STATE OF ILLINOIS
William G. Stratton, Governor
DEPARTMENT OF REGISTRATION AND EDUCATION
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1959

UPPER MISSISSIPPIAN AND PENNSYLVANIAN MEGASPORES AND OTHER PLANT MICROFOSSILS FROM ILLINOIS

Marcia R. Winslow

BULLETIN 86

ILLINOIS STATE GEOLOGICAL SURVEY
JOHN C. FRYE, *Chief*
URBANA, ILLINOIS

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CONTENTS

ILLUSTRATIONS

TABLES

UPPER MISSISSIPPIAN AND PENNSYLVANIAN MEGASPORES AND OTHER PLANT MICROFOSSILS FROM ILLINOIS

MARCIA R. WINSLOW

ABSTRACT

A preliminary investigation of land plant megaspores and other resistant plant parts from the plus 65-mesh maceration residues of coals and carbonaceous layers of upper Mississippian (Chester Series) and Pennsylvanian age indicates that plant megaspores are useful in correlation, especially on a local scale, and may in the future aid in delineating coal swamp heterosporous plant distribution.

The study established that megaspore assemblages of Chester age are dominated by spinose lageniculate and fibrous-coated megaspores representing an arborescent lepidodendrid-lepidocarp flora. Megaspores of the Caseyville Group indicate a more diverse heterosporous flora, including both herbaceous and arborescent lycopsids. Spinose lageniculate, fibrous-coated, auriculate, zonate, and deltoid-bladdered spores dominate the assemblages. The oldest occurrences of sigillarians and medullosans are represented by spinose aphanozonate and monolete spores, respectively. Sphenopsids also are represented.

From the base of the Tradewater Group, to and including the Pope Creek Coal, the assemblages are distinguished by their great diversity of zonate megaspores, by abundant triangulate megaspores, and by the occurrence, apparently restricted, of one new genus. The upper part of the Tradewater Group is characterized by smooth lageniculate spores, abundant monolete medullosan spores, and by the lowest occurrence of spores with lateral bladders.

The assemblages from the Summum (No. 4) Coal to the top of the Carbondale Group are characterized by an abundance of smooth aphanozonate spores of sigillarian alliance, but, except for the absence of zonate spores, are otherwise similar to those of the Tradewater Group. The assemblages of the McLeansboro Group, not investigated extensively, appear to be characterized by heavy-apexed, smooth lageniculate-type spores, smooth aphanozonate spores, auriculate spores, monolete medullosan spores, both deltoid- and lateral-bladdered spores, and by the absence or extreme rarity of the fibrous-coated spores and zonate spores.

Zonation of megaspores from upper Mississippian and Pennsylvanian coals is possible, based on the differentiation of lageniculate spores, restricted ranges of some spores, and, in some instances, marked variation in abundance.

INTRODUCTION

The spores described here are actually the resistant outer coats of the spores or propagative bodies of the gametophytic generation of certain types of land plants that were abundant in the floras of Mississippian and Pennsylvanian age. A great variety of spore types were produced in large numbers and widely dispersed, principally by wind and water. Eventually they were entombed in both continental and marine sediments, although they were produced only by land plants. Such spores occurred in greatest numbers closest to their site of production, and in marine sediments decreased in frequency as distance from the old shoreline increased. As the plants changed or evolved, more or less parallel morphological changes took place in the spore coats. The study of fossil spores, and pollen in beds of younger age, is therefore of value in the correlation of coals and other sedimentary rocks as well as for possible paleobotanical implications.

Coals of Mississippian and Pennsylvanian age are composed largely of more or less chemically altered fossil remains of plants, such as the woody parts of stems and branches, resins, waxes, cork, cuticle, and spore coats. Although spore coats do not make up the bulk of the coal, except in such unusual deposits as the Williamston Spore Coal of Michigan, they are commonly abundant. Because of their small size, less than 15 μ to more than 10,000 μ, vast numbers can be studied easily in the laboratory when they are isolated from coal by one of the various maceration techniques.

The complex problem of correlation of Pennsylvanian coals in Illinois has been greatly simplified by Kosanke's (1950) investigations of small spore occurrences. Because all vascular plants produce small spores or their equivalents among plants of more advanced organization, such a study is of great value not only in the correlation of beds but also in the assessment of the total aspect of the flora existing during Pennsylvanian time. The megaspores, generally the larger spores, are produced by only the heterosporous vascular plants and therefore yield information on only a segment of the flora. However, the megaspore content of coal beds in European coal basins has been studied extensively for almost thirty years and such studies have yielded valuable information on the correlation of coal beds and their relative age. Even in an area where the stratigraphic succession is accurately known, the relative quantity and kinds of megaspores in different coals have provided an accurate basis for comparing an unknown bed to known beds or correlating known beds across a fault zone (Dijkstra, 1946; 1949, fig. 1).

Because fewer megaspores are produced and because they are generally much larger and heavier than the small spores, they probably were not dispersed as widely as isospores and microspores. An uneven distribution of plants throughout a coal swamp might be masked by the wide dispersal of small spores, but the large spores might be used in interpreting the geographic distribution of the heterosporous plants.

In contrast to the intensive megaspore investigations carried on in Europe, very few such studies (Schopf, 1938; Cross, 1947; Arnold, 1950) have been reported in the United States. This is especially true of megaspores of Mississippian age.

Purpose and Scope

The plant megaspore assemblages and some other plant remains in the plus 65-mesh maceration residues, mainly of coals, were investigated to determine their possible significance in the correlation of coal beds and in the delineation of heterosporous plant distribution in the coal swamps that existed periodically and sometimes extensively over Illinois and surrounding states during upper Mississippian and Pennsylvanian time.

General knowledge of the evolution and ecology of the heterosporous plants and of the occurrence and re-occurrence of their spores in various coal beds allows comparison of successions with those found in other coal basins in the world. A general comparison such as this adds to our knowledge of the geographic distribution and evolution of ancient floras, but it does not imply intercontinental correlation of coal beds. Such information has shown the succession in the coal basins of Poland, Czechoslovakia, France, Turkey, and in the Ruhr Basin to be generally similar (Dijkstra, 1949).

The coals in Illinois have been intensively studied and their content of small spores has been noted in previous reports. The coarse residues of the samples used in those investigations were available for study so that a comparison of the occurrences of some megaspores with the occurrences of their botanically related microspores was possible. Aside from the study by Horst (1955) on the coal beds of the Namurian A and B and Westphalian A in Poland, there is very little published information covering both the large and small spore content of the same samples of coal.

The investigation of upper Mississippian megaspores and their comparison with those of the lowermost Pennsylvanian were begun to determine whether megaspores could provide a ready differentiation for distinguishing Mississippian strata from the unconformably overlying Pennsylvanian strata, a key that would be especially useful in studies of drill cuttings and cores and when gross lithologic distinctions are not apparent. The results and possibilities presented supplement the results of more extensive investigations by other methods.

Schopf (1949, p. 511) pointed out that descriptive and taxonomic studies were likely to dominate pollen and spore research for many years, simply because the field to be explored is so enormous. In addition he stated, "It does not follow that significant economic results will invariably follow initial exploratory studies; however, the history of paleontology in general is a sufficient insurance that reasonable benefits will come from progress in this work."

A large part of this report is devoted to the description, some of it very detailed, of plant megaspores, plus some illustration and discussion of spores that are larger than conventional small spores and may be either megaspores or small spores, and of prepollen, cuticle, and seed membranes that occur in the macerations with the megaspores. The primary emphasis is on spores from the coals in the upper Mississippian Chester Series and in the Pennsylvanian Caseyville and Tradewater Groups, but those from some of the coals of the Carbondale and McLeansboro Groups are described in order to present a general overall picture of plant megaspore distribution. Some material of late Mississippian and early Pennsylvanian age from areas outside Illinois also is included for comparative purposes.

Many of the residues and slides examined had already been prepared in the laboratories of the Illinois Geological Survey for other studies, and therefore no statistical approach to the relative abundance of megaspores from one coal to another, or even in segments in the same coal, could be valid. The terms "rare," "present," "common," and "abundant" used relative to megaspore abundance are necessarily subjective because some of the samples were not collected for statistical analysis as were those on which Dijkstra (1946, 1955c) has reported.

This report, therefore, is a general and preliminary survey of the occurrence of megaspores in upper Mississippian and Pennsylvanian coals, preliminary in that the sampling of the individual coal beds was limited and the examination of spores from coals of the McLeansboro Group cursory.

Acknowledgments

I am grateful to J. A. Simon, Head of the Coal Section of the Illinois State Geological Survey, for his interest in and encouragement of this investigation, and to Dr. John C. Frye, Chief of the Survey, for his support. Dr. D. H. Swann collected some of the Mississippian samples and provided guidance in the interpretation of the stratigraphic position of some of the previously collected samples. The advice and guidance regarding the stratigraphy of Illinois coals given by Dr. R. M. Kosanke and his contributions to discussions on problems of taxonomy, nomenclature, and interpretation of some of the results made this report possible.

PREVIOUS INVESTIGATIONS

Kosanke, whose investigations on the small spores of Pennsylvanian coals of Illinois (Kosanke, 1947, 1950, 1954) are well known, has given (1950, p. 7-8) a general history of spore studies from the first observations of fossil plant spores by Witham in 1833 through the important contributions, principally concerning small spores, of the mid-1940's. Many major findings on Carboniferous megaspores also were reported during the period beginning with the study by Bennie and Kidston in 1886. Among the important studies done outside the United States are those of Zerndt (1930a, b, c, d; 1931; 1932a, b; 1934; 1937a, b; 1938a, b; 1940), Stach and Zerndt (1931), Kowalewska-Maslankiewiczowa (1932), Sahabi (1936), Ibrahim (1933), Loose (1934), Wicher (1934a, b), Nowak and Zerndt (1936); from the United States are the studies of Bartlett (1929), Schopf (1936a, b; 1938), and Schopf, Wilson, and Bentall (1944). Bailey (1936) briefly illustrated and described some megaspores.

Many contributions to the study of small spores, megaspores, and spores in organic association in cones have been made since 1944. Those particularly pertinent to the study of larger plant microfossils of Carboniferous age outside the United States are studies by Dijkstra (1946; 1952a, b, c; 1955a, b, c; 1957), Kalibova (1951), Piérart 1956, 1957), Potonié (1954a, b), Potonié and Kremp (1954, 1955, 1956), and Horst (1955). Recent cone studies by Chaloner (1951; 1952; 1953a, b, c; 1954a; 1958a), Dijkstra (1958), Remy and Remy (1956), and, in the United States, by Felix (1954), Hoskins and Abbott (1956), and Chaloner (1956a, 1958a) to mention a few, give much valuable information as to the amount of natural variation in megaspores and their botanical alliances.

Particularly pertinent studies on megaspores and other plant fragments of upper Mississippian and/or Pennsylvanian age done in the United States are those by Cross (1947), Arnold (1948, 1950), Schemel (1950a), Chaloner (1954b), and Guennel (1954). Cross (1947) illustrated and briefly described megaspores found in coals of the Kanawha Group (Pottsville Series), Allegheny Series, and Monongahela Series from the Pennsylvanian of West Virginia and Kentucky.

Arnold (1948) described several types of seed membranes found in the Pennsylvanian coals of the Michigan Basin and (1950) described and illustrated some of the megaspores found there. Schemel (1950a), in a report emphasizing small spores, described megaspores of two species from a Chester or Springer age coal of Utah. Chaloner (1954b) described and illustrated megaspores of Kinderhook or Osage age and of early Chester age from Michigan, Pennsylvania, and Indiana. Guennel (1954) gave a detailed description of spores of *Triletes triangulatus* from the Block Coal of Indiana.

The study of spores contained in coal macerations began at the Illinois State Geological Survey in 1931, under the supervision of G. H. Cady, with an investigation of plant remains in maceration residues from column samples of the Herrin (No. 6) Coal of the Carbondale Group. McCabe (1931) illustrated some cuticle, vascular tissue, and spores from the Pope Creek and No. 5 Coals and (1933) reported his findings on the plant remains of the Herrin (No. 6) Coal in an unpublished doctoral dissertation at the University of Illinois. Henbest (1933) described some of the plant fragments of the Herrin (No. 6) Coal and (1935) described and illustrated a few megaspores of that coal.

Schopf (1936a, b) also illustrated megaspores of the Herrin (No. 6) Coal and described them under binomial designations. In 1938 he presented the detailed results of these investigations on the large spores, including prepollen, found in maceration residues of the Herrin (No. 6) Coal from southern Illinois. Other papers by Schopf (1941a, b; 1948), mainly on fructifications and seeds, presented aspects of the natural affinities and variations of spores. In 1944, Schopf, Wilson, and Bentall discussed the generic groups of Paleozoic spores. Later Schopf (1949) commented further on the taxonomic identity of some spores and reviewed some of the important spore studies.

Most previously published work on Illinois coal megaspores emphasizes the megaspores of individual commercially important coals. The present study provides a general framework within which investigations concentrated on one or several coals over a large area can be related and therefore assume greater significance.

PREPARATION AND EXAMINATION OF SAMPLES

The process of coal maceration, the freeing of resistant plant parts from the rest of the coal, as used at the Illinois State Geological Survey, is a modification (see Kosanke, 1950, p. 8-11) of the method first described by Franz Schulze in 1855. In general the process consists of two phases: the partial oxidation of coal with Schulze's solution (1 part aqueous solution of $KClO_3$ to 2 parts concentrated HNO_3), followed by the solution of the salts of the humic acids by treatment with 10 percent KOH, and subsequent decantation. Some weathered coals require only the latter phases of the treatment, the oxidation phase having been completed by nature.

Spores are isolated from clays, shales, and sandstones with HCL and HF treatments. Other spores may be picked from bedding planes of a sedimentary rock and merely cleaned with dilute HF. A summary of the various methods applicable to the isolation of organic matter from all kinds of rocks, in all degrees of induration, has been published recently by Sittler (1955).

The 65-mesh (the figure indicates the number of meshes to the inch) Tyler screen has mesh openings of about 210 μ. The residue passing through the 65-mesh screen generally is stained in safranin Y and mounted under a cover slip with glycerine, diaphane, or balsam, and examined for small spore content. (A discussion of various mounting media and their advantages and disadvantages is given by Christensen [1954].) The coarse, plus 65-mesh residue may contain sporangial masses of small spores, megaspores, or large spores, spores rather small for "large" spores (200 to 400 μ), cuticle, seed membranes, waxy blebs, resin rodlets, fusinized wood and vascular fragments, and incompletely macerated coal fragments. Additional sieves may be used to separate the coarse residue into various size fractions. The coarse residues commonly are stored in alcohol and glycerine in wax-sealed bottles.

All coarse residues used in this study were examined immersed in water in a petri dish under a binocular microscope at magnifications of 6× to 36×. The large spores, some sporangial masses, cuticles, vascular tissues, and seed membranes were picked from the dish with a flattened needle. Subsequently the specimens were mounted dry on cardboard mounts or, as with the majority of specimens, passed through alcohol to xylol and mounted in balsam on slides, the most permanent media for megaspore mounts. More than 1,000 balsam and dry mounts were examined.

Descriptions and measurements are based largely on the examination of specimens mounted in balsam because the fine ornamentation details are adequately observed only by transmitted light. This phase of the work was done on a research microscope at magnifications of 150× to 500×. Photographs were taken on fine-grained film with both transmitted and reflected light. A red filter was used in photographing some of the highly ornamented thick-walled megaspores in order to show details of the spore body and its ornamentation.

SPORE DEVELOPMENT AND MORPHOLOGY

The spores described and discussed in this report were largely, perhaps entirely, derived from vascular plants, the Tracheophyta. Many of the plants were large and treelike and are referred to as arborescent. Others grew close to the ground and are called herbaceous. All vascular plants produce spores of some kind and have an alternation of sporophyte and gametophyte generation during their life cycles.

The mature plants, part of the sporophyte generation, produce spore mother cells, each of which produces four unicellular spores of the gametophyte generation. Some vascular plants are homosporous, producing spores that germinate into multicellular gametophytes, which in turn produce both male and female gametes. Other plants are heterosporous and bear: 1) megaspores that germinate into multicellular female gametophytes that produce female gametes and 2) microspores that germinate into multicellular male gametophytes that produce only male gametes. The union of female and male gametes initiates the sporophyte generation of the life cycle.

Most spores are enclosed within a protective coat that is resistant to chemical and physical attack. Because of this, the spore coats or exines, referred to generally as spores throughout this paper, commonly are well preserved in coals and many kinds of sediments. The gametophyte inside the spore coat is preserved only under exceptional conditions.

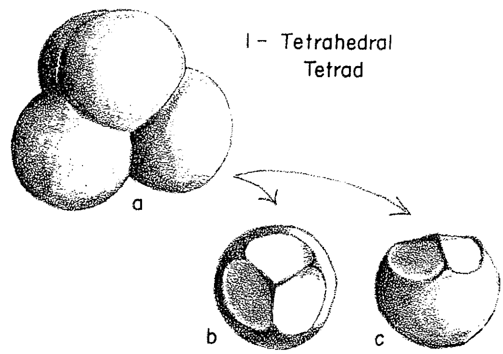
Different plants produce spores of different sizes and shapes and, as plants evolved through time, the size, shape, and ornamentation of the spores changed, although possibly not at the same rate as other observable changes in the plants. Because of the great variety of spore types, their gradual change in appearance through geologic time, and the resistant nature of the spore coat, the spore assemblages found in any one sediment are likely to be different in composition from those found in older or younger beds.

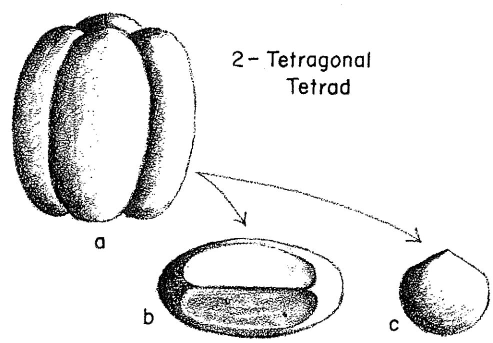
Also, because of possible geographic differences in the distribution of plants, the assemblages from the same bed may have a slightly different aspect from one area to another. Spores, especially microspores and isospores, are produced in great numbers, are small, and are widely dispersed by natural agencies such as wind and water currents. Although megaspores are generally larger, sometimes very large, and are produced by only a segment of the floral population — the heterosporous plants — they, too, are sometimes widely dispersed. However, their distribution is more likely to be restricted to an area close to their site of production.

Because we have very little chance of determining whether a fossil spore performed a male or female function in the life cycle, unless cone studies have provided the knowledge, an arbitrary lower size limit of 200 μ has been given for megaspores (Guennel, 1952). Dijkstra (1946, p. 21) also reviews the size problem. The size limit suggested follows from using the Tyler sieve, with a mesh opening of about 210 μ, to separate the fine from the coarse residue. Guennel further proposes the use of the term "miospore" for all spores or sporelike bodies less than 200 μ in size. These could include isospores, microspores, small megaspores, pollen, and prepollen.

The spores of *Spencerisporites* are isolated spores similar to those occurring in some of the cones of *Spencerites*, reported as eligulate and homosporous. Thus, on available evidence, the spores referred to *Spencerisporites* would be considered isospores. *Renisporites* spores, rather small in comparison with most megaspores, may be megaspores, isospores, or microspores. *Monoletes* and *Parasporites* are considered prepollen. However, most of the spores described here are megaspores of the arborescent and herbaceous lycopsids and lepidocarps.

The larger spores show considerable differences in size. In *Cystosporites* three members of the original tetrad are abortive, much smaller than the fertile specimens, and sometimes much different in aspect.





TEXT FIG. 1 (above).—Orientation of radially symmetrical spores.

a. Spores in tetrad association.
b. Proximal view of a single spore showing trilete suture and contact areas.
c. Lateral view of single spore.

TEXT FIG. 2 (below).—Orientation of bilaterally symmetrical spores.

a. Spores in tetrad association.
b. Proximal view of single spore showing monolete suture and contact areas.
c. Transverse lateral view of single spore.

Spores are characteristically either radially (trilete suture, text fig. 1) or bilaterally (monolete suture, text fig. 2) symmetrical, the type of symmetry being controlled by the division of the spore mother cell. For descriptive purposes, spores are oriented with reference to their original position in the tetrad grouping (text figs. 1, 2; pl. 9, fig. 3). The side of a spore toward, and including, the original areas of mutual contact in the tetrad is designated as proximal (side, surface, or hemisphere). The side of the spore external to, or away from, the center of the tetrad is distal. The axis of a radially symmetrical spore passes through the center of the original tetrad.

The apices of the four spores at the proximal poles originally touched in the tetrad.

Bilaterally symmetrical spores have one axis of symmetry through the long dimension of the spore and another through the proximal surface of the spore and the center of the distal surface. The contact areas are the two or three surfaces of mutual contact in the original tetrad.

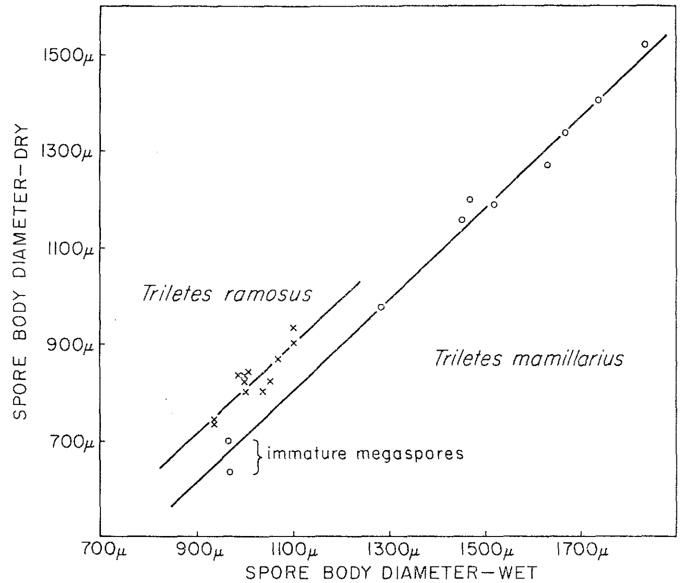
The trilete suture (pl. 15, fig. 2), or line of dehiscence, forms along three radiating lines; the trilete ray refers to one extension of the trilete suture or its expression as lips or as a fold. The monolete suture forms along a single line (pl. 15, fig. 5a). Some spores may possess very insignificant lips bordering the suture, others may have straplike lips (pl. 9, fig. 4a), and still others may have lips surmounted by an apical prominence (pl. 3, fig. 13).

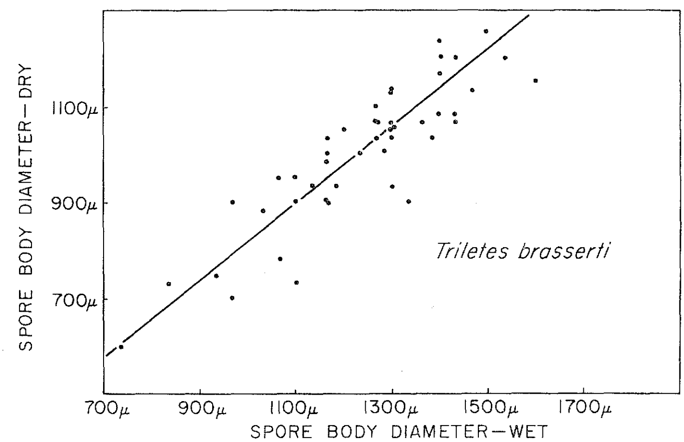
Those features influenced by the contact relationship of spores during growth in a tetrad are designated as haptotypic by Wodehouse (1935). The contact areas may be bounded by arcuate ridges, flanges, or ornamentation which may or may not extend over the entire distal surface. Distal ornamentation, in reference to megaspores, is not generally strictly limited to the distal hemisphere, but extends distally from the arcuate ridges or contact areas. Specifically inherited characters, such as distal ornamentation, of which the type, shape, and size is relatively constant for any one species, are designated as emphytic by Wodehouse (1935).

Some spores (pl. 13, fig. 2; pl. 14, fig. 11) possess bladders or membranous air sacs which are attached to the spore coat. Still others possess a wrinkled inner membrane (pl. 9, fig. 8a, b; pl. 10, fig. 9), sometimes variously ornamented, referred to as an endosporal membrane by Schopf (1938), the mesosporium of Dijkstra (1946) and Høeg, Bose, and Manum (1955). Original spore shape may vary from sac-shaped, to spherical, to distinctly oblate. The shape is usually more or less distorted by compression, the manner of compression being determined by both the original shape and the presence and kind of ornamentation. Thus, the compressional form is usually characteristic of a species, although other species may also show the same form.

In descriptions of the Illinois megaspores particular attention is given to differences in ornamentation noted on the lageniculate megaspores. This general type of megaspore, showing some morphological variations, is known from beds as old as uppermost Devonian, through the Mississippian and Pennsylvanian, and into the Permian. Therefore, any slight variation in ornamentation may be helpful in differentiating these megaspores. In contrast, those apiculate and smooth aphanozonate megaspores, *Triletes mamillarius* Bartlett (sensu Dijkstra) and *T. glabratus* Zerndt (sensu Dijkstra), and the spores of *T. triangulatus* Zerndt (sensu Dijkstra) are the least emphasized as to possible distinctions based on ornamentation because of practical limitations to the investigation.

In the smooth aphanozonate megaspores, possible distinctions would have to be based on thickness of spore coat, length of rays relative to spore diameter, or on the size ranges of the spore diameter. The actual size of a spore, or the range of a group of spores, may mean little relative to its botanical alliance. Bochenski (1936) illustrates the wide range in spore size in cones of *Sigillariostrobus Czarnockii* (400 to 2700 μ in one cone and 450 to 2900 μ in another).





TEXT FIG. 3.—Scatter diagrams showing the spore body dimensions of megaspores of *Triletes ramosus* Arnold, *T. mamillarius* Bartlett (sensu Dijkstra), and *T. brasserti* Stach and Zerndt, before and after drying. Line of best fit determined by eye. Shrinkage averages a little less than 20 percent. All specimens from the Willis Coal (maceration 625B), Gallatin County, Illinois.

The smaller, immature spores are distinguished by a thicker wall and a more triangular shape. Although actual size does not seem to be indicative for distinction, the relative proportion of one feature to another may be a more satisfactory basis for distinction.

Because many megaspores have been observed to shrink noticeably when mounted dry, a preliminary investigation on the amount of shrinkage was made on the spores of three species: *Triletes brasserti, T. ramosus, T. mamillarius.* All these specimens were well preserved, those of *T. brasserti* abundantly represented, in a sample chosen from the lower part (maceration 625B) of the Willis Coal that had been macerated in Schulze's solution in August of 1945 and stored in alcohol and glycerine until February 1956 when the specimens were transferred to water and various measurements were made. Each specimen was transferred to a cardboard mount and allowed to dry. The same measurements were then taken again, unless, of course, the specimen had cracked on drying. The maximum diameter of each specimen, both wet and dry, is well shown on the scatter diagrams that are given in text figure 3. The shrinkage observed ranges from less than 10 percent to more than 35 percent and has a pronounced effect on the means of the maximum diameters of the spores of the three species. In contrast to this large amount of shrinkage, some spores (*T. mamillarius*, sensu Dijkstra) from a Caseyville age coal (maceration 795) macerated in 1954 showed a consistent 5 percent shrinkage.

Probably many factors contribute to the observed differences in size between wet and dry specimens. The preservation of the spores, the type of maceration method used, the length of time specimens are stored, and the kind of medium in which they are stored, all may affect total size when observed wet as opposed to the size when observed dry. The differences in dimensions, if any, of a single specimen, transferred first from water to alcohol, then to xylol, and then mounted in balsam have not been checked as yet.

That some shrinkage occurs, even when freshly macerated specimens are dried, cannot be denied. Extensive, laborious tests would have to be run in order to determine the effect of different maceration processes and length of storage time on the observed differences in size. It is possible that some of the observed distinctions between spores described by different authors, from different coals or from different areas, may be resolved as only the effect of differential shrinkage rather than the result of any botanical distinctions in the plants producing these spores. In any event, this is but one facet to the study of fossil megaspores. The actual expectable differences possible within a cone or between cones of the same plant will not be fully appreciated until many more cone studies have been reported upon.

Probably the most expedient solution to the problem is to give measurements based on either dry or balsam-mounted specimens, indicating clearly which type is used. The descriptions of the spores of the different species are based on my observations of spores, principally from Illinois coals, and not on previously published descriptions unless otherwise indicated, so that the descriptions and size measurements may differ somewhat from previously published ones.

Nomenclature of fossil spores in this paper is that determined by the International Rules of Botanical Nomenclature. These rules are adhered to by most authors in order that the system of reference be understood internationally, and are simple, precise, and, above all, stable. The genera referred to in the present paper are artificial in that they are based on spores of plants, in contrast to the criteria used to determine genera of modern plants, and may correspond generally to categories of familial, or higher, rank. As research continues, especially that on fossil fructifications, these artificial groupings will become restricted to as small a natural category as is possible with fossil plants. Individual interpretation of the magnitude of differences that determine species or varieties within a generic group varies, as does the interpretation of genera based on fossil spores. In time the nomenclature may express the taxonomic position of the plants more closely.

DESCRIPTIONS OF MEGASPORES AND "LARGE" SPORES

Genus TRILETES (Bennie and Kidston) ex Zerndt, 1930

Type species: TRILETES GLABRATUS Zerndt, 1930c

Megaspores referred to *Triletes* are radially symmetrical, marked by a trilete suture on their proximal surfaces. The extremities of the trilete rays may be connected by arcuate ridges. Elaborate processes may be developed at the outer edges of mutual contact of the sister spores in the tetrad. Distal surfaces are smooth to ornamented; proximal surfaces, if ornamented, are generally ornamented to a lesser degree than are distal surfaces. Schopf (1938) pointed out that no spores of well established species of *Triletes* are less than 300 μ in size. Some spores, for example those of *T. superbus,* are as much as 4100 μ in over-all diameter.

The genus is believed to represent a natural grouping of heterosporous free-sporing lycopsids, somewhat equivalent to a suborder in the normal classification.

Potonié and Kremp (1954, 1955, 1956) believed that *Triletes* is an invalid and illegitimate generic designation and therefore redefined and re-emphasized some of Ibrahim's (1933) generic names and established new genera to which they referred megaspores. The confusion arose because of a mistaken but consistent attribution of the generic name *Triletes* to Reinsch. *Triletes,* implying relationship with the lycopods, was used by Bennie and Kidston in 1886 in describing megaspores, although not in combination with specific epithets. It was in the sense of Bennie and Kidston's usage, not Reinsch's, that Bartlett (1929) and Zerndt (1930c) applied it in binomial combination to megaspores. In 1930 Zerndt referred some of his specimens to those first described by Bennie and Kidston. Bennie and Kidston should be considered the effective authors of *Triletes* which became validated no later than 1930 by Zerndt's publication.

Laevigatisporites (Ibrahim) Potonié and Kremp (1954), therefore, is a later synonym of *Triletes.* The use or nonuse of the generic names adopted or initiated by Potonié and Kremp is a taxonomic decision to be made at present by each individual, depending on his interpretation of the taxonomic circumscription of *Triletes.* Such decisions also must be made at the species level. Dijkstra (1946) has interpreted some species as having a wide range of spore variation, an interpretation confirmed in certain instances by cone studies, whereas other authors advocate a narrow circumscription about the holotype specimen. The individual acceptance of a broad or narrow circumscription can be expressed in the taxonomy by use of such a term as "sensu Dijkstra." If each author clearly states his intent and adequately describes and illustrates his material, future modification, which always comes with expanded knowledge, will be relatively simple.

Schopf (1938) proposed the following sectional divisions of *Triletes* based on comparative spore morphology: Aphanozonati, Lagenicula (Bennie and Kidston), Auriculati, Triangulati. The spores referred to any one section are believed to be more closely related to one another than to spores referred to other sections. Such a classification attempts to indicate the phylogeny and natural plant relationships as closely as is possible on the basis of available evidence.

Dijkstra (1946) proposed the use of the section Zonales (Bennie and Kidston) because he believes that some of the zonate spores are not closely allied to those typically referred to the section Triangulati. In addition, he proposed that the auriculate spores should be grouped with the aphanozonate spores, rather than segregated in a separate section.

In the present paper, spores of *Triletes* are referred to the following sections: Lagenicula, Aphanozonati, Auriculati, Zonales, and Triangulati.

Sectio Lagenicula (Bennie and Kidston) Schopf, 1938

Spores of the Lagenicula section of *Triletes* are generally medium-sized, more or less prolate originally, and typically laterally compressed, possessing an apical prominence formed by the elongated and upraised portions of the three contact faces. Arcuate ridges are commonly developed, but extreme zonal appendages are lacking (Schopf, 1938). Spore coat is variable in thickness with a smooth to spinose surface. Spores of *T. horridus* and *T. rugosus* are typical of this section. Lageniculate spores have been found in *Lepidostrobus* fructifications (Chaloner, 1953b; Felix, 1954) in association with *Lycospora*-type microspores, a lepidodendrid alliance.

Potonié (1954b) stated that the megaspores of the Lepidodendraceae never bear "fimbriae ramifères" as do those of the Bothrodendraceae (*Triletes praetextus,* for example). However, there is a tendency for the spinose lageniculate spores found in earliest Chester and older rocks to bear double or even ramifying processes. The earliest such occurrence known from this study is that of megaspores of *T. crassiaculeatus*, each bearing only a few double-tipped spines. Spinose lageniculate-type megaspores in older Mississippian deposits bear such spines in increasing number and degree of ramification.

The coat of the spinose lageniculate spores appears more or less punctate. Wicher (1934a) in a description of *Apiculati-sporites latihirsutus* (*Triletes horridus*) noted that the surface is *"sehr fein netzförming bis punktiert."* The coat sometimes appears very finely meshed and, in this respect, is similar to the coat of some fertile and abortive spores of *Cystosporites* (especially *C. verrucosus*).

Schopf (1938, p. 28) suggested that there appears to be a progressive simplification of the apical prominence during the Carboniferous. This seems to be more or less true for the spinose spores of the section. Among the smooth forms, spores of *Triletes levis* (interpreted as *T. nudus* by some) occur in younger coal beds than do those of *T. rugosus* and possess more highly developed apical prominences. Dijkstra (1958) described some similar spores from *Sigillariostrobus* cf. *major*. The relationship of *T. levis* with the section Lagenicula may be only apparent, however, because *Lycospora*, usually associated with lageniculate spores, is absent from coal beds containing *T. levis*. It is probably unwise to segregate the lageniculate spores as a distinct genus until the relationship of spores of *T. indianensis, T. splendidus, T. globosus, T. hirsutus, T. praetextus,* and *T. levis* to the spores typical of the section is understood more clearly.

The earliest occurrence of lageniculate megaspores bearing double or forked spines is in the older coals of the Chester Series. The more commonly illustrated spinose lageniculate spores are usually characteristic of the Caseyville Group. Smooth lageniculate spores first occur in the Rock Island (No. 1) and Murphysboro Coals, and are present in the younger coals of the Tradewater and Carbondale Groups. Those with a highly developed apical prominence appear to be restricted to coals of the McLeansboro Group. In this study, smooth and spinose lageniculate spores have not been observed together in the same sample.

TRILETES SUBPILOSUS (Ibrahim) Schopf, Wilson and Bentall, 1944 (sensu Dijkstra, 1946)

Plate 2, figures 1-5

1933 *Setosi-sporites subpilosus* Ibrahim, p. 27; pl. 5; fig. 40.
1944 *Triletes subpilosus* (Ibrahim) Schopf, Wilson, and Bentall, p. 26.
1946 *Triletes subpilosus* (Ibrahim) Dijkstra, p. 46-47; pl. 11, figs. 116-128.
1955 *Lagenicula subpilosa* (Ibrahim) Potonié and Kremp, p. 120; pl. 4, fig. 21.

Description.—Megaspores typical of species of medium size, more or less bottle-shaped, with distinct apical prominence, generally compressed obliquely; maximum equatorial diameter, measured perpendicular to the spore axis, from 550 to 1270 μ (mean 960 μ for 25 specimens). Apical prominence, measured from base of lips, generally between 100 and 175 μ in height, up to 300 μ in width; lips thick, obscuring suture, rarely open. Contact areas and lips, especially area at base of lips, set with small spines (pl. 2, fig. 1) generally about 5 μ in diameter and 5 μ in height.

Distal spore coat set with scattered spines ranging from 56 to 128 μ in maximum length* and 10 to 30 μ in width basally. Spines more or less parallel-sided, usually straight to gently recurved, and fluted basally, blunt to ball-tipped. Spines adjacent to contact areas are shorter, more delicate, and more crowded, but on some spores rather widely spaced. No subsidiary distal spines present.

Spore coat punctate, 7 to 15 μ thick, as little as 4 μ thick on contact areas, yellow to orange-brown by transmitted light.

* Range in maximum length is the range of maxima observed on all spores, *not* the minimum-maximum range in length. This range of maxima is considered more meaningful because spores of several species may show comparable minima in spine length. Therefore, in the species above, 56 μ is the shortest maximum spine length observed on any spore; 120 μ is the longest maximum length observed.

Discussion.—Megaspores typical of *Triletes subpilosus* are smaller, have shorter spines and a thinner spore coat than those of *T. subpilosus* forma *major.* The spines may be rather widely spaced, even around the contact areas and somewhat short and blunt ended (pl. 2, fig. 1). The apical expansion is of the same configuration as in *T. subpilosus* forma *major* but somewhat lower. In contrast, spores of *T. horridus* have unornamented, expanded, flaplike lips and possess distal subsidiary spines.

The spores of *Triletes subpilosus,* including variants, exhibit a wide range in overall diameter and spine length, both generally decreasing from older to younger strata. The measured specimens, here referred to as spores typical of the species and described above, are from three coals in the Caseyville Group. Those from the Battery Rock Coal range from 650 to 1030 μ in equatorial diameter (mean 898 μ for 8 spores) and possess spines from 56 to 128 μ in maximum length. Those from an older coal (maceration 795) range from 555 to 1110 μ in equatorial diameter (mean 883 μ for 10 spores) and possess spines from 66 to 123 μ in maximum length. Spine length is generally less than 100 μ. These two assemblages are very similar, but their mean diameters are somewhat greater than that originally cited by Dijkstra (1946, p. 46) for *T. subpilosus.*

It is possible that the spores of *Triletes subpilosus* are more closely comparable with those of *T. subpilosus* forma *major,* originally defined by Dijkstra (1952a, p. 103) as ranging from 500 to 1300 μ (mean 866 μ for 50 spores) in total axial length. Also included here as typical of *T. subpilosus* are seven rather large spores from the oldest coal from a diamond drill core in Wabash County, Illinois (maceration 798), in the Caseyville Group. These have an unusually narrow range in equatorial diameter, 1010 to 1270 μ (mean 1142 μ), and possess spines from 56 to 103 μ in maximum length. Such a narrow size range is not normal; the discovery of a few smaller examples, in addition to the few large ones that were found, would lower the mean considerably. Although the mean diameter of these few spores is at least 100 μ greater than that of spores of *T. subpilosus* forma *major* from two older formations (Chester, macerations 143, 166), the latter have, with a single exception, longer spines.

Spores of *Triletes subpilosus* are present in the youngest coal of the Black Creek Group and are abundant in the overlying coals of the Mary Lee Group in the Warrior Basin, Alabama. They also are known from the Indiana French Lick Coal (maceration 151) and from the shale (maceration 163) above the Pinnick Coal of Indiana.

Previously Reported Occurrences.—Spores typical of the species occur in Upper Westphalian A and Westphalian B in the Netherlands (Dijkstra, 1946), and in Upper Westphalian B to Middle Westphalian C in the Ruhr Basin (Potonié and Kremp, 1955).

Occurrence.—Megaspores of *Triletes subpilosus* are abundant and dominant in the Battery Rock Coal (maceration 587) and in a coal (maceration 795) of the Caseyville Group. They are common in an unnamed coal (maceration 797) and are rare in the "Makanda" Coal (maceration 142) and lowest unnamed coal in a diamond drill core from Wabash County (maceration 798), all of the Caseyville Group in Illinois.

TRILETES SUBPILOSUS forma MAJOR (Dijkstra) ex Chaloner, 1954

Plate 1, figures 1-9

1950 *Triletes subpilosus* forma *major* Dijkstra, p. 871 (nom. nud.).
1952 *Triletes subpilosus* (Ibrahim) forma *major* Dijkstra (1952a), p. 103 (nom. nud.).
1954 *Triletes subpilosus* forma *major* Dijkstra, *in* Chaloner (1954b), p. 27; pl. I, fig. 4 (not pl. I, figs. 5, 6).

Description.—Megaspores of medium size, more or less bottle-shaped with distinct apical prominence, usually compressed obliquely; maximum equatorial diameter, measured perpendicular to spore axis, from 465 to 1790 μ (mean 1195 μ for 74 specimens). Apical prominence rather triangular in lateral outline (pl. 1, figs. 6, 8), from 125 to 340 μ in height from base of lips, usually less than 200 μ. Lips rather thick, obscuring suture, rarely open. Trilete rays equalling about one-third the radius of the spore body; contact areas occupying about two-fifths the proximal hemisphere. Contact areas and lips, especially area at base of lips, generally heavily ornamented with small pointed spines 10 to 20 μ in length and up to 10 μ in width.

Closely spaced distal spines from 90 to 340 μ in maximum length, 10 to 30 μ in width basally. Spines more or less parallel-sided, extending outward from a fluted, hollow-appearing base to a blunt, pointed, or ball- to cup-shaped tip. Spines straight, sinuous, or gently reflexed; some appear ribbon-like (pl. 1, fig. 3), never forked. Spines generally more delicate, crowded, and about one-half the length of the distal spines at the margins of the contact area. No small subsidiary distal spines present.

Spore coat punctate or minutely meshed, 7 to 20 μ thick, thinnest in the contact areas, generally yellow to orange-brown by transmitted light.

Discussion.—These spores are abundant in and characteristic of Chester age rocks. The small gradual decreases in total size, spine length, and spore coat thickness from oldest Chester to youngest Chester age megaspores are not considered adequately delineated at this time for taxonomic separation. The spores of the four samples, upon which most of the measurements were made, seem to fall into two more or less distinct groups within *Triletes subpilosus* forma *major*. Those from the Degonia (maceration 143) and Hardinsburg (maceration 166) Formations of Illinois have comparable mean diameters of 1015 μ (5 spores) and 970 μ (19 spores) with maximum diameters of 1270 μ and 1240 μ respectively.

In contrast, spores from a coal in the Hardinsburg Formation (maceration 810) and from a coal in Bethel (Mooretown) Formation (maceration 943) of Kentucky have comparable mean diameters of 1315 μ (19 spores) and 1295 μ (31 spores) with maximum diameters of 1695 μ and 1790 μ. More than half of the spores from the coal in the Bethel (Mooretown) Formation possess spines having a maximum length of more than 200 μ; one spore has spines up to 340 μ in length. In addition, spore coat thickness exceeds 15 to 16 μ only in this older coal.

All these spores have certain characteristic features in common, also shared by the younger megaspores typical of the species. These features are the rather stunted-appearing apical prominence, at least less expanded than that on spores of *Triletes horridus;* a usually heavy ornamentation of contact areas and lips; more or less parallel-sided spines, blunt to ball-tipped and fluted basally; the absence of small subsidiary distal spines.

The spores of macerations 143 and 166 are somewhat smaller than those described as *Triletes subpilosus* forma *major* by Chaloner (1954b) from the Beaver Bend Limestone of Indiana. They are approximately the same size as, but with a thinner spore coat than, those described as *T.* cf. *T. subpilosus* forma *major* by Dijkstra (1957) from the Namurian of Scotland. However, the spine length and spore coat thickness of the latter are comparable with those of spores from the older Chester formations. These older spores are probably identical to those Chaloner describes from the Beaver Bend Limestone but have more extensive size limits. The other megaspores, of probable Kinderhook age, that Chaloner describes as *T. subpilosus* forma *major* are not characteristic of this species.

Spores of *Triletes subpilosus* forma *major* in the lower part of the Chester bear some similarities to megaspores of *T. crassiaculeatus* with which they may occur. However, spores of *T. subpilosus* forma *major* are smaller, do not have the tall, expanded, apical prominence, lack subsidiary distal spines and forked spines, and have a thinner spore coat.

Most of the spine tip features described by Bennie and Kidston (1886) are found on spores of *Triletes subpilosus* forma *major*.

An extreme development of the cup-shaped tip is shown by a small, probably immature spore (pl. 1, fig. 4). Some of the megaspores described by Horst (1955) as *T. subpilosus* may be similar to those of *T. subpilosus* forma *major.*

Previously Reported Occurrences.—Spores of *Triletes subpilosus* forma *major* have been reported from the Namurian A, B, and C of Turkey by Dijkstra (1952b), from the Namurian of Scotland by Dijkstra (1957), from the Dinantian and Namurian (?) of Scotland by Chaloner (1954b), and from the lower part of the Chester Series of Indiana by Chaloner (1954b).

Occurrence.—Megaspores of *Triletes subpilosus* forma *major* are the dominant and characteristic megaspores of upper Mississippian coals. They are: 1) abundant in the coal in the Bethel (Mooretown) Formation (maceration 943) from Kentucky; 2) present in the coal in the Bethel (Mooretown) Formation of Indiana (macerations 834, 832, 468); 3) abundant in the coal in the Hardinsburg Formation (maceration 810) of Kentucky; 4) present in the coal in the Hardinsburg Formation (maceration 166), in the coal in the Tar Springs Formation of Scottsburg, Kentucky, and in the coal in the Vienna Formation (maceration 758) of Illinois; 5) abundant in the coal in the Vienna Formation of Illinois (macerations 168, 764, 842, 765, 687A-B) and abundant to present in the Degonia Formation (macerations 143, 200).

Triletes horridus (Zerndt) Schopf, Wilson, and Bentall, 1944 (sensu Dijkstra, 1946)

Plate 2, figures 6-12; plate 3, figure 1

1934 *Lagenicula horrida* Zerndt, p. 25-26, fig. 11; pl. 28, figs. 1-5.
1944 *Triletes horridus* (Zerndt) Schopf, Wilson, and Bentall, p. 22.
1946 *Triletes horridus* (Zerndt) Dijkstra, p. 45-46; pl. 12, figs. 129-136. (Dijkstra's synonymy, excluding *Lagenicula* I var. *major* of Bennie and Kidston, accepted.)
1950 *Lagenicula horrida* Zerndt, *in* Arnold, p. 81-82; pl. X, figs. 1-5.
1955 *Lagenicula horrida* Zerndt, *in* Potonié and Kremp, p. 119-120; pl. 20, fig. 4.

Description. — Megaspores of medium size, more or less bottle-shaped with expanded apical prominence, usually compressed laterally; maximum equatorial diameter, measured perpendicular to spore axis, from 555 to 1305 μ (mean 925 μ for 34 specimens). Apical prominence well developed, from 180 to 350 μ in height from base of lip and up to 400 μ in width; lips generally open. Trilete rays one-third or less of the spore radius; contact areas occupying one-half or less of the proximal hemisphere. Contact areas and lips occasionally bearing a few tiny spines.

Distal spore coat ornamented with widely spaced spines from 50 to 160 μ in maximum length and from 15 to 60 μ in width. Spines extending from rather expanded hollow-appearing bases, tapering to a fine point, sometimes ball-tipped and recurved, shorter and more closely spaced at the margins of the contact areas. Small, acuminate subsidiary spines, 5 to 30 μ in length and 3 to 15 μ in width, generally present among the longer distal spines.

Spore coat punctate or minutely meshed, 7 to 22 μ thick, generally thicker than 15 μ, thinnest on contact areas, yellowish orange to reddish brown by transmitted light.

Discussion.—Although these megaspores of *Triletes horridus* have a larger size range than that given by Dijkstra (1946), the spores correspond in their general morphology, especially in the expanded, often open, flaplike lips. Practically all the megaspores of *T. horridus* seen during this study possess, in addition to the large distal spines, small, pointed, subsidiary, distal spines. The presence and abundance of these small excrescences generally is regarded as one of the most variable features of ornamentation of *T. horridus* megaspores. The subsidiary spines have been mentioned by Zerndt (1937a) and illustrated by Arnold (1950). Arnold noted their occurrence on about 80 percent of the specimens he examined. Chaloner (1953b) described the *T. horridus*-type of megaspore from *Lepidostrobus dubius* and noted that megaspores of some cones have an abundance of subsidiary spines, whereas megaspores of other cones of the same species were practically devoid of subsidiary spines.

The few Illinois megaspores devoid of subsidiary spines all possessed rather thin (15 μ) distal spines up to 61 μ in length (pl. 2, fig. 7). These few spores seem to bear a similarity to those originally decribed by Zerndt (1934) as *Lagenicula kidstoni* (included within *Triletes subpilosus* by Dijkstra, 1946).

The megaspores of *Triletes horridus* found in the Degonia Formation (pl. 2, fig. 6), in older coals of the Caseyville Group, and in the Tarter Coal of the Tradewater Group (pl. 3, fig. 1) are typical of *T. horridus* spores as previously described in the literature. The megaspores found in the "Makanda" Coals have generally shorter spines (50 to 87 μ) and a thinner (7 to 11 μ) spore coat (for example, pl. 2, figs. 9, 12). Their form and spine shape and distribution are very similar, however, to those illustrated for *T. horridus* by Chaloner (1953b, fig. 2, 2a).

Megaspores of *Triletes horridus* also occur abundantly in the youngest coal of the Mary Lee Group and in the youngest coal of the Pratt Group in the Warrior Basin of Alabama. Those of the latter coal are typical for the species; some of those in the Mary Lee Group possess distal spines of two sizes, expanded basally and pointed, but their longest spines are only 20 μ in length. In the length and distribution of spines and in the expanded type of apical development, these megaspores seem similar to that originally illustrated by Ibrahim (1933, pl. V, fig. 40) as *Setosi-sporites subpilosus*.

Affinity.—Chaloner (1953b) described these spores, in association with *Lycospora*-type microspores, from cones of *Lepidostrobus dubius*.

Previously Reported Occurrences.—Megaspores of *Triletes horridus* have been found in three coals of the Michigan Basin by Arnold (1950). They also have been reported from the Westphalian A-D from the Netherlands by Dijkstra (1952c), from east Upper Silesia and Mährisch-Ostrau by Horst (1955), and from the Upper Westphalian B of the Ruhr Basin by Potonié and Kremp (1955). *T. horridus*-type megaspores are found in cones occurring in the Westphalian A-B from Scotland and England (Chaloner, 1953b).

Occurrence.—Megaspores of *Triletes horridus* are abundant in the Degonia Formation (maceration 200) of upper Chester age and are present in varying degrees of abundance in some Caseyville coals (macerations 795, 796, 798), in the "Makanda" Coals (macerations 905, 906, 907, 142) of the Caseyville Group, and in the Tarter Coal (maceration 914) of the Tradewater Group.

TRILETES CRASSIACULEATUS (Zerndt) Schopf, Wilson, and Bentall, 1944

Plate 3, figures 2, 3

1937 *Lagenicula crassiaculeata* Zerndt (1937a), p. 12-13, fig. 9.
1944 *Triletes crassiaculeatus* (Zerndt) Schopf, Wilson, and Bentall, p. 21-22.
1946 *Triletes crassiaculeatus* (Zerndt) Dijkstra, p. 44-45.

Description.—Megaspores large, typically bottle-shaped (pl. 3, fig. 2) with large expanded apex, generally laterally compressed; maximum diameter, measured perpendicular to the spore axis, from 1370 to 1795 μ; total length reaching 2300 μ. Trilete structures well developed; apical prominence, measured from base of lip and not from level of arcuate ridge, from 280 to 565 μ in height and 460 to 670 μ in width. Lips and contact areas generally unornamented, rarely bearing scattered, tiny spines.

Distal surface bearing closely spaced spines of two sizes. Large distal spines extending 125 to 290 μ in maximum length from a fluted base 20 to 75 μ wide (pl. 3, fig. 3), terminating in a sharp point or in a ball- to cup-shaped expansion surmounted on the slender neck. As many as three of four large distal spines may be forked at their tips. Large distal spines decrease in length by about one-half and are more closely spaced toward margins of contact areas. Subsidiary acuminate distal spines, up to 36 μ in length and 10 μ in width, are scattered between the large distal spines.

Spore coat punctate or minutely meshed, granulose on lips, 25 to 30 μ thick, deep reddish brown to orange-brown by transmitted light. Spines appearing light yellow and smooth.

Discussion.—The above description is based on the few megaspores of this species, occurring with abundant megaspores of *Triletes subpilosus* forma *major*, found in the coal in the Bethel (Mooretown) Formation (maceration 943) of Hardin County, Kentucky. Similar megaspores are dominant in the same coal (macerations 832, 834) of Lawrence County, Indiana, but occur in equal abundance with megaspores of *T. subpilosus* forma *major* in the same coal (maceration 468) of Washington County, Indiana. Megaspores of *T. crassiaculeatus* of these Indiana coals are identical to those in the coal from Kentucky, but range up to 1860 μ in equatorial diameter and possess spines as long as 350 μ.

These *Triletes crassiaculeatus* spores are similar in most respects to those originally described by Zerndt (1937a) except that the spines are generally not pointed but ball-tipped and the spore coat is thinner than the 48 μ thickness given by Zerndt. They also are similar in over-all size, shape of apical prominence, and in the possession of spines of varying lengths, to those of *Lagenicula* I var. *major* Bennie and Kidston (1886, figs. 20e, 20f, 20n) which occur abundantly at their locality I, the basal beds of the Calciferous Sandstone Series in Scotland. However, the spores from Illinois generally possess a more dense investiture of spines, and these spines may be fluted basally rather than expanded and bulbose. One spine on plate 3, figure 3, shows the extreme development of the fluted spine base. Some of the other spines on the same spore tend to be more bulbose basally and approach more closely the spine configuration considered typical of *T. crassiaculeatus*.

The spores from Kentucky and Indiana generally are comparable with those *Triletes crassiaculeatus*-type megaspores found by Chaloner (1953b) in *Lepidostrobus allantonensis*. Chaloner also noted the presence of enlarged globular spine tips.

The presence of forked spines has not been noted in previous descriptions of typical lageniculate megaspores. In the possession of forked spines, spores of *Triletes crassiaculeatus* are similar to some of the extremely high apexed atypical lageniculate spores of early Mississippian age (compare with Chaloner, 1954b, pl. I, figs. 5, 6).

Affinity. — *Triletes crassiaculeatus*-type megaspores have been found in *Lepidostrobus allantonensis* (Chaloner, 1953b), in sedimentary association with *Lepidodendron nathorsti* Kidston. Dijkstra (1952b) reported the occurrence of this megaspore in close association with *Lepidodendron acuminatum*.

Previously Reported Occurrences.—Megaspores of *Triletes crassiaculeatus* have been reported from the "Randschicten" (Dinantian or Namurian A) of Upper Silesia by Zerndt (1937a), from the Namurian A (abundant occurrence) and B of Turkey by Dijkstra (1952b), and from the Calciferous Sandstone Series (Dinantian) of Scotland by Chaloner (1953b).

Occurrence.—During this investigation megaspores of *Triletes crassiaculeatus* were found only in a coal in the lower part of the Chester Series, in the Bethel (Mooretown) Formation (macerations 943, 832, 834, 468) of Kentucky and Indiana.

TRILETES RUGOSUS (Loose) Schopf, 1938 (sensu Dijkstra, 1946)

Plate 3, figures 4-9

1932 *Sporonites rugosus* Loose, *in* Potonié, Ibrahim, and Loose, p. 452; pl. 20, fig. 59.

1933 *Laevigati-sporites rugosus* (Loose) Ibrahim, p. 18-19; pl. 7, fig. 65.

1934 *Punctati-sporites rugosus* (Loose) Loose, p. 146.

1938 *Triletes* (?) *rugosus* (Loose) Schopf, p. 29-30; pl. 5, fig. 6.

1938 *Triletes translucens* Schopf, p. 28-29; pl. 1, fig. 12; pl. 5, figs. 3-5.

1944 *Triletes rugosus* (Loose) Schopf, *in* Schopf, Wilson, and Bentall, p. 25.

1946 *Triletes rugosus* (Loose) Dijkstra, p. 47-48; pl. 9, figs. 83-99; pl. 10, figs. 100-114; pl. 11, fig. 115.

1950 *Lagenicula rugosa* (Loose) Arnold, p. 82-85; pl. XI, figs. 1-4; pl. XII, figs. 1-4.
1955 *Lagenoisporites rugosus* (Loose) Potonié and Kremp, *in* Potonié and Kremp, p. 122; pl. 4, fig. 22.

Discussion.—These megaspores generally are subround to oval in outline, depending on compressional orientation, and commonly range between 400 μ and 1100 μ in maximum diameter. Trilete structures generally are prominent, characterized by an apical prominence formed by thickened expansions of the contact faces. Arcuate ridges are commonly low but distinct; may be ornamented with scattered tubercles. Generally the spore coat is granulose to punctate or rugose, ranging between 5 μ and 20 μ in thickness. A folded inner membrane is commonly present.

The spores illustrated on plate 3, figures 4 to 9, show the range of variation that has been observed during this study. The spore shown in figure 4 has a thin coat (5 μ) and vaguely developed arcuate ridges. A smaller spore, shown by figure 6, has prominent lips and arcuate ridges. Another spore (not illustrated) of similar size, from the same sample, bears ornamentation similar to that shown by figure 5. The globular-tipped papillae are up to 31 μ in length and generally are concentrated in the equatorial region. None was observed to reach the length of those reported by Chaloner (1953b) from cones of *Lepidostrobus olryi.*

Many spores from different coal beds possess the scattered smaller globules described by Arnold (1950), Chaloner (1953b), and Felix (1954). The spores shown in figures 5 and 8 are characteristic of the Colchester (No. 2) Coal and have distinctly punctate coats. Others from the same coal bed are heavily rugose, and some bear a distal covering of minute spines, more pointed than those shown in figure 7.

Spores with papillae such as are shown in figure 7 are most conspicuous in the Rock Island (No. 1) Coal (macerations 528A, 599B). Extreme rugosity of the spore coat is commonly seen on some of the spores in the Colchester (No. 2) Coal (especially in macerations 603, 826). Those described by Schopf (1938) as *Triletes translucens* from the Herrin (No. 6) Coal have a slightly thicker coat than the majority of those from the older coals of the Carbondale and Tradewater Groups.

I chose to describe these spores in the broader taxonomic sense because no conspicuous morphological variations that have not been described as occurring naturally in the same cone were noted during the study. However, a concentrated study of these forms may prove that such variations do exist. I do not intend to imply disagreement with Schopf's (1938) specific separation of some of the forms. Specific separation could easily be made on the basis of arbitrary size limits, presence or absence of papillae, size of papillae, and on the thickness of the spore coat, but separation does not seem warranted in view of present information on the range of variation among spores found in the same cone. As Arnold (1950) pointed out, factors of preservation and differences in compressional orientation also may render specific separation difficult.

Affinity.—Both Chaloner (1953b) and Felix (1954) described *Triletes rugosus*-type megaspores in association with *Lycospora*-type microspores from cones of *Lepidostrobus.* Their findings support the suspected close relationship between the spinose and nonspinose lageniculate megaspores. As the botanical relationship of lageniculate megaspores with *Lycospora*-type microspores is known from several cone studies, it is puzzling to note the abundance of *T. rugosus* in the Rock Island (No. 1) Coal (in particular maceration 599B) concurrent with the rarity of *Lycospora* (Kosanke, 1950, p. 67).

Previously Reported Occurrences.—Spores of this type have been reported by Dijkstra (1946) to occur, in various coal basins of the world, in the Namurian A-C and in the Westphalian A-E. Because of differing taxonomic circumscriptions of *Triletes rugosus,* occurrences of widely differing age are cited in the literature.

Occurrence.—Spores of *Triletes rugosus* first occur, in some places abundantly, in the Rock Island (No. 1) and Murphysboro Coals of the Tradewater Group. They are rare to common in some of the younger coals of the Tradewater. In the Carbondale Group they are common to abundant in some samples of the Colchester (No. 2) Coal (macerations 611, 825, 826), in the Briar Hill (No. 5a) Coal (maceration 633), and in the Herrin (No. 6) Coal (after Schopf, 1938). Only one spore, questionably referable to *T. rugosus,* was noted from the McLeansboro Group, that from the "Woodbury" Coal (maceration 703).

SECTIO LAGENICULA (?)

TRILETES LEVIS (Zerndt) Schopf, Wilson, and Bentall, 1944

Plate 3, figures 10-14

1937 *Lagenicula levis* Zerndt (1937b), p. 587-588; pl. 15, figs. 1-11.

1944 *Triletes levis* (Zerndt) Schopf, Wilson, and Bentall, p. 23.

Description.—Megaspores trilete, typically laterally compressed, are characterized by an expanded, high, more or less blunt apical prominence (pl. 3, figs. 11, 13). Laterally compressed spores from 450 to 1300 μ in total length, including apical prominence (mean 994 μ for 25 specimens). Spore body probably originally spheroidal, having at least one longitudinal or transverse fold when compressed, from 319 to 978 μ in width and 300 to 927 μ in length. Trilete rays strongly developed, extending nearly to margin of spore body in rare proximodistal compressions. Lips up to 100 μ in height, as measured from inner surface of spore coat, surmounted by a high apical prominence that is typically slightly constricted basally. Apical prominence from 129 to 391 μ in height, as measured from its basal constriction (mean 278 μ for 23 specimens), 154 to 494 μ in width, generally slightly wider than high. Apex, measured from inner edge of arcuate ridge, from 247 to 752 μ in height or 51 to 62 percent of the total spore length. Contact area approximately equal in area to proximal hemisphere of spore body. Arcuate ridges distinct, most noticeable on smallest spores (pl. 3, fig. 10). Spore coat up to 97 μ thick at juncture of arcuate ridge and trilete ray.

Spore coat generally between 25 μ and 35 μ thick (mean 27.5 μ, range 15 to 41 μ for 26 specimens). Distal coat smooth or rugose to distinctly ornamented with small hemispherical tubercles that are 3 to 10 μ in height and 3 to 13 μ in diameter. Inner folded membrane commonly present inside spore body (pl. 3, fig. 12). Spores reddish brown, apical prominence darker than rest of spore by transmitted light but dark and glossy by reflected light.

Discussion.—All of the above measurements were made on spores mounted in balsam. Most commonly the spore coat is smooth, the poorly preserved spores appearing rugose. However, in the "Watson" Coal (maceration 148), a few spores, otherwise typical of *Triletes levis,* possess regularly distributed small hemispherical tubercles the larger of which are near the distal pole whereas the smaller and more closely spaced are close to the arcuate ridges (pl. 3, fig. 14).

Recently Dijkstra (1958) described similar spores with comparable ornamentation from the cone of *Sigillariostrobus* cf. *major* (Germar) Zeiller that was found in the Lawrence Shale of Kansas. In addition he mentioned that Chaloner found identical isolated spores in this shale. Those few ornamented spores found in the "Watson" Coal are only slightly larger than those described by Dijkstra and are of approximately the same age.

Occurring in the "Watson" Coal with these spores are a few smooth-coated spores of *Triletes levis.* Too few spores were observed to determine whether the ornamentation is a consistent character on spores of this type in the "Watson" Coal. Nonetheless, the tubercles are not similar to those irregularly distributed globules, presumably of tapetal origin, described by Felix (1954, p. 359-360) and noted, during the course of this investigation, on some lageniculate spores and on some of the spores of *Cystosporites.*

Spores of *Triletes brasiliensis* Dijkstra (1955a, 1956) also possess hemispherical tubercles 5 to 30 μ in diameter. Although the spores are similar in general appearance to spores of *T. levis*, they have a more robust development of the trilete rays and arcuate ridges. The apical prominence is distinctly pyramidal in shape. The spores also are younger, occurring in the Lower Permian coals of Brazil (Dijkstra, 1956).

Although Dijkstra (1946) considered *Triletes levis* (Zerndt) Schopf, Wilson, and Bentall as a later synonym of *T. nudus* (Nowak and Zerndt) Schopf, these spores from the younger Pennsylvanian coals of Illinois are very similar to those originally described as *Lagenicula levis* by Zerndt (1937b, p. 587-588, pl. 15) from the Westphalian E (according to Dijkstra, 1946) of Bohemia and by Piérart (1956) from the Middle Stephanian of France.

The megaspores described here are referred to *Triletes levis* although they have a slightly thicker spore coat than those described by Zerndt. There is no information regarding the appearance of Zerndt's specimens under transmitted light. The general shape and dimensions of the Illinois spores apparently are identical to those illustrated by Zerndt (1937b, pl. 15). Especially typical of the Illinois spores are the shapes illustrated by Zerndt (1937b, pl. 15, figs. 1, 6, 9) in which the apical prominence is blunt to rounded and rises abruptly from the lips. The spore illustrated by Nowak and Zerndt (1936, pl. 1, fig. 6) and originally designated as *Lagenicula nuda* appears to have a broader apical prominence, relative to spore size, which rises from the lips closer to the radial extremities, and a more oblate body form. At present the spores of *T. levis* are known only from coal beds in the McLeansboro Group, whereas spores more similar in appearance to those of *T. nudus* were noted in a thin coal bed (maceration 455) from a sinkhole deposit of possible early Pennsylvanian age.

Schopf (1938, pl. 5, fig. 7) described some spores, of rare occurrence in the Herrin (No. 6) Coal of the Carbondale Group, that he questionably referred to *Triletes nudus*. The illustrated spore has a rugose coat. The apical prominence is not distinctly darker, by transmitted light, than the remainder of the spore. Schopf, Wilson, and Bentall (1944, p. 23) noted that this form is probably not referable to *T. nudus* although the shape is similar. Neither are these spores similar to those referred here to *T. levis*. However, on the distribution chart, the spores described by Schopf are noted under his original designation, *Triletes* (?) *nudus*.

Cross (1947, p. 287, fig. 2; pl. III, figs. 100-104; p. 305) described spores, designated as *Triletes nudus* (Nowak and Zerndt) Schopf, that appear identical to those described here as *T. levis*. Cross notes their occurrence only in the Waynesburg Coal of the Monongahela Series of the Appalachian Basin. Thus the Illinois and Appalachian Basin spores are similar in appearance, although the spores Cross described are from a somewhat younger coal.

Affinity.—Potonié and Kremp (1955) noted that the alliance of the lageniculate spores is with the Lepidodendraceae. *Lycospora*-type microspores are known to be the microspores associated with many of the lageniculate megaspores (Chaloner, 1953b; Potonié, 1954a, b; Felix, 1954) and with those of *Cystosporites* (Felix, 1954). However, in the McLeansboro Group, abundant lageniculate spores occur (*Triletes levis*), but they are not accompanied by *Lycospora*-type microspores (Kosanke, 1947, 1950). Therefore *T. levis* is referred questionably to the section Lagenicula. Recently similar spores have been discovered (Dijkstra, 1958) in *Sigillariostrobus*.

Occurrence.—These spores are rare in the "West Franklin" Coal (maceration 831a), Indiana, in the Macoupin Coal (maceration 561) of Bond County, in the "Divide" Coal (maceration 811), and in the Friendsville Coal (macerations 135, 153, and 490D). They occur abundantly in the Friendsville (?) Coal (maceration 136) from Wabash County, Illinois, in the "LaSalle" Coal (maceration 600), and in a coal (maceration 146) in the Merom Sandstone. Apparently they are less abundant in the "Watson" Coal (maceration 148) and in the "Woodbury" Coal (maceration 703).

Triletes levis is apparently restricted to coals of the McLeansboro Group in Illinois.

TRILETES INDIANENSIS Chaloner, 1954

Plate 6, figures 1-3

1954 *Triletes indianensis* Chaloner (1954b), p. 28; pl. II, figs. 1, 2.

Description. — Megaspores originally more or less spherical, having no preferred compressional orientation, ranging from 820 to 1590 μ in equatorial diameter (mean 1227 μ for 21 specimens). Apical prominence expanded-pyramidal (pl. 6, fig. 2), sometimes slightly constricted basally, about 165 to 285 μ in height (mean 225 μ for 13 specimens) and 220 to 450 μ (mean 324 μ for 18 specimens) in diameter, generally largest on the largest megaspores. Trilete rays distinct, about 50 μ in width, up to 60 to 65 μ in height (including spore coat thickness), expressed as slight ridges on the bulbose apical prominence. Contact areas occupying two-thirds to three-fourths of the proximal hemisphere, usually ornamented with small spines less than 5 μ in height. Arcuate ridges usually not prominent, but up to 25 μ in height.

Distal spines more or less pointed to blunt ended, up to 20 μ in length and basal width (pl. 6, fig. 3), commonly half as large, rather densely set, especially near the arcuate ridges. Spore coat granulose, 30 to 45 μ thick with extremes of 27 μ and 66 μ, 20 to 26 μ thick at the contact areas; deep reddish brown by transmitted light, dark brown to black by reflected light. Fragments of an inner membrane usually adhering to inner cavity. Description as a whole based on 46 specimens studied principally by transmitted light.

Discussion.—Spores from the coal in the Bethel (Mooretown) Formation are probably identical with those originally described by Chaloner (1954b, p. 28) from the Beaver Bend Limestone of Indiana; they have a slightly different size range, a generally thicker wall, and nearly always possess minute processes on the contact areas. However, the distal processes of the two groups of spores are identical in size, shape, and distribution. The coal in the Bethel (Mooretown) Formation and the Beaver Bend Limestone are both early Chester in age.

The apical prominence is, as Chaloner stated, very thick walled and relatively opaque, but the apices on many of the spores from the coal in the Bethel (Mooretown) Formation could be studied by transmitted light. The three segments of the prominence, probably a hyper-development of the lip at the proximal pole, show a fan-like grain radiating from the center of each apical segment. The segments are joined only along the outer edges, forming a hollow central cavity which is enclosed at its base by an inner membrane (pl. 6, fig. 1). Therefore, the apical prominence is identical in its morphology to that on spores of *Triletes splendidus* (Zerndt) Schopf, Wilson, and Bentall as originally described by Zerndt. He postulated that this upper, completely enclosed cavity was not a microspore receptacle but rather served as a float mechanism aiding in the dispersal of the megaspores.

The rays on the megaspores are commonly open from the arcuate ridges to the base of the apical prominence, but in some specimens the apical prominence is also split open along the incipient suture lines.

Spores of *Triletes indianensis* have a generally larger apical prominence than do spores of *T. subtilinodulatus* (Nowak and Zerndt) Schopf, Wilson, and Bentall. Spores of both species are similar in that they resemble those of *T. splendidus* but are smaller and bear smaller spines.

The following species seem to be related in that the spores have similar shapes, stout apical prominences, and comparably shaped distal processes: *Triletes indianensis* (early Chester); *T. subtilinodulatus* (Dinantian, precise age unknown); and *T. splendidus* (late Chester, Dinantian, Namurian A). Similar megaspores also occur in rocks of Kinderhook and earliest Osage age in Ohio.

Because these megaspores are most closely comparable with those of *Triletes subtilinodulatus* and *T. splendidus,* which Potonié and Kremp (1955) interpret as borne by some arborescent lycopods (Lepidodendraceae), they also may be related to the arborescent lycopods. Their alliance within the section Lagenicula is still in question because we have no information from cone studies as to their botanical affinity.

Occurrence.—Spores of this species were found in the coal in the Bethel (Mooretown) Formation (maceration 943), Hardin County, Kentucky.

TRILETES SPLENDIDUS (Zerndt) Schopf, Wilson, and Bentall, 1944

Plate 5, figure 8

1937 *Lagenicula splendida* Zerndt (1937a), p. 13-14; pl. 18, figs. 1-4; pl. 19, figs. 1-5; pl. 20, figs. 1-4.
1944 *Triletes splendida* (Zerndt) Schopf, Wilson, and Bentall, p. 25.
1946 *Triletes splendidus* (Zerndt) Dijkstra, p. 50; pl. 16, figs. 173-175.
1955 *Lagenicula splendida* Zerndt, *in* Potonié and Kremp, p. 119.

Description.—Megaspores originally more or less spherical, having no preferred compressional orientation, 1200 to 1540 μ in equatorial diameter (four complete specimens, dry mounts). Apical prominence expanded-pyramidal in shape, commonly slightly constricted basally, 205 to 275 μ high and 255 to 340 μ wide. Trilete rays distinct, up to 137 μ in height including spore coat thickness, less distinct on apical prominence. Contact areas occupying a little over three-fourths the proximal hemisphere, some of them ornamented with small acuminate tubercles. Arcuate ridges not distinct, marked by the inception of robust distal ornamentation. Distal tubercles 35 to 70 μ long, 35 to 70 μ in diameter at their large hemispherical bases. Outwards from the expanded bases, processes more slender, usually acuminate at tip. Spore coat 35 μ thick (one specimen measured).

Discussion.—One very small individual found among the above specimens is 755 μ in diameter, rounded triangular in outline, possesses prominent rays and an apical prominence 170 μ in diameter. The distal surface is covered with spines about 25 μ long and 25 μ in diameter basally. Its small size and pronounced subtriangular shape distinguish it from the larger megaspores of *Triletes splendidus*. Probably this spore represents an immature spore of the species comparable with those mentioned by Dijkstra (1957).

These megaspores correspond closely to those originally described by Zerndt (1937a, p. 13-14) from the lower part of the "couches marginales" (Dinantian?, Namurian A of Poland) and to the specimen illustrated by Dijkstra (1952c, pl. 7, fig. 5), but have smaller tubercles than those from Scotland described earlier by Dijkstra (1946, p. 50). Dijkstra (1957) reports these spores as common throughout the Limestone Coal Group (Namurian) of Scotland.

Triletes splendidus and *T. indianensis* spores have the same type of body form, but those of the former species are larger and bear fewer but more robust appendages.

By including these megaspores in the genus *Lagenicula,* Potonié and Kremp (1955, p. 119) implied a relationship with the Lepidodendraceae.

Occurrence.—These spores, not previously reported from this country, were found in the Degonia Formation (maceration 200) in the upper part of the Chester Series, Pope County, Illinois.

SECTIO APHANOZONATI Schopf, 1938

Spores characteristic of the Aphanozonati section of *Triletes* are large, rounded to oval in outline when compressed, more or less saucer-shaped originally (Schopf, 1941b; Chaloner, 1953c). Trilete rays generally are low, lacking the apical prominence that is characteristic of spores of the section Lagenicula. Arcuate ridges commonly are present, but lack flange development or zonate appendages. Spore coat is as a rule thick and smooth to apiculate. Typical of this section are the spores of *Triletes glabratus* and *T. mamillarius* of sigillarian affinity (Schopf, 1941b; Chaloner, 1953c).

Apiculate aphanozonate megaspores are conspicuous in the older coal beds of both the Caseyville and Tradewater Groups and are present in other coals of these groups. Smooth aphanozonate megaspores first occur abundantly in the Summum (No. 4) Coal of the Carbondale Group and generally are present in the younger coals of the Carbondale and McLeansboro Groups. As yet, no characteristically aphanozonate spores are known from coals in the Chester Series.

TRILETES GLABRATUS Zerndt, 1930 (sensu Dijkstra, 1946)

Plate 6, figures 7-10

1930 *Triletes* type I Kidston, *Triletes glabratus* Zerndt (1930c), p. 43-45; p. 1, figs. 1-3.
1946 *Triletes glabratus* Zerndt, *in* Dijkstra, p. 26-28; pl. 1, figs. 1-3, 5-8; pl. 4, fig. 35.

Description.—Spores generally large, unornamented, round to oval in outline when mature, more subtriangular when immature. Spores commonly proximo-distally compressed, originally saucer-shaped. Spore size ranging between 400 μ and 3000 μ, commonly between 1700 μ and 2500 μ. Trilete rays distinct, generally thin, equal in length to one-third to one-half the spore radius. Contact areas lighter in color (pl. 6, figs. 8, 10) by both reflected and transmitted light, in some specimens bounded by low arcuate ridges. Haptotypic features generally strongly developed on immature spores (pl. 6, fig. 7). Spore coat 25 to 40 μ or more thick, smooth, dull to bright black or dark brown by reflected light, deep red by transmitted light.

Discussion.—A few poorly preserved spores of this species were found in the "Makanda" Coals. They range from 1265 to 2035 μ in diameter (six specimens measured dry). The spore coat on one spore is 41 μ thick. Well preserved spores, as illustrated on plate 6, were found in the coals of the Carbondale and McLeansboro Groups. Immature spores (pl. 6, fig. 7) are rare. They were found only in the Summum (No. 4) and Grape Creek (No. 6) Coals, together with many mature spores.

Dijkstra's (1946) broad taxonomic circumscription of this species seems justified in view of the size variation of this type of megaspore found by Bochenski (1936) in *Sigillariostrobus.* According to Dijkstra (1955a) these spores may occur throughout the Westphalian in various coal basins, but are restricted to a part of the Westphalian in some basins. This species is also recorded from the Stephanian of Bohemia. Schopf (1938, p. 25-26) pointed out that because these spores are long-ranging stratigraphically, their chief value is as an ecologic indicator for certain larger lycopods. The large size of these megaspores probably prohibits their distribution at any great distance from their point of origin.

Occurrence.—A few apparently smooth spores of this species first occur in the "Makanda" Coals (macerations 142, 906, 907) of the Caseyville Group. This species is not represented in the coals of the Tradewater Group. The spores occur again, commonly, in the Summum (No. 4) Coal (maceration 463) of the Carbondale Group. They are present to abundant in the No. 5 Coal (macerations 630, 583, and 879). They are, however, rare in the Briar Hill (No. 5a) Coal (maceration 633B), but abundant in the Grape Creek (No. 6) Coal (maceration 878). The most common megaspore in the Herrin (No. 6) Coal (Schopf, 1938) is of this species. In the McLeansboro Group, these spores are abundant to present in the Indiana VII (?) (maceration 939A), "LaSalle" (maceration 600), Friendsville (maceration 135), "Merom" (maceration 146), "Divide" (maceration 811), and "Woodbury" (maceration 703) Coals. This species is also known from the Danville (No. 7) and Macoupin Coals.

TRILETES MAMILLARIUS Bartlett, 1929 (sensu Dijkstra, 1946)

Plate 7, figures 1-6; text figure 3

1929 *Triletes mamillarius* Bartlett, p. 21; pl. XIII, figs. 1, 2; pl. XIV; pl. XV, figs. 1, 2.
1946 *Triletes mamillarius* Bartlett, *in* Dijkstra, p. 28-31; pl. 2, figs. 9-12; pl. 3, figs. 13-15; pl. 8, fig. 78.

Description.—Megaspores from the Willis Coal, of medium to large size, round to oval in outline, subtriangular when immature (pl. 7, fig. 1) (abnormal or abortive according to Chaloner [1953c]), originally saucer-shaped, generally proximo-distally compressed. Spore diameter ranging from 935 to 2270 μ (mean 1600 μ for 37 wet or balsam-mounted specimens). Spore diameter of dry specimens (text fig. 3) from 625 to 1520 μ (mean 1155 μ for 11 specimens). Trilete rays generally low, ranging in length from one-third to two-thirds spore radius, sometimes possessing an apical expansion up to 93 μ in height. Suture may be open, generally throughout half its length.

Contact areas ornamented by spines from 2.5 to 25 μ in diameter and from 2.5 to 28 μ in height, smallest near apex. Distal spines with expanded bases and pointed tips, closely spaced, from 20 to 94 μ in diameter basally and from 31 to 130 μ in length. Spore coat from 21 to 36 μ thick on mature spores, from 36 to 62 μ on immature spores; coat brown to black by reflected light, deep reddish brown by transmitted light.

Discussion.—The description given above is that of the megaspores from the Willis Coal because this species is most abundantly represented in this coal, with the exception possibly of Herrin (No. 6) Coal. Those found in the Caseyville Group from the coals of the Wabash County cores (pl. 7, figs. 6a, 6b) range from 880 to 1965 μ in diameter. Distal spines range from 15 to 113 μ in diameter and from 25 to 100 μ in length. All spores have spinose contact areas. Those of the Herrin (No. 6) Coal are generally about 1900 μ in diameter or less and possess distal spines up to 15 μ in height. Although spores referable to this species (s.l.) have been recognized from Caseyville, Tradewater, and Carbondale coals, only a few specimens from coals other than the Herrin (No. 6) Coal possess the extremely small apiculi described by Schopf (1938) for *Triletes brevispiculus.*

Chaloner (1953c) described *Triletes mamillarius*-type megaspores from cones of *Sigillariostrobus* and noted a wide range of variation in spine development. However, he noted that no spines are as small as those described by Schopf (1938) for *T. brevispiculus* (included in *T. mamillarius* by Dijkstra, 1946) or as slender as those described by Arnold (1950) for *T. fermi.* The spore variation in two species substantiates the variety of types included in *T. mamillarius* by Dijkstra.

According to Dijkstra (1955a) spores of this species occur in the Namurian A—Westphalian C in Poland, in the Westphalian A–D in Turkey, and up to the Westphalian D in Bohemia and in the Saar Basin.

Occurrence.—Spores of this species are present in the Jagger, Newcastle, Gillespie, America, and Pratt Coals of the Warrior Basin; they are particularly abundant in the Jagger and Pratt Coals. The species also is represented in the French Lick Coal (maceration 151) and in the shale (maceration 163) above the Pinnick Coal in Indiana.

The spores are common in the older coals of the Caseyville Group (macerations 796, 795, 798). In the Tradewater Group they are present in the Babylon Coal (maceration 588); common to abundant in the Willis Coal (macerations 625, 631); rare in the Pope Creek (macerations 916, 602), Rock Island (No. 1) (macerations 929, 589), Murphysboro (macerations 915, 628B), unnamed coal bed above DeKoven (maceration 35), DeKoven (?) (maceration 621D) Coals, and in the lower coal from Goose Lake (maceration 950A); common in the Wiley Coal (maceration 525B).

In the Carbondale Group the spores are rare to present in the Colchester (No. 2) Coal (maceration 603C), Summum (No. 4) Coal (maceration 463), and Springfield (No. 5) (maceration 630) Coal. The spores are moderately abundant in the Herrin (No. 6) Coal (Schopf, 1938). As yet, the species is not known to be represented in younger coals.

Sectio Auriculati Schopf, 1938

Spores of the Auriculati section of *Triletes* are of medium size, subtriangular to trilobate in outline. Trilete rays long, usually extending to equator. Lobate expansions of spore coat sometimes developed at radial extremities. Interradially a flange or arcuate ridge may be moderately to weakly developed. Spore coat thick, variously ornamented.

Dijkstra (1955a) noted that some of the spores referred to this section have no ear-lobe-like processes, nor is the spore outline always subtriangular to trilobate. Consequently he grouped the auriculate spores with the aphanozonate spores. Chaloner (1953a, 1958b) described and figured auriculate megaspores with weakly to moderately developed "ears" from lycopod fructifications. Evidence from the range of morphological characters of the megaspores of *Polysporia* suggested to Chaloner (1958b, p. 204), that "Dijkstra's broad specific interpretation [of auriculate megaspores] may be more justified than the larger number of species recognized by Potonié and Kremp." The associated microspores are of the *Endosporites*-type.

Auriculate megaspores are generally present in coal beds throughout the Pennsylvanian, as are microspores of *Endosporites*. As yet, no auriculate megaspores are known from coals in the Chester Series.

Triletes auritus Zerndt, 1930 (sensu Potonié and Kremp, 1956)

Plate 7, figures 7-11

1930 *Triletes auritus* I Zerndt (1930c), p. 46; pl. 1, figs. 4, 5.
1955 *Valvisisporites auritus* (Zerndt) Potonié and Kremp, pl. 6, figs. 38, 40, 41, 43.
1950 *Valvisisporites auritus* (Zerndt) Potonié and Kremp, p. 94-95.

Discussion.—Spores of this species range from about 700 to 1100 μ in size and are generally proximo-distally compressed, roundly deltoid in outline. The spores are characterized by bulbose projections, generally well developed, at their radial extremities (pl. 7, fig. 10). According to Potonié and Kremp (1956), the "ears" are less than one-half the body radius in length, narrower in width, and are less wide than the equatorial distance remaining between the "ear" margins. The trilete rays are thin, high at the apex (pl. 7, fig. 11), but decrease abruptly in height and extend as low lips onto the "ears." Potonié and Kremp (1956) noted their occurrence in the Westphalian B and C of various coal basins.

The maximum radial diameter, including one "ear," noted during this study, ranges from 650 to 1205 μ. The "ears" may be more than 260 μ in length (as measured from inner surface of coat by transmitted light). There is apt to be a complete gradation in "ear" size within the same assemblage. The "ears" may be weakly developed on small specimens (pl. 7, fig. 7) to strongly developed on large specimens (pl. 7, fig. 9). The spores commonly contain an inner membrane ornamented with papillae which are about half the diameter of those of *Triletes brasserti* (pl. 9, fig. 8b). The spore coat ranges from 20 to 52 μ in thickness distally, is thinnest on contact areas, thicker at the arcuate ridges. Although the lips are generally less than 100 μ in height at the proximal pole, they may attain 176 μ in height.

Occurrence.—No spores of this species were observed in the upper Mississippian coals or in the coals of the Black Creek, Mary Lee, and Pratt Groups of the Warrior Basin, Alabama. They are abundant in the Pinnick (maceration 150) and Cannelton (maceration 780) Coals of Indiana, but rare in another coal (maceration 779) in the Mansfield Formation (?), Indiana. The spores are abundant in the Battery Rock Coal (maceration 733) of Kentucky and rare to abundant in the "Makanda" Coals (macerations 142, 905, 906, 907) of Illinois.

Spores of this species occur in most Tradewater coals. They are present to common in the Babylon (macerations 145A-B, 523A), Willis (maceration 625A-B), Tarter (maceration 604A), Pope Creek (macerations 916, 917), Murphysboro (maceration 550), Bald Hill (maceration 520A), and DeKoven (?) (maceration 621D) Coals and in an unnamed coal (maceration 936) nine feet above the DeKoven Coal. The spores are rare in Rock Island (No. 1) (macerations 528A, 599A, 589), an unnamed coal just above the Stonefort (macerations 639, 554F), New Burnside (maceration 938B), and Wiley (maceration 525A) Coals. In the Tradewater Group as a whole, spores of this species seem to be most abundant in a few samples of the Tarter (maceration 914), Rock Island (No. 1) (maceration 929) and Murphysboro (?) (macerations 628A-B) Coals.

In the Carbondale Group the spores are abundant in one sample of the Colchester (No. 2) Coal (maceration 826) and present in another (maceration 603B). They are rare in the Indiana Coal IV (maceration 881) and Springfield (No. 5) Coal (maceration 630), but more common in another sample of the Harrisburg (No. 5) Coal (maceration 583).

In the McLeansboro Group the spores are rare in Friendsville Coal (maceration 490D), present in the "Merom" (maceration 146) and "Woodbury" (maceration 703) Coals, and common in the "LaSalle" Coal (maceration 600). Some large spores with bulbose "ears," occurring in the McLeansboro Group, may be referable to *Triletes auritus* var. *grandis* Zerndt.

TRILETES AUGUSTAE (Loose) Schopf, Wilson, and Bentall, 1944 (sensu Potonié and Kremp)

Plate 7, figures 12, 13

1934 *Zonales-sporites augustae* Loose, p. 150; pl. 7, fig. 32.
1944 *Triletes augustae* (Loose) Schopf, Wilson, and Bentall, p. 20.

Discussion.—These spores range, according to Potonié and Kremp (1956), from 900 to 1100 μ in diameter. Their equatorial outline is strongly rounded deltoid. The projecting, strongly developed trilete rays are ridge-like and give the spores a characteristic outline. Potonié and Kremp note that the coat may be densely covered with small depressions. The species is reported from the Upper Westphalian B-C of the Ruhr Basin.

These spores are here distinguished from those of *Triletes auritus* (which in Dijkstra's interpretation includes *T. augustae*) because there is no evidence that spores of both types may be borne in the same cone.

The spores possess thick straight ridges from apex to spore margin, not thin and abruptly rising at the proximal pole as are those of *Triletes auritus*. The "ears" are the pointed radial extremities and are not bulbose. Small depressions in the coat, especially noticeable on the proximal surface, may be present. Two extremes of ray development are illustrated on plate 7. On one very small specimen the rays are low (pl. 7, fig. 13); on a larger specimen the bases of the rays are thick but the lips appear high and fluted. Most specimens are similar to those illustrated by Potonié and Kremp (1955, pl. 6, figs. 44-47), for this species. The maximum size range noted is from 855 to 1250 μ. The spores may be brown to black by reflected light.

Occurrence.—In the Tradewater Group these spores are present in the Babylon Coal (macerations 588, 145B); abundant in the Pope Creek Coal (maceration 602); rare to common in the Rock Island (No. 1) Coal (macerations 626, 589, 627) and Murphysboro (maceration 549) Coal; common to abundant in the New Burnside Coal (macerations 938B-C); rare in the DeKoven (?) Coal (maceration 621D). In the Carbondale Group these spores are common in the Colchester (No. 2) Coal (maceration 580), Summum (No. 4) Coal (maceration 463), and Harrisburg (No. 5) Coal (maceration 583). They are rare in the "LaSalle" Coal (maceration 600) of the McLeansboro Group.

TRILETES APPENDICULATUS Maslankiewiczowa, 1932

1932 *Triletes appendiculatus* Maslankiewiczowa, p. 163, fig. 39.
1946 *Triletes appendiculatus* Maslankiewiczowa, *in* Dijkstra, p. 34; pl. 16, figs. 176, 177.

TRILETES APPENDICULATUS ?

Plate 7, figure 14

Discussion.—The spores of *Triletes appendiculatus*, according to Potonié and Kremp (1956), are about 800 to 900 μ in diameter. The auriculate projections or "ears" are longer than one-half the radius of the spore body and their basal width is more or less equal to the equatorial distance between the outer margins of the "ears." Potonié and Kremp distinguish these spores from those of *T. auritus* on the basis that the equatorial distance between "ears" is shorter. The spores are distinguished from those of *T. trilobus* on the basis that the equatorial distance between "ears" is longer. The distinctions between the three species may or may not have taxonomic significance.

Potonié and Kremp (1956) report that *Triletes appendiculatus* can occur in the Westphalian A-D in various coal basins.

The "ears" of the illustrated spore (pl. 7, fig. 14) are up to 410 μ in width and 250 μ in length. The "ears" are poorly preserved and folded; originally they were probably longer. The trilete rays are similar to those on spores of *Triletes auritus* in that they are thin, extend to the "ears," and possess an abruptly upraised portion at the apex. The "ears" of another specimen were up to 470 μ in width. The spores are rare and generally occur with spores of *T. auritus.*

Occurrence.—This species is represented by a few spores found in the Tarter Coal (maceration 604A) and in the lower coal (maceration 950A) from Goose Lake, Illinois.

Triletes (Auriculati) spp.

Plate 7, figures 15-18

Some of the other types of auriculate spores noted during this study are illustrated in order to give an over-all picture of the variability between spores referred to the section Auriculati.

The spore shown on plate 7, figures 15a and 15b, is similar to those of *Triletes augustae* in general morphology but is much larger—1900 μ in maximum diameter. Another large auriculate spore (pl. 7, fig. 16) from the same sample has undulatory arcuate ridges and a distinct pattern of small depressions or pits on the contact areas. Of the two illustrated from coals of the McLeansboro Group, that shown on plate 7, figure 17, might be referred, by some, to *T. augustae.* The other (pl. 7, fig. 18) has heavy rays, pitted contact areas, and undulatory arcuate ridges. No spores resembling those of *T. tuberculatus* were noted during this study.

Sectio Zonales (Bennie and Kidston) Dijkstra, 1946

Spores in the Zonales section (Dijkstra, 1946) are of average to large size and possess an equatorial rim provided with an equatorial zone. Some of the spores possess zones or flanges consisting of anastomosing processes. The ornamentation, according to Dijkstra, is of perisporal origin. These spores are much larger than those of the section Triangulati.

The zonate megaspores occur in coal beds in the Caseyville and Tradewater Groups, but are most diversified and conspicuous in the older coals in the Tradewater Group. None has yet been found in coals in the Chester Series or in coals in the Carbondale and McLeansboro Groups. However, Chaloner (1956a) describes a fructification containing zonate megaspores found in a shale above the Colchester (No. 2) Coal of the Carbondale Group.

Triletes rotatus Bartlett, 1929

Plate 8, figures 1, 2

1929 *Triletes rotatus* Bartlett, p. 21; pl. IX; pl. X, figs. 1, 2; pls. XI, XII.
1937 *Triletes rotatus* Bartlett, *in* Zerndt (1937a), p. 8-10; text fig. 6; pls. 6-10.
1946 *Triletes rotatus* Bartlett, *in* Dijkstra, p. 42-43.
1954 *Rotatisporites rotatus* (Bartlett) Potonié and Kremp, p. 163; pl. 15, fig. 65.
1955 *Rotatisporites rotatus* (Bartlett) Potonié and Kremp, *in* Horst, p. 189-190; pl. 18, figs. 10-14.
1956 *Rotatisporites rotatus* (Bartlett) Potonié and Kremp, *in* Potonié and Kremp, p. 135; text fig. 59.

Discussion.—Some spores of *Triletes rotatus,* many of which are fragmentary, are found in the coal beds of Illinois. In comparison to those of *T. ramosus,* they are smaller (720 to 815 μ in diameter), have a thinner spore coat (20 to 30 μ distally, 12 μ proximally), and similar lip development. The spores are characterized by an encircling flange consisting of a single row of straplike appendages (pl. 8, fig. 2) that extend from the spore body, are somewhat proximal to the geometrical equator, and anastomose towards their extremities to form a rimlike border. The outer edge of the rim is commonly ornamented with non-uniformly spaced thorn-shaped spines (pl. 8, fig. 1) rather than with fingerlike projections. On the basis of the rim ornamentation, the spores may be referable to *T. rotatus* var. *denticulata* Zerndt.

However, those spores found in the shale above the Pinnick Coal possessed fingerlike projections on the margin of the rim and are very similar, in the straplike appearance of the radiating processes, to those illustrated by Zerndt (1937a) and by Horst (1955). The straplike processes are apparently not as fully developed on the spores originally described by Bartlett. Bartlett's spores, like those described above, lack the distal ornamentation of, are smaller than, and possess a less copious appendage growth than the spores of *Triletes ramosus*. Bartlett's specimens were macerated from coal pebbles, of assumed early Pennsylvanian age, found in the glacial drift of Michigan.

Although it is assumed that the spores of *Triletes rotatus* and those of *T. ramosus* are allied with the lycopsids, the spores have not yet been found in cones.

Known occurrences of spores of *Triletes rotatus* are in the Dinantian and Namurian A and B in some European coal basins (Potonié and Kremp, 1956). Dijkstra (1952b) noted their occurrence in the Namurian C of Turkey and in the Westphalian B of the Belgian Campine. Dijkstra (1957) also reported their common occurrence in the Limestone Coal Group (Namurian) of Scotland.

Occurrence.—Spores of *Triletes rotatus* are abundant in a Caseyville age coal (maceration 910) sampled in a gob pile of an abandoned mine in a fault block zone, Pope County, Illinois. A few specimens were noted in the shale (maceration 163) above the Pinnick Coal of Indiana. They also are present in a thin coal (maceration 455) in deposits of possible early Pennsylvanian age found in a sinkhole deposit at Lincoln Quarry, Will County, Illinois.

TRILETES RAMOSUS Arnold, 1950

Plate 8, figures 3-6; text figure 3

1950 *Triletes ramosus* Arnold, p. 72-74; pl. III, fig. 2; pl. IV, figs. 1, 2; pl. V, figs. 1-3.
1956 *Rotatisporites ramosus* (Arnold) Potonié and Kremp, p. 134-135.

Description. — Spores trilete, typically compressed proximo-distally or obliquely, characterized by an encircling flange of flattened cylindriform appendages. Spore body round to subtriangular, 705 to 1150 μ in diameter (mean 975 μ for 36 specimens, more than half of which are greater than 1000 μ). Trilete rays prominent, lips straight to sinuous, generally more than 100 μ in height at apex, up to 234 μ on one specimen.

Contact surfaces generally smooth, sometimes ornamented with small tubercles (pl. 8, fig. 3a). Fairly closely spaced appendages arising from the spore body slightly proximal to the geometrical equator, extending outward from juncture with spore body as much as 575 μ (pl. 8, figs. 4a, 5), and fusing and anastomosing near their extremities to form a rimlike border from which fingerlike processes, up to 52 μ in length, project (pl. 8, figs. 4b, 6). Appendages becoming shorter toward the distal pole, but generally present over the entire distal surface (pl. 8, fig. 3b); the shorter distal appendages generally discrete and club-shaped, in some specimens branching or adjacent appendages joined.

Spore coat ranging from 23 to 52 μ in thickness and, in one specimen, enclosing a folded inner membrane. Spore body dark reddish brown, appendages yellow by transmitted light; spore body dull brown, appendages and upper margin of lips glossy dark brown to amber by reflected light.

Discussion.—Some spores of this species were measured both wet and dry. Text figure 3 illustrates the amount of shrinkage observed, averaging about 19 percent. All the measurements given above were made on wet specimens or on those mounted in balsam. Spore coat thickness is variable, even on an individual spore; the spore coat on one spore ranged from 26 to 52 μ and was thinnest in the area of the contact surfaces.

These spores are very similar to, and probably identical with, those originally described by Arnold (1950). However, none is as large or as small as he described, nor were they ever found in such abundance as in the Williamston Coal, a spore coal.

Dijkstra (1952b, p. 167) pointed out that the morphology of the spores of *Triletes dentatus* Zerndt is apparently identical to that of *T. ramosus* Arnold, but said that the ". . . only difference between these two species is difference in age." *T. dentatus,* according to Dijkstra, is known from the Westphalian C (highest part) and D from Poland, Turkey, France, and the Netherlands. In addition to those of the Williamston Coal, Arnold found a few spores of *T. ramosus* in the shale below Cycle "A" at Grand Ledge and from the Big Chief No. 8 mine at St. Charles, Michigan.

The same comments that Dijkstra made in his distinction between spores of *Triletes rotatus* and *T. dentatus* apply equally well in the distinction between those of *T. rotatus* and *T. ramosus.* Compared to spores of *T. rotatus,* the *T. ramosus* spores are generally larger, possess distal appendages, and more numerous equatorial appendages. Although it is possible that *T. ramosus* may prove to be a later synonym of *T. dentatus,* the Illinois spores are referred to *T. ramosus* because comparative material was available. The first really definitive description and adequate illustration of Zerndt's species was published by Dijkstra (1952b, p. 166, 167). The only spore illustration that Zerndt presented for *T. dentatus* was in Zerndt, 1932b, pl. 1, fig. 5, designated at that time as type 24A. Later Zerndt (1938a) noted that these are referred to type 37, and (in Zerndt, 1938b) noted type 37 as *T. dentatus* Zerndt.

The only apparent distinction between the Illinois spores and those described by Arnold and Dijkstra is that the Illinois spores may have higher lips, but at present this is not considered a basis for specific distinction. The Illinois spores also are similar, except for the sometimes greater development of fingerlike processes, to those of *Triletes dentatus* that Piérart (1957) describes as characteristic of the Upper Westphalian C of the Belgian Campine.

Cross (1947, p. 287, fig. 2; pl. I, figs. 2, 3; pl. III, figs. 84-86; p. 301) described spores designated as *Triletes rotatus* from the Powellton, Cedar Grove, Chilton, and Coalburg Coals of the Kanawha Group from the Appalachian Basin. From his description it appears that many of the spores he noted are of the *T. rotatus* type, but two specimens that he illustrated (Cross, 1947; pl. I, figs. 2, 3) are very similar to those Dijkstra (1952b; pl. 5, figs. 1, 2, 6) illustrated and designated as *T. dentatus.*

Occurrence.—Spores of *Triletes ramosus* are most typically found in the older coals of the Tradewater Group, but are sporadic in distribution, and generally do not occur in great quantities. A few spores, along with some more typical of *T. rotatus,* were found in the shale (maceration 163) above the Pinnick Coal in Indiana. They are abundant in the upper part of the Willis Coal (maceration 625A) and common in the lower part of the Willis Coal (maceration 625B) and in the Willis (?) Coal (maceration 631). They are rare in the Tarter Coal (maceration 901), rare to common in the Rock Island (No. 1) Coal (macerations 929 and 626, respectively), and common in the upper part of the New Burnside Coal (maceration 938A). Rare, badly preserved fragments, possibly referable to this species, were found in one of the lower coals (maceration 950A) from Goose Lake and in an unnamed coal (maceration 936) nine feet above the DeKoven Coal.

Triletes superbus Bartlett, 1929

Plate 8, figures 7, 8; plate 9, figures 1, 2

1929 *Triletes superbus* Bartlett, p. 20-21; pl. VII, figs. 1, 2; pl. VIII, figs. 1, 2.

Description.—Megaspores large, trilete, commonly compressed in proximo-distal orientation, up to 4100 μ in total diameter; spore body round to subtriangular in outline, ranging from 1375 to 3260 μ in diameter (mean 1875 μ for 14 specimens). Trilete rays very prominent; lips up to 400 μ in height, generally highest at apex and extremities. Upper margin of lips in some specimens ornamented with spine-like projections, somewhat fluted and sinuous. Contact surfaces smooth to tuberculate. Small spines up to 30 μ in length and 10 μ in diameter may extend from tubercles (pl. 8, fig. 7).

On well preserved specimens distal surface ornamented with processes 35 to 145 μ in length, 10 to 15 μ in minimum diameter, of maximum length immediately distal to distinctive marginal flange. Distal processes generally parallel-sided and rounded or blunt to distinctly club-shaped terminally. Flange elements arising from encircling rows of slender bases in a zone extending both proximal and distal to geometrical equator; processes anastomosing outward forming an irregular fenestrate flange, probably thick, honeycomb-like, and delicate when uncompressed; flange 410 to 1040 μ wide, widest opposite ends of trilete rays. Denuded spores possess tubercles in the flange attachment zone. Spore coat 41 to 51 μ thick. Well preserved specimens dull brown with glossy brown to amber ornamentation by reflected light.

Discussion.—These megaspores seem to be identical to those originally described by Bartlett (1929) in regard to distal ornamentation and flange development, but some specimens are smaller than the minimum size given by him. However, most fall within the size range given by later authors. One spore, 3260 μ in body diameter and 4100 μ in total diameter, is one of the largest recorded for the species. These spores also are similar to those described by Dijkstra (1955a) as *Triletes brasserti* forma 1. His description of the configuration of the flange implies a much closer relationship to spores of *T. superbus* Bartlett than to those originally described as *T. brasserti* by Stach and Zerndt (1931). On the other hand, his description of *T. brasserti* forma 2 is quite similar to that given here for spores referred to *T. brasserti*.

Previously reported occurrences of these spores are in the Westphalian B-D of Europe (Dijkstra, 1952b; Potonié and Kremp, 1956). They were originally described by Bartlett from coal pebbles found in the glacial drift near Ann Arbor, Michigan. Cross (1947, p. 287, fig. 2; p. 300; pl. I, fig. 1; pl. III, figs. 62-65) reported their occurrence in the Winifrede and Coalburg Coals from the upper part of the Kanawha Group of the Appalachian Basin. Although Chaloner's (1956a) *T. superbus*-type megaspores are from a cone compression presumably from the lower part of the Carbondale Group above Colchester (No. 2) Coal, spores of *T. superbus* are most common in coals of the Caseyville and lower Tradewater Groups.

Affinity.—In comparison with the megaspores of the *Triletes superbus*-type that Chaloner (1956a) found in *Sporangiostrobus langfordi* Chaloner, these Illinois spores are similar in most respects except that the lips have not been observed to be as high as 760 μ. *Sporangiostrobus* is assumed to have been borne by arborescent lycopods similar to *Lepidodendron* or *Sigillaria* (Chaloner, 1956a).

Occurrence.—Spores of *Triletes superbus* are common in the "Makanda" Coals (macerations 906, 142). They are rare in the Pinnick Coal (maceration 150), but common to abundant in the shale (maceration 163) above the Pinnick Coal and in the Cannelton Coal (maceration 780) of Indiana. They are rare in a Caseyville age coal (maceration 910) of Illinois, and also are rare in the Jagger Coal of the Warrior Basin of Alabama. In both the "Makanda" Coals (maceration 906) and in the shale above the Pinnick Coal these spores occur in large masses and in tetrad association.

In the Tradewater Group, they are common in the "Sub-Babylon" Coal (maceration 144) and rare in the upper part (maceration 625A) of the Willis Coal and in the Rock Island (No. 1) Coal (maceration 929). Some poorly preserved specimens were found in one of the lower coals (maceration 950) from Goose Lake, Illinois.

TRILETES BRASSERTI Stach and Zerndt, 1931

Plate 9, figures 3-10; text figure 3

1931 *Triletes brasserti* Stach and Zerndt, p. 1123; figs. 28-31.

Description.—Spores of medium to large size, trilete, showing no preferred compressional orientation, up to 2170 μ in total diameter. Spore body round to subtriangular in outline, probably originally somewhat spheroidal, ranging from 735 to 1600 μ in diameter (mean 1230 μ for 64 specimens, 89 percent of which measure more than 1000 μ). Trilete rays prominent, extending onto flange, sometimes to outer margin of flange, so that ray extremities may project as points beyond spore body on an otherwise denuded spore.

Lips may be open, generally about 150 μ in height at apex (range 67 to 250 μ), decreasing in height outward, but increasing to more than apex height near spore body margin. Lips straight to sinuous; upper edges membranous, fluted, ornamented with parallel-sided acuminate spines up to 30 μ in length and 15 μ in diameter. Contact area as a rule smooth, especially on smaller spores, sometimes tuberculate (pl. 9, fig. 4a), equalling in diameter 80 to 95 percent of the spore body diameter.

Base of encircling flange extending proximal to and slightly distal to geometrical equator so that proximal surface of flange sometimes broader than distal surface of flange, up to 240 μ in thickness (pl. 9, fig. 5). Flange extending away from spore body from 62 to 568 μ, generally widest opposite trilete rays. Flange appearing smooth and somewhat leathery, sometimes pleated or striate proximally (pl. 9, figs. 6, 7), rarely, even minutely, fenestrate. Distal surface of flange appearing spongy or coarsely granular (pl. 9, fig. 4b). By transmitted light flange appearing beaded or set with barlike processes at margin, and appearing to consist of imbricated and fused rod-shaped processes distally (pl. 9, figs. 9, 10). In some specimens round processes up to 30 μ in diameter adjacent to distal surface of flange. Flange rather easily detached from spore body. Completely denuded specimens not tuberculate in zone of flange attachment, showing only slightly indented zone of attachment.

Spore coat generally from 42 to 83 μ thick, thickest at juncture of spore coat and flange, thinnest at contact areas. Spore coat on small specimen as little as 26 μ thick. Inner membrane generally present. In some specimens inner membrane ornamented with hemispherical tubercles 6 to 10 μ in diameter, spaced about 25 μ apart (pl. 9, figs. 8a, 8b). Spore body deep reddish brown, flange reddish orange to yellow by transmitted light. Spore body brown to black, upper surface of flange brown to black and glossy by reflected light.

Discussion.—Some smaller megaspores, for example, the one shown on plate 9, figure 7, occur with the larger spores and might be interpreted as *Triletes subbrasserti* Arnold. They are rare and associated only with numerous larger spores of *T. brasserti,* at least in the Illinois coals examined. No distinct size limit is applicable because specimens of intermediate sizes also occur. At present the small spores are interpreted as immature spores of *T. brasserti* rather than as representing a distinct species.

One of the larger specimens possessed a distal membrane about 10 μ thick extending from the distal surface of the flange. The membrane is ornamented with irregularly shaped low tubercles so closely spaced as to effect a reticulate appearance. Similar distal coverings have been noted for some small spores of *Triletes superbus* from a coal from another area.

In the description I noted that these spores apparently had no preferred compressional orientation. This may be more apparent than real. Many spore tetrads of *Triletes brasserti* are present in some of the samples and, if the spores were compressed while in tetrad association, then dissociated during maceration, no compressional orientation would be apparent.

Spores of this species were measured wet and then dry. The scatter diagram given in text figure 3 indicates the amount of shrinkage, averaging about 19 percent. Not only does the spore body shrink on drying, but the width of the flange as well as the height of the lips decreased, either because of shrinkage or because of slight crinkling upon dessication. Unfortunately no measurements of spore coat thickness before and after drying were possible. All the measurements given in the description are those of wet or balsam-mounted specimens.

In contrast, the range of spore body diameter on the dry specimens is from 600 to 1250 μ (mean 1000 μ for 46 specimens).

The dried specimens compare closely in dimensions with those given by Dijkstra (1955a) for spores of *Triletes brasserti* forma 2. His description (Dijkstra, 1955a, p. 334) of the flange of these spores is:

> Appendages of the zone in some (?) rows, strongly anastomosed. Separate shape of the appendages not clearly distinguishable. Border of the zone provided with bar-like processes, 50 μ in length. Periphery of the zone shows some openings, 10-30 μ in diameter. Breadth of zone about 100-500 μ (the mean being 290 μ).

Although he does not mention the aspect of the distal side of the flange, Stach and Zerndt (1931, p. 1123) in their original description of spores of *Triletes brasserti* describe the flange as follows:

> Die Oberseiten der Aquatorleisten sind uneben, und zwar schwach wellenformig, die Unterseiten kornig.

In contrast, Dijkstra (1955a, p. 333) describes the flange development on spores that he designates as *Triletes brasserti* forma 1:

> Equatorial zone 225-350 μ ([rarely] 650 μ) broad, consisting of about eight rows of appendages. Appendages about 12 μ broad, united into groups of 3-5 specimens. Between the appendages a very thin transparent substance. Appendages towards the periphery ramified with flat leaf-like processes. Between the processes openings 30-60 μ in diameter. This part of the zone is 150-200 μ broad. Arcuate ridges granulated, granules 40-50 μ in diameter (only visible with specimens which have lost their zone).

This is an excellent typification of the flange on spores of *Triletes superbus* and, in my opinion, one of the few concrete distinctions between the spores of *T. brasserti* and *T. superbus*. Potonié and Kremp (1956) similarly reemphasized the original interpretation rather than accept the broad interpretation of *T. brasserti,* as applied subsequently to the original description by Stach and Zerndt. Dijkstra (1955a) points out that the spores of *T. nigrozonalis* Stach and Zerndt (1931) should be referred to *T. brasserti* on the basis of a written communication from Zerndt in 1941. However, Potonié and Kremp (1956) have described these spores as a species of *Valvisisporites,* to which they referred the auriculate megaspores.

Dijkstra (1955a, p. 333) pointed out that *Triletes rotatus, T. superbus, T. dentatus,* and *T. brasserti* have some features in common and could be confused when one is dealing with poorly preserved specimens, and that in the past various "types" have been united by Zerndt in his distribution charts so that it is impossible to know the exact stratigraphic distribution of these forms as given in the older literature. Potonié and Kremp (1956) state that the spores of *T. brasserti* are known from the Upper Westphalian B to the Middle Westphalian C in the Ruhr Basin, from the Westphalian B-C in Holland, and from the Westphalian A-C in France.

In contrast similar spores are known from the Namurian B-C in Poland and Dinantian and Lower Namurian in Scotland. Cross (1947, p. 287, fig. 2; pl. I, fig. 22; pl. III, figs. 66-77, 87-90; p. 300-301) reported spores of *Triletes brasserti* questionably from the Lower War Eagle Coal, and from the Cedar Grove, Chilton, Winifrede, and Coalburg Coals of the Kanawha Group of the Appalachian Basin. Arnold (1950) reported *T. brasserti* from the upper third of the coal of Cycle "E" and the Eaton Sandstone (Cycle "H") at Grand Ledge, and *T. subbrasserti* from the Eaton Sandstone, the coal of Cycle "D" at Grand Ledge, and the Williamston Coal of Michigan.

Affinity.—Spores of *Triletes brasserti* are assumed to be allied with the lycopsids as are those of *T. superbus.*

Occurrence.—Spores of *Triletes brasserti* appear to be restricted to the Tarter, Willis, and Pope Creek Coals in the lower part of the Tradewater Group of Illinois. The species is abundantly represented in the Willis Coal (macerations 625A-B) from Gallatin County, in the Tarter Coal (macerations 604A, 901) from Fulton and Warren Counties, and in the Pope Creek Coal (maceration 602) from Fulton County.

Sectio Triangulati Schopf, 1938

Spores in the Triangulati section of *Triletes* are of medium size or smaller. Spore body is round to oval in outline; flange, when present, is generally widest opposite trilete rays and, therefore, more or less triangular in outline. The trilete rays are long relative to spore body diameter. Spore surface is smooth to reticulate. Schopf (1938) noted that these spores are similar to those of herbaceous lycopods such as *Selaginellites* and *Lycopodites* and to those of modern heterosporous lycopods.

Chaloner (1954a) confirmed the general equivalence of the Triangulati and the herbaceous lycopods in his description of *Triletes triangulatus*-type megaspores and *Cirratriradites annulatus*-type microspores from *Selaginellites suissei* cones. Subsequently Hoskins and Abbott (1956) isolated *T. triangulatus*-type megaspores and *C. annulatus*-type microspores from *S. crassicinctus*.

The stratigraphic occurrence and relative abundance of triangulate megaspores approximately parallels that of microspores of *Cirratriradites* as reported by Kosanke (1947). Triangulate megaspores are most abundant in the older coals of the Tradewater Group. Although *Cirratriradites* apparently is not represented in coals of the Caseyville Group, triangulate spores are present. If those Mississippian small spores referred to *Cirratriradites* by Hoffmeister, Staplin, and Malloy (1955) truly are allied within this genus, then triangulate megaspores also should be present. As yet, none has been found in coal beds in the Mississippian Chester Series.

TRILETES TRIANGULATUS Zerndt, 1930 (sensu Dijkstra, 1946)

Plate 10, figures 1-10

1930 *Triletes triangulatus* I, II, Zerndt (1930c), p. 51-54; pl. 7, figs. 19-33.

1946 *Triletes triangulatus* Zerndt, *in* Dijkstra, p. 52-54; pl. 4, figs. 24, 25, 27-31, 33, 34.

Description.—Spores of medium size, trilete, generally compressed proximo-distally, from 410 to 1076 μ in total diameter (including flange). Spore body round to very slightly rounded subtriangular in outline, originally somewhat oblate, from 395 to 640 μ in diameter. Trilete rays distinct, extending to margins of flange (pl. 10, fig. 10). Lips membranous and commonly plicate (pl. 10, fig. 7), up to 100 μ in height. Suture extending only about half way from apex to body margin. Contact areas granulose to ornamented with irregular ridges radiating from apex (pl. 10, fig. 7) to reticulate (pl. 10, figs. 8, 10). Flange extending away from spore body 18 to 267 μ at corners, widest opposite rays causing overall triangular outline of proximo-distally compressed spores. Flange appearing pleated (pl. 10, fig. 10), to striate, to reticulate (pl. 10, fig. 6), often bordered by a narrow lighter-appearing rim, as illustrated by Schopf (1938, pl. 4, fig. 3) and Chaloner (1954a, figs. 2, 3). Distal ornamentation consisting of a perisporal reticulate network, varying considerably in mesh size (pl. 10, figs. 1b, 2b, 3, 4b, 5).

Spore body coat granulose, from 10 to 26 μ thick, enclosing a folded inner membrane, generally of triangular outline. Inner membrane characteristically ornamented with small papillae (pl. 10, fig. 9).

Discussion.—These spores were described in detail by Schopf (1938), Dijkstra (1946), Guennel (1954), and Potonié and Kremp (1956). Potonié and Kremp (1956) distinguished several species (included within Dijkstra's circumscription of *Triletes triangulatus*) on the basis of total size and character of distal ornamentation. Both detailed biometric analyses and cone studies are needed to substantiate such a subdivision if such speciation is to have taxonomic meaning. Guennel (1954) pointed out that the distal perisporal membrane is somewhat elastic and may cause reticulations to vary in size.

According to Guennel (1954) the spore body, except for the contact areas, is covered with a perisporal membrane that forms the distal reticulations, the flange, and the trilete rays. He did not note the presence of proximal reticulations such as were described by Schopf (1938). In the present investigation, spores with distinct proximal reticulations seemed to be most conspicuous in the Harrisburg (No. 5), Springfield (No. 5), and Herrin (No. 6) Coals. In general most variations of distal ornamentation are present in any one coal containing abundant triangulate spores, except that the Rock Island (No. 1) Coal, in particular, seems to have a large preponderance of spores with fine-meshed distal reticulation.

The size range given in the description above exceeds that given by most previously published descriptions. Most specimens are less than 900 μ in over-all diameter. The largest specimen observed, from the Indiana VII (?) Coal (maceration 939A), has a flange 267 μ wide at one radial extremity. This specimen is not comparable to those of *Triletes laxomarginalis* Zerndt (as described by Bhardwaj, 1955), but has all the characteristic features of *T. triangulatus*.

Although many of these spores have papillate inner membranes, the ornamentation does not seem to be present on all externally ornamented spores or on all denuded spores. Perisporal ornamentation effectively masks the internal ornamentation.

Affinity.—The affinity of these spores is with the herbaceous lycopods, as discussed under the section Triangulati.

Previously Recorded Occurrences.—Dijkstra (1955a) noted that these spores occur in the Carboniferous of all coal basins studied so far, but that they are perhaps less abundant in the Stephanian. Guennel's (1954, fig. 3) chart, approximating the vertical and geographic distribution of this species, emphasized the lack of megaspore studies done in this country.

Occurrence.—No triangulate spores were observed in upper Mississippian coals or in the coals of the Black Creek, Mary Lee, and Pratt Groups of the Warrior Basin in Alabama. Although spores of this species are fairly common in the oldest Caseyville age coal in a Wabash County, Illinois, diamond drill core (maceration 798), they are rare to absent in other coals of the Caseyville Group.

In the Tradewater Group triangulate spores are abundant to common in some samples of the Babylon (maceration 588), Willis (maceration 625A-B), Pope Creek (maceration 602), Murphysboro (maceration 550), Wiley (maceration 525A-B), Davis (maceration 518A-B), and DeKoven (maceration 519A) Coals, and in an unnamed coal above the DeKoven Coal.

Although represented in most coals of the Carbondale Group, spores of this species are most abundant in the Summum (No. 4) Coal (maceration 463) and common in the Colchester (No. 2) Coal (maceration 603B-C) and in the Herrin (No. 6) Coal (Schopf, 1938). In the McLeansboro Group these spores are common in the Indiana VII (?) Coal (maceration 939A), present in the Friendsville (maceration 135) and "Bogota" (maceration 133) Coals, rare in the Friendsville (?) (maceration 136) and in the Friendsville (maceration 490-D) Coals. This species is also known from the Danville (No. 7) Coal.

Although the species has a long stratigraphic range in the Illinois coal basin, it is best represented in coals of the Tradewater and Carbondale Groups.

Sectio Incertus

Megaspores of *Triletes hirsutus* (Loose) Schopf, Wilson, and Bentall, and *T. hirsutus* var. *brevispinosa* Zerndt, and those of *T. praetextus* Zerndt were referred to the sections Aphanozonati and Zonales, respectively, by Dijkstra (1946). Schopf, Wilson, and Bentall (1944) had referred *T. hirsutus* questionably to the section Lagenicula. Because they believed *Triletes* to be an illegitimate generic designation and because the above megaspores did not seem to be allied with Lepidodendraceae, as are the typically lageniculate spores, Potonié and Kremp (1954) accepted and amended the generic designation *Setosisporites* of *Setosisporites hirsutus* (Loose) Ibrahim. In 1955 Potonié and Kremp also referred *T. praetextus* Zerndt and *T. globosus* Arnold to *Setosisporites*.

Potonié (1954a, 1954b) stated that the megaspores of *Setosisporites* have been found in cones allied with the Bothrodendraceae. These megaspores are distinct from those typical of the Lepidodendraceae in that the conspicuous apical prominence rises, not from the ends of the rays as in most typical lageniculate spores, but near the apex of the spores. Thus the area of the contact surfaces is much greater than that of the apical prominence. Potonié also stated (1954b):

> Par contre [to the Bothrodendraceae], on sait que les Lepidodendraceae ne portent jamais de fimbriae ramifères.

As discussed in the general comments preceding the discussion of lageniculate megaspores, the morphological distinction between the megaspores of the Lepidodendraceae and Bothrodendraceae, based on apical development and spine configuration, although valid for megaspores of upper Mississippian and Pennsylvanian age, is apparently not applicable to megaspores of lower Mississippian age. These older megaspores possess modified characteristics of the megaspores of both families.

The microspores of cones allied with the Bothrodendraceae are, as yet, unknown. In the present investigation, an intimate association of megaspores of the *Triletes globosus*-type with the small spores of *Densosporites* was noted, particularly in the coal in the Hardinsburg Formation and the Reynoldsburg Coal. It would seem that these megaspores and small spores may be either botanically related or may have been borne by plants with similar ecological requirements. The stratigraphic occurrence of *Densosporites* is compatible with either possibility. *Densosporites* (Kosanke, 1947, fig. 1) is represented abundantly in Caseyville coals, present in coals of the lower part of the Tradewater, sporadic in occurrence in those of the upper part of the Tradewater, and apparently absent from younger coals.

Paralleling the occurrences of *Densosporites,* the megaspores of the *Triletes globosus*-type are characteristic of and abundant in Caseyville coals, present sporadically, at places in abundance, in Tradewater coals up to and including the Rock Island (No. 1) Coal, and apparently absent in coals in the upper part of the Tradewater and in younger coals. That *Densosporites* is abundant in the Mississippian Hardinsburg Formation is known from both the work of Hoffmeister, Staplin, and Malloy (1955) and from my own observations.

In opposition to this relationship, either botanical or ecological, abundant spores of *Densosporites* occur in a Springer or Chester coal described by Schemel (1950a), but are not accompanied by spores of *Triletes globosus* or *T. hirsutus*. In addition, these megaspores also are apparently absent from the sample of Tarter Coal that contained sporangial masses of *Densosporites*. However, recently Chaloner (1958a) described microspores of the *Densosporites*-type and megaspores of the *T. hirsutus*-type from the cone of *Selaginellites canonbiensis* Chaloner, presumably borne by a herbaceous plant.

Some measurements of selected previously described megaspores and of the *Triletes hirsutus*-type and *T. globosus*-type described here are presented in table 1. None of the spores described here is considered at present identical to any of those from European coals designated as *T. hirsutus* (Loose) Schopf, Wilson, and Bentall. Rather they are considered to be most closely related to those of *T. globosus* Arnold described from the Michigan Basin or given varietal status under *T. globosus*. Consequently it seems advantageous to distinguish them from European forms rather than to form conclusions, possibly unjustified, regarding their affinity. Potonié and Kremp (1955) consider *T. globosus* as distinct from *Setosisporites hirsutus*.

I feel that the differences in ornamentation, some slight, between spores typical of *Triletes globosus, T. globosus* var. (A), *T. globosus* var. (B), *T. globosus* var. (C), and *T.* cf. *T. hirsutus* are botanically and stratigraphically significant. Two general statements regarding the Illinois *T. globosus*-type spores are possible: 1) many of the megaspores from coals in the upper part of the Caseyville are identical to those originally described by Arnold as *T. globosus*; 2) no megaspores found, as yet, in Illinois coals appear to possess spines as long as or as ramose and antlerlike as were illustrated by Potonié and Kremp (1955, p. 123, fig. 37; pl. 4, figs. 25, 27, 29a, 29b) for *Setosisporites hirsutus* (Loose) Ibrahim.

Although there may be some confusion between spores of *Triletes globosus* var.

TABLE 1.—COMPARATIVE DATA ON MEGASPORES OF THE *Triletes hirsutus* and *T. globosus* TYPES. Original citation arranged approximately according to age—oldest at bottom. (Measurements in microns.)

Original citation	Spore body diameter (average)	Ray length, ratio of length to spore radius (average)	Maximum apex height range (average)	Spine length	Spine character	Coat thickness range (average)
Triletes tenuispinosus Zerndt, 1934	498–660 (612)	175–257 2/3	90	48–80	Sometimes branching, anastomosing	—
Sporites hirsutus Loose, 1932, *in* Wicher, 1934a	750–850	2/3	—	45–200	Single and branching	20–60
Apiculati-sporites hirsutus Loose, *in* Loose, 1934	700–890	2/3	—	45–80	Branching	28–32
Sporonites hirsutus Loose, 1932	700–890	2/3	—	45–80	Branching	—
Setosi-sporites hirsutus Loose, *in* Ibrahim, 1933	530–620	nearly to margin	30–40(?)	35–50	Single and branching	—
**Triletes globosus* Arnold. var. (C)	480–770 (675)	3/5	115–165	5–26	Tubercles	26–42
**Triletes* cf. *T. hirsutus* (Loose) Schopf, Wilson, and Bentall	565–636	—	65	37–87	Branching	15–35
Triletes globosus Arnold, 1950	390–570 (480)	(180)	(110)	35–50	Peg-like, shallowly cleft	(17)
**Triletes globosus* Arnold	385–640 (535)	2/3–3/4	75	21–61	Peg-like, shallowly cleft	13–28
**Triletes globosus* Arnold. var. (B)	390–640 (545)	2/3–3/4	100	15–57	Catenulate, with flange	usually less than 16
Triletes tenuispinosus v. *brevispinosa* (var. II) Zerndt, 1937a	as in var. I (?)	as in var. I (?)	as in var. I (?)	36–96	Often joined, densely spaced	as in var. I (?)
Triletes tenuisopinosus v. *brevispinosa* (var. I) Zerndt, 1937a	435–644 (520)	130–240 (177)	64–117 (113)	6	Tubercles, sometimes spinose	(12)
Setosisporites hirsutus var. *brevispinosa* (Zerndt), Potonié and Kremp, *in* Horst 1955	450–975 (700)	—	—	to 30 (15)	Kurze "Haare"	—
**Triletes globosus* Arnold var. (A)	330–630 (515)	3/4	80–130	10–20 (flange up to 30)	Catenulate, with flange	10–15

*Described in text.

(A) and abraded spores of *T. globosus* var. (B), no well preserved transitional forms are recognized. Spores typical of *T. globosus* are distinct from the varietal forms, but there are transitional forms (pl. 5, fig. 6) with spines intermediate, with regard to depth of notching or degree of branching, between those described for *T. globosus* and those described for *T.* cf. *T. hirsutus*. Some of these transitional forms occur in the "Makanda" Coal (maceration 906) and in a shale (maceration 957) below the lowest coal at Goose Lake, Illinois, and in a coal (maceration 799) in the Mansfield (?) Formation in Owen County, Indiana.

In addition, some spores typical of *Triletes globosus* occur with those of *T.* cf. *T. hirsutus*. Those of *T. globosus* var. (C) are similar in body form but have a greater apical development, thicker spore coat, and tubercles rather than spinose ornamentation. The ornament does not seem to be a relict of spinose ornamentation caused by abrasion. In general, among four of the five *T. globosus–T. hirsutus* type of megaspores here distinguished there is, from older to younger rocks, a slight increase in spore coat thickness and there are changes from short to long catenulate spines, to short discrete shallowly cleft spines, to longer more ramose spines. Zerndt (1937a) noted somewhat similar changes, from older to younger specimens, on spores of this general type.

Probably all of the megaspores, generally poorly preserved, of the *Triletes globosus*-type found in the Jefferson (rare), Middle Ream, Jagger, and Pratt Coals of the Warrior Basin, Alabama, can be referred to *T. globosus* var. (B). This varietal form is typically developed and beautifully preserved in the lowest coal in a diamond drill core from Wabash County (maceration 798) and in the shale above the Pinnick Coal (maceration 163) in Indiana, but abraded and not as well preserved in the upper coals of the diamond drill cores from Wabash County (macerations 796, 797) and Battery Rock Coal (maceration 587). Characteristic of Caseyville coals is the abundance of typical *T. globosus* spores or those of *T. globosus* var. (B).

In contrast to the above spores, those of *Triletes praetextus* seem to be restricted to the Battery Rock Coal in Illinois, to the shale above the Pinnick Coal in Indiana, and to the Pratt Coal in Alabama. However, in the latter two areas no immediately overlying coals were examined. Although spores described here appear identical to those previously described from European coals, *T. praetextus* in European coals is apparently much more abundant and has a more extended stratigraphic range.

TRILETES GLOBOSUS Arnold, 1950

Plate 5, figures 1-6

1950 *Triletes globosus* Arnold, p. 80-81; pl. IX, figs. 1-5.

Description.—Megaspores typical of species trilete, usually compressed proximodistally, more or less circular in outline (pl. 5, fig. 1), from 385 to 640 μ in diameter (mean 535 μ for 27 specimens). Trilete rays distinct, ranging in length from two-thirds to three-fourths the spore body radius. Lips increasing in height abruptly near apex to form an apical prominence (pl. 5, fig. 4) up to 75 μ in height. Contact areas, occasionally even lips, characterized by rather closely spaced acuminate spines up to 5 μ both in height and diameter.

Distal spines typically discrete, peglike (pl. 5, fig. 2), ranging from 26 to 61 μ in maximum length on different spores, terminating in an expanded, slightly cleft (pl. 5, fig. 2) or barbed (pl. 5, figs. 3, 5) tip.

Distal spore coat ranging from 13 to 28 μ, generally more than 20 μ in thickness, orange-brown to reddish brown by transmitted light. A folded inner membrane is inside the spore body of many specimens.

Discussion.—These typical spores of *Triletes globosus* are differentiated from the varietal forms described below in that they possess comparatively widely spaced, discrete, peglike spines with characteristic terminal barbs. The spine terminations are cleft to a depth of commonly less than 12 μ, not deeply cleft nor anastomosing and branching as on spores typical of *T. hirsutus* (Loose) Schopf, Wilson, and Bentall.

These spores are very similar to those originally described by Arnold although none was observed to have an apex as high as 110 μ. All but a few examples observed during this study have a characteristically apiculate contact area. Although Arnold did not note this contact area ornamentation, distinguishable with difficulty in proximo-distal compressions, one specimen that he illustrated (Arnold, 1950, pl. IX, fig.1) appears to be similarly ornamented. The spores Arnold described were from the shale from the Big Chief No. 8 Mine at St. Charles, Michigan.

Occurrence.—*Triletes globosus* is abundantly represented in Caseyville coals of Illinois, especially in the Reynoldsburg Coal (maceration 618), the Battery Rock Coal (macerations 629, 908, 909), and the "Makanda" Coal (macerations 906, 907). A few additional examples also are present in the "Makanda" Coal (maceration 142) in Illinois and in the Battery Rock Coal (maceration 733) in Kentucky. A few specimens occur with those of *T.* cf. *T. hirsutus* in the Pope Creek Coal (macerations 916, 917) and Rock Island (No. 1) Coal (maceration 929).

Abundant spores, typical of *Triletes globosus,* seem to be characteristic of the upper coals of the Caseyville in Illinois.

TRILETES GLOBOSUS Arnold var. (A)

Plate 4, figures 1-3

Description.—Megaspores trilete, generally compressed proximo-distally, ranging in diameter from 330 to 630 μ (mean 515 μ for 48 specimens), with the polar axis—not including the apical prominence—slightly shorter than the equatorial diameter. Length of trilete rays generally a little less than three-fourths the spore body radius; lips up to 26 μ in height near base of flaplike apical expansion. Lips increasing rather abruptly in height to 80 to 130 μ at apex (pl. 4, fig. 1), forming an apical prominence up to 100 μ in width. Contact areas commonly smooth, sometimes ornamented with indistinct, minute, sharply pointed spines up to 4 μ in length.

Distal surfaces covered with closely spaced spines 10 to 20 μ in length and 5 to 10 μ in width (pl. 4, fig. 2); spines fused into a solid flange up to 30 μ in width at the arcuate ridges. Spines short and irregularly connected to one another near their bases or by spans extending from rather bulbose nodes on the spines above the level of the spore coat (pl. 4, fig. 3). Spines terminating in fine sharp points extending from the bulbose nodes. Spore coat 10 to 15 μ thick, reddish brown by transmitted light.

Discussion.—The ornamentation on these spores, especially characteristic of megaspores of lower Mississippian age, is present on the *Triletes globosus*-type megaspores in upper Mississippian and lowermost Pennsylvanian rocks. Because the ornament gives an irregularly reticulate appearance to the spore coat, I refer to this general type of ornamentation as "catenulate ornamentation."

Spores of *Triletes globosus* var. (A) may be comparable with those designated originally as *T. tenuispinosus* var. *brevispinosa,* type 13a, variety I by Zerndt (1937a), in general form, length of rays, and height of apical prominence. However, they lack the tuberose nodules and characteristic conspicuous contact area folds described by Zerndt as radiating from the apex. The spore, mounted dry and photographed by reflected light (pl. 4, fig. 1), shows only vaguely defined radiating contact area folds; this specimen shows the maximum development of such folds noted on these Hardinsburg megaspores. Zerndt (1937a), in his descriptions, did not mention the presence of a narrow flange or connecting spans joining the spines. According to Dijkstra (1952b) forma I (variety I of Zerndt and *T. tenuispinosa* var. *brevispinosa* Zerndt *in* Schopf, Wilson, and Bentall, 1944) of Zerndt's varietal form of the species is represented in the Namurian A and B of Turkey, whereas forma II (variety II of Zerndt and *T. tenuispinosa* var. *secundus in* Schopf, Wilson, and Bentall) of Zerndt's varietal form is represented in the Namurian C. In addition, Dijkstra (1957) noted that forma I occurred in every coal that he studied from the Limestone Coal Group of Scotland.

Compared to the spores described by Horst (1955) as *Setosisporites hirsutus* var. *brevispinosa* (Zerndt) Potonié and Kremp, those of the coal in the Hardinsburg Formation are smaller. Horst stated that this variety is characteristic of the Rand Group, but those typical of the species occur in younger beds. He noted the sporadic occurrence of the varietal form in the Namurian A, B, and B or C, and in the Westphalian A, B, and C.

The spores of *Triletes globosus* var. (A) may be comparable, except for the less conspicuous development of contact area ridges with those described by Bennie and Kidston (1886, p. 108) as *Triletes* IV from the Calciferous Sandstone Series in Scotland. *Triletes* IV is described thus: "Macrospore very small [570-510 μ], outer surface feebly granulated. Triradiate ridge prominent, occupying about four-fifths of the upper surface, between the arms of which are radiating flexuous lines that usually extend to the curved line that connects the arms of the central three-rayed star."

Occurrence.—*Triletes globosus* var. (A) is abundantly represented in the coal in the Mississippian (lower Chester) Hardinsburg Formation (maceration 810), Kentucky, and present in the Waltersburg Formation, Randolph County, Illinois.

Triletes globosus Arnold var. (B)

Plate 4, figures 4-10

Description.—Megaspores trilete, generally proximo-distally compressed, ranging in diameter from 390 to 640 μ (mean 545 μ for 33 specimens). Trilete rays increasing in height, a little less abruptly than on spores of *Triletes globosus* var. (A), up to 100 μ at apex and forming an apical prominence (pl. 4, fig. 4) about 100 μ in width. Length of trilete rays between two-thirds and three-fourths the radius of the spore body. Contact areas covered with conspicuous small pointed spines up to 5 μ in length. Spore body containing crumpled, apparently unornamented inner membrane.

Distal coat covered by an irregular network of catenulate-type spines (pl. 4, figs. 6, 8, 9), rather bulbose near tips, terminating abruptly in a sharp point. Spine length from 15 to 57 μ, generally more than 35 μ; spines forming a rather solid flange, crenulate only at margins (pl. 4, fig. 10), up to 56 μ in width.

Spore coat commonly less than 16 μ thick distally, several microns thinner at contact areas, orange to reddish brown by transmitted light.

Discussion. — These spores differ from those of *Triletes globosus* var. (A) in having a less abruptly formed apical prominence, slightly shorter rays relative to body size, longer spines, a more prominent development of the arcuate flange, and a more conspicuous development of spines on the contact area.

Similar appearing spores, possessing generally shorter spines, also occur abundantly in the upper coals of the Wabash County core and in the French Lick and Pinnick Coals of Orange County, Indiana. The distal appendages of these spores are generally 15 to 25 μ long, principally discrete rather than joined, and pointed. A flange is developed around the arcuate ridge. Some specimens are obviously abraded (pl. 4, fig. 7). It would seem that all these are more or less abraded specimens of *Triletes globosus* var. (B), the catenulate joinings and tips of distal spines having been removed. The spores range from 360 to 565 μ in diameter (mean 487 μ); the apical prominence is up to 72 μ in height and the coat is 15 to 20 μ thick. The major difference between spores of *T. globosus* var. (B), where typically developed in the lowest coal of the Wabash County cores, and those in the upper coals is that the latter have more discrete and pointed spines, possibly a preservational feature. Some of the abraded specimens are difficult to distinguish from the abraded specimens of *T. globosus* var. (A).

Spores of *Triletes globosus* var. (B) may be comparable to those described by Zerndt (1937a) as variety II of type 13a, *T. tenuispinosus* var. *brevispinosa.* Zerndt noted distal appendages 36 to 96 μ long that are so densely set that some adjacent spines are joined. However, he did not mention any flange development. One of the characteristic features of spores of type 13a is the ridges on the contact areas radiating from the apex. Megaspores of *T. globosus* var. (A) have a vaguely defined ridging, but those of *T. globosus* var. (B) are not ridged (pl. 4, fig. 5).

In his discussion of *Triletes praetextus,* Cross (1947, p. 302) described spores, designated as *T. praetextus* var. I, with a very narrow solid flange and noted that they resemble *T. hirsutus* except that they do not appear lageniculate. In size and possession of a narrow solid flange they are comparable with *T. hirsutus* var. (B). Cross noted their importance in coal beds of the Lower Kanawha, and in the Lower War Eagle and Eagle Coals as given on his figure 2.

Occurrence.—Megaspores of *Triletes globosus* var. (B) are abundant in the early

Pennsylvanian coals from the Wabash County diamond drill cores (macerations 798, 797, 796). They also have been found in the Battery Rock Coal (maceration 587) in Illinois, in the French Lick (maceration 151) and Pinnick (maceration 150) Coals and in the shale (maceration 163) above the Pinnick Coal from Orange County, Indiana. They also are probably present in the Jefferson (rare), Middle Ream, Jagger, and Pratt Coals of the Warrior Basin in Alabama. These spores occur rarely with spores typical of *T. globosus* in the Reynoldsburg Coal (maceration 618).

The general occurrence of *Triletes globosus* var. (B) is therefore in the lower part of the Caseyville Group in Illinois.

TRILETES GLOBOSUS Arnold var. (C)

Plate 4, figures 11, 12

Description.—Megaspores trilete, having no preferred compressional orientation, probably originally oblate spheroidal, ranging in diameter from 480 to 770 μ (mean 675 μ for 20 specimens), polar axis—not including apical prominence—generally 5 to 10 percent less than equatorial dimension. Apical prominence from 115 to 165 μ in height and up to twice as wide (pl. 4, fig. 11). Length of trilete rays about three-fifths the spore radius. Diameter of contact areas from one-half to three-fourths that of the proximal surface. Arcuate ridges generally developed, about 20 μ in width and 15 μ in height. Contact areas generally smooth, in some specimens covered with tubercles similar to, but smaller than, those on the distal surface.

Distal surface covered with tubercles (pl. 4, fig. 12), generally flattened-hemispherical, rarely with pointed tips, up to 5 to 26 μ in length and 5 to 52 μ in diameter on any one spore. Some specimens have large tubercles interspersed among smaller tubercles.

Spore coat 26 to 42 μ thick, deep reddish brown by transmitted light.

Discussion.—These spores are very similar in body form and development of apical prominence to those of *Triletes* cf. *T. hirsutus* and *T. globosus,* although the mean diameter is larger than the maximum diameter found on spores of either species in this investigation. The apical prominence of spores of *T. globosus* var. (C) is also generally higher and wider. The greatest distinction is the tuberose distal ornamentation on spores of *T. globosus* var. (C) as opposed to spinose ornamentation. Their slightly larger body size, generally larger tubercle size, and thicker spore coat distinguish them from the spores originally described by Zerndt (1937a) as *T. tenuispinosus* var. *brevispinosa* variety I. In addition they do not have radiating folds on the contact area. Their body form and apical development, however, indicate a close relationship with spores of the *T. globosus*-type.

Occurrence.—These megaspores are apparently restricted to the Willis Coal, being common in the upper part of the Willis Coal (maceration 625A) and present in the Willis (?) Coal (maceration 631), Gallatin County, Illinois.

TRILETES cf. T. HIRSUTUS (Loose) Schopf, Wilson, and Bentall, 1944

Plate 5, figure 7

Discussion.—Some megaspores, noted in Tradewater coals, bear longer, more deeply notched spines than those that occur on spores typical of *Triletes globosus.* The few measured specimens range from 565 to 635 μ in diameter and possess an apical prominence up to 65 μ in height. The spore coat ranges from 15 to 35 μ thick. The contact areas are generally covered with tiny spines up to 7 μ in length and 5 μ in diameter. Distal spines are 37 to 87 μ long, bifurcate or more deeply notched than spines on *T. globosus.* Although these spores, of all the *T. globosus*-type spores, appear most similar to those of *T. hirsutus,* none has spines as long as 200 μ (reported by Wicher [1934a] and Dijkstra [1955a]) or is as ramose as those illustrated by Potonié and Kremp (1955, pl. 4, figs. 29a, 29b).

Occurrence.—These spores were found in the Tarter (maceration 914) and Pope Creek (macerations 916, 917) Coals, Mercer County, and were found in abundance in the Rock Island (No. 1) Coal (maceration 929), McDonough County, Illinois.

TRILETES PRAETEXTUS Zerndt, 1934

Plate 5, figures 9, 10

1934 *Triletes praetextus* Zerndt, p. 24, fig. 10; pl. 26, figs. 1-6; pl. 27, figs. 1-7.

1944 *Triletes praetextus* Zerndt, *in* Schopf, Wilson, and Bentall, p. 24.

1946 *Triletes praetextus* Zerndt, *in* Dijkstra, p. 43-44; pl. 7, figs. 66, 67; pl. 8, figs. 68, 69.

1955 *Setosisporites praetextus* (Zerndt) Potonié and Kremp, p. 124-125; pl. 5, figs. 30-32.

Description.—Megaspores trilete, generally compressed obliquely; compressional forms circular to rounded subtriangular in body outline, probably originally spheroidal oblate in shape; spore body 1160 μ and 1025 μ in diameter. Trilete rays strongly developed, two-thirds the radius of the spore body in length. Lips increasing in height gradually, more rapidly near apex to form an apical prominence up to 170 μ in height. Spores in many specimens compressed so that strong folds develop on the contact areas on each side of and parallel to each ray (pl. 5, fig. 9a). Spores characterized by single and branching spines that are restricted to a zone (pl. 5, fig. 9b) extending from the arcuate ridges to a point slightly distal to the geometrical equator. Spines up to 170 μ long, branching and single (pl. 5, fig. 10). Remainder of spore coat appearing granulose, about 50 μ in thickness, black by reflected light.

Discussion.—The few complete megaspores and fragments from the Battery Rock Coal, described above, are not well preserved, but as yet are the only spores of this species to be found in Illinois coals. Even though badly preserved, the branched type of spine, the spinose equatorial zone, and the strong development of trilete rays are unmistakably identical to those features on previously described megaspores of *Triletes praetextus.*

Abundant megaspores of *Triletes praetextus,* also not well preserved, were found in the Pratt Coal from the Warrior Basin of Alabama. These range from 750 to 1080 μ in diameter (mean 920 μ for 13 specimens); their apical prominence ranges from 70 to 170 μ in height. Only two (750 μ and 755 μ in diameter) possess apical prominences less than 100 μ in height. The other spores are more than 1000 μ in diameter and possess apical prominences of about 170 μ in height. Whether or not any of the smaller megaspores are comparable with those described by Dijkstra (1952a, p. 103) as *T. praetextus* forma *minor* is not known. These smaller forms were found by Dijkstra only in the Namurian A-C of Turkey, whereas the more typical large forms were found in the Westphalian.

Many beautifully preserved spores of *Triletes praetextus* were found in the shale above the Pinnick Coal (maceration 163), Orange County, Indiana. These megaspores, some still in tetradic association, are generally obliquely compressed and range from 685 to 1200 μ in diameter (mean 1065 μ for 19 specimens). In the same tetrad spores differ from one another in diameter by as much as 104 μ. The smallest spore observed, probably immature, is strongly triangular, as are the immature spores of *Triletes mamillarius* illustrated by Dijkstra (1946, pl. 3, figs. 14, 15) rather than circular in outline, but possess the characteristic high (170 μ) apical prominence.

The range in apical prominence height on these spores is from 100 to 240 μ (mean 190 μ). The ray length ranges from less than two-thirds to more than three-fourths of the body radius, whereas the diameter of the contact area as a whole is about three-fourths that of the spore body. The upper margins of the lips are membranous and frilled or notched to a depth of about 10 μ. The rays are generally bordered on each side by secondary folds of the spore coat. The distinctive ornamentation is confined to a zone extending distally from the juncture of the ray and the arcuate ridge about 410 μ towards the distal pole, extending about half as far distally interradially. The spines are usually branched, 13 to 46 μ wide basally, and have a maximum length ranging from 140 to 275 μ. Distal to the equatorial spinose zone the spore coat is ornamented with low (5 μ) flattened-hemispherical tubercles about 15 μ in diameter. These tubercles probably cause the more or less granulose to rugose appearance of the spores under reflected light. The spore coat is 56 to 72 ä thick and reddish brown by transmitted light. By reflected light the spores are brown, the spines are glossy dark brown basally to more amber colored towards their extremities. An inner membrane, apparently unornamented, was seen in all spores mounted in balsam and in the broken dry spores.

These spores were first described by Bennie and Kidston in 1886 as *Triletes* XIV. Zerndt (1934) described them in detail and referred them to *Triletes praetextus* (type 21 of Zerndt [1931]). He noted the presence of the characteristic secondary folds on the contact area (1931, pl. 8, fig. 25; 1934, pl. 26, fig. 4). Although Wicher (1934a) in his description of *T. diffusopilosus*—later synonym of *T. praetextus* (Dijkstra [1946], Potonié and Kremp [1955])—did not mention the presence of the serrated upper margin of the lips, his figure 23 on plate 8 showed some indication of this feature. There is some question whether or not the spores, from Appalachian Basin coals, illustrated by Cross (1947, pl. I, fig. 20; pl. III, figs. 91-94) and designated as *T. praetextus* and *T. praetextus* var. I are properly referable to this species.

The general occurrence of these spores, as reported by Dijkstra (1955a), is in the Westphalian B and C of most coal basins, although they also are present in the Westphalian A in Turkey, and even in the Namurian of Poland. More detailed records of previously reported occurrences were given by Dijkstra (1946), Potonié and Kremp (1955), and Horst (1955).

Affinity.—These spores are, according to Potonié (1954a, 1954b), allied with the Bothrodendraceae.

Occurrence. — Megaspores of *Triletes praetextus* are present but poorly preserved in the Battery Rock Coal (maceration 587), Hardin County, Illinois; common and beautifully preserved in the shale (maceration 163) above the Pinnick Coal, Orange County, Indiana; abundant but poorly preserved in the Pratt Coal from the Warrior Basin in Alabama. All these coal beds are of early Pennsylvanian age.

TRILETES ECHINOIDES Chaloner, 1954

Plate 6, figures 4, 5

1954 *Triletes echinoides* Chaloner (1954b), p. 28-29; pl. II, figs. 3, 4.

Description.—Megaspores large, originally more or less spherical, up to 2.55 mm in equatorial diameter (three complete specimens measuring 1.76, 2.15, and 2.55 mm). Trilete rays highly developed (pl. 6, fig. 5b); lips fluted, up to 820 μ in height at proximal pole, decreasing in height somewhat towards extremities of the rays. Contact areas in some specimens delimited by weakly developed arcuate ridges, in some specimens bearing tapering spines up to 480 μ in length (pl. 6, figs. 5a, 5b).

Distal spore coat bearing long tapering spines (pl. 6, fig. 4) up to 1690 μ in length and 340 μ in width, most commonly 700 to 900 μ in length and 100 to 200 μ in width. Spines fluted basally. Small spines variable in length and width, up to 100 μ in length, occurring among the long distal spines.

Discussion.—Chaloner's (1954b, p. 28-29) original description was based principally on fragmented specimens as is the one given above. Most of the specimens that I observed were either very poorly preserved and very much compressed or apparently fusinized. The high degree of compression probably accounts for the excessive maximum diameter of the spines. These megaspores, on the basis of both groups of measurements, have a diameter ranging from 1.76 to 2.66 mm, an apex ranging from 600 to 820 μ in height, and distal spines ranging up to 1630 μ in length. Megaspores of this species are unique in their large size, highly developed lips, and long spines.

They were first reported by Chaloner from the Beaver Bend Limestone of Indiana (early Chester). The reported occurrences are still restricted to beds of upper Mississippian age in the Appalachian and Eastern Interior Coal Basins of the United States.

The botanical alliance of these unusual megaspores is unknown.

Occurrence. — Megaspores were found mostly as fragments in the upper part of the Menard and Golconda Formations in the H. Forester No. 1 core, Perry County, Illinois, and in a plant bed believed to be near the base of the Glen Dean Formation (maceration 888) at Big Stone Gap, Virginia. Spine fragments, possibly of this species, were noted in the coal in the Vienna Formation (maceration 687B) from Johnson County, Illinois. No positively identified fragments have yet been found in coals.

TRILETES EREGLIENSIS Dijkstra, 1952

1952 *Triletes eregliensis* Dijkstra (1952a), p. 102-103; pl. VII, fig. 3.

TRILETES cf. T. EREGLIENSIS

Plate 6, figure 6

Discussion.—The three spores found have equatorial dimensions of 940 μ, 1010 μ, and 1130 μ, respectively. They are matte brown by reflected light, opaque by transmitted light. Closely spaced, irregularly formed, distal papillae, up to 25 μ in length, give a dark brown to black appearance to the distal coat. Although the ornamentation is very similar to that shown by Dijkstra, these three spores are smaller, have slightly higher lips, and more prominent arcuate ridges, especially at the juncture of the ridges with the trilete rays. The ridges are similar to a very thick, short flange, the distal surface of which appears free of ornamentation. Two of the spores, although partially torn apart, are still in tetrad association (pl. 6, fig. 6). Immature spores might be expected to have more prominent ridges than mature spores.

Dijkstra originally described *Triletes eregliensis*—one complete spore and several broken ones—from the Westphalian D of Turkey. Piérart (1957) reports one small specimen (720 μ) from the Upper Westphalian C of Belgium.

Occurrence.—These spores were found in one sample of the Tarter Coal (maceration 604A), Fulton County, Illinois.

Genus TRILETES?

TRILETES? SATURNIPUNCTATUS n. sp.

Plate 10, figure 11

Description.—Spores are rather small for megaspores, originally somewhat oblate to disk-shaped, rounded triangular in equatorial outline, ranging from 325 to 440 μ in diameter (mean 400 μ for 20 specimens). Trilete suture is distinct, generally open; trilete rays extend more than two-thirds the spore radius, possessing no labial development.

Spore coat is characterized by a robust equatorial rim up to 60 μ thick, apparently consisting of two layers, a thin inner one about 4 to 5 μ thick and a thick outer layer. Thickness of spore coat at equator equals as much as 10 to 16 percent of the total spore diameter; diameter of inner spore cavity (six specimens) equals 71 to 78 percent of the total diameter. In side view, the outer margin of equatorial rim is rounded, occasionally sharp on poorly preserved spores. Spore coat thins to as little as 5 μ thick near proximal pole, decreases gradually to 10 μ thick at distal pole. Spore coat is rarely folded, except for apical corners of contact areas. Worn specimens commonly lack central proximal surface, some of them also lack central distal surface so that only the dark circular rim remains.

Spore coat is minutely but distinctly punctate, dark reddish brown to yellow by transmitted light, glossy and dark brown by reflected light.

Holotype.—Maceration 916 slide 5, Pope Creek Coal (lower 4 inches), Mercer County, Illinois (pl. 10, fig. 11).

Discussion.—Except for size, spores of *Triletes? saturnipunctatus* are comparable with the smooth-rimmed spores of *Densosporites* and when seen in cross section would have a similar dumbbell shape. The outer surface of the spore coat is distinctly but densely ornamented with tiny puncta. When observed at magnifications less than 400×, the puncta seem to be oriented in convolute rows and cause the crinkled appearance of the spore coat. Proximo-distal compressions are not always symmetrical in outline but may be irregularly rounded triangular or even compressed into an oval outline if the thin proximal and distal surfaces are missing.

These spores have a size range similar to those referred to *Bentzisporites bentzii* Potonié and Kremp (1954, p. 161, pl. 20, fig.

109; 1955, pl. 7, figs. 48, 50; 1956, p. 124) from the Upper Westphalian B and Lower Westphalian C of the Ruhr Basin. Potonié (1954a, p. 115) referred these spores to the Selaginellales—herbaceous lycopods. Although the spores of *Triletes? saturnipunctatus* apparently possess a much thicker development of the coat in the equatorial region than do spores of *B. bentzii,* the relationship of the two species may be closer than is now suspected.

The spores fall within the size range of megaspores, but whether or not they functioned as megaspores is unknown. Their alliance with the genus *Triletes* is also in question, as there is evidence neither for nor against a lycopodiaceous alliance.

Occurrence. — *Triletes? saturnipunctatus* is common in the lower part, but rare in the upper part, of the Pope Creek Coal (macerations 916, 918) from Mercer County, Illinois, near the type locality of the Pope Creek Cyclothem. The spores have not been found yet in samples of Pope Creek Coal from other localities.

TRILETES? CORYCILIS n. sp.

Plate 11, figures 1-3

Description.—Megaspores trilete, originally spherical or slightly elongate and saclike, generally laterally compressed and oval in outline, from 720 to 1350 μ in total length (mean 1100 μ for 10 specimens) and from 670 to 1110 μ in width (mean 840 μ for 10 specimens). Trilete suture well defined, generally open; contact areas small in proportion to total spore size with slightly raised arcuate ridges. Trilete rays from 110 to 270 μ in length; contact areas from 150 to 310 μ in radial dimension. Contact surfaces darker and in some specimens thicker than distal spore coat, characterized by a centrally located quadrant-shaped scar 75 to 120 μ in maximum dimension (pl. 11, fig. 3). The contact area in some specimens covered by what appears to be a triradiate "cap" (pl. 11, fig. 2) that extends outward from spore in a ragged membranous ridge at the arcuate ridge and along rays (pl. 11, fig. 2). Contact area scars not as noticeable when cap is present.

Spore coat about 5 to 10 μ thick, granulose to minutely fibrous, in some specimens appearing much darker and rough-surfaced at the distal pole; coat in area of contact surface darker, about 8 to 10 μ thick.

Holotype.—Maceration 798 slide 10, lowest coal in a diamond drill core from the Caseyville Group, Wabash County, Illinois (pl. 11, fig. 1).

Discussion.—The dimensions given for the total length, and especially the width, are somewhat approximate because of the modified spore shape caused by extensive folding of the spore coat.

The contact area cap is an unusual morphologic feature and at present its origin is not known. When it is present, the characteristic contact area scars generally are not noticeable. The caps could be the contact surfaces torn from the sister spores of a tetrad.

In shape and in the possession of a sometimes dark and rough distal area, the spores resemble those of *Cystosporites.* The coat, however, is not plainly fibrous, but can appear minutely fibrous as does the coat of some spores of *C. verrucosus.* No abortive or immature spores of *Triletes? corycilis* have been recognized. These spores also resemble some of the lageniculate spores in general body outline except that they do not have an expanded apical prominence. The shape is also similar to that of some seed membranes. Although some membranous cuticular material bearing cell wall impressions was seen adhering to some specimens, its organic connection could not be proved. These microfossils are distinctly trilete and must have originated in a tetrahedral tetrad. It seems unlikely that these spores are merely the inner membrane of other larger spores.

At present their lycopodiaceous nature is not proved and therefore their reference to the genus *Triletes* is in question.

Occurrence. — Megaspores of *Triletes? corycilis* are common in and apparently restricted to the oldest Pennsylvanian coals in Illinois and Indiana, the lowest coal (maceration 798) from a diamond drill core in Wabash County, Illinois, and the French

Lick Coal (maceration 151), Orange County, Indiana.

Genus Cystosporites Schopf, 1938

Type Species.—*Cystosporites breretonensis* Schopf, by his designation.

Description.—The fertile spores are large, some are up to more than 10 mm in length, oval or saclike in outline; abortive spores are smaller, circular to oval in outline. Spores of this genus are fundamentally radially symmetrical and trilete. Trilete structures are well developed, but inconspicuous, on the fertile forms, because of their small size relative to spore size. The suture is distinct, and extends to well developed arcuate ridges. Lips in many specimens are moderately developed and in some specimens are elongate at apex. A spongy-appearing apical cushion or tuft is present on both fertile and abortive spores of two species. Abortive spores have well developed trilete structures but details of contact areas and sutures may be masked by folding or by the apical cushion. Ornamentation is variable. Spores of one species possess spines; those of another have closely spaced, low, convex bumps. The spore coat is characterized by a fibrous meshlike structure, generally best developed in medial portions in fertile spores where the coat is thinnest. Abortive spores generally have a thick granulose-appearing coat.

Affinity.—As far as is known, this genus is inclusively correlative with the Lepidocarpaceae (Bochenski, 1936; Schopf, 1938, 1941a; Chaloner, 1952; Schopf, Wilson, and Bentall, 1944).

Occurrence.—Although one species has a long stratigraphic range, represented both in the upper Mississippian and Pennsylvanian, most of the other presently recognized species appear to be restricted to the Pennsylvanian. Dijkstra (1957) recognized one species from the Lower Carboniferous of Egypt.

Cystosporites breretonensis Schopf, 1938
Plate 12, figures 9-11

1936 *Triletes* cf. *T. giganteus* Zerndt *in* Schopf (1936a), fig. 5 (holotype of species, by designation of Schopf, 1938).

1938 *Cystosporites breretonensis* Schopf (in part), *Cystosporites breretonensis* forma *reticulatus* Schopf, p. 40-42; pl. 1, fig. 11; pl. 7, fig. 4.

Discussion.—Spores of *Cystosporites breretonensis* apparently cannot be differentiated from those of *C. varius* on the basis of size, shape, or type of apical prominence, but only on the possession of low, convex bumps which cause an inverse reticulation on the outer surface of the spore coat. The holotype specimen is a large fertile spore showing both a spongiose apical cushion and an inverse reticulate coat in the apical region. Attached to the fertile spore are two abortive spores which also have a spongiose apical cushion and an inverse reticulate coat. The specimens illustrated (pl. 12, figs. 9a, 9b, 9c) show the same features that the holotype shows.

It is important to note that fertile forms of this species possess an apical cushion, as do the fertile forms of *Cystosporites varius*, and that whenever fertile and abortive specimens are still attached, both possess inverse reticulate coats. Although this ornamentation is usually developed over the entire surface of the abortive spores, it is usually confined to the proximal half, or less, of the fertile spores. Spores of *C. varius*, with no apparent inverse reticulation, are apt to occur with those of *C. breretonensis*. They are not necessarily found together, nor do they necessarily occur in equal numbers when found together.

In macerations 588, 580, and 520, abortive spores are associated with strands of spongiose material, loosely connected to the spore body only at the radial extremities and encircling the spores at the position of the arcuate ridges. Some of these spores do not have a well developed inverse reticulation.

The spores of *Cystosporites breretonensis* are not easily distinguished from those of *C. varius* by reflected light. On spores that have an extremely well developed inverse reticulation, as do some from Carbondale coals (pl. 12, fig. 11), the surface ornamentation can be distinguished by reflected light under a binocular microscope. The ornamentation is not internal but occurs on the outer spore coat surface, nor does it seem to be intimately associated with the mesh structure of the fertile spores because the fibers of the coat run across the reticulate pattern. Several previously published reflected light illustrations (Dijkstra, 1946, pl. 14, fig. 154; Potonié and Kremp, 1955, pl. 10, fig. 85) of spores referred to *C. varius* appear to be inversely reticulate.

If the spores were so badly preserved or obscured by adhering materials that positive identification of *Cystosporites breretonensis* was uncertain, they have been referred to *C. varius*. In addition, the reported abundances are based on the comparative abundance of spores of the two species on balsam mounts which may or may not parallel the actual relative abundance.

Two things need to be clarified: 1) whether or not the type of *Cystosporites varius* possesses an inverse reticulate ornamentation and 2) whether or not spores like those of *C. varius* and *C. breretonensis* may occur in the same cone or in cones of the same species.

Occurrence.—Spores of this species are apparently absent from coals of the Caseyville Group. They first occur in the Babylon Coal (maceration 588) and are rare to present in the Willis (maceration 625A-B), Rock Island (No. 1) (macerations 626, 528A, 599B), Murphysboro (maceration 550), New Burnside (maceration 938C), Bald Hill (maceration 520A), an unnamed coal bed just above Stonefort (?) (maceration 554F), and Upper DeLong (?) (maceration 829) Coals of the Tradewater Group. They are abundant in one sample of the Rock Island (No. 1) Coal (maceration 528B).

In the Carbondale Group they are common to present in some samples of the Colchester (No. 2) Coal (macerations 580, 611, 824, 825, 826), but rare in others (macerations 579A-B, 603B). They are rare in the Harrisburg (No. 5) (maceration 583) and Briar Hill (No. 5a) (maceration 633B) Coals, and present in the Herrin (No. 6) Coal (Schopf, 1938).

A few specimens were noted in the Indiana VII (?) Coal (maceration 939A).

Cystosporites varius (Wicher) Dijkstra, 1946

Plate 12, figures 5-8

1934 *Sporites varius* Wicher (1934a), p. 173-174; pl. 8, figs. 3, 4.

1934 *Laevigati-sporites varius* Wicher (1934b), p. 89-92; pl. 6, figs. 2-4, 6.

1938 *Cystosporites breretonensis* forma *abortivus* Schopf, p. 40; pl. 1, fig. 10; pl. 8, fig. 4.

1944 *Cystosporites giganteus* forma *varius* (Wicher) Schopf, Wilson, and Bentall, p. 42.

1946 *Cystosporites varius* (Wicher) Dijkstra, p. 58-59.
(I differ with his interpretation of *C. breretonensis* as he has it in synonymy and text.)

Description.—Fertile forms of *Cystosporites varius* generally smaller than those of *C. giganteus*, ranging from about 1000 to 4000 μ in length (Potonié and Kremp, 1956), typically elongate but well rounded proximally and distally in lateral outline. Spores characterized by an apical tuft or granulose to spongy-appearing trilobate mass which is usually wider than high. Trilete suture and contact areas obscured, except when apical tuft torn away (pl. 12, fig. 7). Spore coat characteristically fibrous (pl. 12, fig. 8) and showing mesh structure. Abortive spores from 350-1000 μ in length (Potonié and Kremp, 1956), rounded subtriangular (pl. 12, fig. 6) to round (pl. 12, fig. 5) or elongate oval in outline. Apical tuft present. Size of tuft or cushion not constant, relative to spore-size; those on abortive spores may be the same size as those on fertile spores. Spore coat thicker than on fertile spores, generally finely granulose.

Discussion.—A number of spores, noted particularly in the Willis, Tarter, and older coals, ranged from 990 to 1300 μ in length. Larger spores, probably fertile, were more than 2000 μ in length. The distinction of fertile from abortive spores on size alone seems rather tenuous.

Occurrence. — The first occurrence of these spores was noted in the "Makanda" Coals (macerations 142, 906, 907) of the Caseyville Group. They were abundant in one sample.

In the Tradewater Group these spores are abundant to common in the "Sub-

Babylon" (maceration 144), Babylon (macerations 145B, 588) and Willis (maceration 625A-B) Coals. They are rare to present in the Tarter (macerations 604A, 901) and Pope Creek (macerations 602, 916) Coals, lower coal (maceration 950A) from Goose Lake, Rock Island (No. 1) Coal (macerations 626, 589, 528A-B), Murphysboro (macerations 550, 608), New Burnside (maceration 938B), an unnamed coal just above the Stonefort (?) (maceration 537Q), Wiley (maceration 525B), and DeKoven (maceration 519B, 621D) Coals, in the unnamed coal (maceration 936) nine feet above the DeKoven Coal, and in an unnamed coal above the DeKoven (maceration 35). They are common in the Bald Hill Coal (maceration 520A) and abundant in the Rock Island (No. 1) (macerations 929, 599A-B) and New Burnside (maceration 938C) Coals.

In the Carbondale Group these spores are rare to abundant in the Colchester (No. 2) Coal (macerations 579A-B-C, 580, 582, 603B, 824, 825, 826). They are rare in the Indiana Coal IV (maceration 881), and in one sample of the Harrisburg (No. 5) Coal (maceration 583). They are present in the Springfield (No. 5) Coal (maceration 630) and Herrin (No. 6) (Schopf, 1938) Coal and abundant in Briar Hill (No. 5a) Coal (maceration 633A).

No spores of *Cystosporites varius* have been noted in coal beds of the McLeansboro Group.

CYSTOSPORITES GIGANTEUS (Zerndt) Schopf, 1938

Plate 11, figures 9, 10; plate 12, figures 1-4

1930 *Triletes giganteus* Zerndt (1930d), p. 71-79; pls. 9-11.
1934 *Triletes giganteus* Zerndt, *in* Zerndt, p. 13, fig. 2; pls. 1-5.
1934 *Sporites giganteus* (Zerndt) Wicher (1934a), p. 172-173; pl. 8, fig. 9.
1934 *Laevigati-sporites giganteus* (Zerndt) Wicher (1934b), p. 88; pl. 6, figs. 1-5.
1938 *Cystosporites breretonensis* Schopf (in part), p. 40-42; pl. 2, fig. 1; pl. 3, fig. 4; pl. 8, figs. 1, 2.
1944 *Cystosporites giganteus* (Zerndt) Schopf, 1938, *in* Schopf, Wilson, and Bentall, p. 42.
1946 *Cystosporites giganteus* (Zerndt) Dijkstra, p. 56; pl. 12, figs. 137, 138; pl. 13, figs. 142-145.
1955 *Cystosporites giganteus* (Zerndt) Schopf, *in* Potonié and Kremp, pl. 10, figs. 76-79.
1956 *Cystosporites giganteus* (Zerndt) Schopf, *in* Potonié and Kremp, p. 150-152.

Description. — Fertile forms generally large, up to 11 mm in length, sac-shaped but variously folded and crumpled when compressed. Trilete structures distinct but small in relation to size of spore (pl. 11, fig. 9; pl. 12, fig. 2). Arcuate ridges very distinct. Lips may be elongate at apex (pl. 11, fig. 10), but not of the massive cushion type. Spore coat characteristically fibrous (pl. 12, fig. 3), usually thinnest and with best developed mesh structure medially (pl. 11, fig. 10). Abortive spores ranging from 350 to 1000 μ in total dimension (Potonié and Kremp, 1956), usually round to oval in outline (pl. 12, fig. 1). Trilete structures well developed, but thickness of coat and frequent radial folds mask details of contact areas and apex. Spore coat generally thick and granulose.

Discussion.—Both the fertile and abortive spores described by Chaloner (1954b) from the Mississippian of this country and the ones noted in the Mississippian and in some older Pennsylvanian coals in this study seem to possess a much more strongly developed apical prominence than do those in younger coals. The largest fertile spore noted in the upper Mississippian is 6210 μ in length; fertile spores in younger coals are generally larger. The distinction between abortive and fertile isolated spores is difficult on the basis of size alone because there seems to be a continuous size gradation in some coals. One example (pl. 12, fig. 4), about 1725 μ in total length, is probably a fertile spore and has one abortive spore adhering to its coat and a distal appendage or "stalk" such as was described by Bochenski (1936). Such spores, generally lacking distal appendages, can hardly be considered abortive, but may never have reached maturation. Complete fertile specimens are generally rare in any one maceration, probably because they were broken in transport, by induration, or in the maceration process.

Occurrence.—The *Cystosporites giganteus* spores are present in the coals in the

Bethel (Mooretown) Formation (maceration 943) and Hardinsburg (maceration 810) Formation of Kentucky. They are rare in most samples of the coal in the Vienna Formation (macerations 687A, 758, 765) of Illinois, but abundant in one sample (maceration 168). They are also present in the coal in the Tar Springs Formation (maceration 760) of Illinois. A number of specimens were noted in the Upper Stony Gap Sandstone (maceration 911) of Kentucky. Therefore, although generally not abundant, spores of this species are commonly present in upper Mississippian coals.

The spores are rare to present in the Lick Creek Coal of the Black Creek Group and in the Upper Ream, Blue Creek, and Newcastle Coals of the Mary Lee Group of the Warrior Basin, Alabama.

The spores are rare to present in all coals of the Caseyville Group, except the Battery Rock Coal (maceration 733) from Kentucky. They are common in older Caseyville coals (macerations 798, 796, 795, 908).

Spores are rare to present in coals of the Tradewater Group: "Sub-Babylon" (maceration 144), Babylon (maceration 523A), Pope Creek (maceration 602), Murphysboro (macerations 550, 915, 628B), New Burnside (maceration 938A), an unnamed coal bed just above the Stonefort (maceration 639), Wiley (maceration 525A-B), Davis (maceration 618A), DeKoven (macerations 619B, 621D), and in an unnamed coal bed above the DeKoven (maceration 35).

In the Carbondale Group the spores are abundant in some samples of Colchester (No. 2) Coal (macerations 824, 825, 826), and rare to present in other samples (macerations 603B-C, 579B-C). The spores are rare in the Indiana Coal IV (maceration 881), abundant in Briar Hill (No. 5a) Coal (maceration 633A), and present in Herrin (No. 6) Coal (Schopf, 1938). They are present in the Indiana VII (?) Coal (maceration 939A), and rare fragments of uncertain identity occur in the "West Franklin" (maceration 813b) Coal. Both of these coals are in strata equivalent to the McLeansboro Group of Illinois.

Cystosporites verrucosus Dijkstra, 1946

Plate 11, figures 4-8

1946 *Cystosporites? verrucosus* Dijkstra, p. 60-61; pl. 15, figs. 161-166.
1955 *Cystosporites verrucosus* Dijkstra, *in* Dijkstra (1955c), p. 114-116; pl. A, figs. 1-7.

Description.—Fertile megaspores saclike and more or less oval in outline, usually laterally compressed, from 1730 to 3260 μ in length (four complete specimens measured). Apical prominence present, partly broken away on all specimens examined. Spore coat 7 to 21 μ thick, composed of fibers arranged in a meshlike structure with the pores or openings in some specimens so minute that they are observable only at high magnifications (pl. 11, fig. 7), arranged in folds radiating from the apical region and extending half or less the length of the spore (pl. 11, fig. 5). Spore coat set with small, bunt to sharply pointed spines 25 to 85 μ in length and 20 to 40 μ in diameter across the base which may be bulbose (pl. 11, figs. 7, 8). Spines most densely set in the apical region, widely spaced distally. Converging spinose folds defining the arcuate ridges, demarcating the distal surface from the smooth, frequently folded contact areas. Some complete fertile specimens possessing a distal appendage (pl. 11, figs. 4, 5), composed of a more or less homogeneous granular material, which is generally readily separable from the megaspore body.

Isolated abortive megaspores (pl. 11, fig. 6) more or less spherical, tending to an oblate shape in lateral compressions, circular in proximo-distal compressions, up to 410 μ in length (excluding apical prominence) and ranging from 320 to 515 μ in equatorial diameter. Apical prominence spatula-like in shape, up to 307 μ in height. Apical prominence and contact areas more or less unornamented. Spore coat densely fibrous to granulose, 15 μ thick on one specimen, set with spines 20 to 40 μ in length and 10 to 20 μ in diameter. Abortive spores still attached to fertile megaspores generally smaller, possessing a less spinose or nonspinose coat.

Discussion.—The above description of the fertile and abortive megaspores found in Illinois coals agrees remarkably well with that recently given by Dijkstra (1955c). His paper should be consulted for the listing of synonyms, discussion of the various aspects of spore morphology, and his reasons for interpreting this species as a species of *Cystosporites.*

The granulater material adhering to the distal portion of the fertile megaspores is considered by Dijkstra (1955c), Chaloner (1954a), and Arnold (1950) as analogous to the "wing-like appendage" or "stalk" described by Bochenski (1936) as attaching the fertile megaspore (*Cystosporites giganteus*-type) to the adaxial wall of the sporangium of *Lepidostrobus major.* A similar mode of attachment was noted by Chaloner (1954a) in the sporangia of *L. monospora.* In this study I noted not only the common occurrence of this appendage on fertile spores of *C. verrucosus* but also its occurrence on several specimens referable to *C. giganteus.*

The spore coat of an individual fertile megaspore of *Cystosporites verrucosus* may vary from a dense fibrous mesh, having gross fibers and small interstices, to a granulose-appearing coat. The mesh is most dense or the coat most granulose in the apical region. Coats of the abortive spores appear granulose. Coats with the very dense mesh structure (pl. 11, fig. 8), bear a marked resemblance to the coats of some lageniculate spores.

Dijkstra (1955c) found, as I have, that the fertile spores of *Cystosporites verrucosus* possess a fibrous coat, at least in the central region of the saclike spore body. This fibrous type of coat is a characteristic feature of the genus *Cystosporites* (Schopf, Wilson, and Bentall, 1944, p. 41). In the original descriptions of *Lagenicula saccata* Arnold, 1950, and of the spores *Lepidostrobus monospora* Chaloner, 1954, the spore coats were described as granular. However, as Dijkstra (1955c) pointed out, high magnification study by transmitted light is usually necessary to distinguish the fibrous nature of the spore coat of *C. verrucosus.* In Dijkstra's opinion the spores of *Lepidostrobus braidwoodensis* Arnold, 1938, and *Lepidostrobus monospora* Chaloner 1954, and *Lagenicula saccata* Arnold, 1950, are all comparable to *Cystosporites.*

Cystosporites verrucosus and *C. verrucosus*-type spores have been reported (Dijkstra, 1955c) from Belgium, Netherlands-Westphalian A, B; Great Britain - Westphalian B (*Lepidostrobus monospora*); Spain - Westphalian A; U. S. A. (Michigan) - Westphalian A, B; U. S. A. (Illinois) - shale above Colchester (No. 2) Coal, lower Carbondale - Westphalian D? (*L. braidwoodensis*).

The spores of this species are not very abundant in Illinois coals but their fragments are readily identifiable because of the characteristically folded, densely meshed spinose coat.

Occurrence.—Spores of this species are rare in the "Makanda" Coals (macerations 905, 907), present in the Pope Creek Coal (maceration 916), rare to common in the Colchester (No. 2) Coal (macerations 824, 825, 826), and present in the Indiana Coal IV (maceration 881). Thus, *Cystosporites verrucosus* is represented by sporadic occurrences in coals of the Caseyville, Tradewater, and Carbondale Groups.

Genus Spencerisporites Chaloner, 1951

Type species.—*Spencerisporites radiatus* (Ibrahim) n. comb. [*Spencerisporites karczewskii* (Zerndt, 1934, pl. XXXI, fig. 3) Chaloner, 1951], by designation of Chaloner, 1951, p. 862.

Discussion.—The spores of *Spencerisporites,* although small (generally 300 to 400 μ) for "large" spores, have a distinctive aspect. The more or less spherical spore body is encircled at the equator by a bladder which is subtriangular or deltoid-shaped in proximo-distal outline and possesses a marginal frill or flange. The spores commonly have strongly developed trilete rays and some are characteristically ornamented with radial striations on the contact areas.

The correct generic designation for these spores, found isolated, is somewhat in question. Similar spores were first described from a lycopod cone designated as *Lepidostrobus* by Williamson (1879, 1894) which Scott (1898) later redescribed and designated as *Spencerites*. Similar but isolated spores were described by Kubart (1910) as *S. membranaceus,* an incorrect generic designation according to the present International Code of Botanical Nomenclature.

Ibrahim (1932) described spores which he designated as *Sporonites radiatus,* later designated as *Zonales-sporites radiatus* Ibrahim by Ibrahim (1933) and by Loose (1934). Zerndt in 1934 described similar spores as *Triletes karczewskii.*

The spores of the two species are apparently identical. Horst (1955, p. 193) stated that Zerndt himself was of this opinion. Dijkstra (1955a, p. 343) stated, "As there exists no doubt that *Microsporites karczewskii* and *Triletes radiatus* (Ibrahim) Schopf, Wilson, and Bentall are identical, the name *karczewskii* must be changed into *radiatus.*"

Later Zerndt (1937b) described spores somewhat similar to, but distinguishable from, those of Ibrahim's *Sporonites radiatus* from the Westphalian E of Bohemia and designated them as *Triletes gracilis.* Schopf, Wilson, and Bentall (1944) recognized three species which they felt were referable to three separate genera: *T. radiatus* (Ibrahim) Schopf, Wilson, and Bentall, *Endosporites? karczewskii* (Zerndt) Schopf, Wilson, and Bentall, and *Cirratriradites? gracilis* (Zerndt) Schopf, Wilson, and Bentall.

Dijkstra (1946) recognized two species of *Microsporites,* used as a generic term but not diagnosed as such: *M. karczewskii* (Zerndt) Dijkstra, and *M. gracilis* (Zerndt) Dijkstra. The author himself (Dijkstra, 1955a) later rejected the name *Microsporites* in favor of a questionable referral to *Endosporites* [*E.? radiatus* (Ibrahim) Dijkstra] as Schopf, Wilson, and Bentall (1944) had done previously in *E.? karczewskii.*

Because the author (Dijkstra, 1955a, 1957) has rejected *Microsporites,* it cannot be considered a valid generic designation (International Code, Article 33, see Lanjouw), although Potonié and Kremp (1954, 1956) and Horst (1955) consider it as such. In 1951 Chaloner fully described the spores of *Spencerites insignis* Scott, and similar but isolated spores which Chaloner referred to *Spencerisporites karczewskii* (Zerndt) Chaloner. Potonié and Kremp (1954, 1956) rejected this generic name on the basis of the priority of *Microsporites* Dijkstra (which Dijkstra has rejected, as noted above) and stated that although neither Dijkstra (1946) nor Chaloner (1951) presented generic diagnoses, their intent was the same and was clear from their specific descriptions. Unlike Dijkstra, Chaloner (1951, p. 861-862) did present a clearly indicated generic diagnosis. Dijkstra (1955a, p. 343) rejected the name *Spencerisporites* on the basis of recommendations made at the 1951 Heerlen Congress. These recommendations have no standing as regards the International Code of Botanical Nomenclature and cannot be considered as a basis for rejecting the name *Spencerisporites.*

Because, in my opinion, these spores are not closely related to *Triletes, Endosporites,* or *Cirratriradites,* because all certainly should be referred to the same genus, and in view of the above comments, it seems that *Spencerisporites* Chaloner is the only correct generic designation. Chaloner (1951, p. 862) designated Zerndt's (1934, pl. XXXI, fig. 3) specimen as the holotype of *S. karczewskii* which in turn is the type of *Spencerisporites.* Although Zerndt's specimen can be regarded as the holotype, his specific epithet is a later synonym of Ibrahim's in *Sporonites radiatus,* so that the holotype is correctly referred to *Spencerisporites radiatus* (Ibrahim) n. comb.

Potonié and Kremp (1956) recognized four species which are: *Microsporites gracilis* (Zerndt) Dijkstra, *M. karczewskii* (Zerndt) Dijkstra, *M.* (*Spencerites*) *membranaceus* (Kubart) n. comb., *M. radiatus* (Ibrahim) Dijkstra (Potonié and Kremp [1956], not Dijkstra, are responsible for this combination). I have been able to recognize only two distinct forms of spores of *Spencerisporites* from Illinois coals. These are referred to *S.* cf. *S. radiatus* (Ibrahim) n. comb. and *S.* cf. *S. gracilis* (Zerndt) n. comb. Detailed descriptions of these spores are given in an effort to shed some light on the morphological changes and intergradations between spores of the two species with the passage of time. Although only 52 measured specimens are reported below, many more observations and spot-check measurements were made during the course of this study.

Dijkstra (1955b, p. 7) stated that Cross (1947) reported *Triletes radiatus* (Ibrahim) Schopf, Wilson, and Bentall in coals of the Appalachian Basin. From Cross' (1947, p. 301) description it is more likely that Cross was referring to *T. radiatus* as described by Zerndt (1937a) (*T. radiosus* Schopf, Wilson, and Bentall) and not to *T. radiatus* (Ibrahim) Schopf, Wilson, and Bentall. Cross (1947, fig. 2, p. 287) did, however, report the occurrence of *Cirratriradites gracilis* in the Cedar Grove, Chilton, Winifrede, and Coalburg Coals from the upper part of the Kanawha Group (Pottsville Series) and from the No. 5 Block Coal from the lower part of the Allegheny Series. Schopf (1949) noted, in his discussion of bladdered spores of this type, the occurrence of spores similar to those of *C.* (?) *gracilis* Schopf, Wilson, and Bentall in some upper Pennsylvanian coals in Illinois. He also questioned Dijkstra's (1946) suggestion that this species and Ibrahim's *Sporonites radiatus* are closely related.

Although seemingly most abundant in older coals of the Caseyville Group of Illinois, some spores of *Spencerisporites* occur sporadically in coals of the Tradewater, Carbondale, and McLeansboro Groups. Those younger coals in which *Spencerisporites* is fairly commonly represented are the Willis Coal, DeKoven Coal, No. 5 Coal, and a few of the coals in the McLeansboro Group. No spores of *Spencerisporites* were noted in the Warrior Basin coals examined or in coals of upper Mississippian age.

SPENCERISPORITES RADIATUS (Ibrahim) n. comb.

1932 *Sporonites radiatus* Ibrahim, *in* Potonié, Ibrahim, and Loose, p. 449; pl. 16, fig. 25.
1933 *Zonales-sporites radiatus* (Ibrahim) Ibrahim, p. 28-29; pl. 3, fig. 25.
1934 *Triletes karczewskii* Zerndt, p. 27; pl. XXXI, fig. 3.
1944 *Triletes radiatus* (Ibrahim) Schopf, Wilson, and Bentall, p. 24.
1944 *Endosporites* (?) *karczewskii* (Zerndt) Schopf, Wilson, and Bentall, p. 45-46.
1946 *Microsporites karczewskii* (Zerndt) Dijkstra, p. 64, pl. 4, fig. 40.
1951 *Spencerisporites karczewskii* (Zerndt) Chaloner, p. 862; figs. 1, 2, 6, 7.
1955 *Endosporites* (?) *radiatus* (Ibrahim) Dijkstra (1955a), p. 314-316, 342-343; pl. XLV, fig. 54.
1955 *Microsporites radiatus* (Ibrahim) Potonié and Kremp, *in* Horst, p. 192-194; pl. 18, fig. 15; pl. 19, fig. 16.
1956 *Microsporites radiatus* (Ibrahim) Dijkstra, *in* Potonié and Kremp, p. 157-158; pl. 20, figs. 449, 450.

SPENCERISPORITES cf. S. RADIATUS (Ibrahim)

Plate 13, figures 1-6

Description.—Spores trilete, commonly in proximo-distal compressions, characterized by a more or less circular body cavity (in proximal view) which is encircled equatorially by an inflated bladder (pl. 13, fig. 2). Bladder triangular to subtriangular in proximo-distal outline, more or less disk-shaped transversely, widest at opposite ends of trilete rays, and possessing a marginal flange. Total diameter of spores, including bladder and marginal flange, from 272 to 412 μ (mean 354 μ for 27 specimens). On any one spore, one diameter, taken from corner to opposite midpoint of interradial margin, seemingly longer than the other two diameters. Marginal flange from less than 15 to 40 μ wide at corners of bladder and less than 10 to 29 μ wide interradially. Total flange width, measured on both sides of specimen, averaging 10.5 percent of the total spore diameter. On several specimens, upper and lower surfaces of bladder at equatorial attachment area appear to be 30 μ apart at the juncture of the trilete rays and bladder, but only 15 μ apart at the interradial margin.

Trilete rays generally prominent. Lips thin, membranous, sometimes split apart (pl. 13, fig. 1), straight to sinuous, up to 36 μ in height, sometimes expressed as thin folds extending from the inner bladder margin to outer margin of flange (pl. 13, figs. 4, 5a). Each contact area invariably ornamented with distinct, fine, sometimes broken lines or striations radiating generally from a central area on the contact surface. Radial striations sometimes appearing as coarse gouges (pl. 13, fig. 3), as opposed to more delicate sinuous striations as shown by figure 5b on plate 13.

Distal side of spore body and, in some specimens, distal surface of bladder appear smooth. Proximal surface of bladder and marginal flange ornamented with vague intersecting or anastomosing fine folds.

Spores golden to brownish yellow centrally, generally very light yellow at flange by transmitted light.

Discussion.—In most details of spore morphology these spores, although somewhat larger, agree with those of *Spencerisporites karczewskii* and of *Spencerites insignis* as described by Chaloner (1951). On one specimen the distal spore body coat is twice as thick (4 μ) as the thickness given by Chaloner. Measurements of the diameter of the spore body, or body cavity, are not given here because it is not measurable with accuracy on compressed specimens. The compressed specimens studied agree with Chaloner's interpretation that the marginal flange is a single membrane (although Potonié and Kremp [1956] regarded it as two membranes) contiguous with the upper surface of the bladder.

The radial striations on each contact face do not all radiate from a common point in the center. More or less parallel lines extend nearly through the center of each contact face from the corners of the spore body. The lines, both towards the apex and towards the margin of the spore body, become more and more flexed near their midpoints (pl. 13, fig. 5b). The general aspect is of slightly superimposed finger-prints on each contact area, and although on some specimens (pl. 13, fig. 3) the lines appear straight and as gouges, the pattern is more or less the same. These lines also appear to extend slightly onto the bladder but end at the base of the lips.

Spores of two slightly different aspects are included in this species because intergrading or transitional forms are numerous, and any distinction, at present, would have to be based on arbitrary numerical values, for example, for width of the marginal flange. Those spores of the lowest coal in a diamond drill core in the Caseyville Group (pl. 13, fig. 3) in Wabash County, Illinois, generally have a narrow marginal flange that accounts for 10 percent or less of the total diameter, and some specimens possess a flange so narrow that it is barely noticeable. The intersecting lines on the bladder generally are vague. The trilete rays in some specimens are expressed as folds on the bladder. They are similar to those illustrated by Horst (1955, pl. 18, fig. 15; pl. 19, fig. 16) from the Hruschau zone of the Namurian A in the Mährische-Ostrau region. Smaller but seemingly related spores reported by Dijkstra (1957) as *Endosporites chaloneri* occur in the coal beds of the Limestone Coal Group of Scotland. In contradistinction, those found in the Reynoldsburg Coal appear to have a generally wider marginal flange accounting for up to 18 percent of the total diameter. A more conspicuous ornamentation appears on the bladder, in some cases even apiculations, and the rays are more commonly expressed as folds on the bladder.

The spores of this species are distinguishable from those of *Spencerisporites* cf. *S. gracilis* by the presence of radial striations on the contact areas and by a generally narrower marginal flange.

Previously reported occurrences of spores referable to *Spencerisporites radiatus* are given in Dijkstra (1946) and Potonié and Kremp (1956). In general this species is represented in the Namurian A, B?, and C? and in the Westphalian A, B, C, and D?.

Occurrence.—These spores are most abundant, even occurring in masses, in the lowest coal in a diamond drill core (maceration 798) of two Wabash County cores, but are rare in two of the upper coals (macerations 795, 797) of these two cores. They are rare in one sample of the Battery Rock Coal (maceration 587), but are present in another sample (maceration 629). They also are present in the "Makanda" Coals (macerations 905, 906) and very abundant in the Reynoldsburg Coal (maceration 618). They are rare in the shale above the Pinnick Coal (maceration 163) and in the

Cannelton Coal (maceration 780) from Indiana. These spores, therefore, are a fairly common constituent in the maceration residues of coals in the Caseyville Group.

A few specimens are found in the Tarter Coal (macerations 604A, 901, 914), in the Willis (?) Coal (maceration 631), and in the lower part of the Willis Coal (maceration 625B). Specimens are rarely present in one sample of the Rock Island (No. 1) Coal (maceration 599A).

SPENCERISPORITES GRACILIS (Zerndt) n. comb.

1937 *Triletes gracilis* Zerndt (1937b), p. 586-587; pl. 10, figs. 1-10.
1944 *Cirratriradites* (?) *gracilis* (Zerndt) Schopf, Wilson, and Bentall, p. 44.
1946 *Microsporites gracilis* (Zerndt) Dijkstra, p. 64-65.

SPENCERISPORITES cf. S. GRACILIS (Zerndt)

Plate 13, figures 7-9

Description.—Spores of *Spencerisporites* cf. *S. gracilis* similar to those of *S.* cf. *S. radiatus* in general body form, bladder development, and compressional orientation. Total diameter of spores, including bladder and marginal flange, from 278 to 468 μ (mean 378 μ for 25 specimens). Marginal flange accounting for 10 to 28 percent (mean 19.4 percent) of the total diameter. Flange width from 25 to 65 μ at corners of bladder and from 15 to 65 μ interradially. More than three-fourths of the spores have a flange width of more than 40 μ.

Trilete rays distinct, lips open in many specimens, membranous, in some specimens expressed as thin folds on bladder (pl. 13, fig. 9). Contact areas apparently not marked by radial striations, in some instances showing an anastomosing network of folds similar to those developed on distal areas of central spore body. Bladder ornamented with vague anastomosing folds, in some specimens appearing radially pleated and finely apiculate. Marginal flange in some specimens almost smooth, pleated, or ornamented with vague intersecting lines; flange generally crenulate or scalloped at outer margin and in some instances clearly demarcated from the outer margin of the bladder (pl. 13, fig. 8).

Spore coat generally light yellow, central portion slightly darker by transmitted light.

Discussion.—These spores are very similar in appearance to those originally illustrated and described by Zerndt (1937b, p. 586-587, pl. 12) as *Triletes gracilis,* especially in the development of a wide marginal flange ("der ausserste Sporensaum" of Zerndt, 1937b, p. 587). Zerndt refers to small ear-like flaps on the corners, about 96 μ wide and 48 μ long. This feature is often cited as characteristic of these spores, but it is not clearly described or illustrated. Zerndt may have been referring to the lobe-like aspect of the outer margin of the bladder or the outer margin of the marginal flange (as shown in his figure 8 on plate 12, at the upper righthand corner). The spores described here may appear to have a lobe-like outline at the outer margin of the marginal flange at two of three corners (pl. 13, fig. 9), but this is caused by slight folds along the margin. Because the position of the ear-like lobes is not at all clear from Zerndt's description or illustrations, I cannot compare adequately these Illinois spores to those originally described as *T. gracilis* by Zerndt, and have, therefore, referred to them as *Spencerisporites* cf. *S. gracilis.*

In comparison to those of *Spencerisporites* cf. *S. radiatus,* these spores have a much lighter colored central area, the proximal and distal surfaces of which usually bear anastomosing folds (pl. 13, fig. 8). The contact areas have no clearly defined radial striations and some even lack the anastomosing folds. The marginal rim is, with few exceptions, much wider relative to total spore size and is not as highly ornamented with anastomosing folds as are spores of *S.* cf. *S. radiatus* (pl. 13, fig. 6). The marginal flange may be smooth and may be scalloped at the edge.

The change from the type of flange of early Pennsylvanian age (pl. 13, fig. 1) to the type of late Pennsylvanian age (pl. 13, fig. 9) is rather gradual and no definite delineation between spores of *Spencerisporites* cf. *S. radiatus* and *S.* cf. *S. gracilis* can be made on the basis of flange width alone.

However, none of the specimens here referred to *S.* cf. *S. gracilis* possesses radially striated contact surfaces. Such surfaces are shown only by spores found in the Rock Island (No. 1) Coal and older coals whereas those with anastomosing folds rather than radial striations on the contact areas are found only in younger coals.

The marginal flange on spores of the Reynoldsburg Coal (maceration 618) accounts for 9 to 18 percent (mean 13.5 percent) of the total diameter; the same spores have well defined contact area striations. The marginal flange on spores from the DeKoven Coal (maceration 519A-B) accounts for 11 to 19 percent (mean 15.7 percent) of the total diameter. None of these spores has contact area striations. On spores from some of the McLeansboro coals the marginal flange accounts for 10 to 28 percent (mean 21 percent) of the total diameter.

The spores to which these Illinois spores are compared were originally described by Zerndt (1937b) from the Westphalian E (Stephanian) of Bohemia.

Occurrence.—This species is represented in the Wiley (maceration 525A), Davis (maceration 518B), and DeKoven (maceration 519A-B) Coals from the upper part of the Tradewater Group. These spores are fairly common in the lower part of the DeKoven Coal. In the Carbondale Group the spores are rare in the Colchester (No. 2) Coal (maceration 580), rare to common in the No. 5 Coal (macerations 630, 879, respectively), and present in the Briar Hill (No. 5a) Coal (maceration 633A).

In the McLeansboro Group spores of this species are rare in a Friendsville Coal (maceration 490D), in the "LaSalle" Coal (maceration 600), and in a coal bed designated as the "Divide" Coal (maceration 811). In the Illinois State Geological Survey maceration records, their presence has been noted in coal beds designated as "Bogota," "Newton," Shelbyville, and Trowbridge, mainly from Effingham, Fayette, and Shelby Counties, Illinois. Many of these have been checked as to their identity with *Spencerisporites* cf. *S. gracilis.* They are common to abundant and well preserved in the "Bogota" Coal (maceration 133), an upper McLeansboro coal in Illinois.

Genus Calamospora Schopf, Wilson, and Bentall, 1944

Type species.—Calamospora hartungiana Schopf, *in* Schopf, Wilson, and Bentall, 1944, by their designation.

Description.—Spores of *Calamospora* are trilete and radially symmetrical. Their original shape is more or less spherical, so that when compressed, they develop characteristic taper-point folds of crescentic or lenticular outline. Spore size may range from 30 to several hundred microns. Horst (1955) extended the upper size limit to more than 1000 μ. Trilete rays are generally short, less than one-half the spore radius in length. Lips may be present. Contact areas may show some differentiation of the spore coat in surface texture or thickening. Spore coat thickness ranges from more than 15 μ in spores larger than 500 μ in diameter to less than 2 μ in those less than 100 μ in diameter. The coat is characteristically smooth and highly refractive.

Discussion.—Only the larger spores of *Calamospora,* undoubtedly megaspores, are described in this paper. The smaller megaspores appear to have a long stratigraphic range, occurring throughout the Pennsylvanian in Illinois; the large megaspores (*C.* cf. *C. sinuosa*) seem to be restricted to older coal beds of the Tradewater Group.

Affinity.—These spores are of sphenopsid alliance and may be borne by plants of the Sphenophyllales, Equisetales, and Noeggerathiales. *Calamospora* is unique among taxa based on spores, in that isospores, microspores, and megaspores are included within it.

Occurrence.—Only one poorly preserved megaspore, questionably referable to *Calamospora,* was found in coals of upper Mississippian age. Megaspores referred to *C. laevigata* are present in many of the Pennsylvanian coals; those referred to *C. sinuosa* occur only in the older coals of the Tradewater Group. In addition, a few specimens, indeterminable on the specific level, were found in the Rock Island (No. 1) Coal (maceration 599B) and in the DeKoven (?) Coal (maceration 554D). *Calamospora* megaspores are also present in the Jagger, Blue Creek, and Newcastle Coals of the Mary Lee Group in the Warrior Basin of Alabama.

CALAMOSPORA SINUOSA (Potonié and Kremp) ex Horst, 1955

1955 *Calamospora (Triletes) sinuosa* (Horst, 1943, fig. 3) Potonié and Kremp, p. 48 (nom. nudum).

1955 *Calamospora sinuosa* (Horst) Potonié and Kremp, *in* Horst, p. 155-156; pl. 17, fig. 3.

CALAMOSPORA cf. C. SINUOSA

Plate 13, figure 10

Description. — Spores large, originally nearly spherical, developing many taper-point folds upon compression. Maximum diameter ranging from 610 to 1020 μ (mean 804 μ for 17 measured specimens). Trilete rays one-third to one-half the spore radius in length with lips up to 20 μ in height. Trilete mark usually incorporated into taper-point folds. Contact areas not differentiated by spore coat thickening or change in spore coat texture. Spore coat ranging from 6 to 13 μ in thickness, golden yellow to brownish yellow by transmitted light, glossy by reflected light.

Discussion.—These spores are of the same size as those described by Horst (1955) but may have slightly higher lips and apparently do not show the infragranulate texture of the contact area described by him. Horst's (1955) suggestion that the spores described as *Sporites plicatus* by Schopf (1938) could be referable to *Calamospora sinuosa* is untenable. Similar megaspores are described by Arnold (1944) from a sphenophyllaceous fructification, *Bowmanites delectus,* found in a shale below Cycle "A" at Grand Ledge, Michigan. The larger spores range from 660 to 750 μ in maximum diameter and some of the abortive spores are one-third this size. Those illustrated by Arnold (1944, figs. 4, 7) appear very similar to the one shown by figure 10 on plate 13.

Horst (1955) originally described this species from the Namurian A of Mährisch-Ostrau and west Upper Silesia.

Occurrence.—These spores are common to present in the Willis Coal (macerations 625A-B, 631) and rare in the Tarter (maceration 604A) and Babylon (maceration 523A) Coals of the Tradewater Group.

CALAMOSPORA LAEVIGATA (Ibrahim) Schopf, Wilson, and Bentall, 1944

1933 *Laevigati-sporites laevigatus* Ibrahim, p. 17; pl. 6, fig. 46.

1934 *Laevigati-sporites laevigatus* Ibrahim, *in* Loose, p. 146; pl. 7, fig. 36.

1934 *(Calamiti?)-sporites laevigatus* Ibrahim, *in* Wicher (1934a), p. 172.

1944 *Calamospora laevigatus* (Ibrahim) Schopf, Wilson, and Bentall, p. 52.

CALAMOSPORA cf. C. LAEVIGATA

Plate 13, figure 11

Description.—Spores originally more or less spherical, when compressed developing characteristic taper-point folds, maximum diameter ranging from 270 to 445 μ (mean 336 μ for 19 specimens). Trilete rays short, ranging in length from 15 to 30 percent of the spore radius. Labial development usually not obvious. Contact areas sometimes appearing punctate (pl. 13, fig. 11). Spore coat ranging from 2 to 10 μ in thickness, thicker and darker at contact areas, golden yellow by transmitted light.

Discussion.—These spores, which may represent several different plants, at present seem to lack distinguishable features. They may not properly be referable to *C. laevigata,* because Potonié and Kremp (1955) stated that there is no contact area differentiation on spores of this species. The size range of the Illinois spores is identical to that given by both Potonié and Kremp (1955) and by Horst (1955). However, the coat thickness of the Illinois spores ranges from less than to greater than the limits given by these authors.

Horst (1955) recorded *Calamospora laevigata* from the Namurian A of the Mährisch-Ostrau region and from the Westphalian A of the west Upper Silesian region. Potonié and Kremp (1955) recorded this species from the Upper Westphalian B of the Ruhr Basin.

Occurrence.—These spores are present to rare in Caseyville coals (macerations 795, 796, 797, 908). They also are present to rare in the following Tradewater coals: Babylon (maceration 588), Tarter (maceration 901), Rock Island (No. 1) (maceration 929), Bald Hill (maceration 520A) and an unnamed coal above DeKoven (maceration 35). In the Carbondale Group they are generally present in the Colchester (No. 2) Coal (macerations 611, 579C, 603B-C, 826, 582), in the Summum (No. 4) Coal (maceration 463), and in the Grape Creek (No. 6) Coal (maceration 878). Spores of this species are rare in the Indiana IV (maceration 881) and Springfield (No. 5) (maceration 630) Coals, but seem to be common in the Briar Hill (No. 5a) Coal (maceration 633A). In the McLeansboro Group they are present in the Indiana VII (?) Coal (maceration 939A), the "Bogota" (maceration 133), and "Woodbury" (maceration 703) Coals; common in the Friendsville Coal (maceration 490D); abundant in the "LaSalle" (maceration 600) and Friendsville (?) (maceration 136) Coals.

CALAMOSPORA sp.

Plate 13, figure 12

This spore is 185 μ in diameter, much smaller than the spores of *Calamospora* cf. *C. laevigata* with which it occurs. The spore coat is extremely thick in relation to spore size, especially at the contact area. This single example was found in the "LaSalle" Coal (maceration 600) of the McLeansboro Group.

Genus MONOLETES (Ibrahim) Schopf, Wilson, and Bentall, 1944

Type species.—Monoletes ovatus Schopf, by designation of Schopf, Wilson, and Bentall, 1944.

Description.—Prepollen of *Monoletes* appear bilateral and monolete although they are asymmetrically bilateral in that the suture deviates from a straight line and exhibits a characteristic angular deflection medially. Occasionally what may be a short vestigial ray is observed at the point of deflection. Schopf, Wilson, and Bentall (1944) noted that the prepollen may have originated in tetrahedral tetrads. Compressed specimens are nearly circular to rounded lenticular in outline, ranging from slightly more than 100 μ to more than 500 μ in length. The distal surface on expanded prepollen is often marked by two longitudinal grooves separated by a well rounded umbo. Compressed examples usually have longitudinal folds parallel to the distal grooves. The coat is minutely granulose, up to 18 μ thick proximally and distally, sometimes less than 5 μ thick at the base of the distal grooves. An inner membrane is frequently present. More complete discussions of the morphology of *Monoletes* prepollen were given by Schopf (1938), Schopf, Wilson, and Bentall (1944), and Schopf (1948).

Discussion.—Schopf, Wilson, and Bentall (1944) pointed out that the two recognized species, *Monoletes ovatus* Schopf and *M. ellipsoides* (Ibrahim) Schopf, are widely distributed and must still be regarded as rather generalized types. Prepollen of these two species were distinguished by Schopf (1938) on the basis of published descriptions and illustrations available at that time which indicated that *M. ellipsoides* lacked distal grooves. It now appears, with the illustration of the type of *M. ellipsoides* by Potonié and Kremp (1956, pl. 22, fig. 478) that these spores also possess distal grooves. It would seem that morphological features of prepollen of the two species overlap to a considerable degree.

Potonié and Kremp (1956) recognized *Monoletes aureolus* Schopf as a species of *Schopfipollenites,* a synonym of *Monoletes,* but Schopf, Wilson, and Bentall (1944) referred this species to *Zonalo-sporites* Ibrahim. This prepollen is similar to that of *Monoletes* but appears to have a thin outer coat and thick inner coat.

The specimens illustrated on plate 14, figures 1 to 9, show some of the natural, compressional, and preservational variations in aspect of isolated, compressed *Monoletes* prepollen. At present there is no advantage to referring these to either of the two widely cited species, although some could readily be referred to *M. ovatus* Schopf.

Affinity.—These prepollen grains are pteridospermic and probably largely coextensive with the Medullosaceae (Schopf, Wilson, and Bentall, 1944). Some may lack distal grooves, as do those of *Codonotheca* (Schopf, 1948), but all seem to be characterized by a medially deflected suture.

Occurrence.—According to Dijkstra (1955a), this prepollen is found in the Westphalian and Stephanian of European coal basins.

Monoletes spp.

Plate 14, figures 1-10

Discussion. — Very few specimens of *Monoletes* were noted to lack the distal longitudinal folds as are typically shown by figures 6 and 9 on plate 14. Many specimens (pl. 14, fig. 8) from the "West Franklin" Coal exhibit long thin folds of the coat, but these generally are variously disposed relative to the long axis. All examples observed have a medially deflected suture and some appear to possess a third ray (pl. 14, figs. 5, 7, 9). The third ray shown by figure 5 on plate 10 is 26 μ in length. One of the smallest prepollen, and also one of the oldest specimens, is 200 μ in length (pl. 14, fig. 1); one of the more robust specimens is more than 500 μ in length (pl. 14, fig. 6).

In a few prepollen grains of many different samples of coal, the inner membrane is observed to be pulled away from the outer coat (pl. 14, figs. 1, 3, 4, 7). In any one prepollen mass where most specimens appear "normal," one or two may have "shrunken" inner membranes. The specimen illustrated by figure 7 on plate 14 is similar to those originally described as *Monoletes aureolus* by Schopf (1938). Although the inner body of this specimen is very dark—the negative of this illustration required extensive dodging in order to show central detail—the inner coat is only 6 μ thick, a few microns thicker than the inner coat of the holotype of *M. aureolus.* The outer coat, poorly preserved, appears very thin, but is actually about 20 μ thick around the margin. The holotype of *M. aureolus* also appears to have an outer coat of similar thickness. Although the prepollen may represent a distinct species of *Monoletes,* it also is possible that it represents "sports" of prepollen which, if normally developed, might be referred to *M. ovatus.* Such "sports" of *Spencerisporites* also possess much smaller and darker central bodies than do the majority of spores of *Spencerisporites.*

Monoletes prepollen often occurs in masses, as that shown in figure 10 on plate 14, from the "Divide" Coal in which *Monoletes* is abundantly represented. The prepollen is very glossy under reflected light.

Occurrence.—*Monoletes* is not represented in upper Mississippian coals. No prepollen was observed in the coals of the Black Creek, Mary Lee, or Pratt Groups from the Warrior Basin of Alabama, although resin rodlets, of medullosan origin and in many instances associated with *Monoletes* prepollen, were present in some of the coal beds of the Black Creek and Mary Lee Groups.

Monoletes is commonly represented in two coals (macerations 795, 910) and sparsely represented in other coals of the Caseyville Group. The prepollen is first abundant in the Babylon Coal (maceration 588). It is also abundant in one sample of the Rock Island (No. 1) Coal (maceration 528B) and in two Tradewater coals (maceration 950, 951B) from Goose Lake, Illinois.

Monoletes prepollen is generally present to common in most coals of the Tradewater Group and may be abundant in the Colchester (No. 2), No. 5, Briar Hill (No. 5a), and Herrin (No. 6) Coals of the Carbondale Group. In the McLeansboro Group, prepollen is common in the Indiana VII (?) Coal (maceration 939A) and the "West Franklin" Coal (maceration 831); abundant in the Friendsville Coal (macerations 153, 135, and 490D), the "Divide" Coal (maceration 811); present in the "LaSalle" Coal (maceration 600), the "Bogota" Coal (maceration 133), and the "Woodbury" Coal (maceration 703); rare in the Friendsville (?) Coal (maceration 136). *Monoletes* is also known from the

Danville (No. 7), Macoupin, and Flannigan Coals. Very few samples of Tradewater or younger coals lack *Monoletes* prepollen.

Genus Parasporites Schopf, 1938

Type species.—Parasporites maccabei Schopf, 1938, by monotypy.

Description.—These prepollen grains are characterized by opposite and distally disposed bladders, appearing bilaterally symmetrical. Fundamentally they are radially symmetrical and possess a proximal trilete mark. Two of the rays, extending more or less towards the lateral bladders, may be well developed; the third ray is shorter than the other two and commonly indistinct. The over-all dimension as given by Schopf (1938) and Schopf, Wilson, and Bentall (1944) is as much as 300 μ. The spore body is round to oval. The body wall is relatively thicker than the bladder membrane, which extends completely around the body but is expanded into bladders only laterally and may be rugose.

Affinity.—The affinity of these prepollen grains is still in question. Schopf, Wilson, and Bentall (1944) stated that they may be allied to the pteridosperms, cordaitaleans, or conifers.

Occurrence.—Previous records of the occurrence of these microfossils show them restricted to coal beds of the upper Carbondale and lower McLeansboro Groups of Illinois (Schopf, Wilson, and Bentall, 1944). Present information extends their stratigraphic range down to the Rock Island (No. 1) Coal of the Tradewater Group. This genus has not been reported in other coal basins.

Parasporites spp.

Plate 14, figures 11, 12

Discussion.—Relatively few specimens were found in any one sample and therefore there is no adequate basis either for referring them to the one described species or for making formal distinction on the specific level. The total size, including bladders, ranges from 257 to 340 μ.

In general the specimens found in Tradewater coals seem to have slightly thicker bladder membranes and a more ovoid body outline (pl. 14, fig. 12) than do those illustrated by Schopf (1938) for *Parasporites maccabei.* The specimen shown in figure 11 on plate 14 also has a more ovoid body outline and the bladders are disposed laterally and distally. The convolute rugose-appearing folds seem to be a result of the bladder membrane folded upon compression rather than the expression of rugosity of the spore body coat. The medial deflection of the suture is commonly obvious, but the third ray is generally not apparent. Wrinkled and poorly preserved specimens of *Monoletes,* as were noted in three different coal beds, are superficially similar in appearance and could easily be mistaken for *Parasporites.*

Occurrence.—*Parasporites* is represented in the Rock Island (No. 1) (maceration 589), Wiley (maceration 525A-B), Davis (maceration 518A), DeKoven (maceration 519A) Coals, and an unnamed coal above the DeKoven (maceration 35), all of the Tradewater Group; in the Colchester (No. 2) (macerations 579B-C, 582), No. 5 (Schopf, 1938; Schopf, Wilson, and Bentall, 1944), Harrisburg (No. 5) (maceration 879), and Herrin (No. 6) (Schopf, 1938; Schopf, Wilson, and Bentall, 1944) Coals of the Carbondale Group; and in the "Divide" (maceration 811), Friendsville (macerations 135 and 490D) Coals of the McLeansboro Group. *Parasporites* is also known from the Danville (No. 7) Coal.

The prepollen seems to be most common in an unnamed coal above the DeKoven, Colchester (No. 2), Herrin (No. 6), and the Friendsville Coals, although compared to *Monoletes, Parasporites* is represented by an insignificant number of prepollen.

DESCRIPTIONS OF "SMALL" SPORES

Genus Punctatisporites (Ibrahim) Schopf, Wilson, and Bentall, 1944

Punctatisporites obesus (Loose) Potonié and Kremp, 1955

1932 *Sporonites obesus* Loose, *in* Potonié, Ibrahim, and Loose, p. 451; pl. 19, fig. 49.

1934 *Laevigati-sporites obesus* Loose, p. 145.

1944 *Calamospora* (?) *obesus* (Loose) Schopf, Wilson, and Bentall, p. 52.
1955 *Punctatisporites obesus* (Loose) Potonié and Kremp, p. 43-44; pl. 11, fig. 124.

PUNCTATISPORITES cf. P. OBESUS

Plate 15, figures 1, 2

Description.—Small spores of *Punctatisporites* cf. *P. obesus* are circular to rounded subtriangular, generally proximodistally compressed, range from 111 to 151 μ in diameter. Trilete suture is distinct, commonly open; rays extend 26 to 35 μ from proximal pole, equalling in length 35 to 55 percent of the spore radius. Labial development is lacking. Spore coat is 3.8 to 5 μ thick, outer surface smooth, sometimes infrapunctate, brown to brownish yellow by transmitted light.

Discussion.—The *Punctatisporites* spores are apparently identical to those originally described by Loose (1932, p. 451) as *Sporonites obesus,* later described by Potonié and Kremp (1955, p. 43-44) as *Punctatisporites obesus* (Loose). The maximum diameter of the Illinois spores is less than that given by Loose, but somewhat greater than that given by Potonié and Kremp. Ray length on the Illinois spores ranges between one-third of the spore radius (the measurement originally given by Loose) and a little more than one-half of the spore radius (the measurement given by Potonié and Kremp).

Horst (1955) described similar spores from the Namurian A and B and the Westphalian A. These generally are smaller and have a somewhat more variable coat thickness and longer rays than those typical of the species.

Potonié and Kremp (1955) stated that the spores of *Punctatisporites,* as they interpret the genus, could be allied with the Psilopsida, Filicineae, and Cycadofilicineae ? .

Punctatisporites obesus occurs in the Middle and Upper Westphalian B in the Ruhr Basin (Potonié and Kremp, 1955).

Occurrence.—Spores are common in the Willis Coal (macerations 625A-B) from Gallatin County, and are present in the Tarter Coal (maceration 901) from Warren County, Illinois.

Genus RETICULATISPORITES (Ibrahim) Schopf, Wilson, and Bentall, 1944

RETICULATISPORITES IRREGULARIS Kosanke, 1950

1950 *Reticulatisporites irregularis* Kosanke, p. 26; pl. 5, fig. 1.

RETICULATISPORITES cf. R. IRREGULARIS

Plate 15, figure 3

Discussion. — The spore of *Reticulatisporites* cf. *R. irregularis* is 158 μ in diameter, 32 μ larger than the maximum diameter given by Kosanke, and shows trilete rays, about 20 μ long, in a vaguely defined circular area. The species apparently is restricted in occurrence to the "Sub-Babylon" Coal.

Occurrence.—This specimen was found in the "Sub-Babylon" Coal (maceration 144), Fulton County, Illinois.

Genus RENISPORITES, n. gen.

Type species.—Renisporites confossus (pl. 15, figs. 4, 5), from the Willis and Tarter Coals in Illinois.

Symmetry.—Spores of *Renisporites* are bilateral, monolete.

Shape.—Spores originally expanded bean-shaped, oval in plane of longitudinal symmetry, more or less round in transverse plane. Compression is generally along longitudinal axis, rarely in transverse plane.

Size.—Greatest dimension is length, from 126 to 217 μ.

Ornamentation.—Spore coat is smooth with scattered puncta or pores completely traversing the spore coat. There are generally two subcircular areas of closely spaced puncta, oriented at the geometrical equator and in the median transverse plane, one on either side of the suture.

Haptotypic features.—Suture is straight, monolete, some specimens have low, vaguely defined, membranous lips, usually longer than half the length of the spore. Well defined arcuate thickenings are present, at least at ends of suture and in some specimens extending completely around and close to the suture.

Spore coat.—Coat ranges from 2.5 to 10 μ in thickness, thickest around ends of suture, golden yellow to yellowish brown by transmitted light.

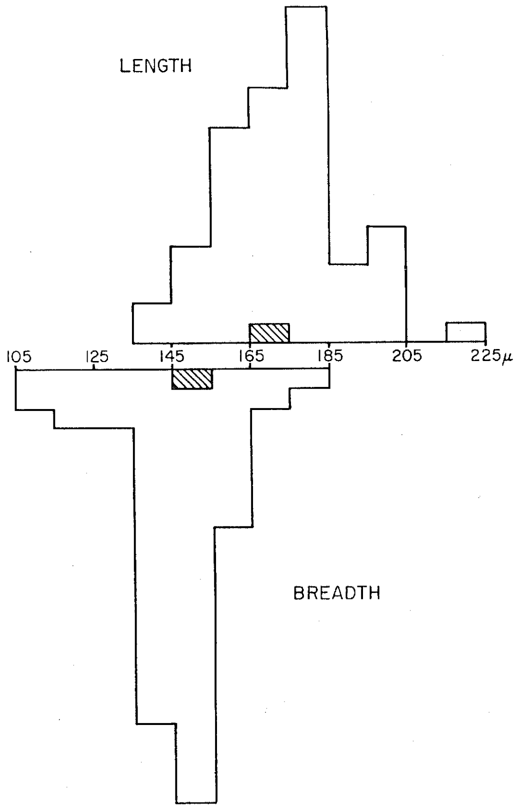
Affinity.—Unknown.

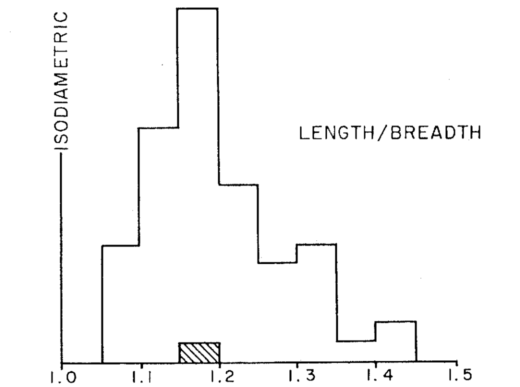
Discussion. — Spores of this genus are much larger than most of those referred at present to the genus *Laevigatosporites* (Ibrahim) Schopf, Wilson, and Bentall. Spores of *Renisporites* have a much thicker spore coat and more clearly defined arcuate ridges. The distinctive ornamentation, discrete puncta completely traversing the coat and groups of puncta, is unknown, at present, on the spores of *Laevigatosporites* or on any other plant spore. The puncta are superficially similar to those found on the unrelated disseminules of *Tasmanites.*

The spores of *Renisporites* cannot be considered, on the basis of present information, as of medullosan affinity because of their generally smaller size, lack of distal grooves, straight rather than medially deflected suture, and punctate ornamentation. In size they are comparable with, but slightly larger than, the spores of the medullosan *Dolerotheca villosa* Schopf (1948), but do not possess the distal grooves. Spores of *Codonotheca* do not possess distal grooves (Schopf, 1948), but do have the typical deflection in the suture.

Because of the size of these spores, one would expect only a few to be found in the minus 65-mesh residue upon which small spore studies are based; unless very common, these spores would scarcely be noticeable in the plus 65-mesh residue, especially if the residues are examined dry.

Renisporites is apparently represented only in the Willis and Tarter Coals of Illinois, but not in all samples of these two coal beds that were examined. The correlation of the two coals has been confirmed on the basis of small spores (Kosanke, 1950).





TEXT FIG. 4 (above).—Length-breadth measurements, groups in 10 μ intervals, from 59 spores of *Renisporites confossus.* Lined area represents holotype.

TEXT FIG. 5 (below).—Length-breadth proportions of spores of *Renisporites confossus,* based on measurements given in text figure 4. Lined area represents holotype.

RENISPORITES CONFOSSUS n. sp.

Plate 15, figures 4, 5; text figures 4, 5

Description.—Spores monolete, large for "small" spores, generally compressed parallel to the long axis, but rarely folded, probably originally of a somewhat rotund bean-shape. Length ranging from 126 to

217 μ (mean 172.5 μ for 65 specimens); breadth from 113 to 179 μ (mean 145 μ for 59 specimens); length-breadth ratio (text fig. 5) averaging 1.19. Monolete suture distinct, in some specimens open, averaging 57 percent (range 44 to 86 percent) of the spore length, between extremes of 75 μ and 151 μ. Suture terminations usually masked, in proximo-distal compressions (pl. 15, fig. 5a), by an arcuate thickening of the spore coat. Thickening most conspicuous around the ends of the sutures (pl. 15, fig. 4), sometimes extending as an elongate oval band completely around suture. Lips difficult to distinguish, membranous, up to 3.7 μ in height.

Spore coat bearing characteristic and unique type of punctate ornamentation. Discrete puncta or pores, completely traversing spore coat and appearing larger at outer surface of coat, scattered randomly over spore coat (pl. 15, fig. 5a), commonly 10 to 20 μ apart. Generally two fairly well defined subcircular areas of closely spaced punctae, also completely traversing spore coat (pl. 15, fig. 5b), occurring at the geometrical equator on either side of the suture, roughly in the median transverse plane (pl. 15, fig. 5a). Puncta group measuring 25 to 40 μ across, sometimes much larger.

Spore coat highly translucent, golden yellow to yellowish brown by transmitted light; coat from 2.5 to 10 μ thick, thickest near terminations of suture (pl. 15, fig. 4).

Holotype.—Maceration 625B-f slide 2, lower part of the Willis Coal, Gallatin County, Illinois (pl. 15, figs. 5a, b).

Discussion.—The histogram presented in text figure 5 characterizes the shape of these spores. The few specimens that possess longitudinal folds are not included. Therefore, the slight skewness—more spores tending beyond the mean towards the elongate rather than isodiametric proportions—cannot be an expression of the tendency to form elongate folds as it is for spores of *Monoletes ovatus* (Schopf, 1938, fig. 2, p. 44). In comparison to spores of *M. ovatus*, these spores tend to be more isodiametric in shape.

The actual measurements of length and breadth are shown in text figure 4. Although 126 μ is given in the text above as the minimum spore length observed, this is not indicated on the histogram (text fig. 4) because the breadth of this spore is not measurable.

The spore coat has a high translucency, somewhat similar to that of the larger spores of *Calamospora*. It may appear thicker (pl. 15, fig. 5b) in the area of the puncta groups. The puncta and suture do not show as clearly on unstained specimens as on the stained ones (compare figures 4 and 5a on plate 15).

Although the groups of puncta are generally two in number, one on either side of the suture, there is some variation in the number, position, and size of the groups. The holotype (pl. 15, figs. 5a, b) and the spore shown by figure 4 on plate 15 are typical examples. On the latter spore one puncta group is in sharp focus whereas the other, on the opposite side of the spore, is out of focus, just above and to the right in the photograph.

A few spores have scattered discrete puncta; one has three groups of puncta; another has two puncta groups covering at least half the spore coat area; the largest spore is completely covered with closely spaced puncta. Worn or poorly preserved spores merely have shredded holes in the coat at the position of the puncta groups. Those specimens that do not have puncta groups appear shallowly infrapunctate. It is possible that this ornamentation is initiated on the inner surface of the spore coat.

Occurrence.—*Renisporites confossus* is abundantly represented in the lower part (maceration 625B), but less abundantly in the upper part (maceration 625A) of the Willis Coal, Gallatin County, and in the Tarter Coal (maceration 901), Warren County, Illinois. A poorly preserved spore, questionably referable to this species, was found in a coal in the Mansfield (?) Formation (maceration 779) in Indiana.

OTHER MICROFOSSILS OF THE PLUS 65-MESH RESIDUES

Plant spores are not the only microfossils found in macerated coal residues. Other microfossils, such as fragments of cuticle that may bear the impressions of the original underlying epidermal cell structure, seed membranes, resin blebs and rodlets, sporangial masses of small spores, or woody fragments, are abundant constituents of some residues.

Some papers that are specifically devoted to seed membranes (Arnold, 1948; Schemel, 1950b) have been published in this country. Harris (1956) has recently emphasized the importance of the study of fossil cuticle. Brief mention is given below to some of the various types of plant and animal (?) microfossils that were encountered during this study.

Sporangial masses of Densosporites

Plate 15, figures 6, 7

Two ovoid sporangial masses, enclosed in a thin membrane, were picked from the maceration residue of the Tarter Coal (maceration 604A). The more or less complete specimen (pl. 15, fig. 6) is about 4200 μ in over-all dimension. The broken specimen, about 2900 μ in length, was dissected and found to contain a mass of spores similar to those of *Densosporites lobatus* Kosanke. These spores also were seen at the margins of the complete specimen. Somewhat smaller, but empty, sporangial sacs showing cell patterns similar to that illustrated by figure 7 on plate 15 were seen in prepared slides of the shale (maceration 163) above the Pinnick Coal of Indiana.

Abundant spores of *Densosporites lobatus* were associated with the sacs, but their origin in the sacs is not demonstrable as it is with those from the Tarter Coal. Of course, many sporangial masses of other kinds of small spores, such as *Schulzospora* in the Mississippian and early Pennsylvanian, also were noted, but *Densosporites* masses are described here because the spores commonly are not found in masses and little was known of their affinity until the recent discovery of this type of spore in the lycopod cone *Selaginellites canonbiensis* Chaloner (1958a).

Seed Membranes

Plate 15, figures 8-10; plate 16, figures 1, 2

Seed membranes are present in many coals, but are especially abundant in the coal in the Tar Springs Formation, the "Sub-Babylon" Coal, and in one of the impure coals from a sinkhole deposit. Some of the seed membranes from the coal in the Tar Springs Formation are extremely large (pl. 15, fig. 9), and some have well preserved apical caps (pl. 15, fig. 10). Large seed membranes also are present in the coal in the Bethel (Mooretown) Formation. Although the one shown from the Willis Coal (pl. 16, fig. 1) is well preserved, the folds have obscured details of the apical portion. Membranes like that shown in figure 2 on plate 16 are fairly common in McLeansboro coals.

One of the most conspicuous seed membranes is illustrated in figure 8 on plate 15. Many of these membranes, very similar to those described as *Spermatites reticulatus* by Arnold (1948), occur throughout the Pennsylvanian. They were not noted in coals of upper Mississippian age or in those that were studied from the Warrior Basin. In the Caseyville Group they occur in the Wayside (maceration 609), Battery Rock (macerations 908, 909), and Reynoldsburg (maceration 618) Coals and in an unnamed coal (maceration 798). In the Tradewater Group they occur in the Babylon (maceration 145A-B), Willis (maceration 625A-B), Pope Creek (maceration 916), Rock Island (No. 1) (macerations 528B, 599B), New Burnside (maceration 938C), Murphysboro (?) (maceration 628B), Bald Hill (maceration 520A), and Wiley (maceration 525A-B) Coals.

In the Carbondale Group they occur in the Colchester (No. 2) (macerations 824, 603C) and Briar Hill (No. 5a) (maceration 633A) Coals. In the McLeansboro Group they occur, sometimes commonly, in the Indiana VII (?) (maceration 939A), "West Franklin" (maceration 831A-B), "LaSalle" (maceration 600), Friendsville (macerations 136, 153), "Merom" (maceration 146), "Watson" (maceration 148), "Divide" (maceration 811), "Woodbury" (maceration 703), and "Bogota" (maceration 133) Coals. Out of twelve instances in which the coal was sampled in two or more portions, these seed membranes are present only, or are more abundant, in the lower samples of ten of the coals.

Miscellaneous Plant Microfossils

Plate 16, figures 3-9

At least half of the maceration residue of the Reynoldsburg Coal contains a distinctive type of cuticle (pl. 16, fig. 7). The cuticles are especially reminiscent of the *Lepidodendron* cuticle illustrated by Bartlett (1929, especially pls. XIX, XX, XXI). He describes small cuticular crests, several of which may occur within a single cell outline as in the case of the areolar dome cells (pl. 16, fig. 7), and other crests up to thirty times as long as a single cell. Athough most abundant in the Reynoldsburg Coal (maceration 618), this type of cuticle also has been seen in the lowest Caseyville coal in a diamond drill core (maceration 798), in "Makanda" (maceration 142), Rock Island (No. 1) (maceration 929), and Colchester (No. 2) (maceration 603A) Coals. It also occurs in the Pinnick (maceration 150) and Cannelton (maceration 780) Coals in Indiana.

The cuticle illustrated in figure 4 on plate 16 shows an arrangement of stomata in parallel rows. This arrangement has been noted in cuticles from several samples of Murphysboro Coal. Cuticular fragments such as are illustrated by figures 5 and 6 on plate 16 also occur in Tradewater Coals. The original cells were radially arranged around the circular openings, becoming more regularly six-sided away from the openings.

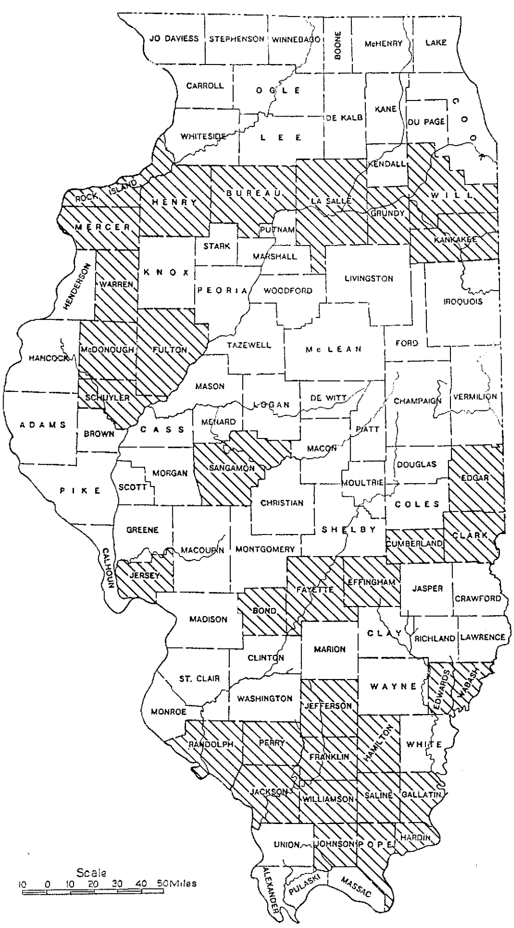
Many macerations contain vascular fragments showing various types of structures (pl. 16, figs. 8, 9). Medullary rays are illustrated by figure 8 on plate 16. The pit mouths on this fragment are narrow, about 10 μ in length, and crossed.

Both resin rodlets and resin blebs are common in some coal beds, generally but not necessarily most abundant in those samples containing abundant *Monoletes* prepollen. Resin blebs may be isodiametric to lenticular, but do not generally show the "stalk" illustrated in figure 3. Resin blebs are easily mistaken for *Monoletes* prepollen under low power binocular microscope.

Animal (?) Membranes

Plate 16, figures 10, 11

Membranes that may be animal in origin occur in several coals, such as the coal in the Bethel (Mooretown) Formation, the Tarter, and the lowest Caseyville age coal



Text fig. 6.—Macerated coal samples examined for this report came from the counties shaded above.

in a diamond drill core from Wabash County, Illinois. The membranes have nearly circular openings and are ornamented with closely spaced pits or depressions. Small round thickenings are present on the example illustrated from the Tarter Coal (pl. 16, fig. 11).

The membranes illustrated in the present paper are similar to the "Cuticle Type B" of Wilson and Hoffmeister (1956, pl. V, figs. 1, 2) in that they have round openings and do not show any cellular structure, but are dissimilar in being thicker and distinctly ornamented with tiny depressions. Eisenack (1956) and Wills (1959) illustrate similar membranes or pellicles of, respectively, eurypterids and "scorpions."

LOCATION OF SAMPLES

Figure 6 indicates the counties in Illinois from which samples of coals and carbonaceous layers have been collected and macerated. Geographic locations are listed by county and maceration number on table 2.

Samples from other states, especially from coals of late Mississippian and early Pennsylvanian age, also were examined. Their geographic locations are given in table 3. In addition, outcrop samples of 15 coals from the Black Creek, Mary Lee, and Pratt Groups from the Warrior Basin, Walker County, Alabama, were examined.

TABLE 2.—GEOGRAPHIC LOCATIONS IN ILLINOIS

Maceration[a] Number	Type[b]	Coal[c]	Location					
			Quarter			Sec.	T.	R.
		Bond County						
561	DD	Macoupin	NW	NE	NE	17	6N	3W
		Bureau County						
600	OU	"LaSalle"	SE	SW	NW	33	16N	11E
579 A-C	SU	Colchester (No. 2)			NW	33	16N	11E
		Clark County						
146	OU	"Merom"		NE	SW	2	11N	12W
830	OU	Cohn	NW	SE	NE	21	10N	12W
		Cumberland County						
703	OU	"Woodbury"			SE	32	9N	8E
		Edgar County						
878	DD	Grape Creek (No. 6)		NW	NE	1	13N	11W
879	DD	No. 5 (u)		NW	NE	1	13N	11W
880	DD	No. 5 (1)		NW	NE	1	13N	11W
881	DD	Indiana IV		NW	NE	1	13N	11W
		Edwards County						
621D	TD	DeKoven (?)	NW	NE	SE	18	1N	10E
		Effingham County						
148	OU	"Watson"			SE	1	6N	5E
		Fayette County						
133	OU	"Bogota"				25	8N	3E
		Franklin County						
554D	DD	DeKoven	SE	NE	NE	18	5S	2E
554E	DD	Davis	SE	NE	NE	18	5S	2E
535	DD	Davis	SE	NW	NE	16	6S	1E
537Q	DD	Unnamed coal just above Stonefort (?)	SE	NW	SE	27	6S	3E
554F	DD	Unnamed coal just above Stonefort (?)	SE	NE	NE	18	5S	2E

TABLE 2—Continued

Maceration[a] Number	Type[b]	Coal[c]	Location					
			Quarter			Sec.	T.	R.
Fulton County								
603A-C	OU	Colchester (No. 2)	NE	NW	NE	16	4N	3E
899	OU	Colchester (No. 2)		W½	NE	16	4N	3E
525A-B	OU	Wiley	NE	NW	NE	16	4N	3E
527B	OU	Upper DeLong	NE	NW	SW	19	5N	2E
528A-B	OU	Rock Island (No. 1)		SW	SW	23	6N	1E
599A-B	OU	Rock Island (No. 1)		SW	SW	23	6N	1E
602	OU	Pope Creek	SE	SW	SE	11	7N	1E
604A	OU	Tarter	NW	NW	SE	19	5N	2E
145A-B	OU	Babylon	NE	NE	SE	2	5N	1E
523A-B	OU	Babylon	NW	NE	NE	14	7N	1E
588	OU	Babylon	NW	NE	NE	14	7N	1E
144	OU	"Sub-Babylon"	NE	NE	SE	2	5N	1E
Gallatin County								
633A-B	OU	Briar Hill (No. 5a)	SE	SW	SE	17	9S	8E
631	OU	Willis (?)	South side of Eagle Valley					
625A-B	SM	Willis		NW	SE	30	10S	9E
Grundy County								
580	ST	Colchester (No. 2)				12	33N	8E
611	ST	Colchester (No. 2)		SE	SE	9	33N	8E
951	ST	Upper coal (Tradewater)[1]			N½	11	33N	8E
950A-B	ST	Lower coal (Tradewater)[1]			N½	11	33N	8E
949	ST	Lower coal (Tradewater)[1]			N½	11	33N	8E
Hamilton County								
581	TD	No. 2 (?)	SW	NE	SW	19	5S	5E
582	TD	No. 2 (?)	NE	NW	NE	15	5S	7E
Hardin County								
587	MD	Battery Rock				27	11S	10E
Henry County								
589	SU	Rock Island (No. 1)	NE	NW	SE	3	16N	1E
626	SU	Rock Island (No. 1)		NE	NE	33	14N	1E
Jackson County								
549	MD	Murphysboro		NW	NW	36	7S	4W
550	MD	Murphysboro			NW	30	7S	2W
608	OU	Murphysboro	SW	NE	SE	21	7S	3W
799A-C	OU	Murphysboro				2	7S	3W
800A-C	ST?	Murphysboro				22	7S	3W
905	MD	"Makanda"	NE	SW	SW	28	10S	1W
906	OU	"Makanda"	NE	SW	SW	28	10S	1W
907	OU	"Makanda"	NE	SW	SW	28	10S	1W
142	OU	"Makanda" (Battery Rock?)		SE	SE	29	10S	1W
143	OU	In upper part of Degonia Formation				13	8S	5W
952	OU	At top of Palestine Formation[2]		SE	SW	16	8S	5W
Jefferson County								
811	OU	"Divide"	NW	SW	SW	7	1S	1E
Jersey County								
463	OU	Summum (No. 4)	NW	SW	SE	16	7N	10W
Johnson County								
938A-C	ST	New Burnside	SW	NE	NE	8	11S	4E
618	MD	Reynoldsburg			SW	32	11S	4E
609	OU	Wayside	SE	NW	NE	4	12S	2E
168	OU	In Vienna Formation		C	S½	12	13S	4E
687A-B	OU	In Vienna Formation		W½	SE	12	13S	4E

TABLE 2.—Continued

Maceration[a] Number	Type[b]	Coal[c]	Location			
			Quarter	Sec.	T.	R.
		Johnson County—Continued				
765	OU	In Vienna Formation	C½ S½	12	13S	4E
842	OU	In Vienna Formation		12	13S	4E
764	OU	In Vienna Formation	W½ SE	12	13S	4E
758	OU	In Vienna Formation	W½ SE	12	13S	4E
760	OU	In Tar Springs Formation	W of C E½ SW	10	13S	3E
166	OU	In Hardinsburg Formation ("Glen Dean, lower bed")	NE NW SE	24	13S	4E
763	OU	In Hardinsburg Formation ("Glen Dean, lower bed")	NE NW SE	24	13S	4E
		Kankakee County				
203	OU	Sinkhole deposit		7	30N	14W
755	OU	Sinkhole deposit		7	30N	14W
		LaSalle County				
567	ST	Colchester (No. 2)	NW NE	25	33N	4E
		McDonough County				
929	OU	Rock Island (No. 1)	SW SE SW	23	6N	3W
		Mercer County				
918	OU	Pope Creek (u)	NE NE SW	33	14N	2W
917	OU	Pope Creek (m)	NE NE SW	33	14N	2W
916	OU	Pope Creek (l)	NE NE SW	33	14N	2W
914	OU	Tarter	NE NE SW	33	14N	2W
		Perry County				
—	DD	Upper part of Menard Formation, 756–758′[3]	SW SW NW	5	6S	1W
—	DD	Upper part of Golconda Formation, 1053–1061′[3]	SW SW NW	5	6S	1W
		Pope County				
908	OU	Battery Rock (l)	NW SE SE	31	11S	5E
909	OU	Battery Rock (u)	NW SE SE	31	11S	5E
910	MD	Caseyville	SW SE SW	35	11S	6E
629	OU	Battery Rock	SE SW	6	11S	6E
200	OU	In Degonia Formation	S½	19	12S	5E
		Randolph County				
—	OU	Waltersburg Formation[4]	NW NE	32	7S	6W
		Rock Island County				
627	SU	Rock Island (No. 1)	NW SE SW	1	16N	1W
		Saline County				
936	ST	Unnamed coal nine feet above DeKoven	E½ NE NE	20	10S	5E
35	OU	Unnamed coal above DeKoven	NW¼	21	10S	5E
518A-B	OU	Davis	NE NW	21	10S	5E
628A-B	OU	Murphysboro (?)[5]	NE SE NW	27	10S	6E
		Sangamon County				
630	DD	Springfield (No. 5)		15	14N	4W
		Schuyler County				
826	OU	Colchester (No. 2) (u)	NE	31	2N	1E
825	OU	Colchester (No. 2) (l)	NE	31	2N	1E
824	OU	Colchester (No. 2) (l)	NE	31	2N	1E
829	OU	Upper DeLong (?)	NE	31	2N	1E
828	OU	Middle DeLong (?)	NE	31	2N	1E

TABLE 2.—Concluded

Maceration[a] Number	Type[b]	Coal[c]	Location			
			Quarter	Sec.	T.	R.
		Wabash County				
135	SU?	Friendsville		13	1N	13W
153	SU?	Friendsville		13	1N	13W
136	OU	Friendsville (?)	NW	13	1N	14W
490D	MD	Friendsville	NW SW SE	29	2S	13W
583	TD	Harrisburg (No. 5)	NE SE NW	27	2S	13W
795	DD	In Caseyville Group	SE NW SE	9	1N	12W
796	DD	In Caseyville Group	SE NW SE	9	1N	12W
797	DD	In Caseyville Group	NW/C SW	3	1N	12W
798	DD	In Caseyville Group	NW/C SW	3	1N	12W
		Warren County				
901	OU	Tarter	NE	26	9N	1W
		Will County				
455	OU	Sinkhole deposit	NE NE	22	35N	10E
		Williamson County				
519A-B	OU	DeKoven	NW SW	13	10S	4E
639	OU	Unnamed coal just above Stonefort	NW SE	25	10S	4E
640	OU	Stonefort	NW SE	25	10S	4E
520A-B	OU	Bald Hill	NW SE	25	10S	4E
915	OU	Murphysboro (?)	NW NW	30	9S	1E

a. —— not macerated
b. DD Diamond drill
TD Rotary drill
SU Underground mine
ST Strip mine
MD Mine dump
OU Outcrop

c. 1. Doehler (1957)
2. Rexroad (1957, locality 15)
3. Cooper (1942, p. 768)
4. Rexroad (1957, locality 11, samples 3, 4)
5. Weller, Henbest, and Dunbar (1942, p. 15, fig. 2)
(l) lower, (m) middle, and (u) upper part of one bed

TABLE 3.—GEOGRAPHIC LOCATIONS IN STATES OTHER THAN ILLINOIS

State and County	Maceration number	Type	Coal	Location			
				Quarter	Sec.	T.	R.
			Indiana				
Lawrence	832	OU	In Bethel (Mooretown) Formation	C E line	11	3N	2W
	834	OU	In Bethel (Mooretown) Formation	SE	5	3N	2W
	836	OU	In Bethel (Mooretown) Formation	SE	3	3N	2W
Orange	163	OU	Shale above Pinnick	SE NW	32	2N	2W
	150	OU	Pinnick	SW	32	2N	2W
	151	OU	French Lick	NW	32	2N	2W
Owen	779	OU	In Mansfield (?) Formation	SW NW	27	12N	4W
Perry	780	OU	Cannelton	NE	5	7S	2W
Posey	831	OU	"West Franklin" (below upper bench)		24	7S	12W
	939A	DD	VII (?)	NW NE SW	12	7S	12W
Washington	468	OU	In Bethel (Mooretown) Formation	N	1	1N	2E
			Kentucky				
Bell	913	OU	In Pennington Shale	(20 B 70 : Carter grid)			
Caldwell	206	OU	In Tar Springs Formation	(5 G 21 : Carter grid)			
Crittenden	733c	SU	Battery Rock	(C S½ 5 L 19 : Carter grid)			
	810	OU	In Hardinsburg Formation	(SW 1 J 18 : Carter grid)			
Hardin	943	OU	In Bethel (Mooretown) Formation	(11 P 41 : Carter grid)			
Letcher	911	OU	Coaly streak in upper Stony Gap Sandstone.	(4 H 83: Carter grid)			
	912	OU	Streak in upper Stony Gap SS.	(4 H 83 : Carter grid)			
			Virginia				
Wise	888	OU	Plant bed base (?) of Glen Dean	(Big Stone Gap)			

SPORE DISTRIBUTION

Introduction

This discussion of the plus 65-mesh residues of samples from coals and carbonaceous layers is a supplement to a preceding report on small spores by Kosanke (1950), who studied the small spores from the minus 65-mesh residues. Many of the macerated samples were used in both studies. The occurrences of spores noted in the plus 65-mesh residues are given for many of the formations in the Chester Series of the Mississippian System and for many of the coals in the Pennsylvanian System of Illinois. A few Pennsylvanian samples from Indiana and Alabama are included. Those of upper Mississippian age were collected from four states: Illinois, Indiana, Kentucky, and Virginia. In general the samples had been collected and macerated long before the immediate project was undertaken. This report therefore represents a general survey of plus-residue material, with primary emphasis on "large" spores, or megaspores, already available in the Illinois State Geological Survey collections.

The spore distribution chart (text fig. 9) records the presence of 33 designated species assigned to six genera and the presence of spores of two other genera. Eleven species and varieties have restricted ranges; others have less restricted but important stratigraphic ranges. Only one species is represented throughout most of the section studied.

In order to present a readable distribution chart, when a coal was collected in two or more samples, the assemblages have been reported as a unit for the whole coal. Forms notably restricted to the bottom or top of a bed are discussed in the text. Because the assemblages of various samples of the same coal may differ considerably from place to place, only the assemblage from a coal (maceration number noted on text fig. 9) at one locality is reported. This sample is either one from a locality nearest the type section of the coal (or from the cyclothem in which the type section occurs) or one judged most representative of the whole bed. The assemblages of these samples and of the others studied are discussed in the following pages.

Portions of the distribution chart have been abstracted and adjusted to illustrate certain features of spore distribution. Text figure 7 illustrates the contrast between assemblages of upper Mississippian and immediately overlying Pennsylvanian rocks. Text figure 8 represents the stratigraphic distribution of seven genera and that of the spores assigned to the sections of *Triletes*. These figures are a composite interpretation, in contrast with text figure 9, and are necessarily generalized.

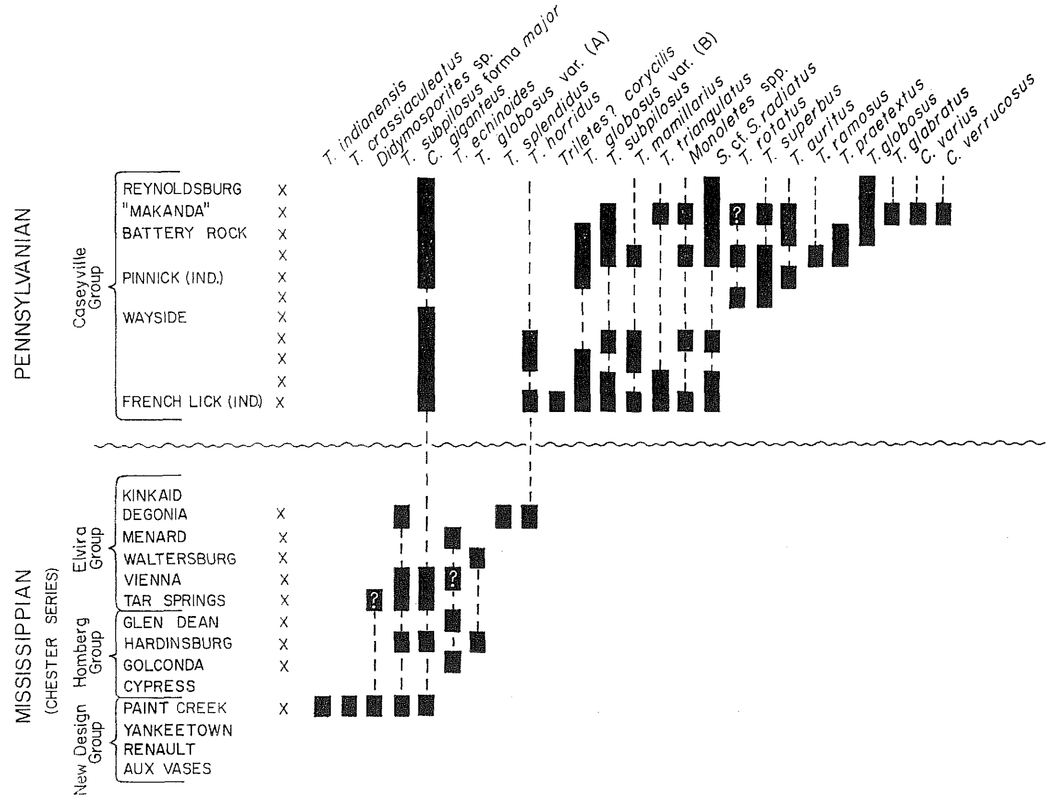
Because the samples were not systematically and uniformly taken for the statistical analysis of megaspore content, the terms, "rare" (R), "present" (P), "common" (C), and "abundant" (A), are subjective and based on the number of specimens observed. In general "rare" denotes less than three specimens noted, whereas "abundant" denotes the presence of a hundred or more specimens. When prepared slides only were available for study and the actual relative abundance was unknown, the term "present" is used unless the maceration records clearly indicate the relative abundance of the various spore types. The occurrences reported in text figure 9 have been handled in the same manner; for example, spores of *Cystosporites varius* are "abundant" in the Rock Island (No. 1) Coal, but "rare" in the DeKoven Coal.

Rough percentages of *relative* abundance of spores of different species are given for some coals in the following discussion.

Mississippian System

CHESTER SERIES

Previous investigations on upper Mississippian megaspores in the United States have been limited in extent, primarily because of lack of commercial coals in rocks of this age. Although cyclic sedimentation is evident in the rocks of the Chester Series of the Illinois Basin, formation of coal was limited to a few thin beds and carbonaceous streaks. Rocks of the Chester Series underlie most of the southern half of Illinois. The 16 alternating limestone-shale



TEXT FIG. 7.—Generalized stratigraphic occurrence of spores of *Triletes, Cystosporites, Spencerisporites, Monoletes,* and *Didymosporites*. Coals or formations sampled are indicated by crossed lines (X). Chart illustrates the contrast between the assemblages found in upper Mississippian rocks and those found in the unconformably overlying Pennsylvanian rocks.

and sandstone-shale formations average from about 30 to 150 feet thick (Workman, Swann, and Atherton, 1950). Mississippian coals are rarely more than a few inches thick and less persistent than those known from Pennsylvanian strata (Wanless, 1947).

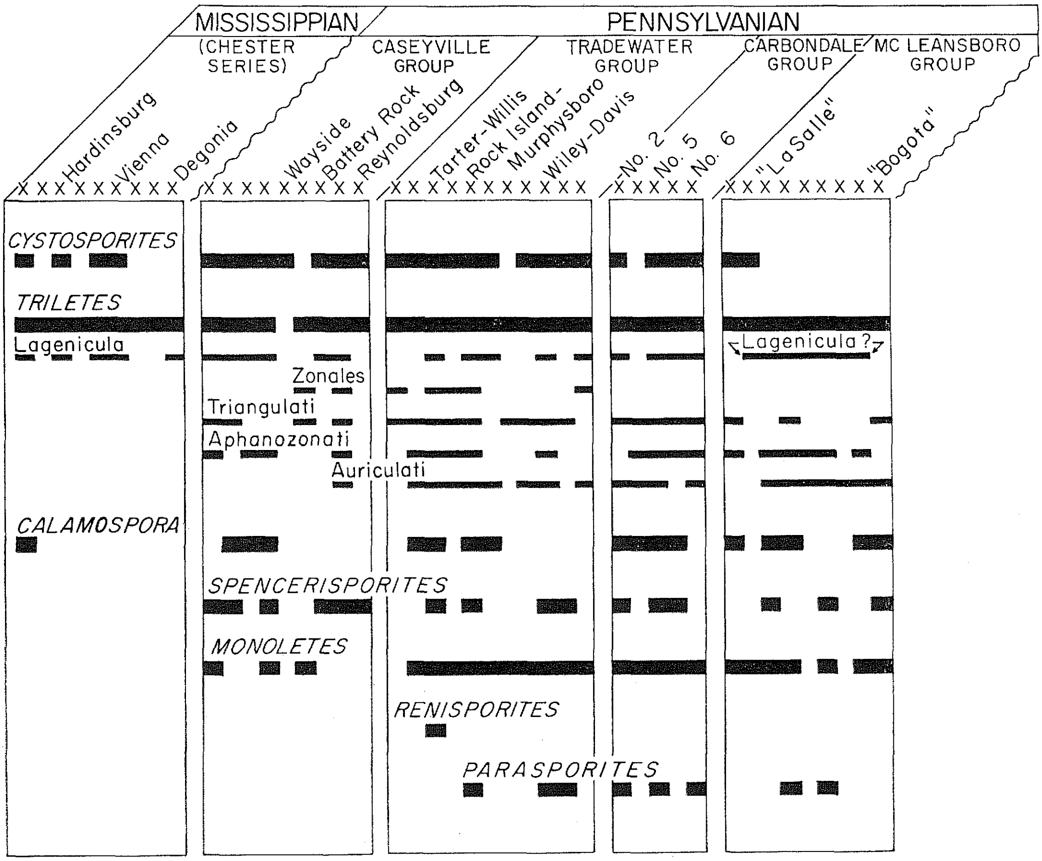
The 26 samples of thin coals or carbonaceous layers investigated are from Illinois, Indiana, Kentucky, and Virginia. Those from southern Illinois were collected from Jackson, Johnson, Perry, Pope, and Randolph Counties. Although sample coverage is by no means satisfactory, it is far more complete than that of previously published investigations.

The samples containing the most abundant megaspores are those of the coal in the Bethel (Mooretown) Formation from Kentucky and of the coal in the Vienna Formation from Illinois. The assemblages of the samples are here discussed in ascending order of their stratigraphic position.

Lower Chester Series

No samples were examined from the three lower formations: the Aux Vases Sandstone, Renault Formation, and Yankeetown Sandstone. The Paint Creek Formation of the Chester outcrop area is represented, in part, by the Bethel Sandstone in Illinois and by the Bethel (Mooretown) Sandstone in Indiana and Kentucky (Swann and Atherton, 1948). Five samples of coals within the Bethel (Mooretown) Formation (reported on the distribution chart, text fig. 9, as Paint Creek) were examined.

The following genera and species have been identified from a 4-inch coal in the Bethel (Mooretown) Formation (maceration 943) from Hardin County, Kentucky:



TEXT FIG. 8.—Generalized stratigraphic occurrence of spores of seven genera and of spores of the five sections of *Triletes* in upper Mississippian and Pennsylvanian rocks of Illinois and adjacent states.

Triletes subpilosus forma *major*	(A)
T. crassiaculeatus	(P)
T. indianensis	(C)
Cystosporites giganteus	(P)
Calamospora sp.	(R)

Megaspores are so abundant in this sample that it could be considered a "spore coal." At least 75 percent of the large spores are those of *T. subpilosus* forma *major*. *T. indianensis* accounts for 20 percent of this assemblage, but is not represented in any of the other samples of the coal in the Bethel (Mooretown) Formation.

Triletes crassiaculeatus and *T. subpilosus* forma *major* also are represented in other samples of this same coal (macerations 468, 832, and 834) from Washington and Lawrence Counties, Indiana. *T. crassiaculeatus* is dominant in one (maceration 832). *Cystosporites giganteus* also was represented in this maceration.

In contrast with the Kentucky sample, a 2-inch coal (maceration 468) from Washington County, Indiana, contained many spores similar to those found in *Bensonites fusiformis* (Surange, 1952), the fructification of *Stauropteris burntislandica*. One specimen also was found in maceration 832. Chaloner (1958c) described isolated spores, *Didymosporites scotti* Chaloner, from the Dinantian and Namurian of Ireland and from the Dinantian of Scotland and England. An additional sample of coal from the Bethel (Mooretown) Formation (maceration 836) was barren of megaspores.

Middle Chester Series

No samples were examined from the Cypress Formation, but megaspores of *Triletes echinoides* Chaloner were found in the uppermost beds of the overlying Golconda Formation. These had been picked from bedding surfaces of the Forester No. 1 core, drilled in Perry County, Illinois. This species was first reported by Chaloner (1954b) from the Beaver Bend Limestone of Indiana.

The following genera and species were identified from a coal (maceration 810) in the Hardinsburg Sandstone, Crittenden County, Kentucky:

Triletes subpilosus forma *major*	(A)
T. globosus var. (A)	(C)
Cystosporites giganteus	(P)

In addition, many small spores, referable to *Densosporites,* were noted adhering to the megaspores of *T. globosus* var. (A). This variety was restricted to this one sample of the Hardinsburg and one from the Waltersburg Formation. Two additional samples (macerations 166 and 763) probably from the Hardinsburg Formation, Johnson County, Illinois, contained cuticles and sporangial masses of small spores referable to *Schulzospora. T. subpilosus* forma *major* was also represented in maceration 166.

The only Glen Dean sample is from a plant bed (maceration 888) at the base (?) of the Glen Dean Formation from Big Stone Gap, Wise County, Virginia. Only a few complete spores of *Triletes echinoides* and additional fragments were present in the coarse residue.

Upper Chester Series

One sample of a 6-inch coal (maceration 206) from the Tar Springs Sandstone, Caldwell County, Kentucky, contained only megaspores of *Triletes subpilosus* forma *major.* However, another sample from 6 inches of a reported 2-foot coal (maceration 760), probably from the Tar Springs Formation, contained no spinose lageniculate megaspores. This assemblage contained many large seed membranes, some abortive spores of *Cystosporites giganteus,* and one spore similar to those of *Didymosporites.*

The following species were identified from the 4-inch coal (maceration 168) in the Vienna Formation, obtained from the Illinois Central Railroad cut, north of Grantsburg, Johnson County, Illinois:

Triletes subpilosus forma *major*	(A)
Cystosporites giganteus	(A)

In addition some seed membranes were present. Five other samples of this coal (macerations 687A-B, 758, 764, 765, and 842, probably all taken from this railroad cut) contain the same assemblage but with variations in relative abundance. Masses of spores of *Schulzospora* also were noted in macerations 764 and 842. The coal sample was macerated in two separate segments. The upper 2 inches of coal (maceration 687A) contained abundant, well preserved megaspores, whereas the bottom portion (maceration 687B) contained only a few spores and cuticle. A spore coat fragment, possibly of *T. echinoides,* was found in this latter sample.

A few megaspores of *Triletes globosus* var. (A) were picked from samples of the overlying Waltersburg Formation, Randolph County, Illinois, during conodont investigations (Rexroad, 1957, locality 11, samples 3, 4). This variety is known only from the Hardinsburg and Waltersburg Formations.

Fragments of spores referred to *Triletes echinoides* were picked from bedding surfaces in the upper part of the Menard Formation during a study of the Forester No. 1 core, drilled in Perry County, Illinois.

A 4-inch coal (maceration 952) at the top of the Palestine Sandstone, Jackson County, Illinois, did not yield any megaspores. Samples were not available from the overlying Clore Formation.

Two samples were obtained from carbonaceous layers in the Degonia Sandstone of Illinois. The sample (maceration 143) from 8 inches below the base of the Kinkaid Formation, Jackson County, Illinois, contained abundant megaspores of *Triletes subpilosus* forma *major,* whereas the sample (maceration 200) from Pope County contained abundant megaspores of *T. horridus* but very few of *T. subpilosus* forma *major.* In addition the Pope County sample yielded a few spores referable to *T. splendidus,* a species that had not been reported from the United States before and is known only from this one sample.

Samples of the Kinkaid, the uppermost formation of the Chester Series, were not available so that the megaspores of at least

100 feet of rocks at the top of the Chester in Illinois are still unknown. This information, when available, could possibly change or soften the apparently abrupt distinction between uppermost Mississippian and lowermost Pennsylvanian assemblages (text fig. 7).

Miscellaneous Samples of Chester Age

Of two samples from two coaly streaks in the upper part of the Stony Gap Sandstone at Pounds Gap, Letcher County, Kentucky, one (maceration 911) contained numerous fertile and abortive spores of *Cystosporites giganteus* and a few megaspores of *Triletes subpilosus* forma *major,* but the other (maceration 912) was barren of megaspores.

A sample from a coal (maceration 913) in shales of the Pennington Formation, Cumberland Gap, Bell County, Kentucky, was barren of megaspores.

Summary

Although megaspores may occur in great numbers in rocks of Chester age, very few types are represented. The assemblages as a whole are dominated by spinose lageniculate and fibrous-coated spores, representing, among the heterosporous plants, a dominant lepidocarp-lepidodendrid flora.

Three genera identified from the Chester Series also are represented in Pennsylvanian coals; four other genera first occur in the Pennsylvanian (text fig. 8).

Spores of *Didymosporites* are known only from the lower part of the Chester Series. Within the genus *Triletes* four species are restricted to rocks of Chester age, whereas eight species are first represented in the Caseyville Group of Pennsylvanian age. Three other species are represented in both the Chester and Caseyville rocks, but varietal forms of only two can be distinguished (text fig. 7). Therefore, of 25 taxonomic entities that are distinguishable (text fig. 7), only two are common to upper Mississippian and Pennsylvanian rocks.

Pennsylvanian System

In late Chester time a long period of subaerial erosion followed uplift and withdrawal of the sea. A second erosion cycle, initiated by a subsequent uplift, resulted in the incision of deep channels in the peneplain surface (Siever, 1951) so that in southern Illinois Pennsylvanian rocks rest on the eroded surfaces of rocks of upper Chester age, but northward they rest on successively older rocks as far down as the St. Peter Sandstone of Ordovician age. This unconformity is one of the most important within the Paleozoic era of the east-central United States (Wanless, 1955).

The Pennsylvanian deposits in the Eastern Interior Coal Basin are noted for their arrangement in repeated successions of rock types designated as cyclothems by Weller (1930) and Wanless and Weller (1932). The rocks are principally shales and fine-grained sandstones with many beds of limestone, black shale, coal, and underclay. In Edwards County, Illinois, and in parts of surrounding counties (Workman, Swann, and Atherton, 1950; Wanless, 1955), the total thickness attains a maximum of about 2500 feet.

The Pennsylvanian succession has been divided into four groups, from oldest to youngest: Caseyville, Tradewater, Carbondale, McLeansboro. Cady (1952) stated that there are 40 to 50 coals in this succession. The coals that are more important commercially are within a section that occupies the upper 200 feet of the Tradewater Group, the Carbondale Group, and the lower 100 feet of the McLeansboro Group. Most of the Pennsylvanian samples used in this investigation were from coals, and, except for a few principally of Caseyville age, were from localities within Illinois.

Caseyville Group

The rocks of the Caseyville Group, the oldest group of Pennsylvanian strata in Illinois, include all those below the base of the Grindstaff Sandstone. These rocks, up to 470 feet thick (Cady, 1952), are characterized by massive cross-bedded sandstones commonly containing quartz pebbles, by somewhat thin discontinuous coals, and by a paucity of limestone. The coals are of only slight economic interest except in southeastern Jackson and northeastern

Johnson Counties in southern Illinois. The coals mined near Makanda in southern Jackson County ("Makanda" Coals in this report) and the Reynoldsburg Coal, at the top of the Caseyville Group, may be as much as 28 inches thick, which is regarded as minable in Illinois (Cady, 1952). The Battery Rock Coal has been mined in eastern Hardin County.

The Caseyville is considered equivalent to the upper part, at least, of the Morrowan of the Midcontinent region (Wanless, 1956), to the New River Group of the Pottsville Series of the Appalachian region (Wanless, 1955), and to the Westphalian A (Moore et al., 1944; Kremp, 1955) and Namurian C of Europe (Moore et al., 1944).

In terms of floral zones, as defined by Read (1947), the Caseyville Group contains plants of zone 2 (Zone of *Mariopteris pottsvillea* and *Aneimites*) and of zone 3 (Zone of *M. pygmaea*). Plants of zone 2 are known from the "Wayside Member"; plants of zone 3 are known from the Drury Shale which overlies the Battery Rock Coal. Kosanke (1947) noted that the dominant genera, defined on the basis of small spores, of the Caseyville Group are *Densosporites* and *Lycospora*. He noted (1950) the absence of three genera that are represented in the Tradewater Group: *Alatisporites, Cirratriradites, Reinschospora.*

The plus 65-mesh residues of 20 samples, five of which were from Kentucky and Indiana, were studied. Samples from southern Illinois were from Hardin, Jackson, Johnson, Pope, and Wabash Counties. In addition, three samples of coaly streaks or thin coals from sinkhole deposits of early Pennsylvanian age were obtained from Kankakee and Will Counties. One sample of coal from the Mansfield (?) Formation in Indiana also was included.

Caseyville Coals

A number of thin coals are known from within 60 feet above the base of the pre-Pennsylvanian unconformity in diamond drill cores in Wabash County, just to the east of the deepest portion of the Illinois Basin. Two coals from each of two cores were examined for plus-residue content.

The following genera and species were represented in a 9¾-inch coal (maceration 798), about 13 feet above the unconformity at a depth of 1543 feet 10 inches in Forest Oil Company core, No. M021, NW¼ C sec. 3, T. 1 N., R. 12 W., Wabash County:

Triletes globosus var. (B)	(A)
Spencerisporites cf. *S. radiatus*	(A)
T. horridus	(A)
T. mamillarius	(C)
T. triangulatus	(C)
Triletes ? corycilis n. sp.	(C)
Cystosporites giganteus	(C)
T. subpilosus	(R)
Monoletes	(R)

The assemblage in the coarse residue of the French Lick Coal (maceration 151), from the Wortinger Whetstone quarry, Orange County, Indiana, bears a marked resemblance to the one described above. The French Lick Coal apparently lacks spores of *T. horridus, T. triangulatus,* and *Monoletes*. However, *T. ? corycilis* is known only from these two coal beds. Wanless (1955) stated that the Indiana coal yields the oldest flora known in the Eastern Interior Coal Basin and correlates with the lower Pottsville or Pocahontas Group of West Virginia.

In the Forest Oil Company core a thin coal, 6 inches thick, occurs at a depth of 1520 feet 1 inch, about 23 feet above the sample described above. A third coal (maceration 797), 13 inches thick, occurs at a depth of 1506 feet 1 inch, about 37 feet above the lowest coal.

The following genera and species were recognized from maceration 797:

Triletes globosus var. (B)	(A)
T. subpilosus	(C)
T. triangulatus	(P)
Spencerisporites cf. *S. radiatus*	(R)
Cystosporites giganteus	(R)
Calamospora cf. *C. laevigata*	(R)

Spores of *T. globosus* var. (B) make up about 95 percent of large spore content of this residue.

Two other thin coals occur in another Wabash County core at depths of 1487 feet 6 inches and 1478 feet 3 inches, the latter being at least 33 feet above the base of the Pennsylvanian. The lower 5¾-inch coal (maceration 796), from Forest Oil Company core, No. K031, SE¼ NW¼ SE¼ sec.

9, T. 1 N., R. 12 W., contained representatives of the following genera and species:

Triletes globosus var. (B)	(A)
T. horridus	(C)
T. mamillarius	(C)
Cystosporites giganteus	(C)
Calamospora cf. *C. laevigata*	(R)

Large spores were extremely abundant in this residue; 95 percent of the spores are referable to *T. globosus* var. (B).

The following genera and species were represented in the upper 17-inch coal (maceration 795), from the Forest Oil Company core No. K031:

Triletes subpilosus	(A)
T. mamillarius	(C)
Cystosporites giganteus	(C)
Monoletes	(C)
T. horridus	(R)
Spencerisporites cf. *S. radiatus*	(R)
Calamospora cf. *C. laevigata*	(R)

Spinose lageniculate spores constitute 90 percent of this assemblage, which is markedly different from those assemblages of the other unnamed coals of these two cores in the abundance of spinose lageniculate spores and in the apparent absence of spores of *T. globosus* var. (B).

At present the exact stratigraphic relationship of the two coals from the two cores is not known. The lowest coal (maceration 798) of core M021 is undoubtedly the oldest Pennsylvanian coal in the cores. The next three coals could be listed above in their proper stratigraphic order with neither coal of core K031 corresponding to the upper coal of core M021; however, it is possible that the coal (maceration 796), of core K031 may represent the unsampled middle 6-inch coal from core M021.

Wayside Coal

One sample of the Wayside Coal (maceration 609) from Johnson County, Illinois, yielded rather numerous small spores but they represented only a few species (Kosanke, 1950). Spores of *Lycospora pseudoannulata* averaged 70 to 75 percent of the total small spore content. The coarse residue contained only some seed membranes and a few abortive spores of *Cystosporites giganteus*.

Battery Rock Coal

The coarse residue of Battery Rock Coal contained many more large spores than did that of the Wayside Coal. A sample of the Battery Rock Coal (maceration 587), collected from the mine dumps at Battery Rock, about one mile from the type section of the Battery Rock Cyclothem in Hardin County, Illinois, contained representatives of the following genera and species:

Triletes subpilosus	(A)
T. praetextus	(P)
T. globosus var. (B)	(P)
Cystosporites giganteus	(P)
Spencerisporites cf. *S. radiatus*	(R)

In addition the coarse residue yielded many spore masses containing small spores referable to *Granulatisporites*. *Triletes praetextus* apparently is restricted to this coal in Illinois. According to Wanless (1955) the roof shale of this coal contains a flora that permits its correlation with the Sharon Coal of Ohio, Sewell Coal of West Virginia, Sewanee Coal of Tennessee, Mary Lee Coal of Alabama, and Baldwin Coal of Arkansas.

Several other samples, identified as Battery Rock Coal, also were examined. One sample (maceration 733), from an abandoned shaft mine in Crittenden County, Kentucky, contained abundant spores of *Triletes auritus* and a few spores typical of *T. globosus*. Another sample (maceration 629) from an outcrop in Pope County, Illinois, contained abundant spores typical of *T. globosus* and some of *Cystosporites giganteus* and *Spencerisporites* cf. *S. radiatus*. Both assemblages differ from that listed above (maceration 587) in that they lack *T. praetextus* and have spores typical of *T. globosus* rather than those typical of *T. globosus* var. (B). One sample also contained abundant auriculate megaspores.

A third coal, called Battery Rock (macerations 908 and 909), cropping out in NE¼ SW¼ SE¼ sec. 31, T. 11 S., R. 5 E., Pope County, Illinois, contained an assemblage almost identical in representation and abundance ratios to that of the Battery Rock sample (maceration 629) from the same county. In addition a few spores of *Calamospora* cf. *C. laevigata* also were present.

Although *Triletes praetextus* was found in only one sample of the Battery Rock Coal (maceration 587) from Illinois, the species also was represented in the shale (maceration 163) above the Pinnick Coal of Indiana.

The following genera and species were identified from a sample of the Pinnick Coal (maceration 150) obtained from the Pinnick Quarry, Orange County, Indiana:

Triletes auritus	(A)
T. globosus var. (B)	(P)
Cystosporites giganteus	(P)
T. superbus	(R)

Assuming that typical spores of *Triletes globosus*, such as those occurring in two of the samples (macerations 629 and 733) referred to the Battery Rock above, are from slightly younger coals, the abundant occurrence of spores of *T. auritis* in the Pinnick Coal marks the lowest known occurrence of this species in the Eastern Interior Coal Basin. *T. superbus* also is represented for the first time in the Pinnick Coal.

The shale (maceration 163) above the Pinnick Coal, from the old Braxton Quarry, Orange County, Indiana, contained the following genera and species:

Triletes globosus var. (B)	(A)
T. superbus	(C)
T. subpilosus	(C)
T. praetextus	(C)
T. mamillarius	(P)
T. rotatus	(P)
T. ramosus	(P)
Cystosporites giganteus	(R)
Spencerisporites cf. *S. radiatus*	(R)
Monoletes	(R)

Spores of *Triletes globosus* var. (B) constituted about 90 percent of the assemblage. *T. rotatus* and *T. ramosus* are represented for the first time. All the species recognized in the Battery Rock Coal (maceration 587) also are represented in this shale.

"Makanda" Coal

The Makanda Sandstone was originally defined as extending from the top of the Drury Shale to the base of the Murphysboro Coal. The term "Makanda" is used here in its restricted sense (Wanless, 1956) as the lower member exposed in Giant City State Park near Makanda, Jackson County, Illinois. The samples of "Makanda" coals (macerations 142, 905, 906, and 907) examined for this report probably include the coal mentioned by Lamar (1925, p. 97) as a 2-foot coal occurring in the SW¼ SW¼ sec. 28, T. 10 S., R. 1 W., in southern Jackson County.

Three samples were taken from around a small coal digging (NE¼ SW¼ SW¼ sec. 28, T. 10 S., R. 1 W.) in the Makanda Sandstone. The main coal was covered, but one sample of coal (maceration 905) found in the dump pile contained spores of the following genera and species:

Triletes horridus	(A)
T. auritus	(A)
Spencerisporites cf. *S. radiatus*	(P)
Cystosporites giganteus	(R)
C. verrucosus	(R)
Monoletes	(R)

About equal numbers of spores of *T. auritus* and *T. horridus* constituted 90 percent of the large spore assemblage. This is the first representation of *C. verrucosus* in the Pennsylvanian of Illinois.

The following genera and species were identified from a sample (maceration 906) of four one-inch coal stringers above the main coal in the western digging:

Triletes globosus	(A)
T. horridus	(C)
T. auritus	(C)
T. superbus	(C)
T. glabratus	(P)
Spencerisporites cf. *S. radiatus*	(P)
T. triangulatus	(R)
Cystosporites giganteus	(R)
C. varius	(R)
Monoletes	(R)

Triletes globosus comprises 35 percent of the total large spore content and *T. auritus*, *T. horridus*, and *T. superbus*, each comprise 20 percent of the total large spore content. This is the first representation of both *T. glabratus* and *Cystosporites varius* in the Pennsylvanian of Illinois.

The following genera and species were identified from the third sample (maceration 907) of coal taken from coal stringers above the eastern digging in the Makanda Sandstone:

Triletes globosus	(A)
Cystosporites varius	(A)
T. auritus	(C)
T. glabratus	(R)
T. horridus	(R)

T. rotatus ?	(R)
C. verrucosus	(R)

Triletes globosus and *Cystosporites varius* each account for about 45 percent of the total large spore content. *T. glabratus* is not represented again in the Pennsylvanian of Illinois until its occurrence, much higher stratigraphically, in the Carbondale Group.

A coal (maceration 142), identified as "Makanda" (?) or Battery Rock (?) (SE¼ SE¼ sec. 29, T. 10 S., R. 1 W.), Jackson County, contained an assemblage very similar to that of the previously described maceration 906, but with slight difference in abundance ratios and the additional presence of a few spores of *T. subpilosus.*

Reynoldsburg Coal

Large spores were extremely abundant in the Reynoldsburg Coal (maceration 618) from Johnson County, but only a few genera and species were represented. *Triletes globosus* and *Spencerisporites* cf. *S. radiatus* each represented more than 45 percent of the total large spore content. A few spores of *T. globosus* var. (B) and *Cystosporites giganteus* also were present. In addition, the coarse residue contains much cuticle similar to that illustrated by Bartlett (1929). Kosanke (1950) reported that the small spore content of this coal is characterized by a dominance of *Densosporites reynoldsburgensis.*

This is the uppermost occurrence of abundant spores of both *Spencerisporites* cf. *S. radiatus* and those typical of *Triletes globosus.* The assemblage is unlike any found in younger, overlying beds of Tradewater age.

Miscellaneous Samples

The coarse residue from a coal of Caseyville age (maceration 910), sampled from a gob pile around the shaft of an abandoned mine in a fault block zone in Pope County, contained spores of the following genera and species:

Triletes rotatus	(A)
Monoletes	(A)
T. triangulatus	(P)
T. superbus	(R)

This assemblage is unlike that of any other Caseyville age coal examined in that it contains abundant spores of both *T. rotatus* and *Monoletes.*

The following genera and species were identified from a Cannelton Coal (maceration 780) from Perry County, Indiana:

Triletes superbus	(A)
T. auritus	(A)
T. triangulatus	(P)
Spencerisporites cf. *S. radiatus*	(R)
Monoletes	(R)

Another sample from Indiana from a coal in the Mansfield (?) Sandstone (maceration 779), Owen County, Indiana, contained spores of the following genera and species:

Triletes rugosus	(A)
T. cf. *T. hirsutus*	(A)
T. auritus	(R)
Monoletes	(R)
Renisporites? n. gen.	(R)

In Illinois, *T. rugosus* is not known below the Murphysboro, Rock Island (No. 1), and New Burnside Coals of the Tradewater Group; *Renisporites* is restricted to the Tarter and Willis Coals; *T.* cf. *T. hirsutus* is known only from the Tarter, Pope Creek, and Rock Island (No. 1) Coals.

Two samples (macerations 203 and 755) of coaly streaks in sinkhole deposits from Lehigh Quarry in Kankakee County, Illinois, and one sample (maceration 455) from similar deposits in Lincoln Quarry in Will County, Illinois, were examined. All three samples contained aphanozonate spores similar to those of *Triletes fulgens* Zerndt. The sample from Will County also contained abundant seed membranes and at least one spore of *T. rotatus.*

Outcrop samples from fifteen coals of the Black Creek, Mary Lee, and Pratt Groups in the Warrior Basin, Walker County, Alabama, were compared. In general, *Triletes mamillarius, T. subpilosus,* and spores probably referable to *T. globosus* var. (B) are fairly common in some of these coals. Although resin rodlets, usually associated with the Medulloseae, occur sporadically, medullosan spores (*Monoletes*) were not seen. *T. praetextus* is represented abundantly in the Pratt Coal.

On the basis of a study of the small spores of these coals and those from well samples from the Warrior Basin of Mississippi, Cropp (1956) concluded that the coals of the Black Creek, Mary Lee, and Pratt Groups are of the lower Pottsville. It is possible that they are older than the lowermost Pennsylvanian coals of Illinois.

Summary

Although large spores are very abundant in upper Mississippian rocks, only two genera, *Cystosporites* and *Triletes*, are well represented. In contrast, even the lower coals in the Caseyville Group of the Pennsylvanian contain spores referable to five genera: *Cystosporites, Triletes, Calamospora, Spencerisporites,* and *Monoletes* (text fig. 8). In addition, spores definitely assignable to all five sections of *Triletes* are present in Caseyville coals; only those of the section Lagenicula, along with some unassigned to a section, occur in upper Mississippian rocks. Although absence of spores common to the Pennsylvanian should not be relied upon too heavily, as yet none of the medullosan, sigillarian, triangulate, zonate, auriculate, or deltoid-bladdered spores have been observed in Chester rocks.

Caseyville megaspore assemblages indicate a more diverse heterosporous lycopsid flora. *Triletes? corycilis* seems to be restricted to the lowermost Caseyville coal in Illinois (maceration 798) and to the French Lick Coal of Indiana. *T. praetextus* seems to be restricted to the Battery Rock Coal of Illinois and to the shale above the Pinnick Coal of Indiana. *T. globosus* var. (B), *T. subpilosus,* and *T. rotatus* are restricted to the Caseyville Group. *T. glabratus, Cystosporites varius,* and *C. verrucosus* appear high in the Caseyville.

In general, the assemblages of the French Lick Coal and those of the four unnamed coals from the Wabash County cores are similar in character and are distinguishable from those in younger coals of the group. The contrast between the spore assemblages of the Chester and the Caseyville (text fig. 7) is very striking in the Eastern Interior Coal Basin.

TRADEWATER GROUP

The next higher major stratigraphic division of Pennsylvanian rocks, known as the Tradewater Group, encompasses strata from the base of the Grindstaff Sandstone in southern Illinois upward to the base of the Palzo and Isabel Sandstones in southern and western Illinois respectively (Wanless, 1956). The Tradewater Group includes sandstones, shales, coals, and, in contrast to the Caseyville Group, several extensive marine limestones.

Some of the coals, such as the Murphysboro, Rock Island (No. 1), Davis, and DeKoven Coals, are commercially important (Cady, 1952). The maximum thicknesses of the group are 445 feet in southern Illinois, 100 feet in western Illinois, and possibly as much as 600 feet (subsurface) in central Illinois (Weller, 1945). The group is considered generally equivalent to the Krebs and lower Cabaniss Groups of the lower Desmoinesian Series of the Midcontinent region (Wanless, 1956), the upper Pottsville (Kanawha Series) and lower Allegheny of the Appalachian region, and the Westphalian B and C of Europe (Moore et al., 1944; Kremp, 1955).

In terms of floral zones, as defined by Read (1947), the Tradewater Group contains plants from zone 4 (Zone of *Cannophyllites*), from zone 5 (Zone of *Neuropteris tenuifolia*) and from the lower part of zone 6 (Zone of *N. rarinervis*). On the basis of small spore studies, Kosanke (1947, 1950) found the flora more diversified than that of the Caseyville Group. He stated that the dominant genus throughout the Tradewater is *Laevigatosporites*, which is replaced as dominant element by *Lycospora* in only one coal. The subdominant genera are *Granulatisporites, Cirratriradites, Triquitrites,* and *Lycospora. Alatisporites, Cirratriradites, Florinites,* and possibly *Reinschospora* appear for the first time in the Pennsylvanian of Illinois in the Tradewater Group.

The large spore occurrences in coals of the Tradewater Group are based on a study of more than 60 samples from 16 counties in southern, western, and northern Illinois. Unfortunately, the coarse residues of several of the samples that served in part as the basis for the previously reported small spore assemblages (Kosanke, 1950, p. 63-73) were not available.

"Sub-Babylon" Coal

The "Sub-Babylon" Coal, the oldest Pennsylvanian coal in western Illinois, is 2 to 3 inches thick, and lies unconformably above Mississippian strata and below the Babylon Coal. The following species were identified from the "Sub-Babylon" Coal (maceration 144) NE1/4 NE1/4 SE1/4 sec. 2, T. 5 N., R. 1 E., Fulton County:

Cystosporites varius	(A)
Triletes superbus	(C)
T. triangulatus	(R)
C. giganteus	(R)

In addition, many small spore masses, especially those of *Lycospora*, are present. Also present is a spore larger than (158 μ), but quite similar in shape and ornamentation to those described by Kosanke (1950) as *Reticulatisporites irregularis.* These small spores are characteristic of, and apparently restricted to, the "Sub-Babylon" Coal. All the megaspores noted in the "Sub-Babylon" Coal are known from older coals. However, common species of older coals such as *T. subpilosus, T. globosus,* and *Spencerisporites* cf. *S. radiatus* are lacking.

Babylon Coal

The Babylon Coal, about 14 inches thick, is exposed along Spoon River, north of Babylon, in Fulton County, Illinois. Three samples were available from areas near the type section of the Babylon Cyclothem. The assemblage given below is from the Babylon Coal overlying the "Sub-Babylon" Coal just discussed.

The following species were identified from maceration 145A-B:

Cystosporites varius	(P)
Triletes auritus	(P)
T. augustae	(P)
T. triangulatus	(P)

No relative abundance determinations were possible. *T. augustae* is represented in the Pennsylvanian of Illinois for the first time.

Another sample from the Babylon Coal (maceration 588) from Fulton County (NW1/4 NE1/4 NE1/4 sec. 14, T. 7 N., R. 1 E.) lacked spores of *Triletes auritus.* The assemblage also differs from that given above in the occurrence of abundant spores of *Monoletes* and a few of T. *mamillarius, Calamospora* cf. *C. laevigata,* and *Cystosporites breretonensis.* This is the first occurrence of *Cystosporites* spores with the reticulate pattern, although weakly developed here, characteristic of *C. breretonensis.*

The third sample of the Babylon Coal (maceration 523A-B) from Fulton County (NW1/4 NE1/4 NE1/4 sec. 14, T. 7 N., R. 1 E.) lacked spores of both *Triletes augustae* and *Cystosporites varius* and also differed from that given for maceration 145A-B in occurrence of *Monoletes, C. giganteus,* and *Calamospora* cf. *C. sinuosa* (spore fragment only).

The most notable discrepancies between assemblages are those between macerations 523A-B and 588, from samples taken within 600 feet of each other. The only species common to the three samples of the Babylon Coal is *Triletes triangulatus.* The botanically related small spores of *Cirratriradites* appear for the first time in this coal and make up 10 percent of the total small spore content (Kosanke, 1950).

Megaspores in the upper 6 inches of the Babylon Coal (macerations 145B and 523A) are more abundant and represent a more varied flora. *Triletes superbus* is conspicuously absent. The Babylon Coal can be readily distinguished from coals above and below on the basis of megaspores, as well as on the basis of small spores which have indicated (Kosanke, 1950) a vast change in the flora compared with that of the Caseyville coals.

Willis and Tarter Coals

The correlation (Moore et al., 1944) of the Willis Coal from Schneider's mine (NW1/4 SE1/4 sec. 30, T. 10 S., R. 9 E., Gallatin County, [southern] Illinois) with the Tarter Coal (NW1/4 NW1/4 SE1/4 sec. 19, T. 5 N., R. 2 E., Fulton County, [western] Illinois) is supported by the study of small spore assemblages (Kosanke, 1950). The Willis Coal, at the locality cited above, is near its type locality; the Tarter Coal cited above is in the area of the type section of the Tarter Cyclothem. Unfortunately, only the coarse residue of the uppermost inch (maceration 604A) of the Tarter Coal at this locality is now available; that of the lower 12 inches below a 12-inch parting is missing.

The following genera and species were identified from the Willis Coal (maceration 625A-B). Relative abundance notations of coals sampled in two or more segments are listed subsequently in the following order: (top, lower) or (top, middle, lower).

Triletes triangulatus	(A,A)
Renisporites confossus n. sp.	(A,A)
T. brasserti	(C,A)
T. ramosus	(A,C)
T. mamillarius	(A,C)
Cystosporites varius	(A,C)
Spencerisporites cf. *S. radiatus*	(A,P)
Punctatisporites cf. *P. obesus*	(P,C)
Calamospora cf. *C. sinuosa*	(C,P)
T. auritus	(C,R)
T. globosus var. (C)	(C, -)
Monoletes	(R,R)
Cystosporites breretonensis	(-, P)
T. superbus	(R, -)

One other sample of the Willis (?) Coal (maceration 631) did not contain the great diversity of spore types. *T. ramosus* is dominant; *T. mamillarius, T. globosus* var. (C), *Calamospora* cf. *C. sinuosa, S.* cf. *S. radiatus,* and *T. triangulatus* also are represented.

For comparison, the following genera and species were identified from the Tarter Coal (maceration 901), NE¼ sec. 26, T. 9 N., R. 1 W., Warren County, Illinois:

Triletes brasserti	(A)
Renisporites confossus n. sp.	(A)
T. triangulatus	(P)
Punctatisporites cf. *P. obesus*	(P)
Monoletes	(P)
Calamospora cf. *C. laevigata*	(P)
T. ramosus	(R)
Cystosporites varius	(R)
Spencerisporites cf. *S. radiatus*	(R)

Triletes brasserti is the dominant species, accounting for 90 percent of the megaspores. *T. brasserti* also was dominant in the uppermost inch of the Tarter Coal (maceration 604A) at another locality. Species from maceration 604A *not* represented in maceration 901 are *T. auritus, T. appendiculatus?, T.* cf. *T. eregliensis,* and possibly *Calamospora* cf. *C. sinuosa.*

However, one sample (maceration 914) of the Tarter Coal, 6 inches thick, from Mercer County, has a unique assemblage. *Triletes auritus* makes up 95 percent of the large spore assemblage; other genera and species represented are *T.* cf. *T. hirsutus, T. horridus, Spencerisporites* cf. *S. radiatus, Cystosporites,* and *Monoletes.* The assemblage is unlike those of the other samples of Tarter or Willis Coals, but in the dominance of *T. auritus* and the occurrence of *T.* cf. *T. hirsutus* is similar to the assemblage of the overlying Pope Creek Coal from the same locality.

The Willis Coal contains abundant and greatly diverse types of spores. The Tarter Coal, with the exception of the one sample from Mercer County, has a similar but less diversified assemblage, lacking some of the species typical of the Willis Coal, such as *Triletes mamillarius* and *T. globosus* var. (C). The two coals are characterized by an abundance of zonate megaspores. Those of *T. brasserti* even occur in tetrad arrangement in both coals. This species also is known from one sample of the Pope Creek Coal. Triangulate spores are abundant as in the Babylon Coal. Kosanke (1950) reported *Cirratriradites* as the subdominant genus of the Willis and Tarter Coals and that it was present in fair abundance in the Babylon Coal. This occurrence of *Cirratriradites* parallels the high incidence of triangulate megaspores.

Both *Renisporites confossus* and *Punctatisporites* cf. *P. obesus* appear to be restricted to the Willis and Tarter Coals. *Triletes globosus* var. (C) is known only from the two samples of Willis Coal. *Spencerisporites* cf. *S. radiatus* is present or abundant for the first time since its abundant representation in the Reynoldsburg Coal of the Caseyville Group. *Monoletes* or other evidence of medullosans, such as resin rodlets, are not common. The assemblages of the Tarter and Willis Coals are among the most distinctive of any of the Pennsylvanian coals and are readily distinguishable from those of older and younger coals.

Pope Creek Coal

Kosanke (1950) correlated the Delwood Coal in NW¼ NW¼ sec. 3, T. 11 S., R. 6 E., Pope County, with the Pope Creek Coal (maceration 602) in SE¼ SW¼ SE¼ sec. 11, T. 7 N., R. 1 E., Fulton County. Unfortunately, the coarse residue of the Delwood Coal is not now available for examination. The coarse residues studied were from the Pope Creek Coal (5 inches thick) cited above and from the Pope Creek Coal (26 inches thick) from the type locality of the Pope Creek Cyclothem, NE¼ NE¼ SW¼ sec. 33, T. 14 N., R. 2 W., Mercer County, Illinois.

The Pope Creek Coal of Mercer County was prepared and studied in three samples: a basal 4-inch block (maceration 916), a middle 12-inch block (maceration 917), and an upper 8-inch block (maceration 918). Because these samples are from an area close to the type locality of the cyclothem, the following list of genera and species identified from them will serve as the standard for the Pope Creek large spore assemblage:

Triletes auritus	(-, C,C)
Triletes? saturnipunctatus n.sp.	(P,-,C)
Monoletes	(P,R,P)
T. cf. *T. hirsutus*	(-, P,P)
Cystosporites varius	(-, -, P)
C. verrucosus	(-, -, P)
T. triangulatus	(-, P, -)
T. mamillarius	(-, -, R)

Both large and small spores are somewhat less abundant in the Pope Creek Coal than in the Tarter and Willis Coals. The basal 4 inches of the Pope Creek Coal contains a much more varied assemblage than either the middle or upper portions. *Triletes auritus* is dominant; *T.? saturnipunctatus, T.* cf. *T. hirsutus,* and *Monoletes* are subdominant. *T.? saturnipunctatis* apparently is restricted to the Pope Creek Coal.

The Pope Creek Coal is distinguished from the underlying Tarter Coal (maceration 914) at the same locality by the presence of *Cystosporites verrucosus, Triletes triangulatus,* and *T.? saturnipunctatus.* It is similar to the older coal in the continued dominance of *T. auritus* and the common occurrence of spores of *T.* cf. *T. hirsutus.*

The Pope Creek Coal (maceration 602) from Fulton County, contains a different assemblage. The dominant element in this sample is *Triletes augustae;* the subdominant elements are *T. triangulatus* and *T. brasserti.* In addition *Cystosporites giganteus, C. varius,* and *T. mamillarius* are represented. This assemblage is similar to that of the underlying Tarter Coal (maceration 604A) in the common occurrence of spores of *T. brasserti* and *T. triangulatus,* but dissimilar in the species of auriculate megaspores. The Pope Creek Coal of Fulton County differs from that of Mercer County in that it contains abundant spores of *T. augustae* rather than *T. auritus,* no *Monoletes, Triletes? saturnipunctatus, T.* cf *T. hirsutus,* or *C. verrucosus. T. brasserti* is not represented in the Mercer County samples.

Rock Island (No. 1) Coal

The Rock Island (No. 1) Coal is an important commercial coal in the Tradewater Group and is known definitely only in western Illinois. It is typically developed in Rock Island and Mercer Counties and is characterized by lenticular occurrence in narrow channel-shaped areas (Cady, 1952).

The large spore content from the coarse residues of six samples from Henry, Rock Island, McDonough, and Fulton Counties is not uniform in character. The following genera and species were identified from a 14-inch coal (maceration 599A-B,—top of bed not represented), in Fulton County near the type section of the Seville Cyclothem:

Cystosporites varius	(A,A)
Triletes rugosus	(-, A)
Monoletes	(-, C)
C. breretonensis	(-, P)
T. triangulatus	(R, -)
T. auritus	(R, -)
Spencerisporites cf. *S. radiatus*	(R, -)
Calamospora	(-, ?)

Lageniculate megaspores referable to *Triletes rugosus* appear for the first time in the Pennsylvanian of Illinois. Another sample from the same area (maceration 528A-B) contains the same variety of megaspores but seems to have a higher proportion of *Cystosporites breretonensis* than *C. varius*. *Monoletes* spores and *Cystosporites* spores with apical tufts are dominant. Kosanke (1950) noted that *Lycospora*, important in coals above and below the Rock Island (No. 1) Coal, is rare. In contrast, botanically related megaspores of *Cystosporites* and *T. rugosus* are common in this coal.

A 6- to 8-inch coal (maceration 929) from McDonough County differs from the assemblage given above in the dominance of *Triletes* cf. *T. hirsutus* and the subdominance of *T. auritus*. Spores of *Cystosporites varius*, *T. mamillarius*, *T. superbus*, *T. triangulatus*, *T. ramosus*, and *Calamospora* cf. *C. laevigata* also are present in this sample.

Triletes augustae is dominant in the Rock Island (No. 1) Coal from Pryce mine (maceration 627), Rock Island County; from Werner mine (maceration 589), Henry County; and co-dominant with *T. ramosus* in the sample from Bugos White mine (maceration 626), Henry County. *T. augustae* is not known from the other samples of the Rock Island (No. 1) Coal. The only other sample that contained *T. ramosus* is maceration 929 from McDonough County.

In the Werner mine sample (maceration 589) one spore of *Parasporites* was found, representing the first occurrence of that genus in the Pennsylvanian of Illinois. None of these northern Illinois samples contains the smooth lageniculate spores found in the Fulton County samples; spores of *Cystosporites* and *Monoletes* range from rare to present. The lack of *Lycospora* (Kosanke, 1950) in the Rock Island (No. 1) Coal from Henry and Rock Island Counties parallels the lack of lageniculate spores and the lack or extreme rarity of *Cystosporites* spores. The assemblages from the Rock Island (No. 1) Coal of northern Illinois compare relatively closely with that found in the coal at New Burnside (maceration 938) from Johnson County in southern Illinois.

Murphysboro Coal

The Murphysboro Coal in southern Illinois is another commercially important coal in the Tradewater Group (Cady, 1952). The coal ranges from 1 to 7½ feet thick and tends to split into two benches toward the margins of the Murphysboro area to the east and north (Cady, 1952). Its maximum thickness occurs only in Jackson County. Its exact equivalent outside of Jackson and Williamson Counties is unknown.

The following genera and species have been identified from a sample (maceration 550) from the mine dump of the abandoned Brinker mine near Oraville, Jackson County:

Triletes triangulatus	(A)
T. rugosus	(C)
Cystosporites varius	(P)
C. breretonensis	(P)
C. giganteus	(P)
T. auritus	(P)
Monoletes	(R)

The uppermost 12 inches (maceration 608) of the Murphysboro Coal from south of Sato only rarely contains spores of *Cystosporites varius* and *Triletes triangulatus*. Spores of *T. augustae* are common and a few specimens of *Monoletes* are present in maceration 549 from an abandoned slope mine south of Ava. Two samples of Murphysboro Coal (macerations 799 and 800) were given only a cursory examination; *T. triangulatus* and auriculate megaspores were present.

A coal (maceration 915) occurring under the sandstone in the spillway of Crab Orchard Lake dam, NW¼ NW¼ sec. 30, T. 9 S., R. 1 E., Williamson County, has a spore content generally similar to that of the Murphysboro Coal. In this coal *Triletes rugosus* and *Monoletes* are co-dominant; *Cystosporites giganteus* and *T. mamillarius* are represented by only a few spores. The assemblage differs from that of the Murphysboro in its lack of *T. triangulatus* and tufted *Cystosporites* spores.

A coal (maceration 628A-B) below the Curlew Limestone (Weller, Henbest, and Dunbar, 1942, p. 15, fig. 2), NE¼ SE¼ NW¼ sec. 27, T. 10 S., R. 6 E., Saline

County, contains spores of the following genera and species:

Triletes auritus	(A,A)
Monoletes	(C,C)
T. rugosus	(-, A)
Cystosporites giganteus	(-, P)
C. sp.	(R, -)
T. triangulatus	(-, R)
T. mamillarius	(-, R)

This coal differs from that of the Murphysboro in the dominance of *T. auritus* rather than *T. triangulatus* and in the absence of tufted spores of *Cystosporites.*

Cady (1952) suggested that a coal, 4 to 5 feet thick, lying below the Curlew Sandstone near New Burnside, Johnson County, may be the equivalent of the Murphysboro Coal. A sample (maceration 938A-C) from a coal 43 inches thick in a strip mine in that area contains spores of the following genera and species:

Monoletes	(A,P,P)
Triletes augustae	(-, C,A)
T. triangulatus	(R,P,P)
Cystosporites varius	(-, R,A)
T. ramosus	(C, -, -)
T. auritus	(R,R, -)
C. breretonensis	(-, -, P)
C. giganteus	(R, -, -)
T. rugosus	(-, R, -)

In the presence of *Triletes augustae* and *T. ramosus* and the rarity of *T. rugosus,* the assemblage resembles those of the Rock Island (No. 1) Coal from northern Illinois. In the same respect maceration 938A-C differs from most of those from the Murphysboro Coal, except for one or two in which *T. augustae* is represented. This New Burnside sample is the only one in southern Illinois with spores of *T. ramosus* at this general horizon.

Bald Hill Coal

The Bald Hill Coal may be as much as 28 inches thick but it is not considered as important economically as the Rock Island (No. 1), Murphysboro, or some of the overlying coals of the Tradewater Group. It has been suggested, Kosanke (1950) noted, that it is equivalent to the Upper DeLong Coal of western Illinois.

The following genera and species were identified from the Bald Hill Coal (maceration 520A-B) near its type locality, NW¼ SE¼ sec. 25, T. 10 S., R. 4 E., Williamson County:

Triletes auritus	(C, -)
Cystosporites varius	(C, -)
C. breretonensis	(P, -)
T. rugosus	(P, -)
Monoletes	(P, -)
Calamospora cf. *C. laevigata*	(R, -)

This assemblage differs from those of the Murphysboro Coal mainly in the lack of *Triletes triangulatus,* and it differs from the coal bed below the Curlew Limestone (maceration 628A-B) in that tufted *Cystosporites* spores are present. One sample of the lower bench of the Upper DeLong Coal (maceration 527B) from Fulton County was barren of megaspores. One sample of Middle DeLong Coal (?) (maceration 828) from Schuyler County, contained only a few spores of *T. triangulatus* and *Monoletes.* A sample of Upper DeLong (?) Coal (maceration 829) from the same locality contained the same spores as the Middle DeLong (?) and a few spores of *Cystosporites breretonensis.*

Stonefort Coal

The Stonefort Coal lies above the Bald Hill Coal and below the Stonefort Limestone. The coarse residue of this coal (maceration 640) near the type Stonefort Cyclothem, Williamson County, yielded only a few spores of *Monoletes* and *Triletes triangulatus.* An unnamed coal (maceration 639), just above the Stonefort Coal, near the same locality, yielded only a few spores of *Cystosporites giganteus, T. auritus, T. triangulatus,* and more abundant spores of *Monoletes.* The residue of this coal consisted almost entirely of cuticle.

One sample of a 12-inch coal (maceration 554F), questionably the unnamed coal just above the Stonefort Coal, Franklin County, contained a few spores of *Triletes auritus* and *Cystosporites breretonensis.* Another sample of an 11-inch coal (maceration 537Q), also questionably the unnamed coal just above the Stonefort Coal, contained only cuticle and spores of *C. breretonensis.*

Davis and Wiley Coals

The Davis Coal, generally of minable thickness in southeastern Williamson and southern Saline Counties, southeastern Illinois, lies above the Stonefort Limestone and from 15 to 40 feet below the DeKoven Coal. This coal has been correlated with the thin but persistent Wiley Coal of western Illinois (Wanless, 1939; Kosanke, 1950; Wanless, 1955). The Wiley Coal lies above the Seahorne Limestone and below the Greenbush Coal.

The following genera and species were identified from the Davis Coal (maceration 518A-B), Saline County:

Triletes triangulatus	(A, -)
T. rugosus	(P,R)
Monoletes	(P,R)
Cystosporites giganteus	(P, -)
Parasporites	(R, -)
Spencerisporites cf. *S. gracilis*	(-, R)

Two other samples from Franklin County, possibly of the Davis Coal, also were examined; one (maceration 535) contained no identifiable spores, and the other (maceration 554E) contained only a few fragments of cuticle, resin rodlets, and spores of *Monoletes*.

The Wiley Coal (maceration 525A-B), 11 inches thick, Fulton County, has an assemblage remarkably similar, with respect to the variety and relative abundance of spores, to that of the Davis Coal. However, in the Wiley Coal the spores are generally more abundant and, in addition, spores of *Triletes mamillarius* are common and *T. auritus* and *Cystosporites varius* are present. The two coals seem to be characterized by the joint, but rare, occurrence of spores of *Parasporites* and *Spencerisporites* cf. *S. gracilis*.

DeKoven Coal

The DeKoven Coal, 30 to 36 inches thick in Saline and Williamson Counties, overlies the Davis Coal and is the highest named coal in the Tradewater Group of southeastern Illinois. In places it has been cut into or entirely cut out by the Palzo Sandstone, the basal unit of the Carbondale Group. The Greenbush Coal of western Illinois has been correlated with the DeKoven Coal by Wanless (1939), a correlation corroborated by studies of small spores (Kosanke, 1950). Wanless (1955) stated that the Greenbush Coal of western Illinois is generally absent or represented by only a thin film of carbonaceous material.

The following genera and species were identified from the DeKoven Coal (maceration 519A-B), Williamson County:

Triletes triangulatus	(C,P)
Monoletes	(P,P)
Spencerisporites cf. *S. gracilis*	(P,C)
Parasporites	(R,R)
Cystosporites giganteus	(-, R)
C. varius	(-, R)

The DeKoven Coal generally is distinguishable from the underlying Davis Coal by the lack of *Triletes rugosus*. *T. triangulatus* and *Monoletes* seem to be dominant elements in both coals.

A sample of the DeKoven (?) Coal (maceration 554D) from a Franklin County core yielded only rare spores of *Monoletes, Calamospora,* and *Triletes rugosus*. The latter species is unknown from the DeKoven Coal (maceration 519A-B) from Williamson County.

A coal was found about 9 feet above the DeKoven Coal, E½ NE¼ NE¼ sec. 20, T. 10 S., R. 5 E., Saline County. Two hundred feet to the west the coal was absent. The following genera and species have been identified from this unnamed coal (maceration 936):

Triletes rugosus	(P)
T. auritus	(P)
Monoletes	(P)
Cystosporites varius	(R)
T. ramosus ?	(R)

T. triangulatus, Parasporites, and *Spencerisporites* cf. *S. gracilis,* found in the underlying DeKoven Coal, are not represented. *T. rugosus* and *T. auritus* are not known from the DeKoven Coal.

A sample of an unnamed coal 12 inches thick (maceration 35) occurring above the DeKoven Coal in the NW¼ sec. 21, T. 10 S., R. 5 E., Saline County, Illinois, contains an assemblage similar to that of the DeKoven Coal (with one exception) in respect to kinds of spores and to relative abundance of the different types. In general, large spores seem to be more abundant in this unnamed coal, which, in contrast to the DeKoven Coal, contains some spores of *Triletes mamillarius, Calamospora* cf. *C. laevigata,* and one questionably referred to

T. rugosus, but no spores of *Spencerisporites* cf. *S. gracilis,* which are fairly common in the DeKoven Coal.

A pre-No. 2 coal (maceration 621D), penetrated by a rotary drill in Edwards County, has a large spore assemblage much more similar to that of maceration 936 than to that of the DeKoven Coal. This coal does not contain any zonate spores, but contains the others listed for the unnamed coal (maceration 936) 9 feet above the DeKoven Coal. In addition a few spores of *Triletes mamillarius, Cystosporites giganteus,* and possibly one of *T. augustae* are present.

Miscellaneous Coals

Two of the lower coals from the Illinois Clay Products pit near Goose Lake, Grundy County, were examined. The Colchester (No. 2) Coal mined in this area lies above these coals outside the vicinity of the pit.

The lower of the two coals may be as much as 6¾ inches thick and is persistent but somewhat irregular in thickness, thinning to 1½ inches within the area of the pit (Doehler, 1957). The following genera and species were identified from this coal at its maximum thickness (maceration 950A-B):

Monoletes	(A,P)
Triletes superbus	(P,P)
Cystosporites varius	(-, R)
T. mamillarius	(-, R)
T. appendiculatus ?	(-, R)
T. ramosus	(-, R)

The other sample (maceration 949) of this coal contains only one spore of *Spencerisporites,* unidentifiable as to species. *Triletes appendiculatus?* is known from only one other sample, the Tarter Coal (maceration 604A). *T. superbus* is known from the "Sub-Babylon" (maceration 144), Willis (maceration 625A), and Rock Island (No. 1) (maceration 929) Coals.

The upper of the two coals, about 3½ inches thick, is not persistent. Maceration 951 contained only abundant spores of *Monoletes.*

Summary

The lower coals of the Tradewater Group, especially the Tarter and Willis Coals, are characterized by a wide variety of megaspores and a maximum development of some of the zonate spores, such as those of *Triletes brasserti.* In addition *Renisporites* and *Punctatisporites* cf. *P. obesus* seem to be restricted to these coals.

With the exception of one sample of the Tarter Coal (maceration 914), the coals of the Tradewater Group lack spinose lageniculate spores that are so common in the coals of the Caseyville Group. However, the smooth, lageniculate megaspores are prominent in the Rock Island (No. 1), Murphysboro, and younger coals of the Tradewater Group. *Parasporites* and *Spencerisporites* cf. *S. gracilis,* although never abundantly represented, are conspicuous in several of the upper coal beds of the Tradewater Group. *Triletes glabratus,* represented in the "Makanda" Coals of the Caseyville Group and generally conspicuous in the coals of the Carbondale Group, has not been recognized in Tradewater Coals.

CARBONDALE GROUP

The Carbondale Group, next higher stratigraphic division of the Pennsylvanian in Illinois, extends from the base of the Palzo Sandstone in southern Illinois and from the base of the Isabel Sandstone in western Illinois to the base of the Anvil Rock Sandstone. The group, up to 400 feet thick (Cady, 1952), contains more prominent marine limestone than does the Tradewater Group and exhibits a more regular cyclic alternation of beds. Some of the coals are extensive; Colchester (No. 2), No. 5, and Herrin (No. 6) Coals are the commercially important coals of Illinois. The Summum (No. 4) Coal is less extensive and the Briar Hill (No. 5a) Coal is restricted essentially to southeastern Illinois (Kosanke, 1950).

The Carbondale Group is considered generally equivalent to the middle third of the Desmoinesian Series of the Midcontinent region, to the middle portion of the Allegheny Series of the Appalachian region (Wanless, 1955), and to the Westphalian D, at least in part, of Europe (Kremp, 1955). At least the upper part of the group contains the flora of zone 7 (Zone of *Neuropteris flexuosa*) of Read (1947). Bhardwaj (1957) considers the lower part of the Illinois Carbondale Group as the transition zone and Briar Hill (No. 5a) and Herrin (No. 6) Coal as roughly equivalent to seam 1 (Stolberg) of the Saar and to the Velener Schicten (Lower Westphalian D) of the Ruhr.

Discussion of the large spore occurrences is based on a study of 24 samples from eleven Illinois counties. J. M. Schopf's extensive report on the megaspores from Herrin (No. 6) Coal is discussed below and incorporated into the spore distribution chart (text fig. 9). Primary emphasis has been placed on the coals of the Caseyville and Tradewater Groups so that discussion of those coals in the Carbondale and McLeansboro Groups is held to a minimum.

Colchester (No. 2) Coal

Wanless (1955) stated that the Colchester (No. 2) Coal is the most extensive Pennsylvanian coal in the United States. Unlike most other coals in Illinois, it has its maximum development in the northern part of the basin.

The small spore content of the Colchester (No. 2) Coal in northern, western, and southern Illinois is uniform; the floral elements of the thinner coal in southern Illinois are in approximately the same relative abundance as in the thicker Colchester (No. 2) Coal from western and northern Illinois (Kosanke, 1950). Samples of Colchester (No. 2) Coal (and probable No. 2 Coal) from nine localities were examined for large spore content. The variation in megaspore content between these coals is marked.

The following genera and species were identified from the Colchester (No. 2) Coal (macerations 824, 825, and 826), more than 30 inches thick, outcropping in Mill Creek, Schuyler County:

Cystosporites giganteus	(C, A, C)
Monoletes	(P, C, C)
C. varius	(P, C, P)
C. breretonensis	(P, C, P)
Triletes rugosus	(C, -, A)
C. verrucosus	(C, R, P)
T. auritus	(A, -, -)
T. triangulatus	(P, -, -)
Calamospora cf. *C. laevigata*	(P, -, -)

The sample from the bottom portion of the bed is dominated by spores of *Triletes rugosus,* accounting for about 50 percent of the assemblage. *Cystosporites* spores clearly dominate in the middle sample of the bed. *T. auritus* is dominant in and restricted to the upper 2 feet of the coal. *T. triangulatus* and *Calamospora* cf. *C. laevigata* also appear to be restricted to the upper portion of the bed. The high incidence of spores of *T. rugosus* and *Cystosporites* parallels the reported dominance (Kosanke, 1950) of the botanically related small spores of *Lycospora.*

Another outcrop sample of the Colchester (No. 2) Coal 19 inches thick (maceration 603A-C), from Fulton County, contains all the genera and species of macerations 824, 825, and 826, except *Cystosporites verrucosus. Triletes mamillarius* is represented by rare spores in the bottom 4 inches of the bed. In addition to a different megaspore distribution throughout the bed, *Cystosporites* seems to be less well represented.

Another sample of the Colchester (No. 2) Coal (maceration 899) from Fulton County only contains abundant spores of *Monoletes* and rare spores of *Triletes triangulatus.*

Four samples of Colchester (No. 2) Coal from northern Illinois were examined. One (maceration 579A-C) from the Spring Valley No. 3 mine, Bureau County, had representatives of the genera and species given for macerations 824, 825, and 826 above, except *Cystosporites verrucosus* and *Triletes auritus.* In addition, *Parasporites* is known from the lower two-thirds of the bed; however, as in macerations 824, 825, and 826, *Cystosporites* and *Monoletes* are dominant.

Two samples from Grundy County exhibit extreme variations in large spore content. One (maceration 611) contains spores of *Triletes rugosus, Monoletes, Calamospora* cf. *C. laevigata, T. triangulatus,* and *Cystosporites breretonensis. T. rugosus* is dominant; *Monoletes* is subdominant. The other sample from Grundy County (maceration 580) contains fairly abundant spores of *Cystosporites. Monoletes* is rare, in marked contrast to the other samples of Colchester (No. 2) Coal. None of the species of *Triletes* in macerations 824-826 nor *Calamospora* is represented. In contrast to all other samples of the Colchester (No. 2) Coal, *T. augustae* and *Spencerisporites* cf. *S. gracilis* are found in maceration 580.

The fourth sample of this coal (maceration 567), from LaSalle County, contains no megaspores.

Two samples, questionably of the Colchester (No. 2) Coal, from rotary drill samples, Hamilton County, were examined. One (maceration 581), probably is a coal of Tradewater age, in that *Triletes ramosus* with adhering spores of *Densosporites* was identified. The other (maceration 582) contains some of the more common spores found in the Colchester (No. 2) Coal.

All of the genera and species represented in the Colchester (No. 2) Coal occur in some of the underlying coals of the Tradewater Group. Although the assemblages from different localities vary considerably, they appear to differ from those of the upper part of the Tradewater Group by 1) a lower incidence of *Parasporites* and *Spencerisporites,* 2) greater relative abundance of *Cystosporites,* and 3) fewer spores of *Triletes triangulatus.* All the samples are distinguishable from the Summum (No. 4) Coal and the overlying coals of the Carbondale Group by the greater relative abundance of *Cystosporites* and the absence of *T. glabratus* (text fig. 9). *C. verrucosus* is represented in the Indiana Coal IV but is not known to occur in any younger coal.

Indiana Coal IV

The Indiana Coal IV is geographically restricted to an area centering in Greene County, Indiana (Wanless, 1955). It is known to extend into parts of Edgar, Clark, Crawford, and Lawrence Counties of Illinois. This coal occurs between the Colchester (No. 2) and the Summum (No. 4) Coals of Illinois.

The Indiana Coal IV is split in a diamond drill core from Edgar County, Illinois. The thinner (8-inch) lower coal of the split (maceration 881) is dominated by spores of *Triletes rugosus* (80 percent). *Monoletes, Cystosporites varius, C. giganteus,* and *C. verrucosus* also were well represented. The assemblage from this coal is similar in content to that of several samples of the Colchester (No. 2) and in the relative abundance of *Cystosporites, T. rugosus,* and *Monoletes.* In this core the Indiana Coal IV is distinct from the overlying No. 5 and Grape Creek (No. 6) Coals, which contain numerous spores of *T. glabratus* but lack those of *Cystosporites.*

Summum (No. 4) Coal

Summum (No. 4) Coal is extensive in southern Illinois, although commonly only a few inches thick. Its equivalent, Indiana IVa, locally attains a thickness of from 1 to 2 feet in Indiana. This coal, like the Rock Island (No. 1) Coal in western Illinois (Cady, 1952), is lenticular.

The following genera and species were identified from one sample of the Summum (No. 4) Coal (maceration 463), Jersey County:

Triletes triangulatus	(A)
T. glabratus	(C)
T. augustae	(C)
T. mamillarius	(P)
Calamospora cf. *C. laevigata*	(P)
Monoletes	(R)

This assemblage is distinct from those of most samples of the Colchester (No. 2), No. 5, Briar Hill (No. 5a), and Herrin (No. 6) Coals, in its lack of *Cystosporites, Triletes rugosus,* and the relative rarity of *Monoletes. T. glabratus* is abundant for the first time in the Pennsylvanian of Illinois. The only previous occurrence was the few spores found in the "Makanda" Coals of the Caseyville Group. Although *Lycospora* is dominant among the small spores (Kosanke, 1950), none of the megaspores known to be botanically related to *Lycospora* are present in this sample of the Summum (No. 4) Coal.

No. 5 Coals

The No. 5 Coal of Illinois, called Harrisburg (No. 5) in southern Illinois and Springfield (No. 5) in central, western, and northern Illinois, is second to Herrin (No. 6) Coal in commercial importance in Illinois.

The following genera and species were identified from the Springfield (No. 5) Coal (maceration 630), Sangamon County:

Monoletes	(A)
Triletes glabratus	(P)
T. triangulatus	(P)
Cystosporites varius	(P)
T. auritus	(R)
T. rugosus	(R)
T. mamillarius	(R)
Spencerisporites cf. *S. gracilis*	(R)
Calamospora cf. *C. laevigata*	(R)

This sample and another (maceration 583) from Wabash County differ from the Summum (No. 4) Coal in that *T. rugosus* and *Cystosporites* are present. Three samples of the No. 5 Coal contained fairly abundant spores of *T. glabratus*. This species is also noted in two other samples of the No. 5 Coal (macerations 422C and 569D, not listed in table 2).

A diamond drill core sample of No. 5 Coal (macerations 880 and 879) from Edgar County did not contain any spores of *Cystosporites* or *Triletes rugosus* and was similar to the sample of Summum (No. 4) Coal in this respect. It did, however, contain fairly abundant spores of *T. glabratus* and representatives of both *Spencerisporites* and *Parasporites*.

Briar Hill (No. 5a) Coal

Briar Hill (No. 5a) Coal is generally restricted to the southeastern part of the Illinois Basin and is rarely mined.

The following genera and species were identified from the Briar Hill (No. 5a) Coal (maceration 633A-B) from the general area of its type section in Gallatin County, where it is 2 feet thick.

Monoletes	(A, A)
Triletes rugosus	(A, C)
Cystosporites giganteus	(A, -)
C. varius	(A, -)
T. triangulatus	(P, P)
Calamospora cf. *C. laevigata*	(C, -)
Spencerisporites cf. *C. gracilis*	(P, -)
Cystosporites breretonensis	(-, R)
T. glabratus	(-, R)

This assemblage differs from those of the No. 5 Coal in the rarity of spores of *Triletes glabratus*, and in the more abundant occurrence of spores of *T. rugosus* and *Cystosporites*. Only *Calamospora* and *T. rugosus* have been identified from one other sample of Briar Hill (No. 5a) Coal (maceration 507A-B, not listed in table 2).

Herrin (No. 6) Coal

The Herrin (No. 6) Coal is the principal commercial coal of Illinois. It may attain a maximum thickness of 14 feet or more. The extensive study by Schopf (1938) of the megaspores of this coal is well known. His results have been incorporated into the distribution chart (text fig. 9). The dominant elements appear to be *Triletes glabratus, T. rugosus, Monoletes, T. triangulatus, T. mamillarius,* and *Cystosporites.*

A sample (maceration 878) of Grape Creek (No. 6) Coal from Edgar County contained very abundant spores of *Triletes glabratus,* but none of *Cystosporites.*

Apparently *Spencerisporites,* found in two samples of the No. 5 Coal and in one of the Briar Hill (No. 5a) and one of the Colchester (No. 2) Coals, is not represented in the Herrin (No. 6) Coal. The larger spores of *Calamospora,* noted in several samples of the No. 2 Coal, the Summum (No. 4) Coal, and in one sample of both the No. 5 and No. 5a Coals, also are missing.

Parasporites is common for the first time since its occurrence in an unnamed coal above the DeKoven Coal of the Tradewater Group, although scattered occurrences are noted in the No. 2 and No. 5 Coals.

Summary

The coals of the Carbondale Group, above the Colchester (No. 2) Coal and the Indiana Coal IV, are distinguished from older coals by a fairly abundant occurrence of both the spinose and smooth aphanozonate megaspores. Spores of *Triletes glabratus* first occur in "Makanda" Coals of the Caseyville Group, are absent from coals of the Tradewater Group and from Colchester (No. 2) Coal and Indiana Coal IV, but reoccur, at many places in great abundance, in the younger coals of the Carbondale Group. Spores typical of *T. auritus* are not as common in the Carbondale coals as they are in some of the Tradewater coals. Spores of the section Zonales of *Triletes* apparently are not represented in the Carbondale and younger coals.

MC LEANSBORO GROUP

The McLeansboro Group is the uppermost group of the Pennsylvanian in Illinois. The base of the group is defined as the base of the Anvil Rock Sandstone. The group is more than 1200 feet thick and is composed predominantly of shales, siltstones, and sandstones, with numerous marine limestones and thin lenticular coals. Cady (1952) noted the presence of from 22 to 27 coals or coal horizons within the group. Of these, the Jamestown, Danville (No. 7), Friendsville, and Trowbridge Coals are of economic importance.

The group is considered to correspond to the upper third of the Desmoinesian Series, the Missourian Series, and possibly to part of the Virgilian Series, all of the Midcontinent region; to the upper Allegheny and Conemaugh Series of the Appalachian Basin (Wanless, 1955); and possibly to part of the Westphalian D and Lower Stephanian of Europe (Kremp, 1955).

Kosanke (1950) noted a major change in the flora shortly after the beginning of McLeansboro deposition but prior to the deposition of the Trivoli (No. 8) Coal. No species of *Lycospora* is known from the Trivoli (No. 8) Coal nor from overlying coals. The change essentially conforms to the Desmoinesian-Missourian boundary of the Midcontinent region and agrees with a major faunal change discussed by Dunbar and Henbest (1942).

Only 14 samples of McLeansboro coals or coaly streaks, principally from six counties in south-central Illinois, have been examined. Most of the samples are from units overlying the Trivoli (No. 8) Coal, or in other words, occurring above the major floral change discussed by Kosanke (1950). The sequence in which the units are listed on the distribution chart (text fig. 9) should be regarded as tentative because many stratigraphic problems in the McLeansboro Group have not yet been resolved.

Each of the assemblages given on the distribution chart represents a single sample from each unit given; therefore, discussion of these assemblages is unnecessary. In addition to the strata shown on the distribution chart, a few slides from three other units were examined. *Parasporites, Monoletes, Triletes triangulatus,* and *T. glabratus* are known from the Danville (No. 7) Coal. *T. glabratus, Monoletes,* and auriculate spores are known from the Macoupin Coal. *Monoletes* and auriculate spores also are known from the Flannigan Coal. Because the total assemblages from these coals were not examined, they have not been given on the distribution chart.

In contrast to the occurrence of *Triletes mamillarius* in some of the coals of the Carbondale Group, the species is not represented in the McLeansboro Group. Neither *T. rugosus,* except for one questionable specimen, nor *Cystosporites* is known from the Trivoli (No. 8) or younger coals. This parallels the absence of the small spores of *Lycospora.* However, lageniculate-type spores, *T. levis,* are very common in upper McLeansboro coals.

In general, the upper McLeansboro coals —Trivoli (No. 8) and those above—seem to be characterized by the presence of common cuticles, seed membranes, the rather small large spores of *Parasporites, Monoletes, Spencerisporites,* and *Calamospora*; megaspores of *Triletes glabratus* and *T. levis* and of the auriculate type; and by rather rare occurrences of the triangulate megaspores.

DISCUSSION

UPPER MISSISSIPPIAN

Published studies concerning plant megaspores of Mississippian age from localities in North America are few (Chaloner, 1954b, three samples at three localities; Schemel, 1950a, one sample). Even the small spore studies have been neglected, mainly for economic reasons, although not to as great an extent since oil companies have increased their interest in this phase of paleobotany (for example, Hoffmeister, Staplin, and Malloy, 1955). More published studies, at least in part dealing with some of the older coals, are available from Europe (Dijkstra, 1952b; Nowak and Zerndt, 1936; Zerndt, 1934, 1937a; Horst, 1955; Potonié and Kremp, 1955, 1956) because many of their older coals are of commercial importance.

Schemel (1950a) reported the occurrence of spores of *Triletes agninus* (Zerndt), Schopf, Wilson, and Bentall and a single specimen referred to *T. radiatus* Zerndt (*T. radiosus* Schopf, Wilson, and Bentall) from a coal of Chester or Springer age in Utah. Zerndt (1937a) originally described spores of these species and of *T. splendidus* (Zerndt) Schopf, Wilson, and Bentall from the Dinantian and Namurian A of the Upper Silesian Coal Basin of Poland. All three species have about the same stratigraphic range in this basin. Although a few spores of *T. splendidus* were found in the uppermost Chester sample examined, neither of the two species reported by Schemel (1950a) was represented.

Chaloner (1954b) described megaspores of probable Osage or Kinderhook age and some from the Beaver Bend Limestone in the lower part of the Chester Series in Indiana. Spores reported from the Beaver Bend Limestone are those of *Triletes subpilosus* forma *major, T. indianensis, T. echinoides, T. paleocristatus* (Chaloner, 1956b), and *Cystosporites giganteus.* All except the latter two species of *Triletes* were represented in the coal in the Bethel (Mooretown) Formation of Kentucky, and *T. echinoides* was noted, as occurring sporadically, higher in the section. No specimens of *T. paleocristatus* were seen during this investigation. Only spores of *T. indianensis* seem to be restricted to the lower part of the Chester; *Didymosporites* is apparently abundantly represented only in the lower part of the Chester; spores of both *T. subpilosus* forma *major* and *C. giganteus* occur, at some places abundantly, throughout the Chester, the latter species alone extending up into Pennsylvanian rocks. Spores other than those described by Chaloner also were found; several of them, or of closely related forms, occur in the lowermost Pennsylvanian coals of Illinois.

Chaloner's interpretation of a lepidodendrid-lepidocarp flora, based on megaspores, is still applicable to the Chester as a whole. From what is known of cone studies, Chaloner's interpretation implies a great abundance of the small spores of *Lycospora* in the Chester Series and this is borne out by the study of Hoffmeister, Staplin, and Malloy (1955) on the Hardinsburg Formation.

PENNSYLVANIAN

The spores reported by Arnold (1950) from the Michigan Basin, with the exception of *Triletes rugosus,* compare favorably with those found in coals from the Makanda Sandstone of the Caseyville Group up to and in Pope Creek Coal of the Tradewater Group in Illinois. The species from Arnold's localities 9 and 11 may occur in Illinois Caseyville coals; most, except *T. rugosus* and possibly *T. ramosus,* from his localities 1, 8, and 10, also are known from the "Makanda" Coals of Illinois. *T. brasserti,* from Arnold's localities 4 and 6, is known in Illinois only from the Tarter, Willis, and Pope Creek Coals of the Tradewater Group. In general terms, therefore, the spores described from the Michigan Basin by Arnold (1950) are similar to those commonly found in coals of the upper part of the Caseyville Group and the lower part of the Tradewater Group.

Bailey (1936), in a description of microfossils from the shales of the Cherokee Formation and lower part of the Henrietta Formation of central Missouri, illustrated and discussed a few megaspores. His illustrations imply that he found spores of *Triletes auritus* and *T. mamillarius* in a sinkhole or channel-fill deposit at the base of the Pennsylvanian section, spores of *T. augustae* from the Bevier (?) Coal, *Cystosporites?* and weakly to strongly apiculate aphanozonate megaspores from the Tebo Coal. Abortive and small, apiculate aphanozonate megaspores are illustrated from the Mulky Coal. In general, the stratigraphic occurrences of the spores that Bailey illustrated are concordant with the occurrence of similar spores in the coals of the Illinois Basin.

A discussion of Schopf's (1936a, 1936b, 1938) extensive studies on the megaspores of the Herrin (No. 6) Coal of Illinois has been included in previous discussion of that coal. The assemblage of that coal is more or less typical of those assemblages in the upper coals of the Carbondale Group but differs in some respects and may prove to be distinguishable.

The only previous comprehensive study of megaspore occurrences throughout the Pennsylvanian of North America is that by Cross (1947) on the spore floras of West Virginia and Kentucky. Using Cross' chart (1947, fig. 2, p. 287), showing spore distribution for West Virginia and Kentucky, some general comparisons can be made with the megaspore occurrences known from Illinois coals.

Cross found smooth aphanozonate spores (in particular those of *Triletes glabratus*, s. l.) in the Lower War Eagle Coal and a few coals in the upper part of the Pottsville Series, but they seem to occur with some regularity, from coal to coal, in and above the Upper Freeport Coal. These occurrences parallel the marked abundance of these spores in the upper part of the Carbondale Group and in the McLeansboro Group of Illinois.

Spinose lageniculate spores apparently are found in some coals of the Pottsville Series but are not known to occur above the No. 5 Block Coal in the lower part of the Allegheny Series. In Illinois, distinctly spinose lageniculate spores are unknown above the Tarter Coal of the Tradewater Group. Smooth lageniculate spores of the *Triletes rugosus* (s. l.) type occur with regularity in the upper coals of the Pottsville Series. This also may parallel their sudden occurrence in, and more or less common occurrence above, the coals of the upper part of the Tradewater Group. Spores similar to those described as *T. levis* and questionably referred in this report to the section Lagenicula were reported by Cross from the Waynesburg Coal in the upper part of the Monongahela Series. Dijkstra (1958) reported similar spores from the Lawrence Shale of Kansas. These spores are typical of the upper portion of the McLeansboro Group in Illinois.

Zonate megaspores are not known with certainty above the No. 5 Block Coal; their most common occurrences appear to be restricted to the Pottsville Series. These spores are not known from Illinois coals above the top of the Tradewater Group.

Triangulate and auriculate megaspores occur sporadically from the Cedar Grove Coal in the Pottsville Series throughout the Pennsylvanian of West Virginia and Kentucky. These megaspores also occur, more or less, throughout the Pennsylvanian of Illinois.

Cross also noted the presence of spores of genera other than *Triletes*. He did not record the presence of *Cystosporites* above the Pittsburgh Coal at the base of the Monongahela Series. The genus occurs through upper Mississippian and most of the Pennsylvanian of Illinois, but is not represented in the upper portion of the McLeansboro Group. *Monoletes* is reported only from the Buffalo Creek and Coalburg Coals of the Pottsville Series although it is represented in most of the coals in the Pennsylvanian of Illinois. Spores, probably of *Spencerisporites*, are noted as occurring up to the lower part of the Allegheny Series. The genus is represented sporadically throughout the Illinois Pennsylvanian.

More detailed comparisons and conclusions are left to the reader. These will necessarily vary depending on each individual's opinion on the circumscription of the various taxa. As more studies on both small and large spores are completed, a clearer total picture of floral elements and their areal and stratigraphic distribution should emerge.

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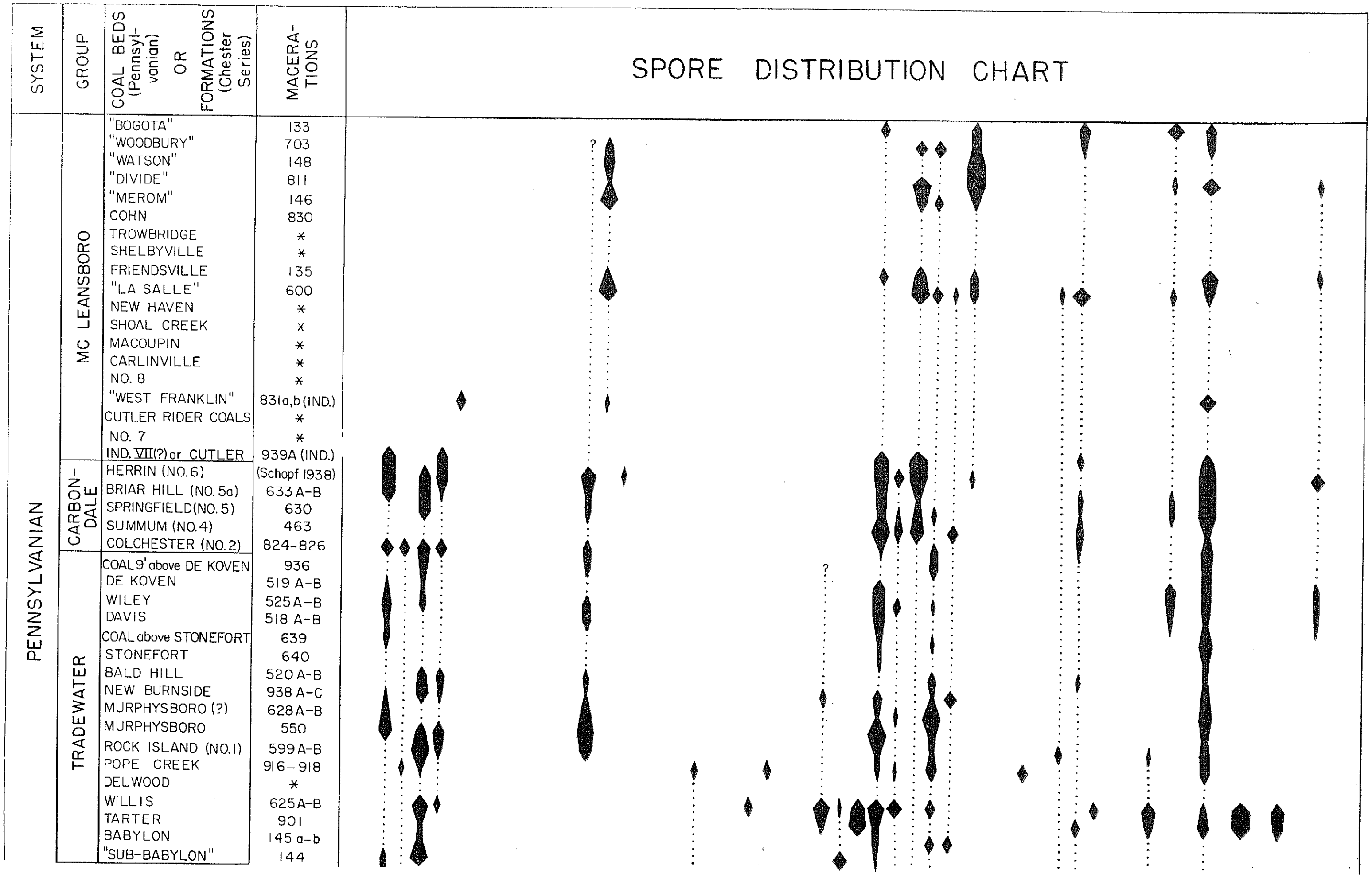
SPORE DISTRIBUTION CHART
SYSTEM
GROUP
COAL BEDS (Pennsylvanian) OR FORMATIONS (Chester Series)
MACERATIONS
PENNSYLVANIAN
MC LEANSBORO
CARBONDALE
TRADEWATER
"BOGOTA" 133
"WOODBURY" 703
"WATSON" 148
"DIVIDE" 811
"MEROM" 146
COHN 830
TROWBRIDGE *
SHELBYVILLE *
FRIENDSVILLE 135
"LA SALLE" 600
NEW HAVEN *
SHOAL CREEK *
MACOUPIN *
CARLINVILLE *
NO. 8 *
"WEST FRANKLIN" 831a,b (IND.)
CUTLER RIDER COALS *
NO. 7 *
IND. VII(?) or CUTLER 939A (IND.)
HERRIN (NO. 6) (Schopf 1938)
BRIAR HILL (NO. 5a) 633 A-B
SPRINGFIELD (NO. 5) 630
SUMMUM (NO. 4) 463
COLCHESTER (NO. 2) 824-826
COAL 9' above DE KOVEN 936
DE KOVEN 519 A-B
WILEY 525 A-B
DAVIS 518 A-B
COAL above STONEFORT 639
STONEFORT 640
BALD HILL 520 A-B
NEW BURNSIDE 938 A-C
MURPHYSBORO (?) 628 A-B
MURPHYSBORO 550
ROCK ISLAND (NO. 1) 599 A-B
POPE CREEK 916-918
DELWOOD *
WILLIS 625 A-B
TARTER 901
BABYLON 145 a-b
"SUB-BABYLON" 144
?
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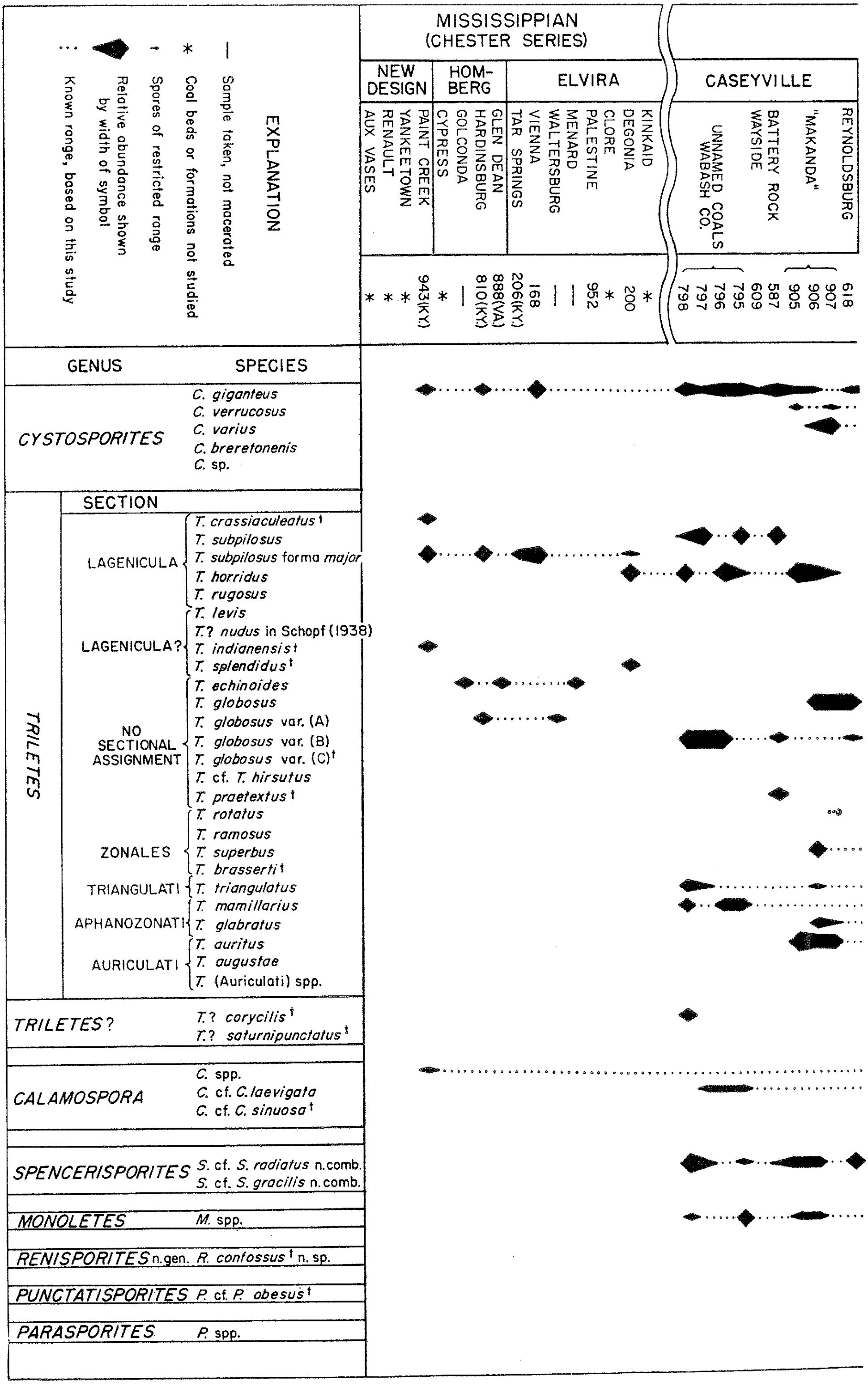


TEXT FIG. 9.—Chart showing distribution of Pennsylvanian and Mississippian megaspores. *Cystosporites* sp. occurs in the Murphysboro (?) Coal (maceration 628A) although not so indicated on this chart.

PLATES

AND

EXPLANATIONS

PLATE 1

All specimens photographed with transmitted light. Color of filter, when used, indicated.

Triletes subpilosus forma *major* (Dijkstra) ex Chaloner . . . . p. 18

FIGURE

1. Characteristic lateral compression with lips partially torn. Total length 1610 μ. Maceration 943 slide 5, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Red filter, same scale as figure 8, (x30).

2a. Smaller spore with more delicate spines. Slightly oblique compression. Maceration 943 slide 6, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Red filter, same scale as figure 8, (x30).

2b. Same spore, detail of spines. Same scale as figures 4, 7b, (x150).

3. Spore with strap-like (preservational?) spines. Slightly oblique compression. Maceration 943 slide 6, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Red filter, same scale as figure 8, (x30).

4. Closely spaced spines of small immature spore. Spines about 154 μ in length with cup-shaped terminations. Maceration 943 slide 9, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Scale indicated below figure, (x150).

5. Broken spore. Spines up to 124 μ in length. Maceration 943 slide 12, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Red filter, same scale as figures 4, 7b, (x150).

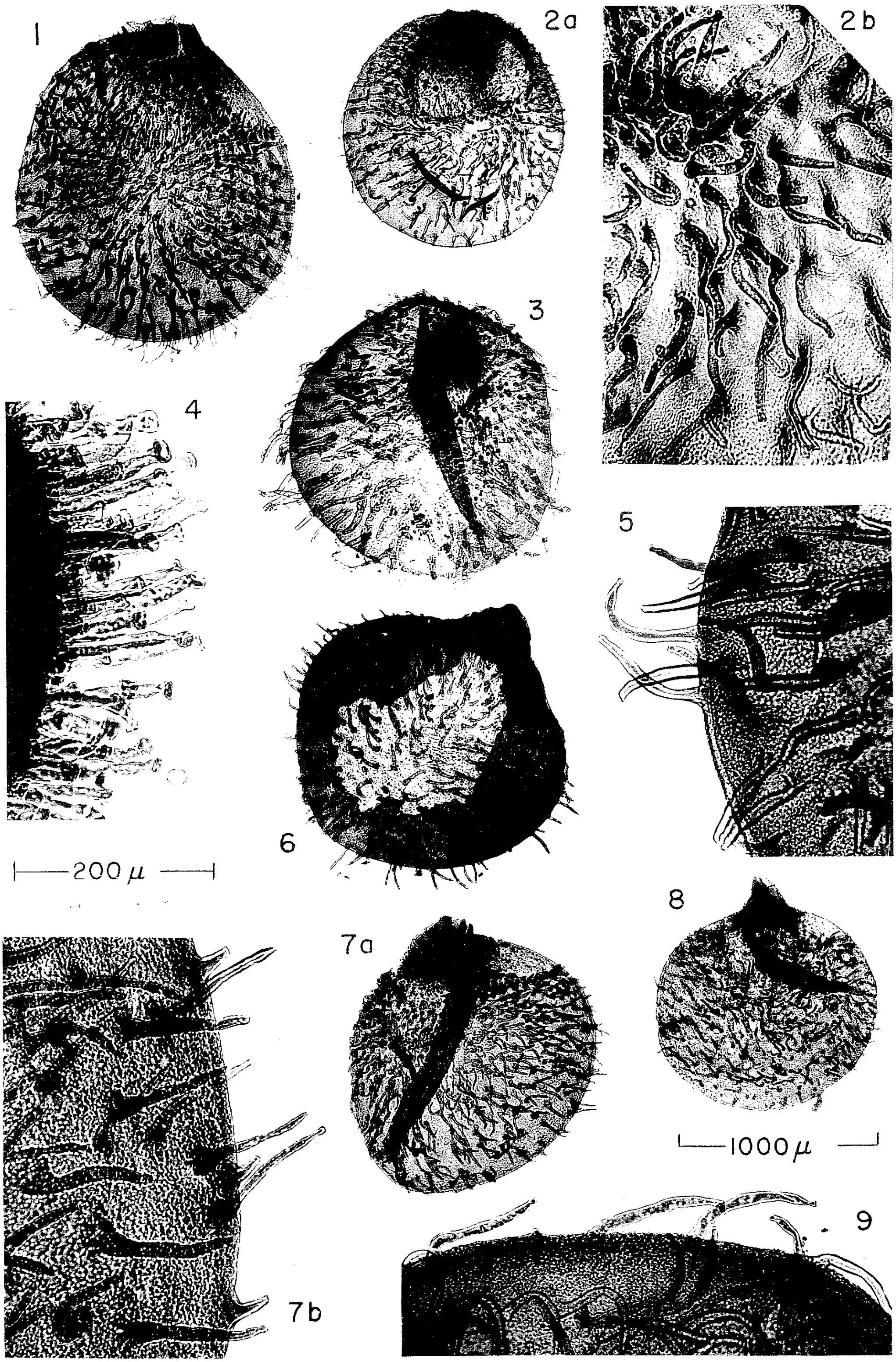
6. Partially broken spore. Lateral compression. Total length 1480 μ. Spines sharper, more delicate, and more closely spaced towards apex. Maceration 810 slide 11, coal in the Hardinsburg Formation, Crittenden County, Kentucky. Red filter, same scale as figure 8, (x30).

7a. Lateral compression. Total length 1385 μ. Maceration 166 slide XXII (5. 6. 7), coal in Hardinsburg Formation, Johnson County, Illinois. Red filter, same scale as figure 8, (x30).

7b. Same spore, detail of spines. Red filter, scale indicated above figure, (x150).

8. Lateral compression. Total length 1170 μ. Maceration 687A slide 1, coal in the Vienna Formation, Johnson County, Illinois. Red filter, scale indicated below figure, (x30).

9. Spines about 124 μ in length. Maceration 200 slide 2, in Degonia Formation, Pope County, Illinois. Red filter, same scale as figures 4, 7b, (x150).


1
2a
2b
3
4
5
6
200 μ
7a
7b
8
1000 μ
9

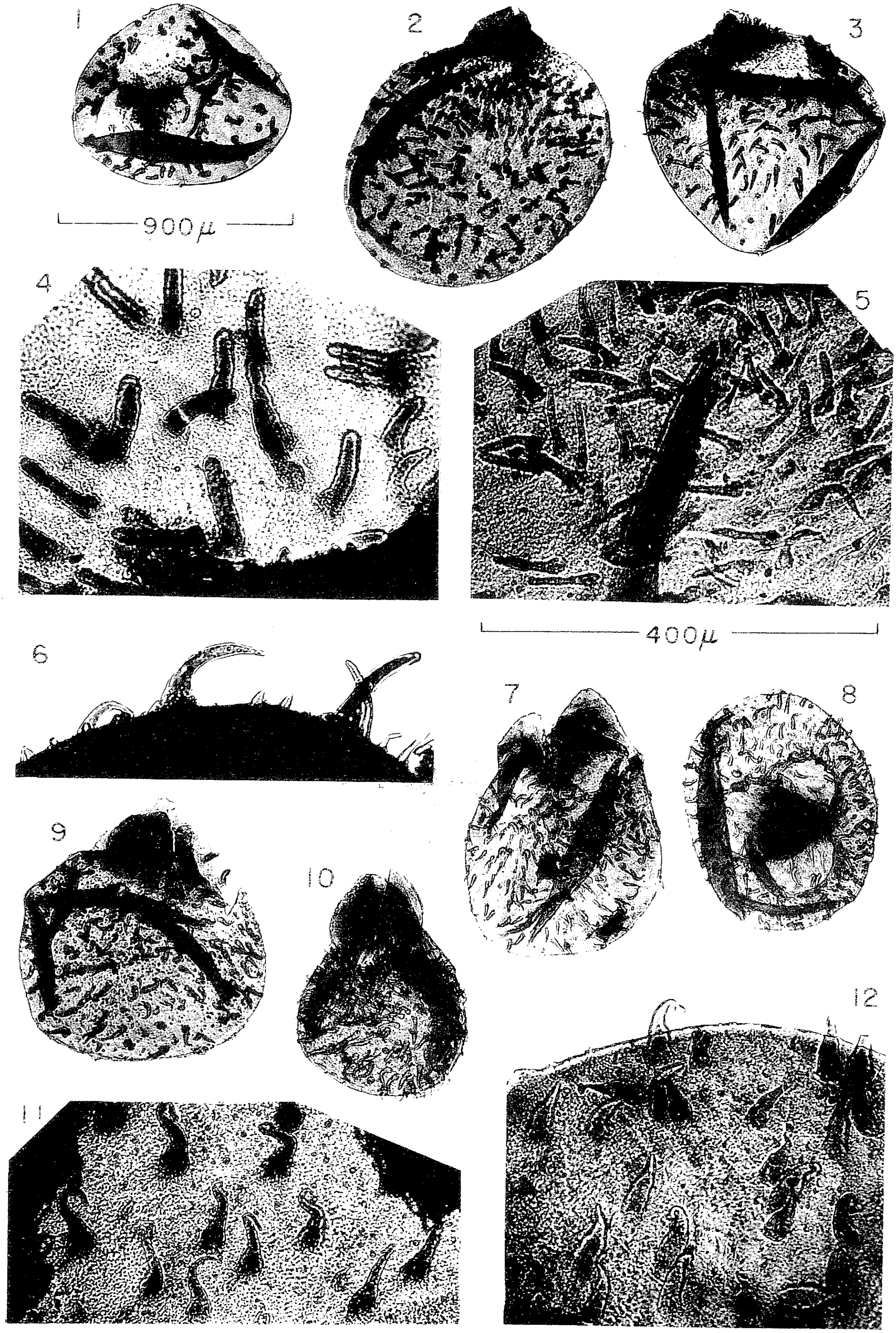

1
2
3
900μ
4
5
400μ
6
7
8
9
10
11
12

PLATE 2

All specimens photographed with transmitted light. Color of filter, when used, indicated.

Triletes subpilosus (Ibrahim) Schopf, Wilson, and Bentall (sensu Dijkstra) . p. 17

FIGURE

1. Proximo-distal compression. Diameter 840 μ. Maceration 795 slide 6, coal in Caseyville Group, Wabash County, Illinois. Red filter, scale indicated below figure, (x40).
2. Lateral compression. Apical prominence and contact area spines characteristically developed. Maceration 795 slide 4, coal in Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 1, (x40).
3. Lateral compression. Width 940 μ. Maceration 795 slide RMK, coal in Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 1, (x40).
4. Detail of stout spines. Maceration 587 slide 3, Battery Rock Coal, Hardin County, Illinois. Red filter, same scale as figure 5, (x150).
5. More delicate spines. Maceration 797 slide 3, coal in Casevville Group, Wabash County, Illinois. Red filter, scale indicated below figure, (x150).

Triletes horridus (Zerndt) Schopf, Wilson, and Bentall (sensu Dijkstra) . . p. 20

6. Side view of large and subsidiary spines. Maceration 200 slide 3, in Degonia Formation, Pope County, Illinois. Red filter, same scale as figure 5, (x150).
7. Lateral compression with delicate spines. Total length 1045 μ. Maceration 905 slide 2, "Makanda" Coal, Jackson County, Illinois. Red filter, same scale as figure 1, (x40).
8. Proximo-distal compression. Diameter 920 μ. Maceration 905 slide 2, "Makanda" Coal, Jackson County, Illinois. Red filter, same scale as figure 1, (x40).
9. Characteristic lateral compression. Total length 1010 μ. Maceration 905 slide 2, "Makanda" Coal, Jackson County, Illinois. Red filter, same scale as figure 1, (x40).
10. Lateral compression. Smaller spore with more closely spaced spines, but with apical prominence of normal size. Total length 865 μ. Maceration 907 slide 6, "'Makanda" Coal, Jackson County, Illinois. Red filter, same scale as figure 1, (x40).
11. Detail of characteristically developed well preserved spines. Small subsidiary spines present. Maceration 796 slide 6, coal in Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 5, (x150).
12. Detail of slightly worn spines. Small subsidiary spines present. Maceration 905 slide 2, "Makanda" Coal, Jackson County, Illinois. Red filter, same scale as figure 5, (x150).

PLATE 3

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes horridus (Zerndt) Schopf, Wilson, and Bentall (sensu Dijkstra) . . p. 20

FIGURE

1. Slightly oblique compression. Maceration 914 slide 2, Tarter Coal, Mercer County, Illinois. Reflected light, same scale as figure 12, (x40).

Triletes crassiaculeatus (Zerndt) Schopf, Wilson, and Bentall . . . . . . p. 21

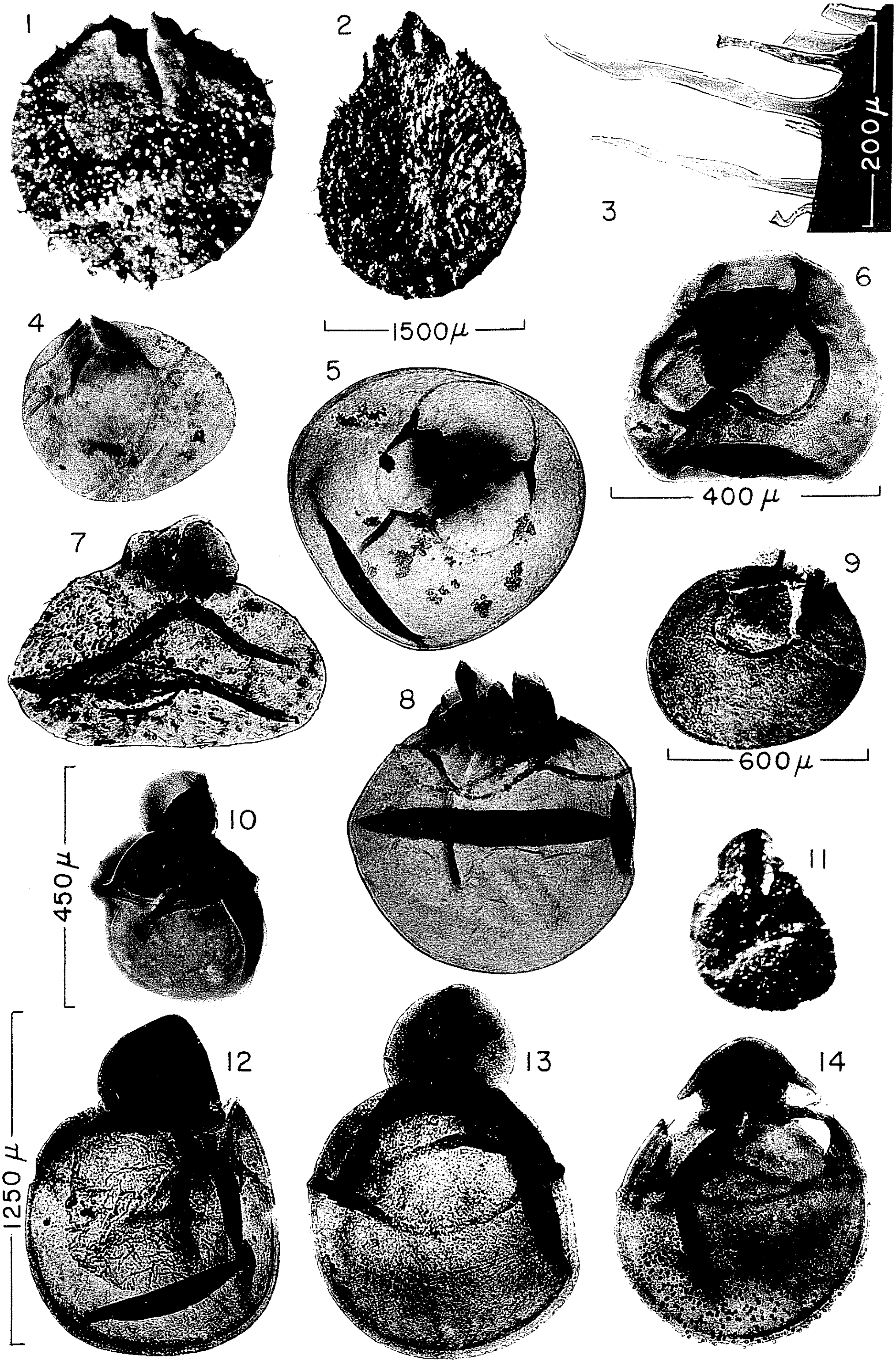
2. Lateral compression. Lips partially torn away. Total length 2155 μ. Maceration 943 slide 2, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Reflected light, scale indicated below figure, (x20).
3. Spines up to 288 μ in length. Maceration 943 slide 9, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Red filter, scale indicated at right of figure, (x150).

Triletes rugosus (Loose) Schopf (sensu Dijkstra) . . . . p. 22

4. Slightly oblique compression. Greatest dimension 645 μ. Spore coat thin. Maceration 599B slide 5, Rock Island (No. 1) Coal, Fulton County, Illinois. Same scale as figure 9, (x50).
5. Slightly oblique proximo-distal compression. Diameter 895 μ. Maceration 825 slide 3, Colchester (No. 2) Coal, Schuyler County, Illinois. Red filter, same scale as figure 9, (x50).
6. Small example. Diameter 410 μ. Maceration 599B slide 7, Rock Island (No. 1) Coal, Fulton County, Illinois. Scale indicated below figure, (x100).
7. Lateral compression. Spore coat ornamented with small spines. Greatest dimension 950 μ. Maceration 599B slide 5, Rock Island (No. 1) Coal, Fulton County, Illinois. Red filter, same scale as figure 9, (x50).
8. Lateral compression. Lips open. Arcuate ridges well defined. Total length 955 μ. Maceration 825 slide 3, Colchester (No. 2) Coal, Schuyler County, Illinois. Red filter, same scale as figure 9, (x50).
9. Oblique compression. Lips open. Maceration 915 slide 3, Murphysboro (?) Coal, Williamson County, Illinois. Scale indicated below figure, (x50).

Triletes levis (Zerndt) Schopf, Wilson, and Bentall . . . . p. 24

10. Lateral compression of small example with relatively thick arcuate ridges and prominent trilete rays. Total length 445 μ. Maceration 600 slide 8, "LaSalle" Coal, Bureau County, Illinois. Scale indicated at left of figure, (x80).
11. Typical lateral compression. Total length 710 μ. Maceration 703 slide 1, "Woodbury" Coal, Cumberland County, Illinois. Reflected light, same scale as figure 12, (x40).
12. Lateral compression with inner membrane. Total length 1305 μ. Maceration 136, Friendsville (?) Coal, Wabash County, Illinois. Red filter, scale indicated at left of figure, (x40).
13. Lateral compression with characteristic outline. Contact areas relatively large. Apical prominence dense. Total length 1400 μ. Maceration 136, Friendsville (?) Coal, Wabash County, Illinois. Red filter, same scale as figure 12, (x40).
14. Lateral compression. Spore coat ornamented with small tubercles. Lips split apart midway between their extremities and apex. Total length 1175 μ. Maceration 148, "Watson" Coal, Effingham County, Illinois. Red filter, same scale as figure 12, (x40).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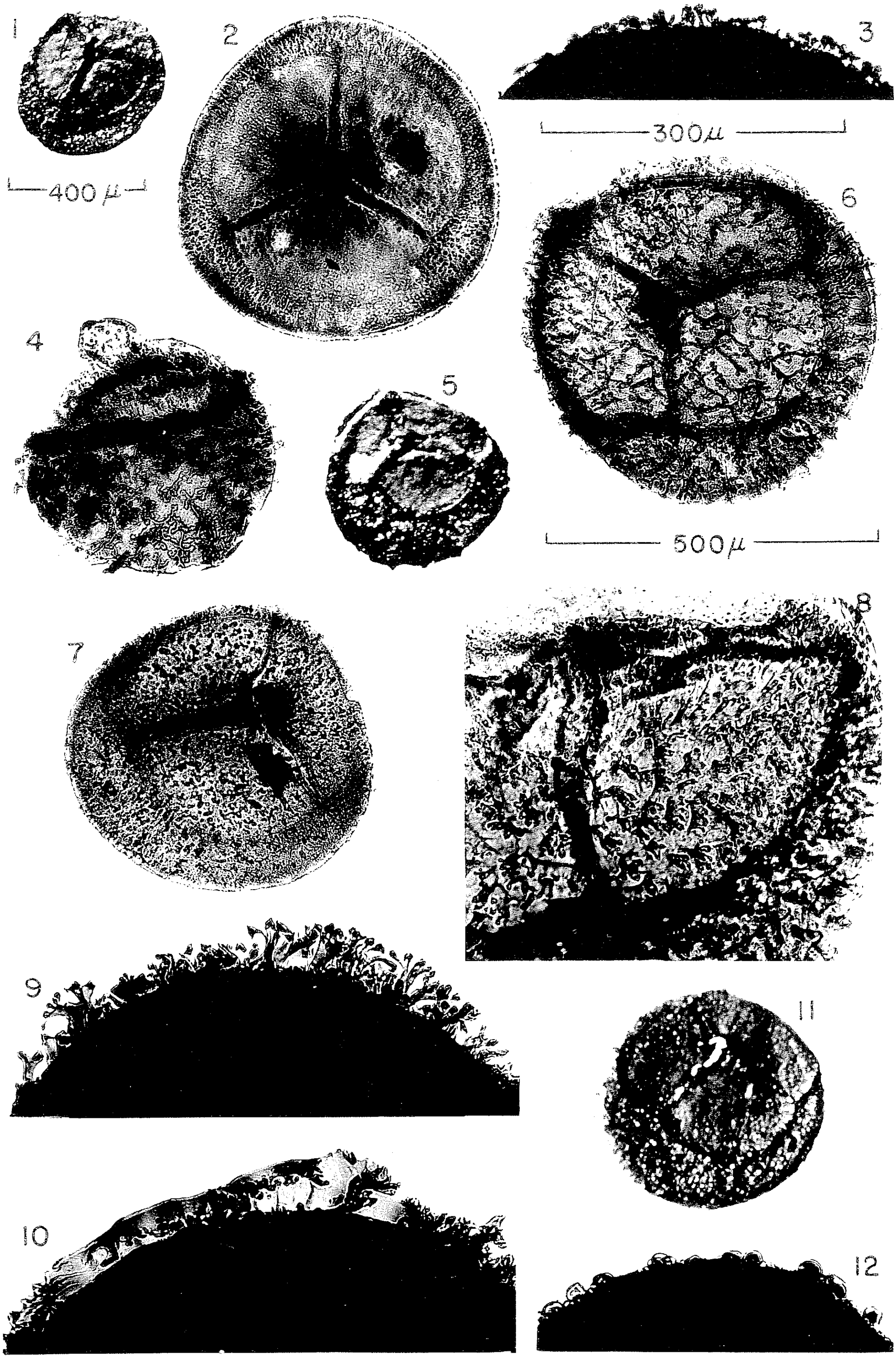
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300μ
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500μ
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PLATE 4

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes globosus Arnold var. (A) . . . . p. 43

FIGURE

1. Proximo-distal compression. Radiating ridges vaguely developed on contact areas. Diameter 480 μ. Maceration 810 slide 12, coal in the Hardinsburg Formation, Crittenden County, Kentucky. Reflected light, scale indicated below figure, (x50).
2. Characteristic proximo-distal compression. Diameter 495 μ. Maceration 810 slide 2, coal in the Hardinsburg Formation, Crittenden County, Kentucky. Red filter, same scale as figure 6, (x100).
3. Maximum spine development observed. Spines up to 22 μ in length. Maceration 810 slide 7, coal in the Hardinsburg Formation, Crittenden County, Kentucky. Green filter, scale indicated below figure, (x150).

Triletes globosus Arnold var. (B) . . . . p. 44

4. Lateral half of spore showing spinose contact area and lips. Total length 420 μ. Maceration 798 slide 12B, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 6, (x100).
5. Proximo-distal compression. Maximum dimension 570 μ. Maceration 798 slide 3, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Reflected light, same scale as figure 1, (x50).
6. Proximo-distal compression. Characteristic development of distal ornamentation and flange. Maximum diameter 555 μ. Maceration 798 slide 11, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, scale indicated below figure, (x100).
7. Proximo-distal compression, apparently abraded. Maximum dimension 470 μ. Maceration 796 slide 7, coal in Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 6, (x100).
8. Detail of spines. Maceration 798 slide 2RMK, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 3, (x150).
9. Extreme development of distal ornamentation. Spines up to 57 μ in length. Maceration 798 slide 1RMK, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Green filter, same scale as figure 3, (x150).
10. Same spore. More or less solid flange, folded over in part, up to 53 μ in width. Green filter, same scale as figure 3, (x150).

Triletes globosus Arnold var. (C) . . . . p. 45

11. Characteristic proximo-distal compression. Maximum diameter 685 μ. Maceration 631 slide 1, Willis (?) Coal, Gallatin County, Illinois. Reflected light, same scale as figure 1, (x50).
12. Detail of ornamentation. Tubercles up to 23 μ in diameter. Maceration 625A_1, slide 14, Willis Coal, Gallatin County, Illinois. Red filter, same scale as figure 3, (x150).

PLATE 5

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes globosus Arnold . . . . p. 42

FIGURE

1. Proximo-distal compression. Radiating ridges only vaguely developed on contact areas. Diameter 545 μ. Maceration 618 slide 2, Reynoldsburg Coal, Johnson County, Illinois. Reflected light, scale indicated below figure, (x50).
2. Detail of rather stout spines. Maceration 909 slide 9, Battery Rock Coal, Pope County, Illinois. Red filter, same scale as figures 3, 5, (x150).
3. Detail of spines. Maceration 618 slide 6, Reynoldsburg Coal, Johnson County, Illinois. Red filter, scale indicated below figure, (x150).
4. Fragment showing lips, torn apical prominence, and ornamentation of contact area and distal surface. Maceration 909 slide 5, Battery Rock Coal, Pope County, Illinois. Red filter, scale indicated below figure, (x100).
5. Deeply cleft spines up to 41 μ in length. Maceration 906 slide 5, "Makanda" Coal, Jackson County, Illinois. Green filter, scale indicated above figure, (x150).
6. Detail of ornamentation. Maceration 929 slide 6, Rock Island (No. 1) Coal, McDonough County, Illinois. Green filter, same scale as figures 3, 5, (x150).

Triletes cf. *T. hirsutus* (Loose) Schopf, Wilson, and Bentall . . . . . . p. 45

7. Detail of characteristic ornamentation. Maceration 929 slide 6, Rock Island (No. 1) Coal, McDonough County, Illinois. Green filter, same scale as figures 3, 5, (x150).

Triletes splendidus (Zerndt) Schopf, Wilson, and Bentall . . . . p. 27

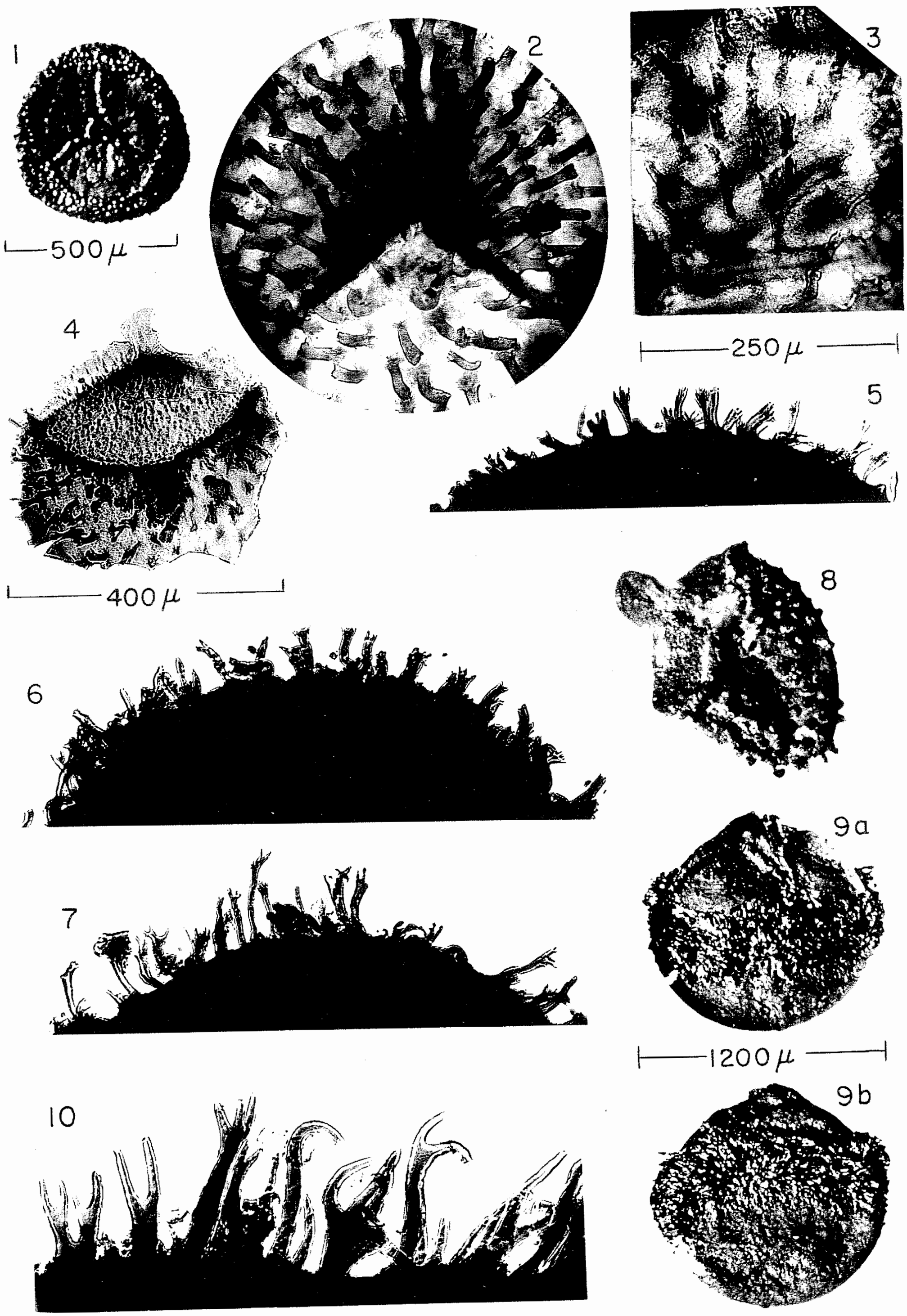
8. Broken lateral compression showing pyramidal apical prominence and stout distal spines. Total dimension, including spines, 1370 μ. Maceration 200 slide 1 XXV, in Degonia Formation, Pope County, Illinois. Reflected light, same scale as figures 9a, 9b, (x30).

Triletes praetextus Zerndt . . . . p. 46

9a. Oblique compression showing prominent apical prominence and ridges parallel to the rays. Equatorial dimension 1160 μ. Maceration 587 slide 1, Battery Rock Coal, Hardin County, Illinois. Reflected light, scale indicated below figure, (x30).

9b. Same spore. View of other side showing the restriction of ornamentation to a zone around the equator. Reflected light, scale indicated above figure, (x30).

10. Detail of the equatorial ornamentation showing the characteristic branching of the spines. Maceration 587 slide 3, Battery Rock Coal, Hardin County, Illinois. Red filter, same scale as figures 3, 5, (x150).



WINSLOW—MISSISSIPPIAN-PENNSYLVANIAN SPORES

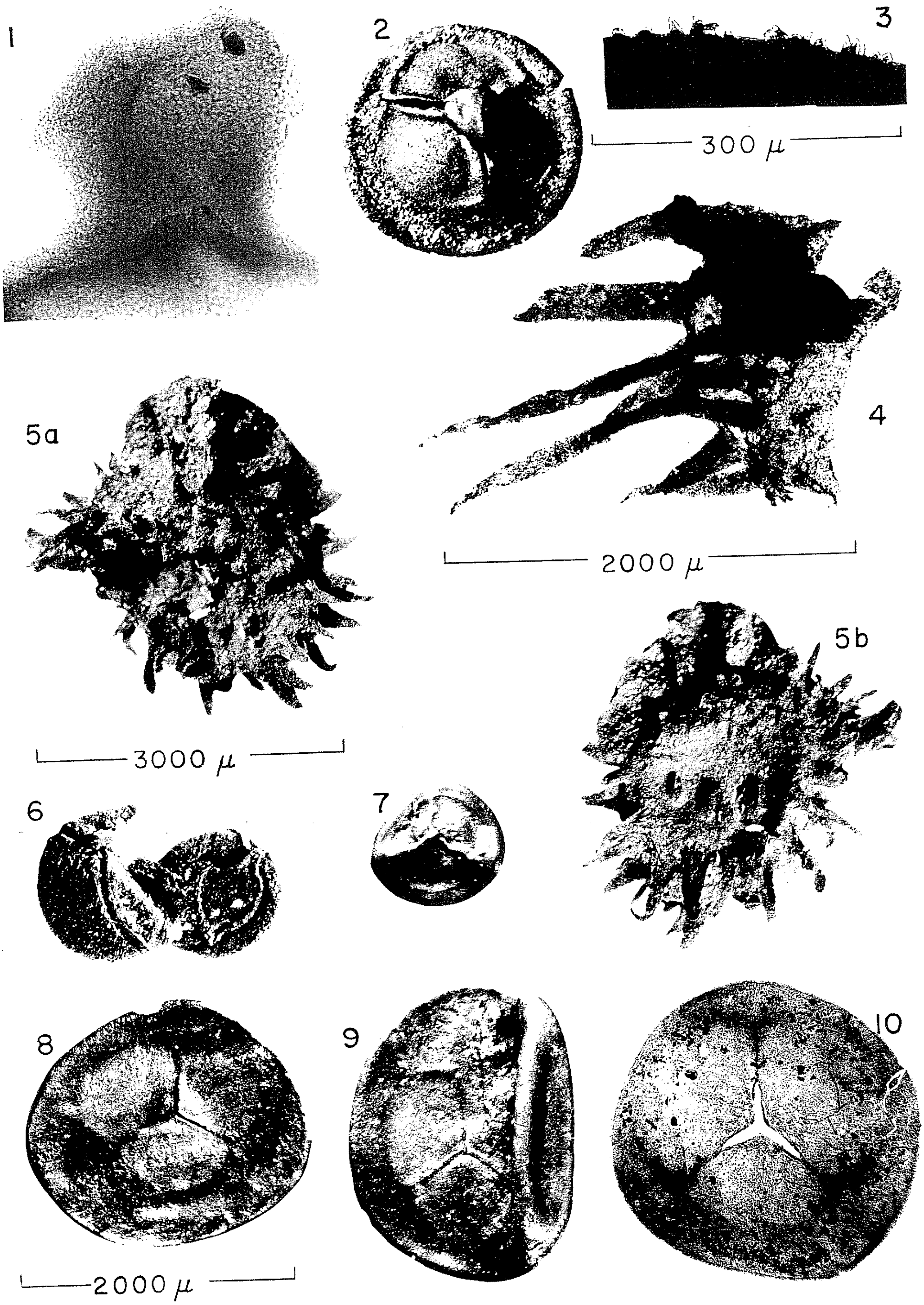

1
2
3
300 μ
4
2000 μ
5a
3000 μ
5b
6
7
8
9
10
2000 μ

PLATE 6

All specimens photographed with reflected light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes indianensis Chaloner . . . . p. 26

FIGURE

1. Inner surface of one of three segments of apical prominence. Lip at apex up to 226 μ in height. Maceration 943 slide 12, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Transmitted light. Red filter, same scale as figure 3, (x150).
2. Proximo-distal compression showing pyramidal apical prominence. Diameter 1195 μ. Maceration 943 slide 1, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Same scale as figure 4, (x30).
3. Maximum development of spines observed. Spines up to 20 μ in length. Maceration 943 slide 14, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Transmitted light, red filter, scale indicated below figure, (x150).

Triletes echinoides Chaloner . . . . p. 47

4. Fragment of spore coat showing detail of spines. Length of straight spine 1595 μ. Maceration 888 slide 3, carbonaceous layer near base (?) of Glen Dean Formation, Wise County, Virginia. Transmitted light, scale indicated below figure, (x30).

5a. Lateral compression of a poorly preserved example. Spines present on contact areas, but longer and more closely spaced on distal surface. Total length including ornamentation 3560 μ. Maceration 888 slide 1, carbonaceous layer near base (?) of Glen Dean Formation, Wise County, Virginia. Scale indicated below figure, (x15).

5b. Same spore. View of other side showing height of lips and contact area spines. Same scale as figure 5a, (x15).

Triletes cf. *T. eregliensis* Dijkstra . . . . p. 48

6. Two spores still in tetrad association along one contact face. Equatorial dimension, measured below arcuate ridge, of larger spore 1130 μ. Maceration 604A slide 6, Tarter Coal, Fulton County, Illinois. Same scale as figure 8, (x20).

Triletes glabratus Zerndt (sensu Dijkstra) . . . . p. 28

7. Immature spore with subtriangular outline. Diameter 665 μ. Maceration 463 slide 2, Summum (No. 4) Coal, Jersey County, Illinois. Same scale as figure 4, (x30).
8. Mature spore. Suture open. Diameter 2100 μ. Maceration 583 slide 1, Harrisburg (No. 5) Coal, Wabash County, Illinois. Scale indicated below figure, (x20).
9. Large specimen with slightly parted low lips. Diameter 2200 μ. Maceration 878 slide 1, Grape Greek (No. 6) Coal, Edgar County, Illinois. Same scale as figure 8, (x20).
10. Proximo-distal compression. Suture open. Diameter 2345 μ. Spore coat 26-31 μ in thickness. Maceration 600 slide 4, "LaSalle" Coal, Bureau County, Illinois. Transmitted light. Red filter, same scale as figure 8, (x20).

PLATE 7

All specimens photographed with reflected light.

Triletes mamillarius Bartlett (sensu Dijkstra) . . . . p. 28

FIGURE

1. Immature spore with subtriangular outline. Diameter 820 μ. Maceration $625A_2$ slide 1, Willis Coal, Gallatin County, Illinois. Same scale as figure 15a, (x20).
2. Slightly larger spore with more rounded outline. Maceration $625A_1$ slide 2, Willis Coal, Gallatin County, Illinois. Same scale as figure 15a, (x20).
3. Still larger example with open trilete suture. Maceration $625A_1$ slide 2, Willis Coal, Gallatin County, Illinois. Same scale as figure 15a, (x20).
4. One of largest examples. Maceration $625A_1$ slide 2, Willis Coal, Gallatin County, Illinois. Same scale as figure 15a, (x20).
5. Largest dry specimen observed in Willis Coal. Diameter 1540 μ. Maceration 625B slide 4, Willis Coal, Gallatin County, Illinois. Same scale as figure 15a, (x20).

6a. Characteristic example showing small contact area spines and well developed distal spines. Suture open. Maceration 795 slide 1, coal in Caseyville Group, Wabash County, Illinois. Same scale as figure 15a, (x20).

6b. Same spore. Distal view. Same scale as figure 15a, (x20).

Triletes auritus Zerndt (sensu Potonié and Kremp) . . . . p. 30

7-9. Proximo-distal compressions illustrating the range in size and "ear" configuration of spores of the species from one coal. Total diameter of spores 855 μ, 955 μ, and 1205 μ, respectively. Maceration 733c slide 1, Battery Rock Coal, Crittenden County, Kentucky. Same scale as figure 16, (x25).

10. Proximo-distal compression. Maximum dimension 830 μ. Maceration 914 slide 1, Tarter Coal, Mercer County, Illinois. Same scale as figure 16, (x25).
11. Lateral compression showing highly developed "ears" and slight apical prominence. Maximum dimension 1110 μ. Maceration 604A slide 2, Tarter Coal, Fulton County, Illinois. Same scale as figure 16, (x25).

Triletes augustae (Loose) Schopf, Wilson, and Bentall (sensu Potonié and Kremp p. 31

12. Proximo-distally compressed spore with the highest lips observed for spores of this species. Maximum dimension 1095 μ. Maceration 588 slide 2, Babylon Coal, Fulton County, Illinois. Same scale as figure 16, (x25).
13. Small example with low, straight rays. Diameter 925 μ. Maceration 602 slide 5, Pope Creek Coal. Fulton County, Illinois. Same scale as figure 16, (x25).

Triletes appendiculatus ? Maslankiewiczowa . . . . p. 31

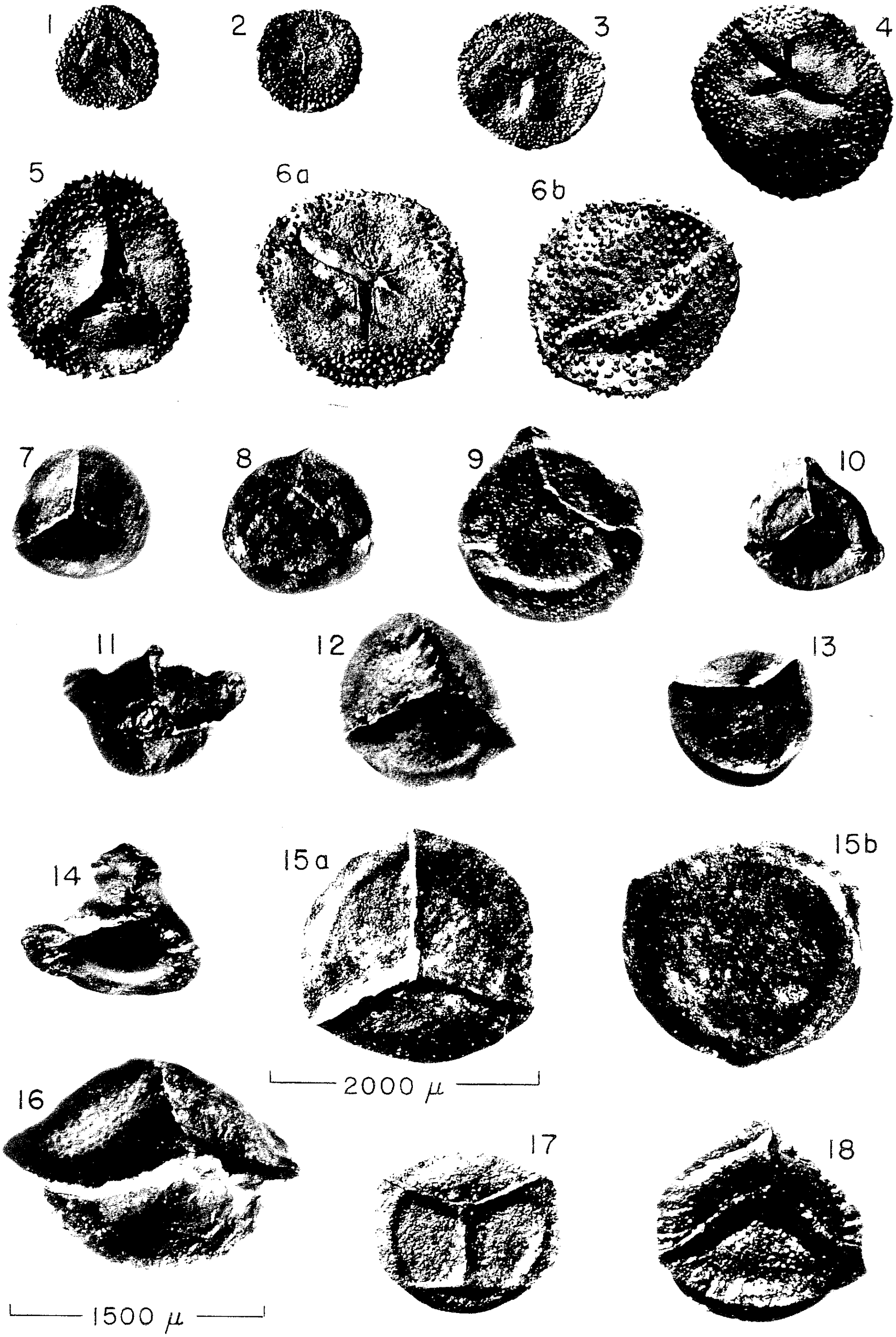
14. Spore with one "ear" and portion of one interradial area broken away. Width of largest ear 410 μ. Maximum dimension 1120 μ. Maceration 950A slide 1, coal in Tradewater Group, Grundy County, Illinois. Same scale as figure 16, (x25).

Triletes (Auriculati) spp. . . . . p. 32

15a. Spore with low ridge-like lips. Total diameter 1900 μ. Maceration 583 slide 1, Harrisburg (No. 5) Coal, Wabash County, Illinois. Scale indicated below figure, (x20).

15b. Same spore. Distal view. Same scale as figure 15a, (x20).

16. Lateral compression with slightly undulatory arcuate ridges and pitted contact areas. Maximum dimension 1795 μ. Maceration 583 slide 1, Harrisburg (No. 5) Coal, Wabash County, Illinois. Scale indicated below figure, (x25).
17. Proximo-distal compression. Diameter 1130 μ. Maceration 703 slide 1, "Woodbury" Coal, Cumberland County, Illinois. Same scale as figure 16, (x25).
18. Spore with undulatory arcuate ridges, pitted contact areas, and straight rays. Diameter 1300 μ. Maceration 811 slide 1, "Divide" Coal, Jefferson County, Illinois. Same scale as figure 16, (x25).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15a
15b
2000 μ
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17
18
1500 μ

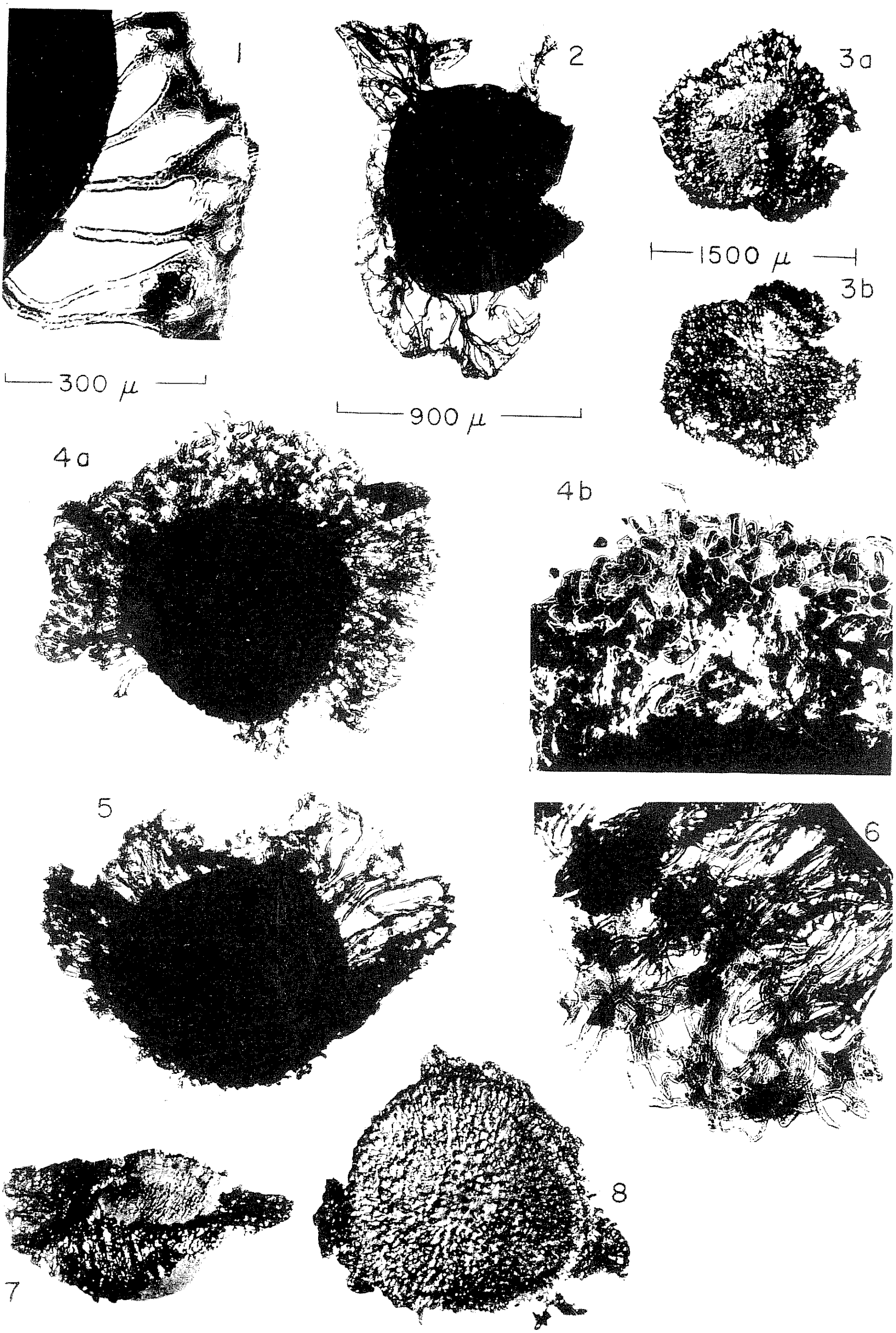

1
2
3a
1500 μ
3b
300 μ
900 μ
4a
4b
5
6
7
8

PLATE 8

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes rotatus Bartlett . . . . p. 32

FIGURE

1. Detail of flange showing short, thornlike projections on rim of flange. Maceration 910 slide 2, coal in Caseyville Group, Pope County, Illinois. Red filter, scale indicated below figure, (x100).
2. Broken proximo-distal compression. Maximum dimension 1465 μ. Maceration 910 slide 2, coal in Caseyville Group, Pope County, Illinois. Red filter, scale indicated below figure, (x40).

Triletes ramosus Arnold . . . . p. 33

3a. Proximal view. Contact areas ornamented with scattered tubercles. Total diameter 1590 μ. Maceration $625A_2$ slide 2, Willis Coal, Gallatin County, Illinois. Reflected light, scale indicated below figure, (x20).

3b. Same spore. Distal view showing ornamentation over entire distal surface. Reflected light, scale indicated above figure, (x20).

4a. Proximo-distal compression. Flange elements closely spaced. Maximum dimension 1600 μ. Maceration $625A_1$ slide 12, Willis Coal, Gallatin County, Illinois. Red filter, same scale as figure 2, (x40).

4b. Same spore. Detail of marginal projections of flange. Red filter, same scale as figure 1, (x100).

5. Oblique compression. Flange elements not as closely spaced as on spore shown in figure 4. Maximum dimension 1600 μ. Maceration $625A_1$ slide 12, Willis Coal, Gallatin County, Illinois. Red filter, same scale as figure 2, (x40).

6. Detail of flange with longer marginal projections. Projections up to 103 μ in length. Maceration 626 slide 4, Rock Island (No. 1) Coal, Henry County, Illinois. Red filter, same scale as figure 1, (x100).

Triletes superbus Bartlett . . . . p. 34

7. Rare example of laterally compressed specimen. Thin processes present on contact areas, apparently absent on distal surface. Maceration $625A_1$ slide 4, Willis Coal, Gallatin County, Illinois. Reflected light, same scale as figures 3a, 3b, (x20).

8. Distal view of proximo-distal compression showing completely ornamented distal surface. Most of flange broken away. Spore body diameter 1830 μ. Maceration 906 slide 1, "Makanda" Coal, Jackson County, Illinois. Reflected light, same scale as figures 3a, 3b, (x20).

PLATE 9

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes superbus Bartlett . . . . p. 34

FIGURE

1. Fragment of flange 1175 μ in width. Maceration 906 slide 3, "Makanda" Coal, Jackson County, Illinois. Same scale as figure 2, (x40).
2. Typically fenestrate flange showing delicate nature of some of the flange elements. Width 1180 μ. Maceration 906KOH slide 3, "Makanda" Coal, Jackson County, Illinois. Red filter, scale indicated below figure, (x40).

Triletes brasserti Stach and Zerndt . . . . p. 35

3. Tetrad. Maceration 604A slide 4, Tarter Coal, Fulton County, Illinois. Reflected light, scale indicated below figure, (x10).

4a. Characteristic proximo-distal compression. Total diameter 1710 μ. Maceration 604A slide 3, Tarter Coal, Fulton County, Illinois. Reflected light, same scale as figure 5, (x20).

4b. Same spore. Distal view showing granulose to spongy appearance of distal surface of flange. Reflected light, same scale as figure 5, (x20).

5. Lateral compression. Part of contact surface, flange, and distal coat torn away showing thickness of flange at its juncture with trilete rays. Maceration 604A slide 3, Tarter Coal, Fulton County, Illinois. Reflected light, scale indicated below figure, (x20).

6. Proximo-distal compression with pleated flange. Total diameter 1795 μ. Maceration 625B slide 1, Willis Coal, Gallatin County, Illinois. Reflected light, same scale as figure 5, (x20).

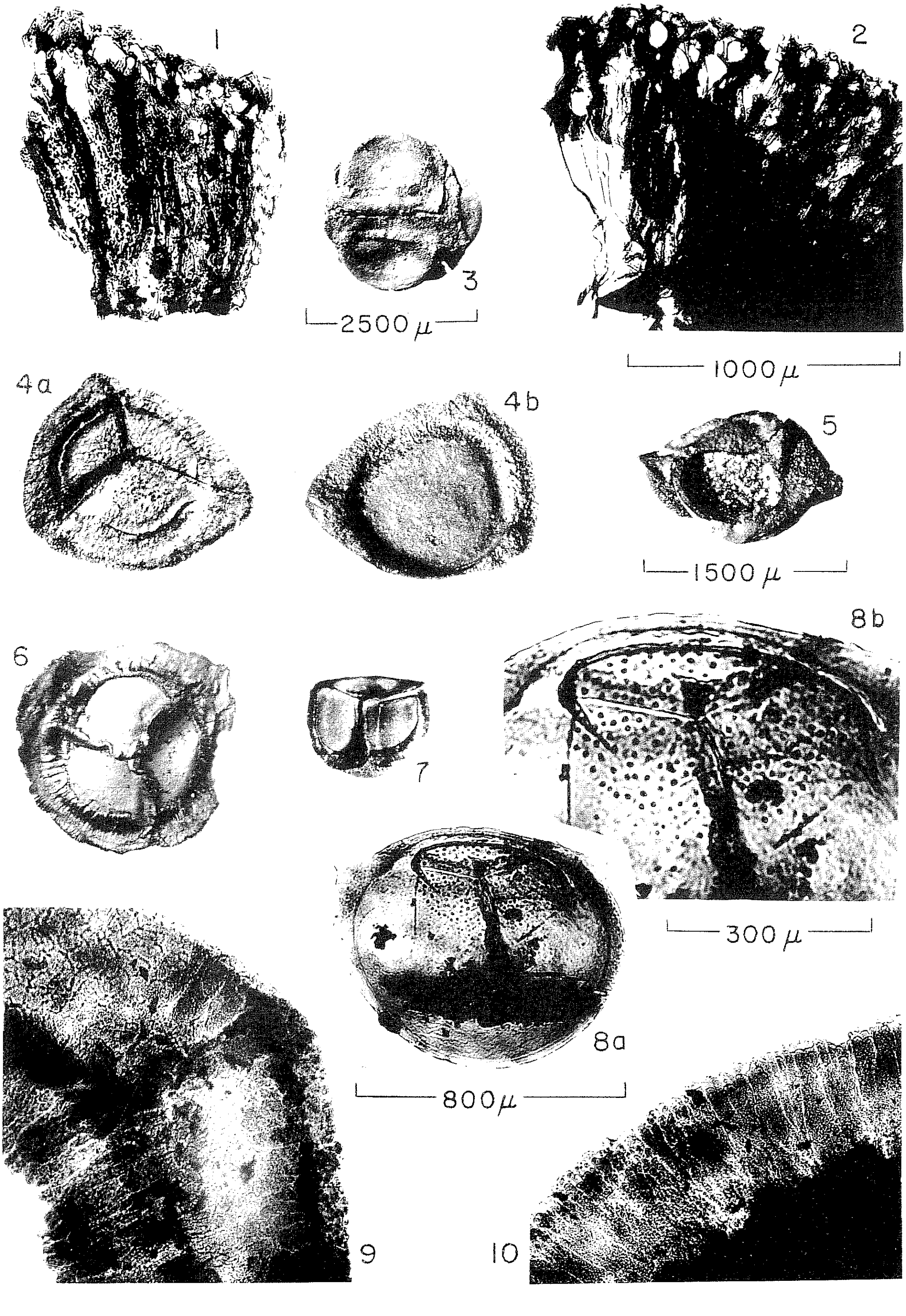
7. Small example, immature (?). Maximum dimension 990 μ. Maceration 625B slide 2, Willis Coal, Gallatin County, Illinois. Reflected light, same scale as figure 5, (x20).

8a. Oblique compression of small example with part of flange attached. Inner membrane distinctly ornamented. Total diameter 925 μ. Maceration $625A_1$ slide 13, Willis Coal, Gallatin County, Illinois. Red filter, scale indicated below figure, (x50).

8b. Same spore. Detail of inner membrane. Red filter, scale indicated below figure, (x100).

9. Corner of flange torn from spore body. Distal margin of contact with spore body shows as dark medial band. Width at corner 490 μ. Maceration 625B slide 7, Willis Coal, Gallatin County, Illinois. Red filter, same scale as figure 8b, (x100).

10. Detail of flange showing imbricating platelike nature of the distal surface of the solid, nonfenestrate flange. Maceration 625B slide 6, Willis Coal, Gallatin County, Illinois. Red filter, same scale as figure 8b, (x100).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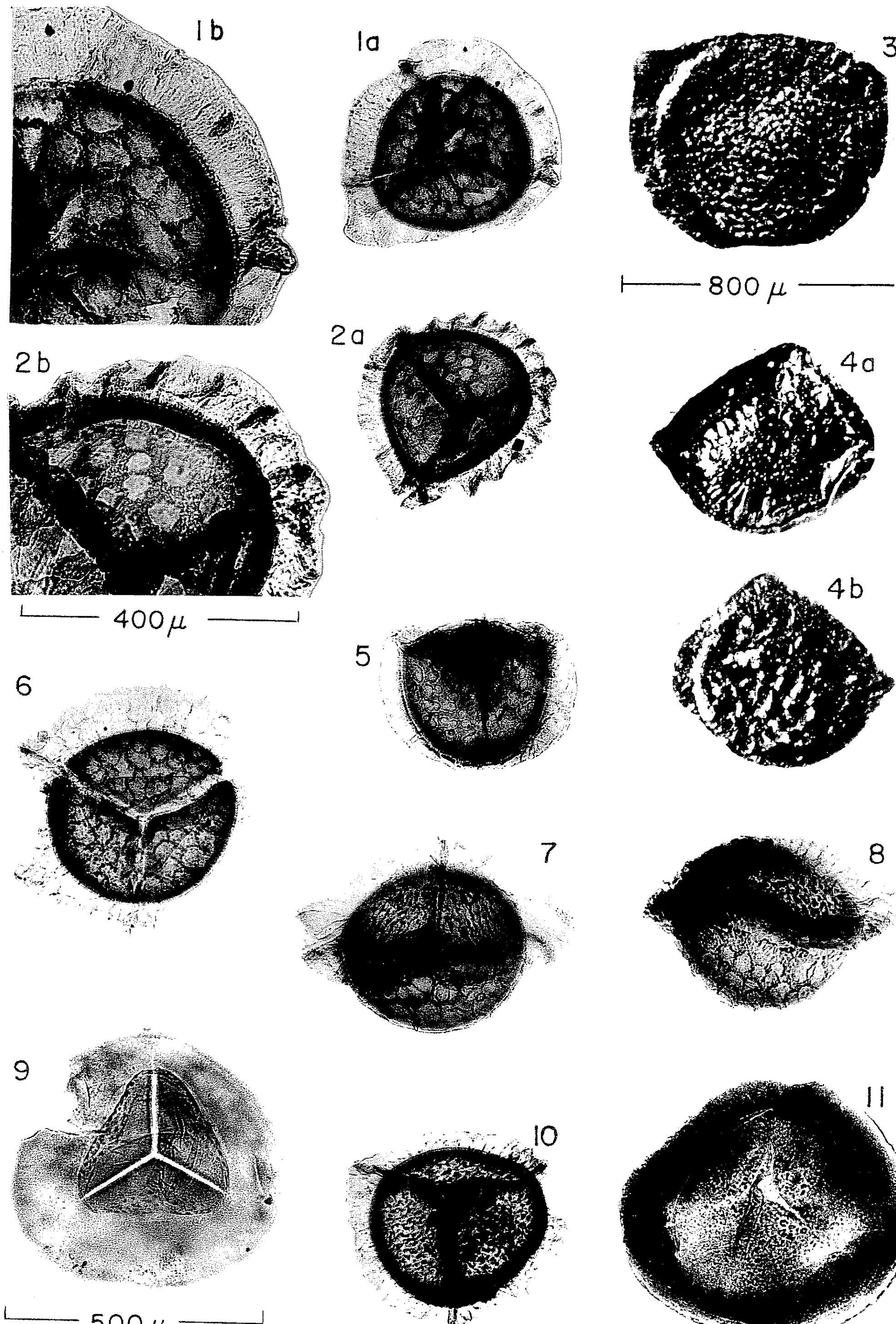
1b
1a
3
800 μ
2a
2b
4a
400 μ
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8
9
10
11
500 μ

PLATE 10

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes triangulatus Zerndt (sensu Dijkstra) . . . . p. 38

FIGURE

1a. Proximo-distal compression showing coarse distal reticulation. Total diameter 740 μ. Maceration 798 slide 12A, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

1b. Same spore. Detail of ornamentation. Red filter, same scale as figure 2b, (x100).

2a. Proximo-distal compression showing distal reticulation of a slightly different aspect. Total diameter 625 μ. Maceration 798 slide 15, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

2b. Same spore. Detail of ornamentation. Red filter, scale indicated below figure, (x100).

3. Distal view showing fine reticulation. Maceration 588 slide 2, Babylon Coal, Fulton County, Illinois. Reflected light, scale indicated below figure, (x50).

4a. Proximal view. Maximum dimension 685 μ. Maceration 604A slide 6, Tarter Coal, Fulton County, Illinois. Reflected light, scale indicated above figure, (x50).

4b. Same spore. Distal view. Reflected light, same scale as figures 3, 4a, (x50).

5. Distal ornamentation in focus. Maximum dimension 595 μ. Maceration 550 slide 2, Murphysboro Coal, Jackson County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

6. Proximo-distal compression showing reticulations on flange. Maceration 603B slide 4, Colchester (No. 2) Coal, Fulton County, Illinois. Green filter, same scale as figures 3, 4a, (x50).

7. Lateral compression showing lips, coarse distal reticulation, and irregularly developed proximal reticulation. Maximum dimension 810 μ. Maceration 603C slide 2, Colchester (No. 2) Coal, Fulton County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

8. Lateral compression showing fine proximal and coarse distal reticulations. Maceration 799B slide 1, Murphysboro Coal, Jackson County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

9. Proximo-distal compression of denuded example. Inner membrane characteristically ornamented. Diameter 540 μ. Maceration 603B slide 4, Colchester (No. 2) Coal, Fulton County, Illinois. Red filter, scale indicated above figure, (x75).

10. Proximal ornamentation in focus. Total diameter 680 μ. Maceration 599B slide 7, Rock Island (No. 1) Coal, Fulton County, Illinois. Red filter, same scale as figures 3, 4a, (x50).

Triletes ? saturnipunctatus n. sp. . . . . p. 48

11. Slightly oblique compression. Holotype. Diameter 433 μ. Maceration 916 slide 5, Pope Creek Coal, Mercer County, Illinois. Red filter, same scale as figure 2b, (x100).

PLATE 11

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Triletes ? corycilis n. sp. . . . . p. 49

FIGURE

1. Lateral compression. Holotype. Suture slightly open. Length 1055 μ. Maceration 798 slide 10, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Red filter, same scale as figure 6, (x50).
2. Lateral compression. Narrow frill shows at edges of one contact area. Length 1110 μ. Maceration 798 slide 10, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Same scale as figure 6, (x50).

3a. Broken lateral compression. Two contact areas show central scar. Maximum dimension 1270 μ. Maceration 798 slide 10, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Same scale as figure 6, (x50).

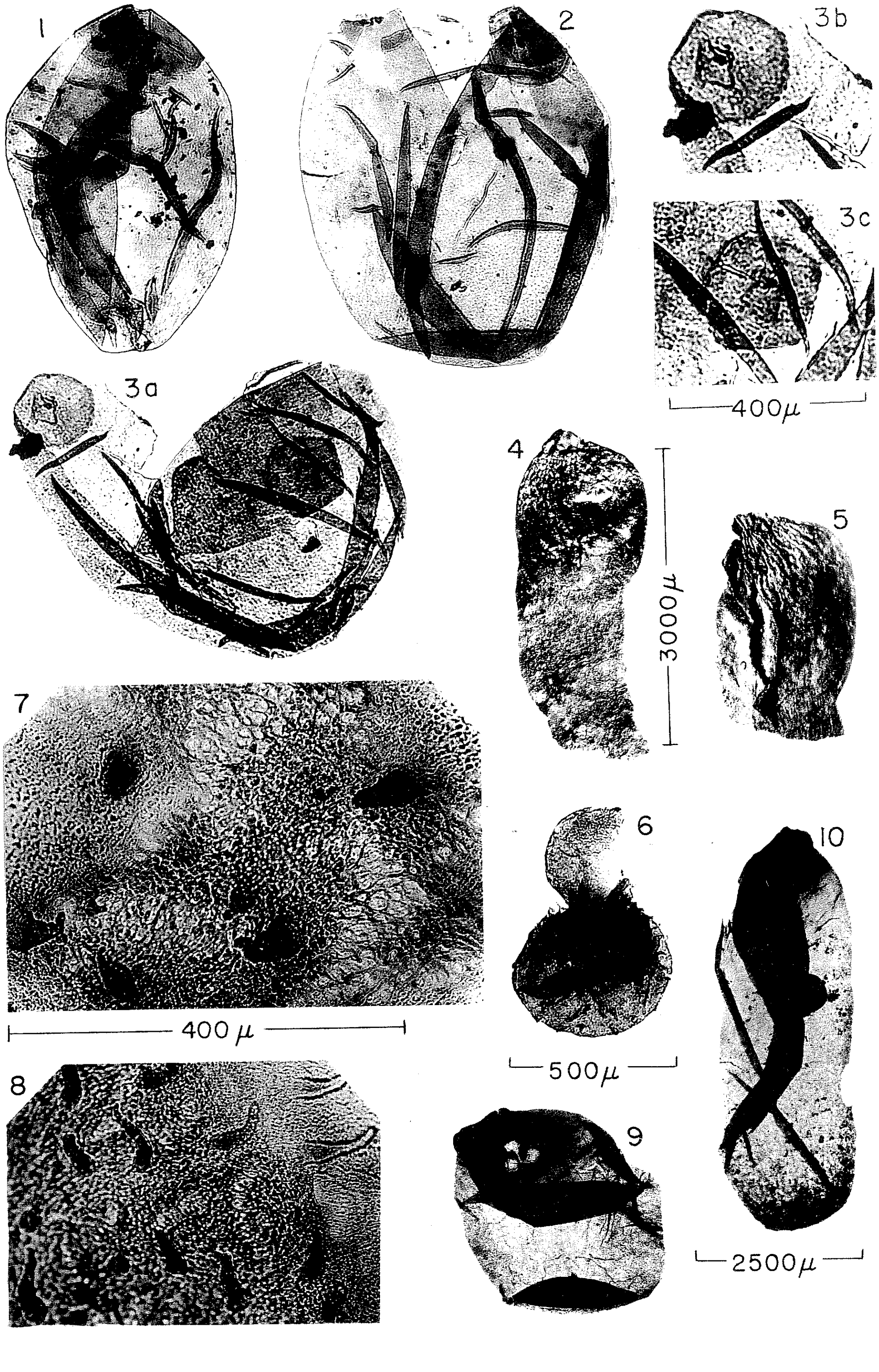
3b, 3c. Same spore. Details of contact areas. Scale indicated below figure 3c, (x75).

Cystosporites verrucosus Dijkstra . . . . p. 53

4. Lateral compression of fertile spore with long distal appendage. Total length 3420 μ. Maceration 825 slide 1, Colchester (No. 2) Coal, Schuyler County, Illinois. Reflected light, scale indicated to right of figure, (x15).
5. Lateral compression of fertile spore. Apical area characteristically pleated. Small portion of distal appendage still attached. Maximum dimension 2535 μ. Maceration 881 slide 1, Indiana Coal IV, Edgar County, Illinois. Reflected light, scale indicated to left of figure, (x15).
6. Lateral compression of abortive spore. Part of spatulate apical prominence torn away. Total length 700 μ. Maceration 916 slide 5, Pope Creek Coal, Mercer County, Illinois. Red filter, scale indicated below figure, (x50).
7. Detail of spinose spore coat from fertile spore. Fibrous meshlike character of spore coat well developed. Maceration 916 slide 2, Pope Creek Coal, Mercer County, Illinois. Scale indicated below figure, (x150).
8. Detail of spinose spore coat from fertile spore. Maceration 916 slide 2, Pope Creek Coal, Mercer County, Illinois. Scale indicated above figure, (x150).

Cystosporites giganteus (Zerndt) Schopf . . . . p. 52

9. Oblique compression showing proximal view of relatively small contact area. Maximum dimension 2600 μ. Maceration 825 slide 2, Colchester (No. 2) Coal, Schuyler County, Illinois. Same scale as figures 4, 5, (x15).
10. Lateral compression of fertile spore. Small abortive spore also present. Total length 6210 μ. Maceration 943 slide 3, coal in the Bethel (Mooretown) Formation, Hardin County, Kentucky. Scale indicated below figure, (x10).


1
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3b
3c
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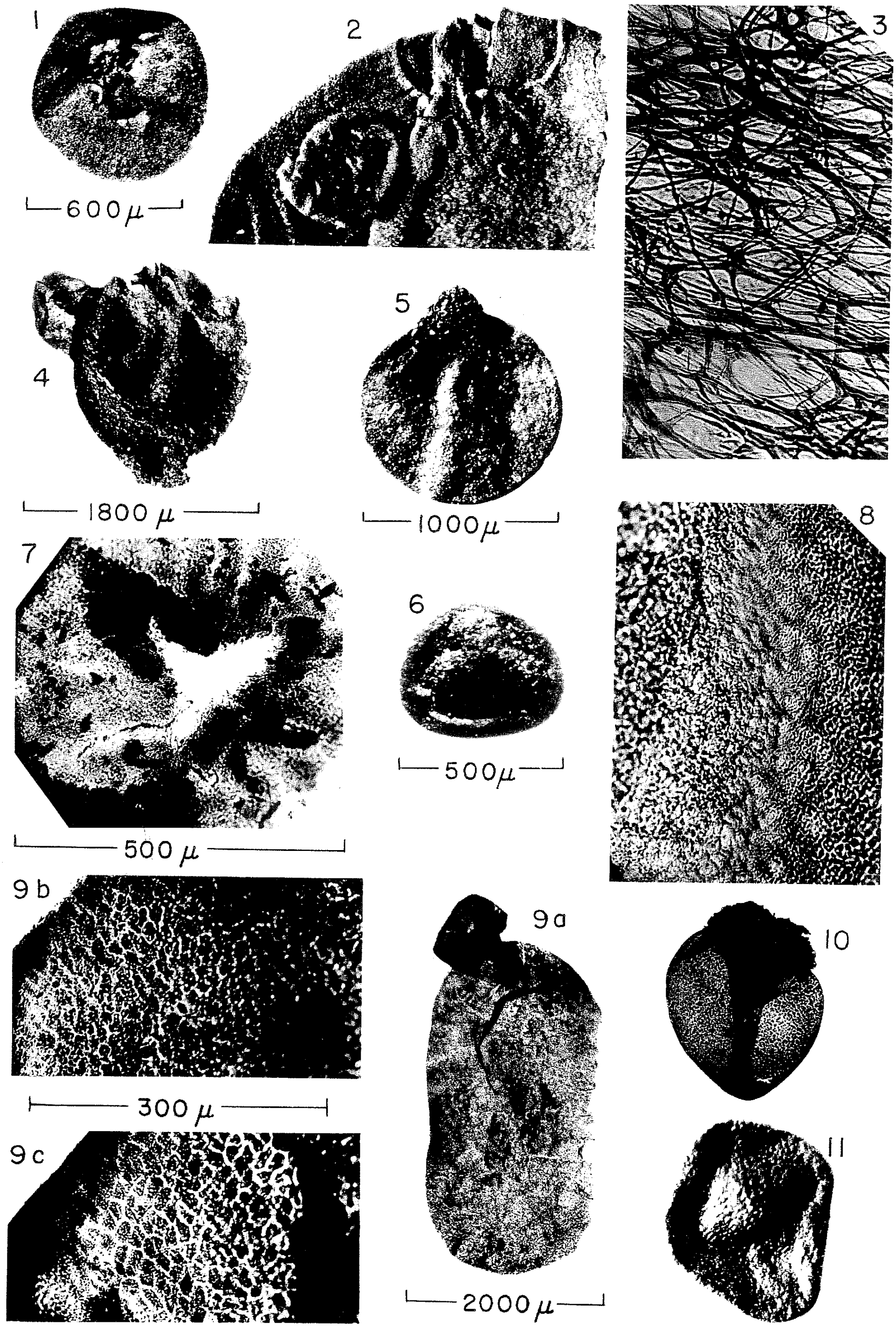
3a
4
3000μ
5
7
400μ
6
500μ
10
8
9
2500μ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600 μ
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9 b
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9 c
9 a
2000 μ
10
11

PLATE 12

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Cystosporites giganteus (Zerndt) Schopf . . . . p. 52

FIGURE

1. Abortive spore. Maximum dimension 720 μ. Maceration 908 slide 2, Battery Rock Coal, Pope County, Illinois. Reflected light, scale indicated below figure, (x40).
2. Apical portion of fertile spore. Abortive spore also present. Maceration 824 slide 2, Colchester (No. 2) Coal, Schuyler County, Illinois. Reflected light, same scale as figure 1, (x40).
3. Detail of spore coat from middle region of fertile spore. Maximum development of fibrous meshlike coat observed. Maceration 824 slide 3, Colchester (No. 2) Coal, Schuyler County, Illinois. Same scale as figures 9b, 9c, (x150).
4. Lateral compression of small fertile spore with distal appendage. Maceration 523A slide 1, Babylon Coal, Fulton County, Illinois. Reflected light, scale indicated below figure, (x20).

Cystosporites varius (Wicher) Dijkstra . . . . p. 51

5. Lateral compression of larger abortive (?) spore. Total length 1180 μ. Maceration 604A slide 1, Tarter Coal, Fulton County, Illinois. Reflected light, scale indicated below figure, (x30).
6. Proximo-distal compression of small abortive spore with prominent three-lobed apical cushion. Maximum dimension 530 μ. Maceration 824 slide 2, Colchester (No. 2) Coal, Schuyler County, Illinois. Reflected light, scale indicated below figure, (x50).
7. Detail of apical region of large abortive (?) spore. Apical cushion torn away revealing open trilete suture. Maceration 625B slide 14, Willis Coal, Gallatin County, Illinois. Scale indicated below figure, (x100).
8. Detail of spore coat from middle region of fertile spore. Fibrous structure not as well developed as is usual for these spores. Maceration 824 slide 8, Colchester (No. 2) Coal, Schuyler County, Illinois. Same scale as figures 9b, 9c, (x150).

Cystosporites breretonensis Schopf . . . . p. 50

- 9a. Fertile and abortive spores, both possessing apical cushions and a reticulate-appearing pattern on the spore coat. Length of fertile spore 3390 μ. Maceration 611 slide 1, Colchester (No. 2) Coal, Grundy County, Illinois. Scale indicated below figure, (x15).
- 9b. Same specimen. Detail of spore coat of fertile spore in apical region showing the reticulate-appearing pattern. Scale indicated below figure, (x150).
- 9c. Same specimen. Detail of spore coat of abortive spore showing somewhat coarser reticulate pattern. Scale indicated above figure, (x150).
- 10. Abortive spore showing granulose outline of apical cushion and reticulate-appearing coat. Total length 1030 μ. Maceration 825 slide 3, Colchester (No. 2) Coal, Schuyler County, Illinois. Red filter, same scale as figure 5, (x30).
- 11. Distal view of abortive spore. Closely spaced, low prominences cause the reticulate appearance of the coat. Maximum dimension 665 μ. Maceration 583 slide 1, Harrisburg (No. 5) Coal, Wabash County, Illinois. Reflected light, same scale as figure 6, (x50).

PLATE 13

All specimens photographed with transmitted light. Color of filter, when used, indicated.

Spencerisporites cf. *S. radiatus* (Ibrahim) n. comb. . . . . p. 56

FIGURE

1. Spore with lips and contact areas split apart and partly folded. Total diameter 375 μ. Maceration 798 slide 13, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Green filter, same scale as figures 2, 5a, (x100).
2. Spore with torn bladder showing upper and lower bladder membranes. Total diameter 365 μ. Maceration 798 slide 1RMK, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Green filter, scale indicated below figure, (x100).
3. Spore showing gouge-like appearance of radial striations and a narrow marginal flange. Total diameter 385 μ. Maceration 798 slide 13, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Green filter, same scale as figures 2, 5a, (x100).
4. Spore showing high lips expressed as folds on upper surface of bladder. Total diameter 345 μ. Maceration 798 slide 13, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Green filter, same scale as figures 2, 5a, (x100).

5a. Spore with slightly wider marginal flange. Total diameter 314 μ. Maceration 618 slide 3, Reynoldsburg Coal, Johnson County, Illinois. Scale indicated above figure, (x100).

5b. Same spore. Detail of spore body and radial striations. Green filter, same scale as figure 6, (x200).

6. Detail of marginal flange. Maceration 618 slide 3, Reynoldsburg Coal, Johnson County, Illinois. Scale indicated below figure, (x200).

Spencerisporites cf. *S. gracilis* (Zerndt) n. comb. . . . . p. 58

7. Poorly preserved spore with wide marginal flange and reticulate-appearing central area. Maximum dimension 443 μ. Maceration 519B slide 3, DeKoven Coal, Williamson County, Illinois. Green filter, same scale as figures 2, 5a, (x100).
8. Small spore showing wide marginal flange and distinct reticulate-appearing folds in central area. Total diameter 315 μ. Maceration 879 slide 4, Harrisburg (No. 5) Coal, Edgar County, Illinois. Green filter, same scale as figures 2, 5a, (x100).
9. Spore with wide marginal flange which appears lobe-like in outline at two of the corners. Total diameter 388 μ. Maceration 133, "Bogota" Coal, Fayette County, Illinois. Green filter, same scale as figures 2, 5a, (x100).

Calamospora cf. *C. sinuosa* (Potonié and Kremp) ex Horst . . . . . . p. 60

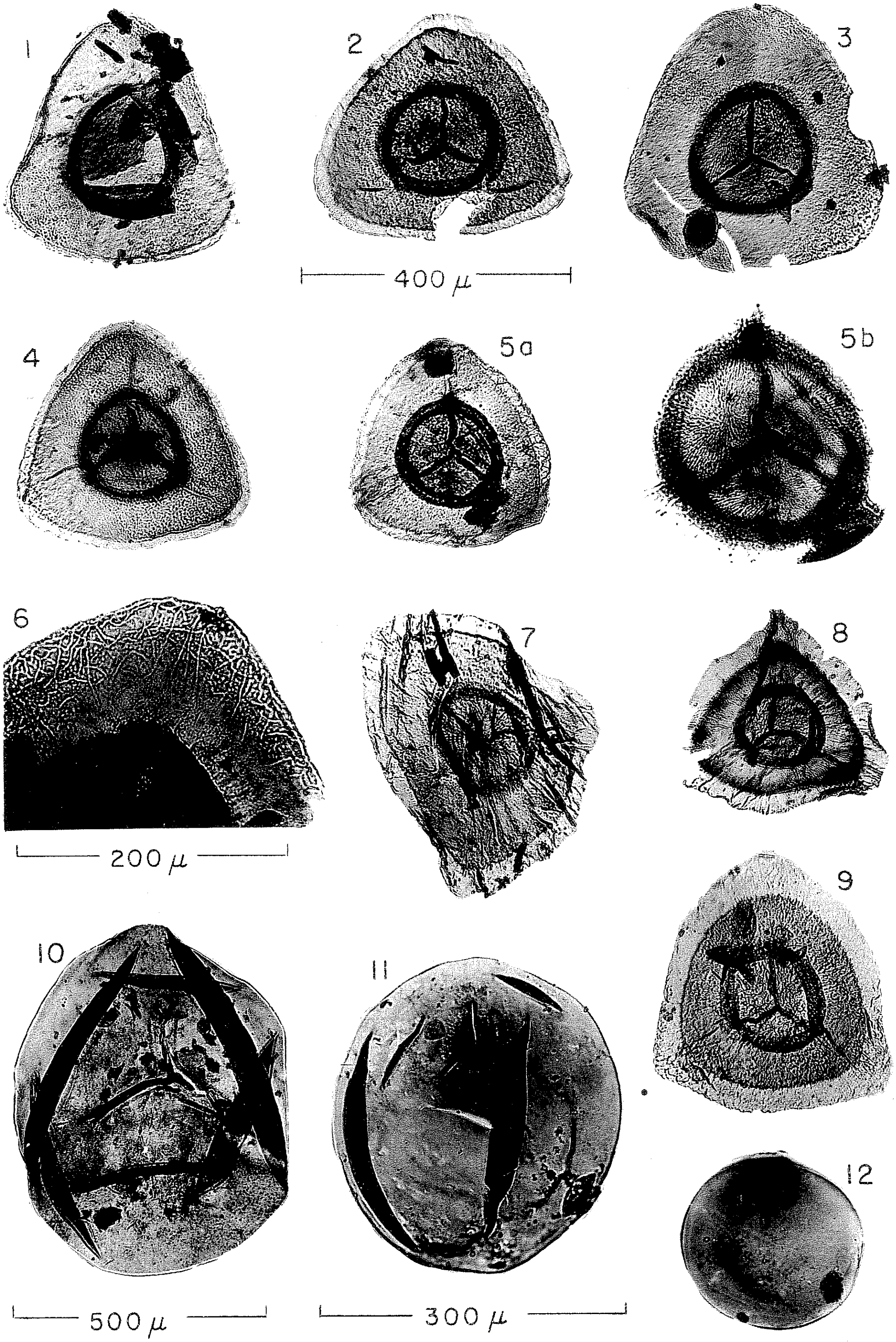
10. Folded proximo-distal compression. Diameter 700 μ. Maceration $625A_1$ slide 10, Willis Coal, Gallatin County, Illinois. Scale indicated below figure, (x75).

Calamospora cf. *C. laevigata* (Ibrahim) Schopf, Wilson, and Bentall . . . p. 60

11. Oblique compression with relatively short suture and vaguely defined contact areas. Diameter 314 μ. Maceration 600 slide 11, "LaSalle" Coal, Bureau County, Illinois. Scale indicated below figure, (x150).

Calamospora sp. . . . . p. 61

12. Oblique compression of small spore with relatively thick coat. Thickening of spore coat in contact area showing at upper margin. Diameter 185 μ. Maceration 600 slide 11, "LaSalle" Coal, Bureau County, Illinois. Same scale as figure 11, (x150).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12
500 μ
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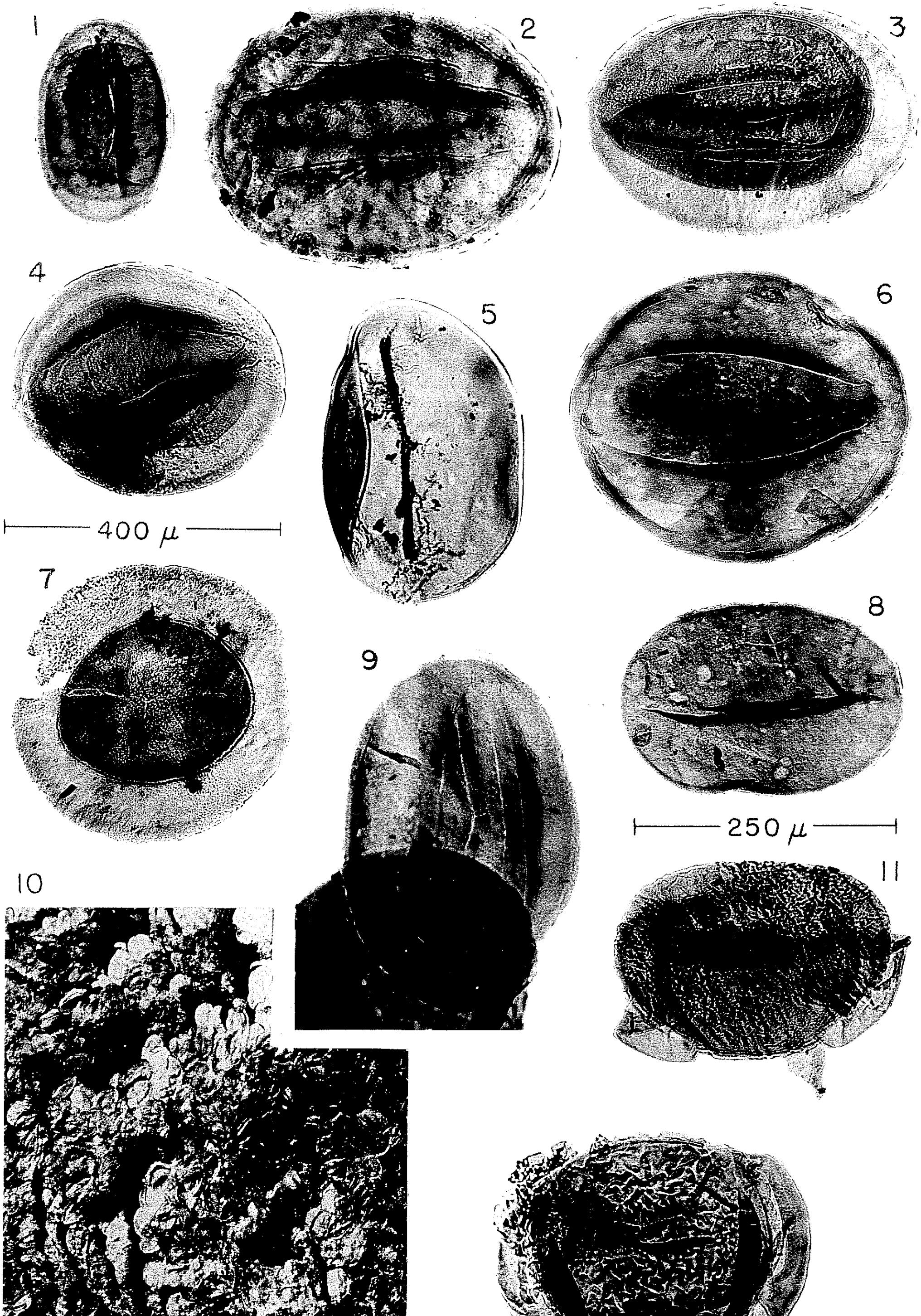
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3000 μ
12

PLATE 14

All specimens photographed with transmitted light, unless otherwise indicated. Color of filter, when used, also indicated.

Monoletes spp. . . . . p. 62

FIGURE

1. Small proximo-distal compression showing distal folds and medially deflected suture. Inner coat detached from outer coat and folded at each end. Total length 200 μ. Maceration 795 slide 11, coal in Caseyville Group, Wabash County, Illinois. Green filter, same scale as figures 8, 11, (x150).
2. Proximo-distal compression showing distal folds and medially deflected suture. Length 353 μ. Maceration 906KOH slide 6, "Makanda" Coal, Jackson County, Illinois. Same scale as figures 8, 11, (x150).
3. Proximo-distal compression. Distal folds and medially deflected suture evident. Inner coat detached from outer coat and folded. Total length 489 μ. Maceration 915 slide 5, Murphysboro (?) Coal, Williamson County, Illinois. Red filter, same scale as figures 4, 7, (x100).
4. Proximo-distal compression showing distal folds and medially deflected suture. Inner coat detached from outer coat and folded. Length 401 μ. Maceration 599B slide 9, Rock Island (No. 1) Coal, Fulton County, Illinois. Red filter, scale indicated below figure, (x100).
5. Proximo-distal compression showing vague outline of distal folds. Suture medially deflected with extremely short possible vestigial third ray. Length 298 μ. Maceration 899 slide 2, Colchester (No. 2) Coal, Fulton County, Illinois. Same scale as figures 8, 11, (x150).
6. Well preserved proximo-distal compression showing distal folds and medially deflected suture. Length 515 μ. Maceration 35 slide 3, unnamed coal above DeKoven Coal, Saline County, Illinois. Same scale as figures 4, 7, (x100).
7. Proximo-distal compression. Central body small with thick coat, 288 μ in length. Short third ray 26 μ in length. Maceration 35 slide 2, unnamed coal above DeKoven Coal, Saline County, Illinois. Red filter, scale indicated above figure, (x100).
8. Proximo-distal compression. Suture masked by thin folds. Length 278 μ. Maceration 600 slide 11, "LaSalle" Coal, Bureau County, Illinois. Green filter, scale indicated below figure, (x150).
9. Proximo-distal compression of spore from spore mass showing distal folds and medially deflected suture. Very short third ray present. Length 355 μ. Maceration 811 slide 9, "Divide" Coal, Jefferson County, Illinois. Same scale as figures 8, 11, (x150).
10. Spore masses. Maceration 811 slide 2, "Divide" Coal, Jefferson County, Illinois. Reflected light, scale indicated below figure, (x15).

Parasporites spp. . . . . p. 63

11. Slightly oblique lateral compression showing position of bladders. Length of spore body 272 μ. Maceration 490D slide 4, Friendsville Coal, Wabash County, Illinois. Scale indicated above figure, (x150).
12. Proximo-distal compression showing medially deflected suture with very short third ray. Total length 309 μ. Maceration 579C slide 5, Colchester (No. 2) Coal, Bureau County, Illinois. Red filter, same scale as figures 8, 11, (x150).

PLATE 15

All specimens photographed with transmitted light. Color of filter, when used, indicated.

Punctatisporites cf. *P. obesus* (Loose) Potonié and Kremp . . . . p. 64

FIGURE

1. Poorly preserved example. Suture open. Diameter 145 μ. Maceration 625Bf slide 4, Willis Coal, Gallatin County, Illinois. Safranin stained. Same scale as figure 3, (x300).
2. Smaller example with more triangular outline. Diameter 112 μ. Maceration 625Bf slide 5, Willis Coal, Gallatin County, Illinois. Safranin stained. Same scale as figure 3, (x300).

Reticulatisporites cf. *R. irregularis* Kosanke . . . . p. 64

3. Proximo-distal compression. Two rays of suture barely visible. Diameter 158 μ. Maceration 144, "Sub-Babylon" Coal, Fulton County, Illinois. Green filter, scale indicated below figure, (x300).

Renisporites confossus n. sp. . . . . p. 65

4. Lateral compression showing thickening of spore coat around suture. One lateral puncta group in focus. Length 169 μ. Maceration $625A_2$ slide 10, Willis Coal, Gallatin County, Illinois. Same scale as figure 3, (x300).

5a. Proximo-distal compression. Holotype. Length 170 μ. Maceration 625Bf slide 2, Willis Coal, Gallatin County, Illinois. Safranin stained. Same scale as figure 3, (x300).

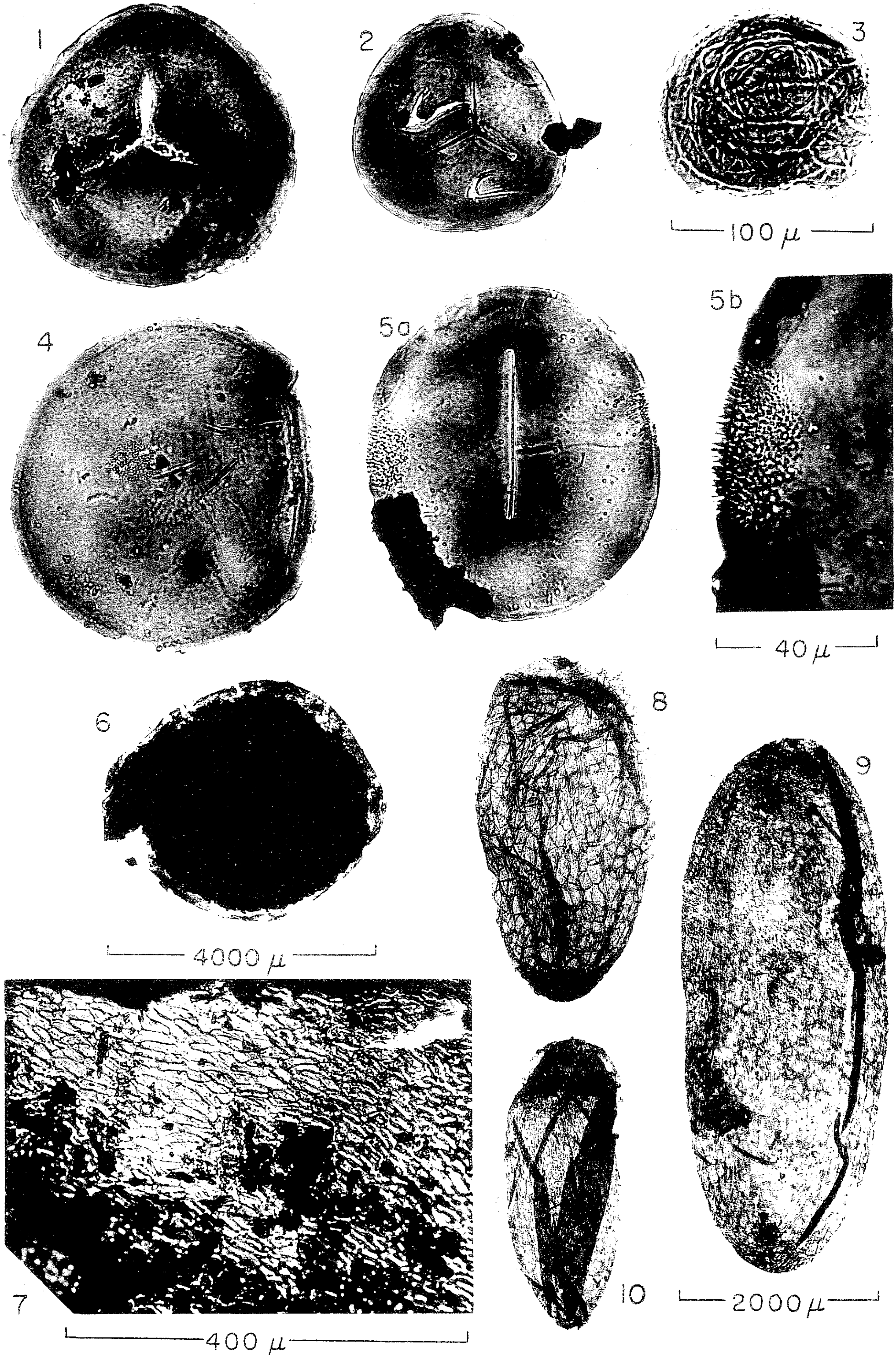
5b. Same spore. Detail of lateral puncta group. Scale indicated below figure, (x600).

Sporangial masses of *Densosporites* . . . . p. 67

6. Total length 4200 μ. Maceration 604A slide 8, Tarter Coal, Fulton County, Illinois. Scale indicated below figure, (x10).
7. Cuticle from sporangial mass of *Densosporites*. Maceration 604A slide 11, Tarter Coal, Fulton County, Illinois. Scale indicated below figure, (x150).

Seed membranes . . . . p. 67

8. Inner membrane enclosed in a thin membrane with coarse reticulate-appearing surface. Length 3435 μ. Maceration 798 slide 7, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Same scale as figure 9, (x15).
9. Large membrane with thick coat. Length about 5345 μ. Maceration 760 slide 1, coal in Tar Springs Formation, Johnson County, Illinois. Red filter, scale indicated below figure, (x15).
10. Seed membrane with apical cap. Length 2980 μ. Maceration 760 slide 4, coal in Tar Springs Formation, Johnson County, Illinois. Same scale as figure 9, (x15).



WINSLOW—MISSISSIPPIAN-PENNSYLVANIAN SPORES

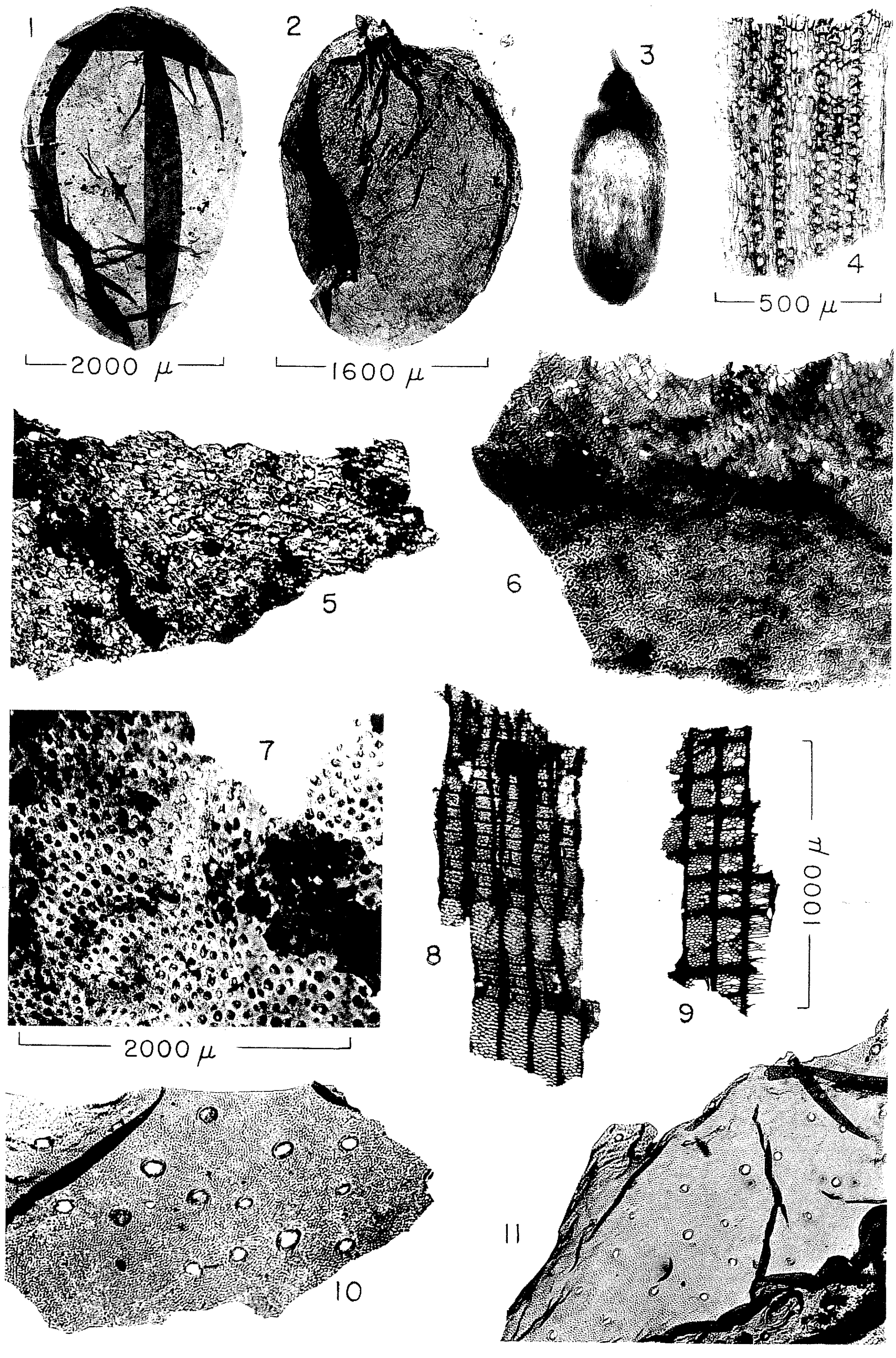

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PLATE 16

All specimens photographed with transmitted light. Color of filter, when used, indicated.

Seed membranes . . . . p. 67

FIGURE

1. Seed membrane? Length 3455 μ. Maceration 625B slide 15, Willis Coal, Gallatin County, Illinois. Scale indicated below figure, (x15).
2. Inner thick membrane enclosed in thin membrane, partially torn away from apical region. Length 2540 μ. Maceration 811 slide 4, "Divide" Coal, Jefferson County, Illinois. Scale indicated below figure, (x15).

Miscellaneous plant microfossils from Illinois coals . . . . p. 68

3. Resin bleb with spinose "stalk." Total length 835 μ. Maceration 599B slide 4, Rock Island (No. 1) Coal, Fulton County, Illinois. Same scale as figure 4, (x50).
4. Cuticle showing arrangement of stomata in parallel rows. Maceration 608 slide 2, Murphysboro Coal, Jackson County, Illinois. Red filter, scale indicated below figure, (x50).
5. Pitted cuticle. Maceration 631 slide 3, Willis (?) Coal, Gallatin County, Illinois. Same scale as figure 9, (x40).
6. Cuticle. Openings up to 46 μ in diameter. Maceration 918 slide 1, Pope Creek Coal, Mercer County, Illinois. Red filter, same scale as figure 9, (x40).
7. Characteristic cuticle of the Reynoldsburg Coal. Cuticle has dome cells with cuticular crests. Maceration 618 slide 5, Reynoldsburg Coal, Johnson County, Illinois. Scale indicated below figure, (x25).
8. Wood fragment with medullary rays. Pit mouths up to 10 μ in length. Maceration 525B slide 6, Wiley Coal, Fulton County, Illinois. Same scale as figure 9, (x40).
9. Fusinized wood fragment. Maceration 906 slide 6, "Makanda" Coal, Jackson County, Illinois. Scale indicated to right of figure, (x40).

Membranes of animal (?) origin . . . . p. 68

10. More or less round openings up to 66 μ in diameter. Membrane as a whole ornamented with closely spaced depressions up to 10 μ in diameter. Maceration 798 slide 7, lowest coal in diamond drill core, Caseyville Group, Wabash County, Illinois. Same scale as figure 9, (x40).
11. Membrane similar in pattern to that shown above, but thinner and with smaller openings and depressions. Maceration 914 slide 7, Tarter Coal, Mercer County, Illinois. Same scale as figure 9, (x40).

Illinois State Geological Survey Bulletin 86
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