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Spores of the Pennsylvanian Toronto Limestone in Kansas and Oklahoma

James F. Carter

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LIMESTONE IN KANSAS AND OKLAHOMA

By
James F. Carter

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Degree of
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Jas. F. Carter

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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DATE

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CONTENTS

FIGURES

CHART

PLATES

ABSTRACT

The Toronto cyclothem is the lower limestone member of the Oread megacyclothem of the Shawnee group, Virgilian series, Pennsylvanian system and crops out in a linear belt extending north-south for a distance of 300 miles across Oklahoma, Kansas, and parts of Missouri and Nebraska.

A total of 367 Toronto limestone, shale, and coal samples were digested, using a standard chemical treatment, and examined for their plant-spore content. Sixty-five of the samples were fossiliferous. The limestone was virtually barren.

Certain dominant spore genera and assemblages seem to be characteristic of the various environmental zones of the Toronto limestone. *Lycospora* and *Cadiospora* are dominant in the lower non-marine shale and *Florinites* in the upper non-marine shale. *Cadiospora*, *Endosporites*, and *Calamospora* are the dominant genera of the underclay. The coal is characterized by *Endosporites*, *Laevigatosporites*, and *Calamospora* which are genera common in many coals of Pennsylvanian age. The transitional shale contains *Cyclogranisporites* as the dominant genus. *Endosporites* and *Planisporites* are most numerous in the marine shale.

The presence of a few grains of the genus *Illinites* in the southern part of the area suggests a dry highland area some distance to the south as a source area for the parent flora and sediment.

ABSTRACT

The Toronto cyclothem is the lower limestone member of the Oread megacyclothem of the Shawnee group, Virgilian Series, Pennsylvanian system and crops out in a linear belt extending north-south for a distance of [illegible] miles across Oklahoma, Kansas, and parts of Missouri and Nebraska.

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Certain dominant spore genera and assemblages seem to be characteristic of the various environmental types of the Toronto limestone. *Lycospora* and [illegible] are dominant in the lower non-marine shale, and *Florinites* in the upper non-marine shale. [illegible], [illegible], and [illegible] are the dominant genera of the underclay. The coal is characterized by [illegible], [illegible], and [illegible] which are genera common in many coals of Pennsylvanian age. The transitional shale contains [illegible] as the dominant genus. [illegible] and [illegible] are most numerous in the marine shale.

The presence of a few grains of the genus [illegible] in the southern part of the area suggests a dry upland area some distance to the south as a source area for the [illegible] and sediment.

The presence of Densosporites in rocks of Virgilian age is definitely established.

INTRODUCTION

Purpose of Investigation

A spore analysis of the Toronto limestone was undertaken to obtain paleoecologic data, substantiate correlations already established, and indicate the direction of shorelines.

Inasmuch as the Toronto cyclothem is predominantly limestone it was expected that most of the rock samples would be barren of spores. However, any spores present might reflect changing environments as evidenced by the rapidly changing lithologies. Total spore content might give a good indication of the direction of the shoreline and source area of the spores.

Regional correlations were expected to be difficult to establish because of the short time interval involved and lack of palynological data concerning units above and below the Toronto limestone.

Acknowledgment

This study was made possible by Shell Oil Company of Midland, Texas and Shell Development Company of Houston, Texas. Company rock samples of the Toronto limestone were used and all laboratory and reproduction facilities were at the disposal of the writer. Special thanks are given to Dr. James M. Parks, Jr. and Jesse B. Pogue, Jr. for their indispensable information concerning all phases of this study.

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GENERAL DISCUSSION OF SPORES

Definition

"The term 'spore' is derived from 'spora', the Greek word for seed" (Guennel, 1952, p. 6). Spores are propagative bodies which represent a stage in the gametophyte generation of the plant reproductive cycle. There are two types of reproductive cycles (Figs. 1 and 2). Ancient free-sporing plants producing spores of different sizes are termed heterosporous. The male spores (microspores) are generally small and the female spores (megaspores) relatively large. Free-sporing plants whose male and female spores are the same size are called isosporous or homosporous (Schopf, 1938, p. 10). The spores of isosporous plants are the same size, generally small and serve both male and female functions. Most fossil spores represent only the resistant outer coat (exine) of the spore which did not lodge in a habitat suitable for development and growth (Schopf, 1957).

The term "microspore" has given rise to much controversy. The term has come to be applied to all spores of relatively small size. Not all small spores are microspores as the term refers only to the male spores of heterosporous plants. Many megaspores may be small enough to be called microspores and there certainly is no definite size boundary to separate the two. Other terminology has been proposed to correct this situation but this only succeeds in adding to an already unfortunately large nomenclature.

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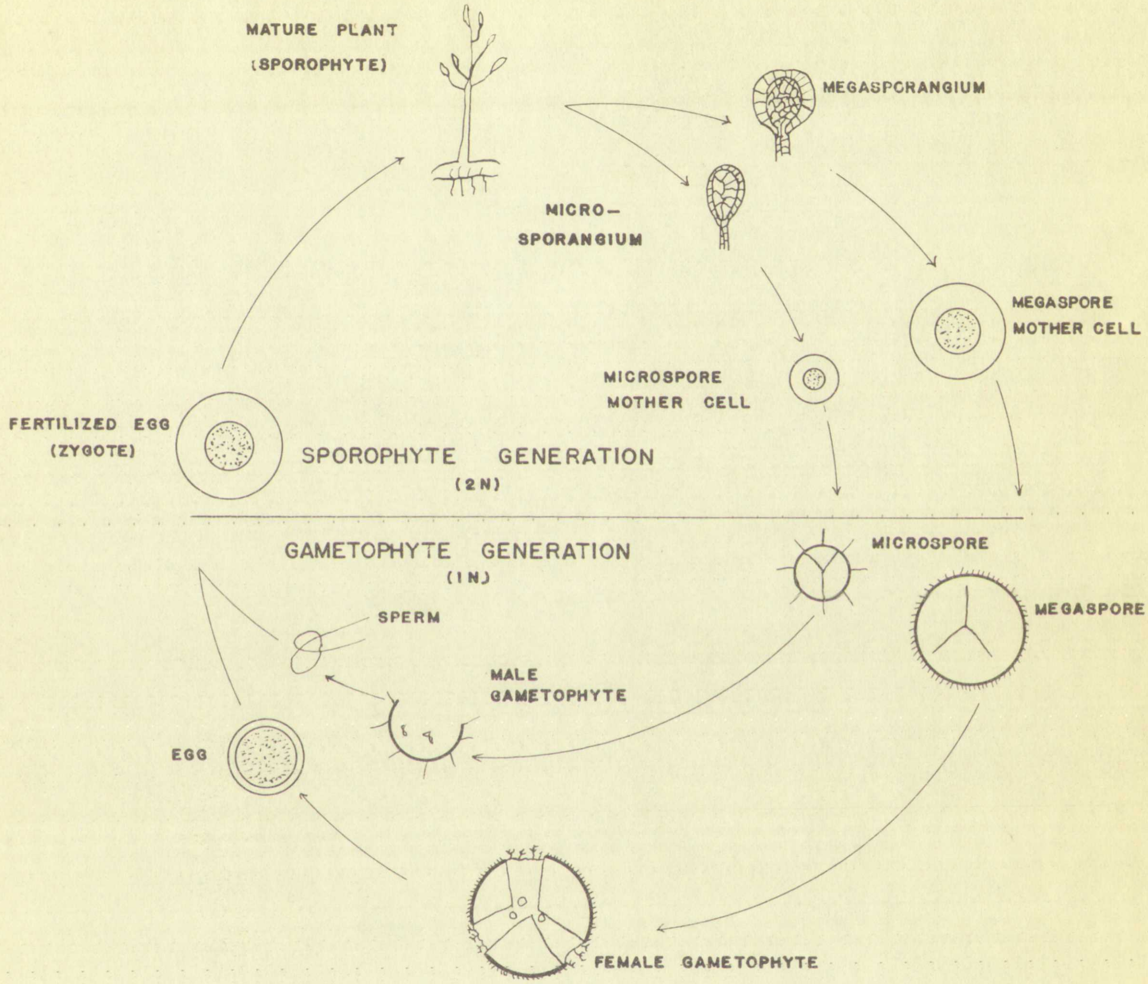

FIGURE 1 — LIFE CYCLE OF TYPICAL HETEROSPOROUS PTERIDOPHYTE

(FROM GUENNEL, 1952)

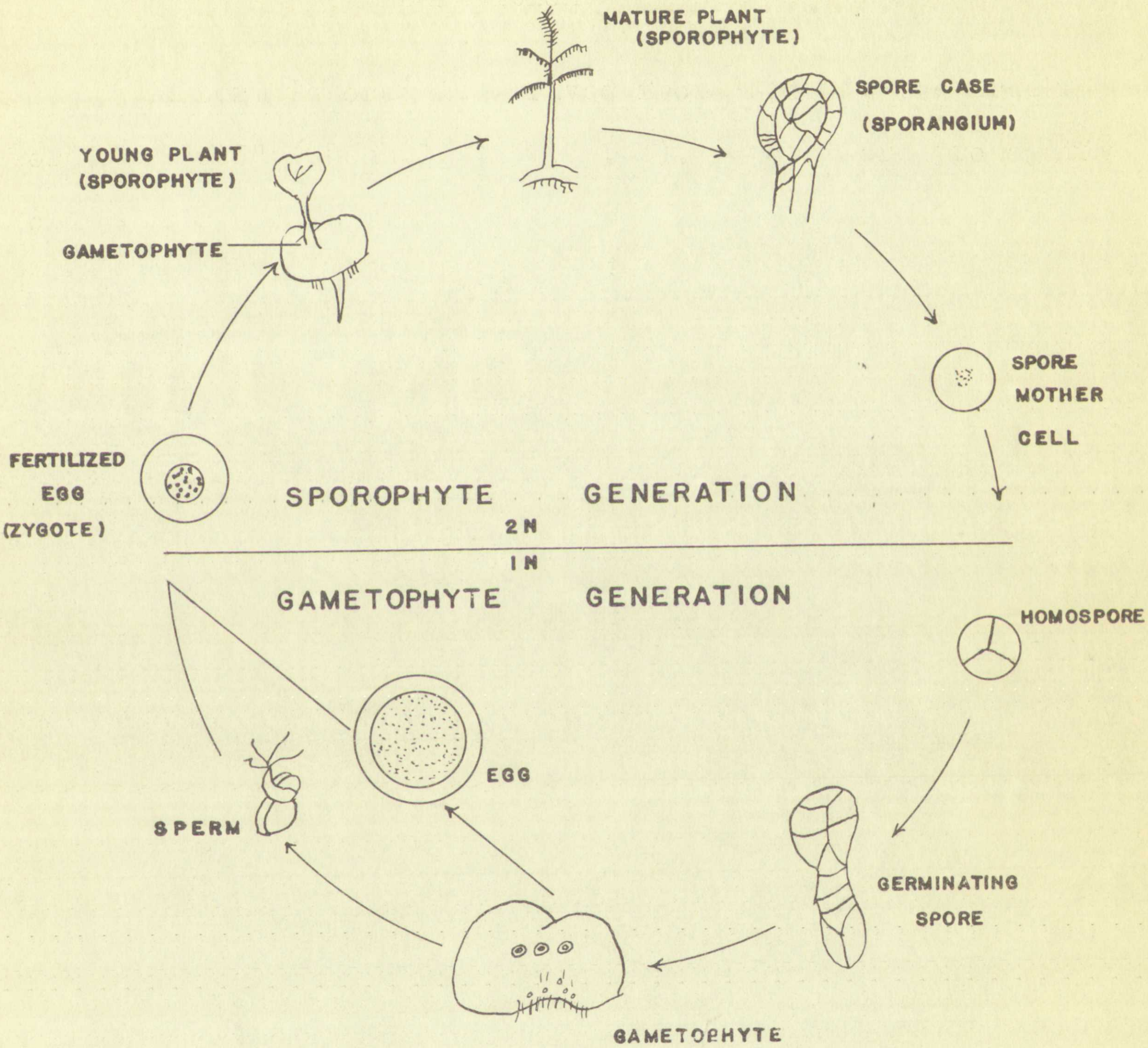

FIGURE 2 — LIFE CYCLE OF TYPICAL HOMOSPOROUS PTERIDOPHYTE

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Stratigraphic Importance

Spores are produced in tremendous numbers. "A single birch catkin may produce in excess of ten million pollen grains. The production of one hectare of wind-fertilized alder trees has been estimated at more than 2×10^{13} grains per annum" (Erdtmann, 1943). Because of their small size (10-100 microns usually) and their low density (ranging from 1.1 to 1.2), spores may be transported by the wind for great distances. Many forms have bladders and other types of appendages which are believed to be an aid to wind transport. Greenland peats contain pollen grains of pine and spruce that must have been carried at least 100 kilometers. Pollen grains from the United States have been found 700 kilometers east of Newfoundland (Erdtmann, 1954). Wind-dispersed spores usually attain a homogeneous mixture so that by analysis of the soil on which they rain a true estimate of the parent flora may be made. Other things being equal the greater number of spores is deposited on sediments nearest the place of origin. The few grains that may be carried a great distance are not important in statistical analyses but may serve as regional correlation markers. Most spores are allochthonous, and because of their unique means of dispersal transgress environments which might limit the distribution of other types of organisms that may be fossilized. Allochthonous spores may be used only to infer the ecologic conditions of the area from which they were derived.

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Certain spores such as those growing in low-lying swamps are not dispersed much beyond the area bearing the parent flora. These autochthonous spores are excellent ecologic indicators.

Spores occur in abundance from the Devonian to the Recent and thus may be used for correlation and ecologic studies during most of the geologic history that contains fossils.

Because of their small size, spores can be easily obtained from well cuttings when as little as one gram of rock is available. The maceration processes are fairly simple and, using the most advanced methods, spores may be extracted from their matrix and be ready for study in several hours.

There are some disadvantages of using spores for stratigraphic studies. Spores may not give a true representation of the flora because of differences in spore reproduction rates of the plants. Accessory plants could possibly produce many more spores than the dominant flora. The floating capacity of spores may be different. The smaller or bladdered forms may be carried further and thus give a false representation of the flora. Preferential preservation may be important. Thin-skinned spores may be more easily destroyed by salt water and other chemical reactions. Spores may be transported by water. Just as other fossils, they may be reworked from older sediments and redeposited. During certain geologic periods, correlations over great distances from north to south may be difficult to determine because of north-south climatic zones and matching floral changes.

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Principal Morphological Features

The following features can be readily noted or inferred from microscopic examination of fossil spores and are used for identification.

Shape: A spore is either radially or bilaterally symmetrical. The original shape is controlled by the nature of the division of the spore in the spore mother cells within the sporangium. "Some or all of the cells of the sporangium which are called spore-mother cells undergo either two successive divisions without wall formation to result in tetrahedral tetrads when the intervening walls do form, or tetragonal tetrads which are arranged in two planes by successive divisions with accompanying wall formation" (Cross, 1950, p. 5).

Form: Spores before compression may be spherical, subspherical, ovoid, subpyramidal, or polyhedral in form. After compression the outline of radially symmetrical spores may be circular, subcircular, triangular, or subtriangular. Bilaterally symmetrical spores when compressed are bean-shaped, oval, or elliptical in outline. Spores may be oriented preferentially after compression because of the original form. The spores will usually be compressed in a plane parallel to their longer axis.

Orientation: Radially symmetrical spores may be divided into proximal and distal hemispheres which may be irregular and of unequal size. The hemisphere bearing the trilete mark was originally the inward-facing hemisphere of the spore which

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Orientation: Radially symmetrical spores may be divided into proximal and distal hemispheres which may be irregular and of unequal size. The hemisphere towards the tetrad center was originally the inward-facing hemisphere of the spore which

was in contact with the three other spores of the tetrad. This hemisphere is called proximal. The outer hemisphere of the originally spherical spore is called distal. An axis from the center of the proximal hemisphere to the center of the distal hemisphere is the proximal-distal axis or polar axis. The axis perpendicular to the polar axis passing through the center point and connecting the points of maximum circumference is the equatorial axis. Bilaterally symmetrical spores which are oval or bean-shaped have a polar axis passing from the center of the straight or concave side (proximal and containing monolete mark) to the center of the periphery of the distal side. The longest dimension of the spore perpendicular to the polar axis is the equatorial axis.

Ornamentation: The exine of spores may be levigate (smooth) and featureless. Fortunately, most spore exines are ornamented principally on the external surface (Cross, 1950, p. 11). The external ornamentation may be granulose, papillate, punctate, reticulate, vermiculate, verrucose, rugose, lobate, striate, spinose, setaceous, or have processes and projections (Fig. 3). These various ornamentations may be dense, sparse, scattered or arranged in definite patterns, cover the entire exine or be confined to one part of the spore coat. Combinations of the various types of sculpturing may be present. Internally the spores may be sculptured, usually with granules or reticulations. Bladders are commonly ornamented internally. The bladders and flanges may have a different ornamentation from that of the spore body.

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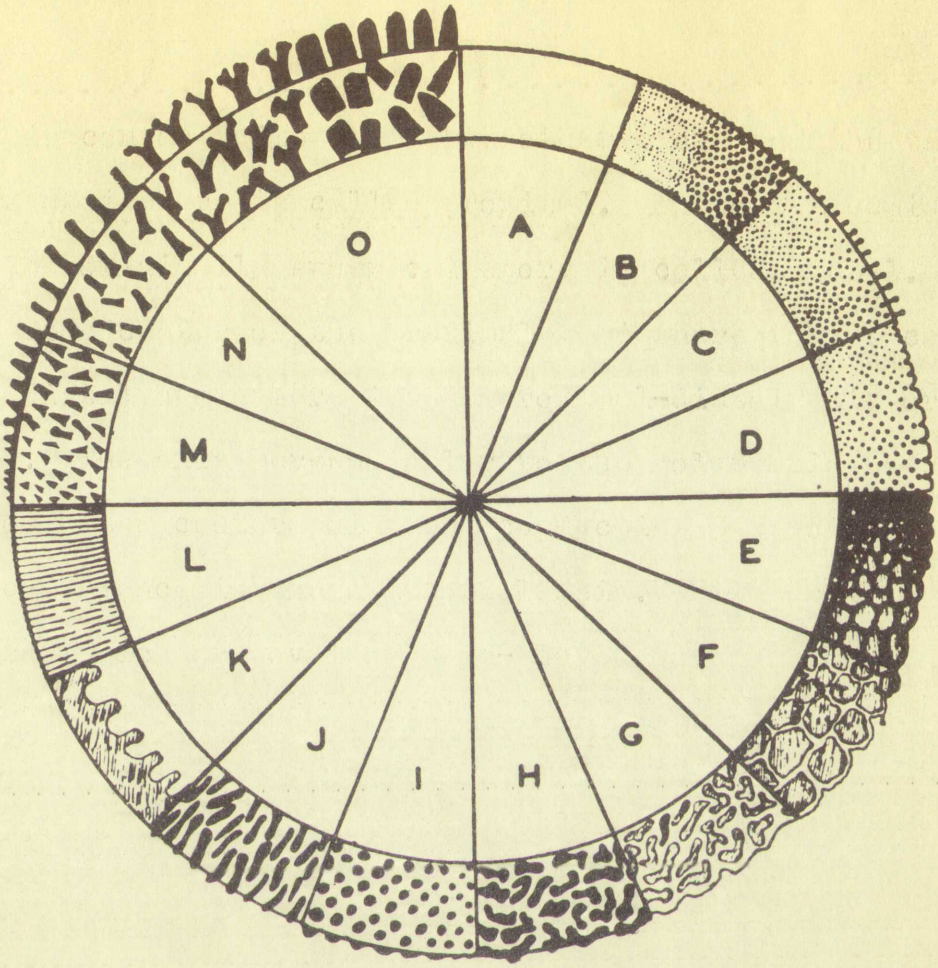

A. Levigate
B. Granulose
C. Papillate
D. Punctate
E. Punctate-Reticulate
F. Reticulate
G. Vermiculate
H. Obervermiculate
I. Verrucose
J. Rugose
K. Lobate
L. Striate
M. Spinose
N. Setaceous
O. Processes-Projections

FIGURE 3 – DIAGRAMMATIC DRAWING OF VARIOUS TYPES OF SPORE COAT ORNAMENTATION (FROM KOSANKE, 1950)

Size: Size is a factor very difficult to evaluate. Spores range from ten microns to about 25 millimeters in size (Cross, 1950). Spores have no fixed size and may vary according to environmental conditions in the sporangium and outside the sporangium. The size of the spores may very with the type of maceration process used. Except when absolutely necessary size should not be used as a sole criterion for identification. However, it may be necessary to determine and use average size ranges in identifying species that have no other distinguishing characteristics.

Germinal apparatus: The trilete mark or triradiate scar is usually quite distinct and evident. The rays or radii may extend only a short distance or completely across the proximal surface. The rays may be different in grains of the same species if the suture has split apart. Accessory upturned ridges along the sutures are called lips. These may be extremely large and prominent or barely discernible. The areas adjacent to the trilete rays may be pressed together in the original tetrad to give a slightly different color and texture at this location. These are called the contact or pyramic areas.

Presence of flanges and bladders: These zonal appendages immediately indicate the larger classification of the spore. The flange consists of tissue generally derived from an outgrowth from the surface of the proximal side at or near the contact area (Cross, 1950, p. 13). Flanges may have typical

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Germinal apparatus: The trilete mark on a tetrad-type spore is usually quite distinct and evident. The rays or radii may extend only a short distance or completely across the proximal surface. The rays may be different in grains of the same species if the suture has split apart. Sometimes enlarged ridges along the sutures are called lips. These may be extremely large and prominent or barely discernible. The areas adjacent to the trilete rays may be pressed together in the original tetrad to give a slightly different coloration or texture at this location. These are called the contact or pyramidic areas.

Presence of flanges and bladders: These zonal appendages immediately indicate the proper classification of the spores. The flange consists of thin [illegible] [illegible] out-growth from the surface of the proximal side or near the contact area (Cross, 1950, p. 41). Flanges may have [illegible]

ornamentation. Bladders are actual outgrowths of the spore wall and function as air sacs to aid wind dispersal or as protective structures against desiccation. The bladders are usually thinner than the spore body and vary in number, shape, and ornamentation.

METHODS OF STUDY

Laboratory Procedures

The purpose of processing rock samples for palynological study is to extract the spores from their matrix and to obtain a residue that contains the least extraneous material and the most well-preserved spores. The methods used depend upon the preference and experience of the investigator, the type of equipment available, and the purpose and time allowed for the study.

Rock samples should be from a fresh, and not from a badly weathered, surface. Spores are resistant to most chemical action but may be destroyed by oxidation over a long period of time.

Care should be taken to avoid contamination during processing. All equipment should be washed and rinsed with distilled water before use. Distilled water is used to dilute the chemicals, to clean the residues, and as a final rinse after washing equipment. Tap water may contain a variety of organisms and harmful salts. Contamination from the air may be minimized by covering the samples. A knowledge of modern pollen and spore types will eliminate any of these

ornamentation. Elaters are actual outgrowths of the spore wall and function as structures to aid wind dispersal of spores and as protective structures against desiccation. The elaters are usually thinner than the spore body and vary in number, shape, and ornamentation.

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from the spore count.

The chemicals used in processing are dangerous to the skin, eyes, and lungs. Hydrofluoric acid is especially dangerous, having a maximum allowable concentration in air of three parts per million (Sax, 1951). This acid may cause medically serious and very painful burns which appear immediately, or several hours later, depending on the concentration of the acid. All chemical work should be done in the fume hood. Long gauntlet type rubber gloves, a transparent plastic face mask, and a rubber apron should be worn. The antidotes to the chemicals used should be handy and if possible a shower should be located just outside the laboratory to permit immediate flooding of acid-burned skin. The centrifuge should be a type that is enclosed in a protective metal case or body.

Different lithologies require slightly different treatment. The following methods were used to process the Toronto rock samples.

Shales, sandstones, clays, carbonaceous limestone:

1. Five grams of the rock are broken into approximately 1/16 inch pieces or smaller with a steel mortar and pestle.
2. The samples are placed in plastic beakers, covered with dilute hydrochloric acid (2 parts water to 1 part 37.5% HCl) and allowed to stand until chemical action ceases. Additional acid may be added if needed. The supernatant liquid is decanted, water added, the samples centrifuged, and the liquid decanted. All centrifuging

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Different lithologies require slightly different treatment. The following methods were used to process the Toronto rock samples.

Shales, sandstones, clays, carbonaceous limestones

1. Five grams of the rock are broken into approximately 1/4 inch pieces or smaller with a steel mortar and pestle.
2. The samples are placed in plastic beakers, covered with dilute hydrochloric acid (1 part water to 1 part 37.5% HCl) and allowed to stand until chemical action ceases. Additional acid may be added if needed. The supernatant liquid is decanted, water added, the sample centrifuged, and the liquid decanted. All centrifuging

is done for three minutes at 1800 revolutions per minute. The calcium ion is decanted in the liquid. This prevents the formation of relatively insoluble calcium fluoride crystals during treatment with hydrofluoric acid.

3. The samples are placed in plastic beakers, covered with 49% hydrofluoric acid and allowed to stand 48 to 72 hours. A pound of acid is sufficient for 6 to 8 samples. Hydrofluoric acid is extremely volatile and more acid may be added during the digestion period. The samples are agitated several times. The acid is decanted, water added, and the residue allowed to settle by gravity. The liquid is decanted. Hydrofluoric acid dissolves the silica and siliceous compounds.

4. The residues are placed in glass centrifuge tubes (which are used in all the following steps), covered with dilute hydrochloric acid, and heated in a boiling water bath for several minutes on an electric hotplate. The liquid will usually turn green. The samples are centrifuged, decanted, acid added, and heated again. The process is repeated until the liquid is clear. The hydrochloric acid clears the residues of complex silico-fluoride gels that form during treatment with the hydrofluoric acid. The gels increase the bulk of the residue and obscure the spores on the slides.

5. The residues are covered with dilute nitric acid (1 part water to 1 part 69.8% HNO_3) and heated in a boiling water bath for ten minutes. Prolonged heating will bleach the

spores. The residues are centrifuged, decanted, water added, and centrifuged again. This continues until the liquid remains clear. The nitric acid oxidizes and partially dissolves the humic material present.

6. Four pellets of potassium hydroxide are added. The residues are heated in a boiling water bath for thirty minutes. The samples are centrifuged, decanted, water added, and centrifuged again. This continues until the liquid remains clear. The centrifuging may have to be repeated 10 to 15 times before the liquid remains clear as lesser concentrations of potassium hydroxide are still effective in dispersing the humic material.

7. The residues are stored in water in small glass bottles. A drop of mercuric chloride is added to prevent growth of fungus spores.

Limestones:

Pure and nearly pure limestones are processed using the first two steps outlined above. Further treatment resulted in the complete disappearance of the residue. Because steps 3 through 6 were not used, microforaminifera were found in several residues. These fossils were not the chitinous linings but were composed of the broken-up mineral matter.

Coals:

No one fixed procedure can be recommended for the various ranks of coal. The maceration process depends on the rank of the coal and the degree of weathering.

1. The coal is powdered in a mortar and pestle.

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Coals:

No one fixed procedure can be recommended for the various ranks of coal. The maceration process depends on the rank of the coal and the degree of weathering.

1. The coal is powdered in a mortar and pestle.

2. Dilute nitric acid is added and the residue is heated (not boiled) for thirty minutes. The residues are centrifuged, decanted, water added, and centrifuged again. This continues until the liquid is clear.
3. 8 to 10 potassium hydroxide pellets are added and the residue warmed at 60° C. for 12 hours. The residues are centrifuged, decanted, water added, and centrifuged again. This continues until the liquid remains clear.
4. Steps 2 and 3 may have to be repeated several times.

Slide Preparation

The equipment listed is used for preparing slides for palynological investigation.

Glass slides: size 25 x 75 mm. Thickness 1 mm. ± 0.05 mm.

Glass cover slides: size 22 x 30 mm. Thinness No. 0.

Toothpicks, eyedroppers, small brush.

Microscopic mounting medium; glycerine jelly.

Constant temperature slide warmer.

General Electric clear varnish No. 1212.

Slides, cover glasses, and the glycerine jelly are placed on a slide warmer which maintains a constant temperature of 60° C. A drop of glycerine jelly is placed on the slide and spread evenly over a small area with a toothpick. The residue in the storage bottle is concentrated by decanting most of the liquid. The residue is agitated to insure a homogeneous mixture. A drop of the residue is placed on the jelly, spread, and allowed to stand until the excess water has evaporated.

The cover glass is placed over the mixture. The slide is labelled and allowed to remain on the warmer 24 to 48 hours so that the mixture loses all moisture and air bubbles and becomes evenly spread. General Electric varnish is painted around the edges of the cover glass to prevent the glycerine jelly from dehydrating. The slides are now permanent and may be stacked and stored.

Microscopic Examination

The microscopic investigation was done with a Leitz Labolux microscope having binocular eyepieces, a four-objective nosepiece, and a graduated mechanical stage. Scanning was done with 10X oculars and a 10X objective. Measuring and identification was done with the 10X graduated ocular and 40X apochromatic objective. In some cases the 70X objective or the oil immersion lens was necessary for critical study.

A minimum of two slides were examined for each sample and all identifiable spores were counted. Where enough spores were present for a statistical percentage count, a minimum of 70 spores were counted.

Photomicrography

Spore pictures were taken using the Leitz Labolux microscope equipped with a monocular tube, a two-diaphragm condenser, a substage lamp, a 6X ocular, and a 40X apochromatic objective. This equipment was used with a Leica

The cover glass is placed over the mixture. The slide is labelled and allowed to remain on the warming plate so that the mixture loses all moisture and air bubbles and becomes evenly spread. General Electric varnish is painted around the edges of the cover glass to prevent the glycerine jelly from dehydrating. The slides are now permanent and may be stacked and stored.

Microscopic Examination

The microscopic investigation was done with a Leitz Labolux microscope having binocular eyepieces, a four-objective nosepiece, and a graduated mechanical stage. Scanning was done with 10X oculars and a 20X objective. Measuring and identification was done with the 15X graduated ocular and 40X apochromatic objective. In some cases the 90X objective or the oil immersion lens was necessary for critical study.

A minimum of two slides were examined for each sample and all identifiable spores were counted. Where enough spores were present for a statistical percentage count, a minimum of 200 spores were counted.

Photomicrography

Spore pictures were taken with a Leitz Lab-lux microscope equipped with a monocular tube, a two-diaphragm condenser, a substage lamp, a 5X ocular, and a 40X apochromatic objective. The equipment was used with a Leitz

35 mm. camera mounted on an adjustable stand and bellows. Kodak Panatomic X film was used.

LOCATION OF AREA AND DESCRIPTION OF LITHOLOGIC UNITS

The Toronto limestone interval crops out in a linear belt trending north-northeast across eastern Kansas, extending southward a short distance into Oklahoma and northward into Missouri, Iowa, and Nebraska. The location of the outcrop localities and shallow-hole cores used in this study are shown in Figure 4.

The Toronto limestone is the lower limestone member of the Oread megacyclothem of the Shawnee group, Virgilian (Cisco) series, Pennsylvanian system (Moore, 1949). The Toronto limestone when considered with the immediately underlying coal, underclay, and shale units may be considered a cyclothem making up a part of the larger Oread megacyclothem.

The Shawnee group includes beds from the base of the Oread limestone to the top of the Topeka limestone. This group is a well-defined assemblage of strata in which thick limestones and cyclic sedimentation are prominent features. Four formations of the Shawnee group are made up largely of limestone. The three intervening formations are made up chiefly of shale and sandstone. This alternation of clastics and calcareous deposits reflects major cyclic oscillations of sedimentation which furnish evidence of shifting of strand lines in Virgilian seas (Moore, 1949). The Shawnee group consists of the following formations starting with the oldest:

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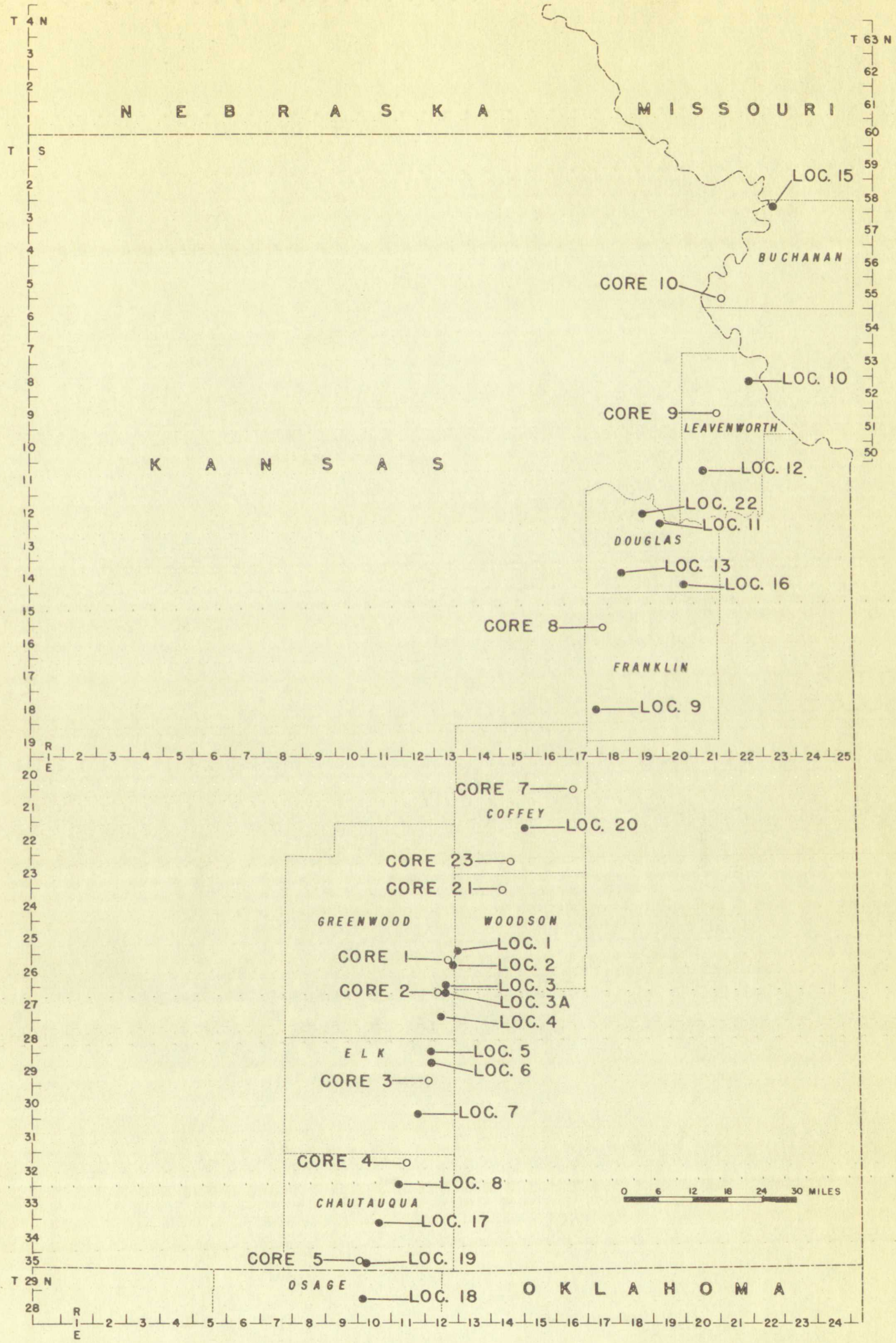

FIGURE 4 — LOCATION MAP OF OUTCROP LOCALITIES AND CORES

Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, Topeka limestone (Fig. 5).

The Oread limestone or formation has a total thickness of 45 feet at the type area at Lawrence, Kansas. The Lawrence shale lies conformably below the Oread and the Kanwaka shale lies conformably above (Moore, 1949).

The Oread limestone contains the following members starting with the oldest: Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, Kereford limestone (Fig. 5).

The Toronto limestone has a maximum thickness of 16 feet and is a richly fossiliferous limestone divided near the middle by a thin shale unit. It is distinguished by its brown color on the weathered outcrop and its massive character. Locally it is sandy. Fossils are numerous locally and include fusulinids, brachiopods, bryozoans, crinoid stems, and mollusks (Moore, 1949).

The lower shale member of the Oread limestone, called the Snyderville, is a bluish to grayish, and in part red, shale which occurs directly above the Toronto limestone (Moore, 1949).

The middle member of the Oread limestone is the Leavenworth limestone. It is rarely more than 1 to 2 feet thick but has distinctive physical characteristics and crops out for several hundred miles. The Leavenworth is a single massive

Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, Topeka limestone (Fig. 5).

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The Oread limestone contains the following members starting with the oldest: Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, Kereford limestone (Fig. 5).

The Toronto limestone has a maximum thickness of 15 feet and is a highly fossiliferous limestone divided near the middle by a thin shale unit. It is distinguished by its brown color on the weathered outcrop and its massive character. Locally it is sandy. Fossils are numerous locally and include fusulinids, brachiopods, bryozoans, crinoid stems, and mollusks (Moore, 1949).

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Wabaunsee group

Shawnee group

- Topeka limestone
- Calhoun shale
- Deer Creek limestone
- Tecumseh shale
- Lecompton limestone
- Kanwaka shale
    - Stull shale
    - Clay Creek limestone
    - Jackson Park shale
- Oread limestone
    - Kereford limestone
    - Heumader shale
    - Plattsmouth limestone
    - Heebner shale
    - Leavenworth limestone
    - Snyderville shale
    - Toronto limestone

Douglas group

- Lawrence shale (part only

Oread megacyclothem (Stull shale through Lawrence shale)

Figure 5 - The Pennsylvanian system, Virgilian series, Shawnee group of Kansas (after Moore et al., 1951).

layer which is uniformly fine-grained, dense, dark bluish in color and is characterized by the prevalence of vertical jointing.

Rock samples from the Toronto limestone and a few from the Snyderville and Leavenworth units were examined for spores.

PALEOGEOGRAPHY

The interior of North America during the Pennsylvanian Period was bounded on the east by Appalachia and on the south by Llanoria which were important sources of detritus. Thick sediments were deposited in the Appalachian and Ouachita geosynclines. The Cincinnati arch and the Ozark dome were positive areas of the interior of the continent. These positive areas never stood high above the neighboring basins, were never rapidly eroded, never contributed large amounts of sediments, and were frequently submerged (Weller, 1957).

The interior lowlands were probably not directly connected with the Atlantic or the Gulf areas during the Pennsylvanian Period. The Midcontinent negative area or shelf was bounded by the Ancestral Rocky Mountains on the west, the Amarillo-Wichita-Arbuckle Mountains on the south, the Ouachita geosyncline on the southeast, the Ozark dome on the east, and to the north lay the ancient stable positive areas of Siouxia and the Canadian Shield. Figure 6 gives the possible paleogeography of the Midcontinent region during a maximum marine stage such as during the deposition of the Toronto limestone.

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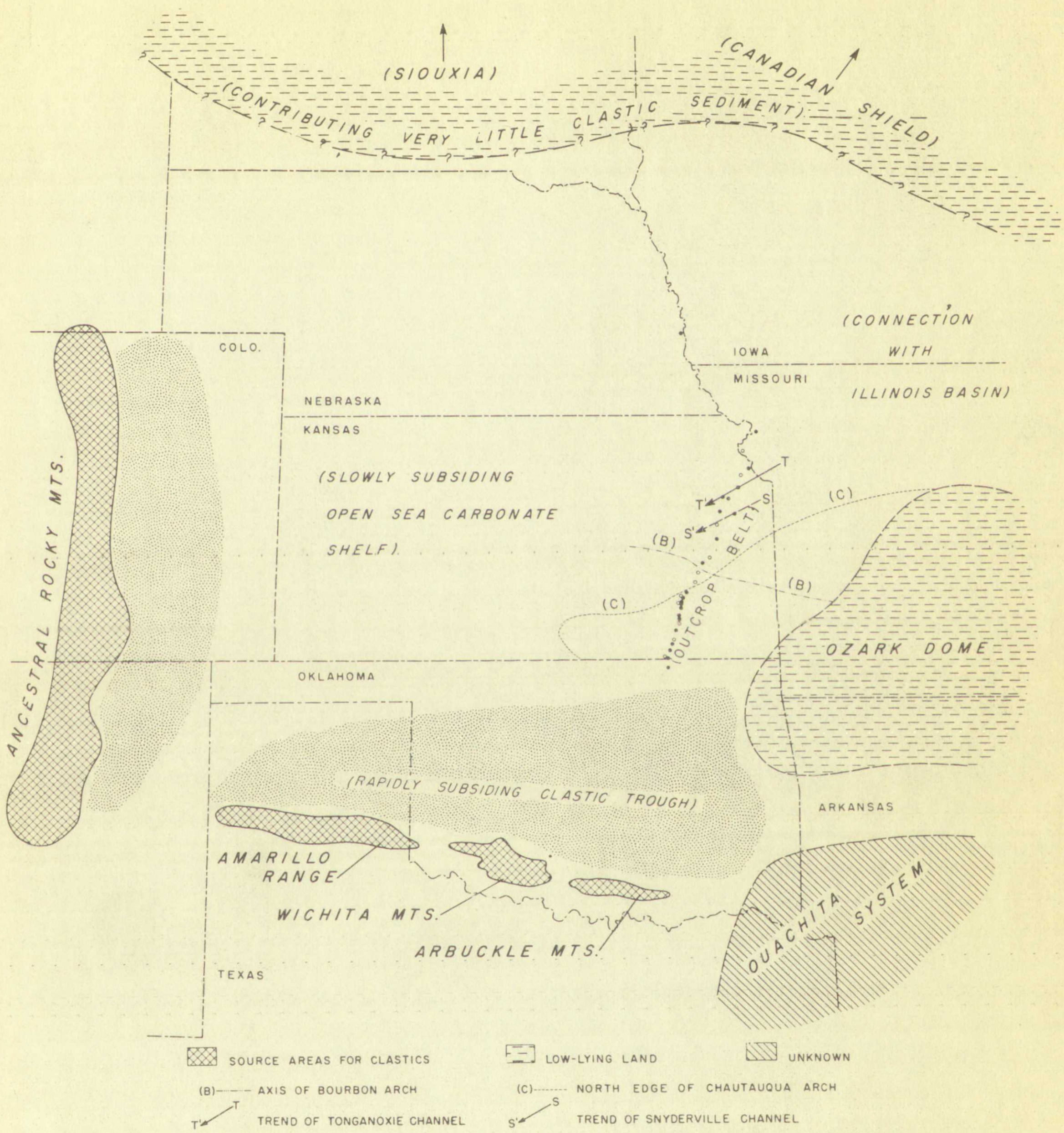

FIGURE 6 — PALEOGEOGRAPHY OF MIDCONTINENT REGION

IN LATE PENNSYLVANIAN

ANALYSIS OF DATA AND CONCLUSIONS

A total of 367 Toronto limestone, shale, and coal samples were digested and examined for spore content. Spore occurrences are scattered and sparse with only 65 samples of coal, shale, and several sandstones being fossiliferous and only a few of these being fossiliferous enough to give a statistical analysis. The limestone was virtually barren. If large amounts of limestone were digested a few spores might have been found but this was not feasible.

Twenty-four genera of spores containing a total of 64 species were found to be present in the Toronto sequence. The genera present include: Leiotriletes, Punctatisporites, Calamospora, Granulatisporites, Cyclogranisporites, Planisporites, Lophotriletes, Acanthotriletes, Pustulatisporites, Raistrickia, Reticulatisporites, Microreticulatisporites, Convolutispora, Triquitrites, Lycospora, Cadiospora, Simozonotriletes, Densosporites, Cirratriradites, Laevigatosporites, Monoletes, Endosporites, Florinites, Illinites.

Microforaminifera were present at several intervals. These were planispirally coiled forms approximately 250 microns in diameter. They resemble the genus Ammodiscus.

Coal

Most of the spores found in the coal are autochthonous. The three dominant genera in the coal, Endosporites, Laevigatosporites, and Calamospora are common in other Pennsylvanian coals of the United States. The genus Laevigatosporites, is

ANALYSIS OF DATA AND CONCLUSIONS

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Coal

Most of the spores found in the coal are [illegible]. The three dominant genera in the coal, [illegible], [illegible]sporites, and [illegible] are common [illegible] coals of the United States. [illegible]

known to occur in almost every coal of Pennsylvanian age that has been studied in Europe and the United States. The genus Calamospora is present in almost every coal bed in Illinois (Kosanke, 1950, p. 27).

The coal intervals are similar in spore genera percentages with the exception of locality 6 (chart showing the percentages of spore genera). At locality 6, Endosporites is not a dominant genus and Cadiospora occurs as a large percentage. Core 3 has a larger percentage of Cyclogranisporites and Planisporites present because the sample consisted of shale and coal. The slight variation in the dominant genera percentages at localities 1, 2, 3A, 9, 13, and core 3 is to be expected. In adjacent rock samples from localities 1A and 1B the percentages vary slightly. Localities 1A and 1B were combined and appear as locality 1 on the percentage chart of spore genera (Chart in pocket). Disregarding slight differences in sampling, the lateral variation may be due to several reasons. Slight differences in ecology and different rates in the regular succession of plants may cause normal variations in a climax vegetation. Plants invade an area in a rather definite order. Because of the short time involved a uniform climax vegetation may not have been attained over the entire area. There were probably small areas of slightly different plants in a forest about to attain uniformity. The normal variations in climax flora and too short a time to attain a climax vegetation could cause the slight variance in spore percentages in the coal intervals.

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The coal intervals are similar in spore genera percentages with the exception of locality 6 (chart showing the percentages of spore genera). At locality 6, *Lycospora* is not a dominant genus and *Calamospora* occurs in a large percentage. Core 3 has a larger percentage of *Punctatisporites* and *Planisporites* present because the sample consisted of shale and coal. The slight variation in the dominant genera percentages at localities 1, 2, 9, 10, 11, and core 2 is to be expected. In adjacent rock samples from localities 13 and 18 the percentages vary slightly. Localities 14 and 17 were combined and appear as locality 1 on the percentage chart of spore genera (Chart in pocket). Disregarding slight differences in sampling, the lateral variation may be due to several reasons. Slight differences in ecology and different rates in the regular succession of plants may cause lateral variations in a climax vegetation. Plant invasion of an area is a more or less definite order. Because of the short time involved a uniform climax vegetation may not have been attained over the entire area. There were probably small areas of slightly different plants in a forest about to attain uniformity. The normal variations in climax flora and the short time to attain a climax vegetation could cause the slight variations in spore percentages in the coal intervals.

Some of the coal intervals such as localities 9 and 13 are much lower stratigraphically and are probably not in the Toronto sequence. Similar floras occur in these beds because of recurrent ecologic conditions.

A fairly good picture of the flora and environment that produced the great Pennsylvanian coal measures can be drawn on the basis of many previous spore studies and studies of larger plant remains. In general, very uniform climatic conditions prevailed during the time in which the coal floras thrived. The climate was probably not tropical but uniform over the swamp areas and similar to the warm temperate rain forest of today. Rainfall could have been moderate or heavy but the humidity was high. Storms and violent winds were probably rare judging from the shallow root systems of the flora. The terrain on which the coal formed in the Toronto sequence would have to have been low-lying.

Clastic Sediments

Many of the spores in the shales and sandstones were allochthonous, being blown in from the adjacent land areas. Since more spores will settle nearer the source and most of the spore-bearing shales occur in the southern part of the traverse, a land source for the parent flora was probably located to the south.

The prepollen genus Illinites occurs in sufficient numbers to give a percentage count in core 5 (as much as 7%) and several grains are present in residues from cores 3, 4,

Some of the coal laminae—such as localities 7 and 12—are much lower stratigraphically and are probably not in the Toronto sequence. Similar floras occur in these beds because of recurrent ecologic conditions.

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Many of the spores in the shales and sandstones were allochthonous, being blown in from the adjacent coal areas. Since more spores will settle near the source and more of the spore-bearing samples occur in the southern part of the traverses, a land source for the parent flora was probably located to the south.

The prevailing genus Lycospora occurs in sufficient numbers to give a representative count in every sample except [illegible] and several genera are present in relative abundance [illegible] [illegible]

and 5 which are in the southern part of the traverse. "*Pityosporites* has been considered indicative of xerophytic upland flora. The similarity of *Pityosporites* and *Illinites* suggests that the latter may be associated with xerophytic climatic conditions" (Kosanke, 1950, p. 51). *Illinites* is a bladdered type and may be wind transported for quite some distance. From the scattered occurrence at the noted intervals a land area with more xeric conditions may be postulated at some distance to the south.

In the Toronto sequence the genus *Florinites* is abundant and characteristic of the non-marine shale (Snyderville) above the limestone and is also present in the non-marine shales above the coal and below the limestone. Schopf, Wilson, and Bentall (1944, p. 57) suggest that the genus *Florinites* is related to the gymnospermic groups that were partially restricted to upland habitats.

Spore Assemblages

There appear to be definite spore genera and assemblages characteristic of the several environmental units of the Toronto sequence. *Lycospora* and *Cadiospora* are dominant in the lower non-marine shale and *Florinites* in the upper non-marine shale. *Cadiospora*, *Endosporites*, and *Calamospora* are the dominant genera of the underclay. The coal is characterized by *Endosporites*, *Laevigatosporites*, and *Calamospora*. The transitional shale contains *Cyclogranisporites* as the dominant

genus. *Endosporites* and *Planisporites* are most numerous in the marine shale. These generalizations are shown on Figure 7 and the Chart (in pocket) and except for the lower non-marine shale, where *Lycospora* makes its only dominant appearance, are based on similar spore assemblages in two or more occurrences of the same environment. The spores listed as dominant usually account for 25 percent or more of the total at some place in the core or locality.

Correlations

The scarcity of data and the short time interval involved hamper regional correlations but several limited correlations may be noted on the percentage chart of spore genera (Chart in pocket).

The genus *Triquitrites* occurs sparingly in some of the intervals and is considered to be a good index fossil of the Pennsylvanian Period.

The genus *Densosporites* was previously thought to occur not higher than the Des Moines although Hoffmeister, Staplin, and Malloy (1955) report it from rocks of questionable Virgilian age. A few specimens of *Densosporites* occur in the Toronto sequence which is of Virgilian age.

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Correlations

The scarcity of data and the short time interval involved hamper regional correlations but several limited correlations may be noted in the percentage chart of spore genera (Chart in pocket).

The genus <u>Triquitrites</u> occurs sporadically in some of the intervals and is considered to be a good index fossil of the Pennsylvanian Period.

The genus <u>Densosporites</u> was previously thought to occur not higher than the Des Moines although Hoffmeister, Staplin, and Malloy (1955) report it from rocks of questionable Virgilian age. A few specimens of <u>Densosporites</u> occur in the Toronto sequence which is of Virgilian age.

Environment	Dominant spores	Associated spores	Occurrences								
			*L-1	L-2	1-3A	L-6	L-7	L-9	L-13	**C-3	C-5
Non-marine shale	*Florinites*	*Calamospora* *Illinites*								X	X
Toronto limestone	Barren	Barren									
Marine Shale	*Endosporites* *Planisporites*	*Calamospora*	X							X	
Transitional (brackish water ?) shale	*Cyclogranisporites*	*Calamospora* Florinites				X	X			X	
Coal	*Endosporites* *Laevigatosporites* *Calamospora*	*Cyclogranisporites*	X	X	X			X	X	X	
Underclay	*Cadiospora* *Endosporites* *Calamospora*	*Triquitrites*				X			X		
Non-marine shale	*Cadiospora* *Lycospora*	*Calamospora* *Laevigatosporites*	X	X							

*L- locality
**C- core

Figure 7 - Environmental occurrence of dominant and associated spores in the several samples studied.

SYSTEMATIC DESCRIPTIONS

For the purpose of this investigation, valid genera arranged in the outline of Potonié and Kremp (1954) were used. Genera not included in this outline were used when spores found were not considered to fit the outline. The species are numbered on the basis of the order in which they are found. The first spore species encountered is called species 1, the second, species 2, etc. Once numbered, the species always retains the same number.

Sporites H. Potonié 1893

Division Triletes Reinsch 1881

Subdivision Laevigati (Bennie and Kidston 1881)

Genus *Leiotriletes* (Naumova 1937) Potonie and Kremp 1954

Spores trilete, radial, subtriangular. Margin between radii usually concave but may be straight. Surface levigate, outline smooth. Trilete rays distinct and of varying lengths.

Leiotriletes sp. 1

Pl. 1, fig. 1

Trilete, radial, subtriangular. Trilete rays distinct, relatively long (1/2 radius). Apices rounded, sides between radii straight or slightly convex. Levigate. Size 48 microns.

Leiotriletes sp. 2

Pl. 1, fig. 2

Trilete, radial, subtriangular. Trilete rays distinct with fairly prominent lips. Sides gently concave. Apices smooth. Size 25-36 microns.

SYSTEMATIC DESCRIPTIONS

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Leiotriletes sp. 2

Pl. 1, fig. 2

Trilete, radial, subtriangular. Trilete rays distinct with fairly prominent lips. Sides slightly concave. Exine smooth. Size 25-35 microns.

Leiotriletes sp. 7

Pl. 1, fig. 3

Trilete, radial, subtriangular. Sides convex, one straight. Very heavy lips. Levigate. Trilete mark prominent. Size 48 microns.

Leiotriletes sp. 8

Pl. 1, fig. 4

Trilete, radial, subtriangular. Sides very sharply concave. Levigate. Size 36 microns.

Genus Punctatisporites (Ibrahim 1933) Potonié and Kremp 1954

Spores trilete, radial, circular. Spore coat finely to coarsely punctate. Trilete rays of variable length. Contact areas absent. Original spherical or subspherical shape indicated by lack of proximal-distal orientation when compressed.

Punctatisporites sp. 10

Pl. 1, fig. 5

Trilete, radial, circular. Trilete rays distinct. Exine evenly and finely punctate. Size 60 microns.

Punctatisporites sp. 12

Pl. 1, fig. 6

Trilete, radial, subcircular. Trilete rays indistinct. Punctations large, evenly distributed, farther apart than width of the pits. Outline shows punctations. Size 40-50 microns.

Genus Calamospora Schopf, Wilson, and Bentall 1944

Spores trilete, radial, circular to subcircular. Exine levigate and usually very thin. Pyramic area often present and may have a different texture than the rest of the exine. Originally spherical. Trilete rays may extend 1/4 to 2/3 the distance to the margin. Intense folding is characteristic of the genus.

<u>Calamospora</u> sp. 19

Pl. 1, fig. 7

Trilete, radial, circular to subcircular. Trilete rays distinct, relatively small. Small dark pyramic area present. Commonly folded. Exine thin. Size 72-80 microns.

<u>Calamospora</u> sp. 20

Pl. 1, fig. 8

Trilete, radial, subcircular. Trilete mark distinct. Levigate. Size 17-36 microns.

<u>Calamospora</u> sp. 21

Pl. 1, fig. 9

Trilete, radial, circular to subcircular. Trilete rays prominent extending almost to margin. Levigate. Spore coat heavy, almost opaque, reddish-brown. Usually not folded. Size 78-90 microns.

<u>Calamospora</u> sp. 23

Pl. 1, fig. 10

Trilete, radial, circular to subcircular. Thin, distinct, relatively long trilete mark. Levigate. Commonly folded. Exine thin. Size 56-63 microns.

Spores trilete, radial, circular to subcircular. Exine levigate and usually very thin. Margin area often thickened and may have a different texture than the rest of the exine. Originally spherical. Trilete rays [illegible] extend [illegible] to 2/3 the distance to the margin. Common folding is characteristic of the genus.

<u>Calamospora</u> sp. 19

Pl. 1, fig. [illegible]

Trilete, radial, circular to subcircular. Trilete rays distinct, relatively small. Rough [illegible] present. Commonly folded. Exine thin. Size 75-80 microns.

<u>Calamospora</u> sp. 20

Pl. 1, fig. [illegible]

Trilete, radial, subcircular. Trilete rays distinct. Levigate. Size 17-[illegible] microns.

<u>Calamospora</u> sp. 21

Pl. 1, figs. [illegible]

Trilete, radial, circular to subcircular. Trilete rays prominent extending almost to margin. Levigate. Spore coat heavy, almost opaque, reddish-brown. Usually not folded. Size 75-90 microns.

<u>Calamospora</u> sp. 22

Pl. 1, fig. 10

Trilete, radial, circular to subcircular. Tri. distinct, relatively long trilete rays. Levigate. Commonly folded. Exine thin. Size [illegible] microns.

Calamospora sp. 24

Trilete, radial, subcircular. Trilete rays long and distinct. Fairly thick coat, reddish brown. Levigate. Size 93-105 microns.

Genus Granulatisporites (Ibrahim 1933) Potonié and Kremp 1954

Spores trilete, radial, subtriangular to triangular in transverse plane. Spore coat densely granulose with granules fine or coarse, circular and evenly distributed. Trilete rays relatively long. Sides either convex or slightly concave and the apices rounded.

Granulatisporites sp. 25

Pl. 1, fig. 11

Trilete, radial, subtriangular. Trilete rays indistinct. Sides gently convex. Very finely granulose. Size 29 microns.

Granulatisporites sp. 26

Pl. 1, fig. 12

Trilete, radial, subtriangular. Trilete rays not prominent and 1/2 length of radii. Sides gently convex. Moderately coarse granules. Granules evenly distributed and fairly dense. Size 21-26 microns.

Genus Cyclogranisporites Potonié and Kremp 1954

Spores trilete, radial, circular to subcircular. Spore coat densely covered with granules. Granules small and spherical to large and slightly irregular in shape (verrucose).

Cyclogranisporites sp. 31

Pl. 2, fig. 1

[illegible] sp. 24

Trilete, radial, subcircular. Trilete rays long and distinct. Fairly thick coat, reddish brown. Laevigate. Size [illegible] microns.

Genus *Granulatisporites* (Ibrahim 1933) Potonie and Kremp 1954

Spores trilete, radial, subtriangular to triangular in transverse plane. Spore coat [illegible] granulose with granules fine or coarse, circular and evenly distributed. Trilete rays relatively long. Sides either concave or slightly convex and the apices rounded.

Granulatisporites sp. [illegible]

Pl. [illegible], fig. [illegible]

Trilete, radial, subtriangular. Trilete rays indistinct. Sides gently convex. Very finely granulose. Size [illegible] microns.

Granulatisporites sp. 2[illegible]

Pl. [illegible], fig. 12

Trilete, radial, subtriangular. Trilete rays not distinct and 1/2 length of radii. Sides gently convex. [illegible] coarse granules. Granules evenly distributed and fairly dense. Size 21-26 microns.

Genus *Cyclogranisporites* Potonie and Kremp 1954

Spores trilete, radial, circular to subcircular. Spore coat densely covered with granules. Granules small and spherical to large and slightly irregular in shape (verrucate).

Cyclogranisporites sp. 31

Pl. [illegible], fig. [illegible]

Trilete, radial, circular to subcircular. Trilete rays distinct to indistinct. Rays extend more than 1/2 the radius. Finely granulose. Size 40-50 microns.

<u>Cyclogranisporites</u> sp. 32

Pl. 2, fig. 2

Trilete, radial, circular to subcircular. Trilete rays prominent, indistinct (suture line not easily discernible). Coarsely granulose. Size 29-38 microns.

<u>Cyclogranisporites</u> sp. 35

Pl. 2, fig. 3

Trilete, radial, circular to subcircular. Trilete rays usually obscured by ornamentation. Densely verrucose. Outline irregular. Size 62-80 microns.

<u>Cyclogranisporites</u> sp. 37

Trilete (?), circular to subcircular. Very coarsely and densely verrucose. Size 76-82 microns.

Suite Apiculati (Bennie and Kidston) Potonié and Kremp 1954

Genus <u>Planisporites</u> (Knox 1950) Potonié and Kremp 1954

Spores trilete, radial, circular to subcircular. Exine evenly and densely covered with small cones or spines. Trilete rays relatively long.

<u>Planisporites</u> sp. 39

Pl. 2, fig. 4

Trilete, radial, subcircular. Trilete rays indistinct. Spore coat has very small spines. Size 25-27 microns.

Trilete, radial, circular to [illegible]. Trilete rays [illegible]
tinct to indistinct. [illegible]
Finely granulose. Size 40-53 microns.

[illegible] sp. 12

Pl. [illegible], fig. [illegible]

Trilete, radial, circular to subcircular. Trilete rays
prominent. Indistinct [illegible] (sometimes totally indiscernible). [illegible]
Coarsely granulose. Size 29-38 microns.

[illegible] sp. 15

Pl. [illegible], fig. [illegible]

Trilete, radial, circular to subcircular. Trilete rays [illegible]
obscured by ornamentation. Densely verrucose. [illegible]
irregular. Size 52-60 microns.

[illegible] sp. 17

Trilete (?), circular to subcircular. [illegible]
densely verrucose. [illegible] microns.

Suite Apiculati (Bennie and Kidston) Potonie and Kremp [illegible]

Genus [illegible] [illegible] Potonie and Kremp [illegible]

Spores trilete, radial, circular to subcircular. [illegible]
evenly and densely covered with small cones or spines. Trilete
rays relatively long.

[illegible] sp. [illegible]

Pl. [illegible], fig. [illegible]

Trilete, radial, circular [illegible]. [illegible]
coat has very small spines. [illegible] microns.

Planisporites sp. 41

Pl. 2, fig. 5

Trilete, radial, circular to subcircular. Trilete rays distinct and relatively long. Finely spinose, spines evenly and densely spread. Size 36-43 microns.

Planisporites sp. 42

Pl. 2, fig. 6

Trilete, radial, circular to subcircular. Trilete rays usually indistinct, relatively long. Evenly covered with small spines. Spines prominent on periphery. Not as densely spinose as *Planisporites* sp. 41. Size 54-72 microns.

Genus *Lophotriletes* (Naumova 1937) Potonié and Kremp 1954

Spores trilete, radial, subtriangular. Spore coat covered with small cones whose basal diameter can equal their height. Base of cones may touch. Edges concave to convex.

Lophotriletes sp. 44

Pl. 2, fig. 7

Trilete, radial, subtriangular. Trilete distinct and extend almost to apices. Exine evenly covered with small cones which are easily discernible on periphery. Sides gently concave. Size 26-42 microns.

Genus *Acanthotriletes* (Naumova 1937) Potonié and Kremp 1954

Spores trilete, radial, subtriangular. Spore coat crowded with attenuated spines which are longer than twice their diameter. Attenuation of spines and sharper tips distinguish this genus from *Lophotriletes* and *Apiculatisporites*.

<u>Planisporites</u> sp. 41

Pl. 2, fig. 5

Triletes, radial, circular to subcircular. Trilete rays distinct and relatively long. Finely spinose, spines evenly and densely spaced. Size 30-45 microns.

<u>Planisporites</u> sp. 42

Pl. 2, fig. 6

Triletes, radial, circular to subcircular. Trilete rays usually indistinct, relatively long. Evenly covered with small spines. Spines prominent on periphery. Not as densely spinose as <u>Planisporites</u> sp. 41. Size 27-32 microns.

Genus <u>Lophotriletes</u> (Naumova 1937) Potonie and Kremp 1954. Spores trilete, radial, subtriangular. Spore coat covered with small cones whose basal diameter can equal their height. Base of cones may touch. Edges concave to convex.

<u>Lophotriletes</u> sp. 43

Pl. 2, fig. 7

Triletes, radial, subtriangular. Trilete distinct and extend almost to apices. Exine evenly covered with small cones which are easily discernible on periphery. Edges gently concave. Size 26-42 microns.

Genus <u>Acanthotriletes</u> (Naumova 1937) Potonie and Kremp 1954. Spores trilete, radial, subtriangular. Spore coat covered with attenuated spines which are longer than their basal diameter. Attenuation of spines and sharper edges distinguish this genus from <u>Lophotriletes</u> and <u>Apiculatisporites</u>.

Acanthotriletes sp. 46

Pl. 2, fig. 8

Trilete, radial, subtriangular. Trilete rays indistinct. Sides range from concave to convex. Exine densely covered with attenuated spines. Size 26-30 microns.

Acanthotriletes sp. 47

Pl. 2, fig. 9

Trilete, radial, subcircular to subtriangular. Trilete rays obscure. Spore coat densely covered with attenuated spines 3.6 microns long. Size 53 microns.

Acanthotriletes sp. 290

Pl. 2, fig. 10

Trilete, radial, subtriangular. Trilete rays strong, extending 3/4 or more of the distance to the periphery. Sides gently convex. Long attenuated (10 microns) sparsely scattered spines. Size 66 microns.

Genus Pustulatisporites Potonié and Kremp 1954

Spores trilete, radial, subtriangular to subcircular. Spore coat bears scattered granules, warts, or short cones. Warts may be small to very large. Trilete rays relatively long.

Pustulatisporites sp. 67

Pl. 2, fig. 11

Trilete, radial, subcircular. Trilete mark obscure. Very sparsely scattered cones. Size 19-24 microns.

[illegible] sp. [illegible]

Pl. [illegible], Fig. [illegible]

Trilete, radial, subtriangular. Trilete rays indistinct. Sides range from concave to convex. [illegible] densely covered with attenuated spines. Size [illegible] microns.

Acanthotriletes sp. [illegible]

Pl. 2, Fig. [illegible]

Trilete, radial, subcircular to subtriangular. Trilete rays obscure. Spore coat densely covered with attenuated spines 3.6 microns long. Size 55 microns.

Acanthotriletes sp. 290

Pl. 2, Fig. 10

Trilete, radial, subtriangular. Trilete rays distinct, extending 3/4 or more of the distance to the periphery. Sides gently convex. Long attenuated (10 microns) sparsely scattered spines. Size 65 microns.

Genus *Pustulatisporites* Potonié and Kremp 1954

Spores trilete, radial, subtriangular to subcircular. Spore coat bears scattered granules, warts, or short cones. Spores may be small to very large. Trilete rays relatively long.

Pustulatisporites sp. 39

Pl. 2, Fig. 11

Trilete, radial, subcircular. Trilete mark obscure. Very sparsely scattered cones. Size [illegible] microns.

<u>Pustulatisporites</u> sp. 70

Trilete, radial, subtriangular. Trilete mark indistinct, 1/2 length of radius. Spore coat covered with scattered small cones. Size 31-37 microns.

<u>Pustulatisporites</u> sp. 72

Pl. 3, fig. 1

Trilete, radial, subtriangular. Trilete rays usually obscure, relatively long. Exine thick and covered with large warts that form prominent projections on periphery. Warts unevenly distributed. Sides concave to convex. Size 46-60 microns.

<u>Pustulatisporites</u> sp. 74

Pl. 3, fig. 2

Trilete, radial, subtriangular. Trilete rays extend almost to edge of spore. Exine covered with scattered cones that are thick and irregular in outline. Sides concave to convex. Size 26-31 microns.

<u>Pustulatisporites</u> sp. 84

Pl. 3, fig. 3

Trilete, radial, subcircular. Trilete rays relatively short and indistinct. Exine thick, dark colored, covered with large warts which show as small projections on periphery. Size 46-51 microns.

Genus <u>Raistrickia</u> (Schopf, Wilson, and Bentall 1944) Potonié and Kremp 1954

[illegible] sp. 70

Trilete, radial, subtriangular. Trilete rays indistinct, 1/2 length of radius. Spore coat covered with contorted small cones. Size 51-57 microns.

[illegible] sp. 70

Pl. [illegible], fig. 1

Trilete, radial, subtriangular. Trilete rays usually obscure, relatively long. Exine thick and covered with large warts that form prominent projections on periphery. Warts unevenly distributed. Sides concave to convex. Size [illegible] microns.

[illegible] sp. [illegible]

Pl. [illegible], fig. [illegible]

Trilete, radial, subtriangular. Trilete rays extend almost to edge of spore. Exine covered with [illegible] cones that are thick and irregular in outline. Sides concave to convex. Size 25-31 microns.

[illegible] sp. [illegible]

Pl. [illegible], fig. [illegible]

Trilete, radial, subtriangular. Trilete rays relatively short and indistinct. Exine thick, [illegible], covered with large warts which show as small projections on periphery. Size 46-51 microns.

Genus [illegible] ([illegible], Wilson, and [illegible] [illegible]) [illegible] and [illegible] 19[illegible]

Spores trilete, radial, circular to subcircular. Original shape probably subspherical. Spore coat densely covered with large blunt processes that are often partate or broadened at their ends. Trilete rays variable in length.

Raistrickia sp. 53

Pl. 3, fig. 4

Trilete, radial, subcircular. Trilete rays usually very indistinct. Exine densely covered with short blunt projections which are prominent at periphery. Projection diameters approximately equal the height. Size 39-65 microns.

Raistrickia sp. 58

Pl. 3, fig. 5

Trilete, radial, subcircular. Trilete rays very indistinct. Exine covered with projections 10 to 12 microns long. Projections have blunt tips and same width over-all. Size 50 microns.

Suite Muronati Potonié and Kremp 1954

Genus Reticulatisporites (Ibrahim 1933) Potonié and Kremp 1954

Spores weakly trilete or show no indication of being trilete. Radial, circular to subcircular in proximal view. Originally spherical or oblate. Exine covered with reticulate network (reticulum). Lumina bordered by high muri. Muri regular or irregular in design. Lumina greater than 6 microns in diameter. Spore coat may appear thinner at periphery and thicker at inner part.

Spores trilete, radial, circular to subcircular. Original shape probably subspherical. Spore coat densely covered with large blunt processes that are [illegible] at their ends. Trilete rays variable in length.

<u>[illegible]</u> sp. B

Pl. [illegible], Fig. [illegible]

Trilete, radial, subcircular. Trilete rays usually [illegible] distinct. Exine densely covered with short blunt projections which are prominent at [illegible]. Projection diameters approximately equal the height. Size [illegible] microns.

<u>[illegible]</u> sp. C

Pl. 1, Fig. [illegible]

Trilete, radial, subcircular. Trilete rays very indistinct. Exine covered with projections 10 to 15 microns long. Projections have blunt tips and same width overall. Size 50 microns.

Suite Murornati Potonie and Kremp 1954

Genus <u>Reticulatisporites</u> (Ibrahim 1933) Potonie and Kremp 1954

Spores weakly trilete or show no indication of being trilete. Radial, circular to subcircular in proximal view. Originally spherical or oblate. Exine covered with reticulate network (reticulum). Lumina bordered by high muri. Muri regular or irregular in design. Lumina greater than [illegible] microns in diameter. Spore coat may appear [illegible] at periphery and thicker at inner part.

<u>Reticulatisporites</u> sp. 96

Pl. 3, fig. 6

Trilete, radial, subcircular to circular. Periphery thinner, middle thicker and darker. Lumina 10 to 12 microns in diameter. Muri fairly high and thick. Trilete rays may not be found in most instances. Size 72-87 microns.

Genus <u>Microreticulatisporites</u> (Knox 1950) Potonié and Kremp 1954

Spores trilete, radial, circular to subcircular. Exine extra-reticulate with small lumina that do not exceed 6 microns in diameter. Muri are imperfect and vary in height. Trilete rays usually difficult to distinguish. Diameter of lumina distinguishes this genus from <u>Reticulatisporites</u>.

<u>Microreticulatisporites</u> sp. 102

Trilete, radial, circular to subcircular. Trilete mark very difficult to discern. Lumina average 4.9 microns across. Muri rounded to six sided. Periphery of spores appears to be thinner than polar region. Size 20-46 microns.

Genus <u>Convolutispora</u> Hoffmeister, Staplin, and Malloy 1955

Spores trilete, radial, circular to subcircular to subtriangular. Probable original spherical shape indicated by lack of orientation preference. Ornamentation closely packed overlapping anastomosing vermiculate or obervermiculate ridge-like processes often causing a convoluted or coarsely reticulate-punctate appearance. Trilete rays short and may have distinct lips, often obscured by the overlapping ridges.

Reticulatisporites sp. [illegible]

(Pl. 3, Fig. [illegible])

Trilete, radial, subcircular to circular. Periphery thinner, middle thicker and darker. (Muri 10 to 12 microns in diameter). Muri fairly high and thick. Trilete rays may not be found in most instances. Size [illegible] microns.

Genus Microreticulatisporites (Knox 1950) Potonié and Kremp 1954

Spores trilete, radial, circular to subtriangular, exine micro-reticulate with small lumina that are not more than 6 microns in diameter. Muri are imperfect and vary in height. Trilete rays usually difficult to distinguish. Diameter of lumina distinguishes this genus from Reticulatisporites.

Microreticulatisporites sp. 100

Trilete, radial, circular to subcircular. Trilete and rays difficult to discern. Lumina average 1.5 microns across. Muri rounded to six sided. Thickness of exine appears to be thinner than polar region. Size 40-45 microns.

Genus Convolutispora Hoffmeister, Staplin, and Malloy 1955

Spores trilete, radial, circular to subcircular to subtriangular. Probable original spherical shape indicated by lack of orientation preference. Ornamentation consists of broad overlapping anastomosing vermiculate or convolute ridge-like processes often causing a convoluted or pseudo-reticulate-punctate appearance. Trilete rays short and may have distinct lips, often obscured by the convoluting ridges.

Spore coat thick, lacking conspicuous folding. Closely packed anastomosing ridges distinguish this genus.

Convolutispora sp. 105

Pl. 3, fig. 7

Trilete, radial, circular to subcircular. Trilete mark indistinct because of ornamentation. Spore coat vermiculate so that vermicules give appearance of being concentrically arranged. Vermicules project slightly at periphery of spore. Vermicules fairly coarse and dense. Size 24-48 microns.

Convolutispora sp. 107

Pl. 3, figs. 8, 9

Trilete, radial, subtriangular. Trilete rays indistinct because of ornamentation. Sides slightly convex. Vermicules form ridges at their bases that give convoluted, reticulate-punctate appearance. Folding absent. Size 37-48 microns.

Convolutispora sp. 109

Pl. 4, figs. 1, 2

Trilete, radial, subtriangular. Trilete mark distinct, relatively long extending 3/4 distance to periphery or more. Sides slightly convex. Outline irregular. Anastomosing ridges appear convoluted. Size 53 microns.

Convolutispora sp. 114

Pl. 4, fig. 3

Trilete, radial, subtriangular. Trilete ray indistinct but relatively long. Sides nearly straight. Ridges heavy, prominent and fluted in places. Size 36-60 microns.

Spore coat thick, lacking conspicuous folding. Closely packed anastomosing ridges distinguish this genus.

Convolutispora sp. 107

Pl. 3, fig. 7

Trilete, radial, circular to subcircular. Trilete rays indistinct because of ornamentation. Spore coat vermiculate so that vermicules give appearance of being concentrically arranged. Vermicules project slightly at periphery of spore. Vermicules fairly coarse and dense. Size 40-45 microns.

Convolutispora sp. 108

Pl. 3, figs. 8, 9

Trilete, radial, subtriangular. Trilete rays indistinct because of ornamentation. Sides slightly convex. Vermicules form ridges at their bases that give convoluted, reticulate-punctate appearance. Folding absent. Size 37-42 microns.

Convolutispora sp. 109

Pl. 4, figs. 1, 2

Trilete, radial, subtriangular. Trilete rays distinct, relatively long extending 3/4 distance to periphery of spore. Sides slightly convex. Outline irregular. Anastomosing ridges appear convoluted. Size 41 microns.

Convolutispora sp. 110

Pl. 4, fig. 3

Trilete, radial, subtriangular. Trilete rays indistinct but relatively long. Sides nearly straight. Ridges heavy, prominent and fluted in places. Size 39-41 microns.

Convolutispora sp. 312

Pl. 4, fig. 4

Trilete, radial, subtriangular. Trilete rays distinct extending 3/4 distance to apices. Sides gently concave. Ornamentation is a combination of convolute-punctate. Punctations medium size, evenly and densely distributed. Outline shows punctations. Size 36 microns.

Sporites H. Potonié 1893

Division Zonales (Bennie and Kidston 1886)

Subdivision Auritotriletes Potonié and Kremp 1954

Suite Auriculati (Schopf 1938) Potonié and Kremp 1954

Genus Triquitrites (Wilson and Coe 1940) Potonié and Kremp 1954

Spores trilete, subtriangular to triangular, auriculate. Trilete rays distinct and usually extend nearly to margin of the spore. Spores usually compressed in good proximal-distal orientation. Folding rare. Interradial margins vary from concave to convex. Exine variously ornamented. Auriculae thickened and darker than the rest of the exine. Auriculae may be levigate, spinose or warty.

Triquitrites sp. 117

Trilete, radial, subtriangular. Trilete rays distinct and greater then 1/2 radii. Sides gently concave. Spore coat granulose(?). Auriculae thin and not strongly developed. Size 35-37 microns.

[illegible] n. sp.

Pl. [illegible]

Trilete, radial, [illegible]. Trilete rays [illegible], extending 3/4 distance to [illegible]. [illegible] Ornamentation [illegible] [illegible], tations medium size, [illegible] shows punctations. Size [illegible].

Sporites [illegible] 1946

Division Zonales (Bennie and Kidston) [illegible]

Subdivision Auritotriletes [illegible]

Suite Auriculati (Schopf) 1938 [illegible]

Genus Triquitrites (Wilson and Coe) 1940, [illegible]

Spores trilete, subtriangular to triangular, [illegible]. Trilete rays distinct and [illegible] extending [illegible] the spore. Spores usually compressed in [illegible] orientation. [illegible] concave to convex. [illegible] thickened and darker than the rest of the exine, [illegible] may be levigate, spinose or [illegible].

[illegible]

Trilete, radial, [illegible] greater than 1/2 radius. [illegible] granulose(?). [illegible]

Size 35-37 [illegible]

<u>Triquitrites</u> sp. 119

Trilete, radial, subtriangular. Trilete rays indistinct to distinct and relatively long. Sides concave. Auriculae project prominently but are thin. Levigate. Size 27-29 microns.

<u>Triquitrites</u> sp. 124

Pl. 4, fig. 5

Trilete, radial, subtriangular. Trilete rays may have darker pyramic area. Sides slightly convex. Auriculae very prominent and dark. Levigate. Size 34-38 microns.

<u>Triquitrites</u> sp. 125

Pl. 4, fig. 6

Trilete, radial, subtriangular. Trilete rays distinct, relatively long. Sides straight to slightly convex. Auriculae prominent and contain attenuated spines. Size 52-54 microns.

<u>Triquitrites</u> sp. 127

Pl. 4, fig. 7

Trilete, radial, subtriangular. Trilete rays strong, distinct, 1/2 length of radii. Auriculae well developed, dark. Exine levigate. Trilete rays have well-developed lips. Sides gently concave. Size 30-34 microns.

<u>Triquitrites</u> sp. 128

Pl. 4, fig. 8

Trilete, radial, subtriangular. Trilete mark indistinct.

Triquitrites sp. 115

Trilete, radial, subtriangular. Trilete rays [illegible] distinct and relatively long. Sides concave. Auriculae project prominently but are thin, levigate. Size 27-29 microns.

Triquitrites sp. 124

Pl. 4, fig. 5

Trilete, radial, subtriangular. Trilete rays may have darker pyramic area. Sides slightly convex. Auriculae very prominent and dark. Levigate. Size 34-35 microns.

Triquitrites sp. 125

Pl. 4, fig. 6

Trilete, radial, subtriangular. Trilete rays distinct, relatively long. Sides straight to slightly convex. Auriculae prominent and contain attenuated spines. Size 52-54 microns.

Triquitrites sp. 127

Pl. 4, fig. 7

Trilete, radial, subtriangular. Trilete rays strong, distinct, 1/2 length of radii. Auriculae well developed, dark. Exine levigate. Trilete rays have well-developed lips. Sides gently concave. Size 30-34 microns.

Triquitrites sp. 128

Pl. 4, fig. 8

Trilete, radial, subtriangular. Trilete mark indistinct.

Sides gently convex. Auriculae distinct, knobby. Exine has very scattered small warts. Size 26 microns.

Subdivision Zonotriletes (Waltz 1935)

Suite Cingulati Potonié and Klaus 1954 (?)

Genus Lycospora (Schopf, Wilson, and Bentall 1944) Potonié and Kremp 1954

Spores trilete, radial, round to subtriangular in transverse plane. Trilete rays distinct and generally extend almost to margin of spore coat. Spore has a distinct cingulum which appears as a cuneiform ring in cross section. Spore coat is levigate, granulose or minutely spinose.

Lycospora sp. 138

Pl. 4, fig. 9

Trilete, radial, subtriangular to subcircular. Trilete mark prominent and extends to cingulum. Trilete rays may have lips. Small spines fairly dense in center and on cingulum. Cingulum well developed and moderately wide. Sides convex. Size 47-55 microns.

Lycospora sp. 140

Pl. 4, fig. 10

Trilete, radial, circular to subcircular. Trilete mark strong, distinct, extending to cingulum. Cingulum well developed and relatively thin. Finely granulose. Size 29-40 microns.

Sides gently convex. Auriculate distinct, [illegible] very scattered small [illegible]. Size [illegible] microns.

Subdivision Zonotriletes (Waltz 1935)

Suite Cingulati Potonié and Klaus 1954

Genus *Lycospora* (Schopf, Wilson, and Bentall 1944) Potonié and Kremp 1954

Spores trilete, radial, round to subtriangular in transverse plane. Trilete rays distinct and generally extend almost to margin of spore coat. Spore has a distinct cingulum which appears as a cuneiform ring in cross section. Spore coat is levigate, granulose or minutely [illegible].

Lycospora sp. 139

Pl. 4, Fig. 9

Trilete, radial, subtriangular to subcircular. Trilete mark prominent and extends to cingulum. Trilete rays may have lips. Small spines fairly dense in center and on cingulum. Cingulum well developed and moderately wide. Sides convex. Size 47-55 microns.

Lycospora sp. 140

Pl. 4, Fig. 10

Trilete, radial, circular to subcircular. Trilete mark strong, distinct, extending to cingulum. Cingulum well developed and relatively wide. Finely granulose. Size 29-40 microns.

Genus *Cadiospora* Kosanke 1950

Spores trilete, radial, circular to subcircular. Trilete rays divide at termini to form arcuate ridges. Cingulum well developed, wide, and dark. Lips thick and prominent. Spore coat thick. Spore coat may be levigate, granulose or finely spinose.

Cadiospora sp. 141

Pl. 4, fig. 11

Trilete, radial, circular to subcircular. Trilete rays strongly developed with wide lips. Rays diverge at termini into arcuate ridge. Spore coat levigate. Cingulum strong, dark, wide. Size 85-99 microns.

Cadiospora sp. 144

Pl. 4, fig. 12;

Pl. 5, fig. 1

Trilete, radial, subcircular. Trilete rays strong with extremely prominent lips. Cingulum dark and broad. Very large granules on exine. Size 100-112 microns.

Genus *Simozonotriletes* (Naumova 1937) Potonié and Kremp 1954

Spores trilete, radial, subtriangular. Trilete rays extremely sharp reaching more or less to the cingulum. Cingulum broad and smooth, broader at corners. Exine levigate or very finely granulose.

Simozonotriletes sp. 149

Pl. 5, fig. 2

Genus [illegible]

Spores trilete, radial, circular to subcircular. Trilete rays divide at terminal to form arcuate ridges. Cingulum well developed, wide, and dark. Rays thick and prominent. Spore coat thick. Spore coat may be laevigate, granulose or finely spinose.

[illegible] sp. 140

Pl. 4, fig. 11

Trilete, radial, circular to subcircular. Trilete rays strongly developed with wide lips. Rays divide at terminal into arcuate ridges. Spore coat laevigate. Cingulum extremely dark, wide. Size 85-99 microns.

[illegible] sp. 145

Pl. 4, fig. 12

Pl. 5, fig. 1

Trilete, radial, subcircular. Trilete rays raised with extremely prominent lips. Cingulum dark and broad. Very large granules on exine. Size 100-112 microns.

Genus [illegible] (Naumova 1937) Potonie and Kremp 1954

Spores trilete, radial, subtriangular. Trilete rays extremely sharp reaching more or less to the cingulum. Cingulum broad and smooth, broader at corners. Exine laevigate or very finely granulose.

[illegible] sp. 149

Pl. 5, fig. 2

Trilete, radial, subtriangular. Trilete rays very sharp extending almost to cingulum. Cingulum is broad, smooth, and slightly thicker at apices. Sides slightly concave to slightly convex. Levigate. Size 35-37 microns.

Simozonotriletes sp. 152

Pl. 5, fig. 3

Trilete, radial, subtriangular. Trilete mark very sharp extending almost to cingulum. Cingulum 6 microns wide. Sides slightly convex. Levigate. Size 56-58 microns.

Genus Densosporites (Berry 1937) Potonié and Kremp 1954

Spores trilete, radial, subtriangular. Trilete mark indistinct to prominent often extending into cingulum. Exine thin in polar regions becoming much thicker toward the equator forming a massive, dark, sometimes opaque cingulum. Spore coat and cingulum may be levigate, granulose, or spinose. Spore coat always characterized by thin proximal-distal portion and much thicker equatorial portion.

Densosporites sp. 157

Pl. 5, fig. 4

Trilete, radial, subtriangular. Trilete mark distinct to indistinct, extending into cingulum. Cingulum 22-26 microns wide. Exine levigate over-all. Sides gently convex. Size 44-46 microns.

Trilete, radial, subtriangular. Trilete rays very sharp ex-
tending almost to cingulum. Cingulum [illegible] ...
slightly thicker at [illegible]. Sides slightly concave to
slightly convex. Levigate. Size 5-38 microns.

Densosporites sp. 156

Pl. 5, Fig. [illegible]

Trilete, radial, subtriangular. Trilete rays very sharp
extending almost to cingulum. Cingulum [illegible] wide. Sides
slightly convex. Levigate. Size [illegible] microns.

Genus Densosporites (Berry) 1937 Potonie and Kremp 1954

Spores trilete, radial, subtriangular. Trilete mark indistinct
to prominent often extending into cingulum. Exine thin in
polar regions becoming much thicker toward the equator forming
a massive, dark, sometimes opaque cingulum. Spore coat and
cingulum may be levigate, granulose or spinose. Spore coat
always characterized by thin proximal-distal portion and much
thicker equatorial portion.

Densosporites sp. 157

Pl. 5, Fig. [illegible]

Trilete, radial, subtriangular. Trilete rays distinct to in-
distinct, extending into cingulum. Cingulum [illegible] microns
wide. Exine levigate over-all. [illegible]. Size
44-46 microns.

Suite Zonati Potonie and Kremp 1954

Genus *Cirratriradites* Wilson and Coe 1940

Spores trilete, radial, circular to subtriangular, flanged. Trilete rays strong often extending into flange. Flange usually relatively broad, frequently radially striate and is definitely thinner and more translucent than the spore body. Spore body may be spinose or granulose.

Cirratriradites sp. 161

Pl. 5, fig. 5

Trilete, radial, circular to subcircular. Trilete rays distinct extending into flange. Finely granulose over-all. Flange translucent, light colored and sometimes radially striated. Size of central body 55-60 microns, over-all size 84-88 microns.

Division Monoletes Ibrahim 1933

Subdivision Azonomonoletes Luber 1935

Genus *Laevigatosporites* Ibrahim 1933

Spores monolete, bilateral, bean-shaped to oval. Suture always monolete and linear, 1/2 to 3/4 the length of the spore, may be inconspicuous if it coincides with edge of compressed spore. Ornamentation always levigate. Folding may occur.

Laevigatosporites sp. 163

Pl. 5, fig. 6

Monolete, bilateral, bean-shaped. Exine thin. Size 17 x 24 microns (average).

Suite Zonati Potonié and Kremp 1954

Genus Cirratriradites Wilson and Coe 1940

Spores trilete, radial, circular to subtriangular, flanged. Trilete rays strong often extending into flange. Flange usually relatively broad, frequently radially sculpted and is definitely thinner and more translucent than the spore body. Spore body may be punctate or granulose.

Cirratriradites sp. 101

Pl. 5, Fig. [illegible]

Trilete, radial, circular to subcircular. Trilete rays distinct extending into flange. Finely granulose over all. Flange translucent, light colored and sometimes radially striated. Size of central body 55-60 microns, over-all size 84-88 microns.

Division Monoletes Ibrahim 1933

Subdivision Azonomonoletes Luber 1935

Genus Laevigatosporites Ibrahim 1933

Spores monolete, bilateral, bean-shaped to oval. Suture always monolete and linear, 1/2 to 3/4 the length of the spore, may be inconspicuous if it coincides with edge of compressed spore. Ornamentation always laevigate. Folds may occur.

Laevigatosporites sp. 103

Pl. 5, Fig. 6

Monolete, bilateral, bean-shaped. Suture [illegible]. Size [illegible] microns (average).

Laevigatosporites sp. 166

Pl. 5, fig. 7

Monolete, bilateral, oval to bean-shaped. Levigate. May be folded. Size 38 x 70 microns (average).

Genus *Monoletes* (Ibrahim 1933) Schopf, Wilson, and Bentall 1944

Spores monolete, bilateral, elliptical to rounded lenticular in outline as viewed from proximal side. Relatively large--100 microns to 1/2 millimeter in length. Usually minutely granulose but may appear smooth at low magnification. When closed the suture is very narrow linear groove, lip area may be slightly raised. Most noteworthy diagnostic feature is slight angular deflection of suture line near the middle. This may be hard to detect but is thought to be universally present.

Monoletes sp. 231

Pl. 5, figs. 8, 9

Monolete, bilateral, elliptical. Levigate. Size 158 x 275 microns (average)

Pollenites R. Potonié 1931

Division Saccites Erdtmann 1947

Subdivision Monosaccites Chitaley 1951

Genus *Endosporites* Wilson and Coe 1940

Spores trilete, radial, elliptical in transverse plane, round to oval or elliptical or slightly triangular in axial plane. Trilete rays distinct and commonly extend to periphery of body and thickened continuations from them may extend into the bladder. Lips may be upraised and definite. Bladder is

Laevigatosporites sp. 1?

Pl. 5, Fig. 3

Monolete, bilateral, oval to bean-shaped, levigate. May be folded. Size 35 x 50 microns (average).

Genus Monoletes (Ibrahim 1933) Schopf, Wilson, and Bentall 1944

Spores monolete, bilateral, elliptical to rounded lenticular in outline as viewed from proximal side. Relatively large-- 100 microns to 1/2 millimeter in length. Usually minutely granulose but may appear smooth at low magnification. When closed the suture is very narrow linear groove, lip area may be slightly raised. Most noteworthy diagnostic feature is slight angular deflection of suture line near the middle. This may be hard to detect but is thought to be universally present.

Monoletes sp. 1?

Pl. 5, Figs. 6, 7

Monolete, bilateral, elliptical, levigate. Size 150 x 275 microns (average)

Pollenites R. Potonie 1931

Division Saccites Erdtman 1947

Subdivision Monosaccites Chitaley 1951

Genus Endosporites Wilson and Coe 1940

Spores trilete, radial, flattened in transverse plane, round to oval or elliptical in slightly rectangular in lateral plane. Trilete rays distinct and generally extend to periphery of body and thickened central body, rays sometimes extend into the bladder. Lips may be prominent and undulate. Bladder [illegible]

thin and translucent. The body is thicker and not translucent. Spore body usually less than 1/2 the total diameter. Bladders are levigate, granulose, punctate or reticulate internally. Bladder ornamentation may appear to be superimposed on the body. Body levigate, punctate, or finely granulose.

Endosporites sp. 183

Trilete, radial, circular to subcircular. Trilete mark small and indistinct. Bladder finely infrareticulate. Body commonly folded. Over-all size 126 microns.

Endosporites sp. 185

Pl. 5, fig. 10

Trilete (?), broadly elliptical. Central body opaque, irregularly shaped, folded small (34 microns). Body levigate. Bladder folded, infrareticulate. Over-all size 70 x 106 microns.

Endosporites sp. 186

Pl. 6, fig. 1

Trilete, radial, circular to subcircular. Trilete rays prominent, distinct, and may extend into bladder. Bladder thin, translucent, and infrareticulate, body dark and levigate. Bladder tends to be folded. Size of body 30-48 microns, overall size 63-116 microns.

Endosporites sp. 190

Pl. 6, fig. 2

Trilete, radial, circular to subcircular. Trilete rays indistinct and extend to periphery of body. Body and bladder

thin and translucent. [illegible] body [illegible] not [illegible].
Spore body usually [illegible]. [illegible]
are levigate, granulose, [illegible].
Bladder [illegible] [illegible] on [illegible]
body. Body levigate, punctate, or [illegible].

[illegible]

Trilete, radial, circular to [illegible]. Trilete [illegible] small
and indistinct. Bladder [illegible]. Body [illegible]
folded. Over-all size 125 [illegible].

[illegible]

Pl. 5, Fig. 10

Trilete (?), [illegible]. Central body opaque, ir-
regularly shaped, [illegible] microns). Body levigate.
Bladder folded, [illegible]. Over-all size [illegible] x 106
microns.

[illegible] sp. 155

Pl. 6, Fig. 1

Trilete, radial, circular to subcircular. Trilete rays
prominent, distinct, and may extend into bladder. Bladder
thin, translucent, and [illegible] wings.
Bladder tends to be folded. [illegible] of body [illegible] over-
all size 93-112 microns.

[illegible] sp. 1[illegible]

Pl. 6, Fig. 2

Trilete, radial, circular to subcircular. Trilete rays [illegible]
distinct and extend to periphery of body. [illegible] and bladder [illegible]

finely granulose. Over-all size 60-70 microns, body 32-34 microns.

Endosporites sp. 278

Pl. 6, fig. 3

Trilete, radial, subcircular. Trilete rays indistinct. Levigate. Bladder and body of approximately equal thickness. Over-all size 31-36 microns, body 17 microns.

Genus Florinites Schopf, Wilson, and Bentall 1944

Pollen trilete, apparently bilateral, broadly elliptical in outline. Trilete mark may be absent, faint, or indistinct. Body spherical and enclosed by a bladder except for a portion of the distal side. Body generally marked by sharp folds especially around periphery. Body levigate, granulose, punctate. Bladder externally levigate or granulose, internally reticulate.

Florinites sp. 195

Trilete mark absent, broadly elliptical. Bladder infrareticulate. Long axis of flattened body coincides with short axis of flattened bladder. Over-all size 45 x 55 microns, size of body 30 x 38 microns.

Florinites sp. 196

Pl. 6, figs. 4, 5

Trilete mark absent, broadly elliptical. Body subcircular. Long axis of flattened body corresponds to short axis of flattened bladder. Exine levigate. Over-all size 80 x 106 microns, size of body 60 x 68 microns.

Florinites (?) sp. 199

Pl. 6, fig. 6

Trilete, broadly elliptical. Trilete mark absent. Body levigate, bladders coarsely infrareticulate. Short axis of body corresponds with short axis of bladder. Over-all size 70 x 110 microns, size of body 47 x 78 microns.

Subdivision Disaccites Cookson 1947

Genus *Illinites* Kosanke 1950

Prepollen, trilete, radial, over-all shape viewed proximally or distally is oval to elliptical. Disaccate. Trilete rays usually small and indistinct. Body ornamentation is levigate or granulose. Bladders are levigate externally and coarsely punctate to reticulate internally.

Illinites sp. 205

Pl. 6, fig. 7

Trilete, radial, elliptical. Trilete mark distinct or indistinct and extends to periphery of body. Body levigate, bladders infrareticulate. Bladders overlap body to form two darkened areas. Over-all size 48 x 60 microns, size of body 31 x 45 microns.

Illinites (?) sp. [illegible]

Pl. 6, fig. [illegible]

Trilete, broadly elliptical. Trilete [illegible] distinct. Body levigate, bladders [illegible] commonly [illegible]. Short axis of body corresponds with short axis of bladder. Over-all size 70 x 110 microns, size of body [illegible] x 70 microns.

Subdivision Disaccites Cookson 1947

Genus Illinites Kosanke 1950

Prepollen, trilete, radial, over-all shape viewed proximally or distally is oval to elliptical. Disaccate. Trilete rays usually small and indistinct. Body [illegible] is levigate or granulose. Bladders are levigate externally and coarsely punctate to reticulate internally.

Illinites sp. [illegible]

Pl. 6, fig. [illegible]

Trilete, radial, elliptical. Trilete mark distinct [illegible] distinct and extends to periphery of body. Body levigate, bladders infrareticulate. Bladders overlap body to form two darkened areas. Over-all size [illegible] x [illegible] microns, size of body 31 x 45 microns.

SPORE COUNTS AND LITHOLOGIC DESCRIPTIONS

The following pages contain detailed lithologic descriptions and the exact location of each locality and core sampled. The lithologic descriptions were done in the field by Dr. J. M. Parks, Jr. and Mr. Jesse B. Pogue, Jr. Following each lithologic description is a detailed species count of the spores found in the rock samples from that particular locality or core.

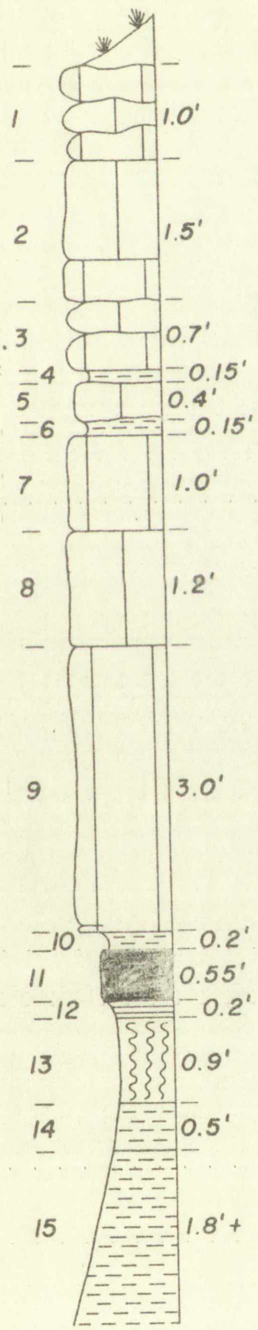
SPORE COUNTS AND LITHOLOGIC DESCRIPTIONS

The following pages contain detailed lithologic descriptions and the exact location of each locality and zone sampled. The lithologic descriptions were done in the field by Dr. J. M. Parks, Jr. and Mr. James E. Forde, Jr. Following each lithologic description is a detailed species count of the spores found in the rock sample from that particular locality or zone.

LOCALITY 1A

CNL NW1/4sec. 35, T. 25 S., R. 13 E., Woodson County, Kansas

(Roadcut on east-west U. S. Highway 54, near Woodson-Greenwood County line)



1. Limestone, light brownish-gray, weathers white, fine-grained and dense. Fossils: crinoid stems, few small fusulinids, small brachiopods, algal structures. Spores absent.

2. Limestone, light brownish-gray, weathers brown, mixed fine-grained and bioclastic. Fossils: crinoid stems, algal growths, fusulinids, bryozoa, brachiopods. Spores absent.

3. Limestone, light brownish-gray, deeply weathered rusty-brown, coarsely bioclastic. Fossils: large crinoid stems, few algal growths, fusulinids, bryozoa, brachiopods, corals. Spores absent.

4. Shale, grayish-green, weathers brown, laminated. Fossils: small brachiopods, mollusks, carbonaceous plant remains. Spores absent.

5. Limestone, light-brown, weathers rusty-brown, medium coarse bioclastic. Fossils: crinoid stems, brachiopods, worm tubes or borings filled with green clay. Spores absent.

6. Shale, olive-green, weathers brown, laminated. Fossils; crinoid stems, brachiopods, gastropods. Spores absent.

7. Limestone, very light brownish-gray, weathers brown. Fossils: crinoid stems, brachiopods, gastropods. Spores absent.

8. Limestone, very light brownish-gray medium coarse bioclastic. Fossils: algal growths, crinoid stems, corals, fusulinids. Spores absent.

LOCALITY 1A

9. Limestone, light-gray to brownish-gray, darker-colored "argillaceous" stringers and lenses, with nodules and stringers of bioclastic material. Fossils: brachiopods, fusulinids. Spores absent.

10. Shale, bluish-gray, grading into coal below. No fossils. Spores moderately abundant.

11. Coal, black, chunky, brittle, sulfur stains. Spores moderately abundant.

12. Shale, dark gray to black, bituminous, fissile. No fossils. Spores very abundant.

13. Underclay, medium dark bluish-gray, unlaminated, plastic, blocky, vertical joints, carbonaceous streaks. Spores rare.

14. Shale, medium bluish-gray, laminated. No fossils. Spores absent.

15. Shale, dark bluish-gray poorly laminated. Fossils: carbonaceous plant fragments.

Stratigraphic Unit	Lithology	Leiotriletes sp. 2	Leiotriletes sp. 7	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 23	Calamospora sp. 31	Calamospora sp. 32	Calamospora sp. 35	Planisporites sp. 39	Planisporites sp. 40	Planisporites sp. 41	Planisporites sp. 42	Pustulatisporites sp. 72	Convolutispora sp. 107	Triquitrites sp. 119	Triquitrites sp. 124	Triquitrites sp. 128	Lycospora sp. 138	Cadiospora sp. 141	Cadiospora sp. 144
10 upper	Shale				2														1		
10 middle	Shale			1	3	1		2		1			27	1		1				1	
10 basal	Shale				1					1									4		
11	Coal				12	38	1	1						1							
12	Shale	2	6	1	38	3	11	1	1		2		11		1	4	4	1	5	5	466
13	Underclay				4			1				1					1		3		1

Locality 1A - Number of spores present in each stratigraphic unit.

Stratigraphic Unit	Lithology	Simozonotriletes sp. 152	Cirratriradites sp. 161	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 186	Florinites sp. 196	Illinites sp.	Acanthotriletes sp. 290
10 upper	Shale								
10 middle	Shale			3	5	26	1	1	
10 basal	Shale			1	1	4			
11	Coal			25		72			2
12	Shale	2	1	29		13			
13	Underclay		1	1					

Locality 1A - Number of spores present in each stratigraphic unit

LOCALITY 1B

Resampled and collected later adjacent to Locality 1A.

Lithologic descriptions same as 1A.

10. Spores moderately abundant.

11. Spores moderately abundant.

12. Spores very abundant.

13. Spores rare.

Stratigraphic Unit	Lithology	Leiotriletes sp. 2	Calamospora sp. 20	Calamospora sp. 23	Cyclogranisporites sp. 31	Cyclogranisporites sp. 32	Planisporites sp. 39	Planisporites sp. 41	Planisporites sp. 42	Pustulatisporites sp. 84	Convolutispora sp. 105	Convolutispora sp. 107	Triquitrites sp. 117	Triquitrites sp. 119	Triquitrites sp. 120	Triquitrites sp. 124	Triquitrites sp. 128	Lycospora sp. 138	Cadiospora sp. 141	Cadiospora sp. 144	Cirratriradites sp. 161
9B middle																					
10B upper	Shale		1			3															
10B lower	Shale	1	11			4		1	10		1	1				1		3	1	1	1
11B	Coal		15	20	3	3	3			1		2	1	1	3	3					1
12B	Shale		11	8					12								1		1	283	
13B	Underclay		1															1			

Locality 1B - Number of spores present in each stratigraphic unit.

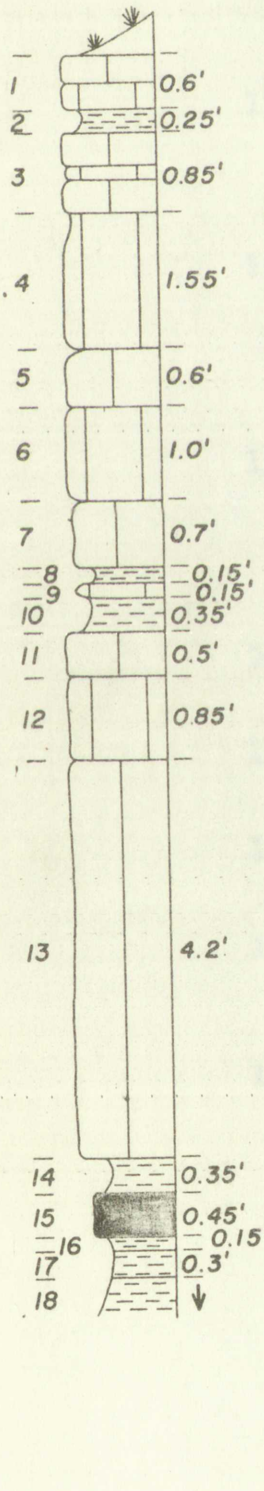
Stratigraphic Unit	Lithology	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 186	Florinites sp.	Florinites sp. 199
9B middle						
10B upper	Shale	2		2		
10B lower	Shale	4	2	41	1	1
11B	Coal	10		43	5	
12B	Shale	8		3		
13B	Underclay					

Locality 1B - Number of spores present in each stratigraphic unit.

LOCALITY 2

NE1/4SW1/4sec. 10, T. 26 S., R. 13 E., Greenwood County, Kansas

(Roadcut and small quarry east of road and south of railroad, approximately 2.5 miles south of U. S. Highway 54)



1. Limestone, light brownish-gray, weathers rusty-brown, coarse bioclastic. Fossils: algal balls, crinoid stems, gastropods, rare fusulinids. Spores absent.

2. Shale, green, weathers brown, poorly laminated. Fossils: numerous crinoid columnals. Spores absent.

3. Limestone, light brownish-gray, weathers rusty-brown, fine-grained to dense. Fossils: fusulinids, bryozoa, crinoid stems, brachiopods. Spores absent.

4. Limestone, light brownish-gray, weathers rusty-brown, dense in lower part to bioclastic in upper part. Fossils: fusulinids, crinoid stems, pelecypods. Spores absent.

5. Limestone, light brownish-gray, dense. Fossils: fusulinids rare, few crinoid stems, algal structures. Spores absent.

6. Limestone, deeply weathered brown, bioclastic. Fossils: fusulinids, crinoid fragments, gastropods, Spores absent.

7. Limestone, deeply weathered brown, bioclastic. Fossils: crinoid stems, brachiopods, algae, bryozoa. Spores absent.

8. Shale, grayish-green, weathers brown, poorly laminated. Fossils: few brachiopods. Spores absent.

LOCALITY 2

9. Limestone, deeply weathered dark-brown, bioclastic. Fossils: crinoid stems, brachiopods. Spores absent.

10. Shale, olive-green, poorly laminated. Fossils: brachiopods, carbonaceous plant remains. Spores absent.

11. Limestone, deeply weathered rusty-brown. Fossils: "worm tubes" on upper surface, algal crusts, brachiopods, corals. Spores rare.

12. Limestone, medium to dark-gray, dark-gray "argillaceous stringers". Fossils: crinoid stems, bryozoa, brachiopods, few fusulinids. Spores absent.

13. Limestone, medium brownish-gray, mixed bioclastic and dense, darker "argillaceous stringers". Fossils: corals, algal crusts, bryozoa, fusulinids, brachiopods. Spores absent.

14. Shale, light- to medium-gray, poorly laminated. No fossils. Spores rare.

15. Coal, black, chunky, white veinlets in cracks. Spores abundant.

16. Shale, black, bituminous, laminated, plant leaf remains. Spores abundant.

17. Shale, medium dark-gray, laminated, carbonaceous material. Spores abundant.

18. Shale, dark bluish-gray, unlaminated, blocky. Spores moderately abundant.

Stratigraphic Unit	Lithology	Leiotriletes sp. 1	Leiotriletes sp. 2	Leiotriletes sp. 7	Calamospora sp. 19	Calamospora 20	Calamospora sp. 23	Cyclogranisporites sp. 32	Planisporites sp. 39	Planisporites sp. 41	Planisporites sp. 42	Pustulatisporites sp. 70	Convolutispora sp. 105	Convolutispora sp. 107	Convolutispora sp. 312	Triquitrites sp. 117	Triquitrites sp. 119	Triquitrites sp. 120	Triquitrites sp. 124	Triquitrites sp. 125	Triquitrites sp. 127
11	Limestone					2											1				
14	Shale										2				1						
15	Coal				3	13	28	1										1			
16	Shale	1		13	1	40	3									5		8			
17	Shale		1	1		51	14		15	4	6	1	1				1		1	1	
18	Shale			1	2	12	4	2						2							

Locality 2 - Number of spores present in each stratigraphic unit

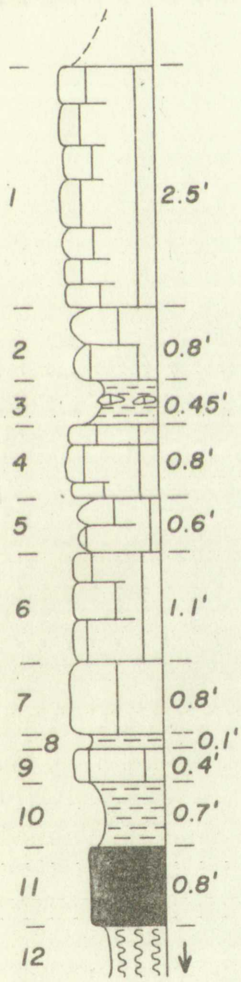
Stratigraphic Unit	Lithology	Triquitrites sp. 128	Lycospora sp. 138	Cadiospora sp.	Cadiospora sp. 141	Cadiospora sp. 144	Simozonotriletes sp. 152	Cirratriradites sp. 161	Laevigatosporites sp. 163	Laevigatosporites sp. 166	Endosporites sp. 186	Florinites sp. 199	Acanthotriletes sp. 290
11	Limestone					1					1		
14	Shale		3	1				1			1	1	
15	Coal									53	92		1
16	Shale				114	2				55	4		
17	Shale	1				227	2		16	18	7		
18	Shale	1	48		2	8				4	1		

Locality 2 - Number of spores present in each stratigraphic unit

LOCALITY 3

CSL SW1/4sec. 33, T. 26 S., R. 13 E., Greenwood County, Kansas

(Roadcut in north-south mid-section road, approximately 8.5 miles south of U. S. Highway 54)



1. Limestone, light brownish-gray, weathers yellowish-brown, bioclastic, Fossils: crinoid stems, gastropods, bryozoa, corals, brachiopods, algae, calcareous sponges, echinoid spines, abundant fusulinids. Spores absent.

2. Limestone, grayish-brown, deeply weathered rusty-brown, bioclastic, coarser than Bed 1. Fossils: abundant crinoid stems, large brachiopods, no fusulinids seen. Spores absent.

3. Shale, green, weathers brown, poorly laminated, lenticular crinoidal limestone streaks near middle. Fossils: carbonaceous plant remains, small brachiopods. Spores absent.

4. Limestone, light brownish-gray bioclastic. Fossils: crinoid stems, fusulinids, algal masses, echinoid plates and spines, brachiopods, trilobites, corals. Spores absent.

5. Limestone, light-gray, weathers dark brown, dense and fine-grained. Fossils: large crinoid stems, fusulinids, echinoid spines, bryozoa, brachiopods, algae, corals. Spores absent.

6. Limestone, light-buff to tan, scattered fossil fragments in dense matrix. Fossils: fusulinids, gastropods, trilobites, brachiopods, algal structures. Spores absent.

7. Limestone, medium-gray to bluish-gray, weathers brown, dense with few fossil fragments. Fossils: large black fusulinids, brachiopods, algal structures. Spores absent.

LOCALITY 3

8. Shale, olive-green, weathers brown, nodular calcareous streaks. No fossils seen. Spores absent.

9. Limestone, light- to dark-gray, dense, appears arenaceous on weathered surface. Fossils: brachiopods, fusulinids, algal structures, corals. Spores absent.

10. Shale, olive-green, weathers brown, poorly laminated. Fossils: brachiopods. Grades into coal below. Spores absent.

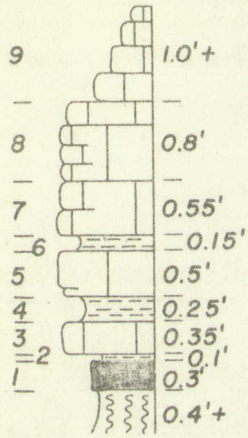
11. Coal, black, soft, weathered. Spores absent.

12. Underclay, bluish-gray, unlaminated, plastic. No fossils. Spores absent.

LOCALITY 3A

SW1/4sec. 4, T. 27 S., R. 13 E., Greenwood County, Kansas

(Dry falls in intermittent stream approximately 1/4 mile east of road)



Units in reverse order as overlying control beds were missing and collectors worked from the bottom up.

9. Limestone, light, brownish-gray, weathers brown, dense matrix, little bioclastic material. Fossils: few fusulinids, crinoid stems, no corals. Spores absent.

8. Limestone, light-tan, weathers tan, dense matrix. Fossils: profuse local development of colonial reef-building type syringoporoid corals, apparently in growth position. Spores absent.

7. Limestone, light brownish-gray, weathers tan, fine-grained, dense. Fossils: few corals, fusulinids. Spores absent.

6. Shale, olive-green, weathers brown, calcareous, poorly laminated. Fossils: abundant fusulinids, crinoid stems, brachiopods. Spores absent.

5. Limestone, light brownish-gray, weathers brown, fine-grained matrix, fine-textured bioclastic material. Fossils: fusulinids, crinoid stems, brachiopods, few corals. Spores absent.

4. Shale, olive-green, weathers brown, calcareous, poorly laminated. Fossils: abundant fusulinids, crinoid stems, brachiopods. Spores absent.

3. Limestone, light brownish-gray, weathers brown, dense. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

LOCALITY 3A

2. Shale, dark-gray, laminated. Fossils: coalified plant remains, few pelecypods. Spores present.

1. Coal, black, brittle, chunky. Underclay, bluish-gray, unlaminated, plastic. This sample and sample 2 were mixed together.

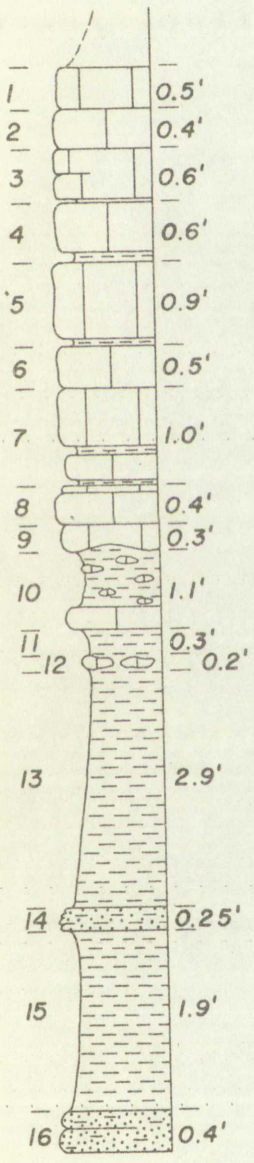
Stratigraphic Unit	Lithology	Calamospora sp. 20	Calamospora sp. 23	Cyclogranisporites sp. 32	Cyclogranisporites sp. 35	Planisporites sp. 42	Pustulatisporites sp. 72	Convolutispora sp. 105	Convolutispora sp. 107	Triquitrites sp. 124	Triquitrites sp. 127	Laevigatosporites sp. 166	Endosporites sp. 186	Endosporites sp.	Florinites sp. 196	Monoletes sp.					
2	Shale, coalified plant remains	24	9	3	1	2	5	1	1	1	1	7	20	2	1	1					

Locality 3A - Number of spores present in each stratigraphic unit

LOCALITY 4

CSL sec.29, T. 27 S., R. 13 E., Greenwood County, Kansas

(Roadcut on east-west section line road approximately 5 miles north of Fall River)



1. Limestone, light-tan, deeply weathered brown, medium fine-grained matrix, bioclastic. Fossils: shell fragments with algal coatings, fusulinids, brachiopods, crinoid stems, pelecypods. Spores absent.

2. Limestone, tan, deeply weathered brown, fine-grained. Fossils: abundant fusulinids, algal coatings on fossil fragments, crinoid stems, bryozoa. Spores absent.

3. Limestone, tan weathers brown, abundant shell detritus. Fossils: algal-coated shell fragments, algal balls, crinoid stems, abundant fusulinids, bryozoa, brachiopods. Spores absent.

4. Limestone, light grayish-tan, coarse textured bioclastic. Fossils: crinoid columnals, no fusulinids, encrusting bryozoa, brachiopods, gastropods. Spores absent.

5. Limestone, light brownish-gray, bioclastic. Fossils: small brachiopods, few fusulinids, bryozoa, crinoid stems, not much algal material. Spores absent.

6. Limestone, light brownish-gray, dense and fine-grained. Fossils: fusulinids, algal structures, calcareous sponge. Spores absent.

7. Limestone, light brownish-gray, dense and fine-grained. Fossils: fusulinids, few algal structures, brachiopods, fragment of trilobite. Spores absent.

8. Limestone, light-brown, coarse texture. Fossils: sparse fusulinids, algal balls, corals, crinoid stems, brachiopods. Spores absent.

LOCALITY 4

9. Limestone, light brownish-gray, dense. Fossils: large fusulinids, large algal structures, gastropods, echinoid spines, crinoid stems, brachiopods. Spores absent.

10. Limestone, light brownish- to greenish-gray, soft, argillaceous, grades into shale. Fossils: abundant fusulinids, algal material, brachiopods. Spores absent.

11. Shale, green, poorly laminated. No fossils seen. Spores absent.

12. Limestone nodules, light greenish-gray, argillaceous. Fossils: fusulinids, algae, gastropods, corals. Spores absent.

13. Shale, olive-green, poorly laminated. No fossils seen. Spores absent.

14. Sandstone, olive-green, silty. No fossils seen. Spores absent.

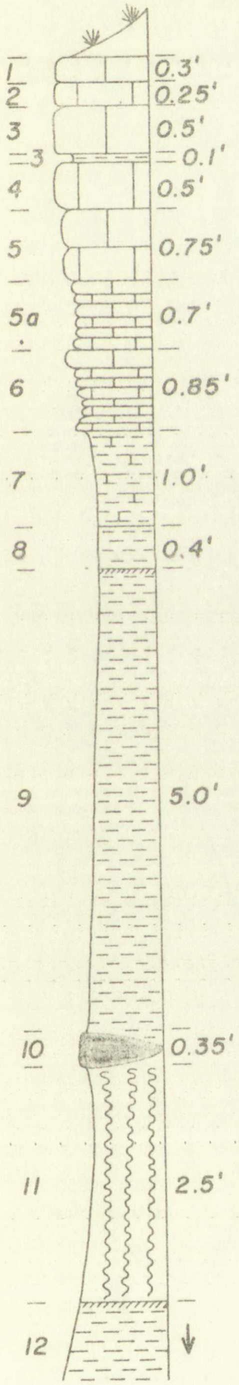
15. Shale, olive-green, poorly laminated. No fossils seen. Spores absent.

16. Sandstone, greenish-brown, fine-grained. No fossils seen. Spores absent.

LOCALITY 5

SL NE1/4sec. 36, T.28 S., R. 12 E., Elk County, Kansas

(Roadcut on east-west road, approximately 2.7 miles south of Fall River, Kansas)



1. Limestone, deeply weathered dark-brown, bioclastic. Fossils: few fusulinids, small and large brachiopods. Spores absent.

2. Limestone, deeply weathered dark-brown, limonitic, fine-grained bioclastic. Fossils: brachiopods, bryozoa, gastropods, crinoidal debris. Spores absent.

3. Limestone, light bluish-gray, weathers light brownish-gray, coarser, bioclastic than Bed 2, thin shale parting at base. Fossils: abundant fusulinids, algae, bryozoa, crinoid stems, large brachiopods, possible worm burrows. Spores absent.

4. Limestone, light brownish-gray, high percentage fine bioclastic material. Fossils: fusulinids, crinoid stems, algae, worm burrows (?). Spores absent.

5. Limestone, light brownish-gray, high percentage fine bioclastic material. Fossils: abundant fusulinids, crinoid stems, large brachiopods, algal crusts. Spores absent.

6. Limestone, light brownish-gray, very fossiliferous. Fossils: abundant fusulinids, large brachiopods, bryoza, corals. Spores absent.

7. Shale, olive-green, weathers tan, poorly laminated, calcareous. Fossils: abundant fusulinids, crinoids, large brachiopods, echinoid plates and spines, bryozoa, pelecypods. Spores absent.

LOCALITY 5

8. Shale, olive-green, weathers brown, well-laminated. Fossils: sparse fusulinids near top grading down to none near base, abundant flattened brachiopods, pelecypods. Spores absent.

9. Shale, bluish-gray, to olive-green, top marked by persistent iron-oxide stained zone, poorly laminated. Fossils rare: coalified plant fragments, pelecypods (?). Spores absent.

10. Coal, varies from black smudge to actual coal bed. Spores absent.

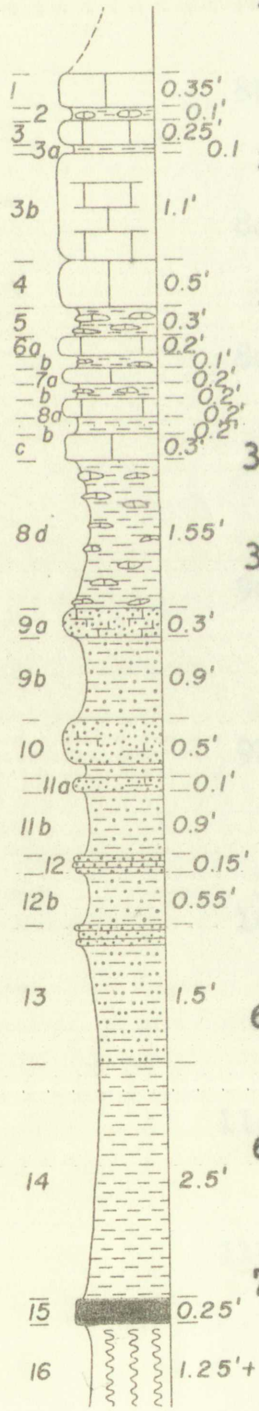
11. Underclay, bluish-gray, unlaminated, plastic. No fossils seen. Spores absent.

12. Shale, bluish-gray, block to slightly laminated, indurated, top marked by persistent limonitic streak. Spores absent.

LOCALITY 6

NE1/4NE1/4sec. 12, T. 29 S., R. 12 E., Elk County, Kansas

(Roadcut and pond excavation on north-south section line road, approximately 6 miles south of Fall River)



1. Limestone, bluish-gray, weathers brown, granular, bioclastic. Fossils: brachiopods, algae, gastropods. Spores absent.

2. Limestone, gray, argillaceous, thin-bedded. Fossils: abundant fusulinids. Spores absent.

3. Limestone, light grayish-blue, weathers grayish-brown, dense, argillaceous. Fossils: fusulinids, brachiopods, bryozoa. Spores absent.

3a. Shale, chocolate-brown, limonitic. Fossils: fusulinids. Spores absent.

3b. Limestone, light grayish-blue, fine-grained, argillaceous. Fossils: crinoid stems, brachiopod fragments, sparse fusulinids. Spores absent.

4. Limestone, light-gray, massive, argillaceous. Fossils: fusulinids, brachiopods, crinoid stems, echinoid spines. Spores absent.

5. Shale, brown, calcareous, with light-gray limestone lenses. Fossils: fusulinids, brachiopods. Spores absent.

6a. Limestone, light gray, dense. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

6b. Shale, brown, limonitic with thin light-gray limestone lenses. Fossils: abundant fusulinids. Spores absent.

7a. Limestone, light-gray, argillaceous, with light green clay partings. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

LOCALITY 6

7b. Shale, light brown, calcareous with light-gray limestone lenses. Fossils: fusulinids, solitary corals. Spores absent.

8a. Limestone, light gray, dense, argillaceous. Fossils: abundant fusulinids, brachiopods. Spores absent.

8b. Shale, light to dark brown, calcareous, limonitic. Fossils: fusulinids. Spores absent.

8c. Limestone, light-gray. Fossils: fusulinids, brachiopods. Spores absent.

8d. Shale and nodular limestone, shale light-gray, well-laminated, calcareous, limestone light brownish-gray, fine-grained, dense. Fossils: abundant fusulinids, corals, brachiopods, bryozoa. Spores absent.

9a. Sandstone, weathers red rusty-brown, calcareous, fine-grained. Fossils: pelecypods, brachiopods. Spores absent.

9b. Shale, olive-green, silty and sandy, slightly calcareous, thick laminae. Fossils: coalified plant fragments. Spores absent.

10. Sandstone, medium bluish-gray, deeply weathered brown, very fine-grained, slightly calcareous, micaceous, argillaceous. Fossils: pelecypod molds, plant fossil fragments. Spores rare.

11a. Sandstone, deeply weathered, slightly calcareous. Fossils: coalified plant fragments. Spores absent.

11b. Shale, greenish-gray, weathers dark brown, sandy, hard and blocky. Fossils: coalified plant fragments, pelecypod molds. Spores rare.

LOCALITY 6

12a. Sandstone, fine-grained, argillaceous, laterally variable. Fossils: pelecypods, plant fragments. Spores rare.

12b. Shale, bluish-gray, sandy, silty, fissile. Fossils: pelecypods, coalified plant fragments. Spores abundant.

13. Shale, olive-green, weathers dark brown, silty, coarsely laminated. Fossils: pelecypods, plant fragments. Spores abundant.

14. Shale, bluish-gray, well-laminated, fissile, limonitic strains. Fossils: pelecypod molds, plant fragments. Spores abundant.

15. Coal, black, blocky, conchoidal fracture. Thin layer of black bituminous shale above. Spores abundant.

16. Underclay, bluish-gray, unlaminated, blocky, hard. No fossils seen. Spores rare.

Stratigraphic Unit	Lithology	Punctatisporites sp. 12	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 21	Calamospora sp. 23	Cyclogranisporites sp. 32	Pustulatisporites sp. 72	Planisporites sp. 42	Convolutispora sp. 105	Convolutispora sp. 107	Convolutispora sp. 114	Triquitrites sp.	Triquitrites sp. 119	Triquitrites sp. 120	Triquitrites sp. 124	Triquitrites sp. 128	Lycospora sp. 138	Cadiospora sp. 141	Cadiospora sp. 144	Simozonotriletes sp. 152
10	Sandstone		1							1										1	
11b	Shale			1			3														
12a	Sandstone					1	5				1					1					
12b	Shale		3		1	2	51					1		1			1				
13	Shale	1		11		10	80	5			1		1			1	1		1		1
14	Shale		2	15	2	1	70	4			1										
15	Coal		7	27		16	13	12	7									2	25	61	
16	Underclay			31				1		1	3			2	4				20	7	

Locality 6 - Number of spores present in each stratigraphic unit

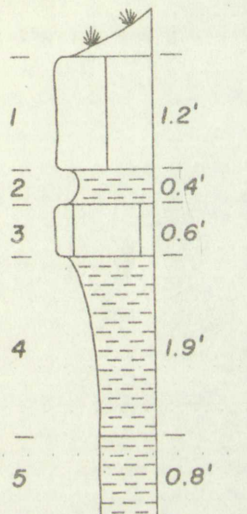
Stratigraphic Unit	Lithology	Densosporites sp. 157	Cirratriradites sp. 161	Laevigatosporites sp. 163	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 186	Florintes sp.	Florinites sp. 196	Florinites sp. 199	Monoletes sp.	Monoletes sp. 231
10	Sandstone					1		3				
11b	Shale							2				
12a	Sandstone				1	1						
12b	Shale			2			3	12			2	5
13	Shale				5	5	6	4	1	1		7
14	Shale	1				6	6	3				
15	Coal		2	8	24		7		1		1	
16	Underclay						2					

Locality 6 - Number of spores present in each stratigraphic unit

LOCALITY 7

NE1/4SW1/4sec. 27, T. 30 S., R. 12 E., Elk County, Kansas

(Roadcut on north-south road at junction approximately 2 miles north of Longton)



1. Limestone, medium dark gray, fine to coarse grained, large amounts of bioclastic material. Fossils: sparse fusulinids, crinoid segments, brachiopods, bryozoa. Spores absent.

2. Shale, olive-green, deeply weathered brown, moderately well laminated. Fossiliferous: corals, small brachiopods, crinoid stems. Spores absent.

3. Limestone, medium dark gray, fine-grained bioclastic. Fossils: few fusulinids, abundant brachiopods. Spores absent.

4. Shale, greenish-brown, deeply weathered brown, calcareous. Fossils: abundant fusulinids, brachiopods, bryozoa. Spores absent.

5. Shale, dark olive-brown, moderately well laminated to blocky. Fossils: few fusulinids, abundant pelecypods, brachiopods. Sample missing.

6. Shale, variable in color from olive-brown to light bluish-gray, laminated. Only fossils are abundant carbonized plant remains on bedding planes. Spores moderately abundant.
Coal, thin streak of poor quality coal, may thicken and thin laterally. Spores abundant.

7. Underclay, bluish-gray, plastic with little structure or bedding. No fossils seen. Spores absent.

Stratigraphic Unit	Lithology	Leiotriletes sp. 2	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 23	Cyclogranisporites sp. 32	Cyclogranisporites sp. 35	Planisporites sp. 42	Pustulatisporites sp. 74	Convolutispora sp. 105	Convolutispora sp. 107	Triquitrites sp. 120	Triquitrites sp. 124	Triquitrites sp. 128	Lycospora sp. 136	Cadiospora sp. 141	Densosporites sp. 157	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 186	Endosporites sp. 190
6 upper	Shale	1	1	14	6	38	1	1				2				1	1	4	2		
6 lower	Coal		1	15	5	86			1	1	1	1	1	1	1			4		4	1

Locality 7 - Number of spores present in each stratigraphic unit

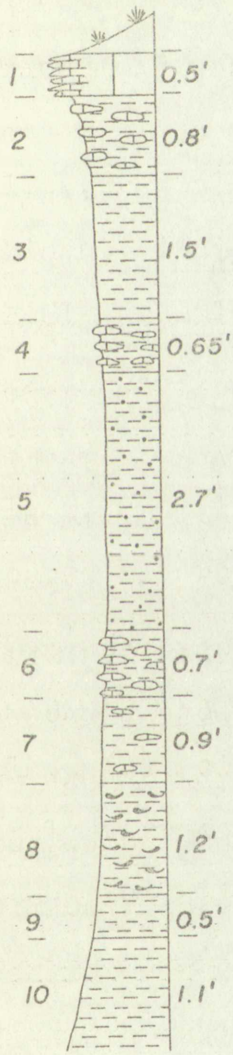
Stratigraphic Unit	Lithology	Florinites sp.	Florinites sp. 196	Florinites sp. 199	Monoletes sp. 231
6 upper	Shale	2		1	1
6 lower	Coal	12	1		2

Locality 7 - Number of spores present in each stratigraphic unit

LOCALITY 8

CEL sec. 36, T. 32 S., R. 11 E., Chautauqua County, Kansas

(Roadcut on north-south section line road, approximately 8 miles north of Sedan)



1. Limestone, medium gray to brownish-gray, weathers dark brown and platy, very argillaceous and silty, bioclastic. Fossils: brachiopods, crinoid stems, very few fusulinids. Spores absent.

2. Shale, brown, deeply weathered with limestone nodules. Fossils: brachiopods. Spores absent.

3. Shale, grayish-brown to olive-brown, not well-laminated. Few fossils: small brachiopods. Spores absent.

4. Shale and limestone nodules, olive-brown to rusty-brown. Limestone nodules argillaceous and fossiliferous. Spores absent.

5. Shale, olive-green to olive-brown, blocky to laminated. Abundant fossils: brachiopods, pelecypods, crinoid stems. Spores absent.

6. Shale and limestone nodules, rusty-brown, deeply weathered. Nodules fossiliferous. Spores absent.

7. Shale, gray to olive-brown, weathers brown, scattered small calcareous nodules. Few fossils. Spores absent.

8. Shale, deeply weathered brown. Abundant large pelecypods. Spores absent.

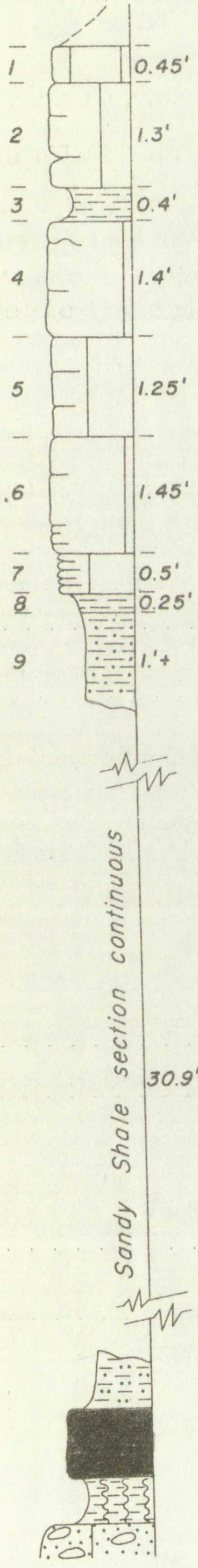
9. Shale, bluish-gray, poorly bedded, calcareous nodules. No fossils seen. Spores absent.

10. Shale, brownish-gray, plastic, little evidence of bedding. Possibly plant fragments. Spores absent.

LOCALITY 9

NW1/4NE1/4sec. 24, T. 18 S., R. 17 E.,
Franklin County, Kansas

(Roadcut on U. S. Highway 50-S, approximately 1 mile southwest of Williamsburg)



1. Limestone, brownish-gray, deeply weathered dark-brown, medium-grained bioclastic, limonitic filling in holes or tubes. Fossils: Algal balls, fusulinids, gastropods, crinoid stems, brachiopods. Spores absent.

2. Limestone, deeply weathered brown, bioclastic. Fossils: fusulinids, algal wafers and pellets, crinoid stems, bryozoa. Spores absent.

3. Shale, greenish-gray, weathers brown, poorly laminated. Fossils: crinoid stems, brachiopods. Spores absent.

4. Limestone, brownish-gray, weathers brown, bioclastic with green shale partings. Fossils: brachiopods, fusulinids, gastropods. Spores absent.

5. Limestone, deeply weathered, less bioclastic than above, finer grained. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

6. Limestone, deeply weathered dark-brown, less bioclastic material, finer grained than above. Fossils: fusulinids, brachiopods, crinoid stems. Spores abzent.

7. Limestone, deeply weathered dark-brown, argillaceous, fine-grained. Fossils: fusulinids, algal crusts, bryozoa, brachiopods. Spores absent.

8. Shale, brown, deeply weathered. Few fossils seen. Spores absent.

9. Shale, greenish-gray, silty, sandy, blocky, poorly laminated. No fossils seen. Spores absent.

This coal is pre-Toronto and was given no number. Spores rare.

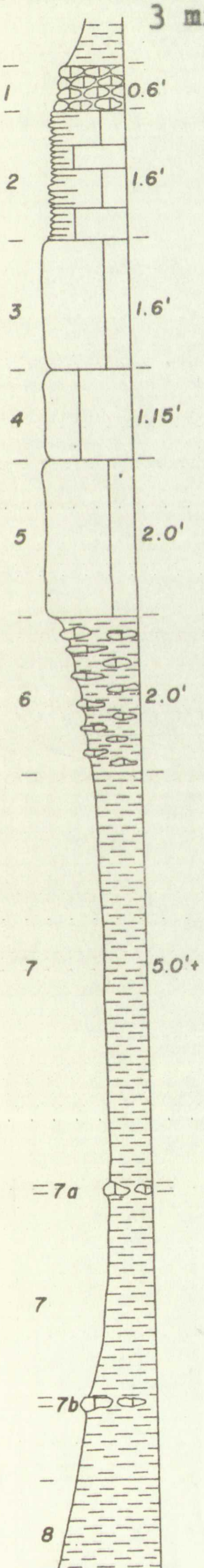
Stratigraphic Unit	Lithology	Calamospora sp. 20	Calamospora sp. 23	Planisporites sp. 39	Pustulatisporites sp. 72	Triquitrites sp. 119	Cadiospora sp. 144	Laevigatosporites sp. 166	Endosporites sp. 186
	Coal	5	10	1	1	1	2	13	43

Locality 9 - Number of spores present in each stratigraphic unit

LOCALITY 10

NW1/4NW1/4 sec. 22, T. 8 S., R. 22 E., Leavenworth County, Kansas

(Roadcut on north-south U. S. Highway 73, approximately 3 miles north of Leavenworth)



1. Limestone, light brownish-gray, weathers brown, nodular, rubbly, very fine-grained. No fossils seen. Spores absent.

2. Limestone, light brownish-gray, weathers light-gray, very fine-grained, dense, with green shale laminae. Fossils: pelecypods and gastropods. Spores absent.

3. Limestone, light brownish-gray, weathers brown, very fine bioclastic. Fossils: pelecypods, brachiopods, bryozoa, crinoid stems, algal crusts. Spores absent.

4. Limestone, greenish-gray, weathers dark-gray, glauconitic (?), less bioclastic material, argillaceous. Fossils: brachiopods, bryozoa, crinoid stems. Spores absent.

5. Limestone, white to very light-gray, fine-grained, dense, little bioclastic debris, green shale stringers. Fossils: fusulinids, brachiopods, "worm tube" fillings. Spores absent.

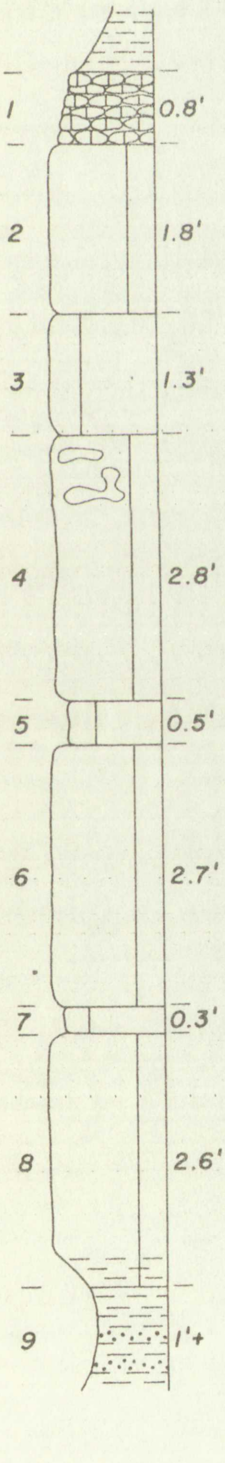
6. Shale, green, calcareous, arenaceous. Fossils: pelecypods, brachiopods, crinoid stems. Spores absent.

7. Shale, dark greenish-gray, silty, laminated to blocky with limestone nodules at two horizons. Few fossils seen. Spores absent.

LOCALITY 11

NW1/4 sec. 36, T. 12 S., R. 19 E., Douglas County, Kansas

(Roadcut on east-west U. S. Highway 40, west side of Lawrence)



1. Limestone, deeply weathered brown, nodular, rubbly, fine-grained, and argillaceous. No fossils seen. Spores absent.

2. Limestone, deeply weathered brown, slightly argillaceous, fine-grained. No fossils seen. Spores absent.

3. Limestone, brownish-gray, weathers brown, dense, small amount of bioclastic material. No fossils seen. Spores absent.

4. Limestone, brownish-gray, weathers brown, slightly argillaceous, fine-grained, dense, chert stringers and nodules in upper part. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

5. Limestone, brownish-gray, deeply weathered brown, thin-bedded, dense, fine-grained. Fossils: brachiopods, crinoid stems, corals. Gray shale partings above and below. Spores absent.

6. Limestone, light brownish-gray, weathers rusty-brown, very fine-grained bioclastic, massive bedded. Fossils: fusulinids, crinoid stems, brachiopods, corals, algal crusts. Spores absent.

7. Limestone, light brownish-gray, weathers brown, bioclastic. Fossils: algal laminations, fusulinids, brachiopods, crinoid stems. Spores absent.

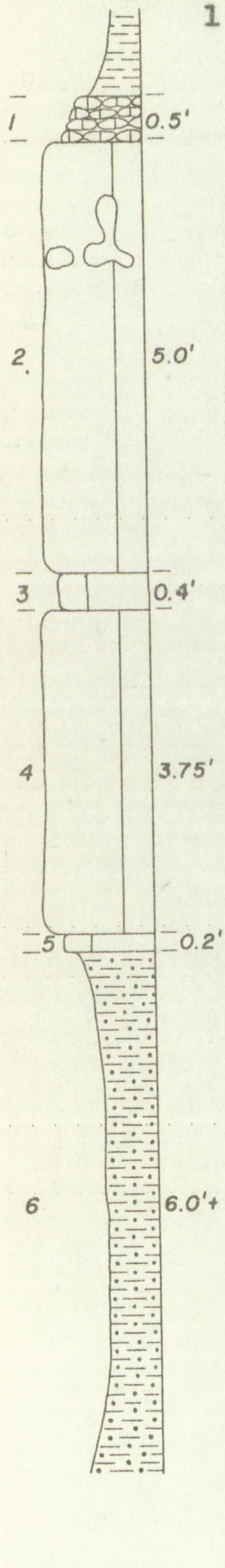
8. Limestone, light brownish-gray, weathers brown, bioclastic, slightly argillaceous toward base. Fossils: fusulinids, algal encrustations, brachiopods, crinoid stems, pelecypods near base. Spores absent.

9. Shale, greenish-gray, silty to sandy. No fossils seen. Spores absent.

LOCALITY 12

CSL NW1/4sec. 8, T. 11 S., R. 21 E., Leavenworth County, Kansas

(Roadcut on east-west State Highway 16,
1 mile west of Tonganoxie)



1. Limestone, deeply weathered rusty-brown, rubbly, nodular, very fine-grained, chalky, limonitic. Fossils: worm tubes (?) filled with green shale. Spores absent.

2. Limestone, brownish-gray, weathers brown, fine-grained toward top, bioclastic toward bottom, zone of tan chert nodules and lenses above middle, massive-bedded. Fossils: mulluscan fauna above chert; no fossils seen in chert zone; lower half contains fusulinids, crinoid stems, brachiopods and algal pellets. Spores absent.

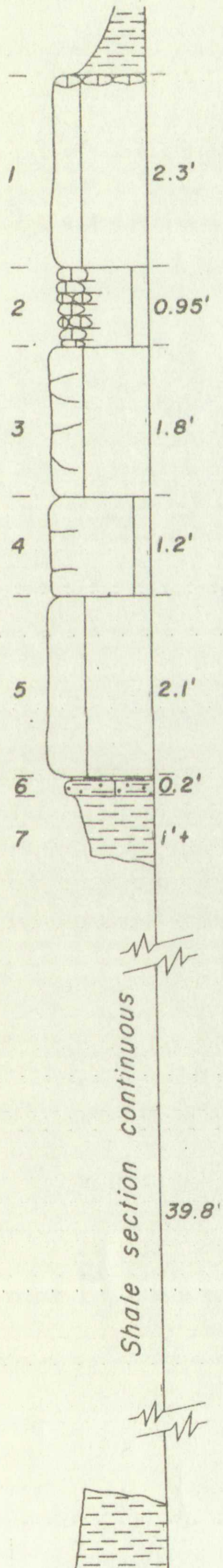
3. Limestone, light brownish-gray, weathers dark-brown, thin shale parting above and below argillaceous, fine-grained. Fossils: crinoid stems, brachiopods. Spores absent.

4. Limestone, light brownish-gray, weathers brown, bioclastic at top, becoming fine-grained toward base. Fossils: fusulinids, crinoid stems, algal structures, brachiopods, bryozoa, coral. Spores absent.

5. Limestone, bluish-gray, weathers brown, fine-grained argillaceous. Few fossils seen. Spores absent.

6. Shale, bluish-gray, sandy and silty, unlaminated to blocky. Fossils: phosphatic brachiopods, pelecypods. Spores absent.

LOCALITY 13



NE1/4NW1/4sec. 14, T. 13 S., R. 18 E., Douglas County, Kansas

(Exposure above west end of dam, Lone Star Lake, southwest of Lawrence)

1. Limestone, light yellowish-brown, weathers rusty-brown, upper part rubbly and fine-grained, most of bed bioclastic. Fossils: brachiopods, crinoid stems, fusulinids, algal balls. Spores absent.

2. Limestone, light-gray, deeply weathered brown, fine-grained, dense, rubbly. Fossils: fusulinids, brachiopods, corals. Spores absent.

3. Limestone, light brownish-gray, weathers dark-brown, medium-grained, almost sucrosic. Fossils: fusulinids, brachiopods. Spores absent.

4. Limestone, light brownish-gray, weathers dark-brown, fine-grained, sucrosic. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.

5. Limestone, white, weathers light-brown, fine-grained, chalky, massive. Fossils: fusulinids, brachiopods, algal structures. Spores absent.

6. Limestone, bluish-gray, weathers brown, argillaceous, arenaceous. Fossils: rare. Spores absent.

7. Shale, bluish-gray, silty, sandy, poorly bedded. Spores absent.

8. Coal. Spores abundant.

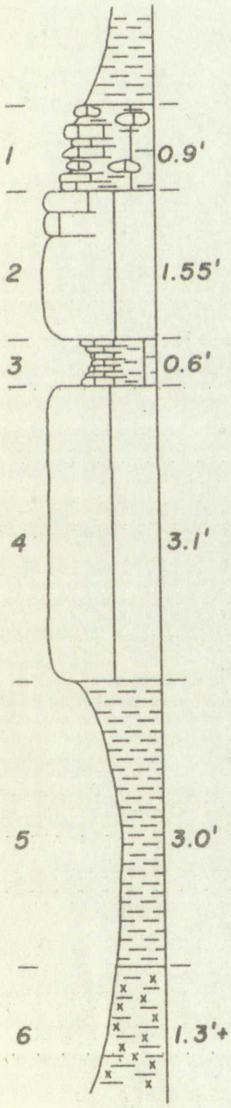
Stratigraphic Unit	Lithology	Leiotriletes sp. 7	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 23	Cyclogranisporites sp. 31	Cyclogranisporites sp. 32	Planisporites sp. 41	Planisporites sp. 42	Pustulatisporites sp. 72	Convolutispora sp. 107	Triquitrites sp.	Triquitrites sp. 120	Triquitrites sp. 127	Triquitrites sp. 128	Cadiospora sp. 141	Cadiospora sp. 144	Laevigatosporites sp. 163	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 186
8	Coal	1	2	28	44	3	4	4	1	1	1			1					46		122
	Underclay		19	21	1		1			2		1	1		1	24	2	3		10	416

Locality 13 - Number of spores present in each stratigraphic unit

LOCALITY 15

NE1/4NW1/4sec. 31, T. 58 N., R. 35 W., Buchanan County, Missouri

(Quarry in east river bluff approximately 3.5 miles north and west of St. Joseph, Missouri)



1. Limestone, brownish-gray, weathers brown, fine-grained, argillaceous, rubbly. Fossils: poorly preserved gastropods. Spores absent.

2. Limestone, light brownish-gray, weathers dark-brown, fine-grained, dense, with green shale flakes and stringers. Fossils: poorly preserved pelecypods. Spores absent.

3. Limestone, brownish-gray, weathers brown, softer and shalier than beds above, medium fine-grained. Fossils: gastropods and pelecypods. Spores absent.

4. Limestone, light yellowish-tan, weathers rusty-brown, bioclastic. Fossils: fusulinids, brachiopods, pelecypods, bryozoa, crinoid stems. Spores absent.

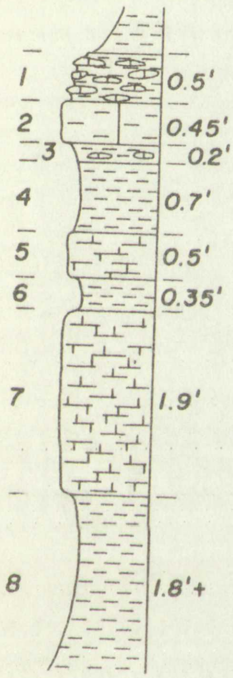
5. Shale, light bluish-gray, calcareous, laminated. Fossils: brachiopods, crinoid fragments, pelecypods. Becomes darker gray toward base, less fossiliferous. Spores absent.

6. Shale, red. No fossils seen. Spores absent.

LOCALITY 17

NE1/4NW1/4sec. 4, T. 334 S., R. 11 E., Chautauqua County, Kansas

(Roadcut on east-west road, approximately 1.8 miles west of Sedan, Kansas)



Leavenworth limestone: Two spores present

1. Limestone, greenish-gray, weathers dark rusty brown, rubbly, nodular, shaly. No fossils seen. Spores absent. Microforams present.

2. Limestone, dark gray, weathers light to dark brown, very argillaceous, bioclastic. Fossils: crinoid stems, brachiopods, fusulinids. Spores absent.

3. Shale, light-brown, hard, calcareous with limestone nodules. Very fossiliferous: brachiopods, pelecypods, crinoid stems, bryozoa.

4. Shale, greenish-gray, poorly to well laminated, small calcareous nodules. Very few fossils. Spores absent.

5. Shale, weathered drab rusty brown, calcareous. Very fossiliferous: pelecypods, crinoid stems. Spores absent.

6. Shale, greenish-gray, fairly well laminated. Unfossiliferous near top, numerous small brachiopods near base. Spores absent.

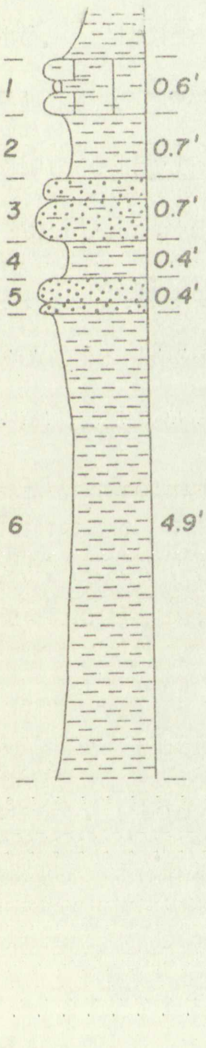
7. Calcareous, shale and argillaceous limestone, light brownish-gray. Very fossiliferous: small brachiopods, crinoid stems, pelecypods. Spores absent.

8. Shale, olive-green to olive-brown, unlaminated, blocky. Very few fossils. Spores absent.

LOCALITY 18

NE1/4sec. 7, T. 28 N., R. 10 E., Osage County, Oklahoma

(Roadcut on County Highway 3 approximately 6.5 miles south of Elgin, Kansas)



1. Limestone, medium-gray, weathers light- to dark-rusty-brown, thin-bedded, slabby, shaly, bioclastic. Spores absent. Microforams present.

2. Shale, weathered olive-brown to brown, poorly laminated, contains calcareous concretions. No fossils seen. Spores absent.

3. Sandstone, light-tan to dark rusty-brown, very fine-grained, probably silty. Upper surface shows "fucoids". Interior contains calcareous streaks. No fossils seen. Spores absent.

4. Shale, olive-brown to greenish-gray, sandy, poorly laminated to blocky. No fossils seen. Spores absent.

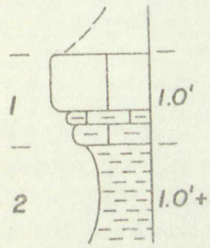
5. Sandstone, light grayish-tan to reddish-brown, very fine-grained, micaceous. No fossils seen. Spores absent.

6. Shale, greenish-gray, poorly laminated to blocky. No fossils seen. Spores absent.

LOCALITY 19

SW1/4NE1/4sec. 12, T. 35 S., R. 10 E., Chautauqua County, Kansas

(Roadcut on north-south road, approximately
2.5 miles north-east of Elgin, Kansas)



1. Upper part:
   Limestone, medium dark gray, weathers dark-brown, fine-grained bioclastic, few recognizable fossils: pelecypods and brachiopods. Spores absent.

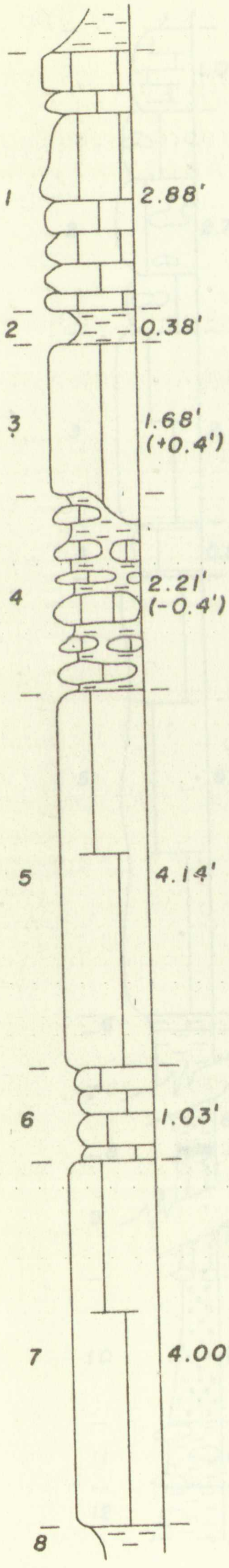
   Lower part:
   Limestone, similar to upper part, but coarser-grained bioclastic material. Crinoidal debris prominent. Spores absent.

2. Shale, olive-gray to olive-brown, poorly laminated to blocky, probably silty to finely sandy. No fossils seen. Spores absent.

LOCALITY 20

C SE1/4sec. 2, T. 22., R. 15.E.,
Coffey County, Kansas

(Small quarry north of east-west section line road, approximately 3.5 miles south and east of Burlington)



1. Limestone, very light-gray, weathers tan, dense to very fine bioclastic, green shale flakes. Fossils: large algal balls, gastropods, no fusulinids. Spores absent.

2. Shale, green, weathers brown, calcareous. No fossils seen. Spores absent.

3. Limestone, light-gray to creamy white, bioclastic, pelletal, semioolitic, algal coated worn fossil fragments. Recognizable fossils rare, no fusulinids seen. Spores absent.

4. Limestone and shale; green shale stringers, weathers brown, light-gray to creamy white limestone stringers and nodules; fine-grained to fine bioclastic. Fossils: crinoid stems. Spores absent.

5. Limestone, light-gray to creamy white, massive, very fine-grained bioclastic, almost chalky. Fossils: brachiopods, bryozoa, crinoid fragments, algal coatings, no fusulinids seen. Spores absent.

6. Limestone, medium light-gray, darker argillaceous stringers common toward top, with 1/3-inch thick shale stringer at top. Fossils: crinoid stems, fusulinids. Spores absent.

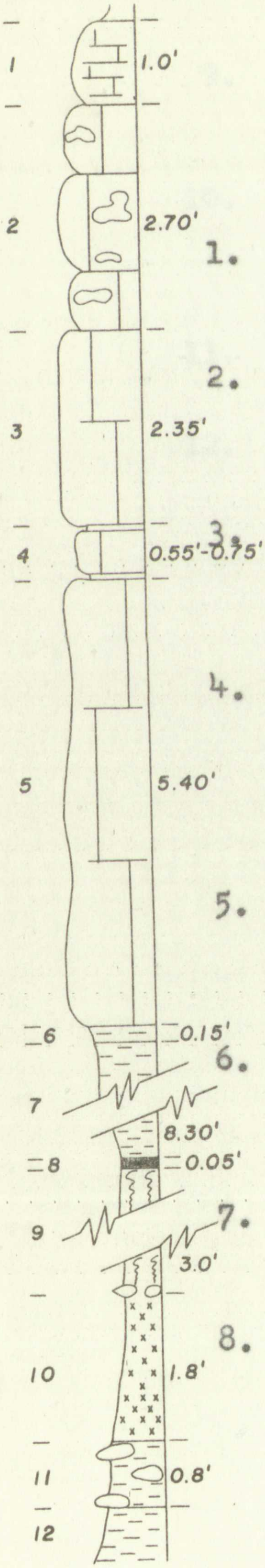
7. Limestone, very light gray to creamy white, fine bioclastic, slightly argillaceous toward base. Fossils: fusulinids abundant in lower third, crinoid stems, brachiopods. Spores absent.

8. Shale, bluish-gray, plastic, blocky. No fossils seen. Spores absent.

LOCALITY 22

C NW1/4sec. 21, T. 12 S., R. 19 E.,
Douglas County, Kansas

(Roadcut on Kansas Turnpike 3.1 miles west of West Lawrence Turnpike Exchange)



1. Limestone, weathered brown, nodular and rubbly. No fossils seen. Spores absent.

2. Limestone, light brownish-gray, weathers brown, very fine grained, white to gray chert nodules and lenses. No fossils seen. Spores absent.

3. Limestone, brownish-gray, deeply weathered brown, very fine grained, chalky, chert absent. Fossils: brachiopods, fusulinids. Spores absent.

4. Limestone with shale break above and below, olive-green shale, weathers brown; fine bioclastic limestone, brownish-gray, weathers brown. Fossils: poorly preserved brachiopods. Spores absent.

5. Limestone, light-brown, weathers brown, massive, fine bioclastic. Fossils: fusulinids, crinoid stems, brachiopods, algal laminations. Spores absent.

6. Shale, very calcareous, light- to medium-gray. Fossils: fusulinids, small brachiopods, clams, crinoid stems. Spores absent.

7. Shale, light bluish-gray, laminated, silty to sandy streaks and beds. Few fossils seen. Spores absent.

8. Thin black argillaceous smudge.

LOCALITY 22

9. Underclay, dark bluish-gray, unbedded, plastic, blocky. No fossils seen. Spores absent.

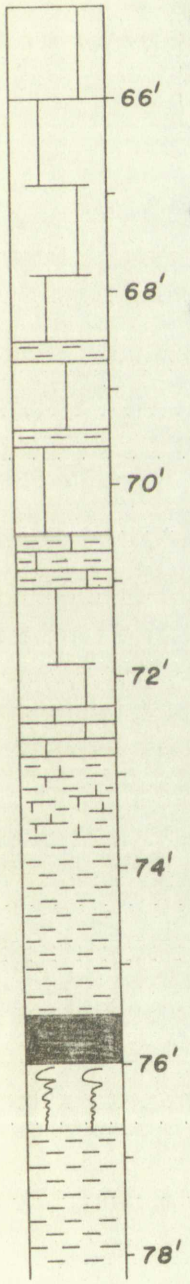
10. Shale, red, silty to sandy, poorly bedded. No fossils seen. Zone of "fresh-water" limestone nodules at top. Spores absent.

11. Shale, dark greenish-gray, laminated with "fresh-water" limestone nodules.

12. Shale, dark greenish-gray, laminated, silty. Spores absent.

CORE 2

NW1/4SW1/4sec. 5, T. 27 S., R. 13 E., Greenwood County, Kansas



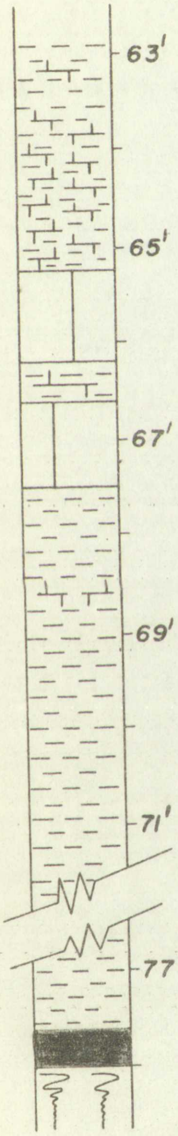
Feet	
65.0-68.5	Limestone, white to light-gray, with dark gray argillaceous streaks, very fine-grained bioclastic. Fossils: fusulinids in lower part. Spores absent.
68.5-68.7	Shale, dark gray, calcareous. Spores absent.
68.7-69.5	Limestone, light-gray, fine-grained bioclastic. Fossils: fusulinids. Spores absent.
69.5-69.6	Shale parting, dark gray. Spores absent.
69.6-70.5	Limestone, light-gray, fine-grained bioclastic. Fossils: fusulinids. Spores absent.
70.5-71.0	Limestone, light-gray, argillaceous, thin-bedded. Spores absent.
71.0-72.3	Limestone, light-gray, medium-grained bioclastic, argillaceous stringers. Spores absent.
72.3-72.9	Limestone, medium-gray, argillaceous. Spores absent.
72.8-73.6	Shale, dark-gray, calcareous, massive. Spores absent.
73.6-75.5	Shale, gray, well laminated.
75.5-76.0	Coal, black, chunky.
76.0-76.7	Underclay, bluish-gray, unlaminated, blocky.
76.7-78.0	Shale, dark-gray, laminated.
75-77	Shale and coal sample. A very few spores present.

Stratigraphic Unit	Lithology	Calamospora sp. 20	Triquitrites sp. 117	Cadiospora sp. 144	Laevigatosporites sp. 166																
75'-77'	Shale and coal	1	1	4	1																

Core 2 - Number of spores present in each stratigraphic unit

CORE 3

NE1/4SW1/4sec. 25, T. 29 S., R. 12 E., Elk County, Kansas



Feet

61-63 Shale, gray, calcareous, fossiliferous. Spores rare.

63-65 Shale, gray, very calcareous, fossiliferous. Spores rare.

65-67 Limestone, medium-gray, fine-grained bioclastic. Fossils: abundant fusulinids. Spores rare.

67-69 Shale, light-gray, calcareous, hard. Spores rare.

69-71 Shale, grayish-brown, laminated, soft. Spores rare.

71-73 Shale, grayish-brown, laminated, soft. Spores abundant.

73-75 Shale, grayish-brown, laminated, soft. Spores abundant.

75-77 Shale, grayish-brown, laminated, soft. Spores abundant.

77-78.5 Coal, black, hard. Spores abundant.

Stratigraphic Unit	Lithology	Leiotriletes sp. 1	Leiotriletes sp. 2	Leiotriletes sp. 7	Leiotriletes sp. 8	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 21	Calamospora sp. 23	Calamospora sp. 24	Granulatisporites sp. 25	Granulatisporites sp. 26	Cyclogranisporites sp. 32	Cyclogranisporites sp. 35	Cyclogranisporites sp. 37	Planisporites sp. 39	Planisporites sp. 42	Lophotriletes sp. 44	Acanthotriletes sp. 47	Raistrickia sp. 58	Pustulatisporites sp. 70
61'-63'	Shale						3		1								1				
63'-65'	Shale						3														
65'-67'	Limestone						1														
67'-69'	Shale		1				5				1										
69'-71'	Shale					2	37						1			1	3				
71'-73'	Shale		2	1		1	9		7	1		1	56	1			1	1		1	
73'-75'	Shale				1	3	8						61				7		1		
75'-77'	Shale					2	3	1	1				71				8				2
77'-78-1/2'	Coal and shale	1				2	21		30				10	1	1		27				

Core 3 - Number of spores present in each stratigraphic unit

Stratigraphic Unit	Lithology	Pustulatisporites sp. 72	Reticulatisporites sp. 96	Convolutispora sp. 105	Convolutispora sp. 107	Triquitrites sp.	Triquitrites sp. 120	Triquitrites sp. 127	Triquitrites sp. 128	Lycospora sp. 138	Lycospora sp. 140	Simozonotriletes sp. 152	Densosporites sp. 157	Cirratriradites sp. 161	Laevigatosporites sp. 163	Laevigatosporites sp. 166	Cadiospora sp. 141	Cadiospora sp. 144	Endosporites sp.	Endosporites sp. 186	Endosporites sp. 278
61'-63	Shale																3			2	
63'-65'	Shale													1							1
65'-67'	Limestone																				
67'-69'	Shale																				
69'-71'	Shale		1						1	1							2				
71'-73'	Shale				1	1		1	2	1	1	1						1	2	7	
73'-75'	Shale	6		1	1		1		2	2	1		3			1		5		14	
75'-77'	Shale	1			2		2							1	1	1	2	2		14	
77'-78-1/2'	Coal and shale	3			1										7	71	3	4	2	86	

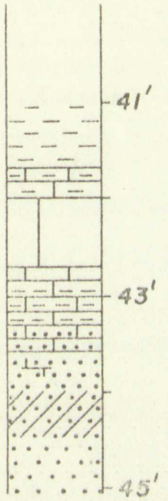
Core 3 - Number of spores present in each stratigraphic unit

Stratigraphic Unit	Lithology	Florinites sp.	Florinites sp. 195	Florinites sp. 196	Florinites sp. 199	Illinites sp.	Illinites sp. 205	Monoletes sp. 31	Simozonotriletes sp. 149	Cyclogranisporites sp.31
61'-63'	Shale	28	1	11	19					
63'-65'	Shale				5					
65'-67'	Limestone	2		1						
67'-69'	Shale				1		1			
69'-71'	Shale	2		3	10		2			
71'-73'	Shale	31		1	7	1		4		
73'-75'	Shale	1		3	9			3		
75'-77'	Shale	13		7	1	1		10		
77'-78-1/2'	Coal and shale	1			1				1	9

Core 3 - Number of spores present in each stratigraphic unit

CORE 4

SE1/4NW1/4sec. 8, T. 32 S., R. 12 E., Chautauqua County, Kansas



Feet

40.0-42.0 Shale, red, laminated, calcareous, at bottom, grades downward into limestone. Spores rare.

42.0-42.7 Limestone, bluish-gray, fine-grained bioclastic. Fossils: fusulinids. Spores absent.

42.7-43.6 Limestone, bluish-gray, thin-bedded, very argillaceous. Fossils: fusulinids. Spores absent.

43.6-44.0 Shale, gray, calcareous to sandy. No fossils seen. Spores absent.

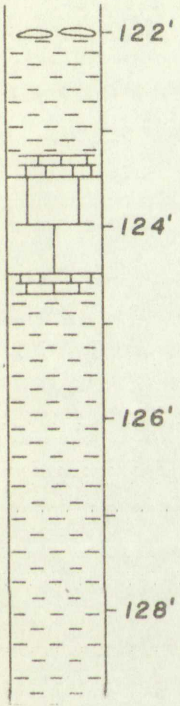
44.0-45.0 Sandstone, light-tan, quartz, cross-bedded. Spores absent.

Stratigraphic Unit	Lithology	Calamospora sp. 20	Florinites sp.	Florinites sp. 196	Illinites sp.
40'-42'	Shale	2	5	1	1

Core 4 - Number of spores present in each stratigraphic unit

CORE 5

NE1/4sec. 12, T. 35 S., R. 10 E., Chautauqua County, Kansas



Feet	
115-117	Shale, light-gray. Spores rare.
117-119	Shale, light-gray. Spores abundant.
119-121	Shale, light-gray. Spores rare.
121-123	Shale, dark-gray, hard, laminated. No fossils seen. Spores rare.
123-125	Shale, dark-gray, soft, calcareous, laminated. Fossils: fusulinids, crinoid stems, brachiopods, pelecypods, plant fragments. Spores rare.
127-128.5	Dark-gray, calcareous shale. Spores rare.

Stratigraphic Unit	Lithology	Leiotriletes sp. 2	Leiotriletes sp. 7	Punctatisporites sp. 10	Calamospora sp. 19	Calamospora sp. 20	Calamospora sp. 23	Granulatisporites sp. 26	Cyclogranisporites sp. 32	Cyclogranisporites sp. 35	Planisporites sp. 39	Planisporites sp. 42	Acanthotriletes sp. 46	Acanthotriletes sp. 50	Raistrickia sp. 53	Pustulatisporites sp. 67	Pustulatisporites sp. 70	Micro-reticulatisporites sp. 102	Lycospora sp. 140	Densosporites sp. 157	Laevigatosporites sp. 163
115'-117'	Shale		3			21	1		1	1	1									1	
117'-119'	Shale	4		1	1	46			2		4			1		2		1	1	3	1
119'-121'	Shale		4		3	29			1	1		1	3		1	1	2		2		
121'-123'	Shale	1			1	29		4	6	1			1							1	
123'-125'	Shale																				
127'-128½'	Shale								1		3	1					1				

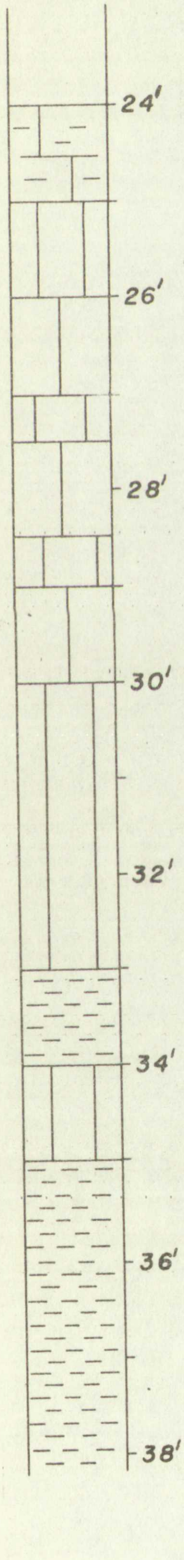
Core 5 - Number of spores present in each stratigraphic unit

Stratigraphic Unit	Lithology	Laevigatosporites sp. 166	Endosporites sp.	Endosporites sp. 183	Endosporites sp. 185	Endosporites sp. 186	Florinites sp.	Florinites sp. 196	Florinites sp. 199	Illinites sp.	Illinites sp. 205	Monoletes sp.	Monoletes sp. 231
115'-117'	Shale		2			1	8	17	15	2			
117'-119'	Shale				1		1				4		1
119'-121'	Shale	2				1		4	7	2	3	1	1
121'-123'	Shale		8			2	4	4	8		1		
123'-125'	Shale						4	1					1
127'-128½'	Shale	1		1			15		7		2		

Core 5 - Number of spores present in each stratigraphic unit

CORE 6

CSL sec. 32, T. 20 S., R. 17 E., Coffey County, Kansas

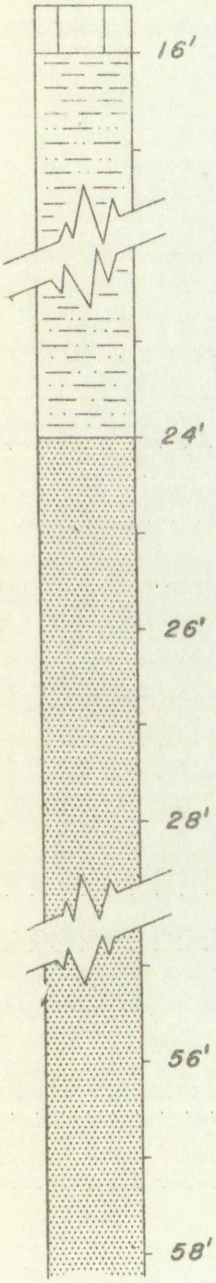


Feet	
24.0-25.0	Limestone, light-gray to white, very fine grained, slightly argillaceous. Spores absent.
25.0-27.0	Limestone, white, dense, very fine grained. Spores absent.
27.0-29.0	Limestone, white to light-gray, bioclastic. Fossils: crinoid stems, brachiopods, bryozoa. Spores absent.
29.0-30.0	Limestone, light-gray, fine-grained bioclastic. Fossils: fusulinids, crinoid stems, algal crusts. Spores absent.
30.0-33.0	Limestone, white to light-gray, fine-grained bioclastic. Fossils: fusulinids, crinoid stems, brachiopods. Spores absent.
33.0-34.0	Shale, medium dark-gray, laminated, calcareous at base. Spores absent.
34.0-35.0	Limestone, light-gray, fine-grained bioclastic. Fossils: fusulinids, brachiopods. Spores absent.
35.0-38.0	Shale, dark-gray, laminated. Spores absent.

CORE 8

NW1/4NW1/4sec. 5, T. 16 S., R. 18 E., Franklin County, Kansas

Not examined for spores.



Feet

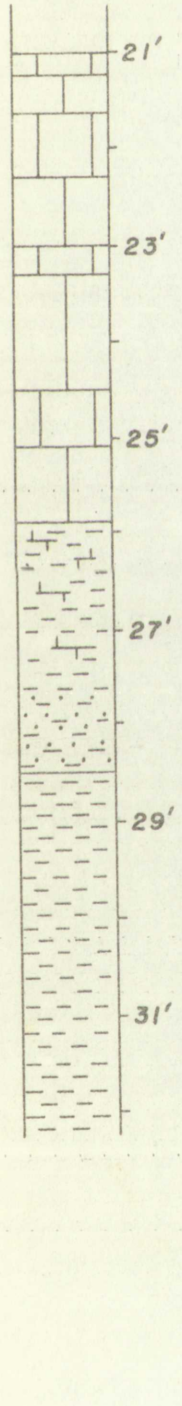
16.0 Base of Leavenworth limestone.

16.0-24.0 Shale, medium-gray to medium dark-gray, silty to finely arenaceous. No fossils seen.

24.0-58.0 Sandstone, light-gray to medium-gray, argillaceous, slightly calcareous, fine-grained. No fossils seen.

CORE 9

CNL sec. 26, T. 9 S., R. 21 E., Leavenworth County, Kansas



Feet

21.0-23.3 Limestone, light-brown, ferruginous, fine-grained bioclastic. Fossils: crinoid stems, brachiopods, fusulinids, algal structures. Spores absent.

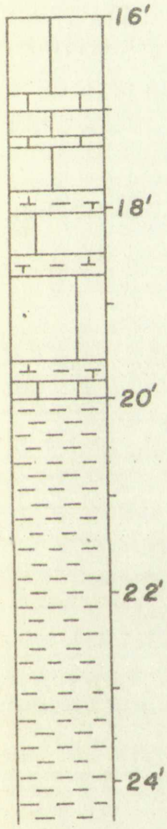
23.3-25.9 Limestone, light brownish-gray, fine-grained bioclastic. Fossils: fusulinids, crinoid stems, brachiopods. Spores absent.

25.9-28.5 Shale, tan to buff, silty, calcareous, gradational into limestone above. Spores absent.

28.5-32.0 Shale, light-tan to buff, siliceous, silty lenses, thinly laminated. Spores absent.

CORE 10

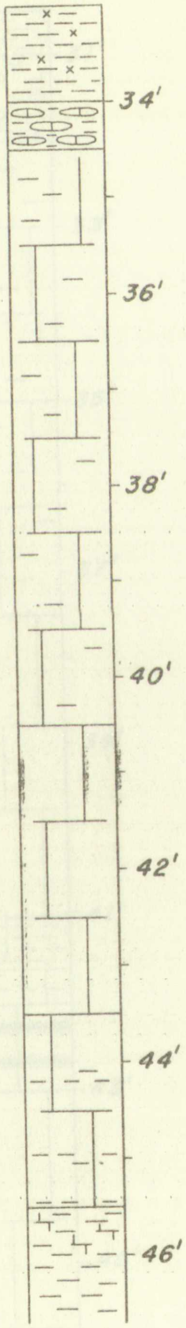
CSL sec. 22, T. 55 N., R. 37 W., Buchanan County, Missouri



Feet	
16.0-17.2	Limestone, light brownish-gray, bioclastic with fine-grained matrix, massive. Fossils: fusulinids, crinoid stems, algal coatings on shall fragments. Spores absent.
17.2-18.5	Limestone, light brownish-gray, bioclastic, possibly solution-channeled top. Fossils: abundant crinoid stems in zones. Spores absent.
18.5-20.0	Limestone, light brownish-gray, more bioclastic than above. Fossils: fusulinids, brachiopods, crinoid stems. Spores absent.
20.0-24.0	Shale, light-gray, silty, finely laminated. Spores absent.
24.0-25.0	Shale, medium-gray, silty, cross-bedded. Spores absent.

GROUP 21

SW1/4SE1/4sec. 31, T. 23., R. 15 E.,
Woodson County, Kansas



Feet

8.0-11.0 Shale, olive-drab, poorly laminated. No fossils seen. Spores absent.

11.0-24.0 Shale, reddish-gray, poorly laminated, silty. No fossils seen. Spores absent.

24.0-34.0 Shale, slightly reddish at top, grading down into greenish-gray, poorly laminated. No fossils seen. Spores absent.

34.0-40.5 Limestone, very light gray to creamy white, dense to finely bioclastic, vuggy porosity and green shale flakes. Algal-encrusted shell fragments. Spores absent.

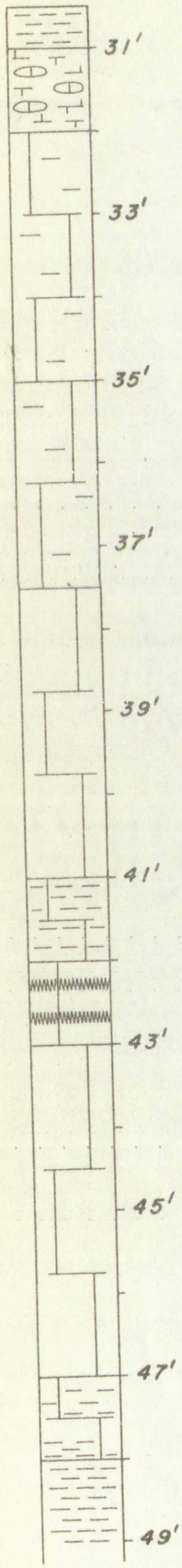
40.5-43.5 Limestone, creamy white, dense to finely bioclastic, no vuggy pores or green shale flakes. Fossils: a few fusulinids. Spores absent.

43.5-45.5 Limestone, very light gray, with darker argillaceous (?) streaks, dense to finely bioclastic. Fossils: few fusulinids. Spores absent.

45.5-46.7 Shale (no recovery). Spores absent.

CORE 23

C N 1/2SW1/4sec. 4, T. 23 S., R. 15 E., Coffey County, Kansas



Feet	
2.3	Base of Leavenworth limestone.
2.3-17.5	Shale, bluish-gray to brownish-gray (poor core recovery).
17.5-22.5	Sandstone, light greenish-gray, very fine-grained. No fossils seen.
22.5-31.0	Shale, medium dark gray, poorly laminated. No fossils seen. Spores absent.
31.0-32.0	Limestone and shale, alternating thin beds or nodular limestone in shale: limestone light-gray with green shale stringers. Spores absent.
32.0-35.0	Limestone, very light greenish-gray, granular, fine bioclastic, with green shale stringers. No fossils seen. Spores absent.
35.0-37.5	Limestone, very light gray to creamy white, fine-grained to finely bioclastic, very abundant vuggy porosity, some with green shale fillings, stylolitic at base. Spores absent.
37.5-41.0	Limestone, light-gray, finely bioclastic, one or two small stylolites. Spores absent.
41.0-42.0	Limestone, light-gray, bioclastic with abundant greenish-gray shale stringers and partings. No fossils seen. Spores absent.
42.0-43.0	Limestone, light-gray, coarser bioclastic, numerous fine stylolites. Spores absent.

C.H. 23

C N 1/2031/Sec. 4, T. 23 ... [illegible] ... 13 ... [illegible] County, Kansas

Feet

2.3 Base of Leavenworth limestone.

2.3-17.5 Shale, bluish-grey to brownish-grey (poor core recovery).

17.5-22.5 Sandstone, light greenish-grey, very fine-grained. No fossils seen.

22.5-31.0 Shale, medium dark grey, poorly laminated. No fossils seen. Spores absent.

31.0-32.0 Limestone and shale, alternating thin beds or nodular limestone in shale; limestone light-grey with green shale stringers. Spores absent.

32.0-35.0 Limestone, very light greenish-grey, granular, fine bioclastic, with green shale partings. No fossils seen. Spores absent.

35.0-37.5 Limestone, very light grey to creamy white, fine-grained to finely bioclastic, very abundant vugy porosity, some with green shale fillings, stylolitic at base. Spores absent.

37.5-41.0 Limestone, light-grey, finely bioclastic, one or two small stylolites. Spores absent.

41.0-42.0 Limestone, light-grey, bioclastic with abundant greenish-grey shale stringers and partings. No fossils seen. Spores absent.

42.0-43.0 Limestone, light-grey, coarser bioclastic, numerous fine stylolites. Spores absent.

CORE 23

43.0-47.0 Limestone, very light gray, medium grained bioclastic, few shale partings. Fossils: sparse fusulinids. Spores absent.

47.0-48.0 Limestone, light- to medium-gray, fine-grained, argillaceous. No fossils seen. Spores absent.

48.0-53.3 Shale, medium dark gray, non-calcareous, moderately well laminated. Fossils: numerous well-preserved carbonaceous plant leaves and other plant remains. Spores absent.

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EXPLANATION OF PLATE 1

Figure 1. Leiotriletes sp. 1, 51 x 51 x 56 microns, p. 31

2. Leiotriletes sp. 2, 35 microns, p. 31

3. Leiotriletes sp. 7, 44 x 44 x 49 microns, p. 32

4. Leiotriletes sp. 8, 22 microns, p. 32

5. Punctatisporites sp. 10, 61 x 61 microns, p. 32

6. Punctatisporites sp. 12, 56 x 48 microns, p. 32

7. Calamospora sp. 19, 72 x 82 microns, p. 33

8. Calamospora sp. 20, 36 x 36 microns, p. 33

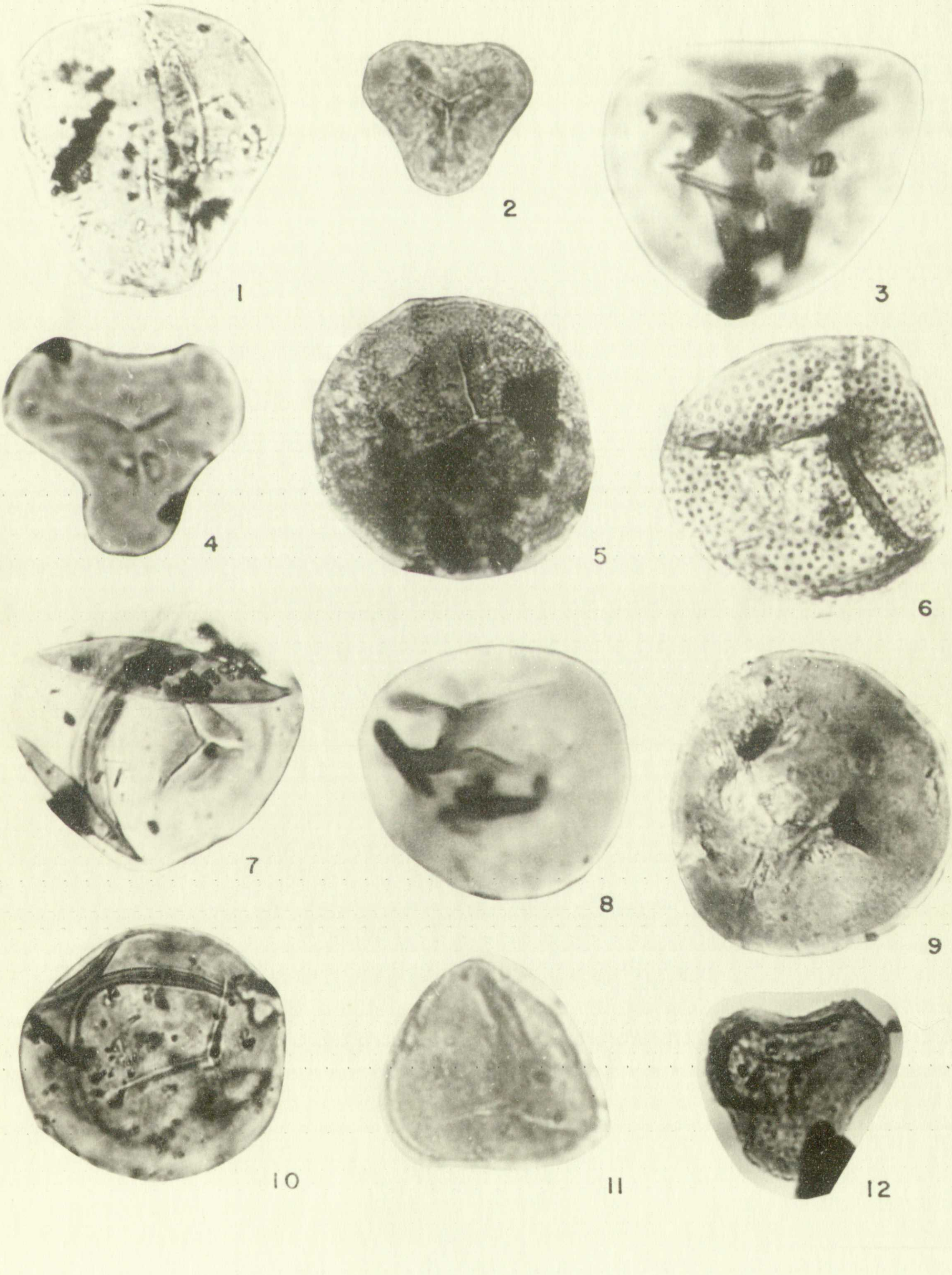
9. Calamospora sp. 21, 83 x 85 microns, p. 33

10. Calamospora sp. 23, 56 x 63 microns, p. 33

11. Granulatisporites sp. 25, 29 microns, p. 34

12. Granulatisporites sp. 26, 24 x 24 x 26 microns, p. 34

PLATE I



EXPLANATION PLATE 2

Figure 1. Cyclogranisporites sp. 31, 49 x 49 microns, p. 34.

2. Cyclogranisporites sp. 32, 36 x 39 microns, p. 35

3. Cyclogranisporites sp. 35, 68 x 69 microns, p. 35

4. Planisporites sp. 39, 22 x 22 microns, p. 35

5. Planisporites sp. 41, 36 x 43 microns, p. 36

6. Planisporites sp. 42, 53 x 58 microns, p. 36

7. Lophotriletes sp. 44, 29 x 32 x 34 microns, p. 36

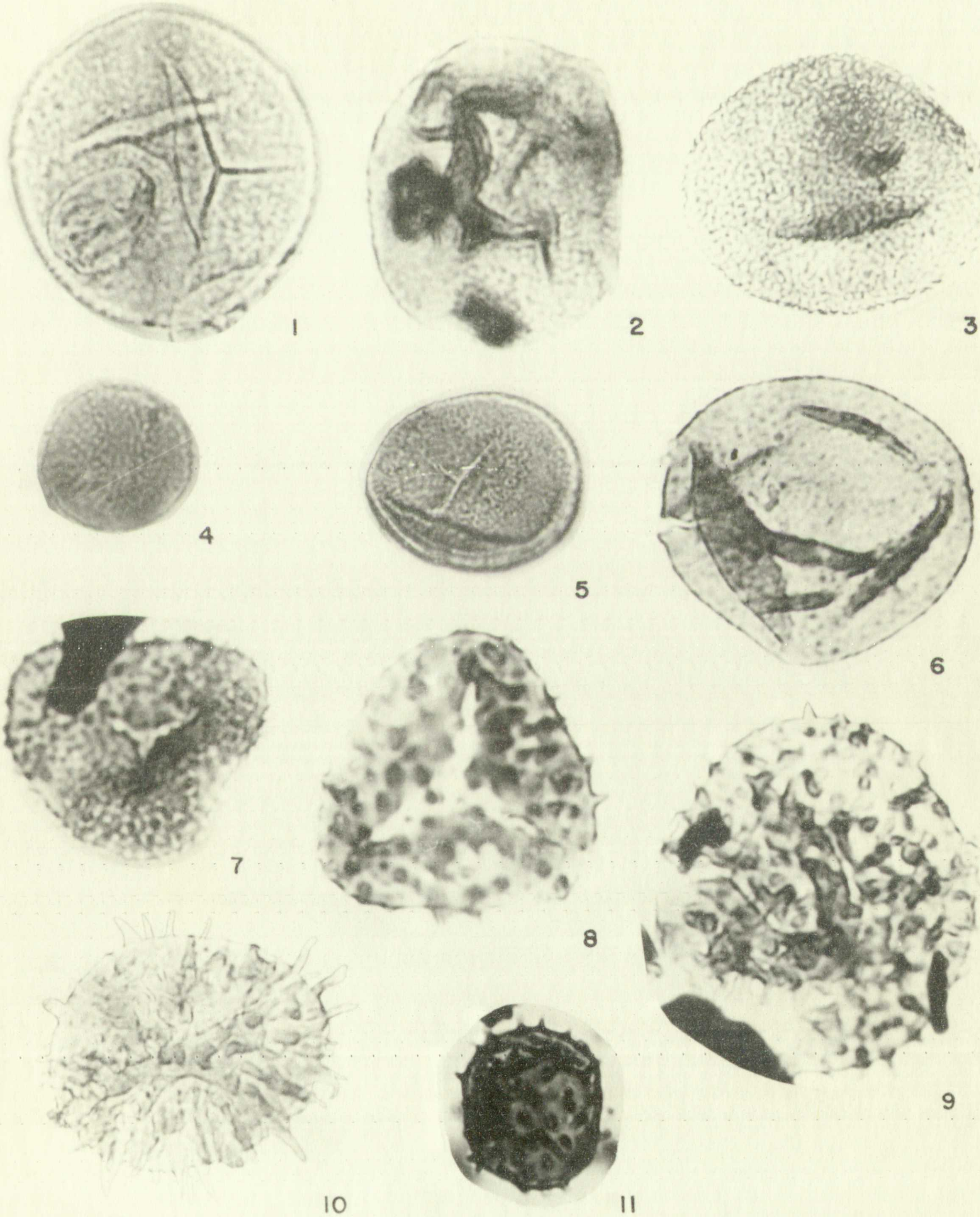
8. Acanthotriletes sp. 46, 29 x 32 x 32 microns, p. 37

9. Acanthotriletes sp. 47, 41 x 44 x 46 microns, p. 37

10. Acanthotriletes sp. 290, 51 x 63 microns, p. 137

11. Pustulatisporites sp. 67, 24 microns, p. 37

PLATE 2



EXPLANATION OF PLATE 3

Figure 1. Pustulatisporites sp. 72, 50 microns, p. 38

2. Pustulatisporites sp. 74, 26 x 28 microns, p. 38

3. Pustulatisporites sp. 84, 46 x 51 microns, p. 38

4. Raistrickia sp. 53, 48 microns, p. 39

5. Raistrickia sp. 58, 46 x 51 microns, p. 39

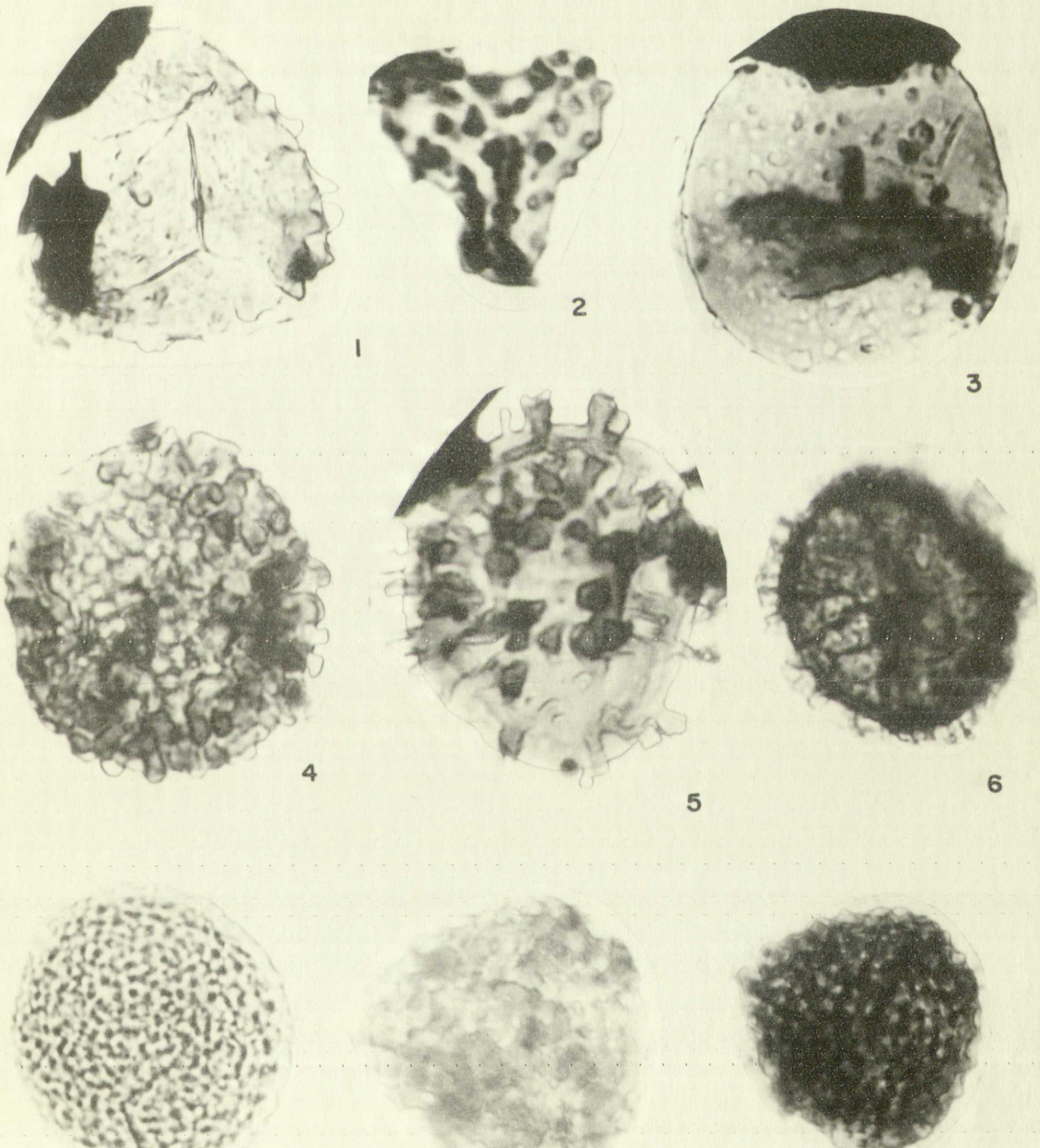
6. Reticulatisporites sp. 96, 36 x 39 microns, p. 40

7. Convolutispora sp. 105, 41 x 43 microns, p. 41

8. Convolutispora sp. 107, 46 x 48 microns, p. 41

9. Convolutispora sp. 107, 46 x 48 microns, p. 41

PLATE 3



EXPLANATION OF PLATE 4

Figure 1. Convolutispora sp. 109, 41 x 46 microns, p. 41

2. Convolutispora sp. 109, 53 x 53 microns, p. 41

3. Convolutispora sp. 114, 43 x 43 microns, p. 41

4. Convolutispora sp. 312, 36 x 36 x 36 microns, p. 42

5. Triquitrites sp. 124, 36 x 36 x 39 microns, p. 43

6. Triquitrites sp. 125, 36 x 39 x 41 microns, p. 43

7. Triquitrites sp. 127, 27 x 29 x 29 microns, p. 43

8. Triquitrites sp. 128, 36 x 36 x 36 microns, p. 43

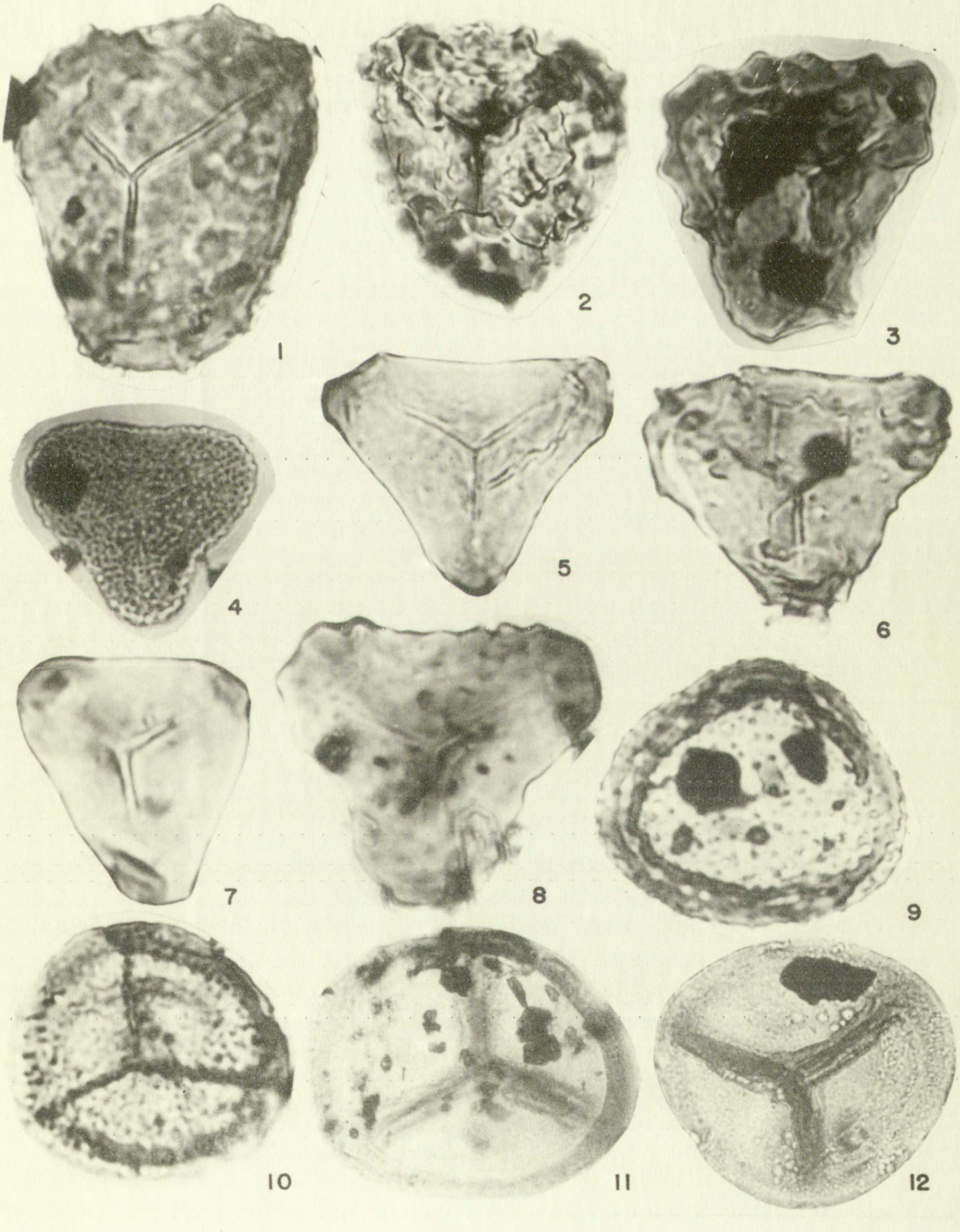
9. Lycospora sp. 138, 56 x 63 microns, p. 44

10. Lycospora sp. 140, 28 x 32 microns, p. 44

11. Cadiospora sp. 141, 102 x 119 microns, p. 45

12. Cadiospora sp. 144, 97 x 102 microns, p. 45

PLATE 4



EXPLANATION OF PLATE 5

Figure 1. *Cadiospora* sp. 144, 75 x 75 microns, p. 45

2. *Simozonotriletes* sp. 152, 56 microns, p. 46

3. *Simozonotriletes* sp. 152, 56 microns, p. 46

4. *Densosporites* sp. 157, 39 x 48 microns, p. 46

5. *Cirratriradites* sp. 161, 66 x 72 microns, p. 47

6. *Laevigatosporites* sp. 163, 32 x 41 microns, p. 47

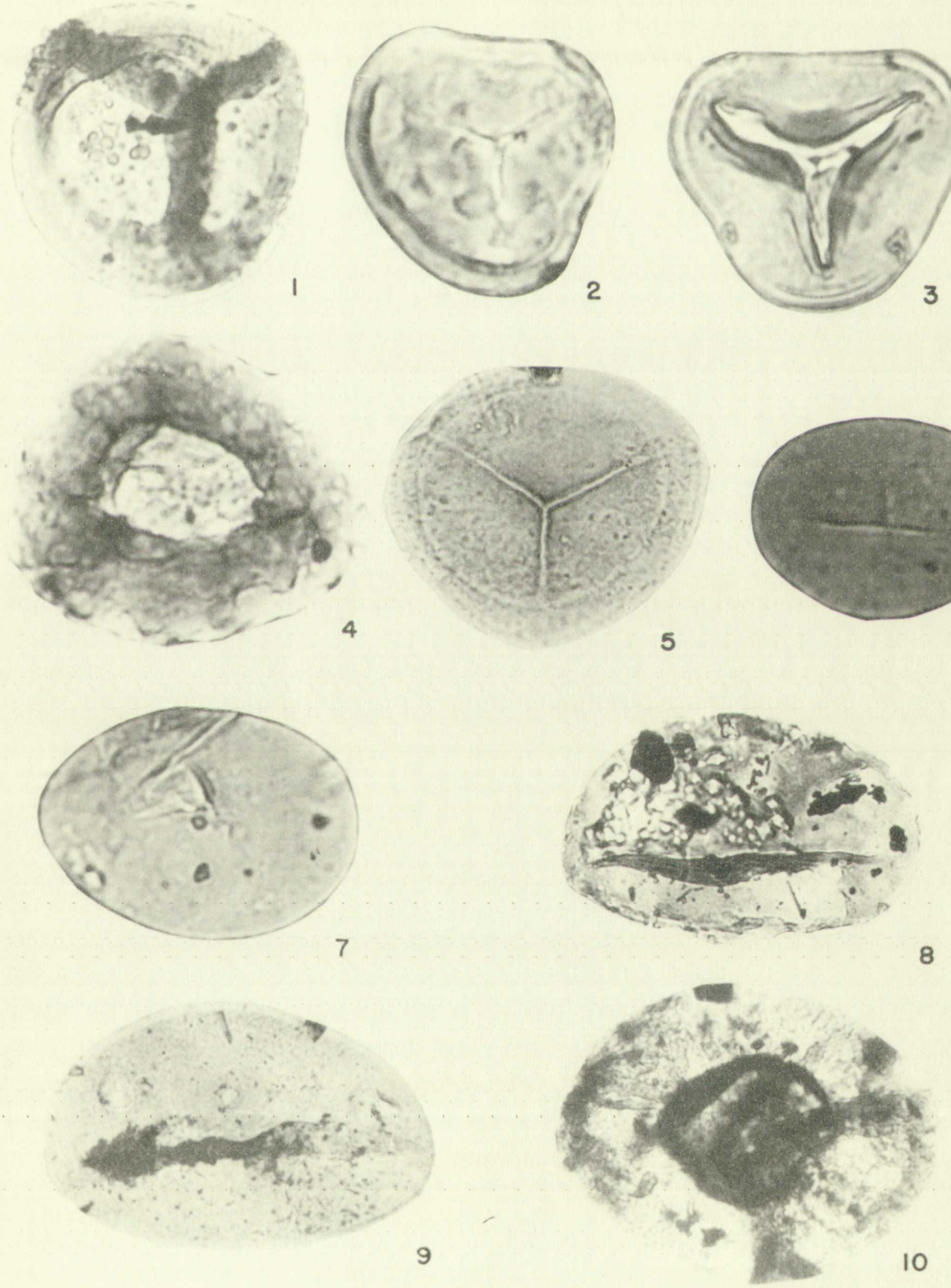
7. *Laevigatosporites* sp. 166, 45 x 65 microns, p. 48

8. *Monoletes* sp. 231, 97 x 148 microns, p. 48

9. *Monoletes* sp. 231, 97 x 158 microns, p. 48

10. *Endosporites* sp. 185, over-all 122 x 122 microns, body 53 x 56 microns, p. 49

PLATE 5



EXPLANATION OF PLATE 6

Figure 1. _Endosporites_ sp. 186, over-all 102 microns, body 46 x 53 microns, p. 49

2. _Endosporites_ sp. 190, over-all 60 x 70 microns, body 32 x 34 microns, p. 49

3. _Endosporites_ sp. 278, over-all 51 x 53 microns, body 29 x 32 microns, p. 50

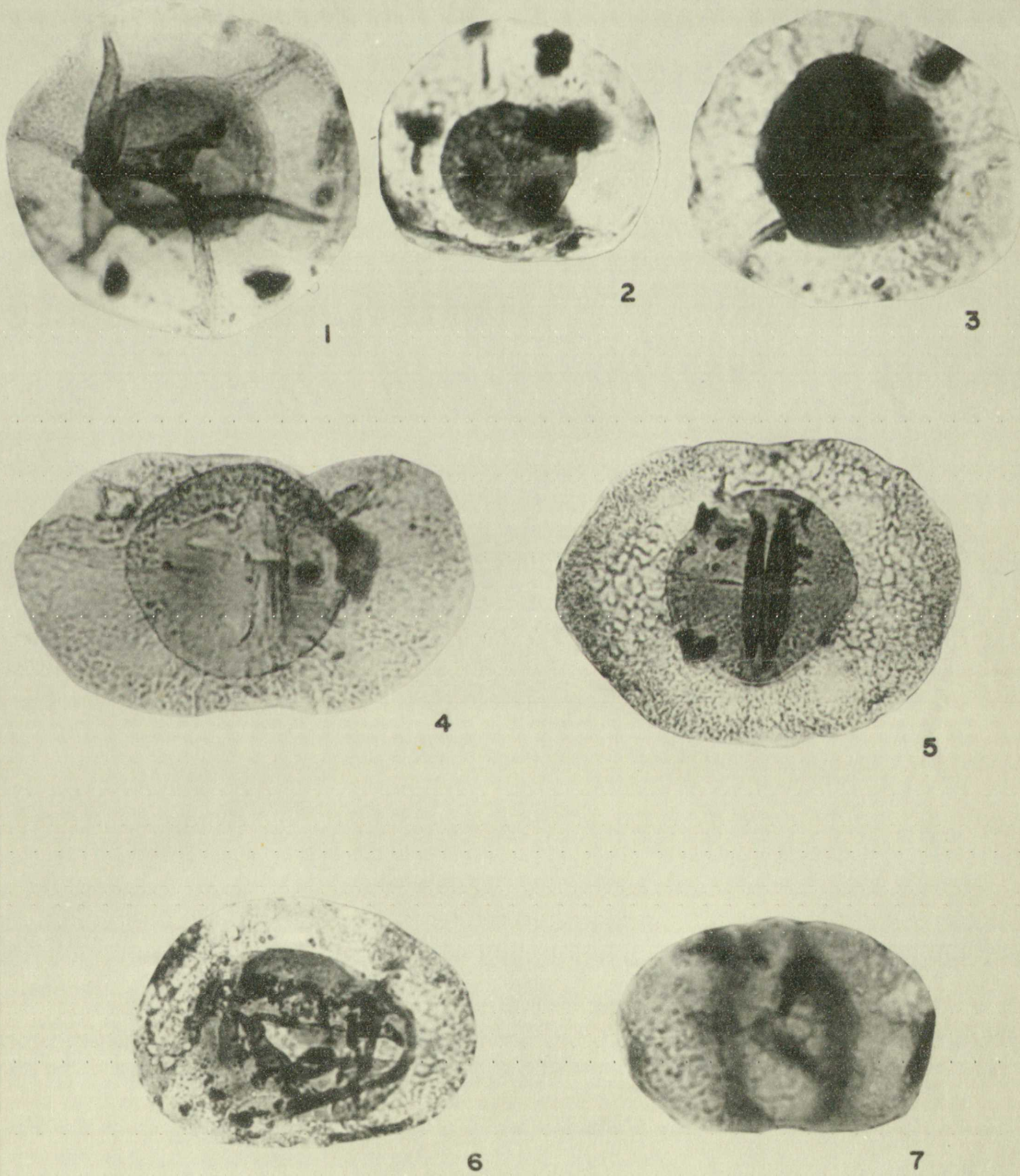
4. _Florinites_ sp. 196, over-all 58 x 104 microns, body 49 microns, p. 50

5. _Florinites_ sp. 196, over-all 97 x 126 microns, body 58 x 61 microns, p. 50

6. _Florinites_ sp. 199, over-all 106 x 138 microns, body 73 x 92 microns, p. 51

7. _Illinites_ sp. 205, over-all 34 x 51 microns, body 22 x 34 microns, p. 51

PLATE 6



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