United States, and other parts of the world. Therefore, the age of this unit is discussed on pages 152-154 because of the significance of its palynomorph assemblage in respect to an age identification that is different from the Woodford Formation.

Interpretation of the environmental zone curve (Table 5e, page 129) illustrates that the basal Woodford (sample Pb5137) was deposited in the Microspore-Acritarch Zone. A transgressive cycle then occurred which is

Table 4--Basal Woodford Formation, Carter #1 King well, SW¼NW¼NW¼ sec. 28, T.1N., R.1E., Garvin County, Oklahoma: a) microspore/acritarch ratio curve, b) microspore/leiosphere ratio curve, c) percentage abundance of acritarchs possessing processes or membranes, d) percentage abundance of leiospheres, and e) environmental zonation curve.



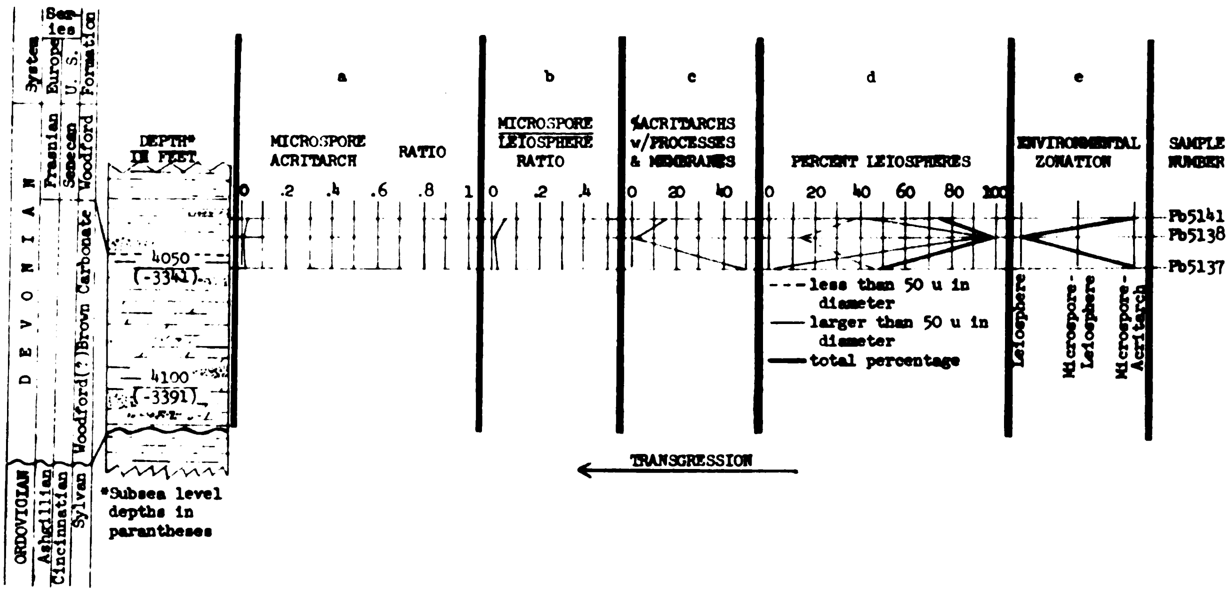
illustrated by the presence of the Leiosphere Zone in sample Pb5138, and evidence supporting a succeeding regressive cycle is the occurrence of the Microspore-Acritarch Zone in sample Pb5141 (Table 5e, page 129).

The microspore/leiosphere ratio curve (Table 5b, page 129) and percentage abundance of leiospheres (Table 5d, page 129) support the preceding environmental zones. The percentage abundance of acritarchs possessing processes or membranes (Table 5c, page 129) illustrates that the sediments in the Microspore-Acritarch Zone (samples Pb5137 and Pb 5141) were probably deposited quite some distance offshore which is also supported by the low microspore/acritarch ratio (Table 5a, page 129).

Leiosphere Size Frequency Distribution Zones

Another approach to the zonation of the Woodford Formation is based solely on size frequency distribution of leiospheres. This type of zonation was reported for a section of the Woodford Formation that was analyzed by Urban (1960) at Locality U (Figure 1, page 2) and subsequently discussed by Wilson and Urban (1967). Urban (1960) established a lower leiosphaerid (leiosphere of this study) zone 145 feet thick that contains a preponderance of leiospheres ranging from 40 microns to 70 microns in diameter, a middle leiosphaerid zone 102 feet thick containing an abundance of leiospheres ranging from 70 microns to 110 microns in diameter and an upper leiosphaerid zone 30 feet thick that contained an abundance of leiospheres ranging from 30 microns to 50 microns in diameter. In an attempt to evaluate the possible validity of this type of zonation of the formation, all residues from the Hickory Creek section (Figure 1, Locality 1, page 2), where samples from a complete section were collected, were utilized to determine if comparable leiosphere zonation exists in the Hickory Creek section. The actual numbers of leiospheres counted by Urban (1960) were changed to percentages and plotted as percentage abundance

Table5--Basal Woodford Formation, Texas Company #1 Gipson well, NE¼NE¼NW¼ sec. 11, T.6S., R.6E., Marshall County, Oklahoma; a) microspore/acritarch ratio curve, b) microspore/leiosphere ratio curve, c) percentage abundance of acritarchs possessing processes or membranes, d) percentage abundance of leiospheres, and e) environmental zonation curve.



distributions (Table 6d, 6e, 6f, page 131), because of the differences in the number counted by Urban (*ibid.*) which was approximately 1263 and the number counted from the Hickory Creek section of this study which was 3164.

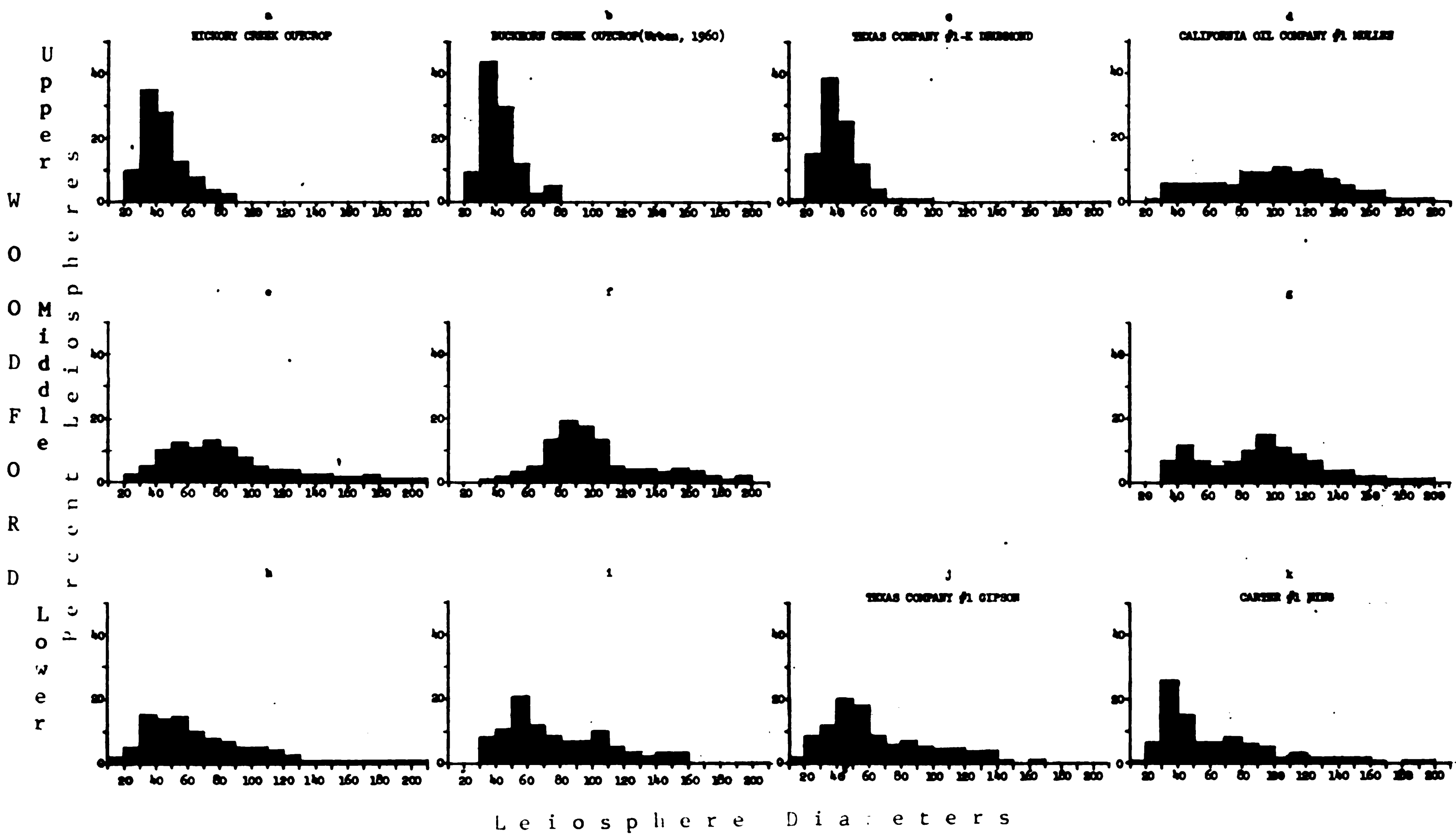
Correlation of Urban's (*ibid.*) lithologic units with those at the Hickory Creek outcrop was not successful. Therefore, percentages of leiospheres from sample residues, from proportionate parts of the 333-foot thick section at Hickory Creek (in respect to a 297-foot thick section at the Buckhorn Creek locality (*ibid.*)), were combined in an attempt to establish zones similar to those from the Buckhorn Creek section (*ibid.*). Zone overlapping probably occurred between the sections, although the general leiosphere distribution should be similar and correlative if environments were similar during deposition of the various parts of the formation in each area, and if leiospheres are significant in zonation of the formation. Percentage histograms of the size frequency distribution of leiospheres were also constructed from the Upper Woodford in the Texas Company #1-K Drummond well and the California Oil Company #1 Mullen well, the Middle Woodford in the California Oil Company #1 Mullen and the Lower Woodford in the Texas Company #1 Gipson and Carter #1 King (Table 6, page 131).

Correlation

Microspore-Acritarch Zone, Microspore-Leiosphere Zone and Leiosphere Zone--These zones are significant in identifying different environments of deposition and should be correlative, although one zone may grade laterally into another if the environment was not the same in 2 different areas at the same time.

Comparison of zones established in the basal part of the formation (Carter #1 King, Texas Company #1 Gipson and Hickory Creek Outcrop)

Table 6--Frequency distribution of leiospheres in the Upper Woodford at a) Hickory Creek, b) Buckhorn Creek, c) Texas Company #1-K Drummond and d) California Oil Company #1 Mullen; Middle Woodford at e) Hickory Creek, f) Buckhorn Creek and g) California Oil Company #1 Mullen; Lower Woodford at h) Hickory Creek, i) Buckhorn Creek, j) Texas Company #1 Gipson and k) Carter #1 King.



indicates that a good correlation cannot be made. The zones present in the Hickory Creek section and the #1 King well illustrate only that a transgressive cycle occurred following deposition nearer shore (compare basal part of Table 1e with Table 4e, pages 122 and 127 respectively).

Comparison of zones established in the Middle Woodford from the California Oil Company #1 Mullen well where only 3 samples from 15 feet of the middle part of the formation were analyzed, and the Hickroy Creek section are correlative in the respect that both sections (specifically the upper part of the Middle Woodford at Hickory Creek) were deposited in the Leiosphere Zone (compare middle part of Table 1e with Table 2e, pages 122 and 123 respectively).

Upper Woodford zones from the California Oil Company #1 Mullen well, Texas Company #1-K Drummond well and the Hickory Creek outcrop were compared, and there is a definite suggestion of a correlation between the Texas Company #1-K Drummond well and the Hickory Creek section (compare Table 3e with Table 1e, pages 125 and 122 respectively). This correlation is supported by the microspore/acritarch and microspore/leiosphere ratio curves (compare Tables 3a and 3b with Tables 1a and 1b, pages 125 and 122 respectively); however, the locus of deposition at the #1-K Drummond was farther offshore than the locus of deposition at Hickory Creek which is illustrated by the presence of less microspores in the #1-K Drummond well.

Size Frequency Distribution of Leiospheres--The Upper Woodford Histograms most similar and correlative with each other are those from Hickory Creek, Buckhorn Creek and the Texas Company #1-K Drummond (Tables 6a, 6b and 6c respectively, page 131), in which leiospheres from 30 microns to 50 microns in diameter comprise over 60% of the leiospheres in the assemblage. The Upper Woodford histogram of the California Oil Company #1 Mullen is not similar to the other Upper Woodford histograms. Although the leiosphere diameter variation is much greater in the Upper Woodford of the #1 Mullen, it does show some similarity to the Middle Woodford at Hickory Creek, Buckhorn Creek and its own subjacent section that is considered to be Middle Woodford (compare Table 6d with Table 6e, 6f and 6g, page 131). The greater variation in leiosphere diameters in the Upper Woodford of the #1 Mullen well is suggestive that the section may have been deposited in a transitional leiosphere environment.

Conclusions

The following conclusions may be drawn concerning environmental zonation of the Woodford Formation in the area of study:

1. The formation is marine.

2. Analysis of palynomorphs can be used to distinguish at least 3 different types of marine units in the formation, some probably deposited farther offshore than others.

3. A relationship, possibly of ecological significance, exists between the occurrence of microspores and acritarchs possessing processes or membranes.

4. Correlation of environmental zones may be inferred, but is not conclusive.

5. Leiosphere zones are present, but in samples collected at 1-foot intervals their size distribution varies considerably and all possible factors controlling their distribution must be studied before they can be effective in correlation.

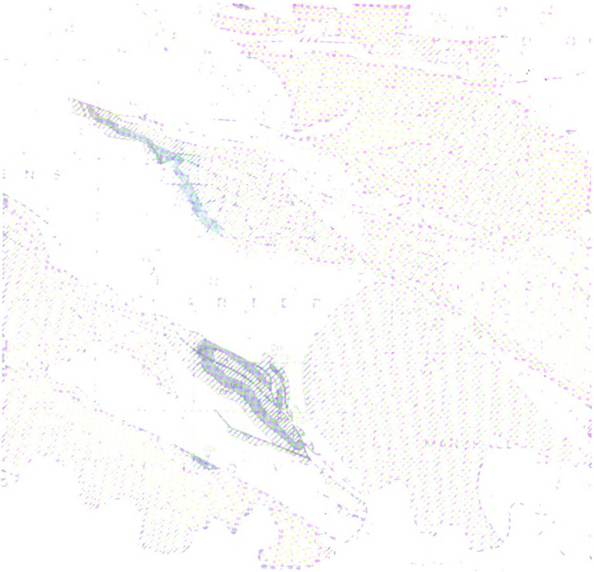
6. The Upper Woodford in the Hickory Creek section, Buckhorn Creek section and Texas Company #1-K Drummond is correlative based on size frequency distribution of leiospheres.

7. As individual entities, the leiospheres are not significantly valuable in environmental zonation.

PALEOGEOGRAPHY

By the end of Lower Devonian time the seas had apparently withdrawn from the area of study because no Middle Devonian strata have been reported in the Area (Tarr, Jordan and Rowland, 1965; Amsden, 1960). The entire sequence of Silurian-Lower Devonian strata of the Hunton Group is missing in parts of the area and much older strata of Late Ordovician Age subcrop below the Woodford Formation (Figure 9, page 135). Periods of uplift and erosion occurred because of several unconformities within the Hunton Group (Amsden, 1960). Physical evidence that an area adjacent to the Texas Company #1 Gipson well was topographically high prior to and at the beginning of Woodford deposition is the presence, in the well, of siltstone containing orthoquartzite stringers in the basal part of the "Woodford(?) Brown Carbonate." Biological evidence that supports the preceding statement, and is indicative that the adjacent area was also structurally high at this time is the abundance of broken and fragmented specimens of Hogisphaera scabiosa (Wilson & Hedlund, 1964) Wilson & Dolly, 1964 (Plate 21, Figures 1,2, and 3), a chitinozoan which has not been reported from strata younger than Late Ordovician Age (Sylvan Shale), in the "Woodford(?) Brown Carbonate."

Throughout Woodford time, in the area of study, the provenance apparently was composed predominantly of low-lying strata. These strata were mainly Lower Paleozoic carbonates which is illustrated by the absence of clastic material larger than clay size observed in the Woodford Formation except in the basal 2 feet of the formation at Hickory Creek (Figure 4, page 9) and at other localities where a complete section of the formation was observed (Figure 1, page 2).



(1965)

GEOLOGIC MAP OF PRE-WOODFORD
ROCKS IN SOUTH-CENTRAL OKLAHOMA
(Tarr, Jordan and Rowland)
Scale 1:750,000

LEGEND

DSh	Silurian-Early Devonian(Hunton Group)
DS	Silurian-Early Devonian(undifferentiated)
Os	Ordovician(Sylvan Shale)
Osv	Ordovician(Sylvan Shale, "Fernvale" Ls., and Viola Ls.
Ov	Ordovician("Fernvale" Ls. and Viola Ls.
Oss	Ordovician(Simpson Group)
O€	Cambrian-Ordovician(Arbuckle Group and Timbered Hills Group)
m€	Early-Middle Cambrian(rhyolite, granite, gabbro, basalt, and meta-graywacke)
p€	Precambrian(granite)

Figure 9--Geologic Map of Pre-Woodford rocks in south-central Oklahoma.

PALEOECOLOGY

Historical Review

The origin and environment of deposition of the Woodford Formation and/or its lateral lithologic equivalents have long been a question of debate. Several authors discuss in detail a possible shallow water origin for such a formation as the Woodford by postulating that 1) it is a residual soil of an ancient peneplain that was reworked by a transgressing sea (Grabau, 1906), 2) neither deep water nor restricted basins are prerequisites for its deposition because of local occurrences of thin coal seams in the Chattanooga (compared to much thicker development of coal in Pennsylvanian black shales) and negative evidence of physical barriers for the Devonian-Mississippian black shale depositing seas (Ulrich, 1911), 3) this deposit may be similar to those black muds of the shallow water swamp deposits in the eastern part of the Baltic Sea (Twenhofel, 1915) and that its extensiveness may be indicative of a shallow epicontinental sea of such lateral extent and with connections to the open sea of such character as to render the epicontinental sea nearly tideless, thereby limiting circulation and wave action because of salt-water benthonic plant growth (Twenhofel, 1939), and 4) it may have originated in deeper quiet water of the littoral zone (Ruedemann, 1934). Campbell (1946), in his detailed study of the New Albany Shale, concluded that outstanding features of the New Albany are "the wide distribution of the type section and the stable conditions and life environment over long periods of time" and the black shale facies of the New Albany was due to the withdrawal of surplus argillaceous elements (in an area previously stated to be covered by shallow water interrupted by shoals and probable small land masses). Fisher (1953), in a study of the Chattanooga-Kinderhook Shale, concludes that the formation was deposited in a shallow epieric sea.

Other authors favor a deep water origin for such a black shale deposit and postulate that 1) such sediments may be accumulating in such places as the Sargasso sea (Schuchert, 1910), 2) such sediments are deposited below effective wave base in a deep basin because fine laminations such as those present in the Devonian-Mississippian black shale could not have formed at depths where they would be affected by wave action (Rich, 1951), and 3) to effect a reducing environment and such a thickness (600+') of fine laminated sediment not disturbed by wave action, water depths of 1200 feet are required (Ellison, 1950).

Hallam (1967) discusses the depth significance of shales with bituminous laminae and, in respect to the relation of phytoplankton and plant material to such sediments, states that: 1) phytoplankton productivity is appreciably greater in continental shelf waters, where nutrients are more abundant, relative to open seas; 2) phytoplankton and fragments of benthonic algae are most important in surface layers of the ocean; and 3) most plant material in suspension is oxidized in the water or by benthonic fauna and very little is incorporated in the bottom sediment. Hallam (<u>ibid</u>.) further equates the environment of deposition of the Chattanooga and equivalent shales to that of the European Jurassic in that these sediments are interpreted to have been deposited in a shallow sea containing an abundance of vegetable matter in a coastal area subjected to a warm, humid climate, and rapid oxidization, but favoring stagnation where there was a minimum amount of water circulation.

Cross and Hoskins (1951b) report <u>Callixylon</u> <u>Newberryi</u> logs, exceedingly delicate plant remains lacking leaves, algal remains (<u>Foerstia</u>), highly waxy or resinous spore coats and sporangia in the New Albany-Ohio Black Shale. Remains of such a great and varied flora in which leaves are totally lacking may be indicative that the fragments are far from their source; however, the presence of such resistant organic material as the algal remains, highly waxy or resinous spore coats and sporangia, and the absence of delicate plant remains (leaves) is suggestive that foul bottom conditions in the black shale environment were not conducive to the preservation of most land plants (Cross and Hoskins (ibid.)).

Staplin (1961) conducted a reef proximity study utilizing the Upper Devonian microplankton of the Leduc reef complex of Alberta, Canada, and his conclusions pertaining to these microplankton are discussed on page 115. No mention is made as to water depth, salinity, or temperature but the reef and off-reef sediments are postulated to have been deposited in a transgressive sea.

Although the Woodford Formation is a marine deposit, it has many characteristics in common with the fresh water Eocene Green River Shale of the Central Rocky Mountains (e.g., high concentration of organic material, organic material predominantly composed of detrital plant remains of unknown origin and land plant spores, high concentration of pyrite, fine laminations, scarcity of invertebrate fossils possessing calcareous skeletons, difficult to disaggregate by chemical processes utilized in palynology). The detailed study of the Green River Shale, and the comparison of its postulated environment of deposition with the environment of deposition in extant fresh-water lakes in the subtropics and tropics of the United States and Africa (Bradley, 1966) may be of value in the interpretation of the environment of deposition of the Woodford Formation. The extant fresh-water lakes, studied by Bradley (ibid.), have the following conditions that may be significant in the interpretation of the environment of deposition of the Woodford Formation: 1) water depths from 2 to 30 feet, 2) 1 to 3 feet of coprolitic algal ooze, containing some viable algae, plant spores and plant detritus that have accumulated as a deposit having a light flocculent consistency on the lake bottoms, 3) a paucity of invertebrates because of the foul bottom conditions, and consistency and apparent indigestibility of the algae, 4) a carbonate source area of low relief with vegetation along the shore that filters out the coarse clastic material and 5) decomposition of organic matter with depth at a very slow rate because 3 feet below the sediment-water interface coprolitic structure and cell walls of blue-green algae remain sharply defined.

Korde (1962), in a study of the Russian sapropels of Quaternary age that were deposited in fresh-water lakes averaging less than 50 feet in depth, has found that blue-green algae and protococcales are predominant when the climate is warm and circulation is poor.

Spackman, Dolsen and Riegel (1966) conducted a study of the phytogenic sediments and sedimentary environments of extreme southwestern Florida. Field observations, core analyses, palynological data and the results of trace elements provided strong evidence for transgression throughout the past 4,000 to 5,000 years with an accelerated transgressive period or a continual land subsidence from about 2,500 years ago to the present time. The sea in this area has been transgressing over the essentially horizontal Floridian Plateau. The coast line during this transgression, and at the present time, supports relatively simple plant communities predominantly composed of red and black mangrove trees. This vegetation is growing on the Miocene Tamiaimi Formation (a calcareous sandstone or sandy limestone containing beds and pockets of quartz sand) and the Pleistocene Miami Oolite (a relatively pure to sandy limestone containing steeply dipping cross-bedded units that are sometimes truncated by shelly layers while in other areas it is massive and oolitic).

Upshaw (1964) discusses the environmental significance of palynomorphs and states that the numbers of spores and pollen grains decrease in number as distance from shore increases in a marine environment, because the actual numbers deposited in a given environment are related to their source, except under unusual circumstances. Hystrichosphaerids, some of which are now classified as acritarchs (Evitt, 1961), seem to be more abundant in water of intermediate depth and decrease in number in deeper and shallower waters (Sarimiento, 1957). They are not found in sediments known to have been deposited in water whose salinity was significantly below that of normal marine (Upshaw, 1964), (from Klement, personal communication). Abundance ratios between land plant spores and acritarchs thus provide a quantitive means of estimating the relative distance from shore of selected sedimentary samples and cycles of sedimentation can be postulated (Upshaw, 1964) in a sequence of sediments that are relatively lithologically homogeneous.

Discussion

The Woodford Formation is relatively homogeneous in respect to lithology in the area of study. Fresh surfaces of samples collected from the outcrop and observed as well cuttings or cores from the subsurface are brown to black and some beds are quite siliceous. Weathered surfaces of the shale observed at outcrops during the course of the field work vary in color (e.g., black, brown, reddish-brown, yellow-brown, green, white). The lateral extent of this shale facies varies, but has been observed in cuttings from wells drilled in west central

Oklahoma and from wells and outcrops in the area of study. Evidence that the shale facies is present in some areas in the subsurface between west central Oklahoma and the area of study is the cuttings and cores from several wells between the two areas that were examined and found to contain the same type of shale. The shale facies may have been quite extensive, but should not be interpreted as contemporaneous deposits throughout its entire lateral extent. Studies of the megaflora (Cross and Hoskins, 1951a, 1951b; Hoskins and Cross, 1952), conodonts (Hass, 1951, 1956a, 1956b; Roen, Miller and Huddle, 1964; Hass and Huddle, 1965) and palynomorphs (McGregor and Owens, 1966; Winslow, 1962) of the shale in different regions indicate that the black shale facies is not necessarily time equivalent from region to region, and that two different facies may be time equivalent in the same area, two different areas, or two different regions.

The relative lithologic homogeneity of the Woodford Formation may be indicative of a similar environment during most of its deposition with respect to water depth, rock type comprising the source area, elevation of the source area, available organic material, presence of reducing conditions at the locus of deposition and distance from shore of the locus of deposition.

The following observations were made while in the field collecting samples and during examination of the organic residues for palynomorph content, and will be discussed prior to postulating an environment of deposition for the Woodford Formation in the area of study.

1. The Bois d'Arc Limestone of Early Devonian (Ulsterian) age is the youngest and most continuous formation directly underlying the Woodford Formation.

2. The contact between the Woodford Formation and the underlying

Bois d'Arc Limestone appears to be disconformable.

3. Portions of silicified logs of Callixylon were observed in place and parallel to the bedding in the lower part of the Woodford Formation (Figure 1, Locality 2, page 2), and a specimen was found lying on the outcrop in a tributary of Hickory Creek near the base of the Woodford Formation (Figure 1, Locality 1, page 2).

4. The Woodford Formation is predominantly composed of organic material with varying amounts of silica, pyrite, and clay.

5. The lithology of the Woodford Formation is relatively homogeneous. The formation becomes thin-bedded to fissile and contains abundant phosphate concretions in the upper 71 feet. A few phosphate concretions and thin, glauconitic shale units were noted in the basal 10 feet of the formation. Rounded quartz grains and glauconite were observed in the "Woodford(?) Brown Carbonate" at one locality (Figure 1, Locality 7, page 2).

6. Palynomorph assemblages obtained from samples utilized in this study vary in respect to the types palynomorphs present. Some residues contain abundant spores and acritarchs possessing processes or membranes, while other residues contain abundant acritarchs of the Subgroup Sphaeromorphitae (leiospheres), some Tasmanititae (Tasmanites) and unidentifiable organic detritus.

The presence of the Bois d'Arc Limestone and its disconformable relationship with the overlying Woodford Formation can be interpreted in two ways:

1. At the end of the Ulsterian Epoch the area of study was broadly uplifted to sea level or slightly higher and during the Erian Epoch no deposition and very little erosion occurred, although faulting occurred in local areas and strata were uplifted to the extent that subsequent

erosion exposed Ordovician Age strata by the end of the Middle Devonian Epoch which is illustrated by the strata that locally underlie the Woodford (Figure 9, page 135) or,

2. Sediments of Middle Devonian Age were deposited, the area was then broadly uplifted at the end of the epoch, eroded down to the Early Devonian Bois d'Arc Limestone, and faulting occurred locally as stated in interpretation 1. The first interpretation is believed applicable to the area of study because of the absence of Middle Devonian strata in southern Oklahoma (Amsden, 1960; Amsden and Rowland, 1967) which certainly should be present in several areas if they had been deposited.

The presence of portions of silicified Callixylon logs in the basal 10 feet of the Woodford may indicate that their source was nearer than during deposition of the remaining part of the formation. The total lack of soils below the Woodford, absence of leaf materials in the Woodford and water worn character and orientation of the Callixylon logs are evidence that Callixylon did not grow in the immediate area but may have been transported some distance from its native habitat as is suggested by Hoskins and Cross (1952). The silica filled joint-like cracks both normal and parallel to the direction of growth that were observed in specimens of Callixylon are probably indicative of successive wetting and drying of the logs, which terminated in shrinking and cracking preburial (modified from Hoskins and Cross, 1951b). Callixylon log fragments are more numerous in the southwestern part of the area of study (Figure 1, Locality 2, page 2) than in other areas of outcrop to the north and northeast (Figure 1, Localities 1 and 3 respectively, page 2). Their abundance in the southwestern part of the area is suggestive that they were derived from a southern source rather than Ozarkia, the nearest known land mass, several hundred miles north of the area. Evidence favoring a possible southern source for the logs is the Ordovician strata that directly underlie the Woodford Formation in Marshall County, portions of adjacent counties, and possibly extending southeast (now covered by younger Ouachita strata) into Texas (Figure 9, page 135). The area(s) where Ordovician strata directly underlie the Woodford Formation was structurally and topographically high prior to deposition of the Woodford. The area may have been an island in the sea such as the island in the New Albany sea postulated by Hoskins and Cross (1952), or a more extensive land mass south of the area of study. Either of these postulated land areas could have been the habitat of Callixylon. The rounded quartz grains in the "Woodford(?) Brown Carbonate," which is interbedded with and subjacent to the basal Woodford in the Texas Company #1 Gipson well (Figure 1, Locality 7, page 2), may be the remains of a soil that developed before the Woodford sea slowly transgressed over the area of study and winnowed and dispersed the clays and humis into the broad, shallow sea. The water worn character of the logs is suggestive that they were transported great distances, possibly from Ozarkia, but their distribution (i.e., more numerous in the southwestern part of the area of study) seems to preclude a northern source. Assuming that the source of the logs was from a land area within and/or adjacent to the southern part of the area of study, their concentration must then be explained as being marginal to their native habitat. If the southern source is accepted then the logs were not transported a great distance although they still appear to be water worn. A reasonable explanation for their water worn appearance could be:

> "A log floating back and forth over a small area would be as water worn as another log which had traveled a great

distance, so long as the interval of time in the water is the same for both." (Fisher, 1953)

The composition of the Woodford Formation (predominantly organic material, with varying amounts of silica, pyrite and clay) may be indicative of a provenance, and water depth at the depositional site, similar to the provenance and water depth of the lakes discussed by Bradley (1966), although the Woodford is definitely marine because of the abundance of acritarchs it contains. The acritarchs may be marine algae and possibly the marine counterparts of the algae reported by Korde (1962); therefore, they could be indicative of a warm climate and poor circulation at the locus of deposition. Abundant organic material and pyrite in the Woodford Formation also indicate poor circulation. The widespread distribution of the black shale in the area of study favors the postulation of a laterally extensive sea of relatively constant water depth.

Phosphate concretions and glauconitic shale in the basal part of the Woodford Formation, abundant phosphate concretions in fissile shale units in the upper 71 feet of the formation, and the absence of coarse clastics in the formation are indicative of a restricted and slow influx of clastic material and extended periods of time when sedimentation was very slow (Cross and Hoskins, 1951b; Krumbein and Sloss, 1956).

Palynomorphs vary in type and abundance in the Woodford Formation. Acritarchs are present in all organic residues examined in this study. In some residues leiospheres constitute 100% of the palynomorphs. They are considered to be marine (Staplin, 1961). These leiospheres are discussed on page 115. Their distribution was probably controlled by ocean currents. Acritarchs possessing processes or membranes are present in some sample residues, but in the majority they are a minor constituent.

Microspores are also present in some of the residues examined in this study. The microspores are of various types (i.e., simple, small, circular with thin exines; simple, small, circular with thick exines; simple, large, circular with thin exines; simple, large, circular with thick exines; small with various external exinal ornamentation; large with various external exinal ornamentation; small, perisporate; large, perisporate), and occur randomly in individual sample residues. Based on their random occurrence, they probably were not greatly affected by winnowing and could have been transported to the depositional site by wind and/or streams. These microspores do appear to have undergone oxidation or some type of degradation in sample residues containing abundant, large leiospheres as many are degraded to the extent that they cannot be identified to genus in residues from the California Oil Company #1 Mullen, Texas Company #1-K Drummond and a portion of the Hickory Creek section. Microspore/acritarch ratios are interpreted to indicate minor transgressive-regressive cyclic marine sedimentation similar to some of the cyclic sedimentation described by Upshaw (1964) and discussed in the Environmental Zonation section of this study.

The occurrence of acritarchs possessing processes or membranes does appear to be related to the occurrence of microspores as these acritarchs are more abundant in residues containing microspores (e.g., Table 1a and 1e, page 122). Ecologically this relationship between microspores and acritarchs possessing processes or membranes may be indicative of the possibility 1) that nutrient supply was more abundant and/or water salinity was such that the environment during deposition of the Microspore-Acritarch biofacies was conducive to support growth and reproduction of acritarchs possessing processes or membranes, and that this was not the situation at the locus of deposition of sediments in the Leiosphere Zone, or 2) that the environment at the locus of deposition of sediments in the Microspore-Acritarch Zone was conducive to the preservation of the acritarchs possessing processes or membranes and that this was not the situation at the locus of deposition of sediments in the Leiosphere Zone. The presence of acritarchs possessing processes or membranes in very scarce numbers and their well-preserved condition in the Leiosphere Zone of sediments lends support to the first postulation.

If leiospheres were dispersed by ocean currents, their constant predominance in all the Woodford Formation residues analyzed in this study is evidence that the Woodford sea was subjected to current action, no matter how slight. The constant predominance of leiospheres and the constant predominance of the same type of unidentifiable organic detritus in this relatively lithologically homogeneous formation is suggestive of the presence of a similar environment during most of its deposition. However, the occurrence of phosphate nodules; blocky, siliceous, organic-rich units interbedded with organic-rich, fissile shale units; absence of coarse clastic material; an increase in the number of microspores; an increase in the number of acritarchs possessing processes or membranes; an increase in the number of leiospheres less than 50 microns in diameter and a decrease in the number of leiospheres larger than 50 microns in diameter in the upper part of the formation (Figure 4, page 9) may be indicative of a near shore, shoal area that prevailed for quite some time. The abundance of acritarchs possessing processes or membranes is suggestive that the area was 5 miles or farther offshore where low energy conditions probably prevailed (Staplin, 1961). Current action was ineffective to the extent that few leiospheres larger than 50 microns in diameter were carried into the area.

An anomalous physical or biological condition must have existed to effect deposition of such a thick, laterally extensive formation as the Woodford. This physical or biological condition must have been in the form of a type of barrier because reducing conditions must have been present throughout the area of study to effect the abundant well-preserved palynomorphs, organic detritus and pyrite in every sample. The unidentifiable organic detritus is evidence that organisms, probably planktonic and/or benthonic marine plants, were present in the area of study throughout Woodford deposition. These plants may have been similar to Sargassum, and extant genus of the Phaeophyta. A concentration of such plants farther than 10 miles from shore on a broad, shallow continental shelf or in a shallow epicontinental sea could form such a barrier. This type of barrier in a shallow sea would effect poor circulation and reducing conditions both within the area where it was present and within the area between it and the adjacent land mass. Nutrients transported to the sea by streams from the adjacent land mass would furnish an abundant amount of food for phytoplankton, possibly acritarchs possessing processes or membranes. Microspores would also be transported into these coastal marine areas by streams and/or wind. The seaward decrease of nutrients would account for a corresponding seaward decrease in certain types of phytoplankton, possibly acritarchs possessing processes or membranes. A corresponding decrease in microspores would occur because the distance from their source is increasing (Upshaw, 1964).

Conclusions

The following environment of deposition for the Woodford Formation in the area of study is postulated utilizing field observations, lithologic examinations and palynological analyses, all of which were made during the course of this study. In addition, interpretations of other geologists, paleobotanists and palynologists, pertaining to environments of deposition of black shales and environment of occurrences of megaflora and palynomorphs in these types of sediments, are utilized in these conclusions.

The locus of deposition of the formation was probably a broad shallow continental shelf, or shallow epicontinental sea that may have been restricted in the sense that it was 1) bounded on each side by relatively flat, low-lying land masses (i.e., the craton to the north and Llanoria to the south and southeast), or 2) bounded on the north side by the relatively flat, low-lying craton and restricted within itself and to the south and southeast by concentrated masses of *Sargassum*-type algae. The presence of plants of this type, whether forming a barrier or being concentrated in the broad shallow depositional area, probably effected an extensive linear brackish to marine environment along the shoreline. The concentration of algae reduced major tidal changes and turbulence, caused by wave action, to a minimum. There were undoubtedly climatic changes during Late Devonian and Early Mississippian time because of the growth rings observed in the *Callixylon* specimens. These climatic changes may have been subtle and the climate may have been subtropical to warm-temperate. There was probably very little water circulation that influenced deposition. A condition toxic to land plant spore preservation and probably lacking enough nutrients to sustain and/or support the growth and/or reproduction of acritarchs possessing processes or membranes also must have been present within the areas of algal concentration because these palynomorphs are rare to absent in the Leiosphere Zone of the Woodford Formation. Evidence that reducing conditions were prevalent during deposition of the formation is the abundant well-preserved organic material, palynomorphs and pyrite present in all samples in the area of study. *Callixylon*, the only megafloral element observed during the course of this study, was never observed in an upright growth position, but as fragments of the bole parallel to the shale laminae. All *Callixylon* specimens were observed in the lower part of the Woodford Formation which is postulated to have been deposited near shore, in a transgressive sea. The genus may have lived along the shore in a habitat similar to the mangroves of southwestern Florida. The area of deposition could have been similar to, but more extensive than, the Floridian Plateau as discussed by Spackman, Dolson and Riegel (1966).

COMPOSITION AND AGE OF ASSEMBLAGES

General Statement

Amsden, Klapper and Ormiston (1968) suggest a Late Devonian age for the "Woodford(?) Brown Carbonate" that is present at the base of the Woodford Formation in the Texas Company #1 Gipson well, Marshall County, Oklahoma. The age assignment is apparently based on the stratigraphic position of the unit and the fact that the upper part of the unit is interbedded with black Woodford Shale (*ibid*.).

The Woodford Formation in southern Oklahoma has been dated as Mississippian and/or Devonian in age. The age identifications are based on its stratigraphic position (superjacent to the Hunton Group of Silurian-Devonian age and subjacent to the Sycamore Formation of Mississippian age). Some current workers (Urban, 1960; Wilson and Urban, 1963; Wilson and Skvarla, 1967) reported the formation to be Devonian age. Hass and Huddle (1965) studied Woodford conodont assemblages from several areas in southern Oklahoma and reported that the upper part of the formation (generally 1 foot, but in some areas at least 10 feet) is of Mississippian (Kinderhookian) age. A significant section, sampled and analyzed by Hass and Huddle (1965) was from Henryhouse Creek (Figure H, page 2). Kinderhookian conodonts were found 211 feet to 212 feet above the base of the formation, which is 9 feet to 10 feet below the top of the exposure, and a covered interval of unreported thickness was present at the top of the exposure (Hass and Huddle, 1965). No other fossils that are significant in age identification have been reported from the formation in southern Oklahoma except for the palynomorphs reported by Urban (1960) who briefly discusses the age and assigns the formation to the Devonian Period. The previously discussed age division of the Woodford Formation does not necessarily compare with the age division of these black shales in other areas, the age of which is discussed by Cross and Hoskins (1951a).

Microspores are not well-preserved in all samples of any section included in this study. Those microspores observed in sample residues from the California Oil Company #1 Mullen, Carter County and the Texas Company #1-K Drummond, Marshall County are so scarce and poorly preserved that their identification to genus and even group is questionable. The poor preservation could be caused by differential preservation in bottom sediments during deposition. Also, many of these palynomorphs probably passed through the alimentary canal of various organisms before they became incorporated in the sediments. The paucity of recognizable palynomorphs, other than leiospheres, in the sample residues from the #1 Mullen and the #1-K Drummond preclude their utilization in attempting to identify the age of the formation.

"Woodford(?) Brown Carbonate"

Microspore Assemblage. Thirty-five species were identified in residues of core chips from the Texas Company #1 Gipson well (Table 7, page 169). Thirteen species, previously reported from Early and/or Middle Devonian age strata of other regions, are present in various samples from the lower 78 feet of the unit (below sample Pb5137). Rhabdosporites langi (Eisenack, 1944) Richardson, 1960 (see Plate 11, Figures 1 and 2) and Retusotriletes dubius (Eisenack, 1944) Richardson, 1965 (see Plate 2, Figure 1) have been reported from probable Middle Devonian strata by Eisenack in 1944 (in Richardson, 1960, 1965); subsequently, from Middle Devonian strata of England by Richardson (ibid.) and Upper Middle Devonian? (Givetian ?) strata of Canada by McGregor and Owens (1966). Retusotriletes tenerimeduim Chibrikova, 1959 (see Plate 1, Figures 5 and 8) has been reported from

Middle Devonian strata of Russian (Chibrikova, 1959) and Upper Lower? to Middle Devonian strata of Australia (de Jersey, 1966). Species of *Emphanisporites* McGregor, 1961 (see Plate 5, Figures 6 through 12) are indicative of an Early to Middle Devonian age when they occur in abundance (McGregor, personal communication, 1967). *Bullatisporites bullatus* Allen, 1965 (see Plate 4, Figures 5 and 6) has been recorded from Lower and Middle Devonian strata of Spitsbergen (Allen, 1965). *Ancyrospora ancyrea* Richardson, 1962 (see Plate 11, Figure 8) has been reported from Upper Lower Devonian strata of Canada (McGregor and Owens, 1966) and Middle Devonian strata of Canada (*ibid*.) and England (Richardson, 1962). *Rhabdosporites scamnus* Allen, 1965 (see Plate 11, Figures 3 and 6) has been reported from Middle Devonian strata of Spitsbergen (Allen, 1965). Specimens of cf. *Dibolisporites echinaceus* (Eisenack, 1944) Richardson, 1965 (see Plate 4, Figures 7, 8 and 9) and ? *Dibolisporites* sp. (see Plate 5, Figures 1, 2 and 3) may be conspecific with *D. echinaceus* (Eisenack, 1944) Richardson, 1965 that has been reported from probable Middle Devonian strata by Eisenack (in Richardson, 1960, 1962), from Middle Devonian strata of England (*ibid*., 1965) and from Lower and Middle? Devonian strata of Canada by McGregor and Owens (1966). *Ancyrospora* cf. *A. parva* de Jersey, 1966 (see Plate 11, Figures 9, 10 and 11) may be conspecific with *A. parva* de Jersey, 1966 that has been reported from Middle Devonian strata of Australia by de Jersey (1966). *Geminospora lemurata* Balme, 1960 (see Plate 10, Figures 7 and 8) has been reported from Late Middle Devonian age strata of Australia (de Jersey, 1966), but is more abundant in Late Devonian (Frasnian; Senecan) age strata and its abundance can be utilized to differentiate between Late Middle and Late Devonian age strata (Balme, 1960; de Jersey, 1966).

The presence of *G. lemurata* Balme, 1960 in samples Pb5132 and Pb5135 is suggestive that the section at least 55 feet above the base of the unit is Upper Devonian in age, although the residues still contain definite Middle Devonian elements. The gradual change in lithology from brown, dolomitic, glauconitic shale containing quartz sand stringers upward into brown to black, blocky, siliceous, pyritic shale is suggestive of a change in the environment at the depositional site and probably in the source area. The change from microspores that are restricted to Early and/or Middle Devonian age strata to those of Late Middle to Late Devonian age strata between samples Pb5132 and Pb5137 (45 feet to 78 feet above the base of the unit) is suggestive that the boundary between Middle and Late Devonian age strata is within this 33-foot interval (see Table 7, page 169). The gradual change in lithology is also suggestive that the boundary is transitional and not a distinct, sharp boundary.

Apiculiretusospora, described as a new genus, was observed in the lower 78 feet of the unit. Perotrilites spinosus (see Plate 6, Figures 10 and 11 and Plate 7, Figures 1-3 and 6) and Apiculiretusospora sp. (see Plate 11, Figures 4, 5 and 7), described as new species, were observed in the lower 78 feet of the unit. Perotrilites sp. C (see Plate 7, Figures 4 and 5), P. sp. E (see Plate 8, Figures 1-7) and Cingulizonates sp. B (see Plate 9, Figures 4, 5, 7, 8 and 10) are also described and discussed, and were observed in the lower 78 feet of the unit.

The section overlying the Lower Devonian Bois d'Arc Limestone in the Carter #1 King well has been called the Woodford Formation by geologists in the petroleum industry. Seven species were identified in the samples analyzed from this well (Table 7, page 169). No microspores previously reported to be restricted to Lower and/or Middle Devonian strata were observed in the shale. Forty-nine feet above the base of the shale, in sample Pb5145, is a waxy, green shale unit that is 5 feet thick. Below the green shale the section is dolomitic, and becomes glauconitic 14 feet above the base of the shale section (below sample Pb5147). In sample Pb5149, in the top of the Bois d'Arc Limestone, are specimens of *Emphanisporites annulatus* McGregor, 1961 (see Plate 5, Figures 8 and 9). The presence of species of this genus, when common, is suggestive that the sediment containing them is Early or Middle Devonian in age (McGregor, 1967, personal communication). The absence of spores restricted to strata no younger than Middle Devonian, plus paleontological dating of the Bois d'Arc Limestone (Amsden, 1960) is evidence of an Early Devonian age for sample Pb5149. *Geminospora lemurata*? Balme, 1960 (see Plate 10, Figures 7 and 8) is present in samples Pb5148 and Pb5147 (14 feet to 39 feet above the base of the shale). The presence of *G. lemurata* Balme, 1960, as discussed in the Texas Company #1 Gipson well, is indicative of Late Middle to Late Devonian age. The occurrence of *G. lemurata*? Balme, 1960 in sample Pb5148, 14 feet above the top of the Bois d'Arc Limestone, and the presence of *Emphanisporites annulatus* McGregor, 1961 in the top of the Bois d'Arc Limestone (sample Pb5149) and its absence in the overlying shale section, is suggestive that the flora in the source area had changed after deposition of the limestone and prior to deposition of the overlying shale. The presence of *Geminospora lemurata*? Balme, 1960 is evidence of a Late Middle or Late Devonian age for the section above sample Pb5148. The absence of quartz sand stringers in the #1 King well may be related to the absence, in this well, of the variety of 12 Lower and/or Middle Devonian microspore species that are present in the #1 Gipson well, only in the respect that the #1 Gipson well was located nearer shore and many more microspores were transported to the depositional site and were preserved.

Acritarch Assemblage. Twenty-eight species were identified in the Texas Company #1 Gipson well (Table 7, page 169). Ten of these species have been reported previously from other areas, and 2 of these species, Lophodiacrodium pepino Cramer, 1964 (see Plate 14, Figures 4-7 and 11) and Maranhites brasiliensis Brito, 1965 (see Plate 19, Figures 1, 2 and 4), appear to be significant in time zonation and correlation between the section analyzed in this well, the section analyzed in the Carter #1 King well and the Texas Company #1-K Drummond well. Lophodiacrodium pepino Cramer, 1964 is present in sample Pb5137, in the Texas Company #1 Gipson well, which is 78 feet above the base of the unit. Sample Pb5137 is the first sample above those that contain microspores not reported from strata younger than Middle Devonian. This sample, collected from the core at a point marked 4043 feet (-3334 feet below sea level) is from the basal Woodford based on electrical log correlations. This point is correlative with 3445 feet (-2726 feet below sea level) in the Texas Company #1-K Drummond well (Figure 10, page 158). Maranhites brasiliensis Brito, 1965 is present in samples Pb5135, Pb5136 and Pb5138, from 63 feet to 92 feet above the base of the unit. Although the interval in which M. brasiliensis Brito, 1965 was observed is thicker than the interval containing Lophodiacrodium pepino Cramer, 1964, its occurrence is restricted within the unit.

Radisphaeridium is described as a new genus and was observed in the upper 71 feet of the unit. Radisphaeridium radiatus (see Plate 18, Figure 11), Quisquilites constrictus (see Plate 13, Figures 11 and 12) and Cymatiosphaera crossi (see Plate 14, Figures 12-15) are described as new species. Furcasphaeridium sprucegrovensis (Staplin, 1961) (see Plate 12, Figures 5, 6 and 8) is proposed as a new combination. Acritarch Genus A, sp. A, (see Plate 19, Figures 6, 7 and 11), Genus B, sp. A (see Plate 19, Figures 8-10), Furcasphaeridium sp. (see Plate 12, Figures 7 and 9), Leiosphaeridia sp. (see Plate 13, Figures 7 and 8), Cymatiosphaera sp. A (see Plate 12, Figures 8-10), C. sp. B (see Plate 12, Figures 2 and 3), C. sp. C (see Plate 15, Figures 4-6), Duvernaysphaera sp. A (see Plate 15, figures 9 and 13), D. sp. B (see Plate 15, Figures 10-12), Tasmanites sp. B (see Plate 17, Figures 7 and 8), T. sp. C (see Plate 18, Figures 1-7) and and Onondagella sp. (see Plate 18, Figures 9 and 10) are described and discussed. Pterospermopsis cf. harti Sarjeant, 1960 (see Plate 16, Figures 1 and 2) is also described and compared with P. harti Sarjeant, 1960.

Twenty-one species were identified in sample residues from the Carter #1 King well (Table 7, page 169). Nine of these species have been reported previously by other palynologists, of which Lophodiacrodium pepino Cramer, 1964 and Maranhites brasiliensis Brito, 1965 (see Plate 14, Figures 4, 7 and 11 and Plate 19, Figures 1, 2 and 4, respectively) are restricted to sample Pb5145 which is 44 feet to 49 feet above the base of the Woodford Formation. The sample interval to which these 2 acritarch species are restricted is significant in the respect that it appears to be time equivalent to the sample interval Pb5138 to Pb5135 in the Texas Company #1 Gipson well to which Maranhites brasiliensis Brito, 1965 is restricted, and is probably equivalent to the interval containing sample Pb5137 to which Lophodiacrodium pepino Cramer, 1964 is restricted. These acritarchs may be facies fossils because the lithology of the samples in which they occur in both the #1 King well and the #1 Gipson well is green, waxy shale. This unit, called the base of the Woodford, based on electric log characteristics, is correlative between the Carter #1 King well, the Texas Company #1 Gipson well and the Texas Company #1-K Drummond well (Figure 10, page 158).

Two acritarchs, Polyedrixium? sp. (see Plate 16, Figures 3-6) and Maranhites? sp. (see Plate 19, Figures 3 and 5), not observed in sample residues from any other localities, are present in the Carter #1 King well

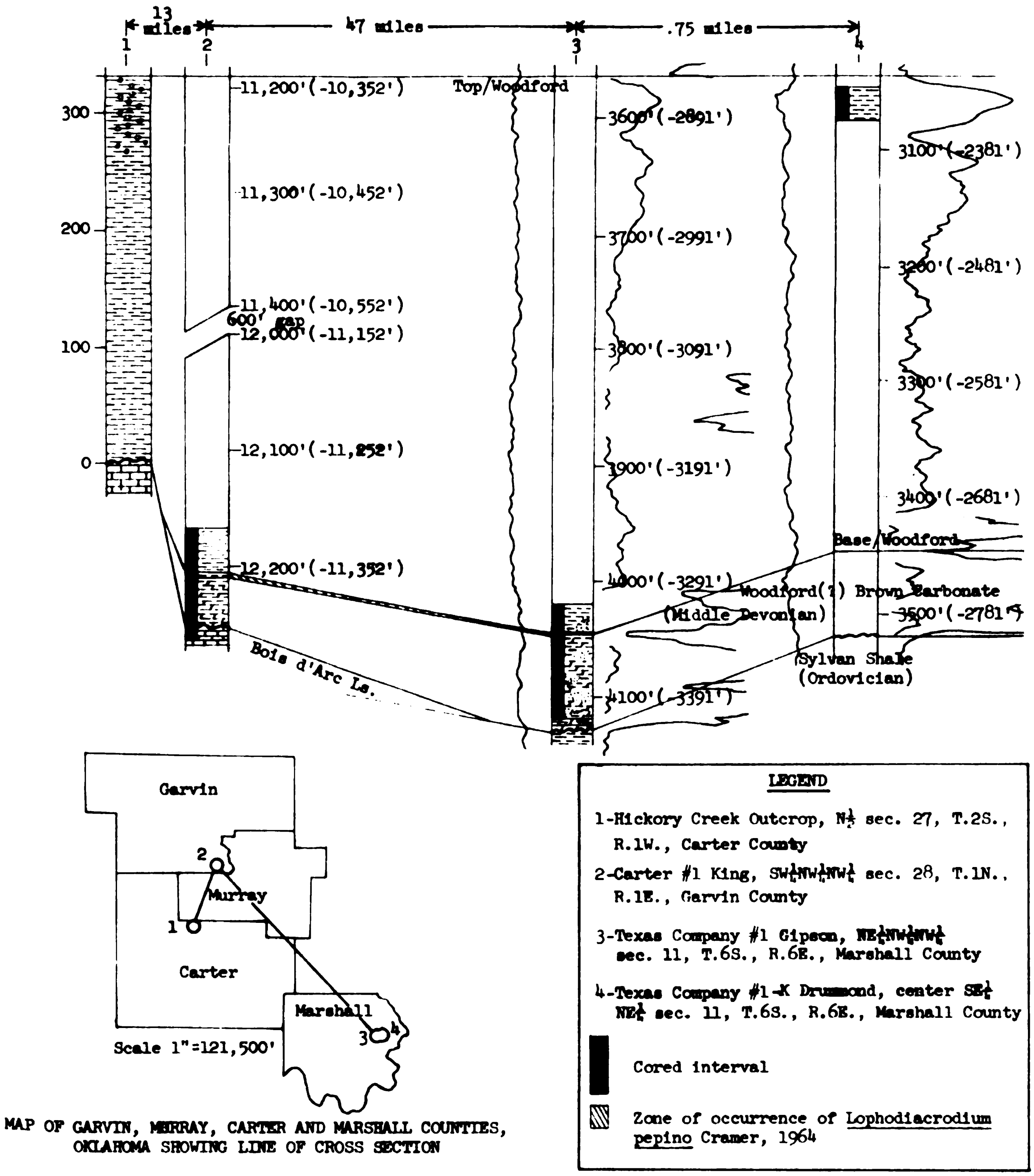


Figure 10--Stratigraphic cross section showing zone of occurrence of *Lophodiacrodium pepino* Cramer, 1964 in the Carter #1 King well, Garvin County and the Texas Company #1 Gipson well, Marshall County, and interpreted occurrence of the zone in the Texas Company #1-K Drummond well, Marshall County and absence of the zone in the Hickory Creek outcrop section, Carter County.

section. The following acritarch species, not described in available literature, are present in both the Texas Company #1 Gipson well section and in the Carter #1 King well section: Leiosphaeridia sp. (see Plate 13, Figures 7 and 8), Cymatiosphaera sp. A (see Plate 12, Figures 8-10), C. crossi sp. nov. (see Plate 14, Figures 12-15), C. sp. B (see Plate 12, Figures 2 and 3), C. sp. C (see Plate 15, Figures 4-6), Duvernaysphaera sp. B (see Plate 15, Figures 10-12), Radisphaeridium radiatus sp. nov. (see Plate 18, Figure 11), Genus A, sp. A (see Plate 19, Figures 6, 7 and 11) and Pterospermopsis cf. harti Sarjeant, 1960 (see Plate 16, Figures 1 and 2).

Additional Taxa. Genus A, sp. A (see Plate 20, Figures 5-8), of uncertain affinity, Radiolaria? sp. A (see Plate 20, Figures 1-4), Hoegisphaera scabiosa (Wilson and Hedlund, 1964) Wilson and Dolly, 1964 (see Plate 21, Figures 1-3) and Scolecodont Genus A, sp. A (see Plate 21, Figures 4 and 6) are present in both the Carter #1 King well and the Texas Company #1 Gipson well. Radiolaria? sp. A was observed in the same approximate interval as Lophodiacrodium pepino Cramer, 1964 and/or Maranhites brasiliensis Brito, 1965 and, therefore, is significant in correlation of the base of the Woodford Formation in these 2 wells. Ildraites sp. (see Plate 21, Figure 5) was observed only in the Texas Company #1 Gipson well.

Conclusions

The following conclusions may be drawn concerning the age of the "Woodford(?) Brown Carbonate" in the Texas Company #1 Gipson well and the basal dolomitic, glauconitic shale in the Carter #1 King well.

1. The "Woodford(?) Brown Carbonate" below sample Pb5137 in the #1 Gipson well is Middle Devonian in age because of the presence of microspores, restricted to Middle Devonian strata, in the assemblage.

2. Age of the dolomitic, glauconitic shale in the #1 King well below sample Pb5148 cannot be specifically identified and could be either Early or Middle Devonian in age, although the absence of palynomorphs restricted to Early Devonian age strata and the presence of palynomorphs that are also present in the Texas Company #1 Gipson is suggestive that it could be Middle Devonian in age.

3. Age identification of the shale in sample Pb5148 and above in the #1 King well is Middle to Late Devonian, based on the presence of questionably identified microspores that have been reported from Middle to Late Devonian age strata.

4. The presence of 2 acritarch species and one questionable radiolarian in a restricted interval in the #1 Gipson well and the #1 King well illustrate that these palynomorphs may be facies palynomorphs because the lithology of the interval in which they occur is the same in both wells, although the interval could also be a time equivalent unit in the area of study. This interval can be correlated with the Texas Company #1-K Drummond and identifies the base of the Woodford Formation in these wells, based on electrical log characteristics.

5. The age of the upper 26 feet of the section analyzed in the #1 Gipson well, and the upper 39 feet of the section analyzed in the #1 King well cannot definitely be identified, although the absence of definite Early and/or Middle Devonian palynomorphs in the upper part of these sections and the presence of a microspore species reported from only Late Middle and Late Devonian age strata in subjacent samples is evidence that these sections are Late Middle and possibly Late Devonian in age.

Woodford Formation

Microspore Assemblage. Thirty-five species were identified in samples from the Hickory Creek outcrop, Texas Company #1 Gipson well and Carter #1 King well from strata considered to be the Woodford Formation (Table 7, page 169).

Microspores present in the Lower Woodford are similar to, or conspecific with, species previously reported from Senecan age strata in other areas. The Middle Woodford was analyzed only from the outcrop section, except for 4 samples of possible Middle Woodford (based on interval thickness only) from the California Oil Company #1 Mullen which are not datable because they contain no microspores that can be positively identified and are significant in age identification. Microspores are scarce to absent in the Middle Woodford, possibly for reasons discussed on page 151. Those assemblages from both the Middle and Upper Woodford contain some species similar to, or conspecific with, species previously reported from Chautauquan-Bradfordian, transitional Devonian-Mississippian and Early Mississippian age strata of other areas. Other species that are significant in age identification, and particularly those utilized in establishing separate microspore suites and probably botanical provinces (Sullivan, 1967) and in defining concise geologic time divisions (Streel, 1967) were not observed in the Woodford assemblages. Some of these species, also reported by Winslow (1962) from Devonian-Mississippian strata of Ohio, were not observed in the Woodford assemblages.

The upper part of the cored interval in the Texas Company #1 Gipson (26 feet) and the Carter #1 King (39 feet) appear to be younger than subjacent strata as discussed in the conclusions as to the age of the "Woodford (?) Brown Carbonate" (page 159). Middle or Late Devonian age is evident because of the presence of Geminospora lemurata Balme, 1960 (see Plate 10, Figures 7, 8). This species, when present in abundance, is significant in identifying Senecan (Frasnian) age strata (Balme, 1960; de Jersey, 1967). The basal part of the Woodford in the outcrop section (samples Pb5102 through Pb5105) contains G. lemurata Balme, 1960, and is probably Senecan in age. Also the upper 26 feet of the cored interval in the #1 Gipson well and the upper 39 feet of the cored interval in the #1 King well, discussed on page 160, may be Senecan in age.

The few microspores identifiable in the Middle part of the Woodford from Hickory Creek do not appear similar to Chautauquan-Bradfordian or Devonian-Mississippian assemblages as recorded by Naumova (1953, Kedo (1957), Streel (1967) or Winslow (1962). A Bradfordian-Kinderhookian transitional aspect is illustrated by the presence of Retusotriletes incohatus? Sullivan, 1964 (see Plate 2, Figures 2, 3), Cyclogranisporites lasuis (Waltz, 1938) Playford, 1962 (see Plate 2, Figure 9), Anapiculatisporites cf. ampullaceus (Hacquebard, 1957) Playford, 1963 (see Plate 3, Figures 1, 2), Anapiculatisporites sp. (see Plate 3, Figures 3, 4), Perotrilites perinatus (Hughes and Playford, 1961) emend. (see Plate 6, Figures 8, 9), P. evanidus (Kedo, 1957) comb. nov. (see Plate 7, Figures 8, 9), P. luteolus (Naumova, 1953) comb. nov. (see Plate 7, Figure 7) and Remysporites? sp. (see Plate 10, Figure 10). Species reported by other palynologists to be present in transitional Devonian-Mississippian age strata such as Hymenozonotriletes lepidophytus Kedo, 1957, Dicrospora multifurcata Winslow, 1962, Vallatisporites vallatus Hacquebard, 1957 and Lophozonotriletes rarituberculatus (Luber, 1941) Kedo, 1957 were not observed in sample residues examined from the Middle Woodford. The apparent absence of the preceding species in the Woodford Formation in the area of study may be that the depositional site of these sediments was too far removed from the major land masses that were the habitat of the parent plants of these microspores. A depositional site such as this, during Middle Woodford time, is supported by the predominance of marine palynomorphs (especially leiospheres) in this part of the formation. Anapiculatisporites cf. ampullaceus (Hacquebard, 1957) Playford, 1963 and Anapiculatisporites sp. (see Plate 3, Figures 1, 2 and 3, 4 respectively) are the only well-preserved species present in the Middle Woodford sample residues. Another possibility for the absence of the other significant species is that disconformities within this formation, that would be very difficult to impossible to delineate, may represent enough time for erosion or nondeposition of a portion of the Senecan, part to all of the Chautauquan-Bradfordian, or part of the Lower Mississippian (Kinderhookian) sediments in the outcrop area of this study. Insufficient evidence for age identification of the Middle Woodford was obtained from sample residues, although the age is suspected to be Senecan or Chautauquan-Bradfordian.

The upper 25 feet of the Woodford is characterized by an assemblage that contains species reported from Lower Mississippian (Kinderhookian) and younger strata by other authors, but not reported from Devonian strata. Pustulatisporites gibberosus (Hacquebard, 1957) Playford, 1963 (see Plate 4, Figure 4), Perotrilites perinatus (Hughes and Playford, 1961) emend. (see Plate 6, Figures 8, 9), P. luteolus (Naumova, 1953) comb. nov. (see Plate 7, Figure 7), P. evanidus (Kedo, 1957) comb. nov. (see Plate 7, Figures 8, 9), Murospora subtera (Waltz, 1941) comb. nov. (see Plate 8, Figures 8, 11), Lophozonotriletes dentatus Hughes and Playford, 1961 (see Plate 8, Figures 9, 10), Discernisporites irregularis (Neves, 1958) emend. (see Plate 9, Figures 9, 11) and D. concentricus Neves, 1958 (see

Plate 10, Figures 1-3) are particularly abundant in Kinderhookian strata but are not present in Devonian strata. Based on the presence of the preceding species in samples Pb5117 and/or Pb5118, the upper 25 feet of the Woodford at the Hickory Creek outcrop appears to be Lower Mississippian (Kinderhookian) in age. The contact between Devonian and Mississippian strata is between samples Pb5116 and Pb5117, or possibly lower. Foot-by-foot sampling of the 25-foot interval of the Upper Woodford, plus palynologic analyses of these samples, may produce species such as *Hymenozonotriletes lepidophytus* Kedo, 1957, *Dicrospora multifurcata* Winslow, 1962, and *Vallatisporites vallatus* Hacquebard, 1957 (or *Lophozonotriletes rarituberculatus* (Luber, 1941) Kedo, 1957) at which time these species can be utilized to further delineate the Devonian-Mississippian contact and be of value in defining world distribution of the Kinderhookian age *Vallatisporites* and *Lophozonotriletes* suites as discussed by Sullivan (1967).

Retusotriletes sp. A (see Plate 2, Figure 7), *Cyclogranisporites* sp. A (see Plate 2, Figure 10), *Anapiculatisporites* sp. A (see Plate 3, Figures 3, 4), *Dictyotriletes* sp. (see Plate 5, Figures 4, 5), *Perotrilites* sp. D (see Plate 7, Figures 10, 11), *Discernisporites* sp. A (see Plate 10, Figures 4, 5) and *D*. sp. B (see Plate 10, Figure 6) were observed only in the Hickory Creek section. *Cyclogranisporites* sp. B (see Plate 2, Figure 12) and *Perotrilites* sp. A (see Plate 6, Figures 1-3, 6) were observed in Woodford residues from the Hickory Creek section, and Woodford and "Woodford(?) Brown Carbonate" residues from the Texas Company #1 Gipson well. *Perotrilites* sp. B (see Plate 6, Figures 4, 5, 7) and *Cingulizonates* sp. A (see Plate 9, Figures 3, 6) were observed in the "Woodford(?) Brown Carbonate" from the Texas Company #1 Gipson well and the Carter #1 King well and Woodford residues from the Hickory Creek section. Geminospora sp. A (see Plate 10, Figures 9, 11, 12) was observed in the basal 10 feet of the Woodford at Hickory Creek, present in one sample (Pb5135) of the "Woodford(?) Brown Carbonate" in the Texas Company #1 Gipson well and is questionably identified in samples Pb5147 and Pb5148 from the Carter #1 King well. The following microspores are either placed in affinity with, or questionably assigned to, previously described genera and/or species: Retusotriletes cf. nigritellus (Luber, 1941, 1945) Streel, 1967 (see Plate 1, Figures 2, 3), cf. R. nigratus (Naumova, 1953) Streel, 1967 (see Plate 2, Figure 6), Cyclogranisporites cf. Azonotriletes punctatus var. minutus Waltz, 1941 (see Plate 2, Figure 8), C. cf. commodus Playford, 1963 (see Plate 2, Figure 11) and Anapiculatisporites cf. ampullaceus (Hacquebard, 1957) Playford, 1963 (see Plate 3, Figure 1, 2).

Acritarch Assemblage. Twenty-nine species were identified in the Hickory Creek Outcrop, Texas Company #1 Gipson well and Carter #1 King well in strata considered to be the Woodford Formation (Table 7, page 169).

The most abundant acritarchs in the Woodford are Leiosphaeridia tenuissima Eisenack, 1958a (see Plate 13, Figures 3-6) and Leiosphaeridia sp. (see Plate 13, Figures 7, 8). Various species of Tasmanites Newton, 1875, are present in some samples of the Woodford. Quisquilites buckhornensis Wilson and Urban, 1963 (see Plate 14, Figures 1-3), reported from Upper Devonian strata (Wilson and Urban, 1963; Wilson and Skvarla, 1967), does not occur above sample Pb5105 (10 feet above the base of the Woodford) in the Hickory Creek Outcrop section but was observed in Upper Woodford strata in the Texas Company #1-K Drummond in sample Pb5122 (22 to 25 feet below the top of the Woodford, is present in the "Woodford(?) Brown Carbonate" in the Texas Company #1 Gipson well (Table 7, page 169) and has also been observed in the Stanley Shale, reported to be Mississippian age, in investigations other than this study. Radisphaeridium radiatus sp. nov. (see Plate 18, Figure 11) is present in most of the analyzed interval in the Texas Company #1 Gipson well (both Middle and Late? Devonian age strata), but was observed only in the upper part of the section (basal Woodford) in the Carter #1 King well, and in the basal part of the outcrop section (Table 7, page 169). Lophodiacrodium pepino Cramer, 1964, Maranhites brasiliensis Brito, 1965 and Radiolaria? sp., which are significant in identifying the base of the Woodford Formation in the #1 Gipson well and the #1 King well, were not observed in residues from the Hickory Creek section. If these palynomorphs are of time significance in the area of study and are not facies palynomorphs, their apparent absence in the Hickory Creek section, plus the presence of Geminospora lemurata Balme, 1960 in the basal Woodford at Hickory Creek, is suggestive that the basal Woodford at this locality is of a different age than in the #1 Gipson well and the #1 King well because the green shale that contains Lophodiacrodium pepino Cramer, 1964, Maranhites brasiliensis Brito, 1965 and Radiolaria? sp., and is significant in correlating the base of the Woodford in these 2 wells, is not present at Hickory Creek. Figure 10 (page 158) is a cross section that shows the occurrence of Lophodiacrodium pepino Cramer, 1964 in the green shale. Fourteen species of acritarchs possessing processes or membranes were observed in the Woodford Formation in the #1 Gipson well, the #1 King well and the Hickory Creek section (Table 7, page 169). In examining 4 residue slides of each sample from the Hickory Creek section only 5 of these species were observed. They are: Furcasphaeridium sprucegrovensis (Staplin, 1961) comb. nov. (see Plate 12, Figures 5, 6, 8), Veryhachium tolontolum Cramer, 1964 (see Plate 13, Figures 1, 2), Cymatiosphaera cubus? Deunff, 1961 (see Plate 15, Figure 1), C. sp. C (see Plate 15, Figures 4-6) and Duvernaysphaera sp. B (see Plate 15, Figures 10-12). In the Hickory Creek section, these acritarchs were observed in the basal part of the section (Microspore-Acritarch Zone or Microspore-Leiosphere Zone), middle part of the section (Microspore-Leiosphere Zone) and/or upper part of the section (Microspore-Acritarch Zone or Microspore-Leiosphere Zone) which is suggestive that they are of more value for environmental interpretation than for age identification.

Additional Taxa. The following taxa were also identified in Woodford Formation sample residues: Scolecodont Genus A, sp. A. (see Plate 21, Figures 4, 6), Radiolaria? sp. (see Plate 20, Figures 1-4), Hoegisphaera scabiosa (Wilson and Hedlund, 1964) Wilson and Dolly, 1964 (see Plate 21, Figures 1-3) and Genus A, sp. A of uncertain affinity (see Plate 20, Figures 5-8). These taxa may be characteristic of Middle and Late Devonian age strata and all may be indigenous to these strata except for the chitinozoan Hoegisphaera scabiosa (Wilson and Hedlund, 1964) Wilson and Dolly, 1964 which, because of its fragmented condition, was probably redeposited into these strata as it is indigenous to Ordovician strata (Hedlund, 1960; Wilson and Hedlund, 1964; Wilson and Dolly, 1964). Radiolaria? sp. is identified only in sample Pb5137 in the Texas Company #1 Gipson well and in samples Pb5143 and Pb5145 in the Carter #1 King well, and appears to be of value in correlating the base of the Woodford Formation in these wells as discussed on page 159. Genus A, sp. A, of uncertain affinity, was observed in most of the cored intervals in both the Texas Company #1 Gipson well and the Carter #1 King well, but is restricted to the basal 5 feet of the Woodford in the Hickory Creek outcrop section. The occurrence of this genus in strata identified as Middle and Late Devonian in the area of study is suggestive that its stratigraphic range may be restricted, although more data concerning its distribution will have to be collected before such a range can be determined.

Conclusions

The following conclusions can be drawn concerning the age of the Woodford Formation in the area of study.

1. The absence of 2 acritarch species and 1 questionable radiolarian species in the Woodford at Hickory Creek and their presence at the base of the formation in the Texas Company #1 Gipson well and the Carter #1 King well is suggestive that the Lower Woodford at Hickory Creek is of a different age than in the 2 wells.

2. The presence of Geminospora lemurata Balme, 1960, a Middle to Upper Devonian species that is more commonly found in Upper Devonian strata, in the basal Woodford at Hickory Creek and the absence of microspores restricted to Middle Devonian strata is suggestive of a Late Devonian (Senecan) age for the basal Woodford at this locality.

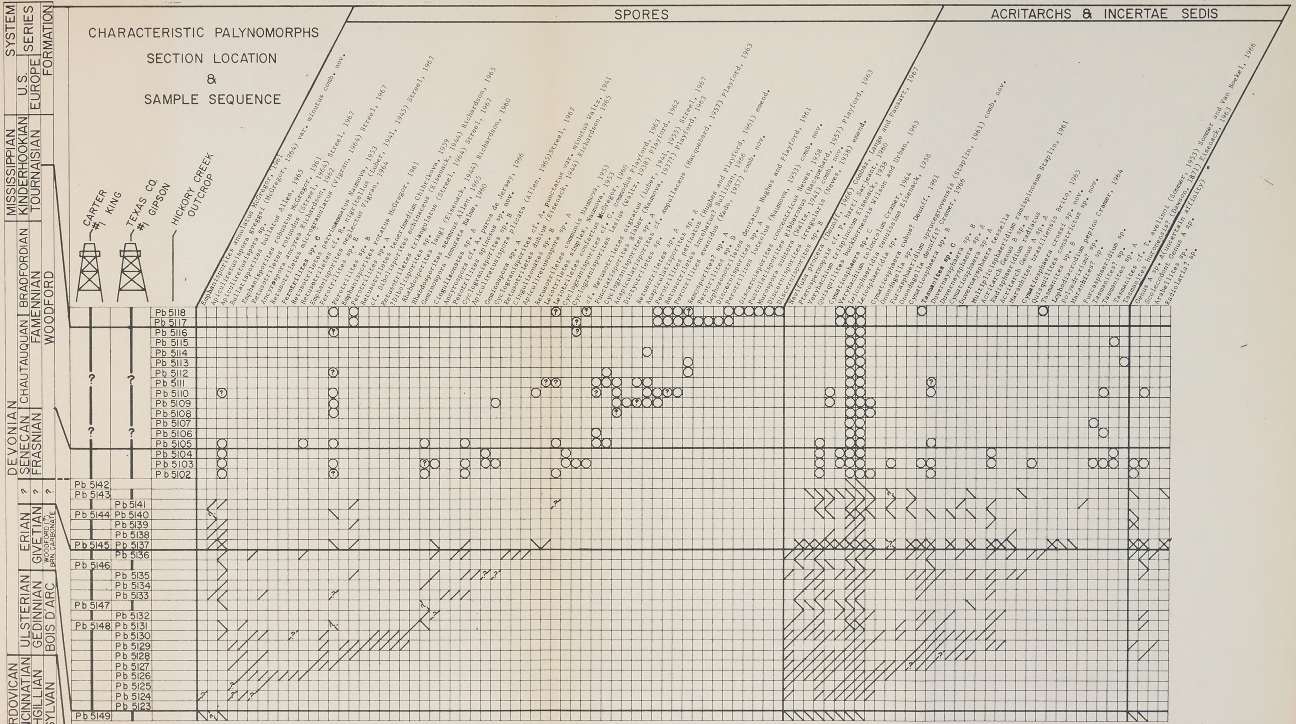
3. The age of the Middle Woodford at Hickory Creek is inconclusive.

4.. Microspore species provide sufficient evidence for an Early Mississippian (Kinderhookian) age identification for the upper 25 feet of the Woodford at Hickory Creek. This age identification may coincide with the Kinderhookian age assigned to the Upper Woodford at Henryhouse Creek, depending on the thickness of the Woodford in the covered interval, which was assigned by Hass and Huddle (1965).

5. Acritarchs possessing processes or membranes are of more value in the area of study for environmental interpretation than for age identification in the Woodford Formation.

TABLE 7

COMPOSITE OCCURRENCE CHART OF PALYNOMORPHS IN THE CARTER #1 KING AND TEXAS CO. #1 GIPSON WELLS, AND THE HICKORY CREEK OUTCROP



LEGEND: CARTER #1 KING \ ; TEXAS CO. #1 GIPSON / ; HICKORY CREEK OUTCROP O

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PLATES

PLATE 1

All figures approximately x665 except where indicated.

Figure

1 Leiotriletes simplex Naumova, 1953. 28u; Slide Pb 5137-3, R 19.7 - U 0.4.

2 Leiotriletes confertus McGregor, 1960. 55u; Slide Pb 5103-2, R 33 - D 0.5.

3 Punctatisporites glaber (Naumova, 1937?) Playford, 1963. 53u; Slide Pb 5105-2, R 16.9 - U 1.6.

4, 7 Retusotriletes cf. nigritellus (Luber, 1941, 1955) Streel, 1967. 4, 53u; Slide Pb 5136-6, R 35.2 - U 7.4. 7, 57u; Slide Pb 5136-13, R 6.2 - U 2.3.

5, 8 Retusotriletes tenerimedium Chibrikova, 1959. 73u; Slide Pb 5129-2, R 6.1 - U 0.4; 5-proximal view; 8-distal view.

6 Retusotriletes (al. Phyllothecotriletes) microgranulatus (Vigran, 1964) Streel, 1967. 73u; Slide Pb 5126-2, L 1.8 - U 3.4.

9 Retusotriletes parvimammatus Naumova, 1953. x530, 90u; Slide Pb 5126-3, R. 35.3 - D 0.5.

10 Retusotriletes triangulatus (Streel, 1964) Streel, 1967. 63u; Slide Pb 5130-1, R 15.6 - U 1.5.

11, 12 Retusotriletes rotundus (Streel, 1964) Streel, 1967. 11, x530, 60u; Slide Pb 5136-2, R 26.5 - D 3.6. 12, 53u; Slide Pb 5130-5, R 11.2 - U 5.

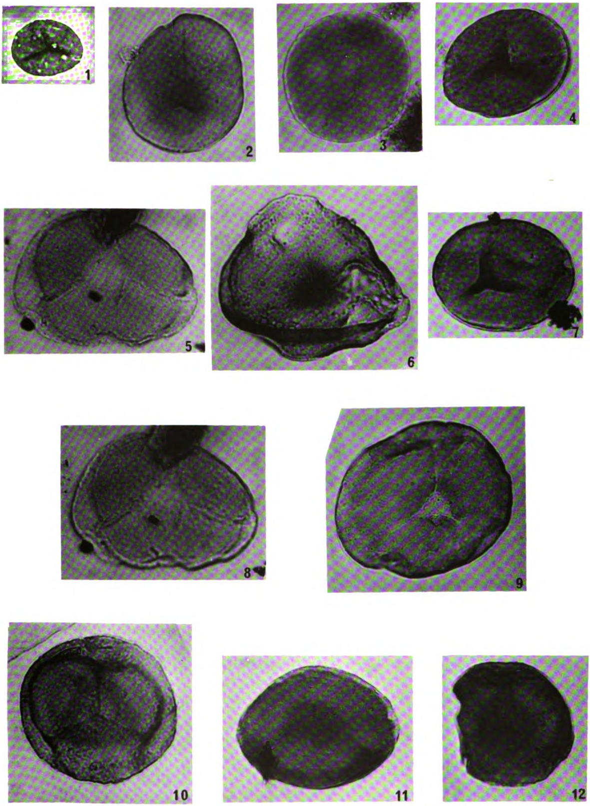

PLATE I

PLATE 2

All figures approximately x665 except where indicated.

Figure	
1	Retusotriletes dubius (Eisenack, 1944) Richardson, 1965. 50u; Slide Pb 5136-2, R 23.3 - D 7.7.
2, 3	Retusotriletes incohatus? Sullivan, 1964. 2, 48u; Slide Pb 5118-2, R 25.4 - U 5.4. 3, 57u; Slide Pb 5118-3 (8), R 13.6 - D 3.3.
4, 5	Retusotriletes communis Naumova, 1953. 34u; Slide Pb 5145-1, R 32.9 - U 0.5; 4-proximal view; 5-distal view.
6	cf. Retusotriletes nigratus (Naumova, 1953) Streel, 1967. 73u; Slide Pb 5103-4, R 30.1 - D 0.9.
7	Retusotriletes sp. A. 48u; Slide Pb 5111-1, R 19.3 - U 1.8.
8	Cyclogranisporites cf. Azonotriletes punctatus var. minutus Waltz, 1941. 57u; Slide Pb 5103-2, R 22.5 - D 0.6.
9	Cyclogranisporites lasius (Waltz, 1938) Playford, 1962. 63u; Slide Pb 5103-2, R 18.6 - D 3.8.
10	Cyclogranisporites sp. A. 49u; Slide Pb 5105-2, R 12.4 - U 7.1.
11	Cyclogranisporites cf. C. commodus Playford, 1963. 44u; Slide Pb 5103-1, R 32 - D 10.
12	Cyclogranisporites sp. B. 54u; Slide Pb 5137-2, R 20.5 - D 6.5.

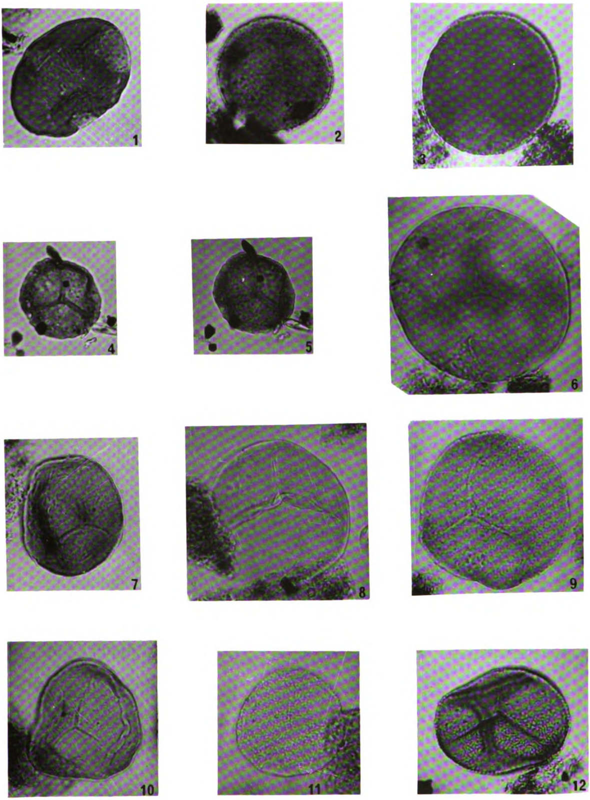

PLATE 2

PLATE 3

All figures approximately x665 except where indicated.

Figure

1, 2	Anapiculatisporites cf. A. ampullaceus (Hacquebard, 1957) Playford, 1963. 1, 50u; Slide Pb 5110-2, R 18.8 - U 5.3. 2, 47u; Slide Pb 5111-1, R 20.3 - D 3.3.
3, 4	Anapiculatisporites sp. A. 45u; Slide Pb 5109-1, R 18.3 - U 0.7; 3-proximal view; 4-distal view.
5-8	Apiculiretusispora greggsi (McGregor, 1964) var. minutus comb. nov. 5 & 6, 38u; Slide Pb 5141-2, R 17.5 - D 3.7; 5-proximal view; 6-distal view. 7 & 8, 53u; Slide Pb 5137-1, R 18.2 - D 8.9; 7-proximal view; 8-distal view.
9, 10	Apiculiretusispora plicata (Allen, 1965) Streel, 1967. 72u; Slide Pb 5135-15, R 23 - D 1.8; 9-proximal view; 10-distal view.
11-14	Apiculiretusispora sp. A. 11 & 14, 53u; Slide Pb 5136-5, L 4 - U 4.9; 11-proximal view; 14-distal view. 12 & 13, 58u; Slide Pb 5136-18, R 11.8 - D 6.4; 12-proximal view; 13-distal view.

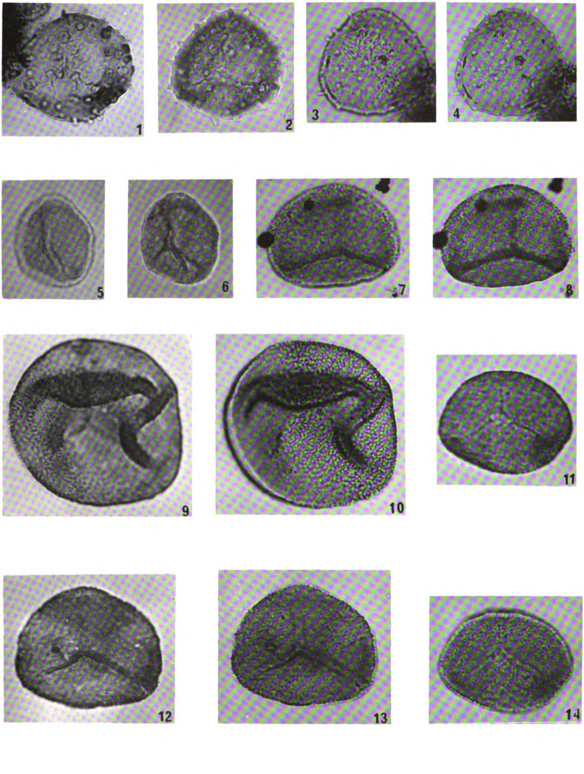

PLATE 3

PLATE 4

All figures approximately x665 except where indicated.

Figure

1-3 Apiculiretusispora sp. A. 1, 68u; Slide Pb 5135-2, R 12.5 - U 6.6. 2 & 3, 60u; Slide Pb 5133-1, R 28.9 - U 3.6; 2-proximal view; 3-distal view.

4 Pustulatisporites gibberosus (Hacquebard, 1957) Playford, 1963. 53u; Slide Pb 5118-3 (8), R 24.6 - D 0.3.

5, 6 Bullatisporites bullatus Allen, 1965. 80u; Slide Pb 5130-5, R 8.3 - U 1.5; 5-proximal view; 6-distal view.

7-9 cf. Dibolisporites echinaceus (Eisenack, 1944) Richardson, 1965. 7 & 8, 86u, excluding processes, central body 73u, maximum process length 7u; Slide Pb 5129-3, R 28.9 - D 3.8; 7-proximal view; 8-x1660 phase, detail of processes. 9, 79u, excluding processes, maximum process length 7u; Slide Pb 5129-4, R 23.2 - D 0.3.

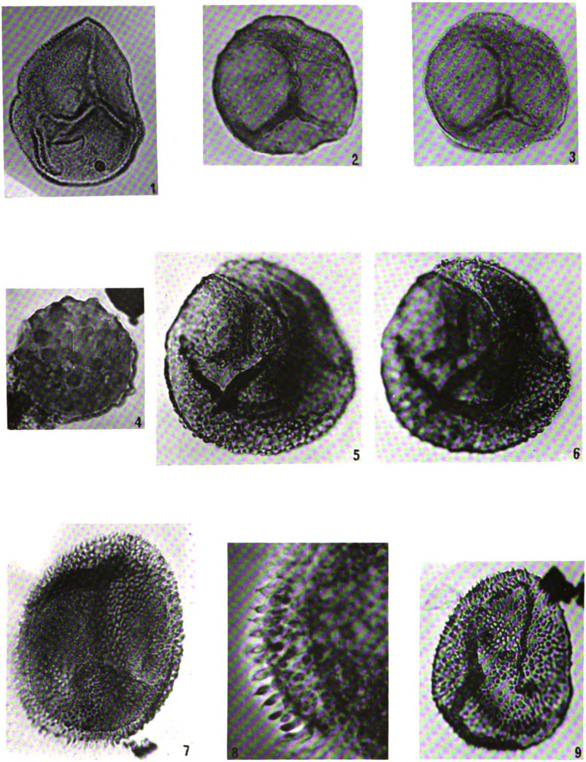

PLATE 4

PLATE 5

All figures approximately x665 except where indicated.

Figure	
1-3	?Dibolisporites sp. 1 & 2 x530, 102u, exoexine width excluding processes 4u, maximum process length 6u; Slide Pb5129-2, R 6.9 - D 3.8; 1-proximal view; 2-phase showing processes. 3, 68u excluding processes, central body 62u, maximum process length 3u; Slide Pb 5129-1, R 5.7 - D 6.5; view shows exoexine "peeled off" central body.
4, 5	Dictyotriletes sp. 41u; Slide Pb 5109-2, R 10.6 - U 0.2; 4-proximal view; 5-distal view.
6, 7	Emphanisporites rotatus McGregor, 1961. 6, 29u; Slide Pb 5129-3, R 23.5 - D 9. 7, 36u; Slide Pb 5129-4, R 27.2 - D 3.6.
8, 9	Emphanisporites annulatus McGregor, 1961. 8, 40u; Slide Pb 5149-3, R 14.9 - U 0.4. 9, tetrad, 40u individual diameter; Slide Pb 5149-3, R 26.6 - D 3.3.
10	Emphanisporites neglectus Vigran, 1964. 40u individual diameter; Slide Pb 5127-1, R 14.9 - D 8.9.
11, 12	Emphanisporites robustus McGregor, 1961. 11, 60u; Slide Pb 5131-4, R 20.5 - D 5.8. 12, 50u; Slide Pb 5126-3, R 3.9 - U 6.6.

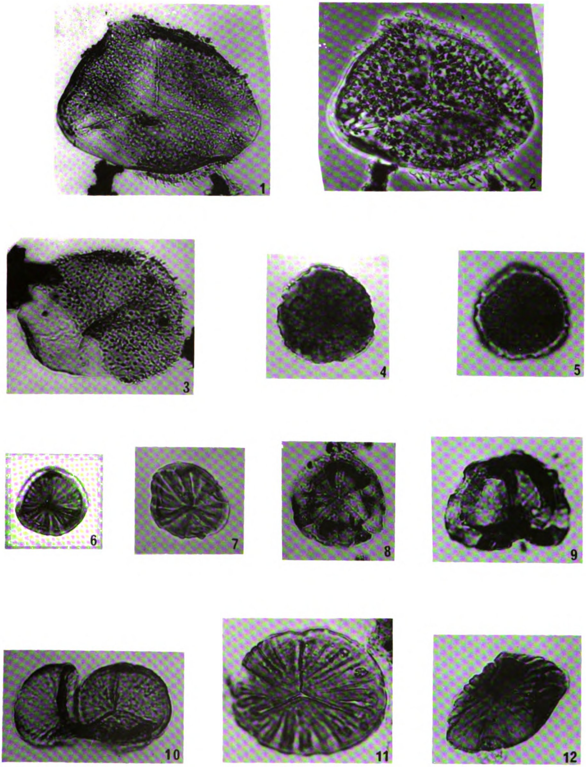

PLATE 5

PLATE 6

All figures approximately x665 except where indicated.

Figure

1-3, 6 Perotrilites sp. A. 1 & 2, 58u central body, maximum perispore width 5u; Slide Pb 5118-1 (8), R 28.1 - U 0.5; 1-proximal view; 2-distal view. 3 & 6, 68u central body, maximum perispore width 8u; Slide Pb 5129-1, R 27.2 - D 6.7; 3-proximal view; 6-distal view.

4, 5, 7 Perotrilites sp. B. 4 & 5, 48u central body, maximum zona width 11u, maximum perispore width 3u; Slide Pb 5118-1 (8), R 28.1 - D 5.8; 4-proximal view; 5-distal view. 7, 58u central body, maximum zona width 8u, maximum perispore width 13u; Slide Pb 5105-1, R 8.4 - D 4.3.

8, 9 Perotrilites perinatus (Hughes & Playford, 1961) emend. 37u central body, maximum perispore width 2u; Slide Pb 5117-4, R 3.7 - U 1.3; 8-proximal view; 9-distal view.

10, 11 Perotrilites spinosus sp. nov. 51u central body, maximum perispore width 15u; Slide Pb 5136-19, R 7.5 - U 2.2; 10-proximal view; 11-phase showing spinose perispore.

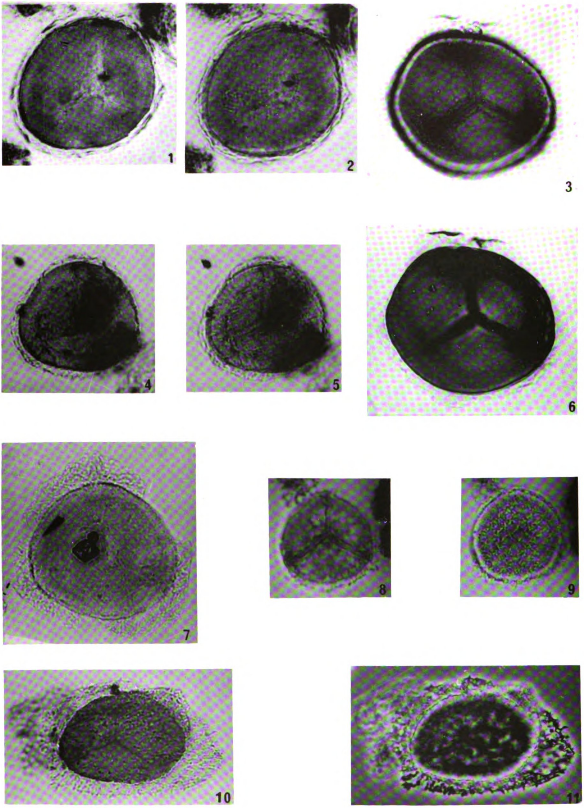

PLATE 6

PLATE 7

All figures approximately x665 except where indicated.

Figure

1-3, 6 Perotrilites spinosus sp. nov. 1 & 2, 50u central body, maximum perispore width 13u; Slide Pb 5136-2, R 24.3 - U 2.2; 1-proximal view; 2-phase showing spinose perispore. 3 & 6, 54u central body, maximum perispore width 33u; Slide Pb 5136-3, R 27.2 - U 1.2; 3-distal view; 6-phase showing spinose perispore.

4, 5 Perotrilites sp. C. 92u central body, maximum perispore width including processes 37u, maximum process length 8u; Slide Pb 5126-1, R 9.1 - U 0.5; 4-x330; 5-phase showing detail of processes.

7 Perotrilites luteolus (Naumova, 1953) comb. nov. 29u central body, maximum perispore width 3u; Slide Pb 5118-1 (8), R 10.6 - D 6.7.

8, 9 Perotrilites evanidus (Kedo, 1957) comb. nov. 36u central body, maximum perispore width 7u; Slide Pb 5117-4, R 23.6 - U 7.4; 8-proximal view; 9-distal view.

10, 11 Perotrilites sp. D. 38u central body, maximum perispore width 3u; Slide Pb 5117-3, R 7.2 - U 4.1; 10-proximal view; 11-distal view.

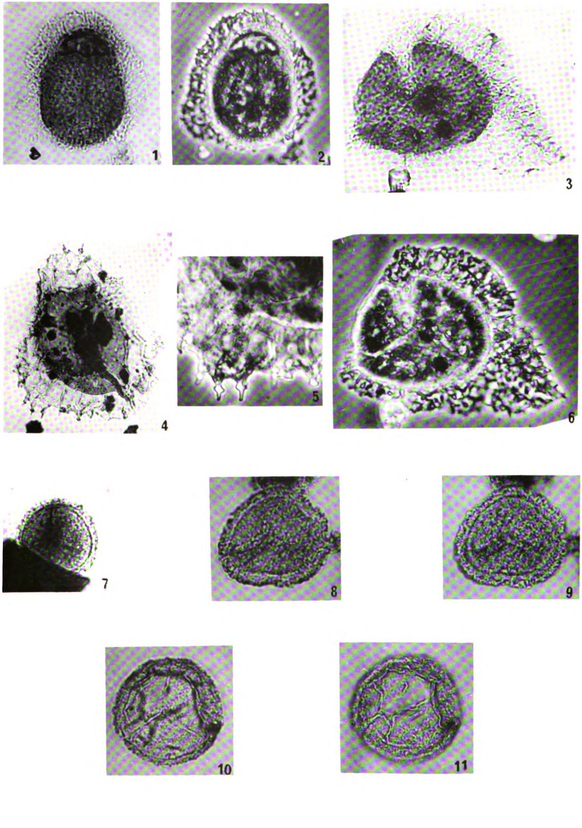

PLATE 7

PLATE 8

All figures approximately x665 except where indicated.

Figure

1-7 Perotrilites sp. E. 1, 54u central body, maximum perispore width 13u; Slide Pb 5129-4, R 34 - D 3.7. 2 & 3 66u central body, maximum perispore width 6u; Slide Pb 5129-1, R 20.6 - D 4; 2-proximal view; 3-distal view. 4 & 5, 70u central body, maximum perispore width 9u; Slide Pb 5129-2, R 24.3 - U 1.5; 4-proximal view; 5-distal view. 6 & 7, 70u central body, maximum perispore width 16u; Slide Pb 5129-1, R 27.1 - D 3.6; 6-hi focus; 7-low focus.

8, 11 Murospora subtera (Waltz, 1941) comb. nov. 38u central body, zona width 7u; Slide Pb 5118-3 (8), R 9.3 - U 1.2; 8-proximal view; 11-distal view.

9, 10 Lophozonotriletes dentatus Hughes & Playford, 1961. 38u; Slide Pb 5117-4, R 8.9 - D 2.5; 9-proximal view; 10-distal vies.

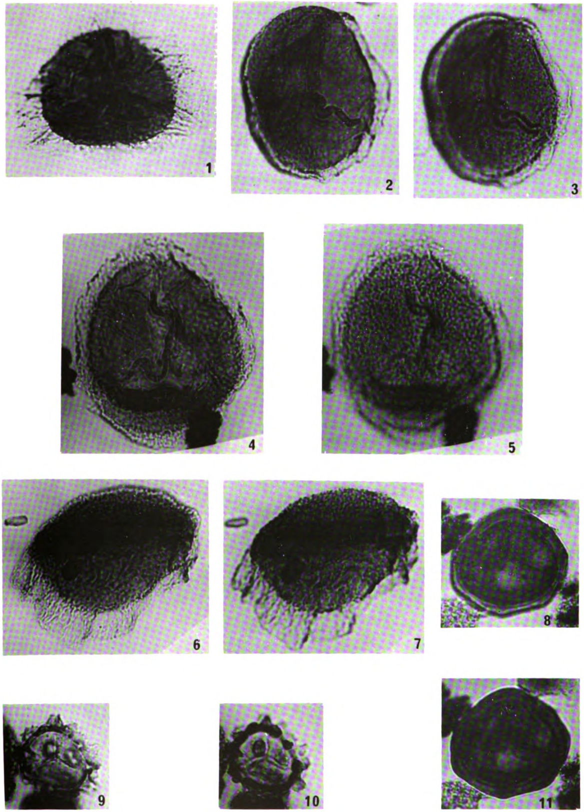

PLATE 8

PLATE 9

All figures approximately x665 except where indicated.

Figure

1, 2 Chelinospora sp. A. 48u central body, maximum zona width 13u; Slide Pb 5155-1, R 31.5 - U 0.4; 1-proximal view; 2-distal view, showing reticulate patina.

3, 6 Cingulizonates sp. A. 3, 31u central area, maximum cuesta width 12u, maximum zona width 16u; Slide Pb 5136-9, L 3.7 - U 7.4. 6, 37u central area, maximum cuesta width 10u, maximum zona width 16u; Slide Pb 5136-5, R 13.8 - D 3.7.

4, 5 Cingulizonates sp. B. 4, 34u central area, maximum cuesta width 8u, maximum zona width 16u; Slide Pb 5136-16, R 1.3 - D 2.3. 5, 37u central area, maximum cuesta width 12u, maximum zona width 20u; Slide Pb 5136-8, R 31.6 - D 6.9.

7, 8, 10 Cingulizonates sp. B. 7 & 8, 42u central area, maximum cuesta width 14u, maximum zona width 23u; Slide Pb 5136-16, R 11.8 - D 7.6; 7-proximal view showing sutural ridges; 8-distal view; 10, x1660, detail of distal ornamentation.

9, 11 Discernisporites irregularis (Neves, 1958) emend. 40u inner saccus, maximum exoexine width 12u; Slide Pb 5118-4, R 29.2 - U 5; 9-proximal view; 11-distal view.

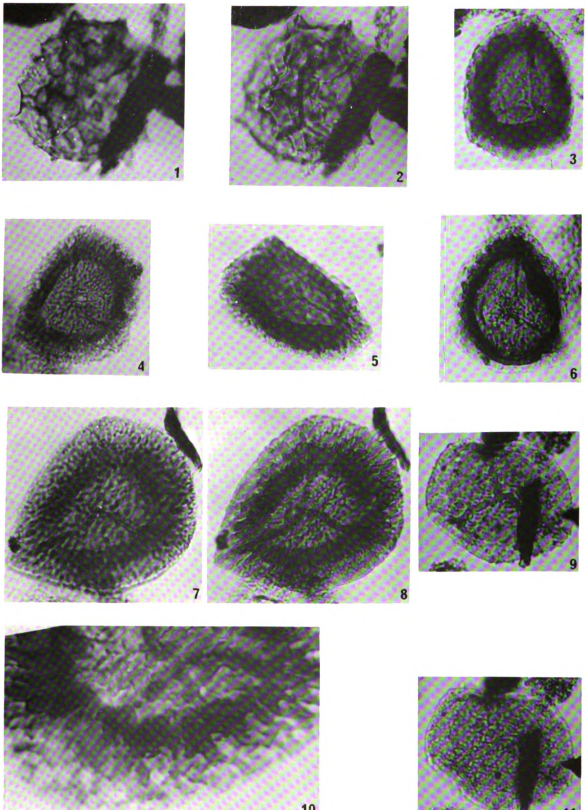

PLATE 9

PLATE 10

All figures approximately x665 except where indicated.

Figure

1-3 *Discernisporites concentricus* Neves, 1958. 1, 46u inner saccus, maximum exoexine width 10u; Slide Pb 5118-1 (8), R 17.5 - U 6.1. 2, 53u inner saccus, maximum exoexine width 26u; Slide Pb 5118-2, R 33.6 - U 8.3. 3, 46u inner saccus, maximum exoexine width 12u; Slide Pb 5118-1, R 10.7 - U 5.5.

4, 5 *Discernisporites sp. A.* 40u inner saccus, maximum exoexine width 13u; Slide Pb 5117-2, R 35.2 - D 8.8; 4-proximal view; 5-distal view showing triradiate folds.

6 *Discernisporites sp. B.* 41u inner saccus, maximum exoexine width 6u; Slide Pb 5118-1 (8), R 30.8 - D 4.9.

7, 8 *Geminospora lemurata* Balme, 1960. 50u inner saccus, 7u exoexine; Slide Pb 5102-1, R 17.8 - U 3.1; 7-proximal viewl 8-distal view.

9, 11 12 *Geminospora sp. A.* 9, 42u inner saccus, maximum exoexine width plus membrane 16u; Slide Pb 5103-3, R 6.3 - U 10.7. 11 & 12, 50u inner saccus, maximum exoexine width plus membrane 15u; Slide Pb 5103-3, R 7 - D 8.9; 11-proximal view; 12-distal view.

10 *Remysporites? sp. A.* 28u inner saccus, maximum exoexine width 16u; Slide Pb 5117-3, R 3.8 - D 7.

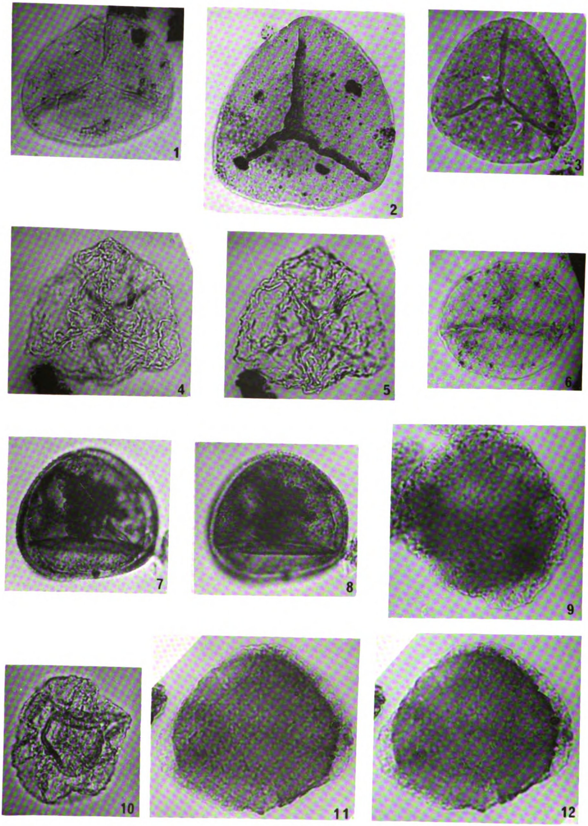

PLATE 10

PLATE 11

All figures approximately x665 except where indicated.

Figure

1, 2 Rhabdosporites langi (Eisenack, 1944) Richardson, 1960. x530, 78u central body, maximum exoexine or bladder width 15u; Slide Pb 5129-4, R 9 - U 0.1; 1-proximal view; 2-distal view.

3, 6 Rhabdosporites scamnus Allen, 1965. x415, 70u central body, maximum exoexine or bladder width 10u; Slide Pb 5131-1, R 21.9 - U 0.7; 3-proximal view; 6-distal view.

4, 5, 7 Apiculiretusospora sp., gen. et sp. nov. 4 & 5, 67u x 48u; Slide Pb 5136-3, R 30 - U 6.5; 4-proximal view; 5-distal view. 7, tetrad, individual 67u x 45u; Slide Pb 5136-2, R 16 - D 4.5.

8 Ancyrospora ancyrea Richardson, 1962. x330, 85u central body, maximum flange width 39u; Slide Pb 5126-4, R 0.2 - D 8.5.

9, 10, 11 Ancyrospora cf. A. parva de Jersey, 1966. 9 & 11, 82u including processes, 42u central body, maximum process length 15u; Slide Pb 5133-2, R 2.1 - U 8.1; 11-proximal view; 9-phase detail of processes. 10, Slide Pb 5133-4, R 8.7 - D 2.8, phase detail of processes.

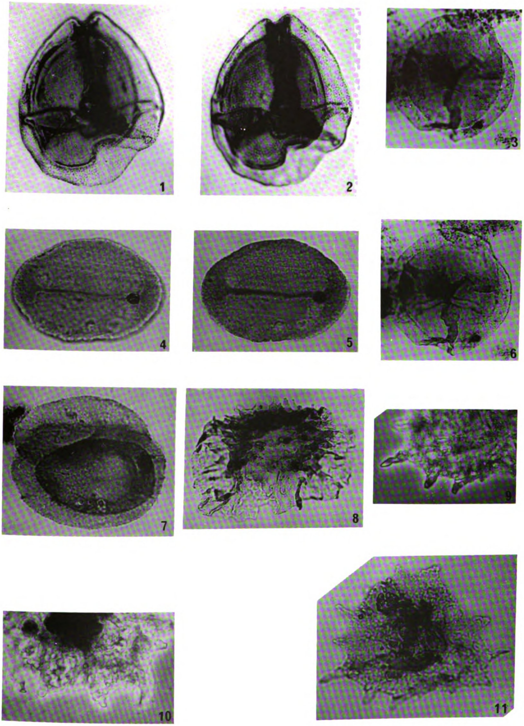

PLATE II

PLATE 12

All figures approximately x665 except where indicated.

Figure

1, 2	Ancyrospora cf. A. parva de Jersey, 1966. 1, x415, 120u including processes, 51u central body, maximum process length 15u; Slide Pb 5133-2, R 20.4 - D 0.6; 2-phase detail of processes.
3, 4	Multiplicisphaeridium ramispinosum Staplin, 1961. 3, phase, 28u vesicle, maximum process length 21u; Slide Pb 5144-1, R 2 - D 0.5. 4, phase, 28u vesicle, maximum process length 17u; Slide Pb 5137-1, R 27.4 - D 3.5.
5, 6, 8	Furcasphaeridium sprucegrovensis (Staplin, 1961) comb. nov. 5, phase, 39u vesicle, maximum process length 13u; Slide Pb 5136-1, R 19 - D 2.9. 6, 62u vesicle, maximum process length 15u; Slide Pb 5141-2, R 25.2 - D 6.1; 8-phase.
7, 9	Furcasphaeridium sp. 7, 63u vesicle, maximum process length 10u; Slide Pb 5141-1, R 23.2 - D 0.8; 9-phase.
10, 11	Veryhachium trispinosum Eisenack, 1938. 10, 31u including processes, maximum process length 10u; Slide Pb 5136-1, R 28.7 - D 5.5. 11, 35u including processes, maximum process length 16u; Slide Pb 5130-1, R 7 - U 1.7.

PLATE 12

PLATE 13

All figures approximately x665 except where indicated.

Figure

1, 2 — Veryhachium tolontolum Cramer, 1964. x530, 33u vesicle (side to side), maximum process length 25u; Slide Pb 5145-2, R 22.3 - D 2.5; 2-phase.

3-6 — Leiosphaeridia tenuissima Eisenack, 1958. 3, x260, 197u; Slide Pb 5152-1, R 8 - D 9.8. 4, 100u; Slide Pb 5114-1 (100+), R 20.3 - U 2.4. 5, x165, 232u x 170u; Slide Pb 5152-2, R 2.2 - D 5.1. 6, x260, 219u x 120u; Slide Pb 5114-1 (100+), L 0.5 - U 4.4.

7, 8 — Leiosphaeridia sp. A. x260. 7, 190u; Slide Pb 5114-1 (100+), R 19.2 - U 2.6. 8, 186u x 70u; Slide Pb 5114-1 (100+), R 8.1 - D 1.1.

9 — Navifusa (Leiofusa) procera (Deunff, 1966) Combaz, Lange & Pansart, 1967. x330, 210u x 30u; Slide Pb 5130-5, R 3 - D 6.

10,11 — Quisquilites constrictus sp. nov. x415. 10, length 180u, maximum width 42u, minimum width 21u; Slide Pb 5103-4, R 11 - D 0.1. 11, length 129u, maximum width 40u, minimum width 22u; Slide Pb 5103-3, R 31.3 - D 6.3.

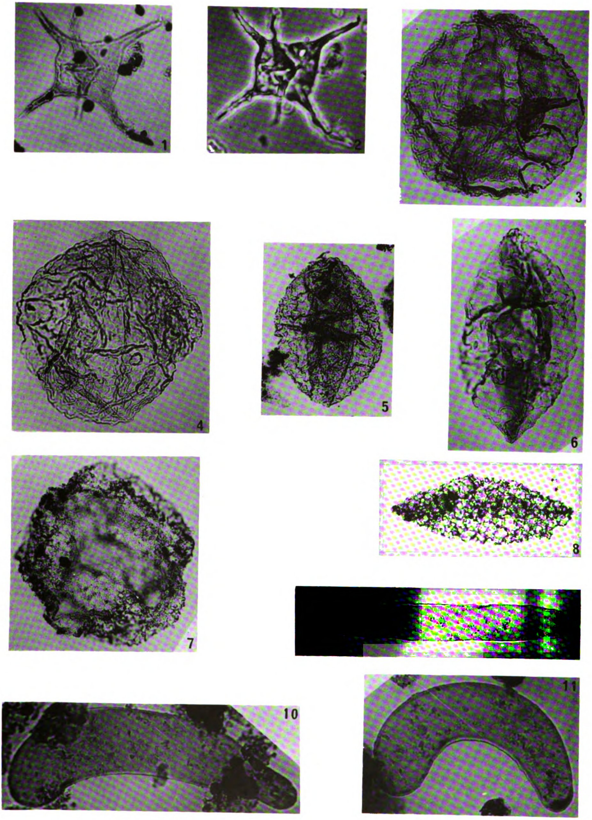

PLATE 13

PLATE 14

All figures approximately x665 except where indicated.

Figure

1-3	Quisquilites buckhornensis Wilson & Urban, 1963. 1, 105u x 70u, wall thickness 3u; Slide Pb 5135-3, R 1.5 - D 0.7. 2, 111u x 74u, wall thickness 5u; Slide Pb 5135-4, R 6.1 - D 9. 3, 107u x 55u, wall thickness 3u; Slide Pb 5137-3, R 19.9 - D 9.5.
4-7, 11	Lophodiacrodium pepino Cramer, 1964. 4, 36u x 17u, 1u process length; Slide Pb 5145-1, R 32.2 - D 4.8; 5-phase. 6, 38u x 18u, 1u process length; Slide Pb 5145-2, R 8 - D 6.6; 7-phase. 11, 18u x 11u, process length 1u, phase; Slide Pb 5137-1, R 24.9 - D 8.5.
8-10	Cymatiosphaera sp. A. 8, 32u vesicle, maximum membrane width 10u; Slide Pb 5145-2, R 2 - D 3.8; 9-phase. 10, 41u vesicle, maximum membrane width 8u; Slide Pb 5137-1, R 23 - D 7.6.
12-15	Cymatiosphaera crossi sp. nov. 12, 32u vesicle (side to side), 40u vesicle (diagonal), maximum membrane width 4u; Slide Pb 5143-2, R 20.1 - U 7.3; 13-phase. 14, 30u vesicle (side to side), 40u vesicle (diagonal), maximum membrane width 6u; Slide Pb 5143-2, R 8.1 - D 1.6; 15-phase.

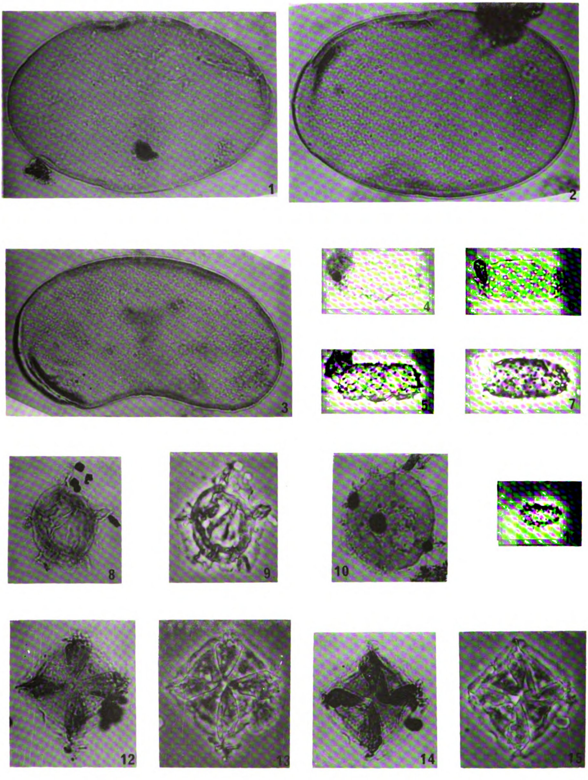

PLATE 14

PLATE 15

All figures approximately x665 except where indicated.

Figure

1 Cymatiosphaera cubus? Deunff, 1961. 41u maximum vesicle, maximum membrane width 8u; Slide Pb 5145-1, R 29.4 - D 2.9.

2, 3 Cymatiosphaera sp. B. 2, phase, 49u maximum vesicle, maximum membrane width 13u; Slide Pb 5136-2, R 0.8 - U 4.2; 3, x1660, phase, detail of vesicle.

4-6 Cymatiosphaera sp. C. 4, 50u maximum vesicle, maximum membrane width 9u; Slide Pb 5145-1, R 8 - D 8.4; 5-phase. 6, 50u maximum vesicle, maximum membrane width 4u; Slide Pb 5143-1, R 14.2 - U 5.3.

7, 8 Duvernaysphaera tessella Deunff, 1964. 7, 30u vesicle (side to side), 44u vesicle (diagonal excluding processes), maximum membrane width 11u; Slide Pb 5130-1, R 7.3 - U 7.9; 8-phase.

9, 13 Duvernaysphaera sp. A. 9, 35u vesicle, maximum membrane width 5u; Slide Pb 5135-13, R 15.2 - D 5; 13-phase.

10-12 Duvernaysphaera sp. B. 10, 30u vesicle, maximum membrane width 7u; Slide Pb 5135-2, R 1.3 - U 10. 11, 36u vesicle, maximum membrane width 9u; Slide Pb 5135-3, R 1.6 - D 0.6; 12-phase.

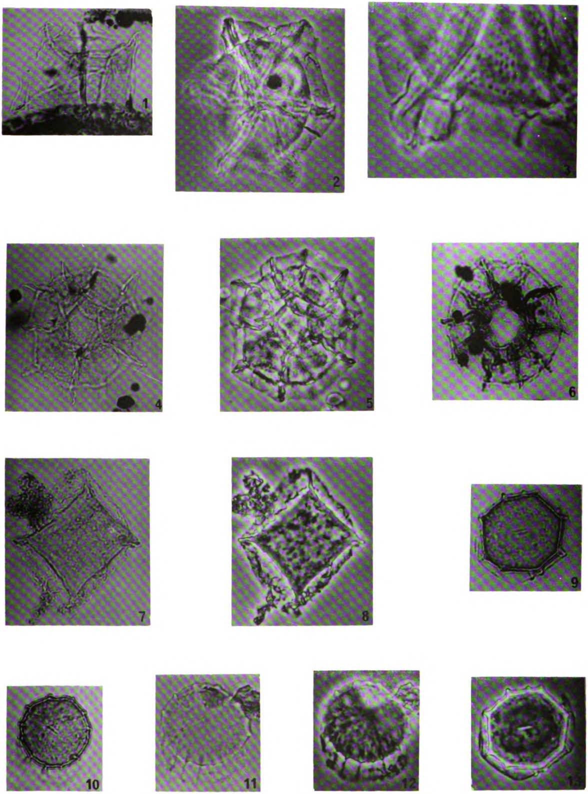

PLATE 15

PLATE 16

All figures approximately x665 except where indicated.

Figure

1, 2 Pterospermopsis cf. P. harti Sarjeant, 1960. 1, 50u vesicle, maximum membrane width 22u; Slide Pb 5145-1, R 14.3 - D 7.8; 2-phase.

3-6 Polyedrixium? sp. 3, 40u (maximum diagonal), 30u (maximum side to side); Slide Pb 5145-1, R 7.1 - U 1.7; 4-phase. 5, 50u (maximum diagonal), 38u (maximum side to side); Slide Pb 5145-2, R 23.8 - D 3; 6-phase.

7, 8, 10 Tasmanites sp. A. 7, x260, 173u, maximum outer wall thickness 7u, maximum inner wall thickness 15u; Slide Pb 5106-1, R 0.8 - D 5.1; 8, x1040, detail. 10, detail; Slide Pb 5103-4, R 6.7 - U 5.9.

9 Tasmanites cf. T. avelinoi (Sommer, 1953) Sommer & Van Boekel, 1966. x165, 252u, maximum wall thickness 15u; Slide Pb 5103-3, R 10.5 - U 4.5.

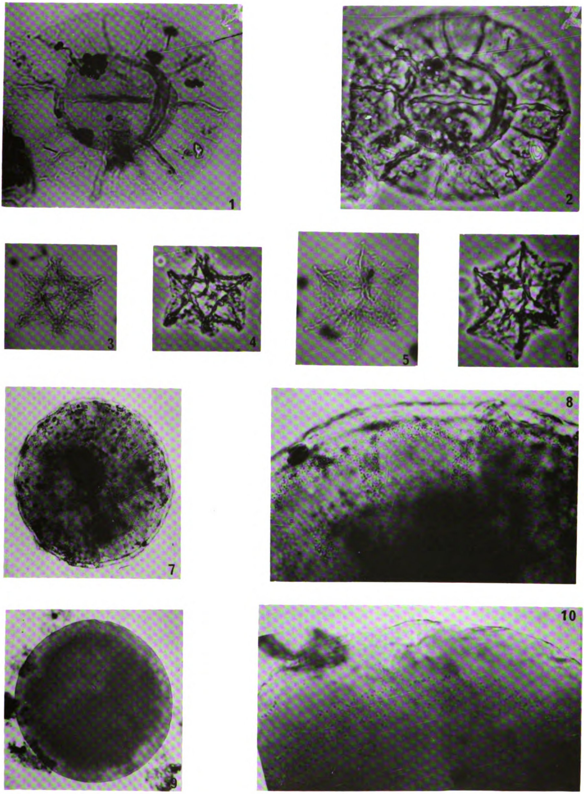

PLATE 16

PLATE 17

All figures approximately x665 except where indicated.

Figure

1-4 *Tasmanites*? *sp.* 1, x330, 165u, 102u maximum plug diameter; Slide Pb 5113-1 (100+), R 1.1 - U 4.2; 2-detail, showing canals in plug. 3, x165, 228u, 37u maximum plug diameter; Slide Pb 5107-2, R 11.8 - D 2.8; 4-detail showing canals in plug.

5, 6 *Tasmanites huronensis*? (Dawson, 1871) Eisenack, 1963. 5, x165, 270u, 39u maximum plug diameter; Slide Pb 5113-6 (100+), R 23.2 - D 3.5; 6-detail.

7, 8 *Tasmanites sp. B.* 7, x330, 160u, maximum wall thickness 12u; Slide Pb 5118-4 (8), R 22.2 - U 1.3; 8-detail showing indistinct canals.

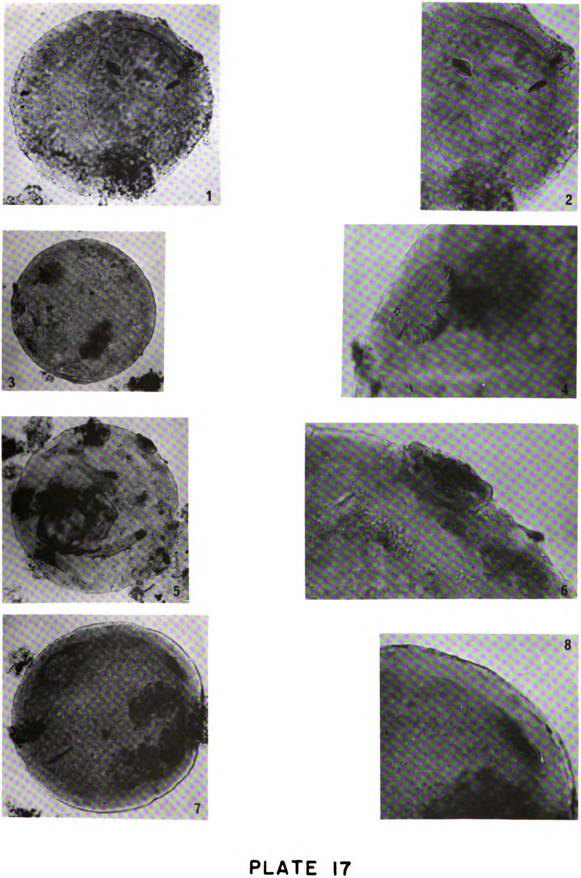

PLATE 17

PLATE 18

All figures approximately x665 except where indicated.

Figure

1-7 *Tasmanites sp. C.* 1, x415, 104u central body, maximum saccus width 51u; Slide Pb 5103-3, R 0.3 - D 2.2. 2, x415, 57u central body, maximum saccus width 40u; Slide Pb 5135-5, R 29.1 - U 2.5; 5-detail showing reticulate central body. 3 & 4, x330, 132u, maximum wall thickness 10u; Slide Pb 5135-3, R 24.3 - D 4.5; 3-hi focus showing reticulate ornamentation; 4-medium focus showing canalate wall. 6, 51u; Slide Pb 5135-2, R 23 - D 3. 7, x530, 74u, maximum wall thickness 6u; Slide Pb 5118-1 (8), L 3.8 - D 1.4.

8 *Onondagella deunffi*? Cramer, 1966. x415, 78u vesicle, maximum process length 22u; Slide Pb 5127-1, R 33.9 - D 7.

9, 10 *Onondagella sp.* 9, 52u vesicle, maximum membrane width 13u; Slide Pb 5130-4, R 32.1 - D 7; 10-phase.

11 *Radisphaeridium radiatus*, gen. et. sp. nov. 37u; Slide Pb 5145-1, R 2.5 - U 0.5.

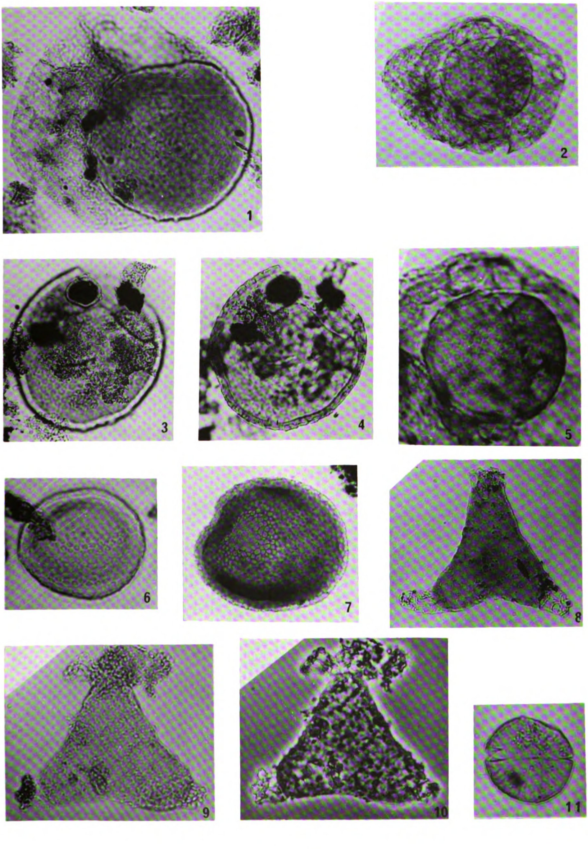

PLATE 18

PLATE 19

All figures approximately x665 except where indicated.

Figure

Figure	
1, 2, 4	*Maranhites brasiliensis* Brito, 1965. x530. 1, 99u; Slide Pb 5145-2, R 5.2 - U 1.4. 2, 97u; Slide Pb 5145-1, R 1.4 - D 3.7; 4-phase.
3, 5	*Maranhites*? *sp.* 3, x415, 130u, maximum process length 26u; Slide Pb 5145-2, R 2.2 - D 3.7; 5-detail showing processes.
6, 7, 11	*Acritarch Genus A. sp. A*, gen. et sp. nov. 6, 44u; Slide Pb 5145-1, R 32 - D 2.6. 7, 52u; Slide Pb 5137-1, R 32.6 - D 2.5. 11, 51u; Slide Pb 5145-2, R 21.8 - D 6.8.
8 -10	*Acritarch Genus B. sp. A*, gen. et sp. nov. 8, 51u, maximum process diameter 5u; Slide Pb 5130-3, R 33.8 - U 8.2; 9-phase. 10, 43u, maximum process diameter 6u; Slide Pb 5129-4, R 16.3 - U 1.7.

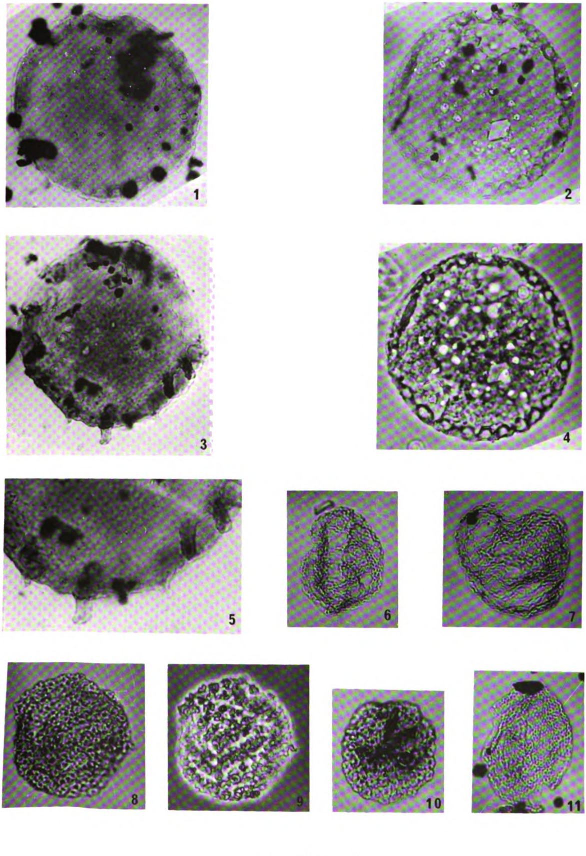

PLATE 19

PLATE 20

All figures approximately x665 except where indicated.

Figure

1-4 Radiolaria? sp. 1, phase, 25u vesicle, maximum process length (broken) 14u; Slide Pb 5137-1, R 28.7 - U 4.3. 2, phase, length 85u, lateral process length 14u; Slide Pb 5137-1, R 30.9 - U 5. 3, x415, length 134u, lateral process length 15u; Slide Pb 5145-2, R 19.3 - D 3; 4-phase.

5-8 Genus A. sp. A, gen. et sp. nov. 5, x530, 118u anterior-posterior length; Slide Pb 5102-1, R 22.8 -U 4.5. 6, x165, 375u anterior-posterior length; Slide Pb 5137-2 (100+), R 0.4 - U 8.4. 7, x260, 264u anterior-posterior length (posterior tip broken off); Slide Pb 5137-2 (100+), R 9.3 - D3. 8, x330, 180u anterior-posterior length; Slide Pb 5137-1, L 3.3 - D 8.3.

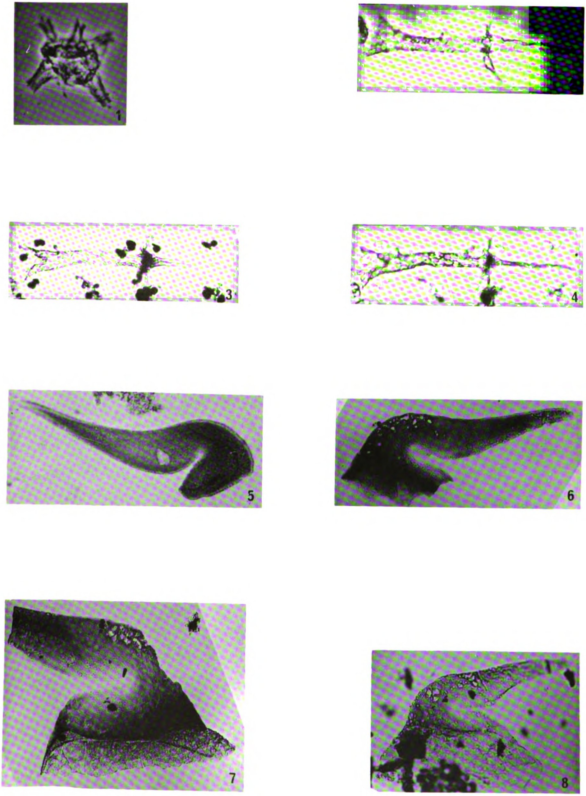

PLATE 20

PLATE 21

All figures approximately x665 except where indicated.

Figure

1-3 Hoegisphaera scabiosa (Wilson & Hedlund, 1964) Wilson & Dolly 1964. 1, Operculum, 40u; Slide Pb 5130-7, R 16.6 - D 7.5. 2, x530, phase, 47u operculum diameter; Slide Pb 5137-2, R 29.4 - U 8.3. 3, 35u operculum diameter; Slide Pb 5130-5, R 16.1 - D 2.9.

4, 6 Scolecodont Genus A. sp. A, gen. et sp. nov. 4, x260, 170u in length; Slide Pb 5136-18, R 18.2 - D 9.6. 6, x415, 153u in length; Slide Pb 5146-1, R 24 - D 3.9.

5 Arabellites sp., x415, 129u in length; Slide Pb 5136-18, R 17.6 - D 3.6.

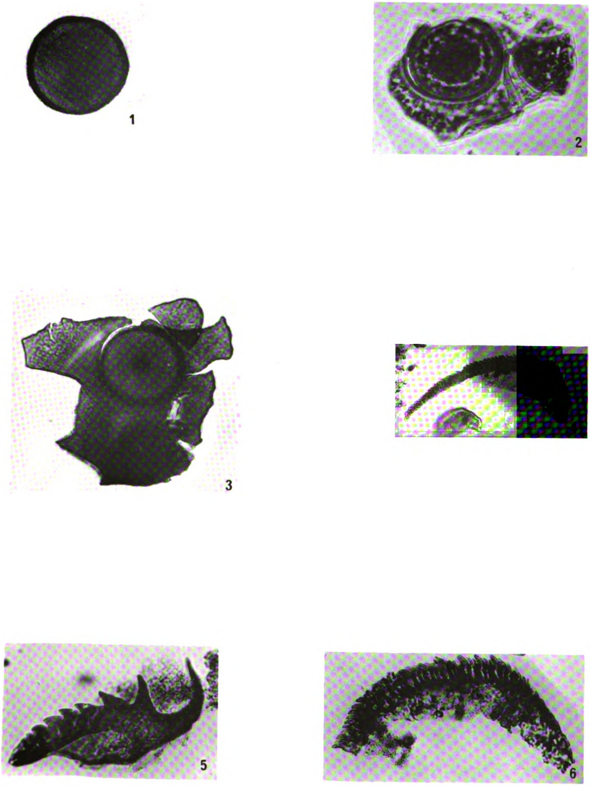

PLATE 21