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DEPARTMENT OF REGISTRATION AND EDUCATION

Spores in Strata of Late Pennsylvanian Cyclothems In the Illinois Basin

R. A. Peppers

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SPORES IN STRATA OF LATE PENNSYLVANIAN CYCLOTHEMS IN THE ILLINOIS BASIN

R. A. Peppers

ABSTRACT

Vertical variation in relative abundance and variety of small spore genera and species that might be useful for correlation of strata was examined in various marine and nonmarine units of cyclothems in the McLeansboro Group (late Pennsylvanian) of Illinois and in equivalent strata of western Kentucky. Sixty-one samples of various lithologies were macerated from two fairly complete sections of the Trivoli Cyclothem in the Modesto Formation of Illinois, from the Fithian Cyclothem in the Bond Formation of Illinois, and from several cyclothems in the Henshaw Formation of Kentucky. Forty of the samples yielded identifiable spores. Nearly all shale samples contained some spores, but most limestones, underclays, and siltstones below underclays were either barren of plant microfossils or contained relatively few, poorly preserved spores.

Of the 200 species of spores recorded, 33 are formally described as new. New taxa include 15 species of *Punctatisporites,* three of *Granulatisporites,* three of *Laevigatosporites,* two of *Calamospora,* and one species each of *Raistrickia, Cadiospora, Crassispora, Secarisporites, Ahrensisporites, Indospora, Lundbladispora, Trivolites, Latipulvinites,* and *Columinisporites.* The last three, which are new genera, are formally described. Sixty-five additional spore taxa are described briefly, but specific names are not assigned to them because not enough specimens of each taxon were found. Scolecodonts and three forms of hystrichospheres also are noted. *Centonites,* a new microfossil genus of uncertain origin, is described.

A comparison of several cyclothems revealed no consistent pattern in the vertical succession of small spore assemblages. In both sections of the Trivoli Cyclothem and in one of the cyclothems of the Henshaw Formation, the abundance of *Florinites* increased upward in strata above the coal. *Florinites* and a small number of other bladder-equipped pollen grains found in several shales overlying coal possibly were dispersed from the upland flora, which was relatively undisturbed during invasion of the sea and the resultant drowning of the coal swamp flora.

Some shales and siltstones yielded small numbers of *Densosporites* and *Lycospora* above the vertical ranges indicated for these fossils in North America by previous spore studies of coals. Such occurrences probably resulted from the reworking of older sediments. *Densosporites* produced by small herbaceous lycopods also could have survived in non-coal-swamp environments after the *Densosporites*-bearing lycopods of the coal swamps became extinct.

Within a single cyclothem, most spore genera range through a wide variety of lithologies, but their relative abundance may vary considerably. Some spore species persist through several successive lithologies in a single cyclothem, but others are more erratic in distribution.

In correlation studies of the Illinois Basin, because of the wide variation in composition of spore assemblages through short stratigraphic intervals, the relative abundance of small spore genera and species in coal appears to be of more value than their abundance in other lithologies. However, if careful consideration is given to type of lithology, deposition of older reworked strata, and factors related to spore dispersal, spore assemblages of non-coal lithologies may prove useful in correlating strata in areas where coals pinch out, are poorly developed, or are essentially barren of spores, and where spore assemblages from two or more coals are not easily differentiated.

INTRODUCTION

Plant microfossil assemblages from Pennsylvanian coals have been extensively reported, but relatively little has been published on the palynology of other Pennsylvanian strata. This report is concerned with the investigation of small spores found in coal, marine, and nonmarine strata of several late Pennsylvanian cyclothems within the McLeansboro Group of Illinois and equivalent strata of western Kentucky (text fig. 1). A fairly complete sequence of spore assemblages was derived from strata of the Fithian Cyclothem in the Bond Formation and strata of the Trivoli Cyclothem in the Modesto Formation (text fig. 2). Samples of various lithologies from at least three cyclothems in the Henshaw Formation of western Kentucky yielded spores at relatively widely spaced vertical intervals.

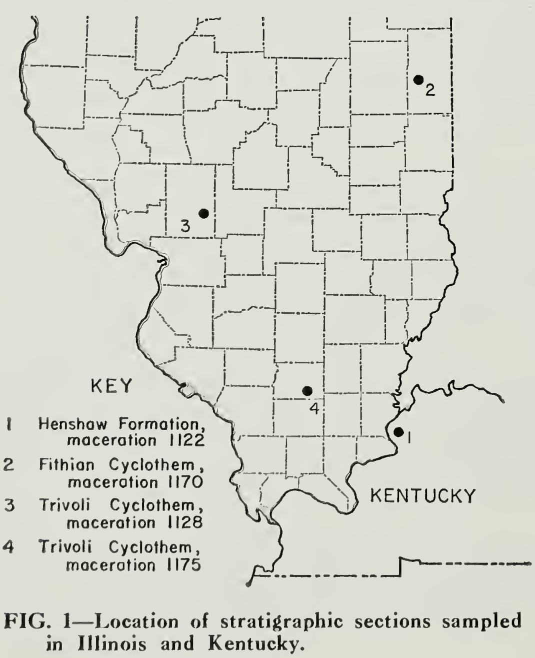

FIG. 1—Location of stratigraphic sections sampled in Illinois and Kentucky.

The first purpose of this study was to investigate the possibility of using plant spores from lithologies other than coal for correlation of Pennsylvanian strata in the Illinois Basin where coals are absent or contain poorly preserved spores. It was first necessary to record and describe spores from a wide range of lithologies from Pennsylvanian strata. As most of the plant microfossils found in non-coal sediments were produced by plants living under paleoecologic conditions different from those operating in the coal swamp environment, palynologic investigations of shales, limestones, siltstones, and underclays were expected to reveal many spore genera and species not previously reported from the Illinois Basin.

The second aim was to determine the relative abundance and variety of spore taxa throughout several sequences of different lithologies so that vertical ranges of spore genera and species could be ascertained. Certain spore genera, such as *Densosporites* and *Lycospora,* are known to be present in strata above the limits determined for these genera by coal macerations.

A third purpose of this study was to determine whether or not bisaccate gymnospermic pollen and prepollen grains, which became such a conspicuous element of plant microfossil assemblages in Permian strata, are present in upper Pennsylvanian strata of the Illinois Basin. Diamond drill core samples from part of the Henshaw Formation of western Kentucky were selected for this purpose because the sampled section is probably younger than any other part of the Pennsylvanian that has been described from the Illinois Basin.

Acknowledgments

I am indebted to Dr. Robert M. Kosanke, U. S. Geological Survey, for his advice on the

identification and interpretation of taxa and his many helpful suggestions while he was a member of the Illinois State Geological Survey staff; to Jack A. Simon, Head of the Coal Section of the Illinois Survey, for his review of the manuscript; and to Mrs. Romayne S. Ziroli, also of the Illinois Survey, for her help in the construction of scientific names proposed for new taxa. This investigation was the subject of a doctoral dissertation in geology submitted in 1961 to the Graduate College, University of Illinois.

PREVIOUS INVESTIGATIONS

Only publications relating to Pennsylvanian spores and pollen of the Illinois Basin and to plant microfossils of Pennsylvanian strata other than coal are summarized here.

McCabe (1931), probably the first to study microfossils in the Illinois Basin, reported on some macerated residues of the Herrin (No. 6) Coal Member. A more detailed investigation of the megaspores from the No. 6 Coal was conducted by Schopf (1938). Brokaw (1942) described spores from the Harrisburg (No. 5) Coal Member and, after comparing them with those of the No. 6 Coal, concluded that the two coals could be distinguished on the basis of their spore content. Schopf, Wilson, and Bentall's (1944) synopsis of Paleozoic spores and definitions of generic groups outlined certain principles to be followed in solving many of the problems in spore nomenclature.

Eddings (1947) studied the small spores of the Chapel (No. 8) Coal Member in Illinois and used them in tracing the lateral extent of the coal and the thickness of the interval between the No. 8 and the No. 6 Coals. Kosanke (1950) carried out a comprehensive study in which he established correlation of the important coals of the Illinois Basin by using spore genera and species, including the 100 new species described in the report. The distribution of Pennsylvanian and Mississippian megaspores in coals of the Illinois Basin was reported by Winslow (1959).

Several significant studies have been made of spores derived from Mississippian and Pennsylvanian strata associated with coal. Hoffmeister, Staplin, and Malloy (1955a) studied Mississippian plant spores from coal

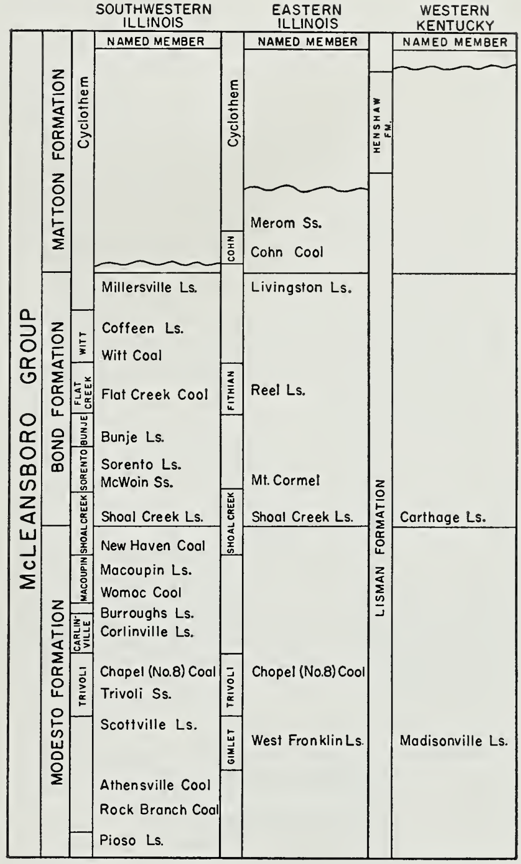

FIG. 2—Rock stratigraphic and cyclical classification of McLeansboro strata of part of Illinois and equivalent strata of western Kentucky (after Kosanke et al., 1960).

and carbonaceous shale of the Hardinsburg Formation of Illinois and Kentucky. They discovered considerable variation in relative distribution of spore genera and species within a short vertical interval, but generally the same genera and species were found throughout the Hardinsburg Formation. Neves (1958) reported on small spore assemblages of the Upper Carboniferous Six Inch Mine coal seam in England and the immediately overlying marine and nonmarine shales, and he later (1961) investigated the spores contained in coal and marine and nonmarine shales of a Namurian (Lower Carboniferous) sequence in the southern Pennines area of England.

Spores obtained from four outcrops of the Harlem Coal and associated strata in West Virginia were studied by Collins (1959). Lower Carboniferous small spore assemblages were described from the Lower Oil-shale

Group of Scotland by Love (1960). He found that small spores in the nonmarine oil shale are very similar in kind and relative abundance to those in the nonmarine limestone, but that a distinct change in proportion of genera occurs in the marine Pumpherston Bed. Staplin (1960, p. 1-3) reported that in the Golata Formation (Mississippian) of Canada the frequency distribution of spore genera in the shale below the underclay, in the underclay, and in the coal differs markedly. The spore assemblage in the shale above the coal is like that of the shale beneath the underclay.

Sullivan (1962), in his study of a Westphalian sequence in South Wales, suggested that the ranges of spore species in coal and shale are quite similar. He noted that changes in composition of spore assemblages between coal and immediately overlying shales were no greater than changes found by Smith (1957) from one thin band of coal to another.

PREPARATION TECHNIQUES

COAL

Plant microfossils were isolated from coal samples by the standard maceration techniques described in detail by Kosanke (1950, p. 9-10). Core samples were cut on a carborundum saw to obtain a representative sample of about 50 grams that would be small enough to handle easily. Outcrop samples were divided with a riffle into workable quantities of about 50 grams. The coal was broken into small fragments, placed in a beaker, and covered with about 250 ml of Schulze's solution (1 part saturated solution of potassium chlorate to 2 parts concentrated nitric acid), which partially oxidizes the coal. After about 3 days, the length of time depending upon the composition of the coal, the residue was neutralized by repeated washings, and 250 ml of a 10 percent solution of potassium hydroxide was added to dissolve the humic matter. The residue was examined frequently in order to determine the length of time required for the appearance of an abundance of spores. From 2 to 4 hours was required, after which the undissolved plant material was freed of potassium hydroxide by several changes of water.

The cleared residue was sieved with a 65-mesh Tyler screen, which has openings of 210 μ. The coarse residue remaining on the screen was examined under a binocular microscope for megaspores. A small portion of the fine residue was stained with safranin Y for 3 hours to help make some spore structures more readily visible and to improve the quality of the photomicrographs. The liquid was decanted and, after dehydration by use of 50 percent, 95 percent, and finally absolute alcohol, the residue in a final solution of 50 percent xylol and 50 percent absolute alcohol was mounted in liquid Canada balsam. The slides were dried in an oven at 105° F for at least 5 days. Surplus residue was stored in vials at the Illinois State Geological Survey. Opaque megaspores were placed on pasteboard slides, and translucent large spores and megaspores were mounted in liquid Canada balsam after dehydration in alcohol.

LIMESTONE, SILTSTONE, SHALE, AND CLAY

From each major lithology above and below the coals, approximately 30-gram samples were selected for maceration. All calcareous samples were first placed in a 20 percent solution of orthophosphoric acid until the liberation of gas had ceased. After repeated washing to remove all the dissolved carbonate minerals, hydrofluoric acid (reagent grade, 48 percent) was added to dissolve the silica minerals present. Frequent stirring was necessary to allow the acid to come into contact with all the sludge. After about 16 hours, water was added and decanted a number of times until the sample was free of acid. Several hard shale samples required an additional treatment of fresh hydrofluoric acid for up to 16 hours. The remaining organic matter was oxidized in Schulze's solution from a few minutes to about 1 hour, cleared of acid, then placed in a 10 percent solution of potassium hydroxide for about 1 hour. Microscopic crystals of undetermined composition that formed after the potassium hydroxide solution was added were dissolved by the addition of a few drops of concentrated hydrochloric acid.

Residues in which spores were present but not abundant were run through a vibraflute, as outlined by Tschudy (1960, p. 325-326), several times in order to eliminate some of the fine organic debris. The plant material was stained and mounted in the same manner as the insoluble botanic remains of the macerated coal.

Percentage distribution of spore taxa was determined by counting 500 spores from each coal sample and 300 from each of the other lithologies. Identification of species was made whenever possible, but in many macerations preservation was so poor that only generic identifications could be made.

LOCATION OF SPECIMENS ON SLIDES

All specimens illustrated in this report are circled in ink on the glass slides, which are deposited at the Illinois State Geological Survey. The serial number of the Spencer Microstar microscope, whose mechanical stage was used in giving the location by coordinates of specimens on the slides, is 417297.

DESCRIPTION OF SMALL SPORES

The system of spore nomenclature outlined by Schopf, Wilson, and Bentall (1944) is used in the following description of new genera and species and in recording previously described spores, except those taxa described under the system proposed by Potonié and Kremp and by other European workers. A complete list of spore genera and species observed in this study and their percentage of distribution in each maceration is given in the spore distribution chart (table 1). Only species that required some discussion are mentioned in the text.

Genus AHRENSISPORITES (Potonié & Kremp) Horst, 1955

Type species. — *Ahrensisporites guerickei* Horst, 1955.

Discussion.—Potonié and Kremp (1954, p. 155) constructed the genus *Ahrensisporites* in which *A. guerickei,* a species described by Horst in 1943 in a dissertation, served as the type species. As the dissertation was not given wide distribution, it probably should not be considered a valid publication. According to the International Code of Botanical Nomenclature (Lanjouw, 1961), Art. 29: "Publication is effected, under this Code, only by distribution of printed matter (through sale, exchange, or gift) to the general public or at least to botanical institutions with libraries accessible to botanists generally." Horst described *A. guerickei* in the publication dated 1955 (p. 178) and thus validated the genus.

Affinity.—Unknown.

Ahrensisporites exertus sp. nov.
Plate 1, figures 1-2

Diagnosis.—The spores are radial, trilete, and more or less triangular in outline with straight to slightly convex interradial sides. The trilete rays are distinct, straight, and more than three-fourths the length of the spore radius. The kyrtomes are connected on the distal surface to the arcuate folds, which are 3.5 to 7 μ long and 16 to 24 μ wide. A single spherical projection, about 5 μ in diameter, is present near the pole on the distal surface. That the exine is somewhat verrucose or rugose is suggested by irregular light and dark areas that appear when the specimens are viewed under high dry objective. The spore coat is about 2 μ thick. Dimensions (10 specimens): size range, 32.7 to 41.5 μ in maximum diameter; median, 38.0 μ.

Holotype.—Plate 1, figure 1; negative 6127; Henshaw Formation, maceration 1122-G, slide 8 ZB, coordinates, 126.5 × 50.3; size, 38.1 by 36.6 μ.

Paratype.—Plate 1, figure 2; negative 6430; Henshaw Formation, maceration 1122-Q, slide 17 ZB, coordinates, 145.2 × 32.5; size, 36.1 by 35.8 μ.

Comparison.—*Ahrensisporites exertus* is similar in appearance to *A. guerickei* Horst, 1955, but is smaller. *A. exertus* differs from *A. symetricus* Alpern, 1959, in having a nonuniformly thick, almost verrucose surface. *A. exertus* differs from all other species of *Ahrensisporites* by its possession of a single spherical projection near the distal pole.

Derivation of name.—The species name refers to its distinctive protruding (*exertus*) distal projection.

Genus Alatisporites (Ibrahim) Schopf, Wilson, & Bentall, 1944

Type species.—*Alatisporites pustulatus* (Ibrahim, 1932) Ibrahim, 1933.

Affinity.—Cordaitales? (Potonié and Kremp, 1954, p. 170).

Alatisporites cf. *hoffmeisterii* Morgan, 1955

Except for the presence of verrucae on the bladders, the few specimens of *Alatisporites* cf. *hoffmeisterii* observed are very similar to those illustrated by Morgan (1955).

Genus Cadiospora Kosanke, 1950

Type species.—*Cadiospora magna* Kosanke, 1950.

Affinity.—Unknown.

Cadiospora magna Kosanke, 1950

Although specimens of *Cadiospora magna* encountered in this study were somewhat smaller (68.1 to 93.9 μ) than those described by Kosanke (1950, p. 50) as 111.3 to 117.6 μ, it did not seem advisable to erect a new species at present solely on this basis.

Cadiospora fithiana sp. nov.
Plate 1, figures 3-4

Diagnosis.—The spores are radial, trilete, roundly triangular to circular in outline, and in good proximal-distal orientation. The rays, 24 to 29 μ long, are distinct. The lips are prominent, somewhat sinuous, and usually have a single swelling near the proximal pole. The lips rise abruptly above the proximal surface and are 3 to 6.5 μ wide on either side of the rays. They bifurcate at their termini to form distinct arcuate ridges, which are usually plicated parallel to the margin of the spore coat. Part of the arcuate ridge is occasionally torn and overlapped onto the body toward the poles. The surface of the spore coat is minutely punctate to granulate viewed under oil immersion objective. The spore coat is 3 to 4 μ thick. Dimensions (9 specimens) : size range, 56.3 to 75.2 μ in maximum diameter; median, 67.5 μ.

Holotype.—Plate 1, figure 3; negative 5700; Fithian Cyclothem, maceration 1170-A, slide 2, coordinates, 124.9 × 46.1; size, 57.0 by 56.7 μ.

Paratype.—Plate 1, figure 4; negative 6139; Fithian Cyclothem, maceration 1170-A, slide 22, coordinates, 126.0 × 37.9; size, 74.5 by 70.3 μ.

Comparison.—*Cadiospora magna* Kosanke, 1950, has broader lips that rise gradually to the rays and a finer surface ornamentation than *C. fithiana*. *C. fithiana* is also distinguished from *C. magna* by the minor folds usually present in the former.

Derivation of name.—The species name refers to the Fithian Cyclothem.

Genus Calamospora Schopf, Wilson, & Bentall, 1944

Type species. — *Calamospora hartungiana* Schopf (*in* Schopf, Wilson, & Bentall, 1944).

Affinity.—Calamarian (Schopf, Wilson, & Bentall, 1944, p. 50). Arnold (1944) reported spores of the *Calamospora* type from a fructification of *Bowmanites*. Fructifications of *Palaeostachya decacnema* Delevoryas (1955, p. 483), *Sphenophyllum hauchecornei* (Weiss) Remy (1955, pl. 12), *Anastachys* (*Sphenophyllum*) *caudata* Weiss (Remy, 1955, pl. 12), several species of *Koinostachys* (*Sphenophyllum*) Remy (1955, p. 29-33, pls. 12-13), and *Eleutherophyllum drepanophyciforme* Remy & Remy (1960, p. 89-100), yielded spores that would be assigned to *Calamospora* if found isolated. Baxter (1963, p. 473-475, figs. 10-13) described and illustrated spores of the *Calamospora* type from a new heterosporous calamitean cone, *Calamocarpon insignis* from the middle Pennsylvanian of Kansas and Iowa.

Calamospora obscura sp. nov.
Plate 1, figures 5-6

Diagnosis.—The spores are radial, originally spherical, and have numerous major folds throughout, but especially around the margin. The rays are very indistinct; in fact, only a few specimens show structures, at least three-fourths as long as the spore radius, that are interpreted as rays. *Area contagionis* is absent. The exine has a glistening rugose and waxy appearance under both high dry and oil immersion objectives. The spore coat is 2 to 2.5 μ thick. Dimensions (20 specimens): size range, 54.4 to 84.2 μ in maximum diameter; median, 67.8 μ.

Holotype.—Plate 1, figure 5; negative 5809; Fithian Cyclothem, maceration 1170-A, slide 1, coordinates, 131.7 × 51.4; size, 65.8 by 61.6 μ.

Paratype.—Plate 1, figure 6; negative 6467; Fithian Cyclothem, maceration 1170-A, slide 24, coordinates, 132.4 × 54.0; maximum diameter, 68.3 μ.

Discussion. — Specimens of *Calamospora obscura* absorbed the stain only slightly, if at all, whereas other spores in the same maceration were deeply stained.

Derivation of name.—The specific name refers to the indistinct (*obscura*) rays.

Calamospora pusilla sp. nov.
Plate 1, figures 7-9

Diagnosis.—The spores are radial, originally spherical, and characterized by an abundance of small and usually evenly distributed folds. Several specimens displayed faint trilete rays that would be very difficult to find on most specimens because of the intense folding. The surface of the spore coat is essentially smooth but appears slightly rugose when viewed under oil immersion objective. The exine is 1 μ or less thick. Dimensions (60 specimens): size range, 23.0 to 38.9 μ in maximum diameter; median, 30.0 μ.

Holotype.—Plate 1, figure 7; negative 6514; Trivoli Cyclothem, maceration 1175-G, slide 23, coordinates, 129.0 × 38.0; size, 31.2 μ in maximum diameter.

Paratypes.—Plate 1, figure 8; negative 6513; Trivoli Cyclothem, maceration 1175-G, slide 15, coordinates, 136.3 × 51.5; size, 30.2 μ in maximum diameter. Plate 1, figure 9, negative 5858; Trivoli Cyclothem, maceration 1175-G, slide 2, coordinates, 143.8 × 38.1; size, 35.8 by 33.2 μ.

Comparison.—*Calamospora pusilla* is distinguished from other species of *Calamospora* by its small size, numerous small folds, and indistinct trilete rays.

Derivation of name.—The name of the species refers to its very small (*pusilla*) size, which is distinctive.

Calamospora sp. 1
Plate 1, figure 10

The spores are radial, trilete, circular in outline, and usually folded. The rays are distinct and about three-fourths the length of the radius. The surface of the spore coat appears levigate when viewed under oil immersion objective. The exine is about 1 μ thick. Dimensions: size range about 28 to 35 μ in diameter.

Figured specimen.—Negative 4748; Trivoli Cyclothem, maceration 1128-I, slide 17, coordinates, 123.4 × 40.7; size, largest specimen 32.7 μ in maximum diameter. This species also was found in macerations 1128-H and 1128-J.

Genus CIRRATRIRADITES Wilson & Coe, 1940
Table 1

Type species.—*Cirratriradites maculatus* Wilson & Coe, 1940.

Affinity.—Probably herbaceous lycopods. Microspores of the *Cirratriradites* type have been described from a *Selaginella* from the Rhaetic by Lundblad (1950, p. 477-486). Spores from *Selaginellites suissai* Zeiller, 1906 (Chaloner, 1954, p. 81-87) and *S. crassicinctus* Hoskins & Abbott (1956, p. 36), also were found to agree closely with *Cirratriradites*.

Genus COLUMINISPORITES gen. nov.
Plate 1, figures 11-14; text figure 3

Type species.—*Columinisporites ovalis* sp. nov.

Diagnosis.—The generic name *Columinisporites* is proposed for small spores having the following characteristics. The spores are bilateral and bean shaped to elliptical in outline. They are probably monolete, but no specimens have been found that show a definite monolete suture. The spore is covered on all surfaces with three to many elevated, anastomosing, and branching ridges, 2 to 3 μ wide, that run more or less parallel to the length of the spore. Numerous smaller, closely spaced, more or less parallel ridges and grooves run approximately transverse to the major ridges. The spore coat is 1 to 2 μ thick. The spores are 37 to 81 μ in longest dimension.

Affinities.—Columinisporites probably belongs to or is closely related to the family Schizaeaceae. The general appearance of the spores is somewhat similar to that of the schizaeaceous spores illustrated by Selling (1944a, pl. 3, fig. 25; 1944b, pl. 3, fig. 24) and by Cookson (1956, pl. 9, figs. 1-3).

Comparison.—Columinisporites differs from *Schizaeoisporites* Potonié, 1951, in having anastomosing and branching ridges rather than regular parallel cicatricos ridges or canals.

Derivation of name.—The generic name refers to the raised (*columen*) ridges.

Columinisporites ovalis sp. nov.
Plate 1, figures 11-12; text figure 3

Diagnosis.—The spores are bilateral and bean shaped to elliptical in outline. They probably are monolete, but no definite suture has been noted in any of the specimens observed. Many specimens are torn parallel to the long dimension, and the tears may represent in part a monolete suture. The spore is covered on all surfaces with elevated anastomosing and branching ridges that run more or less parallel to the length of the spore. The ridges, about 2.5 μ wide and 1 μ high, number from 3 to 10, but usually 5 or 6 are present. In addition, numerous more or less parallel, closely spaced grooves and ridges less than 1 μ wide run transverse to the ridges. The spore coat is about 1 μ thick. Dimensions (15 specimens): 37.3 by 30.2 μ to 51.9 by 34.4 μ; median, 47.7 by 33.7 μ.

Holotype.—Plate 1, figure 11; negative 5791; Fithian Cyclothem, maceration 1170-G, slide 15; coordinates, 138.2 × 48.9; size, 48.9 by 32.4 μ.

Paratype.—Plate 1, figure 12; negative 6126; Fithian Cyclothem, maceration 1170-G, slide 15, coordinates, 128.9 × 52.5; size, 48.6 by 31.4 μ.

Derivation of name.—The specific name refers to the oval (*ovalis*) shape of the spore.

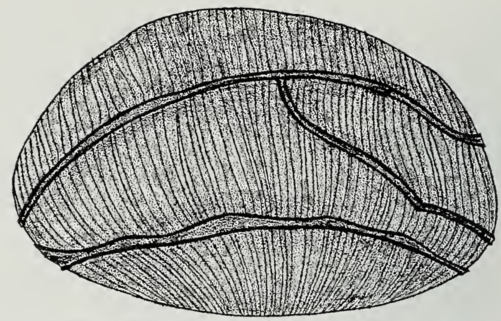

FIG. 3—*Columinisporites ovalis* sp. nov.; diagrammatic reconstruction of holotype; 48.9 by 32.4 μ.

Columinisporites sp. 1
Plate 1, figure 13

The spore is bilateral and bean shaped in outline. No commissure was observed. The surface of the spore coat is covered with two sets of ridges. The larger set of interconnecting sinuous ridges, about 1.5 μ wide, runs more or less parallel to the long dimension of the spore. The closely spaced, crisscrossing ridges, about 1 μ wide, of the second group are approximately perpendicular to the larger ridges and are connected to them.

Figured specimen.—Negative 6007; Trivoli Cyclothem, maceration 1175-B, slide 11, coordinates, 144.7 × 51.3; size, 77.8 by 55.1 μ.

Columinisporites sp. 2
Plate 1, figure 14

The spores are bilateral and bean shaped in outline. No commissure was observed. The spore coat is covered with more or less parallel ridges 2.5 to 3 μ wide and about 2 μ high. Secondary closely spaced ridges less than 1 μ wide are more or less perpendicular to the larger ridges.

Figured specimen.—Negative 6008; Trivoli Cyclothem, maceration 1175-B, slide 20, coordinates, 143.4 × 37.5; size, 81.1 by 56.8 μ. This species was also found in maceration 1175-D.

Genus Convolutispora Hoffmeister, Staplin, & Malloy, 1955a
Plate 1, figures 15-17

Type species.—Convolutispora florida Hoffmeister, Staplin, & Malloy, 1955a.

Affinity.—Unknown; see *Punctatisporites.*

Convolutispora venusta Hoffmeister, Staplin, & Malloy, 1955a
Plate 1, figure 15

Convolutispora sp. 1
Plate 1, figure 16

The spore is radial, trilete, and subcircular in outline. The rays, which are partly obscured by ornamentation, are about 36 μ long. The entire surface of the spore coat is covered with flat, truncated spines, 4 to 5 μ in diameter and about 6 μ long. They are joined to form ridges almost in a reticulate pattern. Minute spines occur at the ends of the major spines. The exine is about 4 μ thick.

Figured specimen.—Negative 5749; Fithian Cyclothem, maceration 1170-C, slide 16, coordinates, 143.0 × 43.0; size, 88.5 by 81.1 μ.

Convolutispora sp. 2
Plate 1, figure 17

The spore is radial, trilete, and subcircular in outline. Its trilete rays are distinct and about two-thirds the length of the spore radius. The lips are 1 μ wide on either side of the suture. The surface of the spore coat is covered with flat ridges 3 to 5 μ wide and about 1 μ high.

Figured specimen.—Negative 5669; Henshaw Formation, maceration 1122-Z, slide 25 ZB, coordinates, 124.0 × 48.4; size, 51.6 by 45.4 μ.

Genus Crassispora (Bhardwaj, 1957a) Bhardwaj, 1957b
Plate 1, figure 18; plate 2, figures 1-2; text figure 4

Type species.—*Crassispora* (*Planisporites*) *ovalis* (Bhardwaj, 1957a) Bhardwaj, 1957b.

Affinity.—Unknown.

Crassispora plicata sp. nov.
Plate 1, figure 18; plate 2, figures 1-2; text figure 4

Diagnosis.—The spores are radial, trilete, and roundly triangular to subcircular in outline. The spore coat is nearly always folded or torn, usually more or less parallel to the margin, to form an irregular, discontinuous thickened zone (text fig. 4). The equatorial margin of an inner membrane, which possesses apical papillae, sometimes can be seen inside and parallel to the margin of the spore exine. The trilete rays, about three-fourths the length of the spore radius, are usually indistinct, and the commissure may be either open or closed. Lips are absent, but folds along the rays may appear to be lips. Apical papillae, about 3 μ in diameter and height, are very conspicuous. The distal surface and margin of the spore coat are covered with coni of various sizes (generally about 1.5 μ long and 1 μ in diameter) distributed rather uniformly at least 1 μ apart. From 50 to 60 coni can be counted along the margin. The surface of the spore coat appears minutely and intensely punctate between the coni when viewed under oil immersion objective. The proximal surface, which is so thin that it can be seen only under oil immersion, also is minutely punctate but lacks coni. The exine is

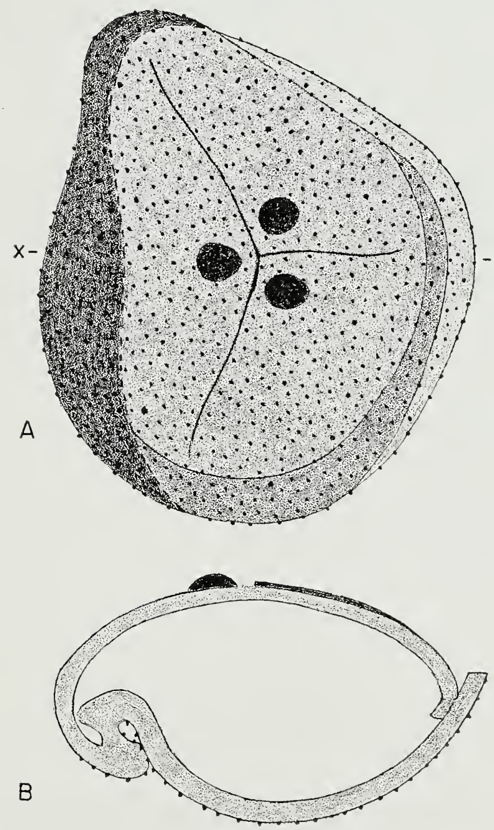

FIG. 4—*Crassispora plicata* sp. nov.; diagrammatic reconstructions.
A. View from proximal side with grana showing through from distal surface.
B. Cross section through spore along X—X′. Proximal surface of exoexine not shown.

about 1 μ thick. Dimensions (30 specimens): size range, 48.6 to 74.9 μ in maximum diameter; median, 60.9 μ.

Holotype.—Plate 1, figure 18; negative 6125; Fithian Cyclothem, maceration 1170-D, slide 24, coordinates, 141.2 × 40.1; size, 58.3 by 52.2 μ.

Paratypes.—Plate 2, figure 1; negative 6510; Fithian Cyclothem, maceration 1170-D, slide 15, coordinates, 128.7 × 45.7; size, 60.5 by 56.9 μ. Plate 2, figure 2; negative 4800; Trivoli Cyclothem, maceration 1128-J, slide 11, coordinates, 132.5 × 55.5; size, 49.1 by 39.0 μ.

Comparison. — *Crassispora plicata* differs from *C. ovalis* (Bhardwaj) Bhardwaj, 1957b, and *C. kosankei* (Potonié & Kremp) Bhardwaj, 1957b, by having more distinct rays, by lacking coni on the proximal surface, and by having prominent apical papillae. Illustrations of *C. ovalis* (Bhardwaj, 1957b, pl. 25, figs. 73-75) show what might be interpreted as apical papillae, but no mention of the latter was made in the original description of *Planisporites ovalis* or in the emended description of *C. ovalis.*

Derivation of name.—The species name refers to its characteristic folded (*plicata*) appearance.

Genus Cyclogranisporites Potonié & Kremp, 1954 Table 1

Type species.—*Cyclogranisporites leopoldi* (Kremp) Potonié & Kremp, 1954.

Affinities.—Psilopsida?, Filices (Potonié & Kremp, 1954, p. 126). See also *Punctatisporites.*

Genus Densosporites (Berry) Schopf, Wilson, & Bentall, 1944 Plate 2, figures 3-6

Type species.—*Densosporites covensis* Berry, 1937.

Affinity.—Lycopsid. Chaloner (1958b) described an Upper Carboniferous, minute, probably herbaceous, lycopod cone, *Selaginellites canonbiensis,* containing *Densosporites* microspores. In 1962 he described microspores resembling *D. solaris* Balme, 1952, from a lycopod cone, *Sporangiostrobus ohioensis* Chaloner. *Densosporites* from a lycopsid cone, *Porostrobus zeilleri* Nathorst, 1934, were reported by Bhardwaj (1958).

Densosporites cf. *marginata* Artuz, 1957

Only one rather poorly preserved specimen similar to *Densosporites marginata* was observed in the samples studied for this report.

Densosporites sp. 1 Plate 2, figure 3

The spore is radial, trilete, and roundly triangular in outline and has an irregular margin. The rays are distinct and extend to the inner margin of an equatorial thickened zone that possesses widely spaced verrucose projections about 2.5 μ in diameter and puncta 1 to 2 μ in diameter. Lips are well developed. The surface of the spore body appears finely punctate under oil immersion objective.

Figured specimen.—Negative 6004; Trivoli Cyclothem, maceration 1175-B, slide 8, coordinates, 140.7 × 38.0; size, 48.0 by 40.5 μ.

Densosporites sp. 2 Plate 2, figure 4

The spores are radial, rectangular to oval in outline, and have an irregular margin. No haptotypic features were observed. The equatorial thickened zone thickens slightly toward the poles and is about 8 μ wide. It is ornamented with irregularly scattered elliptical pits in which the longest dimensions are transverse to the margin. The surface of the spore body is covered with well defined, closely spaced pits 1 to 2 μ in diameter. *Densosporites* sp. 2 is somewhat similar to *D. triangularis* Kosanke, 1950, but has a narrower equatorial thickened zone and is smaller.

Figured specimen.—Negative 5920; Trivoli Cyclothem, maceration 1175-C, slide 14, coordinates, 129.7 × 33.7; size, 42.8 by 40.9 μ. This species was also found in maceration 1175-D.

Densosporites sp. 3 Plate 2, figure 5

The spore is radial, trilete, and roundly triangular in outline. The rays extend to the inner margin of the equatorial thickened zone. Lips are poorly developed. The equatorial zone is levigate, very thick, translucent, and 9 to 10 μ wide. The spore body is discernibly granulate under oil immersion objective.

Figured specimen.—Negative 5919; Trivoli Cyclothem, maceration 1175-C, slide 14, coordinates, 143.9 × 40.6; size, 37.9 by 33.7 μ.

Densosporites sp. 4
Plate 2, figure 6

The spores are radial, trilete, roundly triangular in outline, and have a slightly irregular margin. The trilete rays are very indistinct. The equatorial thickened zone, 8 to 9.5 μ wide, is set with widely scattered, low, well rounded spines about 3 μ wide and 2 μ high and elliptical pits less than 1 μ in diameter. The proximal and distal surfaces of the body are covered with circular, closely spaced pits smaller than those of the equatorial zone.

Figured specimen.—Negative 5581; Henshaw Formation, maceration 1122-A, slide 15 ZB, coordinates, 138.8 × 43.8; size, 37.4 by 32.4 μ. This species was also found in the Trivoli Cyclothem, maceration 1175-F.

Genus Dictyotriletes (Naumova)
Potonié & Kremp, 1954

Type species.—*Dictyotriletes mediareticulatus* (Ibrahim) Potonié & Kremp, 1954.

Affinity.—Filices? (Potonié & Kremp, 1954, p. 144).

Dictyotriletes? camptotus Alpern, 1958
Plate 2, figure 7

The spores encountered in this study that resemble the specimen illustrated by Alpern (1958, pl. 1, fig. 4) are provisionally assigned to *Dictyotriletes camptotus.* A new genus probably should be constructed for this taxon. Most specimens observed lacked the well defined reticulum on the distal side shown by Alpern (1958, fig. 3).

Genus Endosporites Wilson & Coe,
1940
Table 1

Type species.—*Endosporites ornatus* Wilson & Coe, 1940.

Affinity.—Lycopsid. *Lepidostrobus zea* Chaloner, 1953a, a heterosporous lycopod, was found by Chaloner (1953b, p. 109) to have borne microspores identified as *Endosporites.* In addition, Chaloner (1958c, p. 199-209) demonstrated that microspores from a microsporangia of *Polysporia mirabilis* Newberry, 1873, a lycopod cone, agree with the genus *Endosporites.*

Genus Florinites Schopf, Wilson, &
Bentall, 1944

Type species.—*Florinites antiquus* Schopf, 1944 (*in* Schopf, Wilson, and Bentall, 1944).

Affinities.—Gymnospermic, cordaitalean. Schopf, Wilson, and Bentall (1944, p. 57) pointed out the direct relationship between *Florinites* and pollen of cordaitalean material studied by Florin in the 1930s. Delevoryas (1953, p. 146) found pollen grains of the type assigned to *Florinites* from a male cordaitalean fructification.

Florinites sp. 1
Plate 2, figure 8

The prepollen grains are radial, subcircular to elliptical in outline, and usually folded. On one specimen, grooves that may be trilete rays were observed on the body. The bladder is externally levigate and internally sharply punctate to reticulate. Most specimens observed are elliptical in outline and not circular like the obliquely compressed figured specimen. Dimensions: size range, total 157.6 by 130.1 μ, body 98.3 by 90.8 μ.

Figured specimen.—Negative 4745; Trivoli Cyclothem, maceration 1128-I, slide 21, coordinates, 136.9 × 51.9; size, total 124.9 by 115.1 μ, body 96.7 by 64.9 μ. This species was also found in maceration 1128-J.

Genus Granulatisporites (Ibrahim)
Schopf, Wilson, & Bentall, 1944
Plate 2, figures 9-22

Type species.—*Granulatisporites granulatus* Ibrahim, 1933.

Affinity.—Filicinean (Schopf, Wilson, and Bentall, 1944, p. 32). Sporangia of *Botryopteris illinoensis* Mamay (1950, figs. 9-10) were found to contain *Granulatisporites*-like spores.

Harris (1961, p. 101-123, 140-185) illustrated spores of the *Granulatisporites* type from compression fern fossils of Jurassic strata of Great Britain.

Granulatisporites levis Kosanke, 1950

The observed size, about 50 μ, given for *Granulatisporites levis* by Kosanke (1950, p. 21) is increased to include specimens up to 65 μ in diameter.

Granulatisporites deltiformis (Wilson & Coe) Schopf, Wilson, & Bentall, 1944

The several specimens of *Granulatisporites deltiformis* observed were similar to the specimen illustrated by Wilson (1958, pl. 1, fig. 9).

Granulatisporites ibrahimi sp. nov.
Plate 2, figures 9-10

Diagnosis.—The spores are radial, trilete, and triangular in outline and have broadly rounded corners and concave interradial sides. The spores are in good proximal-distal orientation. The trilete rays are equal in length to the spore radius, and the lips are poorly developed and usually not visible. The proximal and distal surfaces of the spore coat are covered with closely spaced spines that usually are broader at their bases (up to 6.5 μ) than they are long (about 4.5 μ). The spines have pointed to slightly rounded ends and are seldom curved or bent. Two spines are occasionally joined in some part of the spore coat and may sometimes form thickened pads or *area contagionis.* Between 20 and 30 spines extend beyond the spore margin. The surface of the spore coat between the spines is obviously levigate under oil immersion objective. The exine is 1 to 1.5 μ thick. Dimensions (25 specimens): size range, 30.2 to 45.7 μ in maximum diameter (not including ornamentation); median, 37.3 μ.

Holotype.—Plate 2, figure 9; negative 6112; Trivoli Cyclothem, maceration 1175-G, slide 21, coordinates, 143.6 × 33.3; size, 36.0 by 35.0 μ.

Paratype.—Plate 2, figure 10; negative 6472; Trivoli Cyclothem, maceration 1175-G, slide 22, coordinates, 137.1 × 35.5; size, 36.7 by 32.5 μ.

Comparison.—The spines of *Granulatisporites ibrahimi* are less sharply pointed and less strongly curved than those of *Acanthotriletes falcatus* (Knox) Potonié & Kremp, 1955. *G. ibrahimi* has larger, fewer coni than *G. gibbosus* (Ibrahim) Schopf, Wilson, & Bentall, 1944, *G. microsaetosus* (Loose) Schopf, Wilson, & Bentall, 1944, and *Lophotriletes mosaicus* Potonié & Kremp, 1955. *G. ibrahimi* is more triangular and usually smaller than *L. insignitus* (Ibrahim) Potonié & Kremp, 1955.

Derivation of name.—The species is named in honor of Dr. A. C. Ibrahim.

Granulatisporites tenuis sp. nov.
Plate 2, figures 11-12

Diagnosis.—The spores are radial, trilete, and triangular in outline. The corners opposite the rays are rounded, and the interradial sides are straight to slightly convex or concave, depending upon the manner of compression. The spore coat is thin and usually folded during compression. The commissure is distinct, straight, extends to the spore margin, and generally is open. Lips are absent. A narrow, slightly thickened contact area is present along the aperture and extends almost to the ends of the rays. The surface of the spore coat is discernibly levigate under oil immersion objective. The exine is 1 to 1.5 μ thick. Dimensions (17 specimens): size range, 23.3 to 33.0 μ in maximum diameter; median, 28.2 μ.

Holotype.—Plate 2, figure 11; negative 6473; Fithian Cyclothem, maceration 1170-A, slide 10, coordinates, 125.9 × 45.9; size, 32.8 by 28.3 μ.

Paratype.—Plate 2, figure 12; negative 6141; Trivoli Cyclothem, maceration 1175-C, slide 24, coordinates, 131.6 × 50.4; size, 26.9 by 24.0 μ.

Comparison.—*Granulatisporites tenuis* is thicker and less angular than *Leiotriletes directus* Balme & Hennelly, 1956, which lacks well defined contact areas. *G. tenuis* is similar to *Laevigatisporites minimalis* Dybova & Jachowicz, 1957, but the latter has rays three-fourths the length of the radius, and apparently possesses no darkened contact areas. *G. tenuis* differs from *Leiotriletes gulaferus* Potonié & Kremp, 1955, in having darkened contact areas along the rays and usually in being smaller. *G. tenuis,* unlike *L. gulaferus,* is not consistently folded along one of the rays. *Leiotriletes subadnatoides* Bhardwaj, 1957a, differs in lacking contact areas and being intrapunctate.

Derivation of name.—The species name refers to the thin (*tenuis*) spore coat.

Granulatisporites elegans sp. nov.
Plate 2, figures 13-15

Diagnosis.—The spores are radial, trilete, triangular in outline, and are usually in good proximal-distal orientation. The corners opposite the rays are rounded, and the interradial sides are slightly convex to straight. The rays extend at least three-fourths the length of the spore radius, usually to the spore margin, but are not often visible due to the coarse ornamentation. Lips are absent. The distal surface and the peripheral areas of the proximal surface are covered with verrucose projections that are quite uniform in size. The verrucae extend to the peripheral areas of the proximal side but gradually decrease in size toward the proximal polar region, where they are less than 1 μ in diameter. Occasionally the margin at the corners is free of verrucae. In cross section, the projections are usually rounded but may be cone shaped to slightly clavate. On certain specimens the verrucae are practically all cone shaped, while on others they are mostly clavate. They are circular to oval in face view and are often so closely spaced that they almost touch at their bases. The verrucae are about 3 μ long and up to 8.5 μ in diameter. Sixty to 75 verrucae extend beyond the margin. The exine is 2 to 2.7 μ thick. Dimensions (13 specimens): size range 53.5 to 83.2 μ in maximum diameter (not including ornamentation); median, 68.1 μ.

Holotype.—Plate 2, figure 13; negative 6133; Henshaw Formation, maceration 1122-A, slide 31 ZB, coordinates, 140.1 $\times$ 31.9; size, 81.0 by 76.0 μ (not including ornamentation).

Paratypes.—Plate 2, figure 14; negative 5565; Henshaw Formation, maceration 1122-A, slide 10, coordinates, 133.9 $\times$ 32.3; size, 74.2 by 66.7 μ. Plate 2, figure 15; negative 5561; Henshaw Formation, maceration 1122-A, slide 14 ZB, coordinates, 134.5 $\times$ 39.5; size, 64.8 by 56.4 μ.

Comparison.—*Granulatisporites elegans* is strikingly similar to *Verrucosisporites naumovai* Hart, 1963, except that it has verrucae that decrease in size toward the trilete rays on the proximal surface.

Discussion.—*Granulatisporites elegans* is a useful stratigraphic marker for the subsurface strata of late Missourian age in Harper and Beaver Counties, Oklahoma (C. J. Felix, personal communication, 1963).

Derivation of name.—The name refers to the ornamentation of the species.

Granulatisporites sp. 1
Plate 2, figure 16

The spores are radial, trilete, and triangular in outline, and have well rounded corners and concave interradial sides. The rays are distinct and almost reach the spore margin. The surface of the spore coat is ornamented with widely spaced, bluntly cone-shaped projections about 1.5 μ long and 1.5 μ in diameter. About 40 coni extend beyond the margin. The exine is about 2 μ thick. This species is more coarsely ornamented than *Granulatisporites commissuralis* Kosanke, 1950, and *G. granulatus* Ibrahim, 1933.

Figured specimen.—Negative 5521; Henshaw Formation, maceration 1122-Q, slide 24 ZB, coordinates, 134.0 $\times$ 40.2; size, 36.7 by 34.0 μ. This species was also found in macerations 1122-G and 1122-A, in the Fithian Cyclothem maceration 1170-G, and in the Trivoli Cyclothem maceration 1175-J.

Granulatisporites sp. 2
Plate 2, figure 17

The spores are radial, trilete, and triangular in outline, and have well rounded corners and concave to straight interradial sides. The rays are distinct, straight, and extend almost to the spore margin. The lips are very narrow and slightly elevated. A conspicuous, raised, thickened pyramidal area is present and extends about one-third of the distance from the poles to the interradial sides and one-half to two-thirds of the distance to the corners opposite the rays. The interradial margins of the *area contagionis* are sharply delineated and usually raised. Granules on the surface of the exine can be seen under oil immersion objective. The spore coat is 1 to 1.5 μ thick. Dimensions (5 specimens): size range, 24.4 to 32.4 μ in maximum diameter; median, 27.2 μ.

Figured specimen.—Negative 5899; Trivoli Cyclothem, maceration 1175-P, slide 7, coordinates, 131.6 × 49.0; size, 28.2 by 24.7 μ. This species also was found in macerations 1175-A through 1175-D.

Granulatisporites sp. 3
Plate 2, figure 18

The spore is radial, trilete, triangular in outline, and has broad corners and concave interradial sides. The rays are distinct and at least three-fourths the length of the spore radius. Lips are poorly developed. The surface of the spore coat is ornamented with widely scattered papillate projections, 4 to 5.5 μ long and up to 3 μ wide. Small scattered grana also are present. The exine is about 2 μ thick.

Figured specimens.—Negative 5535; Henshaw Formation, maceration 1122-Q, slide 11, coordinates, 133.4 × 55.6; size of largest specimen, 32.4 by 29.2 μ.

Granulatisporites sp. 4
Plate 2, figure 19

These spores are very similar to that described and illustrated by Butterworth and Williams (1958, p. 365, pl. 1, fig. 41) as *Pustulatisporites papillosus* (Knox) Potonié & Kremp, 1955. Knox (1950, p. 327) described *P. papillosus* as having concave sides and being ornamented with tuberculate processes 2 μ long. Butterworth and Williams gave the length of the tubercles on their specimens as up to 8.5 μ long, with variable ornamentation even on the same specimen.

Figured specimen.—Negative 6112; Trivoli Cyclothem, maceration 1175-B, slide 5, coordinates, 138.1 × 37.8; size, 41.2 by 35.7 μ. This species also was found in maceration 1175-D.

Granulatisporites sp. 5
Plate 2, figure 20

The spore is radial, trilete, and roundly triangular in outline, and has broad, well rounded corners. The rays are distinct, straight, and about two-thirds the spore radius. *Area contagionis* is slightly thicker than the rest of the spore coat. The spore coat, about 2.5 μ thick, is seen to be levigate under oil immersion objective.

Figured specimen.—Negative 4749; Trivoli Cyclothem, maceration 1128-I, slide 16, coordinates, 130.3 × 52.2; size, 42.2 by 41.2 μ.

Granulatisporites sp. 6
Plate 2, figure 21

The spores are radial, trilete, triangular in outline, and have well rounded corners and convex interradial sides. The distinct, straight rays extend almost to the margin. The proximal and distal surfaces are covered with cone-shaped verrucose projections and flat spines about 3 μ long. The exine is about 2 μ thick.

Figured specimen.—Negative 5552; Henshaw Formation, maceration 1122-A, slide 3 ZB, coordinates, 141.9 × 46.6; size, 38.6 by 37.0 μ. This species also was found in maceration 1122-CC.

Granulatisporites sp. 7
Plate 2, figure 22

The spore is radial, trilete, and triangular in outline, and has well rounded corners and straight to convex interradial sides. The rays are distinct, straight, and about two-thirds the length of the spore radius. The proximal and distal surfaces are covered with grana that are broader than high and vary in size from less than 1 μ to 3 μ in diameter. They are largest at the corners, where they project beyond the margin. The spore coat is about 1 μ thick.

Figured specimen.—Negative 5762; Fithian Cyclothem, maceration 1170-C, slide 11, coordinates, 135.6 × 27.6; size, 44.7 by 44.1 μ.

Genus Gravisporites Bhardwaj, 1954

Type species.—*Gravisporites sphaerus* (Butterworth & Williams) Bhardwaj, 1954.

Affinity.—Unknown; may be closely related to *Cadiospora.*

Gravisporites sphaerus (Butterworth & Williams) Bhardwaj, 1954
Plate 3, figure 1

Genus Hamiapollenites? Wilson, 1962

Type species.—*Hamiapollenites saccatus* Wilson, 1962.

Affinity.—Probably Coniferales.

Hamiapollenites? sp. 1
Plate 3, figure 2

The pollen grain is bilateral, bisaccate, and has four longitudinal ribs and one transverse rib. This species is assigned to *Hamiapollenites* with reservations because the genus as described by Wilson has a larger number of ribs than were observed on the single, eroded specimen studied. The specimen also shows some similarity to *Protodiploxipinus bullaeformis* Samoilovich, 1953.

Figured specimen.—Negative 5663; Henshaw Formation, maceration 1122-Z, slide 3 ZB, coordinates, 136.3 × 37.2; size, total length 68.3 μ, body 38.9 by 36.0 μ.

Genus Illinites Kosanke, 1950
Table 1

Type species.—*Illinites unicus* Kosanke, 1950.

Affinity.—Probably of gymnospermic origin (Kosanke, 1950, p. 51).

Genus Indospora Bhardwaj, 1960
Plate 3, figures 3-6

Type species.—*Indospora clara* Bhardwaj, 1960.

Affinity.—Unknown.

Indospora stewarti sp. nov.
Plate 3, figures 3-4

Diagnosis.—The spores are radial, trilete, strongly triangular in outline, and often in poor proximal-distal orientation. Corners opposite the rays are pointed, and the interradial sides are straight to slightly convex, occasionally slightly concave. A prominent triradiate ridge about 3 μ wide is present on the distal side opposite the trilete rays and at the corners extends about 3 μ beyond the margin. The ridges are most prominent on the inner surface of the distal side and are elevated only slightly above the outer distal surface. The trilete rays are usually distinct and extend to the margin of the spore wall. The spore coat is somewhat darker adjacent to the commissure, which is usually open. The spore is often obliquely compressed, displacing the rays so they are not exactly opposite the distal ridges. The surface of the spore body is covered with widely distributed fan-shaped projections that are usually divided into two or more minute subdivisions at the ends. The major projections are about 3 μ long and 2.5 μ wide at their ends. Scattered between the major projections are widely spaced, small, circular, cone-shaped projections less than 1 μ in diameter. The triradiate ridge has a flat, smooth crest, but under oil immersion objective minute coni can usually be seen along the sides of the ridge. The spore coat is less than 1 μ thick. Dimensions (18 specimens): size range, 29.5 to 38.9 μ in maximum diameter; median, 35.7 μ.

Holotype.—Plate 3, figure 3; negative 6136; Trivoli Cyclothem, maceration 1175-B, slide 5, coordinates 132.0 × 46.4; size, 38.9 by 37.3 μ.

Paratype.—Plate 3, figure 4; negative 4791; Trivoli Cyclothem, maceration 1128-L, slide 19, coordinates, 143.8 × 41.3; size, 35.6 by 35.0 μ.

Comparison.—*Indospora stewarti* is smaller and more angular than *I. clara* Bhardwaj, 1960, and lacks distal polygonal meshes. A single specimen of *I. stewarti* or a similar species has been noted from Permian strata of Texas by Kosanke (1961, personal communication).

Derivation of name.—The species is named in honor of Professor Wilson N. Stewart, paleobotanist, University of Illinois.

Indospora sp. 1
Plate 3, figures 5-6

The spore is radial, trilete, and subtriangular in outline. The commissure is distinct and split open. The rays, which extend to the spore margin, have poorly developed lips. Distal ridges extend about 3 μ beyond the margin and are minutely pitted. Finely pitted clavate projections, approximately 3 μ long and 3 μ in diameter, occur along the interradial areas on the proximal surface. Twenty projections extend beyond the margin.

Figured specimen.—Plate 3, figures 5 and 6; negatives 6142 and 6144; Henshaw Formation, maceration 1122-DD, slide 14, coordinates, 144.6 × 46.5; size, 38.9 by 36.0 μ (not including ornamentation).

Discussion.—The figured specimen shows the relationship in *Indospora* between the commissure and the distal ridges. Figure 5 is focused on the commissure to show overlapping of two of the rays across the distal ridges. In figure 6 the distal ridges, elevated toward the proximal surface, are in focus. The figured specimen was found in maceration 1122-DD, a coal not studied in detail for this report, 50 feet below maceration 1122-E.

Genus Knoxisporites Potonié & Kremp, 1954 Table 1

Type species.—*Knoxisporites hageni* Potonié & Kremp, 1954.

Affinity.—Unknown.

Genus Laevigatosporites (Ibrahim) Schopf, Wilson, & Bentall, 1944 Plate 3, figures 7-12

Type species.—*Laevigatosporites vulgaris* (Ibrahim) Ibrahim, 1933.

Affinities.—Calamarian and filicinean. Kosanke (1950, p. 28) pointed out that spores of a calamarian fructification illustrated by Reed (1938) and of *Zeilleria,* a fern (Florin, 1936), are possibly of the *Laevigatosporites* type. Smooth, monolete spores were described by Mamay (1950, p. 422, 434) from sporangia of Marattiales ferns, *Cyathotrachus altissimus* Mamay, 1950, and *Scolecopteris incisifolia* Mamay, 1950. Remy (1960, p. 124) obtained spores of the *L. ovalis* type from a fructification of *Bowmanites nindeli* Remy, 1960, and *B. simoni* Remy, 1961 (p. 331-336). In addition, *Laevigatosporites* as much as 105 μ long were recorded from a fructification of *Tristachya crockensis* Remy & Remy (1961, p. 220-223).

Laevigatosporites crassus sp. nov. Plate 3, figures 7-8

Diagnosis.—The spores are bilateral, monolete, and oval to bean shaped in outline. The commissure, which is indistinct as viewed from the distal surface, is straight and about two-thirds the length of the spore. The surface of the spore coat has a rough appearance under high dry objective. Under oil immersion, the spore coat is mostly minutely spinose but may appear as punctate, depending upon the spacing of the spines. The spines are cone shaped and about as wide at their bases as they are high. The spore coat is 3 to 4.3 μ thick. Dimensions (6 specimens): size range, 33.4 by 28.5 to 43.6 by 32.5 μ; median, 40.0 by 32.2 μ.

Holotype.—Plate 3, figure 7; negative 5626; Henshaw Formation, maceration 1122-G, slide 3 T, coordinates, 133.2 × 49.6; size, 39.9 by 32.7 μ (not including ornamentation).

Paratype.—Plate 3, figure 8; negative 6469; Henshaw Formation, maceration 1122-G, slide 4 T, coordinates, 140.6 × 34.4; size, 43.6 by 42.5 μ.

Comparison.—*Laevigatosporites crassus* is similar to *Speciososporites laevigatus* Alpern (1959, fig. 353, p. 185), but the latter has a longer monolete suture, and, according to Alpern's description, is more nearly round and levigate than *L. crassus.* The spore coat of *L. crassus* is thicker than the "cingulum" (thickness?) of *S. laevigatus. S. plicatus* Alpern (1959, figs. 354-355) is like *S. laevigatus* and *L. crassus,* but is punctate or finely granulate and has a folded central portion and a suture that is often folded.

Derivation of name.—The species name refers to the thick (*crassus*) spore coat.

Laevigatosporites papillatus sp. nov. Plate 3, figures 9-10

Diagnosis.—The spores are bilateral, monolete, and bean shaped in outline. The straight commissure, 19 to 22 μ long, is sometimes obscured by ornamentation or folding. The exine is covered with minute papillate projections, about 1 μ long and less than 0.5 μ in diameter, that are so closely spaced that the number extending beyond the margin cannot be determined even under oil immersion objective. The spore coat is 1 to 2 μ thick. Dimensions (14 specimens): size range, 31.1 by 22.7 to 36.0 by 22.7 μ; median, 32.6 by 24.4 μ.

Holotype.—Plate 3, figure 9; negative 6509; Henshaw Formation, maceration 1122-Q, slide 22, coordinates, 126.4 × 38.4; size, 32.2 by 25.0 μ.

Paratype.—Plate 3, figure 10; negative 6108; Henshaw Formation, maceration 1122-Q, slide 46 ZB, coordinates, 139.9 × 34.6; size, 31.4 by 26.2 μ in diameter.

Comparison.—*Laevigatosporites papillatus* is somewhat similar to *Punctatosporites granifer* Potonié & Kremp, 1956, but is papillate rather than granulose and is less coarsely ornamented.

Derivation of name.—The species name refers to the papillate (*papillatus*) ornamentation.

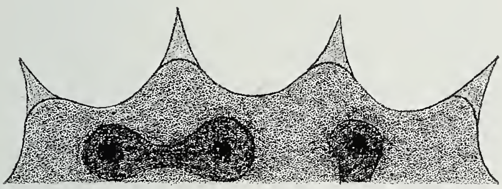

FIG. 5—Diagrammatic detail of portion of exine of *Laevigatosporites spinosus* sp. nov.

Laevigatosporites spinosus sp. nov.
Plate 3, figures 11-12; text figure 5

Diagnosis.—The spores are bilateral, monolete, and elliptical in outline. The margin of the spore is slightly scalloped due to the ornamentation. The distinct, straight commissure is usually open and almost equal in length to the long dimension of the spore. The spore coat is covered with thick spines, about 1.5 μ in length and diameter, that have gently rounded ends. Two or three spines commonly are connected by low irregular ridges. On top of each major spine is a smaller, thin, almost transparent, sharp spine about 1 μ long (text fig. 5). In cross section, under oil immersion objective, the thin spines are barely visible, but in face view they appear as sharp, distinct points. The major spines are 1 to 2 μ apart, and about 35 can be counted along the spore margin. The spore coat is about 2 μ thick. Dimensions (15 specimens): size range, 16.2 by 12.9 μ to 22.7 by 17.8 μ (not including ornamentation); median, 19.2 by 15.2 μ.

Holotype.—Plate 3, figure 11; negative 6109; Henshaw Formation, maceration 1122-Q, slide 29 ZB, coordinates, 141.7 × 43.0; size, 22.4 by 18.5 μ.

Paratype.—Plate 3, figure 12; negative 6465; Henshaw Formation, maceration 1122-Q, slide 11 ZB, coordinates, 139.2 × 45.7; size, 19.8 by 15.6 μ (not including ornamentation).

Derivation of name.—The species name refers to the spinous (*spinosus*) spore coat.

Genus LATIPULVINITES gen. nov.
Plate 3, figures 13-14; text figure 6

Type species.—*Latipulvinites kosankii.*

Diagnosis.—The generic name *Latipulvinites* is proposed for small spores having the following characteristics. The spores are radial, trilete, triangular in outline, and usually in good proximal-distal orientation. They have well rounded corners and straight to slightly concave or convex interradial sides. The distinct, straight, trilete rays that extend to the spore margin have very narrow, slightly elevated lips. The spores possess prominent triradiate ridges. The flat-crested ridges are thickest toward their outer, sharply delineated margin; they extend about half the distance to the interradial spore margin and at least two-thirds of the distance to the corners opposite the rays. The spore coat, about 3 μ thick, is discernibly levigate under high dry objective. The known size range is 38.9 to 48.6 μ.

Discussion.—*Latipulvinites* is distinguished from other small spore genera by its triangular shape and well developed triradiate ridges (text fig. 6). Some specimens of *Latipulvinites* that have small folds extending from the corners opposite the rays to the ends of the triradiate ridges give the gross appearance of *Ahrensisporites.* However, the kyrtomes of *Ahrensisporites,* unlike the elevated structures of *Latipulvinites,* are on the distal spore surface. Some species of *Granulatisporites* with thickened contact areas, for example *G. levis* Kosanke, 1950, are somewhat similar to *Latipulvinites* but do not have the well developed triradiate ridges of *Latipulvinites.*

Affinity.—Unknown. Probably filicinean.

Derivation of name.—The genus is named *Latipulvinites* because of its wide (*latus*), cushionlike (*pulvinus*) triradiate ridges.

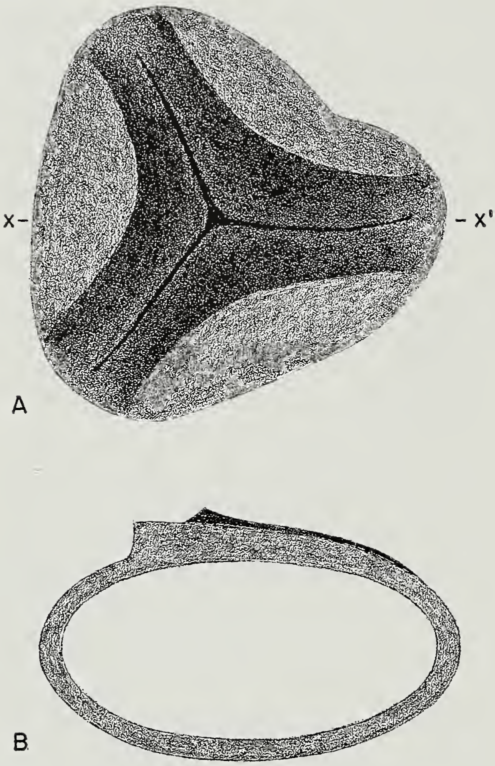

FIG. 6—*Latipulvinites kosankii* sp. nov.; diagrammatic reconstructions of holotype; 40.5 by 35.0 μ.
A. View from proximal side.
B. Cross section through spore along X—X′.

Latipulvinites kosankii sp. nov.
Plate 3, figures 13-14; text figure 6

Diagnosis.—The spores are radial, trilete, and triangular in outline. They are usually in good proximal-distal orientation and have well rounded corners and straight to slightly concave or convex interradial sides. The distinct trilete rays are straight and extend to the margin of the spore coat. Lips are poorly developed, very narrow, and slightly elevated. The elevated triradiate ridges, which are very prominent, are thicker and darker toward their sharply delineated outer margin (text fig. 6). The ridges extend about halfway to the interradial margin and at least two-thirds of the distance to the corners opposite the rays. The surface of the spore coat appears levigate under high dry objective, but with careful focusing under oil immersion objective minute puncta, which are largest marginal to the rays, can be distinguished. The spore coat is about 3 μ thick. Dimensions (8 specimens): size range, 38.9 to 48.6 μ; median, 41.5 μ.

Holotype.—Plate 3, figure 13; negative 5962; Trivoli Cyclothem, maceration 1175-C, slide 24, coordinates, 124.0 × 36.2; size, 40.5 by 35.0 μ.

Paratype.—Plate 3, figure 14; negative 5629; Henshaw Formation, maceration 1122-G, slide 9 T, coordinates, 136.9 × 50.5; size, 44.4 by 37.3 μ.

Comparison.—*Latipulvinites kosankii* appears somewhat similar to *Ahrensisporites minutus* Alpern, 1958, but the latter is smaller (25 μ). *L. kosankii* is also similar to the specimen illustrated by Alpern (1959, fig. 159) and identified as *A.* cf. *angulatus* (Kosanke) Potonié & Kremp, 1956. *L. kosankii* strongly resembles a spore designated by Neves (1958, pl. 2, fig. 6) as spore type "C", except that the latter is more nearly circular in outline and is larger (63 μ).

Derivation of name.—The species is named in honor of Dr. Robert M. Kosanke, paleobotanist, U. S. Geological Survey.

Genus Limitisporites (Leschik)
Potonié, 1958
Table 1

Type species.—*Limitisporites rectus* Leschik, 1956.

Affinity.—Probably gymnospermic.

Genus Lueckisporites
(Potonié & Klaus) Potonié, 1958
Table 1

Type species.—*Lueckisporites virkkiae* Potonié & Klaus, 1954.

Affinity.—*Caytoniales?* (Potonié and Kremp, 1954, p. 177).

Genus Lundbladispora Balme, 1963
Plate 3, figures 15-17

Type species.—*Lundbladispora willmotti* Balme, 1963.

Comparison.—*Lundbladispora willmotti* and *L. simoni* sp. nov. are markedly similar to *Crassispora* except that *Lundbladispora* has a better developed, continuous, thickened equatorial zone, which accounts for its usually good proximal-distal orientation. *Crassi-*

spora and *Lundbladispora* appear to be morphologically closely related.

Affinities.—Probably lycopsid, sigillarian. Balme (1963, p. 22) pointed out the similarity of cavate spores to spores of modern species of *Selaginella* and to those obtained from fossil lycopodiaceous strobili. *Lundbladispora willmotti* and *L. simoni* sp. nov. are quite similar to the microspores of *Mazocarpon oedipternum* Schopf (1941, pl. 5, fig. 4).

Lundbladispora simoni sp. nov.
Plate 3, figures 15-17

Diagnosis.—The spores are radial, trilete, roundly triangular to subcircular in outline, and usually in good proximal-distal orientation. The trilete rays are distinct, often torn, and extend almost to the inner margin of the thickened equatorial zone. The exoexine and intexine marginal to the commissure are usually elevated and sinuous, giving the appearance of lips. Prominent apical papillae are present on the intexine. Surrounding the spore body is a flange or slightly thickened equatorial zone about 6 μ wide that gradually tapers in thickness toward the periphery of the spore. The equatorial zone is slightly thicker opposite the rays in some, but not all, specimens. The proximal surface is convex, and the distal surface is more or less flat and even with the flange. Under oil immersion objective the proximal and distal surfaces and the flange are minutely punctate. In addition, the entire distal surface is ornamented with verrucose or granulose projections, most of which are spherical but some of which are cone shaped, and which vary in size from less than 1 μ to 3.5 μ in diameter and may be up to 3 μ long. The periphery of the flange is set with 35 to 45 verrucae. The very thin levigate intexine may not be apparent in highly compressed specimens. The proximal side is about 1 μ thick, and the distal side is about 2 μ thick. Dimensions (15 specimens): size range, 47.7 to 74.6 μ in maximum diameter; median, 61.5 μ.

Holotype.—Plate 3, figure 15; negative 6130; Henshaw Formation, maceration 1122-Q, slide 28 ZB, coordinates, 129.6 $\times$ 45.0; size, 59.3 by 59.3 μ (not including ornamentation).

Paratypes.—Plate 3, figure 16; negative 6427; Henshaw Formation, maceration 1122-Q, slide 41 ZB, coordinates, 141.2 $\times$ 31.9; size, 69.2 by 68.3 μ. Plate 3, figure 17; negative 5439; Henshaw Formation, maceration 1122-Q, slide 14, coordinates, 135.9 $\times$ 30.8; size, 58.3 by 55.7 μ.

Comparison.—*Lundbladispora simoni* resembles *Lycospora gigantea* Alpern, 1958 (Alpern, 1959, p. 171, pl. 7, figs. 179-181), but the latter has coni over its entire surface and lacks apical papillae. *Lycospora gigantea* probably should be reassigned to *Lundbladispora*. *Lundbladispora simoni* compares closely with *Lundbladispora willmotti*, but the latter has a thicker distal surface (4 to 6 μ) and is larger (71 to 86 μ). The distal surface of *Lundbladispora simoni* is ornamented mainly with verrucae having rounded to blunt ends, rather than with coni or spines such as appear on *L. willmotti*. The intexine of *L. simoni* is not as sharply delineated as that of *L. willmotti*. The latter was described from considerably younger strata (Early Triassic).

Derivation of name.—The species was named in honor of Jack A. Simon, Illinois State Geological Survey.

Genus Lycospora Schopf,
Wilson, & Bentall, 1944
Plate 3, figures 18-21

Type species.—*Lycospora micropapillatus* (Wilson & Coe) Schopf, Wilson, & Bentall, 1944.

Affinities.—*Arboreous lepidodendrids* (Schopf, Wilson, and Bentall, 1944, p. 54). Felix (1954, p. 351-394) described and illustrated microspores of the *Lycospora* type from several arborescent lycopod cones. Sen (1958, p. 160) obtained microspores he assigned to *Lycospora parva* Kosanke, 1950, from a *Lepidostrobus* compression. Spores of the *Lycospora* type from three microsporangiate lycopod strobili—*Lepidostrobopsis princeps* (Lesquereux) Abbott, 1963, *Lepidocarposis angusta* Abbott, 1963, and *L. semialata* Abbott, 1963, were described by Abbott (1963, p. 103-110). Several other investigations also have demonstrated that the affinity of *Lycospora* lies with Lycopsida.

Lycospora pseudoannulata Kosanke, 1950
Plate 3, figure 18

Lycospora cf. *trigonoreticulata* (Loose) Potonié & Kremp, 1956

The size range for *Lycospora trigonoreticulata* given by Potonié and Kremp (1956, p. 104) is 30 to 40 μ. The few specimens encountered in this study were about 28 μ in diameter.

Lycospora cf. *subjuga* Bhardwaj, 1957b

Although the single specimen of *Lycospora* cf. *subjuga* found in maceration 1122-Q has apical papillae, it was assigned to this species. No mention was made by Bhardwaj of these structures, but the holotype illustrated (Bhardwaj, 1957b, pl. 25, fig. 84) appears to possess apical papillae.

Lycospora sp. 1
Plate 3, figure 19

The spores are radial, trilete, and subtriangular in outline. The rays are distinct and extend to the margin of the spore coat. Lips are well developed and about 1.5 μ wide on either side of the commissure. A flattened equatorial ridge, about 3 μ wide, is present. The surface of the spore coat is distinctly granulose under oil immersion objective. The exine is about 1 μ thick.

Figured specimen.—Negative 5871; Trivoli Cyclothem, maceration 1175-G, slide 18, coordinates, 136.6 × 48.1; size, 26.9 by 25.6 μ. This species was also found in maceration 1175-B.

Lycospora sp. 2
Plate 3, figure 20

The spore is radial, trilete, and roundly triangular in outline. The rays, bordered by narrow, elevated lips, are distinct and extend to the spore margin. The flattened equatorial ridge is about 6 μ wide. The spore coat is ornamented with small coni, which are so closely spaced that some areas appear punctate.

Figured specimen.—Negative 6020; Trivoli Cyclothem, maceration 1175-D, slide 5, coordinates, 144.0 × 44.5; size, 35.1 by 32.4 μ.

Lycospora sp. 3
Plate 3, figure 21

The spore is radial, trilete, and roundly triangular in outline. The rays are distinct, straight, and about three-fourths the length of the spore radius. Low, dark lips about 2 μ wide are on either side of the commissure. The surfaces of the body and flange, which is about 3 μ wide, are levigate under oil immersion objective. The body and flange are about 1 μ thick.

Figured specimen.—Negative 5781; Fithian Cyclothem, maceration 1170-G, slide 4, coordinates, 139.1 × 32.6; size, 39.9 by 38.6 μ (including flange).

Genus Microreticulatisporites (Knox) Potonié & Kremp, 1954
Table 1

Type species.—*Microreticulatisporites lacunosus* (Ibrahim) Knox, 1950.

Affinity.—Noeggerathiales? (Potonié and Kremp, 1954, p. 143).

Genus Pityosporites (Seward) Potonié & Klaus, 1954

Type species.—*Pityosporites antarcticus* Seward, 1914.

Affinity.—Coniferae. Somewhat similar to modern Podocarpaceae and Pinaceae (Schopf, Wilson, and Bentall, 1944, p. 28).

Pityosporites sp. 1
Plate 3, figure 22

The prepollen grain is bilateral, bisaccate, and has an elliptical body. The cap is distinct and reticulate. Bladders are externally levigate and internally coarsely reticulate. Lacunae of the reticulations are up to 3 μ in diameter.

Figured specimen.—Negative 5798; Fithian Cyclothem, maceration 1170-G, slide 19, coordinates, 134.0 × 46.9; size, total length 67.7 μ, body 41.5 by 30.8 μ.

Genus Potonieisporites Bhardwaj, 1954
Table 1

Type species.—*Potonieisporites novicus* Bhardwaj, 1954.

Affinity.—Unknown.

Genus Punctatisporites (Ibrahim) Schopf, Wilson, & Bentall, 1944
Plate 3, figures 23-26; plate 4, figures 1-21; plate 5, figures 1-12; text figures 7-9

Type species.—Punctatisporites punctatus (Ibrahim) Ibrahim, 1933.

Affinities.—Pteridospermic and filicinean (Schopf, Wilson, and Bentall, 1944, p. 29). According to Potonié and Kremp (1955, p. 42), the affinities of *Punctatisporites* are with Psilopsida, Filicineae, and possibly Cycadofilicineae. Spores of the *Punctatisporites* type, according to the Schopf, Wilson, and Bentall classification, were reported by Remy and Remy (1955, p. 42-43, 45-47, pls. 14, 16, 17) from compressions of *Acitheca* (*Pecopteris*) *longifolia* Corsin, *Senftenbergia* (*Pecopteris*) *pennaeformis* Brongniart, *Corynepteris silesiaca* Remy & Remy, 1955, and *Schizopteris pinnata* Grand'Eury. Illustrations of spores of *Botyropteris fecunda* Mamay (1950, fig. 4) show some similarity to *Punctatisporites sulcatus* Wilson & Kosanke, 1944. Mamay also pointed out that spores obtained from *Biscalitheca nusata* Mamay (1957, p. 232-237), a Pennsylvanian coenopterid, resembled *P. vermiculatus* Kosanke, 1950.

Punctatisporites sulcatus Wilson & Kosanke, 1944

Hoffmeister, Staplin, and Malloy (1955b, pl. 4, fig. 18) assigned *Punctatisporites sulcatus* to *Cristatisporites.* The species was assigned to *Punctatisporites* by Wilson and Hoffmeister (1956, p. 20) and to *Converrucosisporites* by Guennel (1958, p. 61).

Punctatisporites cf. *obesus* (Loose) Potonié & Kremp, 1955

Specimens observed in this study are similar to the one illustrated by Potonié and Kremp (1955, pl. 11, fig. 124).

Punctatisporites brevivermiculatus sp. nov.
Plate 3, figures 23-24; text figure 7

Diagnosis.—The spores are radial, trilete, circular to subcircular in outline, and have an uneven equatorial margin due to ornamentation. They are in good proximal-distal orientation. The rays are straight, between two-thirds and three-fourths the length of the spore radius (15 to 23 μ), and distinct when seen from the proximal surface. The spore coat, which is 3.5 to 6 μ thick, appears punctate when viewed under high dry objective, but under oil immersion objective the ornamentation is distinctly vermiculate (text fig. 7). The vermiculations are terminated at their ends by deep puncta, about 2 μ in diameter and 1.5 μ deep, and cover about 30 percent of the spore surface. Dimensions (7 specimens): size range, 55.1 to 71.3 μ in maximum diameter; median, 63.2 μ.

Holotype.—Plate 3, figure 23; negative 6471; Henshaw Formation, maceration 1122-A, slide 49 ZB, coordinates, 126.0 × 32.2; size, 63.1 by 58.5 μ.

Paratype.—Plate 3, figure 24, negative 5571; Henshaw Formation, maceration 1122-A, slide 18 ZB, coordinates, 145.4 × 51.9; size, 56.1 by 54.4 μ.

Derivation of name.—The species name refers to the small (*brevi*) vermiculations.

FIG. 7—Diagrammatic detail of portion of exine of *Punctatisporites brevivermiculatus* sp. nov.

Punctatisporites chapelensis sp. nov.
Plate 3, figures 25-26

Diagnosis.—The spores are radial, trilete, circular to subcircular in outline, and usually folded or torn. The rays are usually very indistinct due to the coarseness of ornamentation but can be traced at least half the distance to the spore margin. The rays, which lack lips, are often split open. The spore coat, about 1.5 μ thick, is covered with verrucose projections that vary in shape from rectangular (baculate) to oval in cross section and have flat or rounded ends. Projections may be either broader than high or higher than broad. The verrucae are from less than 1 μ to 3 μ in height and diameter and are 1 to 3 μ apart. Between the verrucae are puncta and minute grana that are only faintly visible under high dry objective but distinct under oil immersion objective. From 30 to 40 verrucae can be counted around the margin of the spore. Dimensions (21 specimens): size range, 32.4 to 42.1 μ in maximum diameter; median, 38.5 μ (not including ornamentation).

Holotype.—Plate 3, figure 25; negative 6115; Trivoli Cyclothem, maceration 1128-H, slide 7, coordinates, 128.1 × 53.9; size, 41.5 by 39.2 μ (not including ornamentation).

Tetrad.—Plate 3, figure 26; negative 4744; Trivoli Cyclothem, maceration 1128-H, slide 15, coordinates, 133.8 × 40.1; maximum diameter of largest specimen, 39.5 μ.

Derivation of name.—The species name refers to the Chapel (No. 8) Coal.

Punctatisporites saetiger sp. nov.
Plate 4, figures 1-2

Diagnosis.—The spores are radial, trilete, subcircular to circular in outline, usually in poor proximal-distal orientation, and often folded, giving the appearance of bilateral spores. The trilete rays may be obscured by folding or ornamentation. Two of the rays are more than three-fourths the length of the spore radius, but the third ray is usually much shorter. The commissure is generally open, and lips may be present but are difficult to distinguish. The proximal and distal surfaces are covered with papillae and occasionally setae, 0.5 to 1.5 μ long and less than 1 μ in diameter. The projections are circular in end view. They are variably spaced—as much as 3 μ apart or so close together that the spore coat in some specimens appears punctate and in others seems partly punctate and partly papillate. From 55 to 70 projections extend beyond the margin of the spore coat but are so crowded that they are difficult to count. The spore coat is 1.5 to 2 μ thick. Dimensions (35 specimens): size range, 19.5 to 32.1 μ in maximum diameter; median, 23.3 μ (not including ornamentation).

Holotype.—Plate 4, figure 1; negative 6470; Henshaw Formation, maceration 1122-Q, slide 34 ZB, coordinates, 134.6 × 42.7; size, 24.1 by 21.1 μ (not including ornamentation).

Paratype.—Plate 4, figure 2; negative 5444; Henshaw Formation, maceration 1122-Q, slide 5 ZB, coordinates, 135.0 × 44.4; size, 25.6 by 23.3 μ.

Comparison.—*Punctatisporites saetiger* is similar to *Planisporites parvus* Lakhanpal, Sah, & Dube, 1958, but the latter has low coni rather than papillae, has about 50 coni at the margin, and has rays of equal length. *Apiculatisporites parvispinosus* Leschik, 1956, has shorter rays (about 5 μ long) and shorter projections (spines about 0.5 μ long) than *Punctatisporites saetiger. P. saetiger* has larger, more abundant, and more distinct projections than *P. minutus* Kosanke, 1950. *P. saetiger* is more intensely ornamented than *Cyclogranisporites pressoides* Potonié & Kremp, 1955, which is thus more like *P. minutus. C. leopoldi* (Kremp) Potonié & Kremp, 1954, is granulose and has rays of equal length that are shorter (half the spore radius) and less conspicuous than those of *P. saetiger.*

Derivation of name.—The species name refers to the many bristle-like projections (*saetiger*).

Punctatisporites compactus sp. nov.
Plate 4, figures 3-4

Diagnosis.—The spores are radial, trilete, and roundly triangular to subcircular in outline. The rays extend to the spore margin and are indistinct, because of the intense ornamentation. The proximal and distal surfaces are densely covered with papillate to granulose projections that show continuous gradations between the two. The papillae have blunt, expanded ends and are 1 to 2 μ long and about 1 μ in diameter, the longer ones being slightly curved. The surface of the spore coat appears to be punctate where the ornamentation is closely spaced so that a single specimen may be partly papillate and partly punctate. Some papillae or grana are joined as elliptical projections. The exine is about 1 μ thick. Dimensions (30 specimens): size range, 19.8 to 31.8 μ in maximum diameter (not including ornamentation); median, 25.3 μ.

Holotype.—Plate 4, figure 3; negative 4928; Trivoli Cyclothem, maceration 1128-G, slide 2, coordinates, 143.0 × 42.8; size, 22.4 by 19.8 μ (not including ornamentation).

Paratype.—Plate 4, figure 4; negative 4742; Trivoli Cyclothem, maceration 1128-H, slide 16, coordinates, 126.4 × 39.0; size, 26.2 by 25.3 μ (not including ornamentation). The paratype illustrates the reduction of papillae to low, grana-like projections.

Comparison.—*Punctatisporites compactus* is similar to *Filicitriletes rectispinus* (Luber) Luber, 1955, but the latter has distinct rays and is ornamented with spines that are not as closely spaced as the papillae of *P. compactus.*

Derivation of name.—The species name refers to the concentrated (*compactus*) nature or density of the projections.

Punctatisporites productus sp. nov.
Plate 4, figures 5-6

Diagnosis.—The spores are radial, trilete, and roundly triangular to circular in outline. The rays extend to the margin but are not always distinct. The proximal and distal surfaces are covered with long, narrow setae, which are widest at their bases and gently taper toward their broadly rounded ends. The gently curved and widely spaced setae are between 3 and 7.5 μ long and 1 to 1.5 μ wide. From 20 to 30 setae extend beyond the spore margin. The surface of the spore coat between the setae appears slightly granular under oil immersion objective. The spore coat is about 1.5 μ thick. Dimensions (8 specimens): size range, 20.1 to 26.9 μ in maximum diameter (not including ornamentation); median, 22.2 μ.

Holotype.—Plate 4, figure 5; negative 6138; Henshaw Formation, maceration 1122-Q, slide 22 ZB, coordinates, 138.8 × 44.0; size, 21.7 by 19.4 μ.

Paratype.—Plate 4, figure 6; negative 5465; Henshaw Formation, maceration 1122-Q, slide 24, coordinates, 144.4 × 41.1; size, 22.7 by 21.4 μ (not including ornamentation).

Derivation of name.—The specific epithet refers to the long (*productus*) projections.

Punctatisporites minutus (Kosanke, 1950) emended
Plate 4, figure 7

Re-examination of the type specimen and other specimens (Kosanke, personal communication, 1961) of *Punctatisporites minutus* has shown that the spore coat is finely granulose (grana less than 1 μ in diameter) rather than punctate as originally described (Kosanke, 1950, p. 15-16). As the grana do not extend as far beyond the margin as one would expect after observing them in face view, they are probably partly submerged in the spore coat.

Punctatisporites bondensis sp. nov.
Plate 4, figures 8-9

Diagnosis.—The spores are radial, trilete, and subcircular to subtriangular in outline. The rays are distinct, straight, and extend at least three-fourths the length of the spore radius. Lips on either side of the commissure are about 1 μ wide. Proximal and distal surfaces of the exine are ornamented with clavate, verrucose to obvermiculate projections less than 1 μ to 4.8 μ in diameter and less than 1 μ to 3 μ long. The ornamentation becomes finer toward the poles. In face view, the projections are subcircular to irregularly shaped in outline. Enough space exists between the projections for additional projections of equal size. Between 20 and 30 projections extend beyond the spore margin. The spore coat is 1.5 to 2 μ thick. Dimensions (22 specimens): size range, 22.7 to 35.4 μ in maximum diameter (not including ornamentation); median, 29.1 μ.

Holotype.—Plate 4, figure 8; negative 6132; Fithian Cyclothem, maceration 1170-C, slide 9, coordinates, 131.2 × 38.9; size, 26.2 by 25.3 μ (not including ornamentation).

Paratype.—Plate 4, figure 9; negative 5733; Fithian Cyclothem, maceration 1170-B, slide 3, coordinates, 142.3 × 31.3; size, 32.4 by 29.7 μ.

Derivation of name.—The species name refers to the Bond Formation.

Punctatisporites racemus sp. nov.
Plate 4, figures 10-11

Diagnosis.—The spores are radial, trilete, and subcircular in outline. The rays, equal in length to the spore radius, are often obscured by the coarse ornamentation. The spore coat is covered with coarse verrucae that are semicircular to oval in cross section and are from 2 to 6.5 μ in maximum diameter. The verrucae are generally so closely spaced that they almost touch at their bases. The spore coat is about 1.5 μ thick. Dimensions (10 specimens): size range, 26.1 to 35.7 μ in maximum diameter; median, 29.4 μ.

Holotype.—Plate 4, figure 10; negative 5876; Trivoli Cyclothem, maceration 1175-G, slide 19, coordinates, 137.2 × 35.9; size, 33.4 × 26.9 μ.

Paratype.—Plate 4, figure 11; negative 6149; Trivoli Cyclothem, maceration 1128-L, slide 17, coordinates, 142.8 × 50.8; size, 30.2 by 27.9 μ.

Derivation of name.—The species name is derived from its resemblance to a bunch of grapes (*racemus*).

Punctatisporites patulus sp. nov.
Plate 4, figures 12-13; text figure 8

Diagnosis.—The spores are radial, trilete, circular to roundly triangular in outline, and often somewhat obliquely compressed. The rays are straight, at least three-fourths the length of the spore radius, and often indistinct because of ornamentation. Lips are poorly developed. The entire surface of the spore coat is covered with closely spaced, clavate, mushroom-shaped projections that vary in size from less than 1 μ to 7.5 μ long and from less than 1 μ to 13 μ in diameter, the smallest generally being in the polar areas. In face view they are circular to subcircular in outline. The projections extend beyond the spore margin in one to three rows. In well preserved specimens the outermost of these rows is made up of very thin, transparent projections that form a continuous, scalloped, flange-like border around the entire spore (text fig. 8). The innermost projections are considerably thicker, darker, and distinctly separated. All gradations exist between well preserved forms and poorly preserved or over-macerated specimens in which the thin, marginal projections are partly or totally absent. The exine is 2 to 3 μ thick. Dimensions (20 specimens): size range, 36.0 to 49.6 μ in maximum diameter (not including ornamentation); median, 44.5 μ.

Holotype.—Plate 4, figure 12; negative 6139; Henshaw Formation, maceration 1122-E, slide 4, coordinates, 140.5 × 48.8; size, 45.4 by 43.7 μ (not including ornamentation).

Paratype.—Plate 4, figure 13; negative 5269; Henshaw Formation, maceration 1122-E, slide 5, coordinates, 142.6 × 48.1; size, 40.5 by 40.5 μ.

Discussion.—Bhardwaj (1955, p. 125) assigned spores with clavate (mushroom-shaped) projections in the genus *Convolutispora.* As proposed by Hoffmeister, Staplin, and Malloy (1955a, p. 384), however, the genus includes spores ornamented with anastomosing convoluted ridges rather than individual projections. *Punctatisporites patulus* therefore was not assigned to *Convolutispora.*

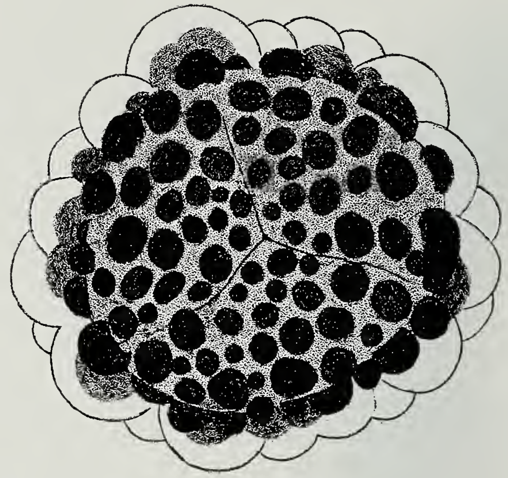

FIG. 8—***Punctatisporites patulus*** **sp. nov.; diagrammatic reconstruction of holotype; 45.4 by 43.7 μ.**

Comparison.—*Punctatisporites patulus* is larger and has coarser, more closely spaced projections than *P. bondensis,* which it resembles.

Derivation of name.—The species name refers to its expanded (*patulus*), clavate projections.

Punctatisporites breviornatus sp. nov.
Plate 4, figures 14-15

Diagnosis.—The spores are radial, trilete, circular in outline, and usually folded. The commissure is distinct, often open, and without lips. The rays are 14 to 26 μ long. The proximal and distal surfaces are indistinctly punctate to granulate under high dry objective. The puncta and coni are 1 μ or less in diameter, and the spore coat is 3 to 4.5 μ thick. Dimensions (16 specimens): size range, 48.0 to 58.7 μ in maximum diameter; median, 54.0 μ.

Holotype.—Plate 4, figure 14; negative 5952; Trivoli Cyclothem, maceration 1175-C, slide 6, coordinates, 137.5 × 45.5; size, 55.1 by 48.6 μ.

Paratype.—Plate 4, figure 15; negative 6429; Trivoli Cyclothem, maceration 1175-C, slide 9, coordinates, 137.4 × 32.3; size, 48.6 by 46.0 μ.

Comparison.—*Punctatisporites breviornatus* is slightly larger and has a considerably thicker exine than *P. orbicularis* Kosanke, 1950, which it resembles.

Derivation of name.—The epithet for the species refers to its being ornamented (*ornatus*) with small (*brevi*) puncta and grana.

Punctatisporites corona sp. nov.
Plate 4, figures 16-17; text figure 9

Diagnosis.—The spores are radial, trilete, circular in outline, and usually folded. The trilete rays generally are visible but not always distinct because of ornamentation and folding. They are about three-fourths the length of the spore radius and without lips. The surface of the spore coat is covered with fine papillate to obvermiculate projections closely and uniformly spaced. The projections are narrow at their bases and widen toward the ends so that their extension beyond the spore margin produces a halo-like effect (text fig. 9). They are about 2.5 μ long, and in end view are 1 to 4 μ in diameter. Approximately 100 projections can be counted at the margin. The spore coat is thin—1.5 to 2 μ thick. Dimensions (18 specimens): size range, 68.1 to 85.6 μ in maximum diameter; median, 77.3 μ (not including ornamentation).

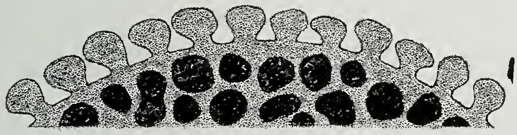

FIG. 9—Diagrammatic detail of portion of exine of *Punctatisporites corona* sp. nov.

Holotype.—Plate 4, figure 16; negative 6111; Henshaw Formation, maceration 1122-Q, slide 44 ZB, coordinates, 141.1 × 40.6; size, 73.9 by 71.3 μ (not including ornamentation).

Paratype.—Plate 4, figure 17; negative 6433; Henshaw Formation, maceration 1122-Q, slide 45 ZB, coordinates, 139.5 × 34.8; size, 83.9 by 78.7 μ.

Derivation of name.—The species name refers to the halo (*corona*) effect produced by the projections at the spore margin.

Punctatisporites transenna sp. nov.
Plate 4, figures 18-19

Diagnosis.—The spores are radial, trilete, subcircular to roundly triangular in outline, and usually in good proximal-distal orientation. The trilete rays are distinct, straight, and at least three-fourths the length of the radius (15 to 30 μ long). The lips on either side of the commissure are about 1 μ wide. Proximal and distal surfaces of the spore coat are ornamented with flat, obvermiculate ridges that are usually slightly narrower at their bases than at their ends. Most of the ridges, 2 to 3 μ high and about 2 μ wide, are joined to form an irregular reticulate pattern. The largest lacuna between the ridges is about 5 μ in diameter. The ornamentation extends beyond the spore margin and is often almost continuous around the periphery, alternating between light translucent areas in which the ridges are parallel to the margin and dark areas in which the ridges are transverse to the margin. The spore coat is so thin (1 to 1.5 μ) that it is difficult to focus on either the proximal or distal surface without picking up the ornamentation from the other surface. Dimensions (12 specimens): size range, 42.1 to 55.4 μ in maximum diameter; median, 48.7 μ (not including ornamentation).

Holotype.—Plate 4, figure 18; negative 6474; Fithian Cyclothem, maceration 1170-C, slide 7, coordinates, 133.2 × 40.4; size, 44.5 by 32.9 μ (not including ornamentation).

Paratype.—Plate 4, figure 19; negative 5754; Fithian Cyclothem, maceration 1170-C, slide 6, coordinates, 137.0 × 43.0; size, 48.6 by 44.1 μ.

Derivation of name.—The species name refers to its reticulate ornamentation, which is like a net (*transenna*).

Punctatisporites grandivermiculatus sp. nov.
Plate 4, figures 20-21

Diagnosis.—The spores are radial, trilete, subcircular to circular in outline, and usually in good proximal-distal orientation. The rays are one-half to two-thirds the length of the spore radius (28 to 39 μ), straight, and indistinct when viewed from the distal surface because of their great thickness and ornamentation. The lips are low and narrow.

About thirty percent of the proximal and distal surfaces are covered with vermiculations 1 to 3 μ wide and about half as deep as the thickness of the spore coat (4 to 6.5 μ). Dimensions (13 specimens): size range, 101.8 to 139.6 μ in maximum diameter; median, 114.1 μ.

Holotype.—Plate 4, figure 20; negative 6516; Trivoli Cyclothem, maceration 1128-G, slide 6, coordinates, 130.8 × 49.4; size, 123.5 μ in maximum diameter.

Paratype.—Plate 4, figure 21; negative 6479; Trivoli Cyclothem, maceration 1128-G, slide 7, coordinates, 124.1 × 57.2; size, 118.8 by 110.2 μ.

Comparison.—*Punctatisporites grandivermiculatus* is larger than *P. vermiculatus* Kosanke, 1950, which measures 57 to 73 μ.

Derivation of name.—The species name refers to its large (*grandis*) vermiculations.

Punctatisporites variusetosus sp. nov.
Plate 5, figures 1-2

Diagnosis.—The spores are radial, trilete, and circular in outline when in good proximal-distal orientation but are usually torn or folded. The rays are distinct and about three-fourths the length of the spore radius, or 19 to 40 μ long. The lips on either side of the commissure are about 1 μ wide. The surface of the spore coat is ornamented with setae and papillae, which vary greatly in size on the same specimen, from less than 1 μ to 3 μ in both diameter and length. Conical projections are occasionally present. The widely and irregularly spaced projections are circular in end view. The number of projections extending beyond the margin of the spore coat varies from approximately 15 to about 30. The spore coat is 2 to 3 μ thick. Dimensions (27 specimens): size range, 57.6 to 74.2 μ in maximum diameter; median, 63.2 μ.

Holotype.—Plate 5, figure 1; negative 4789; Trivoli Cyclothem, maceration 1128-L, slide 20, coordinates, 137.8 × 55.9; size, 55.1 by 55.1 μ.

Paratype.—Plate 5, figure 2; negative 6170; Henshaw Formation, maceration 1122-E, slide 6, coordinates, 137.4 × 47.1; size, 60.6 by 58.7 μ.

Comparison.—*Punctatisporites variusetosus* is similar to *P. setulosus* Kosanke, 1950, but the latter has more numerous setae rather consistently over 3 μ in diameter. *P. variusetosus* has coarser ornamentation, consisting mainly of setae rather than cones, than *P. latigranifer* (Loose) Schopf, Wilson, & Bentall, 1944.

Derivation of name.—The species name refers to the diverse (*varius*) size and spacing of its projections (*setae*).

Punctatisporites rudis sp. nov.
Plate 5, figures 3-4

Diagnosis.—The spores are radial, trilete, circular in outline, and in good proximal-distal orientation due to the great thickness and coarse ornamentation of the spore coat. The trilete rays and commissure are distinct when seen from the proximal side. The rays are straight and 21 to 33 μ long. Lips are absent or range up to 2 μ wide on either side of the commissure. The proximal and distal surfaces are coarsely ornamented with verrucose projections that produce an uneven equatorial margin. As seen along the spore margin, verrucae have truncated to rounded ends, are broader than long, and a few are slightly narrower at the base than at the ends. They are up to 3.7 μ high and 4 to 6.5 μ in diameter. They are very closely spaced, and some are joined to form irregularly shaped, obvermiculate projections. Because of this, the number of projections along the spore margin is difficult to determine. Projections make up 80 to 90 percent of the surface area of the spore coat. The spore coat is 5 to 6.5 μ thick. Dimensions (5 specimens): size range, 81.0 to 93.9 μ in maximum diameter; median, 90.1 μ (not including ornamentation).

Holotype.—Plate 5, figure 3; negative 6445; Henshaw Formation, maceration 1122-A, slide 4 ZB, coordinates, 127.6 × 34.6; size, 90.7 by 84.2 μ (not including ornamentation).

Paratype.—Plate 5, figure 4; negative 6886; Henshaw Formation, maceration 1122-A, slide 30 ZB, coordinates, 136.0 × 48.6; size, 84.2 by 82.6 μ.

Comparison.—*Punctatisporites rudis* is thicker, more coarsely ornamented, and has more closely spaced projections than *P. grandiverrucosus* Kosanke, 1943, which it otherwise resembles.

Derivation of name.—The species name refers to its coarse (*rudis*) ornamentation.

Punctatisporites staplini sp. nov.
Plate 5, figures 5-6

Diagnosis.—The spores are radial, trilete, circular to subcircular in outline, and usually in good proximal-distal orientation. The straight trilete rays, often obscured by ornamentation, are approximately equal to the spore radius (as much as 31 μ long when spore is obliquely compressed). Lips are absent. The proximal and distal surfaces are covered with coarse grana 1 to 2.5 μ in diameter and about 2 μ high. Most of the grana are rectangular in cross section and have truncated flat ends, but some are cone shaped. They are rectangular, circular, or oval in end view. They are uniformly distributed, and there is not enough space between them for additional grana of equal size. About 60 grana extend beyond the margin. The spore coat is about 1.5 μ thick. Dimensions (26 specimens): size range 42.1 to 57.7 μ in maximum diameter; median, 51.4 μ (not including ornamentation).

Holotype.—Plate 5, figure 5; negative 6116; Fithian Cyclothem, maceration 1170-C, slide 16, coordinates, 126.1 × 37.7; size, 51.2 by 50.5 μ (not including ornamentation).

Paratype.—Plate 5, figure 6; negative 5780; Fithian Cyclothem, maceration 1170-G, slide 3, coordinates, 127.6 × 30.3; size, 51.8 by 48.9 μ.

Comparison.—Punctatisporites staplini is coarser grained than *P. nahannensis* Hacquebard & Barss, 1957, and the rays of *P. nahannensis* are shorter, from one-half to two-thirds of the spore radius (9.6 to 16 μ long).

Derivation of name.—The species is named in honor of Dr. Frank L. Staplin, palynologist, Imperial Oil Company, Canada.

Punctatisporites sp. 1
Plate 5, figure 7

The spore is radial, trilete, and circular in outline. The rays are distinct, straight, and extend about two-thirds the length of the spore radius. The proximal and distal surfaces are covered with a fine reticulate pattern in which the muri are 1 to 2 μ wide and the lacunae about 6 μ in diameter. The exine is about 1 μ thick.

Figured specimen.—Negative 4731; Trivoli Cyclothem, maceration 1128-G, slide 3, coordinates, 122.8 × 44.7; size, 58.4 by 56.8 μ.

Punctatisporites sp. 2
Plate 5, figure 8

The spore is radial, trilete, and subcircular in outline, and has two major folds parallel to the margin. The rays are distinct, straight, and at least 22 μ long. Lips are absent. The exine, about 3.5 μ thick, is levigate under oil immersion objective.

Figured specimen.—Negative 5570; Henshaw Formation, maceration 1122-A, slide 11, coordinates, 138.8 × 40.2; size, 64.9 by 54.2 μ.

Punctatisporites sp. 3
Plate 5, figure 9

The spore is radial, trilete, and circular in outline. The rays are distinct, straight, and about 23 μ long. The proximal and distal surfaces are punctate to vermiculate, and when slightly out of focus appear reticulate. Closer examination shows that the sculpture consists of deep pits commonly connected by shallow channels. The exine is about 2 μ thick.

Figured specimen.—Negative 6147; Fithian Cyclothem, maceration 1170-C, slide 7, coordinates, 126.5 × 45.5; size, 64.9 by 62.6 μ.

Punctatisporites sp. 4
Plate 5, figure 10

The spore is radial, trilete, and subcircular in outline. The rays are distinct, straight, about three-fourths the length of the spore radius, and are bifurcated at their ends. Lips are absent, but pyramidal areas are slightly thickened. With oil immersion objective, the slightly granular ornamentation of the spore coat is discernible. The exine is about 4 μ thick.

Figured specimen.—Negative 6515; Henshaw Formation, maceration 1122-A, slide 24 ZB, coordinates, 124.5 × 38.3; size, 75.3 by 69.7 μ.

Punctatisporites sp. 5
Plate 5, figure 11

The spore is radial, trilete, and subcircular in outline. The rays are distinct, straight, and about 17 μ long. The lips on either side of the commissure are low and about 2.5 μ wide. Interray areas are slightly thinner than the rest of the spore coat, which is about 2 μ thick. Because it is covered with grana of irregular size and shape, the spore coat has a very rough appearance.

Figured specimen.—Negative 5672; Henshaw Formation, maceration 1122-Z, slide 8 ZB, coordinates, 125.4 × 31.4; size, 96.7 by 85.3 μ.

Punctatisporites sp. 6
Plate 5, figure 12

The spore is radial, trilete, and roundly triangular in outline. The rays extend to the spore margin but are indistinct due to ornamentation. The surface of the spore coat is covered with closely spaced, flat, pointed spines connected by ridges. About 30 spines, 2 to 3 μ in length and width, extend beyond the spore margin. The exine is about 2 μ thick.

Figured specimen.—Negative 5603; Henshaw Formation, maceration 1122-A, slide 22 ZB, coordinates, 126.9 × 45.0; size, 38.9 by 35.7 μ.

Genus Raistrickia, Schopf, Wilson, & Bentall, 1944
Plate 5, figures 13-15; plate 6, figures 1-2; text figure 10

Type species.—*Raistrickia grovensis* Schopf, Wilson, & Bentall, 1944.

Affinities.—Filicinean (Schopf, Wilson, and Bentall, 1944, p. 55). Mamay (1950, p. 415) described *Botryopteris spinosa* which yielded *Raistrickia*-type spores. The occurrence of *Raistrickia* in sporangia of *Senftenbergia* (*Pecopteris*) *plumosa* Artis was well described and illustrated by Remy and Remy (1955, p. 44-45, pl. 15).

Raistrickia kentuckiensis sp. nov.
Plate 5, figures 13-14; text figure 10

Diagnosis.—The spores are radial, trilete, and circular to roundly triangular in outline. The trilete rays extend to the margin and are without lips. The proximal and distal surfaces are ornamented with club-shaped processes and a few processes of uniform width that are minutely serrate at their apices. Some of the processes are divided into two or more major divisions (text fig. 10). The processes are up to 6 μ long and range from 1 to 7 μ in width, with 3 μ as the average. From 20 to 35 processes extend beyond the spore margin. Between the processes, the surface of the spore coat is levigate under oil immersion

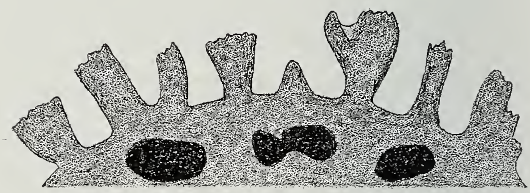

FIG. 10—Diagrammatic detail of portion of exine of *Raistrickia kentuckiensis* sp. nov.

objective. The spore coat is 1.5 to 2 μ thick. Dimensions (6 specimens): size range, 45.3 to 53.0 μ in maximum diameter; median, 49.0 μ.

Holotype.—Plate 5, figure 13; negative 6150; Henshaw Formation, maceration 1122-Z, slide 8 ZB, coordinates, 127.1 × 44.9; size, 47.9 by 42.8 μ (not including ornamentation).

Paratype.—Plate 5, figure 14; negative 6508; Henshaw Formation, maceration 1122-Z, slide 14, coordinates, 132.3 × 31.7; size, 52.0 by 48.8 μ.

Comparison.—*Raistrickia kentuckiensis* has more numerous, more uniform, and longer processes than *R. superba* (Ibrahim) Schopf, Wilson, & Bentall, 1944, which it most closely resembles. The processes of *R. superba* are often conical shaped. *R. kentuckiensis* is similar to the specimen designated by Bhardwaj (1957b, pl. 23, fig. 31) as *R.* cf. *superba,* except that the latter has rays that do not reach the spore margin.

Derivation of name.—The species name refers to the state of Kentucky.

Raistrickia sp. 1
Plate 5, figure 15

The spores are radial, trilete, and subcircular in outline because of folding. The trilete rays, often indistinct due to ornamentation, are about 26 μ long and lack lips. The surface of the spore coat is ornamented with processes that are widest in the middle, although occasional processes are rather uniform in width. The maximum length and width of the processes observed is 13 and 6.5 μ, respectively. The ends of most of the processes have numerous minute divisions 1 or 2 μ long. In end view, the processes are subcircular in outline. Between 20 and 25 processes extend beyond the spore margin. The spore coat is 1.5 to 2 μ thick and with oil immersion objective appears smooth between the processes. Dimensions (4 specimens): size range, 64.9 to 74.6 μ in maximum diameter (not including ornamentation).

Figured specimen.—Negative 5622; Henshaw Formation, maceration 1122-A, slide 10, coordinates, 131.1 × 31.7; size, 64.9 by 55.5 μ. This species was also found in maceration 1122-E and in the Trivoli Cyclothem, macerations 1175-I and 1175-B.

Raistrickia sp. 2
Plate 6, figure 1

The spores are radial, trilete, and subcircular in outline. The rays are distinct and about 34 μ long. The proximal and distal surfaces are covered with spines 5 to 10 μ long and about 4 μ wide at their bases. The spines taper toward pointed or gently rounded ends and are transversely striated.

Figured specimen.—Negative 5741; Fithian Cyclothem, maceration 1170-B, slide 12, coordinates, 133.8 × 40.6; size, 57.8 by 55.8 μ. This species was also found in maceration 1170-B.

Raistrickia sp. 3
Plate 6, figure 2

The spore is radial, trilete, and circular in outline. Rays are distinct and about 29 μ long. Proximal and distal surfaces are covered with closely packed projections 5 to 10.5 μ long and 5 to 13 μ wide. The ends of the projections are split into numerous subdivisions. The exine is about 2.5 μ thick.

Figured specimen.—Negative 6114; Trivoli Cyclothem, maceration 1128-G, slide 5, coordinates, 126.5 × 46.0; size, 81.1 by 78.5 μ.

Genus Reinschospora Schopf, Wilson, & Bentall, 1944
Plate 6, figures 3-4

Type species.—*Reinschospora bellitas* Bentall, 1944 (*in* Schopf, Wilson, and Bentall, 1944).

Affinity.—Unknown, possibly filicinean (Schopf, Wilson, and Bentall, 1944, p. 53).

Reinschospora sp. 1
Plate 6, figure 3

The spore is radial, trilete, triangular in outline, and has strongly concave interradial sides. The well rounded corners opposite the rays are folded back over the proximal surface. The rays are distinct and extend almost to the margin. The well developed lips on either side of the commissure are about 1.5 μ wide. The processes, about 40 along each interradial side, vary in length from about 4 μ at the corners to 17 μ midway between the radii. They are embedded as much as 5 μ in the proximal side of the spore coat. The processes, 1 to 2 μ wide at their bases, gradually taper toward their ends, some of which terminate in small knobs. The surface of the exine appears levigate under oil immersion objective. *Reinschospora* sp. 1 has interradial sides that are more strongly concave, processes that are not as deeply embedded in the spore coat, and better developed lips than *R. magnifica* Kosanke, 1950, which it otherwise resembles.

Figured specimen.—Negative 6517; Trivoli Cyclothem, maceration 1128-L, slide 10, coordinates, 126.7 × 61.0; size, 55.3 by 51.0 μ (including processes). This species also was found in maceration 1175-I.

Reinschospora triangularis Kosanke, 1950
Plate 6, figure 4

Genus Reticulatisporites (Ibrahim) Schopf, Wilson, & Bentall, 1944
Plate 6, figures 5-6

Type species.—*Reticulatisporites reticulatus* (Ibrahim) Ibrahim, 1933.

Affinities.—Sphenopsid (Schopf, Wilson, and Bentall, 1944, p. 34), Sphenophyllales, Hepaticae (Kosanke, 1950, p. 26). Mamay (1954, p. 234-235, pl. 14) described and illustrated spores from a sphenopsid cone, *Litostrobus iowensis* Mamay, 1954, that are analogous to *Reticulatisporites.*

Reticulatisporites reticulatus (Ibrahim) Ibrahim, 1933

The single specimen of *Reticulatisporites reticulatus* found in maceration 1175-I is very similar to the holotype illustrated by Ibrahim (1933) and by Potonié and Kremp (1955, fig. 310).

Reticulatisporites sp. 1
Plate 6, figure 5

The spore is radial, trilete, and subcircular in outline, and has an irregular margin. The rays are straight and extend to the margin of the coarsely reticulate spore coat. Polar areas are darker and thicker than the rest of the spore coat. The muri are sinuous, 3 to 4.5 μ wide and about 3 μ high. Eighteen muri extend beyond the spore margin. Lacunae are 15 to 20 μ wide. *Reticulatisporites* sp. 1 is similar to *R. reticulatus,* but the former has longer rays and more numerous muri.

Figured specimen.—Negative 5945; Trivoli Cyclothem, maceration 1175-I, slide 10, coordinates, 136.2 × 39.1; size, 81.0 by 79.4 μ.

Reticulatisporites sp. 2
Plate 6, figure 6

The spores are subcircular in outline. No haptotypic features were observed. The reticulate spore coat has muri 2 to 3 μ wide, and lacunae about 4.5 μ in diameter.

Figured specimen.—Negative 6024; Trivoli Cyclothem, maceration 1175-D, slide 8, coordinates, 122.4 × 39.4; size, 52.3 by 48.7 μ. This species was also found in maceration 1175-C.

Genus Rhizomaspora Wilson, 1962

Type species.—*Rhizomaspora radiata* Wilson, 1962.

Affinity.—Unknown.

Rhizomaspora cf. *radiata* Wilson, 1962
Plate 6, figure 7

The pollen grain is bilateral and bisaccate. The body, subcircular in outline, is covered with ribs radiating outward from the polar region to the body margin. The bladders are externally levigate and internally reticulate (lacunae 1 to 2 μ in diameter). The specimen observed in this study is considerably smaller than the specimens of *Rhizomaspora radiata* (140 to 170 μ long) described by Wilson (1962, p. 20).

Figured specimen.—Negative 5812; Fithian Cyclothem, maceration 1170-G, slide 8, coordinates, 125.2 × 41.5; size, total 93.7 by 60.8 μ, body 44.4 by 42.2 μ.

Genus Savitrisporites? Bhardwaj, 1955

Type species.—*Savitrisporites triangulus* Bhardwaj, 1955.

Affinity.—Unknown.

Savitrisporites? sp. 1
Plate 6, figure 8

The spore is radial, trilete, and has an irregular, triangular outline. Corners opposite the rays are slightly thickened. The rays are distinct and extend to the inner margin of the well defined, thickened, equatorial zone, which is 6 to 7 μ wide. The distal surface of the spore coat is covered with low spines that are joined to form an irregular reticulum.

Figured specimen.—Negative 5897; Trivoli Cyclothem, maceration 1175-P, slide 8, coordinates, 142.0 × 51.2; size, 62.7 by 60.8 μ.

Genus Secarisporites Neves, 1961
Plate 6, figures 9-12

Type species.—*Secarisporites lobatus* Neves, 1961.

Affinity.—Unknown.

Secarisporites crenatus sp. nov.
Plate 6, figures 9-12

Diagnosis.—The spores are radial, trilete, roundly triangular to subcircular in outline, and in good proximal-distal orientation. The distinct trilete rays and commissure are torn, contorted, and extend as far as the inner margin of the thickened equatorial zone or occasionally part way into it. The poorly developed lips are usually folded. The notched equatorial zone is made up of a series of expanded lobate or clavate projections that are uniformly dense and almost opaque. The width of the zone is often greatest at the corners opposite the rays and varies from 5 to 10.5 μ. The very thin, often folded, proximal surface is seen to be minutely granulose to punctate under oil immersion objective; it gradually becomes coarsely punctate to vermiculate toward the equatorial zone. A distinct, deeply pitted groove concentric to the spore periphery lies at the junction of the proximal surface and the thickened zone. The distal surface of the spore coat is thick and ornamented with deep, circular or vermiculate pits that are sometimes joined almost enough to form an areolate pattern. Some of the vermiculations at the margin extend between, or part way into, the projections. Under oil immersion objective, the distal surface is seen to be finely rugose between the vermiculations. The surface of the thickened equatorial zone is discernibly levigate under oil immersion objective. Dimensions (30 specimens): size range, 41.8 to 64.8 μ in maximum diameter (including equatorial thickening); median, 49.8 μ.

Holotype.—Plate 6, figures 9, 12; Henshaw Formation, maceration 1122-Q, slide 26 ZB, coordinates, 122.9 × 45.3; size, 59.0 by 48.6 μ (including thickened equatorial zone). Figure 9, negative 6106, is focused on the equatorial thickened zone; figure 12, negative 6506, is focused on the distal surface.

Paratypes.—Plate 6, figure 10; negative 5602; Henshaw Formation, maceration 1122-A, slide 22, coordinates, 128.4 × 41.5; size, 58.0 by 54.1 μ (including thickened equatorial zone). Plate 6, figure 11; negative 6505; Henshaw Formation, maceration 1122-Q, slide 30 ZB, coordinates, 129.9 × 41.2; size, 49.7 by 43.6 μ (including thickened equatorial zone).

Comparison.—*Secarisporites crenatus* is very similar to *S. remotus* Neves, 1961, except that the distal surface of the former is pitted, vermiculate, or areolate. The distal surface of *S. remotus* is ornamented with narrow ridges and small warts.

Derivation of name.—The species name refers to the spore's lobate, notched (*crenatus*) equatorial margin.

Genus Striatosporites Bhardwaj, 1954

Type species.—*Striatosporites major* Bhardwaj, 1954.

Affinity.—Unknown.

Striatosporites cf. *pfalzensis* Bhardwaj & Venkatachala, 1957
Plate 6, figure 13

Genus Strotersporites Wilson, 1962

Type species.—*Strotersporites communis* Wilson, 1962.

Affinity.—Unknown.

Strotersporites sp. cf. *Striatites* (*Lueckisporites*) *rickteri* (Klaus) Potonié, 1958
Plate 6, figure 14

This species of *Strotersporites* resembles *Striatites* (*Lueckisporites*) *rickteri* (Klaus) Potonié, 1958, which probably should be assigned to *Strotersporites* as suggested by Wilson (1962, p. 18).

Genus Triquitrites Wilson & Coe, 1940
Plate 6, figure 15; plate 7, figures 1-6

Type species.—*Triquitrites arculatus* Wilson & Coe, 1940.

Affinity.—Filicinean?

Triquitrites arculatus Wilson & Coe, 1940

The specimens of *Triquitrites arculatus* in this study were compared with the one illustrated by Wilson (1958, pl. 8, fig. 1).

Triquitrites cf. *discoidius* Kosanke, 1950

Only one specimen of *Triquitrites* cf. *discoidius* was observed.

Triquitrites cf. *truncatus* Bhardwaj & Kremp, 1955

Only one specimen of *Triquitrites* cf. *truncatus* was observed.

Triquitrites cf. *inusitatus* Kosanke, 1950

The size range of *Triquitrites inusitatus* observed by Kosanke (1950, p. 39) was 60.5

to 73 μ. The single specimen encountered in this study is 39.5 μ in diameter.

Triquitrites spinosus Kosanke, 1943

The maximum size of *Triquitrites spinosus* observed in this study is 71 μ, which is somewhat greater than the maximum size of 55 μ reported by Kosanke (1943, p. 128).

Triquitrites simplex Bhardwaj, 1957a
Plate 6, figure 15

Triquitrites sp. 1
Plate 7, figure 1

The spores are radial, trilete, triangular in outline and have concave interradial margins. The rays are distinct, straight, and about two-thirds the length of the spore radius. Auriculae at the corners are broad, rounded, and notched at one end. With oil immersion objective, the surface of the spore coat is revealed as slightly rugose. The spore coat is about 1.5 μ thick.

Figured specimen.—Negative 4723; Trivoli Cyclothem, maceration 1128-H, slide 21, coordinates, 136.8 × 53.5; size, 34.3 by 34.3 μ. This species was also found in maceration 1175-I.

Triquitrites sp. 2
Plate 7, figure 2

The spore is radial, trilete, triangular in outline, and has strongly concave interradial sides and angular corners that are only slightly thickened. The commissure is distinct and the rays are about half the length of the spore radius. Lips are absent. The spore coat, about 1 μ thick, is covered with widely spaced grana.

Figured specimen.—Negative 4740; Trivoli Cyclothem, maceration 1128-H, slide 18, coordinates, 122.8 × 36.5; size, 28.2 by 26.6 μ.

Triquitrites sp. 3
Plate 7, figure 3

The spore is radial, trilete, triangular in outline, and has angular corners and concave interradial sides. The rays are distinct, straight, and two-thirds to three-fourths the length of the spore radius. The pyramidal area is greatly thickened. Auriculae are thick, have angular margins, and are about 3 μ long and 14 μ wide. Widely scattered, minute, cone-shaped spines are present on the proximal and distal surfaces and along the margin.

Figured specimen.—Negative 5854; Trivoli Cyclothem, maceration 1175-P, slide 16, coordinates, 127.8 × 44.3; size, 32.4 by 32.4 μ.

Triquitrites sp. 4
Plate 7, figure 4

The spores are radial, trilete, triangular in outline, and have well rounded corners and straight to convex interradial margins. The rays are distinct, straight, and about two-thirds the length of the spore radius. Lips are absent. The spore coat is only slightly thickened at the corners, and its proximal and distal surfaces are irregularly reticulate with low muri. The spore coat is about 1.5 μ thick.

Figured specimen.—Negative 5761; Fithian Cyclothem, maceration 1170-C, slide 10, coordinates, 132.8 × 29.5; size, 48.0 by 48.0 μ. This species was also found in maceration 1170-B.

Triquitrites sp. 5
Plate 7, figure 5

The spores are radial, trilete, triangular in outline, and have well rounded corners and concave interradial sides. The trilete rays are distinct, straight, and about two-thirds the length of the spore radius. Arcuate thickenings are only slightly developed and do not protrude. The interray areas are distinctly pitted, whereas other areas of the spore coat are levigate. The exine is about 1 μ thick.

Figured specimen.—Negative 5892; Trivoli Cyclothem, maceration 1175-G, slide 13, coordinates, 137.7 × 35.0; size, 39.2 by 37.3 μ. This species was also found in maceration 1175-C.

Triquitrites sp. 6
Plate 7, figure 6

The spores are radial, trilete, triangular in outline, and have well rounded corners. The rays are distinct, straight, and about three-fourths the length of the spore radius. The corners are only slightly thicker than the rest of the spore coat. Blunt spines are sparsely distributed over the distal surface. The exine, about 3 μ thick, is slightly rugose between the spines.

Figured specimen.—Negative 4736; Trivoli Cyclothem, maceration 1128-H, slide 19, coordinates, 143.6 × 41.9; size, 53.5 by 48.7 μ. This species was also found in macerations 1128-I, 1128-J, and 1175-P, and in the Fithian Cyclothem, maceration 1170-B.

Genus Trivolites gen. nov.
Plate 7, figures 7-8; text figure 11

Type species.—*Trivolites laevigata* sp. nov.

Diagnosis.—The generic name *Trivolites* is proposed for small spores having the following characteristics. The spores are radial,

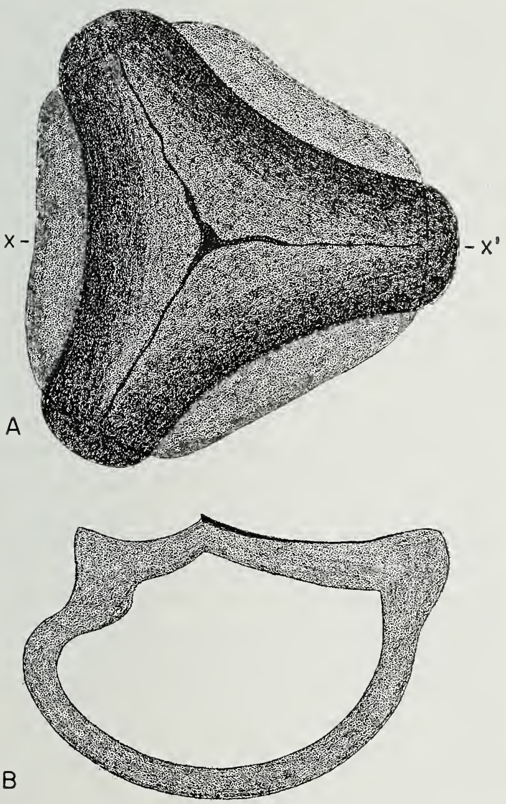

FIG. 11—*Trivolites laevigata* sp. nov.; diagrammatic reconstructions of holotype; 36.9 by 35.6 μ.
A. View from proximal side.
B. Cross section through spore along X—X′.

trilete, triangular in outline, and usually in good proximal-distal orientation. The corners are narrow and well rounded, and the interradial sides are straight to slightly concave. The trilete rays are distinct, have well developed lips on either side of the commissure, and extend almost to the spore margin. On the proximal surface the *area contagionis* is greatly thickened and extends at the radial points beyond the distal margin of the spore coat (text fig. 11). The outer margins of the *area contagionis* are sharply delineated, but the inner margins taper in thickness toward the trilete rays. The surface of the spore coat is levigate. The spore coat is 4 to 6 μ thick. Known size range is 29.1 to 44.4 μ.

Affinity.—Unknown.

Derivation of name.—The name of the genus refers to the Trivoli Cyclothem.

Trivolites laevigata sp. nov.
Plate 7, figures 7-8; text figure 11

Diagnosis.—The spores are radial, trilete, triangular in outline, and usually in good proximal-distal orientation. The narrow corners are well rounded, and the interradial sides are straight to slightly concave. The rays are distinct, between 18 and 22 μ long, and extend almost to the ends of the radial points. Lips are well developed, between 1 and 1.5 μ wide on either side of the commissure, and are slightly undulatory. The greatly thickened, dense *area contagionis* projects at the corners 3 to 4 μ beyond the distal margin of the spore coat. The outer margins of the *area contagionis* are sharply delineated, but the inner margin tapers in thickness toward the trilete rays where the exine may be as thick as other parts of the spore coat. The surfaces of the spore coat are levigate, even under oil immersion. The spore coat is from 4 to 6 μ thick. Dimensions (7 specimens): size range, 29.1 to 44.4 μ in maximum diameter; median, 35.4 μ.

Holotype.—Plate 7, figure 7; negative 5915; Trivoli Cyclothem, maceration 1175-G, slide 17, coordinates, 130.3 × 51.9; size, 36.9 by 35.6 μ.

Paratype.—Plate 7, figure 8; negative 6140; Trivoli Cyclothem, maceration 1175-E, slide 4, coordinates, 138.4 × 33.6; size, 45.4 by 44.4 μ.

Comparison.—The specimen illustrated by Alpern (1959, pl. 13, fig. 371) probably belongs to this species but was not formally named by Alpern.

Derivation of name.—The species name refers to the smooth (*levigatus*) surface.

Genus Vesicaspora (Schemel) Wilson & Venkatachala, 1963

Type species.—Vesicaspora wilsonii Schemel, 1951.

Affinities.—Gymnospermic (Schemel, 1951, p. 749). Possibly Caytoniales (Potonié and Kremp, 1954, p. 175).

Vesicaspora? sp. 1
Plate 7, figure 9

The prepollen or pollen monosaccate grain is dumbbell shaped in polar view. The body is subcircular in outline. The bladder, which is externally levigate and internally reticulate to punctate, is greatly expanded at opposite ends of the body so the grain appears almost bisaccate.

Figured specimen.—Negative 5676; Henshaw Formation, maceration 1122-Z, slide 14, coordinates, 130.6 × 31.2; size, total length 74.2 μ, body 48.9 by 47.0 μ; bladder about 53.8 μ wide at the ends.

Genus Vestigisporites (Balme & Hennelly) Hart, 1960

Type species.—Vestigisporites rudis Balme & Hennelly, 1955.

Affinity.—Unknown; probably gymnospermic.

Vestigisporites sp. 1
Plate 7, figure 10

The prepollen grain is bilateral, monolete, and monosaccate. The suture is straight, open, and 26 μ long. The bladder, drawn in around the margin of the body, is externally levigate and internally finely reticulate. The body appears granulate under oil immersion objective.

Figured specimen.—Negative 5665; Henshaw Formation, maceration 1122-Z, slide 16 ZB, coordinates, 123.2 × 45.9; size, total 85.7 by 71.0 μ, body 48.7 by 43.5 μ.

Genus Wilsonites Kosanke, 1950

Type species.—Wilsonites vesicatus Kosanke, 1950.

Affinity.—Gymnospermic (Kosanke, 1950, p. 13).

Wilsonites delicata Kosanke, 1950

The size range of 81 to 98 μ given by Kosanke (1950, p. 55) for *Wilsonites delicata* is extended to include grains as small as 58 μ.

Wilsonites sp. 1
Plate 7, figure 11

The prepollen grains are radial, trilete, monosaccate, and subcircular in outline. The body is subcircular, practically always obliquely compressed, and usually folded along the rays. The rays, usually indistinct, extend to the margin of the body. The bladder is thick (slightly thicker at the periphery) and completely surrounds the body. The bladder is externally levigate and internally finely reticulate. Dimensions: total size range about 45 to 62 μ.

Figured specimen.—Negative 5896; Trivoli Cyclothem, maceration 1175-P, slide 8, coordinates, 141.1 × 36.6; size, total 55.1 by 48.0 μ, body 38.3 by 35.7 μ.

MISCELLANEOUS SMALL SPORES

Bisaccate grain 1
Plate 7, figure 12

The pollen or prepollen grain is bilateral and has two small bladders attached to opposite sides of a subcircular body. A heavy meridial fold and at least five indistinct grooves occur on the body. The body is thickest at the periphery and is discernibly very finely punctate when examined under oil immersion objective. The bladders are externally levigate and internally coarsely reticulate.

Figured specimen.—Negative 5640; Henshaw Formation, maceration 1122-G, slide 9 T, coordinates, 134.8 × 31.2; size, total length 77.8 μ, body 55.1 by 48.7 μ, bladders about 38 by 32 μ.

Bisaccate grain 2
Plate 7, figure 13

The pollen or prepollen grains are bilateral and elliptical in outline and have a subcircular body. The crescent-shaped bladders almost join to form a distal furrow. The body is covered with distinct, irregularly branched fissures that vary in number from specimen to specimen. Some specimens show several strong grooves that may be trilete marks. With oil immersion magnification, the body between the fissures appears levigate. The bladders are externally levigate and internally finely punctate to reticulate.

Figured specimen.—Negative 5720; Fithian Cyclothem, maceration 1170-A, slide 13, coordinates, 126.9 × 36.8; size, total length 51.6 μ, body 39.2 by 30.2 μ. This species was also found in macerations 1170-B through 1170-E, and 1170-G.

Monosaccate grain 1
Plate 7, figure 14

The pollen or prepollen grain is broadly elliptical in outline. A bladder covers the distal surface of the body and the part of the proximal surface where it is attached and folded back to form a furrow. Two rays are distinct and about 13 μ long, and a third ray may be present. The bladder is externally levigate and internally finely reticulate.

Figured specimen.—Negative 5538; Henshaw Formation, maceration 1122-Q, slide 14, coordinates, 124.0 × 39.5; size, total 55.4 by 48.3 μ, body 50.6 by 35.1 μ.

Monosaccate grain 2
Plate 7, figure 15

The pollen or prepollen grain is bilateral, trilete, and elliptical in outline. The body is subcircular in outline and is folded. Two of the distinct trilete rays are 12 μ long and the third is 3 μ long. The distal surface of the body is polygonally areolate. The bladder is externally levigate, internally finely punctate to reticulate, and thickest around the periphery.

Figured specimen.—Negative 5691; Fithian Cyclothem, maceration 1170-A, slide 4, coordinates, 140.6 × 39.8; size, total 113.1 by 75.8 μ, body 69.4 by 55.1 μ.

Monosaccate grain 3
Plate 7, figure 16

The pollen or prepollen grain is bilateral, trilete, and subcircular in outline. The elliptical body possesses distinct rays about 12 μ long. The bladder completely covers the distal surface and most of the proximal surface of the body. A sulcus with a wide fold on either side extends to the equator of the bladder. The surface of the body is levigate, and the bladder is externally levigate and internally finely punctate.

Figured specimen.—Negative 5601; Henshaw Formation, maceration 1122-A, slide 22 ZB, coordinates, 140.4 × 48.0; size, total 48.7 by 42.2 μ, body 35.7 by 24.4 μ.

Monosaccate grain 4
Plate 7, figure 17

The pollen or prepollen grain is radial, trilete, roundly triangular in outline, and folded. The rays are distinct and extend to the spore margin. The body is completely enclosed within a bladder that is externally levigate and internally uniformly and sharply punctate. The puncta are about 1 μ in diameter. The bladder is about 3 μ thick and tapers toward the margin. Ornamentation of the body could not be determined because it is obscured by the bladder.

Figured specimen.—Negative 5557; Henshaw Formation, maceration 1122-A, slide 5 ZB, coordinates, 140.0 × 49.5; size, total 51.9 by 43.1 μ, body 27.6 by 26.7 μ.

Spore A
Plate 7, figure 18

The spore is radial, trilete, and roundly triangular in outline. The prominent lips are contorted, about 3 μ wide, and extend to the spore margin at the corners. A thin, coarsely reticulate flange completely surrounds the body. As seen under oil immersion objective, the proximal and distal surfaces of the body are finely reticulate.

Figured specimen.—Negative 5998; Henshaw Formation, maceration 1122-Q, slide 2 ZB, coordinates, 131.6 × 45.3; size, 93.4 by 85.0 μ.

Spore B
Plate 7, figure 19

The spore is radial, trilete, roundly triangular to subcircular in outline and in good proximal-distal orientation. The trilete rays and commissure are distinct and extend at least three-fourths the length of the spore radius. A triradiate ridge, 3 to 4 μ wide, is joined to the thickened equatorial zone. This zone is dense and almost opaque, and its thickness tapers toward the poles. In specimens that are obliquely compressed, the inner margin of the thickened zone may be sharply delineated. The zone is divided into two parts by a concentric groove running parallel to the margin. The proximal and distal surfaces of the spore body and equatorial zone are covered with widely spaced puncta or vermiculations. Shallow vermiculations connect two or more distinct, deep puncta that are 1 μ or less in diameter. The proximal and distal surfaces of the spore coat between the pits and vermiculations are minutely punctate as viewed under oil immersion objective. Dimensions: size range, 37.6 to 56.4 μ in maximum diameter.

Figured specimen.—Negative 6121; Henshaw Formation, maceration 1122-A, slide 44 ZB, coordinates, 134.0 × 41.5; size, 56.4 by 50.2 μ.

Spore C
Plate 8, figure 1

The spore is radial, trilete, triangular in outline, and has well rounded corners. The rays are distinct, straight, and extend to the inner margin of the thickened equatorial zone. This zone, 9 to 10 μ wide (slightly wider at the corners), is shingle-like and thickest toward the inner margin. The outer margin of the zone is irregular and notched. The main body has shingled thickenings, especially adjacent to the rays, and the proximal surface is discernibly punctate under oil immersion objective.

Figured specimen.—Negative 5585; Henshaw Formation, maceration 1122-A, slide 16 ZB, coordinates, 130.8 × 42.3; size, 64.9 by 63.3 μ.

Spore D
Plate 8, figure 2

The spore is radial, trilete, triangular in outline, and has well rounded corners. The indistinct rays extend to the spore margin. The spore coat is ornamented with very closely spaced, clavate projections about 3 μ long and 2 to 3 μ wide at their ends. From 50 to 60 projections extend beyond the periphery of the spore. The spore coat is about 1.5 μ thick.

Figured specimen.—Negative 6475; Henshaw Formation, maceration 1122-Q, slide 2, coordinates, 138.6 × 51.6; size, 35.1 by 29.9 μ (not including ornamentation).

Spore E
Plate 8, figure 3

The spore is radial, trilete, triangular in outline, and has convex interradial sides. The commissure is distinct, and the rays are straight and equal in length to the spore radius. The spore coat is covered with a reticulate ornamentation in which the muri are 2 to 3 μ wide by about 3 μ high and the lacunae are 3 to 4 μ in diameter. The exine is about 1.5 μ thick.

Figured specimen.—Negative 5479; Henshaw Formation, maceration 1122-Q, slide 9 ZB, coordinates, 124.1 × 43.7; size, 41.3 by 38.3 μ.

Spore F
Plate 8, figure 4

The spore is radial, trilete, triangular in outline, and has greatly expanded corners. The trilete rays are distinct, straight, and about two-thirds the length of the spore radius. Pyramidal areas are darker and thicker than the rest of the spore coat. Under oil immersion objective, the surface of the spore coat is distinctly granular. The exine is about 2.5 μ thick.

Figured specimen.—Negative 5605; Henshaw Formation, maceration 1122-A, slide 22 ZB, coordinates, 123.1 × 48.6; size, 59.4 by 59.0 μ.

Spore G
Plate 8, figure 5

The spores are radial, trilete, broadly triangular in outline, and have a scalloped margin. The rays are distinct and extend to the margin of the spore body. The spore body is surrounded by a broad, contorted flange that is usually widest at the corners. Broad, branching ridges are present over the distal surface of the body and flange. Under oil immersion objective, the surface of the body and flange appear finely granulate. Dimensions: 25 to 40 μ in maximum diameter.

Figured specimen.—Negative 5580; Henshaw Formation, maceration 1122-A, slide 16 ZB, coordinates, 125.3 × 45.4; size, 35.7 by 33.4 μ.

Spore H
Plate 8, figure 6

The spores are radial, trilete, roundly triangular in outline, and have well rounded corners and concave interradial sides. The rays are distinct, straight, and extend to the inner margin of the thickened equatorial zone. Lips are poorly developed. The proximal surface of the spore coat is smooth, but the distal surface of the body and the thickened zone are ornamented with numerous pointed to rounded spines connected by ridges.

Figured specimen.—Negative 6428; Fithian Cyclothem, maceration 1170-A, slide 10, coordinates, 127.1 × 42.4; size, 55.1 by 49.0 μ. This species was also found in macerations 1170-B and 1170-G, in maceration 1175-D of the Trivoli Cyclothem, and in macerations 1122-Z and 1122-F of the Henshaw Formation.

Spore I
Plate 8, figure 7

The spores are radial, trilete, roundly triangular in outline, and usually folded. The rays are distinct and extend about three-fourths the length of the spore radius. Lips are thin and sinuous. Large, conspicuous, apical papillae are present. The spore coat, less than 1 μ thick, is levigate. These spores may be bodies of *Endosporites* or detached portions of other spore taxa. Dimensions: about 30 to 58 μ in maximum diameter.

Figured specimen.—Negative 6512; Trivoli Cyclothem, maceration 1175-J, slide 10, coordinates, 131.1 × 32.3; size, 52.0 by 38.7 μ. This form was also found in macerations 1170-A through 1170-C of the Fithian Cyclothem and in macerations 1122-A and 1122-E through 1122-T of the Henshaw Formation.

Spore J
Plate 8, figure 8

The spore is radial, trilete, triangular in outline, and has well rounded corners. The rays are distinct, straight, and about two-thirds the length of the spore radius. Lips are about 1 μ wide on either side of the commissure. Flat, rectangular processes about 5 μ wide are widely distributed on the proximal surface. Two or more minor projections occur at the ends of the processes. Under oil immersion objective, the surface of the spore coat is visibly levigate between the processes. The exine is about 1 μ thick.

Figured specimen.—Negative 5559; Henshaw Formation, maceration 1122-A, slide 5 ZB, coordinates, 124.0 × 44.6; size, 48.0 by 42.5 μ.

Spore K
Plate 8, figure 9

The spore is radial, trilete, and roundly triangular in outline. The distinct trilete rays extend to the spore margin. Opposite the interradial sides are large auriculae, the largest of which is 9 μ long. The exine is smooth and about 1 μ thick.

Figured specimen.—Negative 5443; Henshaw Formation, maceration 1122-Q, slide 4 ZB, coordinates, 123.7 × 35.3; size, 35.1 by 29.2 μ (not including auriculae).

Spore L
Plate 8, figure 10

The spore is radial, trilete, and subcircular in outline. The rays are distinct, straight, and about 19 μ long. The surface of the spore coat is covered with long, anastomosing, and branching vermiculations, or grooves, about 1 μ wide. One vermiculation measured is at least 33 μ long.

Figured specimen.—Negative 5556; Henshaw Formation, maceration 1122-A, slide 5 ZB, coordinates, 144.2 × 33.9; size, 49.0 by 44.1 μ.

Spore M
Plate 8, figure 11

The spore is radial, trilete, and subcircular in outline. The commissure is distinct, sinuous, and about two-thirds the length of the spore radius. Lips, about 1.5 μ wide, are on either side of the commissure. A wide, slightly thicker and darker zone in the area of the rays extends to the margin. The spore coat is about 2 μ thick.

Figured specimen.—Negative 4868; Trivoli Cyclothem, maceration 1128-G, slide 15, coordinates, 137.5 × 42.8; size, 33.7 by 32.4 μ.

Spore N
Plate 8, figure 12

The spore is radial, trilete, and triangular in outline. The rays are distinct and extend at least three-fourths the length of the spore radius. Prominent triradiate ridges, about 2 μ wide on either side of the commissure, extend to the margin of the spore coat. As viewed under oil immersion objective, the surface of the spore coat is levigate. The exine is about 2 μ thick.

Figured specimen.—Negative 5953; Trivoli Cyclothem, maceration 1175-C, slide 25, coordinates, 130.9 × 38.7; size, 65.2 by 53.0 μ.

DESCRIPTION OF LARGE SPORES AND MEGASPORES

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

Type species.—*Monoletes ovatus* Schopf, 1938.

Affinities.—Pteridospermic, Medullosaceae (Schopf, Wilson, and Bentall, 1944, p. 38).

Genus SPENCERISPORITES Chaloner, 1951
Table 1

Type species.—*Spencerisporites karczewskii* (Zerndt) Chaloner, 1951.

Affinity.—Lycopodian. Chaloner (1951, p. 861-873) obtained *Spencerisporites* from the lycopod cone, *Spencerites insignis* Scott, 1898. Spores found in a sporangium, assigned to *Spencerites*, were correlated by Leisman (1962a and b) to *Spencerisporites gracilis* (Zerndt) Winslow, 1959.

Genus TRILETES (Bennie & Kidston) Zerndt, 1930
Table 1

Type species.—*Triletes glabratus* Zerndt, 1930.

Affinities.—Free-sporing lycopsids (Schopf, Wilson, and Bentall, 1944, p. 19). Lundblad recorded megaspores of the *Triletes* type from a strobilus of a *Selaginella*-like plant from the Triassic of Greenland (1948, p. 356-357) and *Selaginella* from the Rhaetic of East Greenland (1950, p. 480-482). Chaloner obtained megaspores comparable to *T. auritus* Zerndt, 1930, from *Lepidostrobus zea* Chaloner (1953b, p. 102-104) and megaspores (Chaloner, 1954, p. 81-87) similar to *T. triangulatus* Zerndt, 1930, from the herbaceous lycopod *Selaginellites suissei* Zeiller, 1906. Four other species of *Triletes* were correlated with megaspores obtained from four species of *Lepidostrobus* (Chaloner, 1953a, p. 263-293). Felix (1954, p. 351-394) also correlated a number of species of *Triletes* with various species of *Lepidostrobus.* The megaspores of *S. crassicinctus* Hoskins & Abbott, 1956, were compared with those described as *T. triangulatus.* Sen (1958, p. 160-161) also reported *T. triangulatus* from *L. variabilis* Lindley & Hutton, and *T. mamillarius* Bartlett from *Sigillariostrobus goldenbergi* Feistmantel. *T. glabratus* Zerndt, 1930, from *Sigillariostrobus leiosporous,* and *T. auritus* from *Lepidostrobopsis missouriensis* were described by Abbott (1963, p. 96-100). Many other investigations have demonstrated the affinities of *Triletes* to lycopods.

DESCRIPTION OF OTHER MICROFOSSILS

HYSTRICHOSPHAERIDEA

Only four specimens representing three types of hystrichospheres, all from one sample, were observed in this investigation.

Hystrichosphere 1
Plate 8, figure 13

The body is triangular and has four appendages about 15 μ long. The ends are probably broken off.

Figured specimen.—Negative 4770; Trivoli Cyclothem, maceration 1128-J, slide 16, coordinates, 128.4 × 38.3; body size 25.6 by 24.0 μ.

Hystrichosphere 2
Plate 8, figure 14

The body is elliptical, folded, and has at least eight appendages, the largest 22.8 μ long and 3.5 μ wide at its base. Appendages that taper toward the ends are probably broken off.

Figured specimen.—Negative 4849; Trivoli Cyclothem, maceration 1128-J, slide 4, coordinates, 123.2 × 59.9; body size 37.9 by 30.5 μ.

Hystrichosphere 3
Plate 8, figure 15

The body is subcircular, folded, and has at least five appendages 15 to 18 μ long. The ends of the appendages are expanded, are divided into numerous subdivisions, and are 7 to 8 μ wide. The body is covered with grana about 1 μ in diameter.

Figured specimen.—Negative 4850; Trivoli Cyclothem, maceration 1128-J, slide 5, coordinates, 123.9 × 48.3; body size 34.0 by 29.5 μ.

SCOLECODONTS

Although several species of scolecodonts were found in some of the shales, only one is illustrated.

Scolecodont 1
Plate 8, figure 16

The scolecodont has eight large dentitions, from 20.8 to 8.5 μ long, and numerous small, joined dentitions.

Figured specimen.—Negative 5800; Fithian Cyclothem, maceration 1170-G, slide 19, coordinates, 129.8 × 34.9; size, 69.7 μ long.

INCERTAE SEDIS

Genus CENTONITES gen. nov.
Plate 8, figures 17-19; text figure 12

The generic name *Centonites* is proposed for microfossils, probably of plant origin, having the following characteristics. The microfossils are composed of 5 to approximately 15 polygonal segments joined to form radially or bilaterally symmetrical bodies, their symmetry depending upon their number and arrangement. Most of the microfossils are flatly compressed, but many are folded. Straight grooves are present on one side of the body where the segments are joined. Elevated, flattened ridges or folds occur adjacent to and along both sides of the grooves but are absent along the smooth outer margin of the microfossils. The microfossils usually are made up of an odd number of segments. The most common variation consists of five segments arranged in a boat-shaped pattern with two small, pointed segments at one end, two larger segments in the middle, and one pointed segment at the opposite end (text fig. 12).

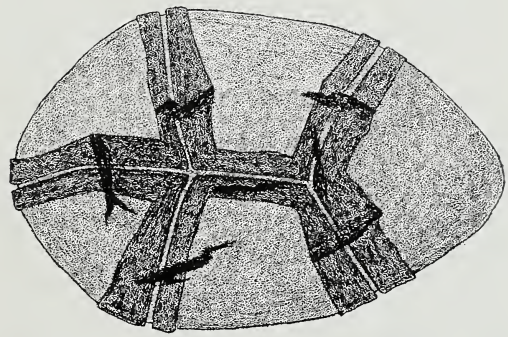

FIG. 12—*Centonites symmetricus* sp. nov.; diagrammatic reconstruction.

In the largest specimens two to four segments in the center are almost completely bordered by other segments. Along the margins of the largest specimens three small indentations may occur, almost equal distances apart, where segments are absent. These indentations either have smooth edges and look almost like pores or they have uneven edges as if segments had been torn out. The microfossils are revealed under oil immersion objective as levigate. They are 1 to 2 μ thick. The known size range is 50.2 to 123.2 μ in maximum diameter.

Type species.—*Centonites symmetricus* sp. nov.

Affinities.—The affinities of *Centonites* are not known, but they are most likely of plant origin, perhaps a peculiar kind of spore.

Derivation of name.—The generic name refers to the polygonal, "patchwork" (*cento*) segments composing the fossil.

Centonites symmetricus sp. nov.
Plate 8, figures 17-19; text figure 12

Diagnosis.—The microfossils, of unknown origin, are composed of several polygonal segments joined to form radially or bilaterally symmetrical bodies, their symmetry depending upon the number and arrangement of the segments. The microfossils are usually in good, flattened compression, but many are folded. Straight grooves are present on one side of the body where the segments are joined, and adjacent to the grooves are elevated, flattened ridges or folds. These grooves and ridges are absent along the smooth margin of the microfossils. The number of segments in the specimens observed varies from 5 to 15, usually an odd number. The specimens having five segments are quite common and are probably the basic pattern. They are boat shaped, with two segments at one end, one at the opposite more pointed end, and two in the middle. In the largest specimens two to four segments in the center are usually bordered by other segments. If some of the bordering segments are missing, the indentations (usually three) thus formed have smooth margins except where the segments appear to have been torn out. The microfossils are seen to be levigate under oil immersion objective and are 1 to 2 μ thick. Dimensions (33 specimens): over-all size range, 50.2 to 123.2 μ in maximum diameter, median, 68.1 μ; individual segments, 24.4 to 39 μ in maximum diameter, median, 29 μ.

Holotype.—Plate 8, figure 17; negative 5901; Trivoli Cyclothem, maceration 1175-E, slide 4, coordinates, 131.8 × 41.3; size, 69.7 by 66.7 μ.

Paratypes.—Plate 8, figure 18; negative 5688; Henshaw Formation, maceration 1122-A, slide 41 ZB, coordinates, 143.6 × 41.0; size, 122.5 by 101.1 μ; figure 19; negative 6124; Trivoli Cyclothem, maceration 1175-C, slide 17, coordinates, 134.8 × 50.7; size, 57.7 by 48.9 μ.

Discussion.—Although there is considerable variation in the number and arrangement of segments, all the specimens are placed in the same species because they probably represent different stages of development.

Felix (personal communication, 1963) has reported that *Centonites* is especially prominent in subsurface material of late Missourian age from Harper and Beaver Counties of Oklahoma and is regarded as a useful stratigraphic marker for the Missourian of that area.

Derivation of name.—The species name refers to the symmetrical arrangement of the segments.

DISTRIBUTION OF SMALL SPORE GENERA

SPORES OF THE TRIVOLI CYCLOTHEM

The Trivoli Cyclothem of the Modesto Formation was first described by Wanless (1931, p. 182, 192). His generalized section showed the cycle delineated by a sandstone at the base and a shale at the top. Wanless (1957, p. 121-122, 193) later described the cyclothem in detail from its type exposure in Peoria County.

For this study, spores of the Trivoli Cyclothem were examined from two Illinois diamond drill cores, one from Macoupin County, the other from Franklin County, so that assemblages of substantially the same stratigraphic interval but different localities could be compared. Both core sections are described at the end of the report.

Macoupin County, Illinois

From the Macoupin County core, macerated samples from the Trivoli Cyclothem and the overlying 8 feet of strata were examined. Text figure 13 shows the distribution, in percentage, of small spore genera found. Of the six samples (macerations 1128-A through 1128-F) from strata below the No. 8 Coal that were macerated, only that of the underclay directly below the coal yielded spores, and they generally were poorly preserved. Although spores were obtained from macerations of all the samples above the coal, they were not abundant in relation to the amount of fine organic matter. Spores in the shaly limestone (maceration 1128-K) were greatly eroded and specific identification was difficult. The least diversity of spore genera and species, which can be partly attributed to lack of preservation, occurred in the underclay and shaly limestone, whereas the greatest diversity was found in the coal, where preservation of spores was good. To conform to the system of nomenclature outlined by

Schopf, Wilson, and Bentall (1944), *Cyclogranisporites* was included with *Punctatisporites* in all the figures (text figs. 13-16) showing distribution of genera.

In the underclay (maceration 1128-F), the lowest stratum sampled in the cyclothem, 73 percent of the spores were *Punctatisporites. Calamospora* was second in relative abundance (10 percent) and *Endosporites* was third (5.3 percent). *Gravisporites* proved to be more abundant (3.3 percent) in the underclay than in the other strata sampled. *Florinites* (3.0 percent), *Laevigatosporites* (1.3 percent), *Triquitrites* (1.7 percent), and *Granulatisporites* (2.0 percent) also were found in the underclay.

The relative abundance of small spore genera in the No. 8 Coal (maceration 1128-G) did not differ greatly from that in the underclay. *Punctatisporites* (83.4 percent) was at its peak in the coal, but *Calamospora* (7.4 percent) and *Endosporites* (3.4 percent) decreased in abundance. *Laevigatosporites, Granulatisporites, Triquitrites,* and *Florinites* were relatively rare. *Cadiospora, Reinschospora, Trivolites,* and *Raistrickia* occurred in the coal but were not observed in the statistical count.

Three samples from the gray, carbonaceous shale overlying the coal were examined. In the lowest sample (maceration 1128-H), *Punctatisporites* accounted for well over half (60.3 percent) the spore population. The most conspicuous change in the spore distribution was the increase in *Calamospora* (19.7 percent), *Endosporites* (10.7 percent), and *Florinites* (5.7 percent). *Laevigatosporites, Triquitrites, Raistrickia, Granulatisporites,* and *Lycospora* each formed less than 2 percent of the total spore population.

In the sample (maceration 1128-I) from the middle of the shale sequence, *Calamospora* (36.3 percent) was more abundant than in any other sample from the cyclothem and was almost as plentiful as *Punctatisporites* (38.3 percent). *Granulatisporites* (6 percent) also reached its maximum for the cyclothem. *Florinites* (7.3 percent) was only slightly more common than in the lower shale sample. *Endosporites* (4 percent), *Laevigatosporites* (3.7 percent), and *Lycospora* (3.3 percent) were in significant abundance, but *Triquitrites, Indospora,* and *Densosporites* each accounted for less than 1 percent. Although rare, the presence of *Densosporites* is significant and will be discussed later.

In the sample (maceration 1128-J) taken from the upper part of the gray shale, the top of the cyclothem, *Florinites* (22 percent) was at peak abundance for the cyclothem, but *Punctatisporites* (47 percent) was still the dominant genus. *Calamospora* (15.3 percent), *Granulatisporites* (3.7 percent), and *Endosporites* (0.3 percent) were noticeably less important than in the underlying sample, while *Lycospora* (3 percent), *Laevigatosporites* (3 percent), *Triquitrites* (<1 percent), and *Densosporites* (<1 percent) appeared in about the same percentage as in maceration 1128-I. *Wilsonites, Cirratriradites, Reticulatisporites, Ahrensisporites, Secarisporites, Crassispora,* and *Pityosporites* appeared for the first time. Three species (4 specimens) of hystrichospheres also were observed.

In the dark gray, shaly, marine limestone (maceration 1128-K) directly overlying the cyclothem, *Punctatisporites* accounted for up to 67.3 percent of the spore assemblage. *Calamospora* (19.7 percent) and *Endosporites* (3.7 percent) were second and third in relative abundance. The most conspicuous change from the underlying shale sample is the diminution of *Florinites.* The percentages of *Laevigatosporites, Granulatisporites,* and *Triquitrites* were not significantly different from those of maceration 1128-J. *Lycospora, Reinschospora,* and *Indospora* were also present but rare.

In the sample from the gray shale (maceration 1128-L) above the limestone, *Calamospora* (10 percent) was again subordinate to *Punctatisporites* (70.7 percent.). *Laevigatosporites* (8 percent) was at its maximum for the cyclothem, whereas *Granulatisporites* (5.3 percent) and *Florinites* (4.3 percent) increased slightly in relative abundance. *Wilsonites, Crassispora, Gravisporites, Reinschospora, Indospora, Triquitrites,* and *Vesicaspora* each made up less than 1 percent of the total spore population.

Franklin County, Illinois

Samples from the diamond drill core of the Trivoli Cyclothem from Franklin County, Illinois, were macerated for comparison of

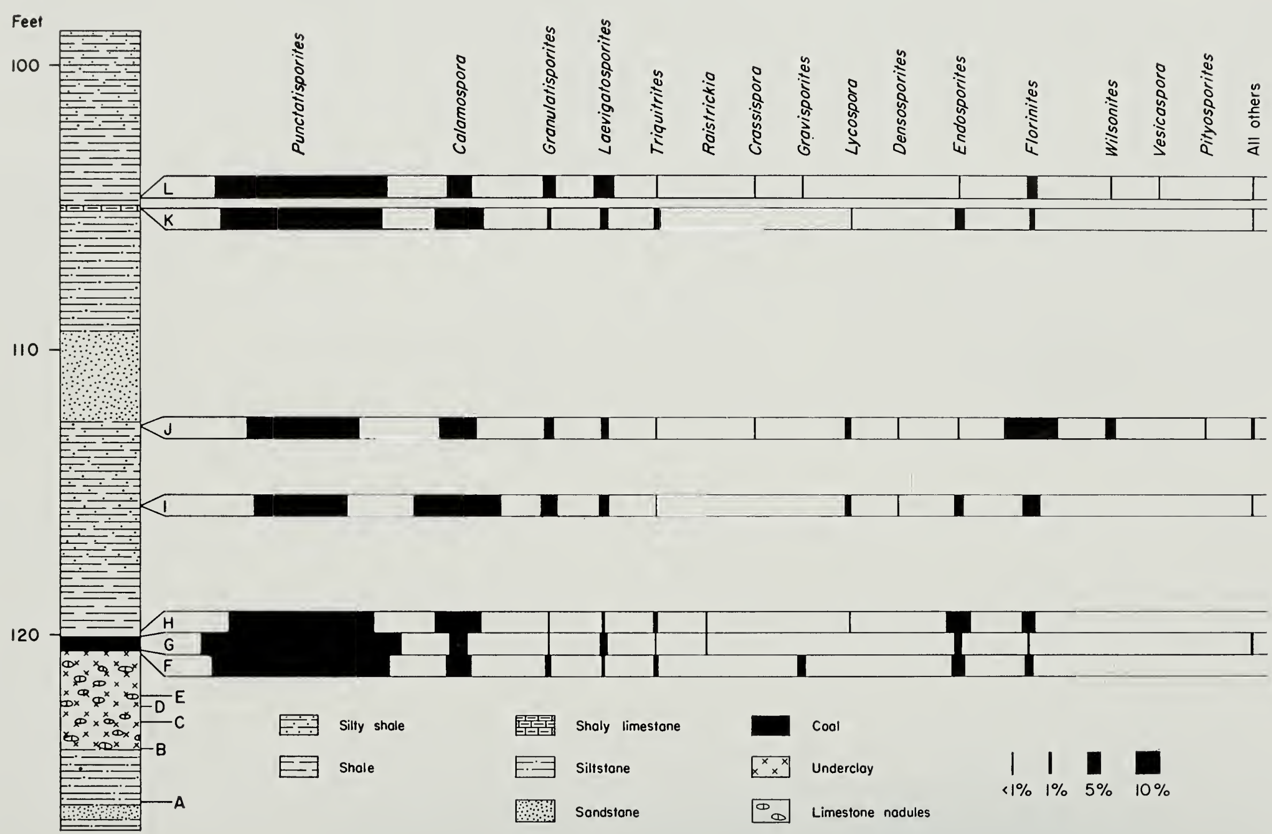

FIG. 13—Relative abundance of small spores, by genera, in the Trivoli Cyclothem and immediately overlying strata in Macoupin County, Illinois (macerations 1128-A through 1128-L).

spore assemblages with those of approximately the same stratigraphic interval from Macoupin County. As the Macoupin County samples of strata below the No. 8 Coal had proved barren of spores (except for the sample from the top of the underclay—maceration 1128-F), only the spore assemblages of the coal and overlying strata from Franklin County could be compared.

All 16 samples from Franklin County (maceration 1175, text fig. 14) yielded spores of sufficient number and preservation to be used in this study. Preservation of spores in the coal and underlying strata generally was good, but in the shale above the coal preservation was so poor that only generic identification could be made of most of the spores. Direct comparison of spore assemblages of the section of the Trivoli Cyclothem in Macoupin County and the section in Franklin County is therefore of limited value. The greatest diversity in genera and species was found in the shale and silty shale (macerations 1175-A through 1175-D) below the coal. The smallest number of spore taxa was found in the gray, fossiliferous shale (macerations 1175-K through 1175-P) above the coal, probably largely due to lack of preservation of many spores present at the time of deposition.

The distribution of small spore genera in the silty shale (macerations 1175-A through 1175-C) showed little variation. *Punctatisporites* was the dominant genus, making up about 50 percent of the total distribution. *Florinites* was second in abundance and varied from 8 percent at the base of the section (maceration 1175-A) to 21.7 percent in the sample above and then decreased to 10.7 percent in maceration 1175-C. *Wilsonites* was almost as abundant (11.7 to 13 percent) and showed little variation in the three macerations. *Calamospora* decreased from 9 percent in maceration 1175-A to 3 percent in maceration 1175-C. The occurrence of *Granulatisporites* (10.3 to 4.3 percent), *Triquitrites* (3.3 to 1.7 percent), and *Endosporites* (1 to 2 percent) fluctuated somewhat. *Lycospora, Laevigatosporites,* and *Crassispora* increased slightly toward the top of the silty shale. Other genera observed in the three samples included *Gravisporites, Raistrickia, Latipulvinites, Cirratriradites, Indospora, Dictyotriletes?, Lundbladispora, Columinisporites, Convolutispora, Savitrisporites, Trivolites, Secarisporites,* and *Illinites.*

Punctatisporites (36.3 percent) decreased in abundance in the gray, carbonaceous shale samples (macerations 1175-D, E). *Florinites* increased from 10.7 percent in maceration 1175-C to 24 percent in maceration 1175-D. *Granulatisporites* and *Calamospora,* both at 10.7 percent, were fourth and fifth in relative abundance in maceration 1175-D. *Lycospora* (5.3 percent), *Laevigatosporites* (1.0 percent), and *Densosporites* (1.0 percent) showed a slight increase, whereas *Wilsonites* decreased to only 1.7 percent of the assemblage. *Triquitrites* (3.7 percent), *Endosporites* (1.7 percent), *Crassispora* (1.3 percent), and *Gravisporites* (<1 percent) maintained about the same relative abundance as in the lower samples. *Reticulatisporites, Lundbladispora,* and *Latipulvinites,* were present but were not observed on the slide used in the statistical count.

Farther up in the same gray shale sequence (maceration 1175-E), *Punctatisporites* (26 percent) decreased while *Lycospora* increased to its maximum abundance for the cyclothem —17.3 percent. *Endosporites* increased sharply to 16.3 percent to become the fourth most plentiful genus. *Granulatisporites* (11 percent), *Calamospora* (10.3 percent), *Laevigatosporites* (2.3 percent), *Wilsonites* (1.7 percent), *Triquitrites* (1 percent), and *Gravisporites* (<1 percent) showed no significant change in relative abundance. *Crassispora,* with 8 percent of the total spore population, was at its maximum for the cyclothem. *Florinites* took a sharp dip to 3.3 percent. The presence of *Densosporites* (1.3 percent) was again noted, but the genus was not a major constituent. *Trivolites* and *Dictyotriletes* also were present.

At the base of the underclay, in maceration 1175-F, *Endosporites* (30.3 percent) and *Calamospora* (26 percent) reached their peaks and were followed by *Punctatisporites* (17.3 percent), which was at its lowest percentage for the cyclothem. *Lycospora* and *Crassispora* decreased considerably to 9.7 percent and <1 percent, respectively. *Granulatisporites* (6.3 percent) showed a slight decrease, while *Laevigatosporites* (3.3 percent), *Florinites* (2.3 percent), *Triquitrites* (1.7

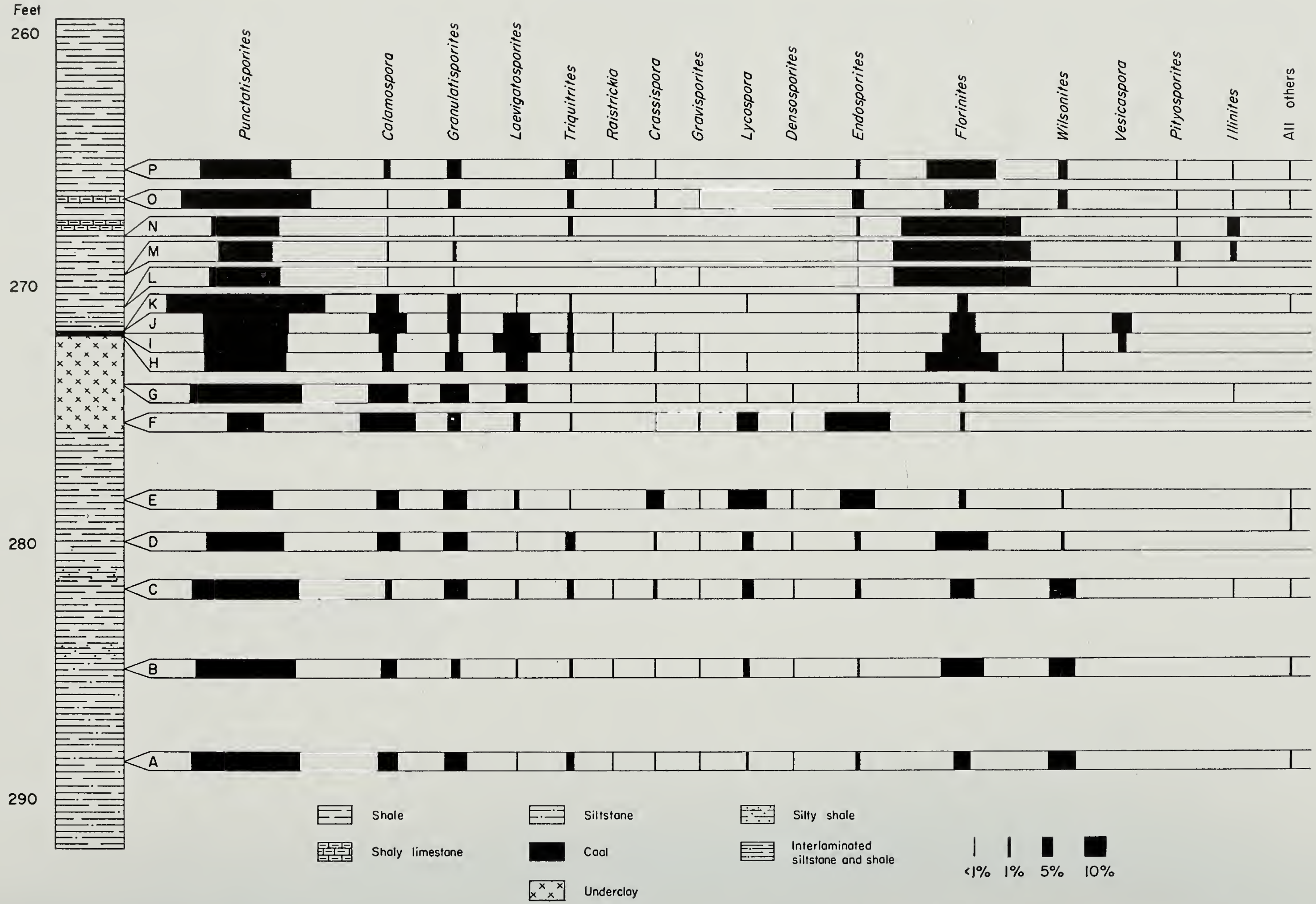

FIG. 14—Relative abundance of small spores, by genera, in the Trivoli Cyclothem in Franklin County, Illinois (macerations 1175-A through 1175-P).

percent), and *Densosporites* (1.3 percent) remained at about the same percentage as in maceration 1175-E.

Punctatisporites (52 percent) was by far the dominant genus farther up in the underclay (maceration 1175-G). *Calamospora* decreased to 18.3 percent, and *Granulatisporites* increased to its maximum for the cyclothem, 13.3 percent. A conspicuous change took place in the population of *Endosporites* and *Lycospora*—they declined to less than 1 percent each. *Laevigatosporites* (10 percent) and *Florinites* (3.3 percent) were important constituents of the spore population. *Triquitrites, Crassispora, Densosporites, Reinschospora, Indospora, Trivolites,* and *Illinites* each made up 1 percent or less of the total spore population.

In maceration 1175-H from the top of the underclay, *Punctatisporites* (38.7 percent) was followed in abundance by *Florinites,* which showed a marked increase to 34.3 percent. *Laevigatosporites* again composed 10 percent of the spore assemblage. *Calamospora* and *Granulatisporites* diminished in relative abundance to 4.7 percent and 8.7 percent, respectively. Minor constituents in the spore population included *Triquitrites, Gravisporites, Crassispora, Wilsonites, Endosporites,* and *Lycospora.*

In the shaly coal (maceration 1175-I), *Punctatisporites* (39.3 percent) remained at about the same level of abundance as in the underclay. *Laevigatosporites* increased considerably and reached its maximum for the section at 22.7 percent. *Florinites* (18 percent) began a decline that continued through the coal into the immediately overlying shale. *Calamospora* (8.7 percent) increased slightly in frequency, whereas *Granulatisporites* (4.3 percent) decreased slightly. *Triquitrites* (3 percent) and *Vesicaspora* (3.7 percent) were not uncommon. *Raistrickia, Ahrensisporites, Reinschospora, Reticulatisporites, Convolutispora, Gravisporites, Crassispora, Endosporites,* and *Wilsonites* together totaled less than 1 percent.

In the coal (maceration 1175-J), *Punctatisporites* (39.6 percent) was followed in abundance by *Calamospora* at 17.4 percent, its secondary peak for the sequence, and by *Florinites* (12.6 percent) and *Laevigatosporites* (12.6 percent). *Vesicaspora* and *Granulatisporites* were next in relative abundance with 9.2 percent and 6 percent, respectively. *Triquitrites, Raistrickia, Endosporites,* and *Indospora* were rare.

Punctatisporites (74 percent) reached its maximum abundance for the cyclothem in the gray siltstone (maceration 1175-K) immediately above the coal. *Calamospora* (10.7 percent) and *Florinites* (5.3 percent) decreased. The relative abundance of *Granulatisporites* (6 percent), *Endosporites* (1.7 percent), *Triquitrites* (1.3 percent), and *Laevigatosporites* (<1 percent) showed little change. *Lycospora, Reticulatisporites,* and *Secarisporites* each made up less than 1 percent of the spore population.

In the overlying dark gray shale sequence, *Florinites* increased to 64.7 percent and became the dominant genus in maceration 1175-L. *Punctatisporites* (33.3 percent), *Calamospora* (<1 percent), and *Granulatisporites* (<1 percent) were considerably less abundant than in the underlying shale. *Endosporites, Gravisporites, Crassispora,* and *Pityosporites* were rare.

The spore distribution in the overlying dark gray to black fossiliferous shale samples (macerations 1175-M and N) was not greatly different from that in maceration 1175-L. *Punctatisporites* (25.7 percent) decreased slightly in maceration 1175-M, and *Florinites* (56 percent) decreased slightly in maceration 1175-N. *Illinites* increased from 3.3 percent in maceration 1175-M to 6.3 percent in maceration 1175-N, where it reached its maximum occurrence. *Granulatisporites, Calamospora,* and *Endosporites* showed some minor fluctuations in frequency. *Pityosporites* accounted for 3 percent of the spore population in maceration 1175-M.

In the shaly limestone (maceration 1175-O), *Punctatisporites* suddenly increased to 61.3 percent, more than double its total in the underlying shale sample. *Florinites* (16.3 percent) showed a correspondingly sharp decrease in abundance. *Granulatisporites* and *Endosporites* increased slightly to 6 percent and 5.7 percent, respectively. *Wilsonites* (4.0 percent), *Triquitrites* (2.7 percent), *Crassispora* (1.3 percent), *Illinites* (1.0 percent), *Gravisporites* (<1 percent), *Calamospora* (<1 percent), and *Pityosporites* (<1

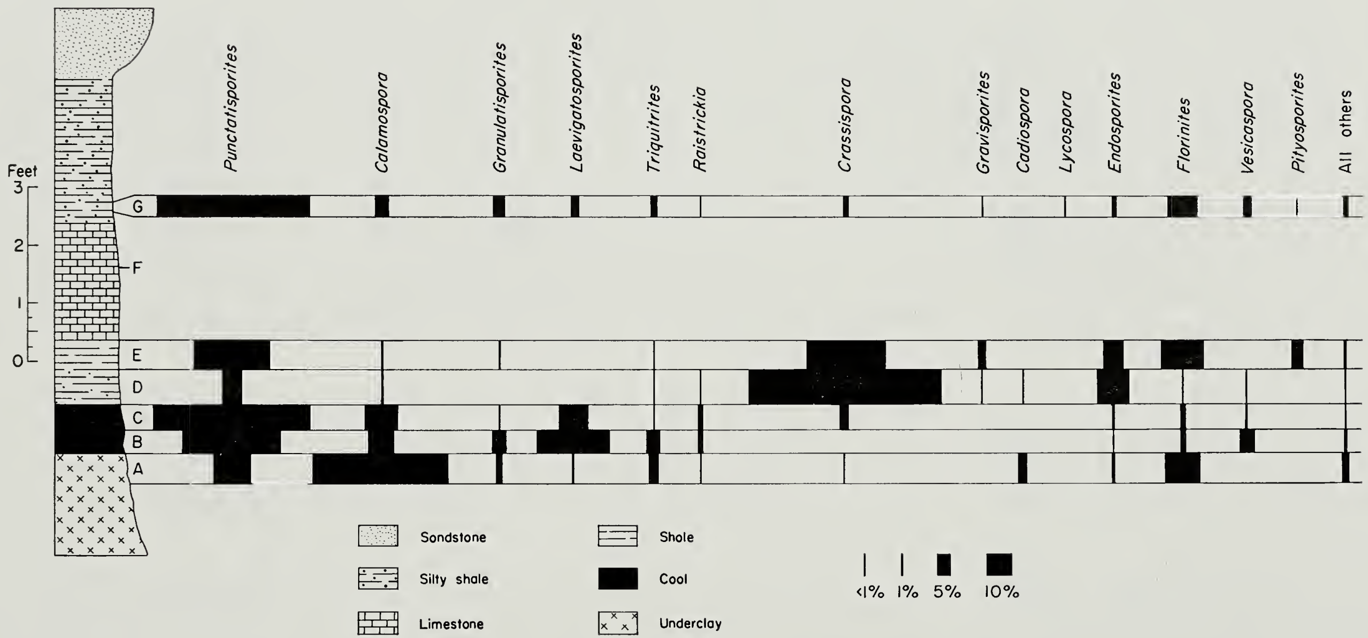

FIG. 15—Relative abundance of small spores, by genera, in the Fithian Cyclothem in Vermilion County, Illinois (macerations 1170-A through 1170-G).

percent) also occurred in the shaly limestone.

Punctatisporites (43.7 percent) continued to predominate in the uppermost fossiliferous shale (maceration 1175-P) sampled in the cyclothem. *Florinites* was next in abundance with 33.3 percent of the total small spore assemblage. *Granulatisporites* (6.7 percent) and *Wilsonites* (4.3 percent) remained at about the same percentage as in the shaly limestone. *Triquitrites* reached its maximum at 5.7 percent. *Calamospora* (3.0 percent) was not uncommon. Other genera included *Raistrickia, Crassispora, Illinites, Pityosporites,* and *Hamiapollenites,* each being represented by less than 1 percent of the spores present.

SPORES OF THE FITHIAN CYCLOTHEM, VERMILION COUNTY, ILLINOIS

The type locality of the Fithian Cyclothem was designated by Wilson (1944) as an outcrop in NW ½ sec. 31, T. 19 N., R. 13 W., Vermilion County, Illinois, along the east bank of the Salt Fork River, south of a concrete bridge, and about 2 miles south of the village of Fithian. The first published use of the name "Fithian Cyclothem" was made by White et al. (1958). Outcrop samples from the type section of the Fithian Cyclothem were collected for this investigation; they are described at the end of the report. The Fithian Cyclothem is stratigraphically equivalent, or approximately so, to the Flat Creek Cyclothem of southwestern Illinois (Kosanke, personal communication, 1961).

Of the seven samples from the Fithian Cyclothem (text fig. 15) only the marine limestone (maceration 1170-F) failed to yield spores. Those obtained from the remaining samples are generally in a good state of preservation, especially those from the underclay, which had the best preserved spores of any underclay macerated for this study. The greatest diversity of species and genera was found in the shale (maceration 1170-G) overlying the limestone, whereas the least variety was found in the shale (macerations 1170-D, E) between the coal and limestone.

At the top of the underclay (maceration 1170-A) *Calamospora* was the dominant genus and was at its maximum abundance for the cyclothem, making up 55.3 percent of the small spore assemblage. *Florinites* (14.7 percent) was second and *Punctatisporites* (15.0 percent) third in abundance. *Triquitrites* (4 percent), *Cadiospora* (2.7 percent), *Granulatiporites* (2.3 percent), *Endosporites* (1.3 percent), and *Laevigatosporites* (1 percent) also occurred in the underclay. The "bisaccate grain 2" accounted for 2 percent of the total, and the remainder was made up of *Raistrickia, Crassispora,* and unassigned spores, each of which were less than 1 percent of the spore population.

Punctatisporites (40.2 percent) was the most abundant genus in the bottom half of the coal (maceration 1170-B). *Laevigatosporites* increased significantly to reach its maximum (29 percent) in this sample. *Calamospora* (10.4 percent), the third most dominant genus, and *Florinites* (1.8 percent) decreased markedly from their profusion in the underclay. *Vesicaspora* (6.6 percent), *Triquitrites* (5 percent), and *Raistrickia* (1.4 percent) reached their greatest occurrence in the lower half of the coal but were not numerically significant in terms of the total spore assemblage. *Granulatisporites* (4.6 percent) was rather common. *Cirratriradites, Reticulatisporites,* and *Endosporites* totaled less than 1 percent.

The small spore assemblage in the upper half of the coal (maceration 1170-C) was dominated by *Punctatisporites* (64.4 percent) which there reached maximum distribution. *Calamospora* (13.4 percent) showed a slight increase over the percentage found in the lower part of the coal while *Laevigatosporites* (12.4 percent) decreased sharply. *Crassispora* (3.4 percent) was statistically well represented. Other genera included *Florinites* (1.8 percent), *Endosporites* (1.4 percent), *Raistrickia* (1.2 percent), *Vesicaspora* (1.0 percent), *Reinschospora, Reticulatisporites, Triquitrites, Alatisporites, Convolutispora, Granulatisporites,* and *Indospora.* The last 6 genera were represented by less than 1 percent each.

The most striking change in the distribution of small spore genera in the dark gray shale (maceration 1170-D) overlying the coal was the great increase in *Crassispora,* from 3.4 percent in the upper half of the coal to 78.7 percent in the shale. *Endosporites* (12.3

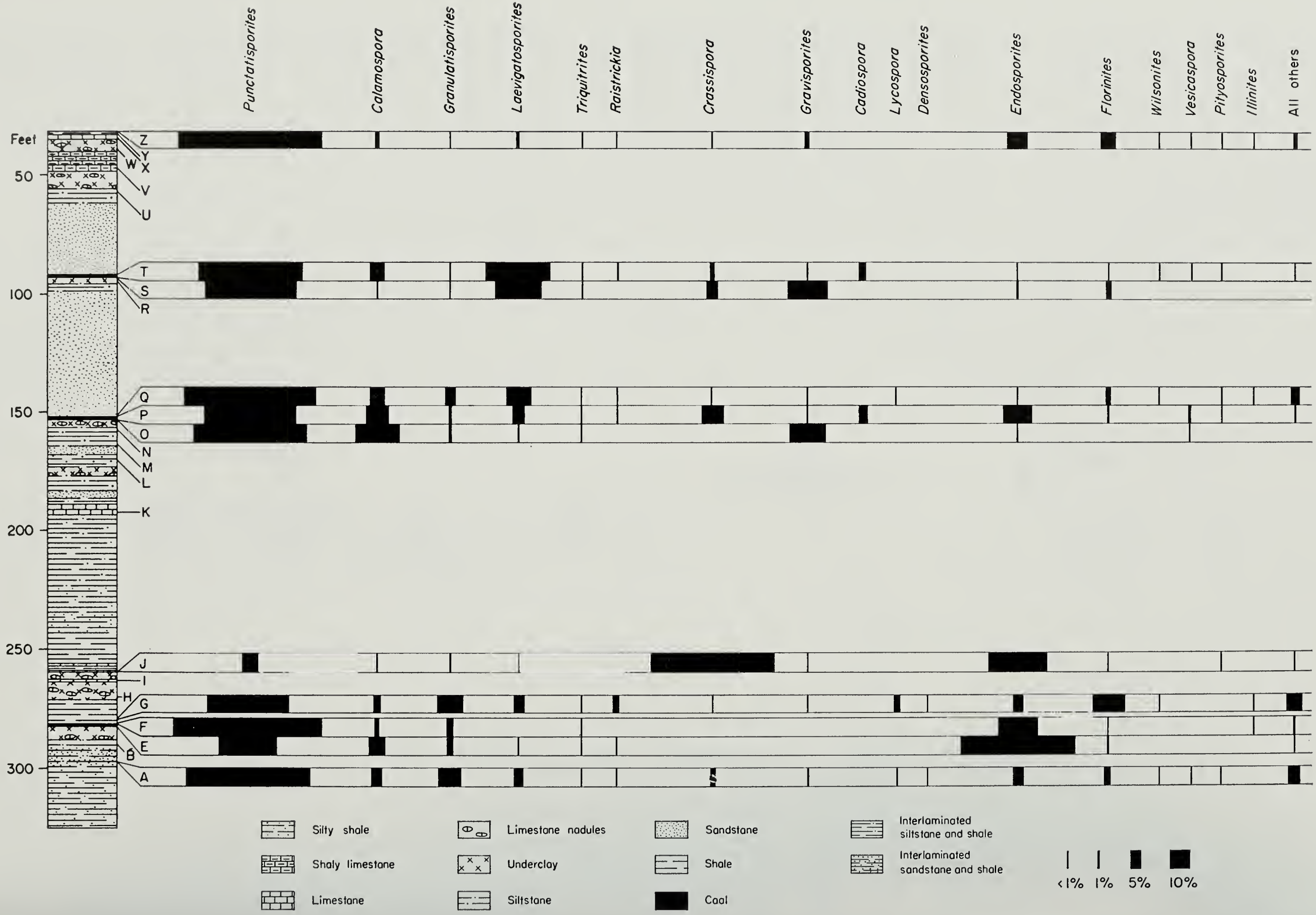

FIG. 16—Relative abundance of small spores, by genera, in the Henshaw Formation in Union County, Kentucky (macerations 1122-A through 1122-Z).

percent) also increased sharply to become second in importance, but *Punctatisporites* (7.7 percent) was at its minimum for all the samples macerated from the Fithian Cyclothem. *Calamospora, Triquitrites, Reticulatisporites, Raistrickia, Cirratriradites, Alatisporites, Cadiospora, Gravisporites, Florinites,* and *Vesicaspora* were numerically minor constituents of the small spore assemblage.

Crassispora (32 percent) and *Punctatisporites* (31 percent) were of almost equal abundance in the black shale (maceration 1170-E) underlying the limestone. *Florinites* increased significantly to 17.7 percent and was at its observed maximum for the cyclothem, as was *Pityosporites* (4.7 percent). *Endosporites* decreased to 7.3 percent, and *Gravisporites* increased to 3.3 percent. *Granulatisporites, Calamospora, Triquitrites, Cirratriradites,* and *Alatisporites* were rare.

In the gray shale (maceration 1170-G) above the limestone, *Punctatisporites* (62 percent) again became by far the dominant genus, followed by *Florinites,* which constituted 12.3 percent of the total. *Calamospora* (5.7 percent), *Granulatisporites* (4.0 percent), *Laevigatosporites* (3.3 percent), and *Vesicaspora* (2.7 percent) were fairly common. *Crassispora* decreased markedly to only 2.3 percent. Other genera included *Triquitrites* (2.3 percent), *Endosporites* (1.7 percent), and *Columinisporites* (1 percent). *Raistrickia, Cirratriradites, Latipulvinites, Gravisporites, Indospora, Limitisporites, Pityosporites, Rhizomaspora,* and *Lycospora* were each less than 1 percent of the spore assemblage.

SPORES OF THE HENSHAW FORMATION, UNION COUNTY, KENTUCKY

The uppermost 250 feet of a diamond drill core of the Henshaw Formation of western Kentucky, sampled (maceration 1122) for the present study, is described at the end of the report. The top of the core is approximately 1200 feet above the Carthage Limestone Member (equivalent to the Shoal Creek Limestone Member of Illinois).

Of 26 samples of various lithologies (text fig. 16) macerated from the section, only 11 yielded spores. Preservation of the spores in many of these samples was very poor. As a large number of samples failed to yield spores (macerations 1122-B through 1122-D, 1122-H, 1122-I, 1122-K through 1122-N, 1122-R, and 1122-U through 1122-Y), several wide gaps exist in the data concerning the plant microfossil succession. In maceration 1122-A, a dark shale, and maceration 1122-Q, a sandstone directly overlying the middle coal of the part of the Henshaw Formation studied, a great variety of well preserved spores was obtained.

Punctatisporites (61.3 percent) was by far the dominant genus in the dark gray shale (maceration 1122-A), the lowest sample macerated. *Granulatisporites* and *Endosporites* were second and third in relative abundance, with 10.7 percent and 5.3 percent, respectively. *Calamospora* (5 percent), *Laevigatosporites* (4.0 percent), *Florinites* (3.0 percent), and *Crassispora* (2.3 percent) were frequently encountered. *Lycospora* and *Densosporites* totaled less than 1 percent, and the significance of their presence is discussed later. The rest of the small spore assemblage included minor percentages of *Triquitrites, Raistrickia, Ahrensisporites, Cirratriradites, Reticulatisporites, Microreticulatisporites, Reinschospora, Convolutispora, Striatosporites, Lundbladispora, Latipulvinites, Secarisporites, Gravisporites, Indospora, Trivolites, Dictyotriletes?, Wilsonites, Strotersporites, Potonieisporites,* and *Pityosporites.*

The most obvious feature in the spore distribution of the lower coal (maceration 1122-E) was the great increase in the percentage of *Endosporites* (57.6 percent) compared to the occurrence of this genus in the associated underclay. *Punctatisporites* (29.2 percent) was next in abundance, followed by *Calamospora* (8.0 percent), *Granulatisporites* (2.8 percent), and *Florinites* (1.2 percent). *Triquitrites, Raistrickia, Laevigatosporites,* and *Convolutispora* were each less than 1 percent of the small spore assemblage.

Punctatisporites (73.7 percent) again became the dominant genus in the coaly shale (maceration 1122-F) immediately above the coal, where it reached its maximum observed peak. *Endosporites* decreased sharply to 19.3 percent. *Calamospora* declined to 2.7 percent, and *Granulatisporites* remained at about the same relative abundance. *Triquitrites* and

Illinites, both at less than 1 percent, made up the remainder of the spore population.

Continuing upward in the overlying gray shale (maceration 1122-G), *Punctatisporites* (40.3 percent) and *Endosporites* (5.3 percent) showed a decline in comparison with their appearance in the underlying coaly shale, while *Florinites* and *Granulatisporites* reached their maxima of 17 percent and 13.3 percent, respectively. *Laevigatosporites* (4.7 percent), *Lycospora* (3.0 percent), *Secarisporites* (4.3 percent), *Calamospora* (3.3 percent), *Raistrickia* (2.3 percent), and *Lundbladispora* (2.0 percent) were fairly common. *Wilsonites, Illinites, Convolutispora, Ahrensisporites, Latipulvinites, Gravisporites, Crassispora, Indospora,* and *Densosporites* were sparsely represented.

Crassispora increased very conspicuously to 62 percent and became the most abundant genus in a fossiliferous limestone (maceration 1122-J). *Endosporites* also showed a sharp increase, to 29 percent, while *Punctatisporites* declined sharply to its observed minimum of 7.7 percent. *Florinites, Calamospora, Laevigatosporites, Cirratriradites, Knoxisporites, Gravisporites,* and *Pityosporites* were relatively rare.

In the underclay (maceration 1122-O) below the middle coal of the sequence, *Punctatisporites* (57.3 percent) was followed in abundance by *Calamospora,* which reached its maximum abundance for the section at 22.3 percent. *Gravisporites* also showed a sharp increase to 18 percent and was third in occurrence. *Granulatisporites* (1.7 percent), *Endosporites, Triquitrites, Laevigatosporites,* and *Vesicaspora* infrequently occurred in the small spore assemblage.

The middle coal (maceration 1122-P) was characterized by a decrease in *Punctatisporites* (46.8 percent), *Calamospora* (10.8 percent), and *Gravisporites* (< 1 percent). *Endosporites* (14.6 percent), *Crassispora* (10.8 percent), and *Laevigatosporites* (5.4 percent) were present in considerable proportions. *Cadiospora* (3.8 percent), *Florinites* (1.4 percent), *Granulatisporites* (1.8 percent), *Triquitrites, Raistrickia, Pityosporites,* and *Vesicaspora* were minor spore constituents in the coal.

The thick sandstone (maceration 1122-Q) overlying the middle coal had a spore assemblage composed predominantly of *Punctatisporites* (66.7 percent), *Laevigatosporites* (11.7 percent), *Calamospora* (7.7 percent), *Granulatisporites* (5.3 percent), and *Florinites* (2.3 percent). Other genera included *Lycospora, Raistrickia, Triquitrites, Ahrensisporites, Gravisporites, Crassispora, Secarisporites, Lundbladispora, Trivolites, Endosporites, Wilsonites, Illinites, Pityosporites, Strotersporites, Lueckisporites,* and *Potonieisporites.*

In the underclay (maceration 1122-S) of the upper coal, *Punctatisporites* and *Laevigatosporites* were only slightly less abundant than in the sandstone—45.7 percent and 23.3 percent, respectively. *Gravisporites* reached its greatest peak for the section with 20.3 percent of the total spore population, and *Crassispora* was a significant constituent with 5.7 percent. *Florinites* (2.3 percent), *Endosporites* (1.3 percent), *Calamospora, Granulatisporites, Latipulvinites,* and *Triquitrites* made up the rest of the spore population.

In the top coal (maceration 1122-T), *Punctatisporites* (52.4 percent) was followed in abundance by *Laevigatosporites,* which reached its maximum abundance for the section at 32.6 percent. *Calamospora* (7.4 percent) and *Cadiospora* (3.4 percent) were third and fourth in occurrence, followed by *Crassispora* (2.0 percent). *Gravisporites, Triquitrites, Raistrickia, Granulatisporites, Endosporites, Florinites, Wilsonites, Pityosporites,* and *Vesicaspora* were each less than 1 percent of the total small spore assemblage.

Punctatisporites (72.7 percent) was by far the most dominant genus in the gray calcareous uppermost shale sample (maceration 1122-Z). *Endosporites* and *Florinites* increased significantly to 10.7 percent and 7.7 percent, respectively, while *Laevigatosporites* (1.7 percent) and *Calamospora* (2.0 percent) declined sharply. *Gravisporites, Granulatisporites, Triquitrites, Crassispora, Raistrickia, Reticulatisporites, Convolutispora, Potonieisporites, Wilsonites, Illinites, Pityosporites, Vesicaspora, Vestigisporites, Strotersporites,* and *Hamiapollenites* were minor constituents of the small spore population.

CONCLUSIONS

The variety and relative abundance of small spore genera and species of the upper

Pennsylvanian cyclothems studied were found to vary vertically through strata formed under changing environments of deposition. Spore assemblages recovered from rocks do not, however, give a complete or necessarily true picture of the flora growing in a given area at the time of deposition. This is due to several factors, which are summarized below.

1. Plants that produced prolific numbers of spores are represented out of proportion to those that bore relatively few spores.

2. Spores and pollen that possessed structures such as bladders, flanges, processes, spines, and reticulations to aid in dispersal are scattered over a wider area than those not so equipped.

3. Spores produced by tall arborescent plants presumably are disseminated by wind over a greater area than those produced by low herbaceous plants.

4. Areas of deposition receive spores from a great distance if prevailing wind and water currents from the source area are favorable.

5. Spores introduced from reworking of older strata may be incorporated in clastic sediments along with spores produced by indigenous plants.

6. Spores with resistant exines are more likely to be preserved during and subsequent to deposition than those with weak exines.

7. Sampling techniques vary in reliability. A column sample provides a better representation of the floral assemblage living at the time of deposition than do small samples taken at wide intervals.

8. Errors in maceration technique and identification of taxa, of course, lead to erroneous conclusions.

When changes in variety and relative abundance of plant microfossils throughout a cyclothem or a relatively short sequence of lithologies are being considered, evolution probably is less important than environmental changes and factors related to spore dispersal.

RELATION OF SPORE DISTRIBUTION TO LITHOLOGY

Palynology of the McLeansboro Group indicates that *Punctatisporites* is the most abundant genus in all but a few of the samples macerated. *P. minutus* is the most abundant species. The relative abundance of *Punctatisporites* fluctuates throughout the sections in such a way that no relation between abundance and either lithology or position within a cyclothem is evident. In the Fithian Cyclothem, *Punctatisporites* decreases upward from the coal into the overlying shale. In contrast, a siltstone (maceration 1175-K) overlying the No. 8 Coal, a shale (maceration 1122-F) overlying the lower coal in the Henshaw Formation, and a sandstone (maceration 1122-Q) directly overlying the middle coal in the Henshaw Formation display more *Punctatisporites* than do their underlying coals. Other workers have found a greater abundance of the genus in shale than in coal. Hoffmeister, Staplin, and Malloy (1955a, p. 355) found that *Punctatisporites* is more abundant in the shale of the Hardinsburg Formation than in the coal. Neves (1958, p. 13-14) also found the greatest abundance of *Punctatisporites* in marine shales of the Upper Carboniferous of England. *Punctatisporites* reaches its maximum development in the shale immediately overlying the Harlem Coal of West Virginia (Collins, 1959, figs. 11-14).

Calamospora is an important component in all the cyclothems studied. In the Fithian Cyclothem, the Trivoli Cyclothem in Franklin County, and the middle coal of the Henshaw Formation, *Calamospora* is most abundant in the underclays. In the Trivoli Cyclothem in Macoupin County, the greatest concentration of *Calamospora* was found in a silty shale (maceration 1128-I) above the No. 8 Coal. Collins (1959, fig. 14) found *Calamospora* most abundant in the Harlem Coal and in minor amounts in the underclay.

Granulatisporites was found in all the samples except maceration 1170-D, the shale directly above the coal in the Fithian Cyclothem. The greatest relative percentage of *Granulatisporites* occurs either in strata above coal (Trivoli Cyclothem, maceration 1128-I; section of the Henshaw Formation, maceration 1122-G; Fithian Cyclothem, maceration 1170-G) or strata below coal (Trivoli Cyclothem, macerations 1175-C through E, G) but not in coal. Collins (1959, figs. 11-14) found the maximum abundance of *Granulatisporites* in the Ames Shale above the Harlem Coal.

The distribution of *Crassispora* is peculiar. It is abundant (78.7 percent) in the shale directly overlying the coal of the Fithian Cyclothem but composes only 3.4 percent of the spore assemblage in the upper half of the coal and is absent in the lower half of the coal. It is the most abundant genus (62 percent) in maceration 1122-J, a limestone, but accounts for only 0.3 percent of the small spore population in a shale (maceration 1122-G) 22 feet below. *Crassispora* occurs throughout most of the Trivoli Cyclothem in Franklin County but does not become a major constituent.

Gravisporites is a major component of the spore population at the top of the underclay of the middle and upper coals described from the section of the Henshaw Formation studied. It is also abundant in the shale (maceration 1170-E) above the coal of the Fithian Cyclothem.

Cadiospora, probably closely related genetically to *Gravisporites,* was found only in coal (maceration 1122-P) or directly above and below coal (Fithian Cyclothem).

The vertical ranges of *Densosporites* and *Lycospora* in coal have proved valuable for correlation in many regions. In the coals of the Illinois Basin, the range of *Lycospora* extends as high as the Athensville Coal Member below the No. 8 Coal (Kosanke, 1950, pl. 17), whereas *Densosporites* reaches only into the DeKoven Coal Member at the top of the Spoon Formation. Cross and Schemel (1951, p. 128) placed the upper limit of the *Lycospora* Zone "approximately at the Des Moinesian-Missourian (lower mid-McLeansboro) boundary in the mid-continent area and in the middle Conemaugh in West Virginia." The upper limit of *Densosporites* is slightly above the Pottsville-Allegheny boundary in West Virginia. *Densosporites* was recorded from the Jura Basin, France, by Alpern (1959, p. 297-308) from coal of the Stephanian B, which is stratigraphically equivalent to approximately the middle of the McLeansboro Group of Illinois.

In the present investigation, *Densosporites* and *Lycospora* were found in shales from the Trivoli Cyclothem above and below the No. 8 Coal, and from the Henshaw Formation. The spores in the Henshaw shales are well above the vertical ranges of the genera previously determined from coal studies in North America. Collins (1959, p. 44) found *Densosporites* in the Ames Shale, also above the range of the genus as determined by spore studies of coal. The occurrences of *Densosporites* and *Lycospora* in clastic beds above their known vertical ranges in coal in North America can be attributed to deposition of reworked older sediments. The fact that these genera were usually found together in the clastic sediments tends to support this explanation. Some of the species of *Densosporites* and *Lycospora* found during this investigation were identified with species described from coals older than the McLeansboro. Species of the two genera that could not be identified may have been undescribed species deposited from reworked older sediments.

A second possible explanation for the presence of *Densosporites* in the upper Pennsylvanian is that the spores may have been borne by lycopods that lived in environments at some distance from the coal swamps. Species of *Densosporites* have been correlated with minute, probably herbaceous, lycopod cones (Chaloner, 1958b, 1962; Bhardwaj, 1958), and some of these lycopods may have lived in slightly higher regions and survived after the lycopods that lived in the coal swamps became extinct. Spores borne by herbaceous lycopods, rather than being widely distributed, would be quickly buried by clastic sediments, and so few spores might reach the coal swamps that there would be little likelihood of finding them in coal macerations. The fact that Alpern reported *Densosporites* in a Stephanian coal of France indicates that some species of *Densosporites*-producing lycopods may have continued to live in late Pennsylvanian time.

The large number of *Lycospora* found in shale between the Athensville Coal (the youngest coal in which *Lycospora* has been reported) and the No. 8 Coal in the Trivoli Cyclothem in Franklin County are probably within the normal vertical range of the genus in the Illinois Basin.

Florinites is a common constituent in all the cyclothems studied except the upper part of the Henshaw Formation. *Florinites* is most plentiful in the shales above the coals in the Trivoli Cyclothem. After marine inundation of most of the coal swamp, these spores, which were equipped with bladders for wide dispersal by wind, were probably carried out to sea from uplands in larger numbers than spores produced by plants growing in marginal coastal swamps. This interpretation was suggested by Chaloner (1958a, p. 261; 1959, p. 64) in referring to a study by Neves (1958) in which *Florinites* was reported to increase from 1 percent in a coal to 58.3 percent in the marine strata of the *Gastrioceras subcrenatum* Zone.

Although minor constituents, *Illinites* and *Pityosporites* are at their maximum abundance in the Trivoli Cyclothem in Franklin County in the sediments in which *Florinites* abounds. In the Henshaw Formation the occurrence of *Pityosporites* is more erratic.

A large variety but relatively small number of bisaccate pollen grains also was found most often in shales in the upper parts of the cyclothems. Many of the pollen grains probably were produced in upland areas by conifers and other gymnospermic plants that were going through major transitions in evolution during late Pennsylvanian time to become an important element of the Permian flora.

Vesicaspora was found most abundantly in the No. 8 Coal in Franklin County and the coal of the Fithian Cyclothem.

Laevigatosporites, Endosporites, Triquitrites, Raistrickia, Ahrensisporites, Cirratriradites, Reinschospora, Reticulatisporites, Trivolites, Indospora, and other genera were erratic in distribution.

RELATION OF SPORE RECOVERY TO LITHOLOGY

No definite relation was noted between the recovery and preservation of spores and the lithology in which they were found. Of 61 samples macerated from at least six cyclothems and four locations, 40 yielded spores identifiable at least generically. Each of the six coal samples yielded abundant, generally well preserved spores.

Spore preservation in underclay was variable. Very well preserved spores were recovered from the top 6 inches of the underclay of the Fithian Cyclothem, the only outcrop sampled in this study. Only six of the thirteen other underclay samples contained recognizable spores, some of which were badly corroded. Collins (1959, p. 20) obtained spores from the underclay of the Harlem Coal of West Virginia at only one outcrop, which had been recently exposed along a roadcut. He attributed the absence of spores in three older outcrops to oxidation. However, lack of preservation or absence of spores in the core samples used in this study cannot be attributed to weathering. Several explanations could be offered for their erratic distribution in underclay. Some spores and other organic debris that were deposited in the coal swamp on top of the underclay might have penetrated into the soft clay through openings left by decomposition of roots. Weight of the overlying sediment also may have been a contributing factor. Where spores are completely absent, deposition may have been so rapid that relatively few spores were incorporated in the sediment.

All but one (maceration 1122-L) of 23 shale samples yielded some identifiable spores. Most residues of macerated shales below coals contain a considerable quantity of large cuticular and other plant fragments. Maceration 1122-A, a dark gray shale, yielded an unusually large variety of very well preserved spores and abundant plant fragments. Macerations of shales above coals (probably mostly marine) generally yielded thin, fairly well to poorly preserved spores and very fine plant fragments.

All the siltstones (macerations 1122-B, M, U, and 1128-A) sampled from directly below the underclay were barren of recognizable plant microfossils.

Only one sample from what is interpreted as a channel fill deposit was macerated (maceration 1122-Q). The sandstone immediately overlies the middle coal described from the part of the Henshaw Formation studied and contains pyrite, coal fragments, and carbonaceous laminae. The spores were well preserved and were not nearly so greatly compressed as spores in all the other samples studied.

The limestones contained poorly preserved spores and plant fragments or were barren of spores. The four nodular, clayey limestones occurring in underclay (macerations 1122-I, V, X, and 1128-D) were barren. Spores found in three marine limestones (macerations 1122-J, 1128-K, and 1175-O) were abundant but greatly corroded and fragmented. Two marine limestones (macerations 1122-K and 1170-F) failed to yield spores. The attack of fungi and bacteria no doubt played an important role in the destruction of spore exines. Calcite crystal growth has been mentioned by Collins (1959, p. 38) as being possibly detrimental to preservation of spores.

The diversity of spore taxa in a single sample is partly a function of spore preservation, and this is especially true of many of the shales (probably marine) in which many spores are scarcely recognizable. The greatest diversity of genera and species occurs in shales (macerations 1122-A, 1175-A, E), probably nonmarine, below coals and in one channel sandstone (maceration 1122-Q). Staplin (1960, p. 1-2) found the greatest number of species in the shale below the coal of the Golata Formation (Chesterian in age) of Alberta, Canada. Neves (1958, p. 15) identified the largest number of species from marine beds of the *Gastrioceras subcrenatum* Zone of the Upper Carboniferous of England. However, nonmarine shale from the Namurian (Lower Carboniferous) strata studied by Neves (1961, p. 275) yielded the greatest diversity of spore genera and species. The greatest variety of spore taxa in the Lower Oil-shale Group of Scotland (Love, 1960, p. 107-109) was recorded from marine shale (i.e., Pumpherston Shell Bed).

Spores recovered from the sandstone (maceration 1122-Q) represent a peculiar assemblage from which a large number of species was recorded. Many of them are spiny or highly ornamented forms (*Laevigatosporites papillatus, L. spinosus, Secarisporites crenatus, Punctatisporites productus, P. corona*) generally not found in other macerations studied. In addition, *Pityosporites, Strotersporites, Lueckisporites, Potonieisporites, Illinites,* and miscellaneous saccate forms are present but not abundant. The sandstone is interpreted as a channel fill deposit in which many of the spores were transported by stream currents from a large upland watershed area.

SUMMARY

From the foregoing discussion several generalizations can be made concerning the distribution of small spores through various lithic units in the McLeansboro cyclothems studied.

1. Forty of the 61 samples macerated contained some plant microfossils in various states of preservation, from good to very poor.

2. No consistent pattern was apparent in the relation between the occurrence and relative abundance of spore taxa and type of lithology.

3. Many spore genera and species were common to all the cyclothems studied.

4. Within a cyclothem the same spore genera, with a few exceptions, ranged through a wide variety of lithologies, but considerable variation was found in their relative abundance.

5. Some spore species occurred through several successive lithologies within a cyclothem, whereas other species were more erratic in distribution. The great bulk of a genus may be made up almost entirely of one species, but a species is often represented by only one or a few specimens.

6. In clastic sediments, a strong possibility exists that spores were introduced from reworked older strata.

7. The selection of samples is an important consideration in correlation studies because of the wide variation in composition of spore assemblages through short stratigraphic intervals, even within the same lithic unit.

8. Relative abundances of taxa in small spore assemblages of coals appear to be more useful than those of other lithologies for correlation of strata in the Illinois Basin. This is probably because, although an interval of clastic sediment may appear quite uniform over a wide area, the interval may represent several different sources of sediment, each with a different spore population. By comparison, the swamps where coal was formed had relatively uniform environments.

If the type of lithology and the factors related to environment of deposition and spore dispersal are carefully considered, however, palynology of strata other than coal should be useful in correlating Pennsylvanian strata of the Illinois Basin in areas where spore assemblages from two adjacent coals are not particularly distinctive, or where coals pinch out, are poorly developed, or are essentially barren of spores.

TABLE 1 — DISTRIBUTION OF SPORES

Numbers = percentage of spores present

X = less than 0.5% present

	TRIVOLI CYCLOTHEM																						
	Macoupin County, Illinois							Franklin County, Illinois															
	Maceration 1128							Maceration 1175															
	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
SMALL SPORES																							
Genus AHRENSISPORITES (Pot. & Kr.) Horst, 1955					X											X							
A. exertus sp. nov.																X							
A. symetricus Alpern, 1959					X																		
Genus ALATISPORITES (Ibr.) S.W. & B., 1944																							
A. cf. hoffmeisterii Morgan, 1955																							
A. punctatus Kos., 1950																							
A. spp.																							
Genus CADIOSPORA Kos., 1950		X																					
C. fithiana sp. nov.																							
C. magna Kos., 1950		X																					
Genus CALAMOSPORA S.W. & B., 1944	10	7	20	36	15	20	10	9	7	3	11	10	26	18	5	9	17	11	1	1	X	X	3
C. breviradiata Kos., 1950		2	7	12	8	13	6		2		2	X	5	2	2	7	6						
C. hartungiana Schopf, 1944			X	4			1	1	1	X	1		X	X		1	X	X					2
C. liquida Kos., 1950		X												X									
C. obscura sp. nov.																							
C. pedata Kos., 1950		X																					
C. straminea Wils. & Kos., 1944		X	X	1			X										X						
C. pusilla sp. nov.													18	14	X								
C. spp.	10	5	13	20	7	6	3	8	4	3	8	10	3	2	2	1	11	10	1	1	X	X	1
Genus CIRRATRIRADITES Wils. & Coe, 1940					X				X	X													
C. cf. annulatus Kos. & Brok., 1950					X				X														
C. spp.										X													
Genus COLUMINISPORITES gen. nov.									X	X	X												
C. ovalis sp. nov.									X														
C. spp.									X	X	X												
Genus CONVOLUTISPORA Hoff., Stap., & Mall., 1955									X							X							
C. venusta Hoff., Stap., & Mall., 1955									X							X							
C. spp.									X							X							
Genus CRASSISPORA (Bhard.) Bhard., 1957b																							
C. plicata sp. nov.					X		X	X	X	2	1	8	X	X	1	X			X			1	X
Genus CYCLOGRANISPORITES Pot. & Kr., 1954	X		X			1		1	X	1				X		X	X						
C. cf. aureus (Loose) Pot. & Kr., 1955	X		X			1																	
C. cf. leopoldi (Kr.) Pot. & Kr., 1954																							
C. pergranulus Alpern, 1958								1	X	1				X		X	X						
Genus DENSOSPORITES (Berry) S.W. & B., 1944				X	X			X	X	X	1	1	1	X									
D. annulatus (Loose) S.W. & B., 1944								X			X		X	X									
D. cf. bacatus Dyb. & Jach., 1957																							
D. cf. marginata Artuz, 1957													X										
D. parvus Hoff., Stap., & Mall., 1955										X													
D. spp.				X	X				X	X	1	1	1	X									
Genus DICTYOTRILETES? (Naum.) Pot. & Kr., 1954																							
D.? camptotus Alpern, 1958								X	X	X		1											
Genus ENDOSPORITES Wils. & Coe, 1940	5	3	11	4	X	4	X	2	1	2	2	16	30	1	X	X	X	2	1	1	2	6	2
E. formosus Kos., 1950		X	5	3		3	X	1	X		1	12	22	1		X	X					1	2
E. plicatus Kos., 1950	4	1	X				X	X		X	X	1		X	X		X						
E. vesicatus Kos., 1950		1	X	1																			
E. spp.	2	2	5		X	1		1	1	1	1	3	9		X	X		2	1	1	2	5	X
Genus FLORINITES S.W. & B., 1944	3	1	6	7	22	2	4	8	22	11	24	3	2	3	34	18	13	5	65	64	56	16	33
F. antiquus Schopf, 1944		1	6	5	15	2	2										2						
F. similis Kos., 1950		X																					
F. triletus Kos., 1950							1	7	16	8	13		2	1	12	18	10						15
F. spp.	3	1		3	7		1	1	6	2	11	3		2	22	X	1	5	65	64	56	16	18

	FITHIAN CYCLOTHEM						HENSHAW FORMATION										
	Vermilion County, Illinois						Union County, Kentucky										
	Maceration 1170						Maceration 1122										
	A	B	C	D	E	G	A	E	F	G	J	O	P	Q	S	T	Z
SMALL SPORES																	
Genus AHRENSISPORITES (Pot. & Kr.) Horst, 1955							2			X				X			
A. exertus sp. nov.							2			X				X			
A. symetricus Alpern, 1959																	
Genus ALATISPORITES (Ibr.) S.W. & B., 1944			X	X	1												
A. cf. hoffmeisterii Morgan, 1955			X	X													
A. punctatus Kos., 1950				X	1												
A. spp.			X		X												
Genus CADIOSPORA Kos., 1950	3			X									4			3	
C. fithiana sp. nov.	3			X													
C. magna Kos., 1950													4			3	
Genus CALAMOSPORA S.W. & B., 1944	55	10	13	1	1	6	5	8	3	3	1	22	11	8	X	7	2
C. breviradiata Kos., 1950	5	3	2	1		3			X		X	9		6		3	1
C. hartungiana Schopf, 1944	28	2	X			X	4	7		3	X	9	1	1		2	1
C. liquida Kos., 1950			1										4	X		X	
C. obscura sp. nov.	2																
C. pedata Kos., 1950																	
C. straminea Wils. & Kos., 1944	3	3	8										4				
C. pusilla sp. nov.																	
C. spp.	21	3	3	1	1	3	1	1	3	1		4	2	1	X	2	
Genus CIRRATRIRADITES Wils. & Coe, 1940		X	X	X	X	1	X				X						
C. cf. annulatus Kos. & Brok., 1950		X	X				X										
C. spp.		X		X	X	1	X				X						
Genus COLUMINISPORITES gen. nov.						1											
C. ovalis sp. nov.						1											
C. spp.																	
Genus CONVOLUTISPORA Hoff., Stap., & Mall., 1955			X				X	X		1							X
C. venusta Hoff., Stap., & Mall., 1955								X									X
C. spp.			X				X			1							X
Genus CRASSISPORA (Bhard.) Bhard., 1957b																	
C. plicata sp. nov.	X		3	79	32	2	2			X	62		11	X	6	2	X
Genus CYCLOGRANISPORITES Pot. & Kr., 1954	3		4		1	1	3	3	X	X		1	13	X		1	
C. cf. aureus (Loose) Pot. & Kr., 1955	3		2				2	3				1	12			2	
C. cf. leopoldi (Kr.) Pot. & Kr., 1954						1		X					1				
C. pergranulus Alpern, 1958			2		1	X	1	X	X	X			X	X			
Genus DENSOSPORITES (Berry) S.W. & B., 1944							X			X							
D. annulatus (Loose) S.W. & B., 1944																	
D. cf. bacatus Dyb. & Jach., 1957										X							
D. cf. marginata Artuz, 1957																	
D. parvus Hoff., Stap., & Mall., 1955							X										
D. spp.							X			X							
Genus DICTYOTRILETES? (Naum.) Pot. & Kr., 1954																	
D.? camptotus Alpern, 1958							X							X			
Genus ENDOSPORITES Wils. & Coe, 1940	1	X	1	12	7	2	5	58	19	5	29	X	15	1	1	1	11
E. formosus Kos., 1950	X	X	X	1	1	X	4	38	8	3	23		9	X			3
E. plicatus Kos., 1950	1	X	1	11	2	X	1	X		1	6		X	X			
E. vesicatus Kos., 1950																	
E. spp.					4	1	X	20	11	1		X	6		1	7	7
Genus FLORINITES S.W. & B., 1944	15	2	2	X	18	12	3	1	X	17	X		1	2	2	X	8
F. antiquus Schopf, 1944	1	X	1		13			1	X	15	X		1	1		X	
F. similis Kos., 1950	3	1	X														
F. triletus Kos., 1950						9											
F. spp.	11	X	X	X	4	4	3	1		2			1	2	2		8

(Continued on next page)

TABLE 1 — DISTRIBUTION OF SPORES — Continued

Numbers = percentage of spores present; X = less than 0.5% present	TRIVOLI CYCLOTHEM																						FITHIAN CYCLOTHEM						HENSHAW FORMATION										
	Macoupin County, Illinois							Franklin County, Illinois															Vermilion County, Illinois						Union County, Kentucky										
	Maceration 1128							Maceration 1175															Maceration 1170						Maceration 1122										
SMALL SPORES (Cont'd)	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	A	B	C	D	E	G	A	E	F	G	J	O	P	Q	S	T	Z
Genus GRANULATISPORITES (Ibr.) S.W. & B., 1944	2	1	1	6	4	1	5	10	4	10	11	11	6	13	9	4	6	6	X	2	1	6	7	2	5	X		1	4	11	3	3	13	X	2	2	5	X	X	X
G. aculeolatus Kos., 1950				1	1																																X			
G. convexus Kos., 1950											1					X	X																							
G. deltiformis (Wils. & Coe) S.W. & B., 1944			X		X		1	X			1			X																										
G. elegans sp. nov.																														X							X			
G. granularis Kos., 1950				2	X				1	1	X			X		X																								
G. granulatus Ibr., 1933																								X	X															
G. ibrahimi sp. nov.										X			X	1	X	X	X						X	X	1															
G. levis Kos., 1950		X						X		X		3										X		X					X	2	2	3	2			1	1	X	X	X
G. cf. microgranifer Ibr., 1933																																					X			
G. parvus (Ibr.) S.W. & B., 1944		X	X																											1	X		2			1	1		X	
G. tenuis sp. nov.				X				4	1	2	1		2	X										X	X															
G. verrucosus (Wils. & Coe) S.W. & B., 1944	2	X	X	1	2	1	3	3		2	1		4	12	7	4	6	5		X	X	2	2	X	3	X			2	2			4		2	X	X			
G. spp.		X		2	1		1	4	3	6	7	8	1	1	1	X	X	1	X	2	1	4	4	2	X	X		1	2	6	1		6	X			3	X	X	
Genus GRAVISPORITES Bhard., 1954																																								
G. sphaerus (Butt. & Will.) Bhard., 1954	3						X	X	1	X	1	X	1	1	X	X			X			X					X	3	X	1			X	X	18	X	1	20	X	2
Genus HAMIAPOLLENITES Wils., 1962																																								
H. sp.																							X																	X
Genus ILLINITES Kos., 1950										X				X						3	6	1	1									X	X				X			X
I. elegans Kos., 1950														X																										
I. unicus Kos., 1950										X										3	6	1	1									X	X				X			X
Genus INDOSPORA Bhard., 1960																																								
I. stewarti sp. nov.				X		X	X		X	X				X			X									X			X				1							
Genus KNOXISPORITES Pot. & Kr., 1954																																								
K. polygonalis (Ibr.) Pot. & Kr., 1955																																		X						
Genus LAEVIGATOSPORITES (Ibr.) S.W. & B., 1944	1	3	1	4	3	3	8	X	1	2	1	2	3	10	10	23	13	X						1	29	12			3	4	X		5	X	X	5	12	23	33	2
L. crassus sp. nov.																																	1							
L. desmoinensis (Wils. & Coe) S.W. & B., 1944		X						X	X	X				X			X													X							X		3	
L. medius Kos., 1950		X					1																		X					X							X			
L. minutus (Ibr.) S.W. & B., 1944	1	2		3	1	3	5		X			X		X										X	X					X			X		X	4			3	X
L. ovalis Kos., 1950	1	1	1	X	2		2	X	1	1	1	2		1	1	X		X						1	29	12			3	4	X		2			1	7	23	24	1
L. papillatus sp. nov.																																	1				X			
L. perminutus Alpern, 1959																																		X						X
L. spinosus sp. nov.																																					4			
L. pseudothiessenii Kos., 1950					X																																			
L. punctatus Kos., 1950													3	9	9	23	12																							
L. robustus Kos., 1950		X								X							1									X				X	X									1
L. spp.																															X								2	
Genus LATIPULVINITES gen. nov.																																								
L. kosankii sp. nov.								X		X	X																		X	X			1					1		
Genus LIMITISPORITES (Leschik) Pot., 1958																																								
L. spp.																													X											
Genus LUECKISPORITES (Pot. & Klaus) Pot., 1958																																								
L. spp.																																					1			
Genus LUNDBLADISPORA Balme, 1963																																								
L. simoni sp. nov.								1	2	X	X																			X			2				X			
Genus LYCOSPORA S.W. & B., 1944			X	3	3	X		1	2	5	5	17	10	1	X			X											X	X			3				X			
L. brevijuga Kos., 1950				3	2																																			
L. nitida Artuz, 1957																																	X							
L. pseudoannulata Kos., 1950					X	X		1	1	3	1	16	8	1																							X			
L. cf. subjuga Bhard., 1957																																	3				X			
L. torquifer (Loose) Pot. & Kr., 1956													1																											
L. cf. trigonoreticulata (Loose) Pot. & Kr., 1956									X	X	3		X																											
L. spp.			X		1				1	2	1	2	1	X	X			X											X	X										

(Continued on next page)

TABLE 1 — DISTRIBUTION OF SPORES — Continued

Numbers = percentage of spores present

X = less than 0.5% present

	TRIVOLI CYCLOTHEM: Macoupin County, Illinois, Maceration 1128							TRIVOLI CYCLOTHEM: Franklin County, Illinois, Maceration 1175															
SMALL SPORES (Cont'd)	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Genus MICRORETICULATISPORITES (Knox) Pot. & Kr., 1954									X		X												
M. concavus Butt. & Will., 1958									X		X												
M. cf. lunatus Knox, 1950																							
Genus PITYOSPORITES (Seward) Pot. & Klaus, 1954																							
P. spp.					X														X	3	1	X	X
Genus POTONIEISPORITES Bhard., 1954																							
P. spp.																							
Genus PUNCTATISPORITES (Ibr.) S.W. & B., 1944	73	83	60	38	47	66	71	50	47	49	36	26	17	52	39	39	40	74	33	26	32	61	44
P. bondensis sp. nov.		X																					
P. breviornatus sp. nov.									X	3													X
P. brevivermiculatus sp. nov.																							
P. chapelensis sp. nov.		5	15	3	1																		
P. compactus sp. nov.		1	7	1	4																		
P. corona sp. nov.																							
P. firmus (Loose) S.W. & B., 1944																							
P. grandivermiculatus sp. nov.		X	X																				
P. minutus (Kos.) emend.	63	49	14	11	15	45	57	14	12	7	15	6	6	35	5	6	17	25	9	7	10	20	8
P. cf. obesus (Loose) Pot. & Kr., 1955																							
P. obliquus Kos., 1950		1			X												1	3					2
P. orbicularis Kos., 1950		15	6	7	10	13	7	34	31	34	19	18	12	17	32	33	20	46	25	19	22	41	28
P. patulus sp. nov.																							
P. productus sp. nov.																							
P. racemus sp. nov.					X	X	X							X									
P. rudis sp. nov.																							
P. saetiger sp. nov.				2	4			X	2	3	1												4
P. staplini sp. nov.	1	X					2	X	1	1	1	3		X	1	X	X				X	X	X
P. sulcatus Wils. & Kos., 1944		X						X	X	X				X	1	X	X					X	X
P. transenna sp. nov.																	X						
P. variusetosus sp. nov.		X	2	2	2	2	X	X	X	X					X	X	1						X
P. spp.	10	13	16	13	11	6	4	2		1	X					X							1
Genus RAISTRICKIA S.W. & B., 1944		X	X					X	X	X						X	X						1
R. aculeata Kos., 1950																							
R. aculeolata Wils. & Kos., 1944																							
R. crinita Kos., 1950																							
R. irregularis Kos., 1950		X																					
R. kentuckiensis sp. nov.																							
R. spp.		X	X					X	X	X						X	X						1
Genus REINSCHOSPORA S.W. & B., 1944		X				X	X							X		X							
R. triangularis Kos., 1950		X				X								X		X							
R. sp.							X									X							
Genus RETICULATISPORITES (Ibr.) S.W. & B., 1944					X					X	X					X		X					
R. annulatus Guennel, 1958																							
R. areolatus Guennel, 1958					X																		
R. reticulatus (Ibr.) Ibr., 1933																X							
R. spp.					X					X	X					X		X					
Genus RHIZOMASPORA Wils., 1962																							
R. cf. radiata Wils., 1962																							
Genus SAVITRISPORITES? Bhard., 1955																							
S. spp.																							X

	FITHIAN CYCLOTHEM: Vermilion County, Illinois, Maceration 1170						HENSHAW FORMATION: Union County, Kentucky, Maceration 1122										
SMALL SPORES (Cont'd)	A	B	C	D	E	G	A	E	F	G	J	O	P	Q	S	T	Z
Genus MICRORETICULATISPORITES (Knox) Pot. & Kr., 1954						X	1										X
M. concavus Butt. & Will., 1958						X	X										
M. cf. lunatus Knox, 1950							1										X
Genus PITYOSPORITES (Seward) Pot. & Klaus, 1954																	
P. spp.					5	X	X				X		X	X		X	X
Genus POTONIEISPORITES Bhard., 1954																	
P. spp.							X							X			1
Genus PUNCTATISPORITES (Ibr.) S.W. & B., 1944	12	40	60	8	30	61	58	26	74	40	8	56	34	67	46	51	73
P. bondensis sp. nov.		X	3	X													
P. breviornatus sp. nov.																	
P. brevivermiculatus sp. nov.							X										
P. chapelensis sp. nov.																	
P. compactus sp. nov.																	
P. corona sp. nov.														X			
P. firmus (Loose) S.W. & B., 1944								X									
P. grandivermiculatus sp. nov.																	
P. minutus (Kos.) emend.	7	26	24	5	13	25	15	21	74	12	8	56	27	19	45	49	71
P. cf. obesus (Loose) Pot. & Kr., 1955														X			X
P. obliquus Kos., 1950		X	X		3												
P. orbicularis Kos., 1950	1	11	28	3	13	25	X			2				X			1
P. patulus sp. nov.								3									
P. productus sp. nov.														1			
P. racemus sp. nov.																	
P. rudis sp. nov.							1										
P. saetiger sp. nov.		X			1	7	39			25				43	X		
P. staplini sp. nov.	1		1			1							1			X	
P. sulcatus Wils. & Kos., 1944	X	1		X		3	1	X		1			2	X	X		1
P. transenna sp. nov.			1	X													
P. variusetosus sp. nov.	3	1	2	X		X	X	X					X				
P. spp.	X	X	1			X	1	2			X	X	4	4		1	X
Genus RAISTRICKIA S.W. & B., 1944	1	1	1	X		X	X	1		2			1	X		X	X
R. aculeata Kos., 1950							X							X			
R. aculeolata Wils. & Kos., 1944													X			X	
R. crinita Kos., 1950	1	1	1	X		X							X			X	
R. irregularis Kos., 1950																	
R. kentuckiensis sp. nov.										X							X
R. spp.	X	X					X	1		2			1				
Genus REINSCHOSPORA S.W. & B., 1944			X														
R. triangularis Kos., 1950			X														
R. sp.																	
Genus RETICULATISPORITES (Ibr.) S.W. & B., 1944		X	X	X			X										X
R. annulatus Guennel, 1958		X	X	X			X										
R. areolatus Guennel, 1958																	X
R. reticulatus (Ibr.) Ibr., 1933																	
R. spp.																	
Genus RHIZOMASPORA Wils., 1962																	
R. cf. radiata Wils., 1962						X											
Genus SAVITRISPORITES? Bhard., 1955																	
S. spp.																	

(Continued on next page)

TABLE 1 — DISTRIBUTION OF SPORES — Concluded

Numbers = percentage of spores present

X = less than 0.5% present

P = present but relative abundance not determined

	TRIVOLI CYCLOTHEM																							FITHIAN CYCLOTHEM						HENSHAW FORMATION										
	Macoupin County, Illinois							Franklin County, Illinois																Vermilion County, Illinois						Union County, Kentucky										
	Maceration 1128							Maceration 1175																Maceration 1170						Maceration 1122										
SMALL SPORES (Cont'd)	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	A	B	C	D	E	G	A	E	F	G	J	O	P	Q	S	T	Z
Genus SECARISPORITES Neves, 1961																																								
S. crenatus sp. nov.					X			X	X									X												X			4				2			
Genus STRIATOSPORITES Bhard., 1954																																								
S. cf. pfalzensis Bhard. & Venk., 1957																														X										
Genus STROTERSPORITES Wils., 1962																																								
S. cf. Striatites rickteri (Klaus) Pot., 1958																														X							X			X
Genus TRIQUITRITES Wils. & Coe, 1940	2	1	2	1	1	3	X	3	2	3	4	1	2	1	2	3	2	1			2	3	6	4	5	X	X	1	2	X	X	1	1		X	X	X	1	X	X
T. arculatus Wils. & Coe, 1940										X																														
T. auriculatus Bhard., 1957										X	X		1	X		1	X																							
T. bransonii Wils. & Hoff., 1956	X	X	X		1	1	X							X		X	X																1							
T. cuspidatus Bhard., 1957								X	X	X																														
T. cf. discoideus Kos., 1950																									X															
T. dividuus Wils. & Hoff., 1956										X														3	X															
T. cf. inusitatus Kos., 1950																																					X			
T. mamosus Bhard., 1957									X	X							1				X																			
T. minutus Alpern, 1958										X			X	X		X	X								X				X											
T. sculptilis Balme, 1952					X																																			
T. simplex Bhard., 1957									X		1																													
T. spinosus Kos., 1943		X	X		X	1	X	X	1	X	X				1	1	X				X		1	1	1	X			X	X	X				X	X	X		X	X
T. cf. truncatus Bhard. & Kr., 1955																	X																							
T. spp.	1	X	1	1	X	1		3	1	3	3	1	1	1	1	1	X	1			1	3	5	1	4	X	X	1	2	X		1						1		
Genus TRIVOLITES gen. nov.																																								
T. laevigata sp. nov.		X							X			X		X																X							X			
Genus VESICASPORA (Schemel) Wils. & Venk., 1963							X									4	9								7	1	X		3	X					X	2			X	X
V. ovatus (Bal. & Henn.) Hart, 1960							X									4	9								7	1	X		3	X					X	2			X	
V. spp.																														X										X
Genus VESTIGISPORITES (Bal. & Henn.) Hart, 1960																																								
V. spp.																																								X
Genus WILSONITES Kos., 1950					4		1	13	12	12	2	2			X	X						4	4							X			X				X		X	X
W. delicata Kos., 1950					3		1	13	12	12	2	2				X																							X	X
W. spp.					1				X						X	X						4	4							X			X				X			
UNDIFFERENTIATED SPORES AND POLLEN		X	X		X				X	X	1						X					1		3	1	X	X	X	1	3	X	1	X	X	X	1	1	X	X	1
LARGE SPORES AND MEGASPORES																																								
Genus MONOLETES (Ibr.) S.W. & B., 1944								P	P		P	P			P	P	P								P	P	P			P									P	
M. ovatus Schopf, 1938											P														P	P	P			P										
M. spp.								P	P			P				P	P																						P	
Genus SPENCERISPORITES Chaloner, 1951																																								
S. cf. gracilis (Zerndt) Winslow, 1959																														P										
Genus TRILETES (Bennie & Kid.) Zerndt, 1930	P	P	P	P		P				P							P							P	P	P	P		P		P	P			P	P	P	P	P	P
T. augustae (Loose) S.W. & B., 1944	P	P				P																			P	P						P								
T. auritus Zerndt, 1930		P	P																												P									
T. glabratus Zerndt, 1930		P	P														P								P	P	P		P										P	
T. levis (Zerndt) S.W. & B., 1944																																			P					
T. triangulatus Zerndt, 1938																									P															
T. (Auriculati) sp.		P	P	P																						P				P										
T. spp.						P				P														P			P									P	P	P		P
SCOLECODONTS																						P	P				P		P											
Genus CENTONITES gen. nov.																																								
C. symmetricus sp. nov.								P	P	P	P	P							P											P			P							

DESCRIPTION OF GEOLOGIC SECTIONS

TRIVOLI CYCLOTHEM — MACERATION 1128

Diamond drill core No. 6, Mount Olive and Staunton Coal Company (1300 ft N, 200 ft E of SW cor. of SE NW, 8-8N-7W, Macoupin Co., Ill.). Illinois Geological Survey core described by K. E. Clegg and D. H. Reinertsen, 1958.

	Thickness (ft	*in)*	*Depth to top (ft*	*in)*
Pennsylvanian System				
Modesto Formation				
Siltstone, gray to light gray, thinly and irregularly laminated, argillaceous, micaceous; light gray portion becomes harder and coarser toward bottom	7	1	85	5
Shale, gray, silty, argillaceous, micaceous, well laminated, weak, very uniform; grades into shale below	10	4	92	6
Shale, gray, carbonaceous, rather well laminated, fissile; becomes darker in bottom 6″	1	7	102	10
Shale, as above but contains shells and occasional sideritic nodule up to ½″ in diameter	0	4	104	5
Shale, dark gray, carbonaceous, well laminated, weak. (Maceration 1128-L: 104′ 10″ to 104′ 10½″.)	0	3	104	9
Limestone, dark gray to black; contains abundant brachiopod and pelecypod shells; intermixed with black, silty, very carbonaceous shale; grades into siltstone. (Maceration 1128-K: 105′ ½″ to 105′ 1¼″.)	0	2	105	0
Siltstone, gray, argillaceous, very micaceous, interlaminated with light gray to white coarser siltstone; light siltstone becomes coarser downward; grades into sandstone	4	4	105	2
Sandstone, light gray, medium grained, argillaceous, micaceous, massive	3	0	109	6
Shale, medium gray, silty, micaceous, well laminated, uniform; some parting surfaces are very micaceous and very carbonaceous with abundant coalified plant fragments, especially in bottom 1′. (Maceration 1128-J: 112′ 8″ to 112′ 8¾″; maceration 1128-I: 115′ 4½″ to 115′ 5″.)	2	11	112	6
Shale, light gray, silty, micaceous, rather well laminated, uniform; becomes darker and smoother downward; grades into shale below	2	5	115	5
Shale, gray, carbonaceous, well laminated, weak. (Maceration 1128-H: 120′ 1½″ to 120′ 2″.)	2	4	117	10
Chapel (No. 8) Coal, bright banded. (Maceration 1128-G: 120′ 2″ to 120′ 7″.)	0	5	120	2
Underclay, dark gray to greenish gray, carbonaceous, smooth, slip-fractured; *Stigmaria*; grades into claystone. (Maceration 1128-F: 120′ 7″ to 120′ 7½″.)	0	4	120	7
Claystone, dark gray to dark greenish gray, weak, slip-fractured and slickensided; a 2″ zone 6″ above base contains abundant brown limestone nodules up to ½″ in diameter. (Maceration 1128-E: 122′ 2½″ to 122′ 3″; maceration 1128-D: nodules 122′ 6″ to 122′ 8″; maceration 1128-C: 123′ 1½″ to 123′ 2″.)	2	3	120	11
Core marker			124	0
Siltstone, greenish gray, argillaceous, micaceous, poorly laminated in upper 4″, better laminated downward; grades into sandstone. (Maceration 1128-B: 124′ to 124′ ½″, maceration 1128-A: 125′ 11″ to 125′ 11½″.)	2	0	124	0
Sandstone, gray, fine grained, silty and argillaceous in lower part; grades into siltstone	0	6	126	0
Siltstone, greenish gray, coarse, argillaceous, micaceous, rather well laminated, irregularly interlaminated with dark gray silty shale; occasional zones up to 1′ thick consist almost entirely of dark gray shale	15	9	126	6

TRIVOLI CYCLOTHEM — MACERATION 1175

Diamond drill core No. 42, Old Ben Coal Corporation (700′ S and 30′ E of NW cor. of 25-7S-3E, Franklin Co., Ill.). Illinois Geological Survey core described by G. H. Cady, 1944.

	Thickness (ft	*in)*	*Depth to top (ft*	*in)*
Pennsylvanian System				
Modesto Formation				
Shale, gray, smooth, rather well laminated, uniform	4	3¾	252	1
Shale, gray, well laminated, noncalcareous	3	5½	256	4¾
Shale, dark gray, noncalcareous, smoother than above; occasional ironstone layer or concretion up to 1″ thick	4	0	259	10¼
Core marker			264	0
Shale, as above, calcareous toward base; contains pelecypods and ostracodes; occasional sideritic layer. (Maceration 1175-P: 265′ 4½″ to 265′ 5½″.)	1	7½	264	0
Shale, gray; at least one ironstone layer; shell fossils toward base	0	11½	265	7½
Limestone, gray, carbonaceous, very fossiliferous; small brachiopod and pelecypod shells; intermixed with dark gray shale. (Maceration 1175-0: 266′ 7¼″ to 266′ 8″.)	0	2½	266	7
Shale, gray, dense, calcareous; contains small shells like those above.	0	8½	266	9½
Limestone, gray, very argillaceous; contains abundant brachiopods and pelecypods; grades into shale	0	4¼	267	6
Shale, dark gray to black, carbonaceous; abundant brachiopods and pelecypods; grades into shale below. (Maceration 1175-N: 267′ 10½″ to 267′ 11¼″; maceration 1175-M: 269′ 5½″ to 269′ 6¾″.)	1	9	267	10¼
Shale, black, carbonaceous; a few pyritized pelecypods near top; coaly streaks at bottom	0	8¾	269	7¼
Shale, dark gray, calcareous, carbonaceous, fossiliferous; contains pelecypods and gastropods that increase in abundance downward; grades into shale below. (Maceration 1175-L: 270′ 9¼″ to 270′ 10¼″.)	0	9½	270	4
Shale, gray, very calcareous and fossiliferous; grades into siltstone	0	1¾	271	1½
Siltstone, gray, micaceous; small shell fossils; plant compression fossils in lower ½″ to ¼″; calcareous in upper 2″. (Maceration 1175-K: 271′ 8¾″ to 271′ 9½″.)	0	6¼	271	3¼

	Thickness (ft	in)	Depth to top (ft	in)
Coal, bright banded. (Maceration 1175-J: 271′ 9½″ to 271′ 11¼″.)	0	1¾	271	9½
Coal, shaly, very impure; grades into shale. (Maceration 1175-I: 271′ 11¼″ to 272′ ¼″.)	0	1	271	11¼
Shale, gray, nearly black at top, lighter downward; abundant carbonized plant compressions that decrease downward; grades into shale below. (Maceration 1175-H: 272′ ¼″ to 272′ 1½″.)	1	8¼	272	¼
Shale, as above but less carbonaceous; contains abundant small pyritic aggregates. (Maceration 1175-G: 273′ 10¼″ to 273′ 11″.)	0	4	273	8½
Underclay, gray, pyritic; contains carbonized plant remains. (Maceration 1175-F: 275′ 4″ to 275′ 5¼″.)	1	8¼	274	½
Shale, gray, like above; becomes silty downward in bottom 4″; abundant carbonized plant fragments including *Cordaites* leaves. (Maceration 1175-E: 278′ 4½″ to 278′ 5½″; maceration 1175-D: 279′ 11½″ to 280′ ¼″.)	5	9	275	8¾
Shale, gray, micaceous; contains carbonized plants including ferns. (Maceration 1175-C: 281′ 10¾″ to 281′ 11½″.)	0	7¾	281	5¾
Core marker			284	0
Shale, gray, silty; carbonized plant fragments but not as abundant as above; grades into shale below	0	7¾	284	0
Shale, gray, fine grained, interlaminated with light gray siltstone containing plant fragments; fairly evenly interlaminated but some flow casts present. (Maceration 1175-B: 285′ 1½″ to 285′ 2½″; maceration 1175-A: 288′ 9½″ to 288′ 10½″.)	4	3¼	284	7¾
Shale, gray, very micaceous, finely interlaminated with gray siltstone; laminae somewhat inclined; some slumping and flow casts	3	5	288	11
Shale, gray, micaceous, finer than above; lenses of light gray siltstone	2	3½	292	4
Shale, gray, micaceous, interlaminated with light gray siltstone, more evenly interlaminated than above	5	10¼	294	7½

FITHIAN CYCLOTHEM — MACERATION 1170

Outcrop section (NE SW NE 31, 19N-13W, N bank Salt Fork, Fithian Quad., Vermilion Co., Ill.). Illinois State Geological Survey samples described by R. A. Peppers, 1961.

	Thickness (ft	in)
Pennsylvanian System		
Bond Formation		
Sandstone, light gray, fine grained, micaceous, medium bedded to massive	14	0
Shale, gray, silty, fossiliferous; brachiopod and pelecypod impressions; plant fragments. (Maceration 1170-G: 2″ interval 3″ above base.)	2	4
Limestone, light gray, massive; abundant shell fragments—crinoids, brachiopods. (Maceration 1170-F: 1″ interval 14″ above base.)	1	11
Shale, black, carbonaceous, hard, poor cleavage; contains ostracodes; grades into shale below. (Maceration 1170-E: 6″ interval.)	0	6
Shale, dark gray, silty, calcareous, carbonaceous, contains brachiopods and ostracodes. (Maceration 1170-D: 7″ shale interval.)	0	7
Coal, somewhat shaly. (Maceration 1170-C: top 5″; maceration 1170-B: bottom 5″.)	0	10
Underclay, black, yellow iron stain, crumbly. (Maceration 1170-A: top 6″.)	4	0

HENSHAW FORMATION — MACERATION 1122

Diamond drill core No. 49, Peabody Coal Company, X-1,371,700, Y-472,400 (Kentucky coordinate system), Union Co., Ky. Illinois Geological Survey core described by W. H. Smith and D. H. Reinertsen, 1959.

	Thickness (ft	in)	Depth to top (ft	in)
Pennsylvanian System				
Henshaw Formation				
Shale, medium gray, slightly silty, calcareous, rather hard, well laminated; ostracodes, occasional carbonized plant fragment; grades into shale below. (Maceration 1122-Z: 30′ 1¾″ to 30′ 2½″.)	0	8½	30	0
Shale, similar to above but contains abundant shells and ostracodes. (Maceration 1122-Y: 30′ 9¾″ to 30′ 10″.)	0	1½	30	8½
Limestone, medium gray; single dense bed; contains abundant ostracodes.	0	3½	30	10
Shale, medium gray, silty; bottom 4″ contains ostracodes and other shells; grades into limestone	1	1	31	1½
Limestone, light olive gray; single dense bed containing abundant ostracodes. (Maceration 1122-X: 34′ ¼″ to 34′ 1″.)	2	3	32	2½
Shale, dark gray, fissile, very carbonaceous	0	1	34	5½
Core broken and disturbed				
Underclay, medium gray, silty, crumbly	0	10	34	6½
Shale, dark gray, carbonaceous	0	1½	35	4½
Clay, medium gray, slightly silty, rather hard but crumbly; occasional limestone nodule and nodular bed up to 2″ thick; contains ¾″ very carbonaceous shale band 1′ 2″ above base; grades into limestone. (Maceration 1122-W: 38′ 3¼″ to 38′ 4″.)	4	0	35	6
Limestone, light olive gray, very dense; contains abundant shell fossils	0	9	39	6
Limestone, light olive gray; light greenish gray clay intermixed; occasional shale band; grades into limestone below	3	7	40	3
Limestone, similar to above but more nodular and has greater proportion of greenish gray clay matrix. (Maceration 1122-V: 47′ 2¾″ to 47′ 3½″.)	4	1	43	10
Clay, greenish gray, crumbly; buff limestone nodules in top 5″; dark pyritic nodules in lower 1′	1	6	47	11
Clay, dark gray, very soft, carbonaceous	0	3	49	5
Clay, light greenish gray, very soft; contains abundant limestone nodules	1	6	49	8
Clay, core loss, probably clay	1	3	51	2
Clay, greenish gray, silty, poorly laminated but crumbles readily into small angular fragments; contains limestone and pyritic nodules; grades into siltstone	3	6	52	5
Siltstone, light greenish gray, slightly argillaceous and arenaceous; bottom 4″ interlaminated with sandstone like that below; contains occasional calcareous nodule; prominent nodular zone 3′ below top. (Maceration 1122-U: 56′ 1″ to 56′ 1½″.)	7	1	55	11
Sandstone, light gray, fine grained; beds 6″ to 2′ thick; bottom 10′ medium grained and contains carbonaceous, micaceous laminae on bedding planes	30	0	63	0
Coal, normally bright banded. (Maceration 1122-T: 93′ to 93′ 4″.)	0	4	93	0
Underclay, medium gray, very friable. (Maceration 1122-S: 93′ 4″ to 93′ 4½″.)	0	8	93	4

Underclay, medium gray, silty; crumbles to small angular fragments; grades into siltstone. (Maceration 1122-R: 94′ 1″ to 94′ 1¾″.)	0	10	94	0
Siltstone, gray, very argillaceous, poorly indurated; grades into siltstone below	1	0	94	10
Siltstone, medium to light gray, interbedded with sandstone like that below; grades into sandstone	2	9	95	10
Sandstone, light gray, fine to medium grained; beds up to 2′ thick; contains occasional laminae and zones of thin laminae of abundant carbonaceous and micaceous material; grades into sandstone below	43	2	98	7
Sandstone, light gray, medium grained; top 1′ and bottom 5′ 6″ contain numerous thin, irregular, very carbonaceous laminae and occasional coal fragments up to ¾″; abundant pyrite nodules in bottom 1″. (Maceration 1122-Q: 152′ 1¼″ to 152′ 2″.)	10	5	141	9
Coal bright banded; bottom 1″ shaly. (Maceration 1122-P: 152′ 2″ to 152′ 7″.)	0	5	152	2
Underclay, medium gray, rather hard; breaks into angular fragments; carbonaceous streaks; grades into underclay below. (Maceration 1122-O: 152′ 7″ to 152′ 7¾″.)	0	8	152	7
Underclay, similar to above but more silty; occasional small dark limestone nodules which become numerous in lower 18″; grades into siltstone. (Maceration 1122-N: limestone nodules, 155′ 10¼″ to 155′ 11¼″.)	2	9	153	3
Siltstone, medium gray, very argillaceous, poorly indurated; contains occasional limestone nodule. (Maceration 1122-M: 162′ 2″ to 162′ 2¾″.)	8	6	156	0
Sandstone, light gray, fine grained, irregularly interlaminated and interbedded with about 30% siltstone like above	2	9	164	6
Shale, medium gray, silty	0	5	167	3
Shale, medium to dark gray, smooth, fissile, carbonaceous. (Maceration 1122-L: 167′ 8½″ to 167′ 9″.)	0	1	167	8
Shale, medium gray, silty, poorly bedded; sideritic veinlets and crack fillings	1	4	167	9
Shale, medium to dark gray, fissile, carbonaceous	0	1	169	1
Shale, medium gray, silty, poorly bedded; contains sideritic veinlets and crack fillings	0	8	169	2
Sandstone, light gray, thinly laminated; occasional limestone nodule	1	5	169	10
Siltstone, medium gray, rather well laminated; grades into clay	1	0	171	3
Clay, medium gray, very silty; crumbles to angular fragments	1	6	172	3
Clay, medium gray, very soft, weakly bedded; contains abundant small limestone pellets, granular siderite, and occasional dark pyritic mass; grades into siltstone	2	5	173	9
Siltstone, medium gray, very argillaceous, very poorly bedded; fractures and crumbles readily; contains limestone nodules	7	7	176	2
Sandstone, light gray, fine grained, argillaceous, soft, very thinly and irregularly interlaminated with siltstone like that above; grades into shale	1	11	183	9
Shale, medium gray, thinly laminated, soft; crumbles readily	2	0	185	8
Siltstone, medium gray, very argillaceous, weak	0	8	187	8
Limestone, light olive gray, fossiliferous; contains pelecypods and brachiopods, undulatory bedding; coarsely nodular with about 25% greenish gray shale matrix	1	8	188	4
Limestone, as above but more massively bedded, hard, dense; interbedded greenish shale forms about 10% of total	2	6	190	0
Limestone, medium to dark gray, argillaceous; abundant crinoids. (Maceration 1122-K: 192′ 8¼″ to 192′ 9″.)	0	3	192	6
Shale, medium to dark gray, very silty, well laminated; grades into siltstone	0	10	192	9
Siltstone, medium to dark gray; laminae and lenses of light gray, fine-grained sandstone; grades into siltstone below	14	9	193	7
Siltstone, medium gray, interlaminated with medium to dark gray shale and occasionally with very fine-grained siltstone; grades into shale	11	8	208	4
Shale, medium gray, very silty, interbedded with shaly siltstone and occasionally interlaminated with light gray sandstone; becomes less silty and more thinly laminated at base; grades into shale below	24	0	220	0
Shale, medium gray, thinly laminated, fissile, very uniform, darker downward; grades into shale below	10	4	244	0
Shale, dark gray, very fissile	1	2	254	4
Limestone, medium gray, very argillaceous and fossiliferous; contains brachiopods, crinoids	0	9½	255	6
Shale, dark gray; abundant fossils and fossil fragments	0	10½	256	3½
Shale, dark gray, hard	0	7	257	2
Limestone, medium gray, argillaceous, very fossiliferous; contains brachiopods, pelecypods, and crinoids. (Maceration 1122-J: 258′ 3¼″ to 258′ 4″.)	0	7	257	9
Clay, medium gray, very crumbly; small limestone nodules in lower 1′.	4	2	258	4
Limestone, medium gray, argillaceous, finely brecciated with void spaces filled with network of calcite veinlets. (Maceration 1122-I: 263′ 5¼″ to 263′ 6″.)	1	1	262	6
Clay, medium gray; occasional limestone and sideritic nodule; somewhat shaly but crumbles readily to small angular fragments; bottom 3″ contain nodular argillaceous limestone beds with abundant siderite nodules. (Maceration 1122-H: 269′ 1½″ to 269′ 2½″.)	6	5	263	7
Shale, medium gray, fissile, weak; crumbles readily; several dark gray carbonaceous laminae in bottom 1′; grades into shale below	2	4	270	0
Shale, medium gray, thinly laminated, rather weak; grades into shale below	5	8	272	4
Shale, medium gray, well laminated, relatively fissile. (Maceration 1122-G: 280′ 0″ to 280′ ½″.)	3	0	278	0
Shale, black, coaly, hard. (Maceration 1122-F: 281′ 3″ to 281′ 3½″.)	0	3½	281	0
Coal, bright banded. (Maceration 1122-E: 281′ 3½″ to 281′ 4½″.)	0	1	281	3½
Shale, dark gray, bony	0	½	281	4½
Shale, medium to dark gray, slightly silty, hard. (Maceration 1122-D: 281′ 5″ to 281′ 5½″.)	0	2	281	5
Clay, medium gray; limestone granules; very weak and crumbles readily	1	1	281	7
Clay, greenish gray, calcareous; top 1′ well indurated; bottom part breaks into large fragments; contains numerous granules and occasional nodule of light to medium gray limestone. (Maceration 1122-C: 282′ 11½″ to 283′ ¼″.)	4	0	282	8
Siltstone, medium gray, micaceous, very argillaceous, poorly indurated in top 1′; laminae better developed below; contains irregular nodules, masses, and veinlets of brownish limestone and siderite. (Maceration 1122-B: 289′ 8″ to 289′ 8½″.)	3	6	286	8
Sandstone, light gray, fine grained; interlaminated with shale like that below	4	9	290	2
Shale, medium gray in top 2″, medium to dark gray below, very silty, micaceous, interbedded and interlaminated with fine-grained sandstone like that above. (Maceration 1122-A: 297′ 2″ to 297′ 2¾″.)	5	8	294	11
Shale, medium to dark gray, very silty; some thin siltstone beds in top 5′; lower part becomes finer grained and better laminated	19	5	300	7

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PLATES

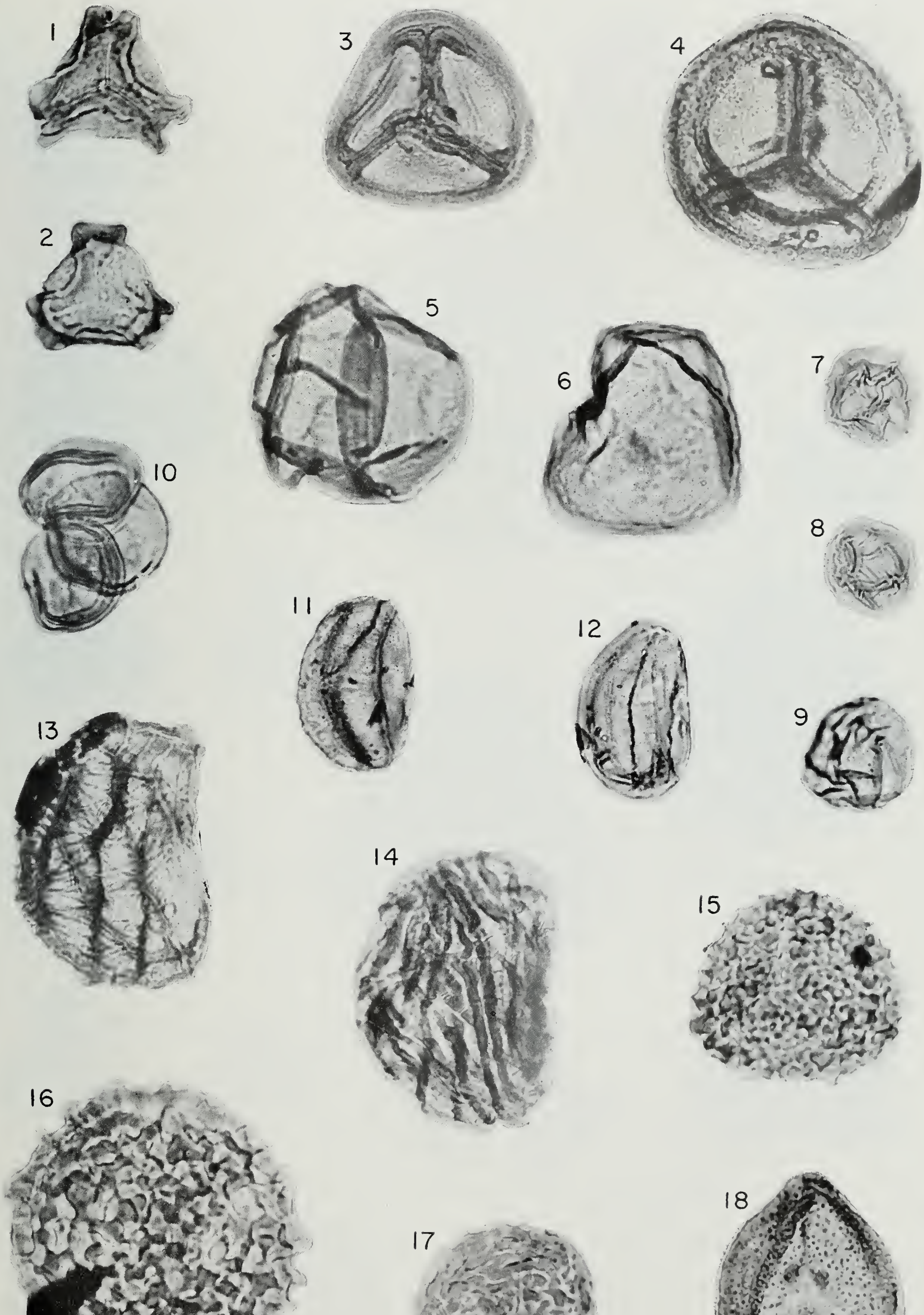
AND

EXPLANATIONS

PLATE 1

FIGURE

1. *Ahrensisporites exertus* sp. nov., holotype, Henshaw Formation, maceration 1122-G, slide 8 ZB; 38.1 by 36.6 μ; p. 13.
2. *Ahrensisporites exertus* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 17 ZB; 36.1 by 35.8 μ; p. 13.
3. *Cadiospora fithiana* sp. nov., holotype, Fithian Cyclothem, maceration 1170-A, slide 2; 57.0 by 56.7 μ; p. 14.
4. *Cadiospora fithiana* sp. nov., paratype, Fithian Cyclothem, maceration 1170-A, slide 22; 74.5 by 70.3 μ; p. 14.
5. *Calamospora obscura* sp. nov., holotype, Fithian Cyclothem, maceration 1170-A, slide 1; 65.8 by 61.6 μ; p. 14.
6. *Calamospora obscura* sp. nov., paratype, Fithian Cyclothem, maceration 1170-A, slide 24; 68.3 μ in maximum diameter; p. 14.
7. *Calamospora pusilla* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-G, slide 23; 31.2 μ in maximum diameter; p. 15.
8. *Calamospora pusilla* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-G, slide 15; 30.2 μ in maximum diameter; p. 15.
9. *Calamospora pusilla* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-G, slide 2; 35.8 by 33.2 μ; p. 15.
10. *Calamospora* sp. 1, Trivoli Cyclothem, maceration 1128-I, slide 17; largest specimen 32.7 μ in maximum diameter; p. 15.
11. *Columinisporites ovalis* sp. nov., holotype, Fithian Cyclothem, maceration 1170-G, slide 15; 48.9 by 32.4 μ; p. 16.
12. *Columinisporites ovalis* sp. nov., paratype, Fithian Cyclothem, maceration 1170-G, slide 15; 48.6 by 31.4 μ; p. 16.
13. *Columinisporites* sp. 1, Trivoli Cyclothem, maceration 1175-B, slide 11; 77.8 by 55.1 μ; p. 16.
14. *Columinisporites* sp. 2, Trivoli Cyclothem, maceration 1175-B, slide 20, 81.1 by 56.8 μ; p. 16.
15. *Convolutispora venusta* Hoffmeister, Staplin, & Malloy, 1955a, Henshaw Formation, maceration 1122-Z, slide 15 ZB; 60.3 by 52.5 μ.
16. *Convolutispora* sp. 1, Fithian Cyclothem, maceration 1170-C, slide 16; 88.5 by 81.1 μ; p. 17.
17. *Convolutispora* sp. 2, Henshaw Formation, maceration 1122-Z, slide 25 ZB; 51.6 by 45.4 μ; p. 17.
18. *Crassispora plicata* sp. nov., holotype, Fithian Cyclothem, maceration 1170-D, slide 24; 58.3 by 52.2 μ; p. 17.

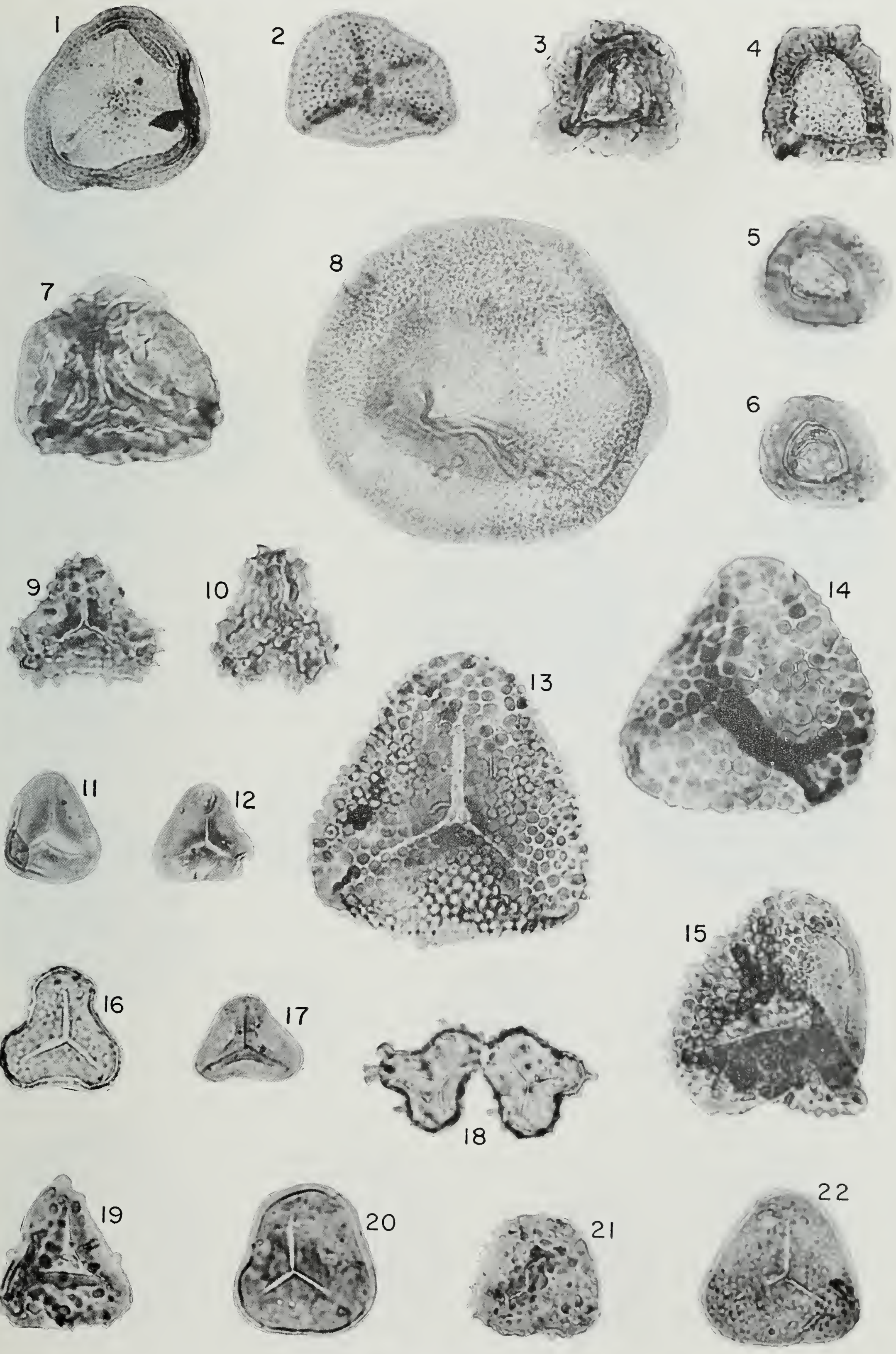


Peppers — Pennsylvanian Spores

PLATE 2

FIGURE

1. *Crassispora plicata* sp. nov., paratype, Fithian Cyclothem, maceration 1170-D, slide 15; 60.5 by 56.9 μ; p. 17.
2. *Crassispora plicata* sp. nov., paratype, Trivoli Cyclothem, maceration 1128-J, slide 11; 49.1 by 39.0 μ; p. 17.
3. *Densosporites* sp. 1, Trivoli Cyclothem, maceration 1175-B, slide 8; 48.0 by 40.5 μ; p. 18.
4. *Densosporites* sp. 2, Trivoli Cyclothem, maceration 1175-C, slide 14; 42.8 by 40.9 μ; p. 18.
5. *Densosporites* sp. 3, Trivoli Cyclothem, maceration 1175-C, slide 14; 37.9 by 33.7 μ; p. 18.
6. *Densosporites* sp. 4, Henshaw Formation, maceration 1122-A, slide 15 ZB; 37.4 by 32.4 μ; p. 19.
7. *Dictyotriletes? camptotus* Alpern, 1958, Henshaw Formation, maceration 1122-A, slide 25 ZB; 63.7 by 56.6 μ; p. 19.
8. *Florinites* sp. 1, Trivoli Cyclothem, maceration 1128-I, slide 21; 124.9 by 115.1 μ including bladder; p. 19.
9. *Granulatisporites ibrahimi* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-G, slide 21; 36.0 by 35.0 μ; p. 20.
10. *Granulatisporites ibrahimi* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-G, slide 22; 36.7 by 32.5 μ; p. 20.
11. *Granulatisporites tenuis* sp. nov., holotype, Fithian Cyclothem, maceration 1170-A, slide 10; 32.8 by 28.3 μ; p. 20.
12. *Granulatisporites tenuis* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-C, slide 24, 26.9 by 24.0 μ; p. 20.
13. *Granulatisporites elegans* sp. nov., holotype, Henshaw Formation, maceration 1122-A, slide 31 ZB; 81.0 by 76.0 μ; p. 21.
14. *Granulatisporites elegans* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 10; 74.2 by 66.7 μ; p. 21.
15. *Granulatisporites elegans* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 14 ZB; 64.8 by 56.4 μ; p. 21.
16. *Granulatisporites* sp. 1, Henshaw Formation, maceration 1122-Q, slide 24 ZB; 36.7 by 34.0 μ; p. 21.
17. *Granulatisporites* sp. 2, Trivoli Cyclothem, maceration 1175-P, slide 7; 28.2 by 24.7 μ; p. 21.
18. *Granulatisporites* sp. 3, Henshaw Formation, maceration 1122-Q, slide 11; 32.4 by 29.2 μ; p. 22.
19. *Granulatisporites* sp. 4, Trivoli Cyclothem, maceration 1175-B, slide 5; 41.2 by 35.7 μ; p. 22.
20. *Granulatisporites* sp. 5, Trivoli Cyclothem, maceration 1128-I, slide 16; 42.2 by 41.2 μ; p. 22.
21. *Granulatisporites* sp. 6, Henshaw Formation, maceration 1122-A, slide 3 ZB; 38.6 by 37.0 μ; p. 22.
22. *Granulatisporites* sp. 7, Fithian Cyclothem, maceration 1170-C, slide 11; 44.7 by 44.1 μ; p. 22.

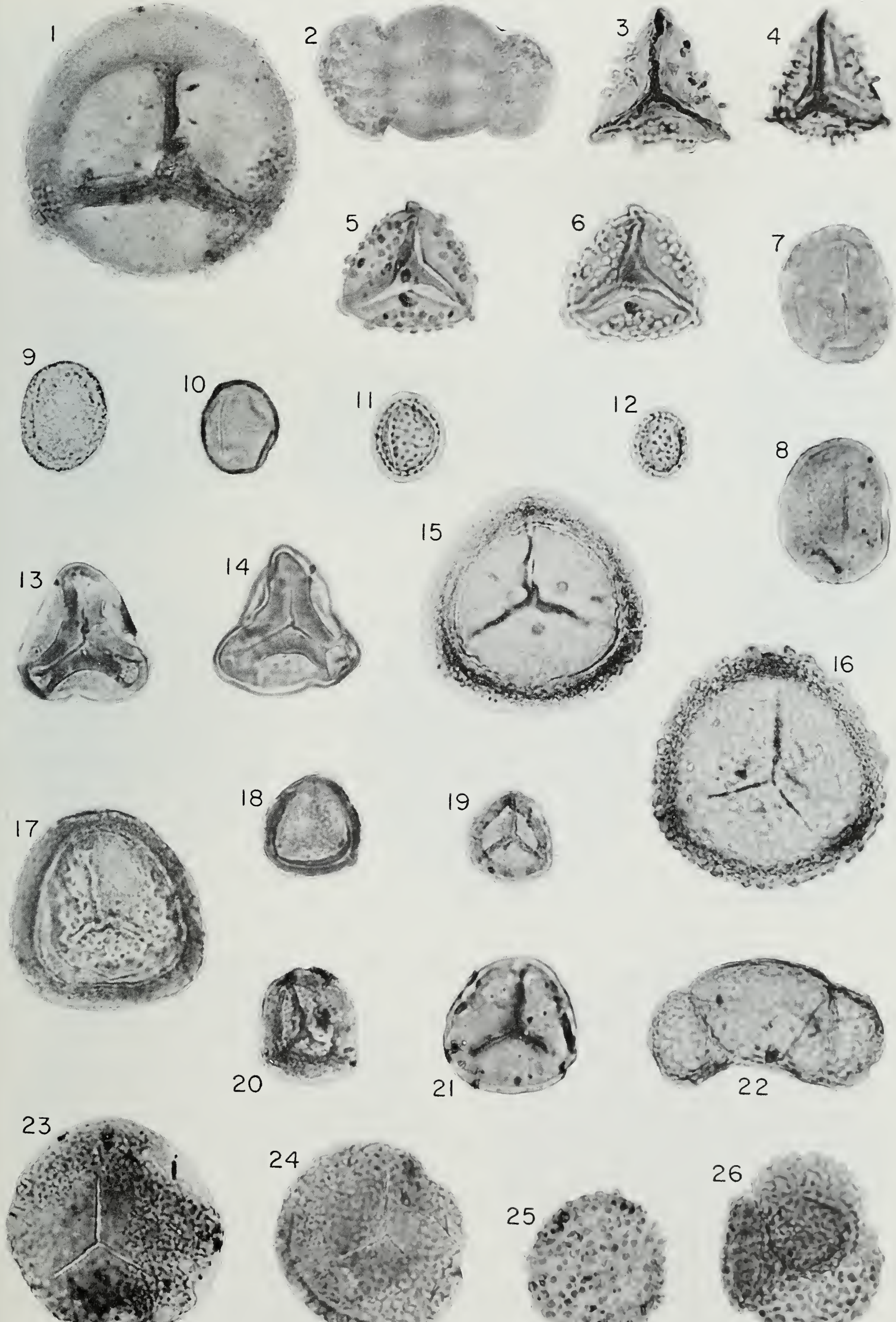


Peppers — Pennsylvanian Spores

PLATE 3

FIGURE

1. *Gravisporites sphaerus* (Butterworth and Williams) Bhardwaj, 1954, Trivoli Cyclothem, maceration 1128-L, slide 19; 91.7 by 90.7 μ.
2. *Hamiapollenites?* sp. 1, Henshaw Formation, maceration 1122-Z, slide 3 ZB; total length 68.3 μ, body 38.9 by 36.0 μ; p. 23.
3. *Indospora stewarti* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-B, slide 5; 38.9 by 37.3 μ; p. 23.
4. *Indospora stewarti* sp. nov., paratype, Trivoli Cyclothem, maceration 1128-L, slide 19; 35.6 by 35.0 μ; p. 23.
5. *Indospora* sp. 1, Henshaw Formation, maceration 1122-DD, slide 14; 38.9 by 36.0 μ; focused on proximal surface; p. 23.
6. Same as figure 5 but with focus on distal surface; p. 23.
7. *Laevigatosporites crassus* sp. nov., holotype, Henshaw Formation, maceration 1122-G, slide 3 T; 39.9 by 32.7 μ; p. 24.
8. *Laevigatosporites crassus* sp. nov., paratype, Henshaw Formation, maceration 1122-G, slide 4 T; 43.6 by 42.5 μ; p. 24.
9. *Laevigatosporites papillatus* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 22; 32.2 by 25.0 μ; p. 24.
10. *Laevigatosporites papillatus* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 46 ZB; 31.4 by 26.2 μ; p. 24.
11. *Laevigatosporites spinosus* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 29 ZB; 22.4 by 18.5 μ; p. 25.
12. *Laevigatosporites spinosus* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 11 ZB; 19.8 by 15.6 μ; p. 25.
13. *Latipulvinites kosankii* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-C, slide 24; 40.5 by 35.0 μ; p. 26.
14. *Latipulvinites kosankii* sp. nov., paratype, Henshaw Formation, maceration 1122-G, slide 9 T; 44.4 by 37.3 μ; p. 26.
15. *Lundbladispora simoni* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 28 ZB; 59.3 by 59.3 μ; p. 27.
16. *Lundbladispora simoni* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 41 ZB; 69.2 by 68.3 μ; p. 27.
17. *Lundbladispora simoni* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 14; 58.3 by 55.7 μ; p. 27.
18. *Lycospora pseudoannulata* Kosanke, 1950, Trivoli Cyclothem, maceration 1175-G, slide 23; 30.6 by 30.0 μ.
19. *Lycospora* sp. 1, Trivoli Cyclothem, maceration 1175-G, slide 18; 26.9 by 25.6 μ; p. 28.
20. *Lycospora* sp. 2, Trivoli Cyclothem, maceration 1175-D, slide 5; 35.1 by 32.4 μ; p. 28.
21. *Lycospora* sp. 3, Fithian Cyclothem, maceration 1170-G, slide 4; 39.9 by 38.6 μ; p. 28.
22. *Pityosporites* sp. 1, Fithian Cyclothem, maceration 1170-G, slide 19; 67.7 μ in length; p. 28.
23. *Punctatisporites brevivermiculatus* sp. nov., holotype, Henshaw Formation, maceration 1122-A, slide 49 ZB; 63.1 by 58.5 μ; p. 29.
24. *Punctatisporites brevivermiculatus* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 18 ZB; 56.1 by 54.4 μ; p. 29.
25. *Punctatisporites chapelensis* sp. nov., holotype, Trivoli Cyclothem, maceration 1128-H, slide 7; 41.5 by 39.2 μ; p. 29.
26. *Punctatisporites chapelensis* sp. nov., tetrad, Trivoli Cyclothem, maceration 1128-H, slide 15; maximum diameter of largest specimen, 39.5 μ; p. 29.

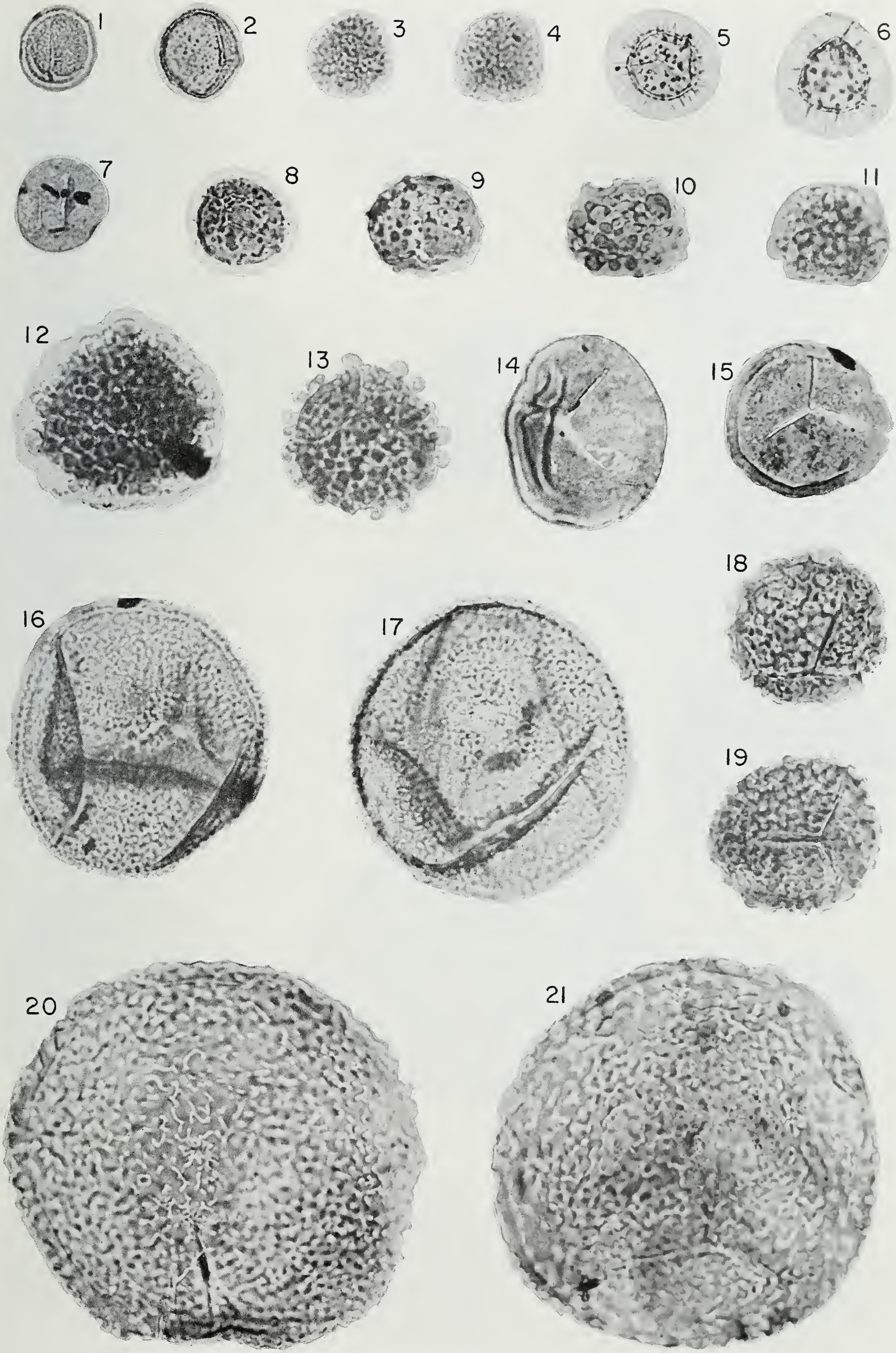


Peppers — Pennsylvanian Spores

PLATE 4

FIGURE

1. *Punctatisporites saetiger* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 34 ZB; 24.1 by 21.1 μ; p. 30.
2. *Punctatisporites saetiger* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 5 ZB; 25.6 by 23.3 μ; p. 30.
3. *Punctatisporites compactus* sp. nov., holotype, Trivoli Cyclothem, maceration 1128-G, slide 2; 22.4 by 19.8 μ; p. 30.
4. *Punctatisporites compactus* sp. nov., paratype, Trivoli Cyclothem, maceration 1128-H, slide 16; 26.2 by 25.3 μ; p. 30.
5. *Punctatisporites productus* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 22 ZB; 21.7 by 19.4 μ; p. 31.
6. *Punctatisporites productus* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 24; 22.7 by 21.4 μ; p. 31.
7. *Punctatisporites minutus* (Kosanke, 1950) emended, Fithian Cyclothem, maceration 1170-C, slide 9; 28.3 by 27.0 μ; p. 31.
8. *Punctatisporites bondensis* sp. nov., holotype, Fithian Cyclothem, maceration 1170-C, slide 9; 26.2 by 25.3 μ; p. 31.
9. *Punctatisporites bondensis* sp. nov., paratype, Fithian Cyclothem, maceration 1170-B, slide 3; 32.4 by 29.7 μ; p. 31.
10. *Punctatisporites racemus* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-G, slide 19; 33.4 by 26.9 μ; p. 31.
11. *Punctatisporites racemus* sp. nov., paratype, Trivoli Cyclothem, maceration 1128-L, slide 17; 30.2 by 27.9 μ; p. 31.
12. *Punctatisporites patulus* sp. nov., holotype, Henshaw Formation, maceration 1122-E, slide 4; 45.4 by 43.7 μ; p. 32.
13. *Punctatisporites patulus* sp. nov., paratype, Henshaw Formation, maceration 1122-E, slide 5; 40.5 by 40.5 μ; p. 32.
14. *Punctatisporites breviornatus* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-C, slide 6; 55.1 by 48.6 μ; p. 32.
15. *Punctatisporites breviornatus* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-C, slide 9; 48.6 by 46.0 μ; p. 32.
16. *Punctatisporites corona* sp. nov., holotype, Henshaw Formation, maceration 1122-Q, slide 44 ZB; 73.9 by 71.3 μ; p. 33.
17. *Punctatisporites corona* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 7 ZB; 83.9 by 78.7 μ; p. 33.
18. *Punctatisporites transenna* sp. nov., holotype, Fithian Cyclothem, maceration 1170-C, slide 7; 44.5 by 32.9 μ; p. 33.
19. *Punctatisporites transenna* sp. nov., paratype, Fithian Cyclothem, maceration 1170-C, slide 6; 48.6 by 44.1 μ; p. 33.
20. *Punctatisporites grandivermiculatus* sp. nov., holotype, Trivoli Cyclothem, maceration 1128-G, slide 6; 123.5 μ in maximum diameter; p. 33.
21. *Punctatisporites grandivermiculatus* sp. nov., paratype, Trivoli Cyclothem, maceration 1128-G, slide 7; 118.8 by 110.2 μ; p. 33.

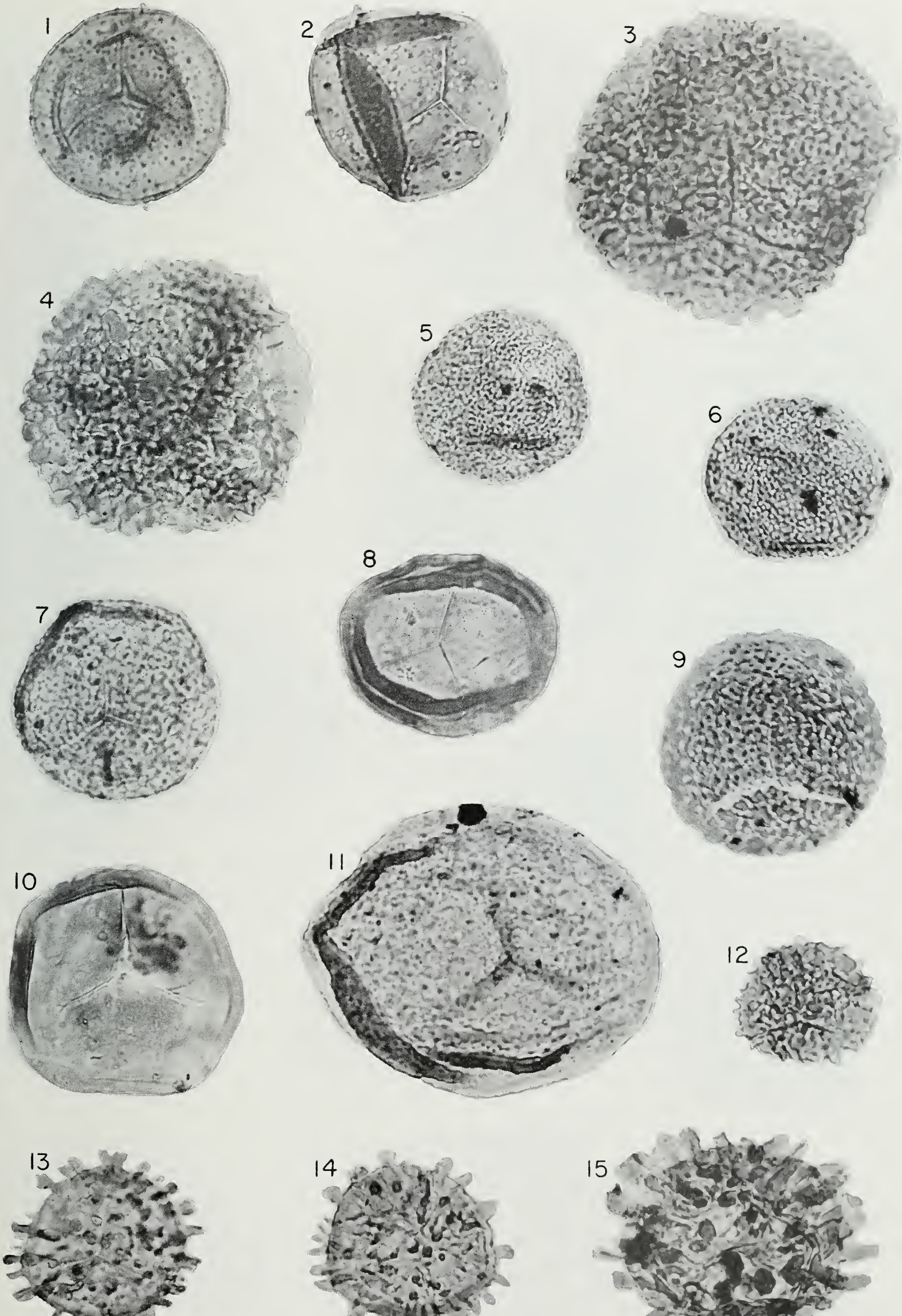


Peppers — Pennsylvanian Spores

PLATE 5

Figure

1. *Punctatisporites variusetosus* sp. nov., holotype, Trivoli Cyclothem, maceration 1128-L, slide 20; 55.1 by 55.1 μ; p. 34.
2. *Punctatisporites variusetosus* sp. nov., paratype, Henshaw Formation, maceration 1122-E, slide 6; 60.6 by 58.7 μ; p. 34.
3. *Punctatisporites rudis* sp. nov., holotype, Henshaw Formation, maceration 1122-A, slide 4 ZB; 90.7 by 84.2 μ; p. 34.
4. *Punctatisporites rudis* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 30 ZB; 84.2 by 82.6 μ; p. 34.
5. *Punctatisporites staplini* sp. nov., holotype, Fithian Cyclothem, maceration 1170-C, slide 16; 51.2 by 50.5 μ; p. 35.
6. *Punctatisporites staplini* sp. nov., paratype, Fithian Cyclothem, maceration 1170-G, slide 3, 51.8 by 48.9 μ; p. 35.
7. *Punctatisporites* sp. 1, Trivoli Cyclothem, maceration 1128-G, slide 3; 58.4 by 56.8 μ; p. 35.
8. *Punctatisporites* sp. 2, Henshaw Formation, maceration 1122-A, slide 11; 64.9 by 54.2 μ; p. 35.
9. *Punctatisporites* sp. 3, Fithian Cyclothem, maceration 1170-C; slide 7; 64.9 by 62.6 μ; p. 35.
10. *Punctatisporites* sp. 4, Henshaw Formation, maceration 1122-A, slide 24 ZB; 75.3 by 69.7 μ; p. 35.
11. *Punctatisporites* sp. 5, Henshaw Formation, maceration 1122-A, slide 22 ZB; 38.9 by 35.7 μ; p. 36.
12. *Punctatisporites* sp. 6, Henshaw Formation, maceration 1122-Z, slide 8 ZB; 96.7 by 85.3 μ; p. 36.
13. *Raistrickia kentuckiensis* sp. nov., holotype, Henshaw Formation, maceration 1122-Z, slide 8 ZB; 47.9 by 42.8 μ; p. 36.
14. *Raistrickia kentuckiensis* sp. nov., paratype, Henshaw Formation, maceration 1122-Z, slide 19; 52.0 by 48.8 μ; p. 36.
15. *Raistrickia* sp. 1, Henshaw Formation, maceration 1122-A, slide 10; 64.9 by 55.5 μ; p. 36.

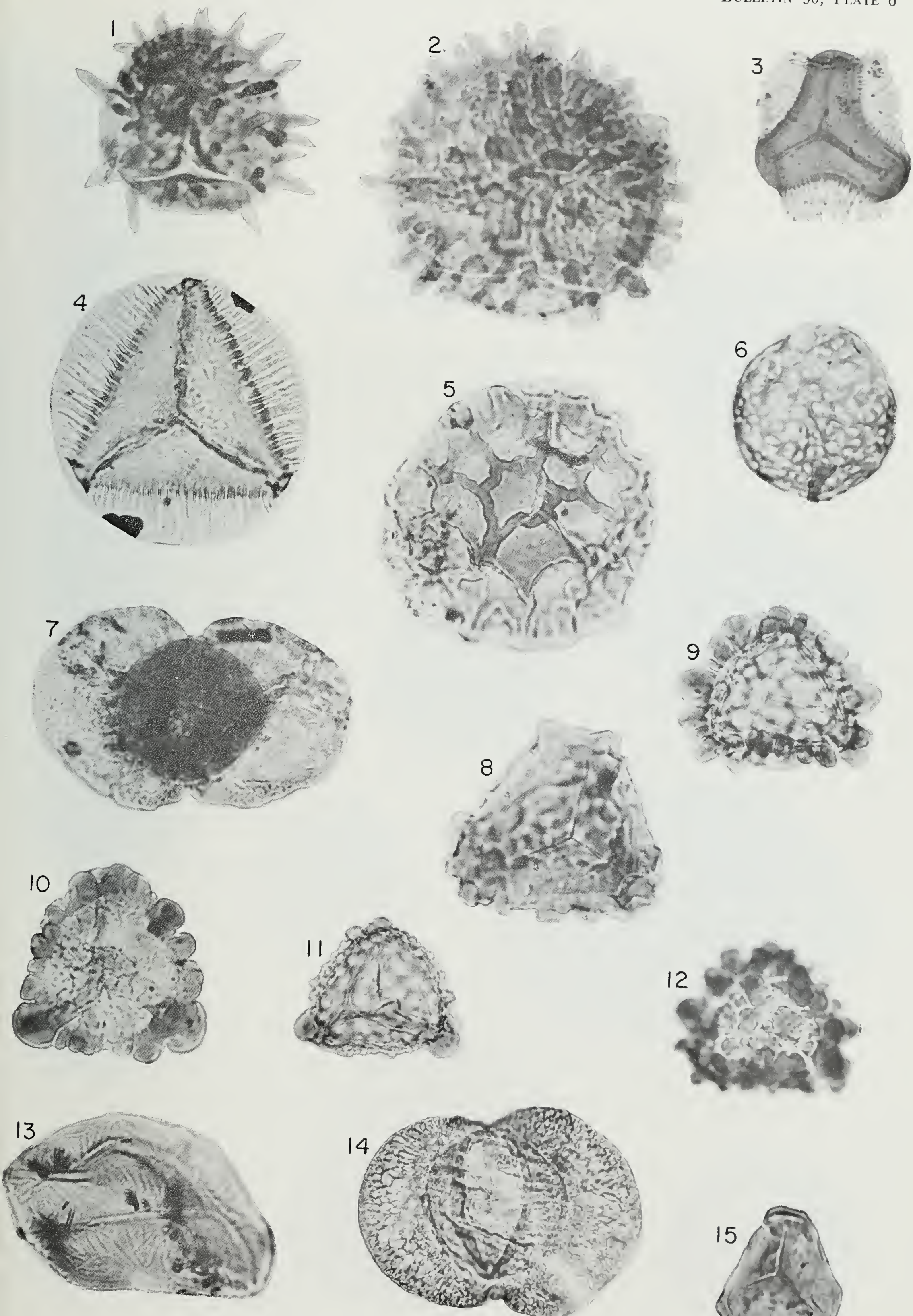


Peppers — Pennsylvanian Spores

PLATE 6

Figure

1. *Raistrickia* sp. 2, Fithian Cyclothem, maceration 1170-B, slide 12; 57.8 by 55.8 μ; p. 37.
2. *Raistrickia* sp. 3, Trivoli Cyclothem, maceration 1128-G, slide 5; 81.1 by 78.5 μ; p. 37.
3. *Reinschospora* sp. 1, Trivoli Cyclothem, maceration 1128-L, slide 10; 55.3 by 51.0 μ; p. 37.
4. *Reinschospora triangularis* Kosanke, 1950, Trivoli Cyclothem, maceration 1175-G, slide 1 S; 64.9 by 60.6 μ.
5. *Reticulatisporites* sp. 1, Trivoli Cyclothem, maceration 1175-I, slide 10; 81.0 by 79.4 μ; p. 38.
6. *Reticulatisporites* sp. 2, Trivoli Cyclothem, maceration 1175-D, slide 8; 52.3 by 48.7 μ; p. 38.
7. *Rhizomaspora* cf. *radiata* Wilson, 1962, Fithian Cyclothem, maceration 1170-G, slide 8; 93.7 by 60.8 μ; p. 38.
8. *Savitrisporites?* sp. 1, Trivoli Cyclothem, maceration 1175-P, slide 8; 62.7 by 60.8 μ; p. 38.
9. *Secarisporites crenatus* sp. nov., holotype with focus on equatorial thickened zone, Henshaw Formation, maceration 1122-Q, slide 26 ZB; 59.0 by 48.6 μ; p. 38.
10. *Secarisporites crenatus* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 22; 58.0 by 54.1 μ; p. 38.
11. *Secarisporites crenatus* sp. nov., paratype, Henshaw Formation, maceration 1122-Q, slide 30 ZB; 49.7 by 43.6 μ; p. 38.
12. *Secarisporites crenatus* sp. nov., holotype with focus on distal surface; p. 38.
13. *Striatosporites* cf. *pfalzensis* Bhardwaj & Venkatachala, 1957, Henshaw Formation, maceration 1122-A, slide 16 ZB; 83.6 by 53.8 μ.
14. *Strotersporites* sp. cf. *Striatites rickteri* (Klaus) Potonié, 1958, Henshaw Formation, maceration 1122-Q, slide 15 ZB; 148.7 by 110.2 μ; p. 39.
15. *Triquitrites simplex* Bhwardaj, 1957a, Trivoli Cyclothem, maceration 1175-B, slide 17; 38.9 by 33.4 μ.

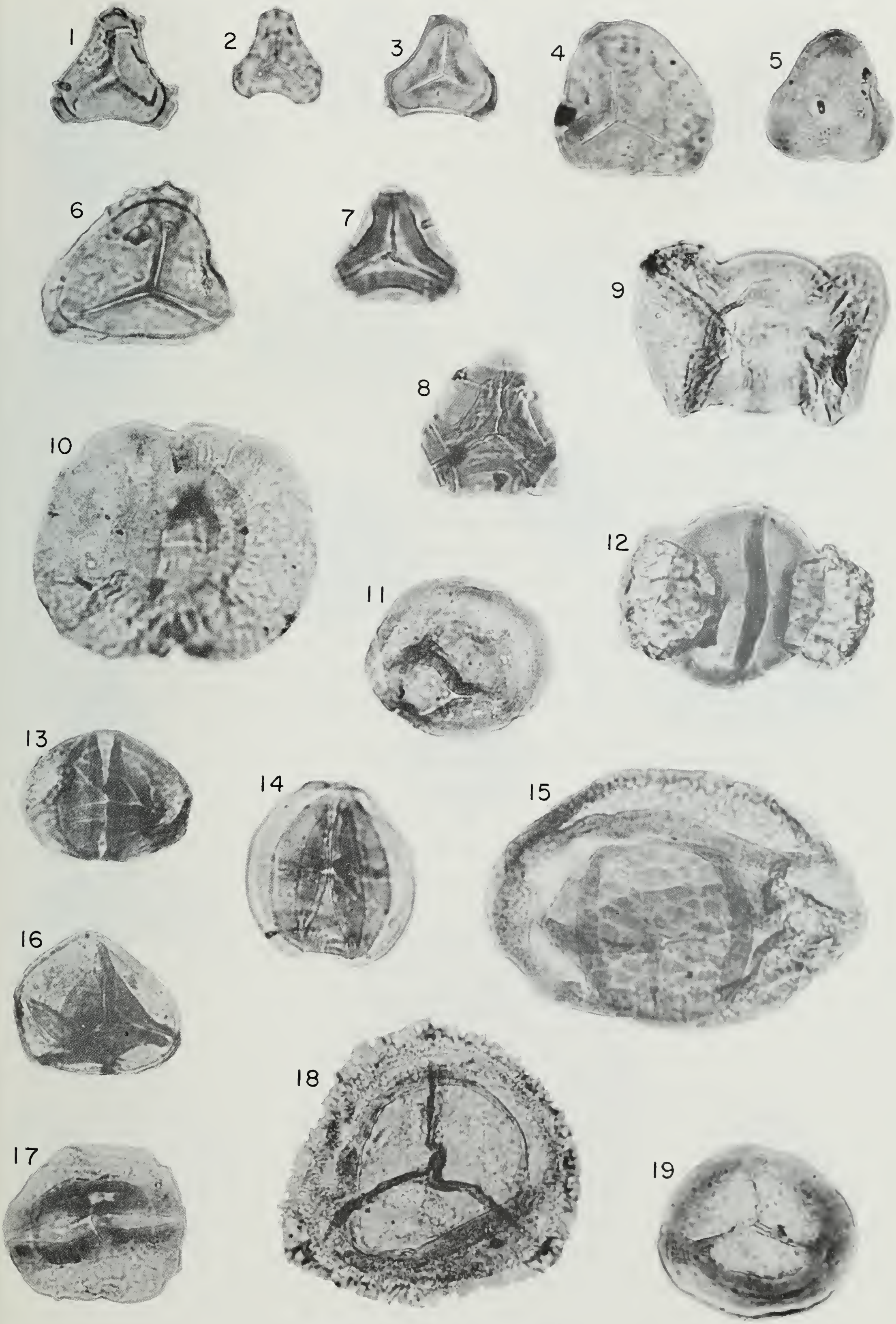


Peppers — Pennsylvanian Spores

PLATE 7

FIGURE

1. *Triquitrites* sp. 1, Trivoli Cyclothem, maceration 1128-H, slide 21; 34.3 by 34.3 μ; p. 40.
2. *Triquitrites* sp. 2, Trivoli Cyclothem, maceration 1128-H, slide 18; 28.2 by 26.6 μ; p. 40.
3. *Triquitrites* sp. 3, Trivoli Cyclothem, maceration 1175-P, slide 16; 32.4 by 32.4 μ; p. 40.
4. *Triquitrites* sp. 4, Fithian Cyclothem, maceration 1170-C, slide 10; 48.0 by 48.0 μ; p. 40.
5. *Triquitrites* sp. 5, Trivoli Cyclothem, maceration 1175-G, slide 13; 39.2 by 37.3 μ; p. 40.
6. *Triquitrites* sp. 6, Trivoli Cyclothem, maceration 1128-H, slide 19; 53.5 by 48.7 μ; p. 40.
7. *Trivolites laevigata* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-G, slide 17; 36.9 by 35.6 μ; p. 41.
8. *Trivolites laevigata* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-E, slide 4, 45.4 by 44.4 μ; p. 41.
9. *Vesicaspora?* sp. 1, Henshaw Formation, maceration 1122-Z, slide 14; total length 74.2 μ, body 48.9 by 47.0 μ; p. 42.
10. *Vestigisporites* sp. 1, Henshaw Formation, maceration 1122-Z, slide 16 ZB; 85.7 by 71.0 μ, including bladder, body 48.7 by 43.5 μ; p. 42.
11. *Wilsonites* sp. 1, Trivoli Cyclothem, maceration 1175-P, slide 8; 55.1 by 48.0 μ, including bladder, body 38.3 by 35.7 μ; p. 42.
12. Bisaccate grain 1, Henshaw Formation, maceration 1122-G, slide 9 T; total length 77.8 μ, body 55.1 by 48.7 μ; p. 42.
13. Bisaccate grain 2, Fithian Cyclothem, maceration 1170-A, slide 13; total length 51.6 μ, body 39.2 by 30.2 μ; p. 42.
14. Monosaccate grain 1, Henshaw Formation, maceration 1122-Q, slide 14, 55.4 by 48.3 μ, including bladder, body 50.6 by 35.1 μ; p. 43.
15. Monosaccate grain 2, Fithian Cyclothem, maceration 1170-A, slide 4; 113.1 by 75.8 μ, including bladder, body 69.4 by 55.1 μ; p. 43.
16. Monosaccate grain 3, Henshaw Formation, maceration 1122-A, slide 22 ZB; 48.7 by 42.2 μ, including bladder, body 35.7 by 24.4 μ; p. 43.
17. Monosaccate grain 4, Henshaw Formation, maceration 1122-A, slide 5 ZB; 51.9 by 43.1 μ, including bladder, body 27.6 by 26.7 μ; p. 43.
18. Spore A, Henshaw Formation, maceration 1122-Q, slide 2 ZB; 93.4 by 85.0 μ; p. 43.
19. Spore B, Henshaw Formation, maceration 1122-A, slide 44 ZB; 56.4 by 50.2 μ; p. 43.

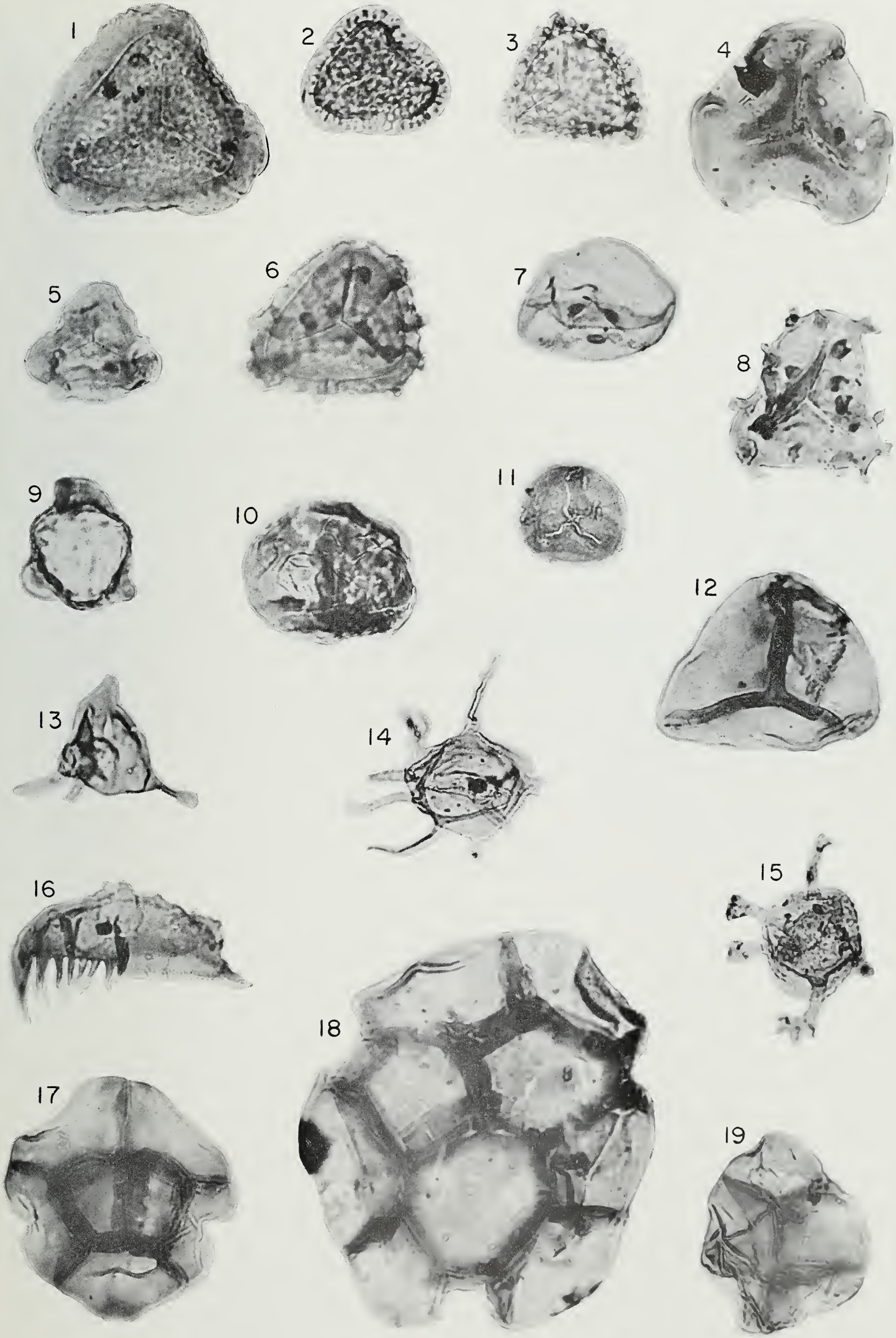


Peppers — Pennsylvanian Spores

PLATE 8

Figure

1. Spore C, Henshaw Formation, maceration 1122-A, slide 16 ZB; 64.9 by 63.3 μ; p. 44
2. Spore D, Henshaw Formation, maceration 1122-Q, slide 2; 35.1 by 29.9 μ; p. 44.
3. Spore E, Henshaw Formation, maceration 1122-Q, slide 9 ZB; 41.3 by 38.3 μ; p. 44.
4. Spore F, Henshaw Formation, maceration 1122-A, slide 22 ZB; 59.4 by 59.0 μ; p. 44.
5. Spore G, Henshaw Formation, maceration 1122-A, slide 16 ZB; 35.7 by 33.4 μ; p. 44.
6. Spore H, Fithian Cyclothem, maceration 1170-A, slide 10; 55.1 by 49.0 μ; p. 45.
7. Spore I, Trivoli Cyclothem, maceration 1175-J, slide 10; 52.0 by 38.7 μ; p. 45.
8. Spore J, Henshaw Formation, maceration 1122-A, slide 5 ZB; 48.0 by 42.5 μ; p. 45.
9. Spore K, Henshaw Formation, maceration 1122-Q, slide 4 ZB; 35.1 by 29.2 μ; p. 45.
10. Spore L, Henshaw Formation, maceration 1122-A, slide 5 ZB; 49.0 by 44.1 μ; p. 45.
11. Spore M, Trivoli Cyclothem, maceration 1128-G, slide 15; 33.7 by 32.4 μ; p. 45.
12. Spore N, Trivoli Cyclothem, maceration 1175-C, slide 25; 65.2 by 53.0 μ; p. 46.
13. Hystrichosphere 1, Trivoli Cyclothem, maceration 1128-J, slide 16; body 25.6 by 24.0 μ; p. 46.
14. Hystrichosphere 2, Trivoli Cyclothem, maceration 1128-J, slide 4; body 37.9 by 30.5 μ; p. 46.
15. Hystrichosphere 3, Trivoli Cyclothem, maceration 1128-J, slide 5; body 34.0 by 29.5 μ; p. 47.
16. Scolecodont 1, Fithian Cyclothem, maceration 1170-G, slide 19; 69.7 μ long; p. 47.
17. *Centonites symmetricus* sp. nov., holotype, Trivoli Cyclothem, maceration 1175-E, slide 4; 69.7 by 66.7 μ; p. 47.
18. *Centonites symmetricus* sp. nov., paratype, Henshaw Formation, maceration 1122-A, slide 41 ZB; 122.5 by 101.1 μ; p. 47.
19. *Centonites symmetricus* sp. nov., paratype, Trivoli Cyclothem, maceration 1175-C, slide 17; 57.7 by 48.9 μ; p. 47.



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