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AN INTRODUCTION TO THE STRATIGRAPHIC PALYNOLOGY OF THE CHEROKEE GROUP (PENNSYLVANIAN) COALS OF IOWA

by

ROBERT L. RAVN

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ABSTRACT

The Cherokee Group of southern Iowa consists of a complex sequence of sediments including numerous coals. Lateral relationships of the coal seams are unclear on the basis of lithologic evidence alone. Preliminary palynological studies suggested the need for detailed examination of vertical variability of miospore populations within selected coal seams as a supplement to routine channel sample analyses for biostratigraphic correlation. A thick coal of uncertain stratigraphic relations, designated CP-19-4, was sampled to test the utility of detailed miospore profile evaluation.

CP-19-4 yielded a diverse, well-preserved miospore population with marked vertical variation, appearing to relate closely to gross petrologic variability of coal lithotypes. Three major miospore associations were distinguished, dividing the seam into nearly equal sub-units;—a lower interval, dominated by gymnospermous prepollen and pollen grains, designated the Florinites interval; a middle interval, characterized by an abundance of lycopsid-related spores, designated the Densosporites-Crassispora interval; and an upper interval, dominated by the arborescent lycopsid spore Lycospora granulata, designated the Lycospora interval. The overall miospore assemblage is equivalent in age to that of the Pope Creek Coal of the Illinois Basin.

A paleoecologic reconstruction of the coal swamp depositional history is suggested on the basis of the miospore profile. The distribution of specific miospores within the seam indicates a series of depositional events, evidence of which may be traceable laterally and useful for correlation. A comparison with coals obtained from other cores illustrates the utility of the approach in complex stratigraphic sections.

Formal taxonomic information is provided for 171 miospore species; eight new genera, 13 new species and 4 new combinations are proposed. Additionally, diagnoses of 3 species are formally emended, and 1 new name is proposed to replace a previous name found to be a junior homonym under provisions of the International Code of Botanical Nomenclature (1978). New taxonomic names proposed in this report are: Leiotriletes guennelli nom. nov. emend., Calamospora nebulosa sp. nov., Adelisporites multiplicitus gen. et sp. nov., Lophotrilites conferitus sp. nov., Cuneisporites rigidus gen. et sp. nov., Telenisoritess granulatus gen. et sp. nov., Apiculatisporis saetiger (Peppers) comb. nov., Crassispora annullata sp. nov., Cirratiradites reticulatus sp. nov., Thysanites densus gen. et sp. nov., Vestispora luminata sp. nov., Diaphanospora parvigracula (Peppers) comb. nov., Potonieisporites solidus sp. nov., Wilsonites circularis (GuenneL) comb. nov., Pseudoillinites diversiformis (Kosanke) gen. nov. et comb. nov. emend., Peppersites ellipticus gen. et sp. nov., Wapellites variabilis gen. et sp. nov., and Phillipsites tenuis gen. et sp. nov. Reinschospora triangularis (Kosanke, 1950) is emended.

ACKNOWLEDGMENTS

The writer wishes to thank a number of people who provided counsel and support during the course of this study: Dr. Richard G. Baker of the Department of Geology, University of Iowa, served as chairman for the thesis committee, and permitted use of laboratory facilities under his direction. Dr. Russel A. Peppers of the Illinois Geological Survey advised the author on taxonomic matters and allowed study of both his and Dr. R. M. Kosanke's (1950) type material. Dr. Matthew J. Avcin of the Iowa Geological Survey provided material and technical support throughout the study. Dr. Tom L. Phillips of the Department of Botany, University of Illinois, aided in comparison of Pennsylvanian coal swamp floral successions based on macrofossil analyses of midwestern coals. Thanks are also due to Dr. L. R. Wilson of the Department of Geology, University of Oklahoma, for valuable personal communication concerning patterns of floral succession as revealed by the palynology of Oklahoma coals, and to Dr. Gene Mapes of the Department of the Department of Botany, Ohio University, for bringing to the writer's attention the plant-group affinities of a number of newly discovered fructifications containing miospores from Midcontinent Pennsylvanian shales.

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Text figures were prepared by John Knecht and Charmaine Shreve, staff illustrators, Iowa Geological Survey. Special thanks are given to Barbara Miller, Iowa Geological Survey, for her patience in typing the manuscript during the course of numerous editorial reviews.
INTRODUCTION

The Cherokee Group (Des Moines Series, Pennsylvanian System) of southern Iowa consists of interbedded marine and non-marine sediments that include numerous coals (fig. 1). Complex facies relationships characterize the strata, and exposures are sparse due to a thick Pleistocene cover over much of the region. These factors historically have prevented detailed stratigraphic correlation, particularly in the lower portion of the sequence (fig. 2). The recent renewal of economic interest in Iowa coal has fostered a need for more precise knowledge of the stratigraphy of Cherokee coals and of their lateral continuity as minable units.

Accordingly, in 1973, the Iowa Geological Survey began a systematic coal resource project including a coring program, concentrating initially in the southeasternmost portion of the coal-bearing region where strippable deposits were thought to exist. Samples secured through coring have been subjected to various forms of stratigraphic analysis, including the study of conodonts, ostracodes and fusulinid foraminifera from marine strata, and palynomorphs from coals and non-marine shales. Coal palynology has proven particularly effective in correlation. This report is the first of a series addressing the palynology of Iowa coals, and is derived in large part from a Master's thesis at the Department of Geology, University of Iowa (Ravn, 1977a). Portions of the report have been presented previously at scientific meetings (Ravn, 1977b, 1977c).

Figure 1. Sub-Pleistocene exposure of the Cherokee Group and beds believed of equivalent age in Iowa, (shaded) with the locality of Iowa Geological Survey corehole CP-19.
PREVIOUS WORK

Stratigraphy — The stratigraphy of the Pennsylvanian System in Iowa was first outlined by White and St. John (1870). They, and other early workers (e.g., Bain, 1894; Hinds, 1909), noted the complex nature of the stratigraphy, particularly as related to the coal beds. The correlation problem was most acute in the lower portion of the Iowa Pennsylvanian section, the Cherokee Group (fig. 2). The present coring program has helped compensate for the paucity of surface exposure of the Cherokee, but also has confirmed the observations of the early workers concerning its complexity.

The Cherokee Group has been divided informally into Upper and Lower units on the basis of the relative persistence of traceable lithologic horizons (Landis and Vah Eck, 1965). The stratigraphy of the Upper Cherokee is somewhat better known; its major rock units have been identified and correlated with equivalent units in Illinois (Weller, Wanless, Cline and Stookey, 1942). The level of understanding of the Lower Cherokee was summarized by Landis and Van Eck (1965, p. 37): “The stratigraphy of the Lower Cherokee in Iowa is virtually unknown, both because stratigraphic relations are very complex and because data are insufficient in several critical areas ... the lateral relations of coal beds of minable thickness are doubtful or unknown in many areas.” The table of estimated coal reserves (Landis and Van Eck, 1965, p. 95-141) emphasizes the lack of stratigraphic control. Included in the reserves of most counties are uncorrelated coal beds or beds of questionable relationship; in many instances these beds are of commercial thickness and are estimated to contain significant reserves.

Palynology — Prior to the current project, palynological investigation of Iowa coals was limited to a number of short papers concerned principally with taxonomy (Wilson and Brokaw, 1937; Wilson and Coe, 1940; Wilson, 1943, 1958, 1960; Wilson and Kosanke, 1944; Schemel, 1951). An abstract (Hornbacker and Habib, 1962) discussed the palynology of the Bevier and Wheeler coals of Iowa, Kansas and Missouri, though the data remain unpublished. The most extensive study of Carboniferous palynology in Iowa previous to the current project is that of Urban (1971) who described an Upper Mississippian miospore assemblage from eastern Iowa. A number of paleobotanical papers concerned with reproductive structures and miospore affinities of Pennsylvanian plants have described material collected in Iowa (Hoskins and Cross, 1943; Mamay, 1950 and 1954a; Baxter, 1955 and 1963; Murdy and Andrews, 1957; Baxter and Leisman, 1967; Eggert and Kryder, 1969; Millay and Taylor, 1974 and 1976; Courvoisier and Phillips, 1975; Baxendale and Baxter, 1977). In summary, the stratigraphic distribution of miospores in Iowa coals is virtually unknown, and the basic taxonomy of the miospore population has not been documented thoroughly. (The term miospore as defined by Guennel, 1952, refers to spores and pollen smaller than 200 microns in maximum dimension; it is a purely descriptive term having no implications concerning precise biological function, and can include isospores, microspores, small megaspores and pollen grains.)

Figure 2. Generalized stratigraphic nomenclature in the Upper Mississippian and Pennsylvanian Systems south-central Iowa (strata equivalent to the shaded area are not known to be present in south-central Iowa).
A considerable body of literature exists concerning miospores of Pennsylvanian or Carboniferous age from coal-bearing strata elsewhere. It is beyond the scope of this report to summarize the literature in any detail, although many works are referenced in the Taxonomy section of the paper. Of special importance to this study were the extensive reports on the palynology of the Illinois Basin coals by Kosanke (1950) and Peppers (1964 and 1970), and the detailed stratigraphic study of miospores from the British Coal Measures by Smith and Butterworth (1967), whose biostratigraphic framework has proven useful in assessing the age of other Iowa coals not considered in this report (Ravn and Fitzgerald, 1978).

SCOPE AND PURPOSE

Palynological correlation of coal seams elsewhere has been accomplished largely through analysis of channel samples representative of the entire thickness of each given seam. This technique has the advantage of simplicity and speed of evaluation, and has been proved an effective stratigraphic method in areas where coal seams and associated strata are widespread and persistent (e.g., Peppers, 1970). In such areas lateral variation in miospore populations of seams tends not to be great, usually allowing clear differentiation of individual coals on the basis of total miospore population counts. The complexity of the Cherokee section in Iowa, coupled with the lack of previous palynological data from the coals, created uncertainty about the reliability of simple channel sample correlation here. Preliminary work with cores has confirmed the need, at least in certain areas, for a more sophisticated approach toward miospore biostratigraphy.

As a result, it was considered necessary to investigate the potential usefulness of the vertical miospore succession within seams as a stratigraphic tool. Knowledge of the progression of plant successions through the depositional history of the coal swamp, as recorded in the miospore profile, also was considered to have potential value in understanding other coal characteristics, such as geochemistry, which are under examination. An appropriate coal seam of uncertain stratigraphic relationship therefore was chosen to be sampled at closely spaced intervals, to determine the character of its miospore profile.

The coal was recovered from core CP-19, located in the NW1/4, NE1/4, NE1/4, Section 18, T. 73N, R. 14W, Wapello County, Iowa. The seam is designated lithologic unit 4 in the core log (Iowa Geological Survey Core Log, CP-19), and is 180 cm (5 ft. 7 in.) thick; it immediately overlies a 10 cm (4 in.) thick coaly shale (unit 5), which was sampled for miospores as part of the coal seam. Hereafter in this report the entire interval sampled (units 4 and 5) is referred to as CP-19-4, unless specified otherwise.

As indicated in fig. 3, a cross-section illustrating its position relative to coals recovered in nearby cores, stratigraphic relations of CP-19-4 are far from obvious. In addition, CP-19-4 is both thick enough and shallow enough to be of economic interest, and several old mining operations near the site of the corehole probably extracted coal from this seam (M. J. Avcin, personal communication, 1977).

The seam proved to contain an exceptionally diverse and well-preserved miospore assemblage which served to document for the first time a major portion of the miospore population encountered in the Cherokee Group coals of Iowa. The formal taxonomic description of this miospore assemblage is a principal purpose of this report and is designed to provide a base from which further palynological correlation can proceed. The character and interpretation of the miospore profile, and its utility in correlation, form the second major purpose of the study.

METHOD

The coal was recovered in eleven segments of varying length, due to fracturing at natural points of weakness in the seam during coring; coaly shale CP-19-5 constituted a twelfth segment, and each segment was assigned a numerical designation denoting its relative position within the core (fig. 4). The segments were split into units 1 to 2 cm (0.4 to 0.8 in.) thick (it was difficult to be more precise due to natural breaks in the core). These units were assigned alphabetic designations within their respective segments (see Appendix II).

Samples from 86 of the units were macerated for miospores, employing variations of standard Schulze solution techniques (Schulze solution, KOH, HF) described by Peppers (1970); detailed preparation procedures are given in Appendix I. Throughout most of the seam alternate sections were selected for maceration, but in portions of special interest, such as the top and bottom and around certain petrologic changes in the seam, several adjacent sections were processed and examined. A minimum of four microscope slides from each sample processed were prepared, with residues mounted either in Canada Balsam, Piccolyte Resin or Permount Cement (see discussion of mounting media in Appendix I). After a review of statistical considerations (Barkley, 1934; Tomlinson, 1957; Dimbleby, 1957; Mosimann, 1965) a miospore population sample size of 250 miospores was selected for counting under a high-power dry objective. Following the basic count, four slides of each sample were scanned under low-power to determine the presence of rare species not observed during the population count. Additional slides of samples found to contain miospores of undescribed or undetermined types were examined when appropriate. Data from these examinations are included in Appendix II. Sample residues and slides are reposited at the Department of Geology, University of Iowa, Iowa City, IA 52242.
Figure 3. Uncorrelated cross-section through the Cherokee Group of Wapello County, illustrating present elevational relationships of coal seams encountered in a typical group of Iowa Geological Survey coreholes including CP-19.

PALYNOLOGY OF CP-19-4

The following miospore species observed in the study of CP-19-4 are provided with formal systematics:

Leiotriletes guennelii nom. nov. emend.
Leiotriletes levis (Kosanke) Potonié and Kremp 1955
Leiotriletes priddyi (Berry) Potonié and Kremp 1955
Leiotriletes sphaerotriangulus (Loose) Potonié and Kremp 1955

Leiotriletes turgidus Marshall and Smith 1964
Punctatisporites aerarius Butterworth and Williams 1958
Punctatisporites cf. curviradiatus Staplin 1960
Punctatisporites edgarensis Peppers 1970
Punctatisporites cf. edgarensis Peppers 1970
Punctatisporites kankakeensis Peppers 1970
Punctatisporites minutus (Kosanke) Peppers 1964
Punctatisporites nitidus Hoffmeister, Staplin and Malloy 1955
<table>
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<tr>
<th>Core Segments</th>
<th>Overlying sediments —— siltstones, shales</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>LENGTH</td>
</tr>
<tr>
<td>11</td>
<td>23.0 cm (9.1 in)</td>
</tr>
<tr>
<td>10</td>
<td>29.0 cm (11.4 in)</td>
</tr>
<tr>
<td>9</td>
<td>6.5 cm (2.6 in)</td>
</tr>
<tr>
<td>8</td>
<td>20.3 cm (8.0 in)</td>
</tr>
<tr>
<td>7</td>
<td>15.0 cm (5.9 in)</td>
</tr>
<tr>
<td>6</td>
<td>18.0 cm (7.1 in)</td>
</tr>
<tr>
<td>5</td>
<td>16.0 cm (6.3 in)</td>
</tr>
<tr>
<td>4</td>
<td>6.7 cm (2.7 in)</td>
</tr>
<tr>
<td>3</td>
<td>23.0 cm (9.1 in)</td>
</tr>
<tr>
<td>2</td>
<td>14.3 cm (5.6 in)</td>
</tr>
<tr>
<td>1</td>
<td>7.7 cm (3.1 in)</td>
</tr>
<tr>
<td>CP-19-5</td>
<td>10.0 cm (4.0 in)</td>
</tr>
</tbody>
</table>

Underlying sediments —— siltstones, sandstones

Figure 4. Measurements and general physical description of segments of coal seam CP-19-4 and adjacent sediments.
Punctatisporites cf. nudus Artie 1957
Punctatisporites obliquus Kosanke 1950
Calamospora breviradiata Kosanke 1950
Calamospora hartungiana Schopf, in Schopf, Wilson and Bentall 1944
Calamospora liquida Kosanke 1950
Calamospora cf. mutabilis (Loose) Schopf, Wilson and Bentall 1944
Calamospora nebulosa sp. nov.
Calamospora cf. pedata Kosanke 1950
Calamospora straminea Wilson and Kosanke 1944
Elaterites triferens Wilson 1943
Lophotriletes gibbosus (Ibrahim) Potonie and Kremp 1955
Lophotriletes commissuralis (Peppers) Peppers and Ravn 1967
Lophotriletes copiosus sp. nov.
Lophotriletes confertus (Loose) Smith and Butterworth 1967
Kewaneesporites patulus (Peppers) Peppers 1970
Kewaneesporites tuberculatus (Loose) Schopf, Wilson and Kosanke 1944
Kewaneesporites triangularis Kosanke 1950
Punctatisporites cf. gen. et sp. nov.
Adelisporites multiplicatus Artie 1957
Lophotriletes granoomatus (Peppers) Pi-Radondy and Doubinger 1968
Lophotriletes ibrahimii (Peppers) Pi-Radondy and Doubinger 1968
Lophotriletes juvencus (Peppers) Peppers 1970
Lophotriletes microsaetosus (Loose) Smith and Butterworth 1967
Lophotriletes rarispinosus Peppers 1970
Lophotriletes mosaicus Potonie and Kremp 1955
Lophotriletes variocomeus (Loose) Smith and Butterworth 1967
Lophotriletes saetiger (Peppers) Peppers and Ravn 1967
Lophotriletes aculeatus (Loose) Smith and Butterworth 1967
Lophotriletes irregularis (Kosanke) Potonie and Kremp 1955
Reinschospora triangularis (Kosanke) emend.
Cuneisporites rigidus gen. et sp. nov.
Tetanisporites granulatus gen. et sp. nov.
Savitsriporites nux (Butterworth and Williams) Smith and Butterworth 1967
Grumosisporites (?) rufus (Butterworth and Williams) Smith and Butterworth 1967
Cristatisporites indignabundus (Loose) Staplin and Jansonius 1964
Radizonates cf. difformis (Kosanke) Staplin and Jansonius 1964
Cingulizonates loricatus (Loose) Butterworth and Smith, in Butterworth et al., 1964
Crasispora annulata sp. nov.
Crasispora kosankei (Potonié and Kremp) Smith and Butterworth 1967
Cappasporites distortus Urban 1966
Densosporites anulatus (Loose) Smith and Butterworth 1967
Densosporites irregularis Hacquebard and Bars 1957
Densosporites spheroetriangularis Kosanke 1950
Densosporites spinifer Hoffmeister, Staplin and Malloy 1955
Densosporites triangularis Kosanke 1950
Lycospora granulata Kosanke 1950
Lycospora microbapillata (Wilson and Coe) Schopf, Wilson and Bentall 1944
Lycospora belludica (Wi cher) Schopf, Wilson and Bentall 1944
Lycospora rotunda Bharadwaj 1957
Lycospora cf. L. torqui(e) (Loose) Potonié and Kremp 1956
Cirratiradites annuliformis Kosanke and Brokaw, in Kosanke, 1950
Cirratiradites maculatus Wilson and Coe 1940
Cirratiradites reticulatus sp. nov.
Cirratiradites saturni (Ibrahim) Schopf, Wilson and Bentall 1944
Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944
Endosporites staplinii Gupta and Boozer 1969
Endosporites zonalis (Loose) Knox 1950
Alatisporites hoffmeistertii Morgan 1955
Alatisporites postulatus (Ibrahim) Ibrahim 1933
Laevigatosporites desmoinesiensis (Wilson and Coe) Schopf, Wilson and Bentall 1944
Laevigatosporites cf. dunkardensis Clendening 1970
Laevigatosporites globosus Schmel 1951
Laevigatosporites medius Kosanke 1950
Laevigatosporites minutus (Ibrahim) Schopf, Wilson and Bentall 1944
Laevigatosporites ovalis Kosanke 1950
Laevigatosporites striatus Alpern 1959
Laevigatosporites vulgaris (Ibrahim) Ibrahim 1933
Laevigatosporites cf. vulgaris (Ibrahim) Ibrahim 1933
Thymospora cf. pseudothiessenii (Kosanke) Wilson and Venkatachala 1963
Torispora securis Balme 1952
Tuberculatosporites robustus (Kosanke) Peppers 1970
Vestispora fenestrata (Kosanke and Brokaw) Spode, in Smith and Butterworth, 1967
Vestispora laeavigata Wilson and Venkatachala 1963
Vestispora luminata sp. nov.
Vestispora pseudoreticulata Spode, in Smith and Butterworth, 1967
Vestispora cf. reticulata (Laveine) Lobziak 1971
Aumancisporites striatus Alpern 1958
Thysanites densus gen. et sp. nov.
Colatisporites decorus (Bharadwaj and Venkatachala) Williams, in Neves et al., 1973
Hymenospora multirugosa Peppers 1970
Diaphanospora paruigracula (Peppers) comb. nov.
Florinites mediapudens (Loose) Potonié and Kremp 1956
Florinites milloti Butterworth and Williams 1954
Florinites occultus Habib 1966
Florinites visendus (Ibrahim) Schopf, Wilson and Bentall 1944
Florinites cf. volans (Loose) Potonié and Kremp 1956
Potoniéisporites elegans (Wilson and Kosanke) Habib 1966
Potoniéisporites solidus sp. nov.
Costatascyclus crenatus (Felix and Burbridge) Urban 1971
Wilsonites circularis (Guennel) Peppers and Ravn comb. nov.
Wilsonites delicatus (Kosanke) Kosanke 1959
Wilsonites vescatus (Kosanke) Kosanke 1959
Pityosporites westphalensis Williams 1955
Platyacoccus saarenensis (Bharadwaj) Jizba 1962
Peppersites ellipticus gen. et sp. nov.
Illinites unicus (Kosanke) Helby 1966
Pseudoillinites diversiformis (Kosanke) gen. et comb. nov.
Phillipsites tenuis gen. et sp. nov.
Wapelites variabilis gen. et sp. nov.
Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954
Trihyphaecites triangulatus Peppers 1970

In addition, a number of miospores were encountered in CP-19-4 which could be assigned to genera but not with confidence to any described species. Several of these are illustrated and provided with informal description; although they were not observed in numbers sufficient to delimit morphologic variation adequately for formal new species diagnoses, they may be useful for future biostratigraphic comparison of CP-19-4 and other coals.

**Miospore Distribution in CP-19-4**

*Physical Profile*—Distinct petrologic differences exist in the physical characteristics of the twelve segments of CP-19-4, and a brief discussion of the gross petrology of the seam is in order.

The lengths of the segments are illustrated in figure 4. The lowermost segment (lithologic unit CP-19-5) is a dark gray to black, tough, non-fissile shale with occasional stringers of bright vitrain, possibly representing individual plant remains such as cordaita
leaves. Segments 1, 2 and 3 of the coal seam proper are rather uniform in appearance, consisting of alternating bands of vitrain ("bright coal") and clarain (petrologic terms as defined by Stopes, 1919, and Stach, 1968) usually in bands 5 mm (0.2 in.) or less thick. Segment 4 is a friable gray coal whose basic petrologic character is difficult to determine; during maceration, it was found to contain appreciably more fusain and silicate material than the surrounding segments. Segments 5 through 8 are characterized by a dominance of tough, dense durain ("dull coal"); vitrain bands are virtually absent except in the lower portion of segment 5 and in the upper part of segment 8. Segment 9 resembles segment 4, but is not as friable. The upper two segments, 10 and 11, contain abundant vitrain bands exceeding in number and thickness those observed in the basal portion of the seam.

CP-19-4 occupies the interval 27.9 to 29.8 meters (91'8" to 97'7") below the ground surface in the core (the core was logged using feet-and-inch measurements which will be retained here for descriptive clarity; the log is unpublished, but along with other coal coring project logs, is on open file at the Iowa Geological Survey in Iowa City). The seam is immediately overlain by 2.7 meters (9 feet) of dark gray, pyritic, shaley siltstone to silty shale which is interlaminated with minor, occasionally calcareous, light gray, bioturbated siltstone. The upper coal contact is gradational over about 0.5 cm (¼ inch). The base grades into a medium dark gray clayey, sandy siltstone which grades downward into a light gray massive sandstone; the sandstone grades into an interbedded sandstone-siltstone sequence with a total thickness from the base of the seam to the next major lithologic change of about 4 meters (13 feet). The relative influences of marine and non-marine conditions on the sediments above and below the coal seam are not obvious, and therefore it is not possible to define from the sedimentology whether the sequence containing coal CP-19-4 resulted from a transgression or regression of marine waters, or from some non-marine succession of events. This ambiguity of sediment origin is common to coal-bearing sequences in the Lower Cherokee, and contributes strongly to the difficulties of lithostratigraphic correlation noted earlier.

Miospore Profile—Three major miospore associations which are related closely to the petrologic categories of the seam have been recognized. For purposes of discussion, these associations have been designated after their characteristic miospore genera: The Florinites interval, the Densosporites-Crassispora interval, and the Lycospora interval. It is to be stressed that these designations apply only to the miospore distribution of CP-19-4, and are not considered a model for miospore paleoecology of other Iowa coals: insufficient data exist at present to permit such generalizations about miospore distributions in coals of the Cherokee Group.

The Florinites interval: The lower third of the seam (CP-19-5, segments 1-3 of CP-19-4) contains a high percentage of gymnosperm-related miospores, dominated by Florinites mediapudens (fig. 5). Lesser percentages of Florinites milloti, Pityosporites westphalensis, Wilsonites spp., Potonietsporites elegans and other
Figure 6. Miospore profiles of *Densosporites sphaerotriangularis*, *Crassispora kosankei* and *Triquiritites* spp. within CP-19-4.
Figure 7. Miospore profiles of Lycospora granulata and Lycospora pellucida within CP-19-4.
gymnospermous saccate taxa occur. Lycospora pellucida, Endosporites globiformis, Punctatisporites minutus and Laevigatosporites globosus are characteristic species having plant-group affinities other than gymnospermous. Other frequently observed species include Laevigatosporites minutus, Laevigatosporites ovalis, Cappasporites distortus, Calamospora breviradiata, Vestispora laevigata and Cyclogranisporites aureus. Certain horizons display a high diversity of miospore species; many rarer species, such as Reinschospora triangularis and Dictyotriletes reticulocingulum are contained almost exclusively in such horizons. In summary, the Florinites interval is characterized by an abundance of gymnospermous miospores, a high diversity of taxa, and restricted vertical distribution of several taxa not observed elsewhere in the seam.

The Densosporites-Crassispora interval: The middle portion of the seam (segments 4-9) is marked by a sharp reduction in the number and diversity of gymnospermous miospores, and by the appearance in high percentages of Densosporites sphaerotriangularis and Crassispora kosankei (fig. 6). Various species of Triquitrites, Cyclogranisporites minutus, and fern-related miospores of the genus Granulatisporites also increase. The abundance of Lycospora pellucida varies widely throughout the interval. The species increases in abundance to over 30% of the miospore population in segment 4, declines to 2-10% through segments 5 and 6, and increases sharply in segment 7, reaching peaks of over 50% in segments 8 and 9. Cyclogranisporites aureus, Calamospora breviradiata, Punctatisporites minutus, Laevigatosporites minutus, Laevigatosporites ovalis, Cappasporites distortus, Vestispora laevigata and Endosporites globiformis remain relatively common throughout the interval.

In general, fern-related taxa are more important in the miospore population of the Densosporites-Crassispora interval than they are in the Florinites interval, and gymnosperm-related taxa, conversely, are much less important. A few species (e.g., Vestispora lumina, Dictyotriletes distortus) are confined to the interval, but the presence of vertically-restricted taxa is not as characteristic of the Densosporites-Crassispora interval as it is of the Florinites interval. Diversity of species in the Densosporites-Crassispora interval is somewhat less than that in the Florinites interval.

The Lycospora interval—The upper third of the seam (segments 10 and 11) is characterized by the dominance of Lycospora granulata, which consistently constitutes 50% or more of the miospore population (fig. 7). The change in the most abundant species of Lycospora from L. pellucida in the lower two intervals to L. granulata in the uppermost interval is abrupt, occurring at the base of segment 10. Crassispora kosankei becomes uncommon above segment 8, and is observed only occasionally in the Lycospora interval. Densosporites sphaerotriangularis is also seldom observed from the top of segment 8 to the top of segment 10, where it again appears in abundance ranging up to nearly 10%. Florinites mediapudens is virtually the only gymnosperm-related taxon seen in the Lycospora interval; it increases slightly in abundance over the numbers encountered in the Densosporites-

Crassispora interval.

The Lycospora interval is characterized also by a reduction in the diversity of the miospore population. Triquitrites spp. virtually disappear, as do a number of fern-related taxa important in the Densosporites-Crassispora interval (e.g., Cyclogranisporites minutus, Granulatisporites adnataoides, Lophotriletes spp., Acanthotriletes triquetrus). The total miospore profile, categorized by major plant-group affinities, is shown in fig. 8. It reveals that changes in the flora throughout peat deposition tend to be reflected most strongly by various lycopsid-related miospores, whereas certain other plant groups, particularly sphenopsids, appear to have remained constant throughout the existence of the coal swamp. In addition to the sphenopsid-related miospores (Calamospora spp., larger Laevigatosporites spp., Vestispora spp.), the more uniform components of the miospore flora include Cappasporites distortus and a group of miospores believed related to marattialean ferns (smaller Laevigatosporites spp., Punctatisporites minutus, Torispora securis).

PALEOECOLOGICAL INTERPRETATION OF MIOSPORE PROFILES

A primary interest of this study is the evaluation of the floral paleoecology of the coal swamp as recorded in its miospore profile. The progression of peat deposition through changing environmental conditions may have had an influence on certain physico-chemical features of the coal, such as its sulfur content; stratigraphic relations of coal seams may also be clarified through comparison of the miospore profiles of seams to their overall population frequencies. These points will be discussed in more detail shortly.

In order to interpret the paleoecology of the seam from its miospore profile, several questions must be answered: How much is known of the paleobotanical affinities of dispersed miospores in the Pennsylvanian? How accurately does the dispersed miospore population record the actual local plant community? How reliable are analogies between modern environments and the plant fossil record of the Pennsylvanian? What were the paleoecological preferences of the various Pennsylvanian plant groups?

Many major miospore genera have been associated directly with major plant groups through paleobotanical studies; as related to the miospore population of CP-19-4, these affinities are discussed in the Taxonomy. Genera with known plant affiliations include nearly all of those quantitatively important in CP-19-4. It must be noted, however, that miospore genera are based on morphological characteristics, and do not imply phylogenetic affinity of the various species assigned to them. Some genera (e.g., Punctatisporites, Laevigatosporites, Cyclogranisporites), are known to contain species of varied phylogenetic affinities; others (e.g., Granulatisporites) probably do as well. Nonetheless, many important genera (e.g., Calamospora, Lycospora) have been correlated repeatedly with
Figure 8. Total mioseopore profile of CP-19-4, with taxa keyed to major plant groups according to known paleobotanical affinities.
particular plant groups, and others (e.g., *Vestispora*) display morphologies so distinctive that it is likely the form genus reflects a phylogenetically related group of species.

Certain gross miospore morphologies appear to be characteristic of major plant groups, although interpretations based on simple physical characteristics must be approached with caution. Many round to sphaerotriangular trilete spores with conspicuous cinguli or similar equatorial structures (e.g., *Lycospora*, *Densosporites*, *Cirratriradites*) are known to be of lycopsid origin. Small deltoid trilete spores of various ornamentation (e.g., *Leiotriletes*, *Lophotriletes*) have been associated consistently with ferns, suggesting that a similar genus such as *Anapiculatisporites*, which has never been reported in situ, is probably fern-related also.

The parent plants of many genera presently remain unknown, although future paleobotanical study seems certain to resolve some of these mysteries. Some distinctive spores (e.g., *Cadiospora*, *Reinschospora*) have not been isolated from fructifications; others (e.g., *Alatisporites*) have been observed in situ, but the affinities of the fructifications are uncertain (Courvoisier and Phillips, 1975).

Study of modern pollen suggests proceeding with caution in interpreting the paleoecological significance of miospore form species and form genera. The taxonomic level to which one can distinguish pollen from modern plants varies widely from group to group. Pollen of the various major species of walnuts (*Juglans*) ordinarily can be differentiated; pollen of the major species of elms (*Ulmus*) cannot. Both genera contain species that grow in the family level to which one can distinguish pollen from modern plants, but the affinities of the fructifications are uncertain (Courvoisier and Phillips, 1975).

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Preservation—Modern pollen grains are affected differentially by physical and chemical decomposition of organic detritus (Sangster and Dale, 1961), and ancient miospores probably suffered in a similar manner. Examples exist in modern pollen studies where certain grains, for instance *Populus*, are not preserved, or are destroyed during sample preparation (Erdtman, 1969). This phenomenon may occur with pre-Quaternary samples as well. Some taxa with thinner exines are normally found in torn or folded condition, while thicker or more compact miospores are usually better preserved. Unidentifiable fragments of exine found in most samples are more likely to be pieces of diaphanous genera such as *Calamospora* or *Cappasporites* than they are to be from *Densosporites* or *Triquitrites*. Large saccata taxa such as *Endosporites* and *Florinites* often can be identified at least to the generic level from partial specimens; a consistent criterion must be applied for identification of individual specimens in such cases.

Spore preservation in CP-19-4 generally was excellent. Minor corrosion of grains was noted in the upper third of the seam, though it was not severe enough to prevent identification of well-oriented specimens.

Coals of the North American Midcontinent commonly exhibit poorer preservation in upper portions of seams than in lower portions (L. R. Wilson, personal communication, 1977), perhaps due to slight oxidation related to sediments overlying the coal seam. The exine degradation in CP-19-4 is not believed to result in significant selective loss of taxa, though this possibility must not be discounted. The presence throughout the seam of miospores such as *Cappasporites distortus*, which has a thin and easily broken exine, argues against major preservational bias between different horizons of CP-19-4.

Miospore rain—The relationship of the miospore population to the contemporaneous flora at any given time is difficult to assess. The tool of the Quaternary palynologist, comparison of the pollen rain to the extant plant population of a particular environment, is not available for study of Paleozoic deposits. Even in Quaternary studies, projection of a local or regional plant community from a pollen record is difficult and often speculative (Moore and Webb, 1978). It is necessary, therefore, to deal with numbers of various miospores as relative amounts, and to take into consideration the possibility that abundant spore producers in the Pennsylvania may bias a given miospore population disproportionately to their actual presence in the coal swamp.

An assumption central to interpretation of paleoecology on the basis of dispersed spores is that the spore population is derived dominantly from the contemporaneous flora of the local environment, i.e., as sediment, the spores are autochthonous. By analogy with studies of modern pollen rain, it seems probable that the quantitative influence of miospores from sources other than local or near-local is minor, especially if the Carboniferous peat swamp was a forest (Janssen, 1966). Exceptions may exist, however. The organic sediments of most coals are believed to be autochthonous, although examples of allochthonous or semi-allochthonous coals are known (Hacquebard and Donaldson, 1969). Modern peat-forming environments thought to be similar to Carboniferous coal-forming environments usually do not display great amounts of transport of pollen by moving water, although some has been postulated (Habib and Groth, 1967). In instances of large-scale transport, miospores are subject to oxidation and tend to be poorly preserved. Other indications of sediment transport (e.g., significant amounts of fusain) are often present (Hacquebard and Donaldson, 1969).

Aerial transport of miospores into the peat swamp from adjacent areas is another potential source of difficulty in paleoecological interpretation. Observations of modern forests indicate that pollen from distant sources does not contribute greatly to the total pollen rain (Faegri and Iversen, 1975), though individual grains can be transported great distances (Maher, 1969); some rare grains in Paleozoic sediments may have been transported in this manner. The situation in environments of more open vegetation, such as open moors and marshes, is less clear. Pollen rain from an adjacent forest can be significant, but the pollen production of modern marshes and grassy environments also can exceed that of forests.
(Faegri and Iversen, 1975), tending to dilute allochthonous pollen contribution.

Few studies have been done comparing microfossils with macrofossils in Carboniferous coals. Those that exist (e.g., Phillips, Peppers, Avcin and Laughnan, 1974) indicate a good correlation between the miospore content and the macrofossil content of many coals. Similar results have been obtained in comparisons of Quaternary palynology and macrofossil study of autochthonous sediments (Watts and Winter, 1966; Baker, 1976; Van Zant, 1976). Studies of extant flora and pollen production (e.g., Davis and Webb, 1975) suggest that the relationship of pollen rain to flora generally is close, and the quantitative effect of pollen grains foreign to the flora is minimal. In the absence of other evidence or anomalies, the miospore population of most coals is believed to reflect accurately the contemporaneous local flora. A thorough discussion of the transport problem in deposition of pollen and spores may be found in Tschudy (1969).

Modern environmental analogs—Determination of modern analogs to Carboniferous coal swamps has been a matter of controversy and debate for many years. Our limited knowledge of plant group affinities of miospores and of the paleoenvironmental tolerances of ancient plants restricts direct comparisons of Carboniferous miospore successions with palynological profiles of recent peat swamps. Without postulating an exact environmental analog, it is possible through study of modern swamps to suggest the potential lateral and vertical variation in miospore populations and petrographic character of coals in areas as complex stratigraphically as the Lower Cherokee Group of Iowa.

Cohen (1974) described and illustrated spatial variation in peat-forming environments and corresponding plant communities within the Okefenokee Swamp in Georgia. The swamp complex consists basically of shrub-and-tree swamps, unforested marshes or “prairies” with standing water and floating vegetation, sand islands, and open-water lakes. Cohen related these variations to pre-swamp topography, and noted that they had changed little in basic extent and character through the history of the swamp. He also observed a basal zone of charcoal and abundant siliceous sponge spicules, and suggested that it indicated a period of peat oxidation before the peat now present began to accumulate. A phenomenon similar to this could produce high-silica, fusain-rich layers in Carboniferous coals, such as segment 4 of CP-19-4.

Comparison of a pollen diagram with a petrologic study of peat from the Whitewater Bay area near Cape Sable, southern Florida (Cohen and Spackman, 1972) revealed a strong correlation between palynological and petrological characteristics. Similar observations were made by A. H. V. Smith (1957, 1962) and other workers on Carboniferous coal seams. In contrast to the Okefenokee Swamp study (Cohen, 1974), Cohen and Spackman (1972) noted that both the petrology and the palynology of the southern Florida swamp peat recorded a number of environmental alterations through time, including a major shift from fresh-water peats near the base to salt-water peats above.

Spackman, Riegel and Dolsen (1969) described lateral relations of various peat-forming environments in the same region. They noted that a few inches difference in elevation relative to the water table often resulted in considerable differences in vegetation and organic sedimentation. Variations in the spore-pollen content of surface samples in the Whitewater Bay area were observed previously by Spackman, Scholl and Taft (1964), who distinguished associations of certain plants with marine (Rhizophora, Avicennia), brackish (Conocarpus, Polypondium, Taxodium, Typha, Cyperaceae, Compositae) and fresh-water (Ovoidites, Pinus, Nymphaea, Sagittaria, Cephalanthus, Chenopodiaceae) environments. Spackman, Cohen, Given and Casagrande (1974) observed correlative petrographic variations in the peat at several localities in the Whitewater Bay area. Palynological analyses were not performed on all localities, but, if the observations of Cohen and Spackman (1972) apply, similar correlative variations in the spore-pollen content of the peats reflecting changing environments might be expected. A form of “event stratigraphy” recorded by changes in the palynological content of the peat might allow correlation between localities even when total pollen populations vary widely at separate localities due to local environmental factors.

CARBONIFEROUS MIOSPORE SUCCESSIONS

The most extensive previous investigations of miospore successions in Carboniferous coal seams are those of A. H. V. Smith (1957, 1962) on the Coal Measures of Great Britain. Smith (1957) presented a depositional model for the British coal swamps based on correlation of coal petrography with miospore assemblages. As the coals he studied span the stratigraphic horizon represented by CP-19-4 and contain many of the same miospore taxa, a comparison of Smith's (1957) model and the miospore succession of CP-19-4 is in order.

Smith (1957) described a series of miospore “phases” which tended to occur in a particular order in the British coal seams. These he labeled “Lycospore”, “Transition”, “Densospore” and “Incursion”. The Lycospore and Densospore Phases were named after their respective dominant miospore genera. The Transition Phase was, as its name implies, transitional in miospore content and, presumably, in paleoenvironment between the Lycospore and Densospore Phases. The Incursion Phase was believed to be a record of a period of inundation of the swamp by fresh water. Smith (1957) observed that the Lycospore Phase always occurs at the base of British coal seams, and that the Lycospore and Densospore Phases never occur vertically adjacent to one another; the Transition Phase always intervenes. The Incursion Phase is an irregular component which might be found anywhere within a seam. The Lycospore-Transition-Densospore-Transition-Lycospore sequence might be repeated any number of times, with two or more Lycospore or Densospore Phases repeated around a Transition, and with Incursion Phases randomly present.
Petrographically, the Lycospore Phase is associated with "bright coal" (vitrain) and the Densospore Phase with "dull coal" (vitrain-durain); these associations were recognized by earlier workers (e.g., Knox, 1942) in less formal ways, and are consistent with the gross petrographic character of the various intervals of CP-19-4 (see figure 3). It is tempting to equate Smith's (1957) Lycospore Phase with both the Florinites and Lycospora intervals of CP-19-4, his Densospore Phase with the Densosporites-Crassispora interval, and his Transition Phase with the two silica-fusain rich units (segments 4 and 9); an Incursion Phase might be considered perhaps as the cause of the vertically-restricted occurrences of rare taxa in the Florinites interval. However, although similarities exist in the distributions of some major taxa (e.g., Densosporites sphaerotriangularis), between Smith's (1962) model and CP-19-4, there are many important differences: Crassispora kosankei is an important component of the Densosporites-Crassispora interval of CP-19-4, but Smith (1962) considered it characteristic of his Incursion Phase; Lycospora granulata dominates the Lycospora interval of CP-19-4, but is a Transition Phase species in the British coals. Certain species (e.g., Dictyotritieae bireticulatus, Verrucosisporites spp., Apiculatisporis abditus) are much more abundant in the British coals than in CP-19-4; others significant to CP-19-4 (e.g., Cappasporites distortus, Triquiritieae spp., Potonieisporites elegans) are not mentioned in Smith's (1962) report. Gymnosperm-related miospores are much more abundant in the miospore population of CP-19-4 and other Iowa coals than they appear to be in the British coals. Smith (1962) also stressed the importance of making paleoecological interpretations on the basis of species level taxonomy. The various species of the genus Densosporites, for example, do not occur in association with the same miospore phase in the British coals. A similar observation may be made for the two major species of Lycospora in CP-19-4 (fig. 7). A number of investigations of the paleoecology of coal seams have relied on the abundances of both these genera as taxonomic units with no note of species profiles.

Several other miospore successions have been studied by various workers in different geographical regions (Habib and Groth, 1967; Habib, 1968; Hacquebard and Donaldson, 1969; Kovalchuk and Uziyuk, 1973; Wilson, 1976). A variety of miospore succession patterns has been revealed. The likelihood emerges that coal swamps in local paleoecographical regions had different floral and sedimentological successions, influenced by a variety of tectonic, climatic and seral factors. The swamps may have originated and been terminated by a number of different mechanisms, and no single model will serve to explain all or even most of the paleoecological successions.

Our knowledge of the actual paleoecology of Carboniferous plants is extremely limited. Evidence regarding paleoenvironmental conditions of ancient floral communities is largely drawn through inference and is equivocal. Analogies drawn between fossil and recent plants based on apparent similarity of structures or presumed habitat must be approached with caution (Scott, 1977).

Disagreement exists over the paleoenvironmental relationships of the major plant groups reflected in the miospore successions. Neves (1958) suggested that the cordaites, represented by the distribution of Florinites, were marine-margin plants; Chaloner (1958c), employing the same data, argued that the cordaites were upland plants. Later, Chaloner (1968) suggested climatic control as a possible factor in cordaite distribution, as well. A similarity of root structure led Cridland (1964) to postulate a potential similarity of ecology between certain cordaites and modern mangroves. Other cordaite species appear to have had more upland habitats (Cridland and Morris, 1963). The rise of the gymnosperm-dominated florals of the Upper Pennsylvanian and Permian has been connected to the probable upland habitat of many earlier Pennsylvania gymnosperms (Frederiksen, 1972).

As another example, Smith (1968) attributed the development of his Densospore Phase to the seral buildup of peat above the water surface, allowing plants favoring drier conditions to colonize the swamp. In contrast, Habib and Groth (1967) believed the upward increase in abundance of Densosporites in the Lower Kittanning Coal to indicate a change from a fresh- to a brackish-water environment as marine waters encroached upon the swamp during transgression. Their argument was based on comparison of the miospore distribution in their coal to palynological successions observed in the peat of the Whitewater Bay area (Spackman, Dolsen and Riegel, 1966), and suggests a mangrove-like role for the Densosporites-lycopods.

Owing primarily to lack of data, these and other similar interpretational problems remain unresolved. Detailed discussions of the major environmental controls on coal-swamp development may be found in Smith (1962) and Chaloner and Muir (1968).

**INTERPRETATION OF CP-19-4**

**Palynology and Paleoecology**

Based on the gross physical properties of the seam and on inferences drawn from other Carboniferous coals and modern peat swamps, the following working hypothesis is proposed to account for the miospore succession in CP-19-4:

**Stage 1**—Peat developed initially in an environment conducive to rapid variation in plant communities and/or occasional influx of miospores from an environment outside the immediate locality. Certain horizons in the lower portion of the seam contain miospores rare to absent elsewhere (e.g., level 1Z, which contains Dictyotritieae reticulocingulum, Reinschospora triangularis, and Alatisporites pustulatus). The predominance of Florinites mediapudens, Pityosporites westphalensis, Potonieisporites elegans and other gymnosperm-related taxa, plus Endosporites globiformis, indicates that the local flora was dominated by cordaites and Endosporites-producing lycopods. This flora is similar to that found in shales immediately beneath the Lower Kittanning Coal by Habib and Groth (1967). Various tree ferns (represented by Punctatisporites minutus, Laevigatosporites globosus and other species) and lepidodendrons (Lycospora pellucida) were also...
prominent. Abundant fusain fragments in the lowermost samples suggest the possibility of a period or periods of peat destruction during the early stage of swamp development; a similar phenomenon has been noted in certain modern peat swamps (Cohen, 1974).

Two major possibilities, or a combination of the two, could account for the high diversity and rapid changes in minor elements of the miospore population during peat deposition: (1) Fluctuations in water level may have caused rapid changes in the local plant community; (2) An occasional environmental event, such as a storm or flood, may have contributed a brief pulse of allochthonous miospores from regions outside the peat swamp, and mixed them with miospores from the local flora. The first case resembles the situation observed by Spackman, Riegel and Dolsen (1969) in the Whitewater Bay area of southern Florida, where considerable differences in flora from one locality to another are controlled by relatively small differences in elevation with respect to the water table.

Stage 2—A concentration of fusain and a high silica content (possibly a residual concentrate) suggest a period of drier conditions which resulted in partial peat destruction and/or a reduced rate of peat accumulation during the time represented by segment 4 of CP-19-4. Significant changes in both major and minor elements of the miospore population support the likelihood of a major environmental change, although it is not possible from the miospore population alone to determine the exact character of the alteration of environment.

Stage 3—A period of more open marsh conditions is suggested by the abundance of *Densosporites sphaerotriangularis* (herbaceous lycopod), *Cyclogranisporites minutus*, *Lophotriletes* spp., *Granulatisporites* spp., (small ferns) and *Triquirites* (probable small ferns) in segments 5 through 8. Herbaceous plants appear to be more strongly represented in the miospore population of the *Densosporites* interval than they are in other portions of the seam. Miospores known to have affinities with arboreous plant species are present, however, particularly the lycopod represented by *Crassispora kosankei* (Sigillaria: Courvoisier and Phillips, 1975). Perhaps these latter plants were more suited to open growth than were lepidodendrons (*Lycospora*), which appear to have been closed-forest plants; *Lycospora* is poorly represented in the miospore population until segments 7 and 8, when *L. pellucida* becomes the dominant miospore species. *Densosporites sphaerotriangularis* and the small fern-related miospores conversely decrease in abundance in segments 7 and 8. These changes are relatively gradual, and appear to record the encroachment of a more forested swamp into the open marsh.

Several hypotheses have been proposed to account for horizons that show abundant *Densosporites* in other coals, ranging from a lowering of the water table in the swamp (Smith, 1962, 1968) to increased salinity during a marine transgression (Habib and Groth, 1967). Again, from the miospore succession alone, it is not possible to determine which of these hypotheses is more applicable, or if other paleoecological factors were involved. Correlation of palynology with other lines of inquiry, such as petrography and geochemistry, might be of assistance in interpreting the depositional environments of such palynologically distinct horizons within coal seams.

Stage 4—A second period of partial peat destruction and/or slowed accumulation similar to that of Stage 2 is recorded in segment 9 of CP-19-4. The change in composition of the miospore assemblage in this instance is very abrupt, occurring at the top of segment 9. The sudden shift in dominant species of *Lycospora* from *L. pellucida* to *L. granulata* has been discussed previously in the Description of CP-19-4. The abruptness of this and other changes noted in the miospore population at this horizon indicates a period of peat destruction or non-accumulation during which the character of the local flora changed.

Stage 5—The final major stage of peat deposition appears to have taken place in a relatively stable forested swamp. Lepidodendrons (*Lycospora granulata*) dominated the flora, and the diversity of plants was reduced. Few changes in the miospore succession are recorded in segments 10 and 11 of CP-19-4. *Densosporites sphaerotriangularis* does become abundant again in segment 11, possibly indicating development of more widespread areas of herbaceous vegetation within the forest, although the other herbaceous plant miospores common to Stage 3 do not return in abundance. Cordaites (*Florinities mediapudens*) and Endosporites-producing lycopods were moderately abundant, and sphenopsids (*Calamospora, Laevigatosporites* spp.) were somewhat reduced in number.

**STRATIGRAPHIC POSITION OF CP-19-4**

The miospore population of CP-19-4 indicates an age equivalent to the Pope Creek Coal of Illinois (Peppers, personal communication, 1977), the uppermost coal of the Abbott Formation, which is conventionally correlated to the uppermost Atoka Series of the Midcontinent (Willman et. al., 1975). Stratigraphic relationships between Atoka and the overlying Des Moines Series are poorly known, but the miospore biostratigraphy of CP-19-4 and other coals from Iowa Geological Survey core holes suggest an older age for the lower portion of the Pennsylvanian section in southeast and south-central Iowa than was thought previously.

A number of relatively rare miospore species were observed in CP-19-4 which appear to be at or near the upper limit of their range in comparison to the Illinois Basin, and to other coals in Iowa. These taxa include *Endosporites stapolini*, *Dictyotriletes bireticulatus*, *Radizonates cf. difformis*, *Densosporites anulatus* and *Cristatisporites indignabundus*. Certain species, e.g., *Densosporites irregularis* and *Waltzispora sagittata* were observed in CP-19-4 above their previously reported stratigraphic ranges; it is possible that these taxa were re-deposited from older sediments, although the source of such sediments is problematical. It seems more likely that these spores represent rare local plants in or adjacent to the coal swamp. Similar circumstances certainly existed for rare species observed well below their previously reported ranges, e.g., *Platyssaccus saarenensis* and *Atumancisporites stratus*. As the palynology of coals from the stratigraphic horizon represented by CP-19-4 has not been described extensively from the Midcontinent,
seemingly anomalous occurrences such as these are not surprising.

Several other taxa appear to have narrow ranges of occurrences in Iowa, confined to one or two coals in the lower portions of other cores; these include Zosterosporites triangularis, Peppersites ellipticus, Wapellites variabilis, Pseudoillinites diversiformis, Adelisporites multiplices, Cuneisporites rigidius, and Tetanisporites granulatus. Ordinarily, the absence of certain miospores from the population would be regarded as negative evidence of dubious value, but as the miospore population of CP-19-4 was examined much more exhaustively than are most samples (22,000 spores counted plus scanning of several hundred slides for rara taxa), the absence of taxa known to become prominent in coals only slightly higher in the section is also considered diagnostic. Conspicuous by their absence were such species as Vesicaspora wilsonii Schemel 1951, Micoreticulatisporites sulcatus (Wilson and Kosanke Smith and Butterworth 1967, Schopfites dimorphus Kosanke 1950, S. colchesterensis Kosanke 1950, Cadiospora magna Kosanke 1950, Mooreisporites inusitatus (Kosanke) Neves 1952, Murospora kosankei Somers 1952, and Thymospora pseudothissenii (Kosanke) Wilson and Venkatachala 1963; a species somewhat similar to the latter was observed (Plate 16, figs. 2-4), but was very rare. Species mentioned above are not described and illustrated in this report, but will be in a forthcoming study dealing with stratigraphic range of miospores in the Cherokee Group coals, (Iowa Geological Survey Technical Paper 7, in preparation).

Finally, the overall population frequencies of abundant taxa such as Lycospora granulata, L. pellucida, Cappasporites distortus, Punctatisporites minutus, Laevigatosporites globosus, L. ovalis, Endosporites globiformis and Florinites mediapudens (as noted in diagrams and data table) are typical of the lower Des Moines-upper Atoka interval in the Illinois Basin (Peppers, personal communication, 1977). The miospore assemblage described above is present in equivalent coals from other Iowa Geological Survey cores, and is easily distinguished from those found in horizons both above and below. It appears to be one of the more persistent and laterally continuous in the Iowa section studies so far and is frequently of potential economic thickness, although other factors such as thickness of overburden and sulfur content will affect minability. The coal provides one of the best defined biostatigraphic horizons for subsurface correlation of the lower Cherokee.

On the basis of its palynology, CP-19-4 correlates with the coals indicated in fig. 9, the same diagrammatic cross-section of cores shown in fig. 3, with proposed correlations added. CP-19-4 represents the lower of two persistent seams that occur in a close relationship in many of the cores studied in the course of the drilling project. One or the other of these seams occasionally is absent (as in CP-17), perhaps because of a channel cut-out or some other post- or syndepositional factor; the absence of the upper seam in CP-19 appears to result from post-depositional erosion. The palynological character of these two seams is similar, and when only one is present, distinction of the stratigraphic relationship is difficult on the basis of the total miospore population.

CONCLUSION

A series of events is reflected in the miospore profile of CP-19-4. This palynological record of depositional events may differ from that of another coal seam, even though total miospore populations averaged over the total thickness of each seam (i.e., channel-sampled) may be similar. The miospore profile of a seam may relate additionally to a larger progression of depositional environments as might be expected during phases of marine transgression or regression common to the Pennsylvanian of the North American Midcontinent. These phases of deposition, in turn, may exert significant control over physico-chemical characteristics of coal seams, such as their sulfur and trace-element contents. Such potential relationships between the palynology of coals and other characteristics remain virtually unexamined.

Sampling intervals as fine as those employed in the analysis of CP-19-4 probably are not necessary in order to determine only the major characteristics of miospore profiles of coal seams. Following the initial research on CP-19-4, procedures were established at the Iowa Geological Survey Coal Division whereby coal cores are routinely split into benches ranging from 4 to 12 cm. (1.6 to 4.7 inches) in thickness. These benches are crushed individually and portions are removed and combined to create a composite sample for each seam, which is then processed for palynology. After evaluation of the composite (essentially a channel) sample, bench samples may be processed and examined as appropriate for resolution of specific problems. Data from these examinations are on open file at the Iowa Geological Survey, and are being employed for stratigraphic correlation within the Cherokee Group. Reports on correlations within specific study areas are in preparation and will be published as the project proceeds.
Figure 9. Correlated cross-section from figure 3, with seam correlations based on palynological data.
TAXONOMY

Generic classification follows the system of Potonié and Kremp (1954, 1955, 1956), except for those genera described subsequently by others.

No formal taxonomic classification of miospores is attempted above the generic level, although for convenience of comparison with other literature, the organization of taxa generally follows that of Smith and Butterworth (1967) and Peppers (1970). The author agrees with the objections expressed by Schopf (1969) to form taxonomy above the level of the genus; thorough discussions of the intricacies of miospore systematics and nomenclature may be found in Smith and Butterworth (1967) and Schopf (1969).

Comparison of palynological studies is not always easy due to differences in reporting techniques employed by various investigators (Turnau, 1978). This is particularly vexing in comparison of the occurrence of less abundant species. Some investigators have chosen to disregard rare miospores in making stratigraphic or palaeoecological interpretations of miospore assemblages, although the experience of Quaternary palynologists suggests that proper evaluation of palynological samples must include consideration of scarce taxa as well as abundant ones (Moore and Webb, 1978). As this report and its companion paper (Ravn, IGS Technical Paper 7, in preparation) are intended as basic reference reports, both are designed to be as comprehensive in description of the Iowa Pennsylvanian miospore assemblages as is reasonably possible. A major concern of the studies has been to assess the relative utility of the various miospore taxa for stratigraphic purposes in Iowa; notes concerning the stratigraphic usefulness (or lack thereof) of each miospore species described will be given in Technical Paper 7.

Only those species observed in CP-19-4 are noted in this report. Other miospore species important to correlation of Iowa coals which occur at different stratigraphic horizons will be described in future publications. In a few instances, specimens from coals other than CP-19-4 have been illustrated for comparison, or because they demonstrated more clearly the diagnostic characteristics of proposed new taxa.

As floral paleoecology of the coal swamp is a principal concern of this paper, notes are made of the known affinities or affinities of the miospore genus as it is applied to indicate relative abundance are modified and expanded from Smith and Butterworth (1967) as follows:

<table>
<thead>
<tr>
<th>Size</th>
<th>Common</th>
<th>Rare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abundant</td>
<td>10.0-25.0%</td>
<td>0.5-2.0%</td>
</tr>
<tr>
<td>Frequent</td>
<td>2.0-5.0%</td>
<td></td>
</tr>
<tr>
<td>Dominant</td>
<td>Greater than 25.0%</td>
<td></td>
</tr>
<tr>
<td>Infrequent</td>
<td>Less than 0.5%</td>
<td></td>
</tr>
</tbody>
</table>

The general distribution of each miospore species within CP-19-4 also is noted. Those species indicated simply as "Rare" without subsequent modifying comment were considered to be too few in number to assess the characteristics of distribution meaningfully. Specific information on the occurrence and abundance of all miospore species in seam CP-19-4 may be found in Appendix II.

Genus LEIOTRILETES (Naumova) Potonié and Kremp 1954

Type species—L. sphaerotriangulus (Loose) Potonié and Kremp 1955.

Discussion—Genus Leiotriletes encompasses trilete, deltoid miospores having laevigate external surfaces, though they may on occasion bear fine infrasculpture. The Mesozoic genera Deltioidospora Miner 1935 and Cyathidites Couper 1953 are very similar, but the name Leiotriletes is in general use for miospores of this type from the Paleozoic.

Affinity—Filicales (Remy and Remy, 1957; Potonié, 1962); coenopterids (Good, 1979).

Leiotriletes guennellii nom. nov. emend.

(Plate 1, fig. 1)

1958 Leiotriletes parvus Guennel, p. 57, text-fig. 14, pl. 2, fig. 7, 8.
1953 Leiotriletes parvus Naumova, p. 44, pl. 5, fig. 10.
1958 Leiotriletes parvus Nilsson, p. 30, pl. 1, fig. 1.

Diagnosis—(emended from Guennel, 1958, p. 57) Miospores radial, trilete, triangular in equatorial outline, usually in good proximal-distal orientation. Interradial margins straight to slightly concave, angles rounded. Laesaurea straight, extend 1/2 to 3/4 to margin. Lips present, thin, sometimes indistinct. Exine laevigate both externally and internally, relatively thin, seldom folded.

Size—(from Guennel, 1958, p. 57) 16-28 microns maximum diameter.

Discussion—L. parvus Guennel 1958 appears to be a junior homonym of the Mesozoic L. parvus Nilsson 1958 (Nilsson is one of the few Mesozoic palynologists to employ the generic name Leiotriletes), necessitating the adoption of a new name for the species. L. parvus Naumova 1953 is also a homonym, but Naumova’s names were not erected in accordance with provisions of the International Code of Botanical Nomenclature and are generally considered invalid among Western workers, although many (e.g., genus Leiotriletes) have been validated through emendation by later investigators.

Loboziak (1971) considered L. parvus Guennel 1958 to be synonymous with L. subadnatoides Bharadwaj 1957, but the latter species is described as "intra-punctate" (Bharadwaj, 1957a), whereas specimens observed in CP-19-4 display no internal ornamentation, even under a high-power oil immersion.
objective. The emendation of Guennel's (1958) description of L. parvus is made to clarify and emphasize the absence of ornamentation of L. guennelii. The small size distinguishes L. guennelii from the larger L. priddyi (Berry) Potonie and Kremp 1955.

**Derivation**—The specific name is proposed in recognition of G. K. Guennel, who originally described the species.

**Occurrence**—Rare. 

**Leiotriletes levis** (Kosanke) Potonie and Kremp 1955  
(Plate 1, figs. 4, 8)

1950 Granulati-sporites levis Kosanke, p. 21, pl. 3, fig. 5.  
1955 Leiotriletes levis (Kosanke) Potonie and Kremp, p. 38.  
1966 Ahrensisporites vagus Habib, p. 640, pl. 106, fig. 5.

**Discussion**—L. levis differs from the type species, L. sphaerotriangulus (Plate 1, fig. 3), in the possession of conspicuous thickened areas around the trilete mark.

**Occurrence**—Rare, lower portion of the Florinites interval.

**Leiotriletes priddyi** (Berry) Potonie and Kremp 1955  
(Plate 1, fig. 2)

1937 Zonales-sporites priddyi Berry, p. 156, text-fig. 2.  
1944 Granulati-sporites (?) priddyi Schopf, Wilson and Bentall, p. 33.  
1950 Planisporites priddyi (Berry) Knox, p. 316, pl. 17, fig. 220.  
1955 Leiotriletes priddyi (Berry) Potonie and Kremp, p. 38.

**Discussion**—As noted by Smith and Butterworth (1967), the original description and illustration of this species are inadequate for proper comparison. Nonetheless, the general size range and dimensions given by Berry (1937) and modified through usage of later workers cover forms of Leiotriletes not assignable to other described species. In practice, during study of CP-19-4 and other Iowa coals, forms ranging in maximum diameter from 28 to 36 microns, and having straight to convex interradial margins are assigned to L. priddyi.

**Occurrence**—Rare, observed most often in the Florinites interval.

**Leiotriletes sphaerotriangulus** (Loose) Potonie and Kremp 1955  
(Plate 1, fig. 3)

1932 Sporonites sphaerotriangulus Loose in Potonie and Ibrahim, p. 451, pl. 18, fig. 45.  
1933 Leovolati-sporites sphaerotriangulus (Loose) Ibrahim, p. 20.  
1944 Punctati-sporites sphaerotriangulus (Loose) Schopf, Wilson and Bentall, p. 31.  
1950 Planisporites priddyi (Berry) Knox, p. 316, pl. 17, fig. 214.  
1954 Leiotriletes sphaerotriangulus (Loose) Potonie and Kremp, p. 120.  
1955 Leiotriletes sphaerotriangulus (Loose) Potonie and Kremp, p. 41, pl. 11, figs. 107-109.  
1965a Deloidisporites sphaerotriangulus (Loose) Laveine, p. 131, pl. 10, fig. 6.

**Discussion**—In practice in this report, unornamented forms of Leiotriletes having straight or convex interradial sides and a maximum diameter of 36-50 microns are assigned to L. sphaerotriangulus. The combination L. sphaerotriangulus was proposed by Potonie and Kremp in 1954, but not properly validated until their 1955 publication (Kremp and Ames, 1959).

**Occurrence**—Rare, Florinites interval.

**Leiotriletes turgidus** Marshall and Smith 1964  
(Plate 1, fig. 7)


**Occurrence**—Rare, coaly shale CP-19-5.

**Leiotriletes sp. 1**  
(Plate 1, fig. 5)

**Description**—Radial, trilete, triangular in equatorial outline with distinctly concave interradial margins. Exine laevigate, moderately thin (1.5-2 microns). Laesurae straight, 2/3 to 3/4 of spore radius, angles rounded. Darkened contact area surrounds trilete mark. Size of illustrated specimen 32.5 microns maximum diameter.

**Discussion**—L. sp. 1 resembles L. priddyi in size, but differs in possession of concave interradial margins.

**Occurrence**—Rare.

**Leiotriletes sp. 2**  
(Plate 1, fig. 6)

1970 Leiotriletes sp. 1, Peppers, p. 82, pl. 1, fig. 10.

**Description**—Radial, trilete, triangular in equatorial outline, with straight to slightly concave interradial margins. Exine faintly infrapunctate (?), thin (1.0-1.5 microns), with occasional crescentic folds adjacent to equator near angles. Laesurae straight 2/3 of spore radius, faint contact area may be present. Size of illustrated specimen 31.9 microns maximum diameter.

**Discussion**—This miospore appears to be identical to L. sp. 1 of Peppers (1970).

**Occurrence**—Rare.

**Leiotriletes sp. 3**  
(Plate 1, fig. 9)

**Description**—Radial, trilete, triangular in equatorial outline, inter-radial margins slightly convex. Exine laevigate, possibly infragranulose, thick (about 3 microns) and dark, appearing in compression as a faint equatorial “zona”. Laesurae straight 1/2 of spore radius. Size of illustrated specimen 55.5 microns maximum diameter.

**Discussion**—L. sp. 3 is uncommonly large for the genus.

**Occurrence**—Rare.

**Genus PUNCTATISPORITES** (Ibrahim) Potonie and Kremp 1954

**Type species**—P. punctatus (Ibrahim) Ibrahim 1933.

**Affinity**—Punctatisporites is a broadly defined, generalized form genus encompassing spores of many different plants of fern affinities (Mamay, 1950, 1957; Remy and Remy, 1955a; Abbott, 1961; Pfefferkorn, Peppers and Phillips, 1971; Courvoisier and Phillips, 1975). Miospores conforming to the species P. kankakeensis Peppers 1970 recently have been isolated.
from a pteridosperm fructification (Stidd, 1978). Long (1977a) also illustrated spores possibly corresponding to *Punctatisporites* from a pteridosperm.

*Punctatisporites aerarius* Butterworth and Williams 1958
(Plate 2, figs. 4, 5)

1958 *Punctatisporites aerarius* Butterworth and Williams, p. 360, pl. I, figs. 10, 11.

**Occurrence**—Rare, but widely distributed in the *Florinites* and *Densosporites-Crassispora* intervals.

*Punctatisporites* cf. *curviradiatus* Staplin 1960
(Plate 1, figs. 13-15)


1965 *Punctatisporites curviradiatus* Staplin 1960; Omara and Schultz, p. 52, pl. 24, fig. 5.

**Discussion**—Miospores assigned to *P. cf. curviradiatus* resemble the type description of Staplin (1960), except for being more oval in outline and having the appearance of a narrow zona. Miller (1966) described similar spores with granulose surface, erecting the genus *Circlettisporites* on the basis of the off-polar compression and what he interpreted to be a peculiar sort of zona. Wilson and Venkatachala (1967) determined that the "zona" was merely the appearance of the relatively thick exine in compression, invalidated *Circlettisporites*, and assigned the species erected by Miller (C. dawsonensis) to *Leschikisporis* Potonié 1958; they also assigned another species with an asymmetrical trilete mark, *Punctatisporites obliquus* Kosanke 1950, to *Leschikisporis*. Staplin (1960) noted the similarity of *P. curviradiatus* to species of *Leschikisporis*, but stated that *P. curviradiatus* did not possess the single shortened trilete ray characteristic of *Leschikisporis*; nonetheless, his illustrated specimens appear to possess a shortened ray similar to that observed in *P. curviradiatus*.

Peppers (1970) considered the asymmetrical laesurae to be of insufficient importance to warrant assignment to a new genus and retained *P. curviradiatus* and *P. obliquus* under *Punctatisporites*. Peppers' practice is followed in this report. Specimens of *P. cf. curviradiatus* observed in CP-19-4 and other Iowa coals closely resemble the specimen illustrated by Omara and Schultz (1965) from the Lower Carboniferous of North Africa. *P. resolutus* Playford 1971, from the Lower Carboniferous of Australia, is similar in general aspects to *P. cf. curviradiatus*, but is larger and has a finely granulose infrasculpture.

**Occurrence**—Rare, but widely distributed in the *Florinites* and *Densosporites-Crassispora* intervals.

*Punctatisporites edgarensis* Peppers 1970
(Plate 2, fig. 7)

1970 *Punctatisporites edgarensis* Peppers, p. 82-83, pl. 1, figs. 16, 17.

**Occurrence**—Rare, observed only in coaly shale CP-19-5.

*Punctatisporites* cf. *edgarensis* Peppers 1970
(Plate 2, fig. 8)

**Discussion**—*P. cf. edgarensis* differs from the type in possessing conspicuous, well-defined vermiform to convolute ridges on the distal surface. The occurrence of *P. cf. edgarensis* in CP-19-4 and other Iowa coals does not always coincide with that of *P. edgarensis*, but frequently the two forms are found together. They appear to be morphologically distinct; it is not clear whether *P. cf. edgarensis* should be regarded as a separate species or merely as a variant of the type.

**Occurrence**—Rare, lower levels of the *Florinites* interval.

*Punctatisporites kankakeensis* Peppers 1970
(Plate 2, fig. 2)

1970 *Punctatisporites kankakeensis* Peppers, p. 83-84, text-fig. 12, pl. 2, figs. 2, 3.

**Occurrence**—Rare.

*Punctatisporites minutus* (Kosanke) Peppers 1964
(Plate 1, figs. 10, 11)

1950 *Punctatisporites minutus* Kosanke, p. 15, pl. 16, fig. 3.

1964 *Punctatisporites minutus* (Kosanke) Peppers, p. 31, pl. 4, fig. 7.

1967 *Punctatisporites minutus* Kosanke 1950, Smith and Butterworth, p. 126, pl. 1, figs. 15, 16.

**Discussion**—In this report, assignment of miospores to *P. minutus* adheres to the emendation of Peppers (1964). The spores described and illustrated by Smith and Butterworth (1967) as *P. minutus* Kosanke 1950 do not appear to be the same species.

**Occurrence**—*P. minutus* is abundant throughout CP-19-4, occasionally a dominant species at certain horizons in the *Florinites* interval.

*Punctatisporites nitidus* Hoffmeister, Staplin and Malloy 1955
(Plate 1, fig. 12)

1955 *Punctatisporites nitidus* Hoffmeister, Staplin and Malloy, p. 393-394, pl. 36, fig. 4.

**Occurrence**—Rare.

*Punctatisporites* cf. *nudus* Artúz 1957
(Plate 2, fig. 1)

1957 *Punctatisporites nudus* Artúz, p. 241, pl. 1, fig. 4.

1970 *Punctatisporites* sp. 1 Peppers, p. 84, pl. 2, fig. 8.

**Discussion**—*P. cf. nudus* closely resembles the type description of Artúz (1957), but, as the miospore is spherical, laevigate, and has a thick exine, it resembles a number of other described species as well. The assignment of miospores to this species is made, therefore, with reservation. It appears to be identical to *P. sp. 1* of Peppers (1970).

**Occurrence**—Rare.

*Punctatisporites obliquus* Kosanke 1950
(Plate 15, fig. 7)

1950 *Punctatisporites obliquus* Kosanke, p. 16, pl. 2, fig. 5.


**Discussion**—As noted by Peppers (1970), distinction of *P. obliquus* from *Laevigatosporites globosus* Schemel
1951 is difficult in practice. Peppers employed a size boundary of 30 microns maximum dimension to distinguish the species, *P. obliquus* being the larger. Forms displaying the vestigial third ray were comparatively rare in CP-19-4, whereas monolete forms larger than 30 microns occurred more commonly; orientation of individual grains frequently obscures the laesura such that the possible presence of a third ray is uncertain. The reliability and usefulness of distinguishing the two species for statistical purposes in CP-19-4 was considered questionable; the population figure given for *L. globosus* in the data includes *P. obliquus*. A specimen assignable to *P. obliquus* is displayed on plate 15 adjacent to specimens of *L. globosus* for visual comparison.

**Occurrence**—See *Laevigatosporites globosus* Schemel 1951.

**Punctatisporites** sp. 1

(Plate 2, fig. 3)

**Description**—Miospore radial, trilete, circular in equatorial outline. Laesurae simple, straight, length about ⅓ of spore radius. Exine finely punctate, moderately thick, appearing in compression as a zona approximately 3 microns wide. Size of illustrated specimen 43.3 microns maximum diameter.

**Discussion**—*P. sp. 1* bears resemblances to a number of species of *Punctatisporites*, but is not assignable with certainty to any.

**Occurrence**—Rare.

Genus **PHYLLOTHECOTRILETES** Luber 1955

**Type species**—*P. nigrifellus* (Luber) Luber 1955.

**Affinity**—Unknown.

**Phyllothecotriletes** sp. 1

(Plate 2, fig. 6)

**Description**—Miospore radial, trilete, circular in equatorial outline. Laesurae simple, straight, length less than ½ of spore radius. Exine finely punctate, moderately thick, with round to elongate pits 1-3 microns in maximum dimension and about 1 micron deep, scattered irregularly over the entire surface. Slightly darkened contact area in region of trilete mark on proximal surface. Size of illustrated specimen 102.2 microns maximum diameter.

**Discussion**—*Phyllothecotriletes* sp. 1 is considerably larger than other described species of *Phyllothecotriletes*.

**Occurrence**—Rare.

Genus **CALAMOSPORA** Schopf, Wilson and Bentall 1944

**Type species**—*C. hartungiana* Schopf in Schopf, Wilson and Bentall 1944.

**Affinity**—Various sphenopsids (Arnold, 1944; Delevoryas, 1955; Kosanke, 1955; Remy, 1955; Walton, 1957; D. L. Smith, 1962; Baxter, 1963; Hibbert and Eggert, 1965; Abbott, 1968; Thomas, 1969; Courvoisier and Phillips, 1975; Good and Taylor, 1975; Good, 1976). The studies of Good and Taylor (1975) and Good (1976) have suggested strongly that the morphologic speciation of *Calamospora* is unreliable for stratigraphic utility. Few palynologists in recent years have considered species *Calamospora* as having much stratigraphic significance, and the discussions of the various species in this report indicate the taxonomic difficulties within the genus. Millay (1979) isolated spores from a species of the marattialean fern *Scolecopteris* which, if found in dispersed spore residues, probably would be assigned to *Calamospora*.

**Calamospora breviradiata** Kosanke 1950

(Plate 3, fig. 2)

1950 *Calamospora breviradiata* Kosanke, p. 41, pl. 9, fig. 4.

1957a *Calamospora minutula* Bharadwaj, p. 80, pl. 22, figs. 8, 9.

1950 *Calamospora minutula* Knox, p. 332, pl. 19, fig. 301.

1957a *Calamospora saariana* Bharadwaj, p. 81, pl. 22, figs. 13-15.

1965a *Calamisporites breviradiatus* (Kosanke) Laveine, p. 131.

1966 *Calamisporites minutus* (Bharadwaj) Coquel, p. 17, pl. 1, fig. 15.

**Discussion**—A maximum size boundary of 70 microns is employed in this study to differentiate *C. breviradiata* from the larger *C. hartungiana*; most specimens of *C. breviradiata* were smaller than 65 microns maximum diameter, whereas most specimens of *C. hartungiana* were larger than 75 microns, indicating a bimodal size distribution for the two forms. The darkened contact area common to both species is less pronounced in *C. hartungiana* than in *C. breviradiata*. At the lower end of the size range quoted by Smith and Butterworth (1967, p. 131-132) for *Cf. breviradiata* of 42 microns, no similar natural break occurs, at least in the coal examined for this report. The smaller but otherwise morphologically identical *C. minutula* Bharadwaj 1957 is therefore considered conspecific with *C. breviradiata*. *C. saariana* Bharadwaj 1957 appears indistinguishable from *C. breviradiata*.

**Occurrence**—*C. breviradiata* is the most abundant species of *Calamospora* observed in CP-19-4. It is frequent to common throughout the seam, with greatest abundance in the Florinites interval and lower levels of the Densosporites-Crassispore interval.

**Calamospora hartungiana** Schopf in Schopf, Wilson and Bentall, 1944

(Plate 3, fig. 5)

1944 *Calamospora hartungiana* Schopf, in Schopf, Wilson and Bentall, p. 51-52, text-fig. 1.

1965a *Calamisporites hartungianus* (Schopf) Laveine, p. 131.

1966 *Calamospora elliptica* Habib, p. 632-633, pl. 104, figs. 9, 10.

**Occurrence**—Rare, but widely distributed in the Florinites and Densosporites-Crassispore intervals.

**Calamospora liquida** Kosanke 1950

(Plate 3, fig. 3)

1950 *Calamospora liquida* Kosanke, p. 41-42, pl. 9, fig. 1.

1965a *Calamisporites liquidus* (Kosanke) Laveine, p. 131, pl. 10, fig. 9.

**Occurrence**—Rare.
Calamospora cf. mutabilis (Loose) Schopf,
Wilson and Bentall 1944
(Plate 3, fig. 4)

1932 Calamitis-Sporisporites mutabilis Loose in Potonić Ibrahim
and Loose, p. 451, pl. 19, figs. 50a-c.
1934 Calamitis-Sporisporites mutabilis Loose, p. 145.
1944 Calamospora mutabilis (Loose) Schopf, Wilson and
Bentall, p. 52.
1965a Calamisporites mutabilis (Loose) Laveine, p. 131, pl. 10,
fig. 7.

Discussion—C. mutabilis is somewhat larger than C. hartungiana and is described and illustrated as possessing longer laesurae and no darkened contact area. Spores designated in this report as C. cf. mutabilis possess rather short laesurae and are somewhat thicker and less folded than are specimens referred to C. mutabilis by other authors (e.g., Peppers, 1970, pl. 2, fig. 12). In this study, specimens larger than 75 microns in maximum dimension displaying no darkened contact area were assigned to C. cf. mutabilis.

Occurrence—Rare.

Calamospora nebulosa sp. nov.
(Plate 3, figs. 8-12)

Diagnosis—Miospores radial, trilete, circular in equatorial outline, normally in good proximal-distal orientation. Laesurae straight, with distinct lips, ½ to ¾ of spore radius. Distal hemisphere possesses an irregular thickened region around pole, commonly superimposed through compression upon trilete mark, giving the appearance of a proximal contact area. Crescentic compression folds along equator common, but polar regions seldom folded. Exine moderately thick for the genus, 2-2.5 microns.

Size—(11 specimens) 63-94 microns maximum diameter.

Discussion—C. nebulosa is similar to C. hartungiana in size, but differs in the possession of a distal thickening and the absence of a proximal contact area. The generally good proximal-distal orientation in compression is unusual for the genus and suggests either that the spore originally was subspherical or possibly that the distal thickening may represent a remnant of an attachment structure for elaters (see distal thickening. The distal thickening may represent a remnant of an attachment structure for elaters (see

Genus ELATERITES Wilson 1943

Type species—E. triferens Wilson 1943.

Affinity—Spores of genus Elaterites were first described from an Iowa coal ball (Wilson, 1943), where they were found associated with Calamarian fructifications. Similar reports of Elaterites from Calamitean cones were made from Kansas (Wilson, 1963a) and again from the original Iowa locality (Baxter and Leisman, 1967). More recently, elater-bearing spores have been described from a variety of Pennsylvanian sphenoid fructifications (Good and Taylor, 1974, 1975; Good, 1975, 1976). Good and Taylor (1975) reviewed previous reports of perisporate or elater-bearing spores suggestive of Elaterites and suggested that the dispersed spore genera Calamospora, Elaterites and Vestispora (Wilson and Hoffmeister) Wilson and Venkatachala 1963 may represent ontogenetic stages of phylogenetically similar spores. The similarity of Elaterites and certain species of Vestispora with striate exoexines (e.g., V. costata (Balme) Spode in Smith and Butterworth, 1967; V. lucida (Butterworth and Williams) Potonić 1960; V. colchesterensis Peppers 1970) tends to support their view. Non-striate species of Vestispora (e.g. V. fenestrata (Kosanke and Brokaw) Spode in Smith and Butterworth, 1967; V. luminata (Kosanke 1950) et al., 1977), evaluation of potential phylogenetic and/or ontogenetic relationships between Calamospora, Elaterites and Vestispora is by no means simple.

Elaterites triferens Wilson 1943
(Plate 4, fig. 1)

1943 Elaterites triferens Wilson, p. 518, figs. 1-6.

Discussion—E. triferens has been reported only once previously from macerated coal residues (Peppers, 1970).
Specimens observed in CP-19-4 invariably displayed corroded and torn perispores, suggesting that the elaters and perispores did not withstand conditions of preservation or preparation techniques well. In the absence of the perispore, the main spore body of *E. triferosus* would be assigned to *Calamospora*. It is therefore possible that these spores originally were much more abundant in the spore population than presently recognized. Similar observations were made by Good and Taylor (1975). 

**Occurrence**—Rare.

**Genus ADELISPORITES** gen. nov.

*Type species*—*A. multiplicatus* sp. nov.

**Diagnosis**—Miospores radial, trilete, usually in good proximal-distal orientation. Laesurae raised, sinuous, commonly associated with folds near the margin, tending to support proximal face of grain upon compression, resulting in folds at the margin and on the distal surface, commonly resulting in a more or less hexagonal equatorial outline.

**Derivation**—The generic nomen refers to the inconspicuous appearance of the spore (*adelos* hidden), as it sometimes may be mistaken for a folded fragment of exine, especially at low magnifications.

**Affinity**—Unknown.

**Adelisporites multiplicatus** sp. nov.

(Plate 4, figs. 2-6)

**Diagnosis**—Miospores conforming to the characteristics of the genus. Central region often dark, obscuring laesurae. Exine 1.5-2 microns thick, laevigate. Laesurae often appear as a trilete-shaped fold 2-4 microns, wide; no commissure has been observed.

**Size**—(23 specimens) 21-34 microns maximum diameter.

**Discussion**—The rather irregular morphology of this spore may cause it to pass unrecognized in some samples. It may resemble folded small specimens of *Calamospora*, but it differs in the pseudohexagonal outline. Though not known to be abundant, its occurrence is frequent enough in Iowa coals to have potential stratigraphic utility.

**Derivation**—The specific nomen refers to the much-folded (*multiplicatus*) appearance of the spore.

**Occurrence**—Rare, but widely distributed in CP-19-4, especially in the *Florinites* interval.

**Holotype**—Plate 4, fig. 2, slide 1C2 coordinates 136.5-60, 26.8 maximum diameter.

**Paratype**—Plate 4, fig. 3, CP-19-5 slide B-2 coordinates 137-65, 29.1 microns.

**Paratype**—Plate 4, fig. 4, CP-19-5 slide Z-7 coordinates 128-51, 23.9 microns.

**Paratype**—Plate 4, fig. 5, slide 1C3 coordinates 137.5-45.5, 26.2 microns.

**Paratype**—Plate 4, fig. 6, slide 5H2 coordinates 120-52.5, 23.4 microns.

**Genus VERRUCOSISPORITES** (Ibrahim) Smith and Butterworth 1967

*Type species*—*V. verrucosus* (Ibrahim) Ibrahim 1933.

**Affinity**—Miospores assignable to *Verrucosisporites* have been correlated with a variety of fern fructifications


**Verrucosisporites donarii** Potonie and Kremp 1955

(Plate 4, fig. 7)

1955 **Verrucosisporites donarii** Potonie and Kremp, p. 67, pl. 13, fig. 193.

**Occurrence**—Rare, but widely distributed throughout CP-19-4.

**Verrucosisporites microtuberosus** (Loose) Smith and Butterworth 1967

(Plate 4, fig. 9)

1932 **Sporonites microtuberosus** Loose in Potonie, Ibrahim and Loose, p. 450, pl. 18, fig. 33.

1934 **Tuberculatisporites microtuberosus** Loose, p. 147.

1944 **Punctatisporites microtuberosus** (Loose) Schopf, Wilson and Bentall p. 31.

1950 **Planisporites microtuberosus** (Loose) Knox, p. 316, pl. 17, fig. 211.

1955 **Microreticulatisporites microtuberosus** (Loose) Potonie and Kremp, p. 100, pl. 15, figs. 273-277.

1955 **Microreticulatisporites verrucosus** Potonie and Kremp, p. 102-103, pl. 15, fig. 286.

1959 **Cyclogranisporites pergranulatus** Alpern, p. 142, pl. 2, figs. 55, pl. 3, figs. 56-58.

1964 **Verrucosisporites verrucosus** (Potonie and Kremp) Smith et al., p. 1075, pl. 3, fig. 8.

1967 **Verrucosisporites microtuberosus** (Loose) Smith and Butterworth, p. 149, pl. 5, figs. 9-11.

**Occurrence**—Rare.

**Verrucosisporites sifati** (Ibrahim) Smith and Butterworth 1967

(Plate 4, fig. 10)

1933 **Reticulatisporites sifati** Ibrahim, p. 35, pl. 8, fig. 67.

1955 **Microreticulatisporites sifati** (Ibrahim) Potonie and Kremp, p. 102, pl. 15, figs. 282-285.

1967 **Verrucosisporites sifati** (Ibrahim) Smith and Butterworth, p. 152, pl. 6, fig. 1.

**Occurrence**—Rare.

**Verrucosisporites verrucosus** (Ibrahim) Ibrahim 1933

(Plate 4, fig. 8)

1932 **Sporonites verrucosus** Ibrahim in Potonie, Ibrahim and Loose, p. 448, pl. 15, fig. 17.

1933 **Verrucosisporites verrucosus** (Ibrahim) Ibrahim, p. 25, pl. 2, fig. 17.

1938 **Azonotriletes verrucosus** (Ibrahim) Luber in Luber and Waltz, pl. 7, fig. 95.

1944 **Punctatisporites verrucosus** (Ibrahim) Schopf, Wilson and Bentall, p. 32.

1950 **Verrucosisporites verrucosus** (Ibrahim) Knox, p. 319, pl. 17, fig. 230.

**Occurrence**—Rare, widely distributed in the *Florinites* and *Densosporites-Crasisporites* intervals of CP-19-4.

**Genus KEWANEESPORITES** Peppers 1970

*Type species*—*K. reticuloides* (Kosanke) Peppers 1970.

**Affinity**—Unknown.
Kewaneesporites patulus (Peppers) Peppers 1970
(Plate 4, figs. 11-14)

1964 Punctatisporites patulus Peppers, p. 32, pl. 4, figs. 12, 13.
1970 Kewaneesporites patulus (Peppers) Peppers p. 95.

Discussion—Specimens observed in CP-19-4 did not possess the membrane noted by Peppers (1970). In his generic description, however, Peppers (1970, p. 94) stated that the membrane frequently is absent, due either to preservation or preparational difficulties. Specimens of K. patulus clearly displaying a membrane have been observed in other Iowa coals. Trilites decoratus Gupta 1970 has a similar ornament, but is smaller.

Occurrence—Rare.

Genus CYCLOGRANISPORITES Potonié and Kremp 1954

Type species—C. leopoldi (Kremp) Potonié and Kremp 1955.

Affinity—Various ferns and lyginopterid pteridosperms. Spores of Cyclogranisporites were listed as of pteridosperm affinity by Potonié (1962). Andrews and Mamay (1948) recovered a spore possibly corresponding to the genus from a fern sporangium. Spores resembling C. minutus Bharadwaj 1957 have been isolated from a fern fructification of the Mazon Creek flora of Illinois (Pfefferkorn, Peppers and Phillips, 1971), and spores resembling C. micaceus Imgrund 1960 have been described from a Midcontinent fern fructification (Mapes and Schabilion, 1979). Apparent prepollen or pollen grains corresponding morphologically to Cyclogranisporites have been described from lyginopterid pteridosperm fructifications (Millay and Taylor, 1976, 1977; Millay, Eggert and Dennis, 1978). Hagemann (1966) recovered spores resembling smaller species of Cyclogranisporites from a lycopod fructification, but some of his illustrated specimens appear to possess a faint cingulum, a feature not characteristic of Cyclogranisporites.

Cyclogranisporites aureus (Loose) Potonié and Kremp 1955
(Plate 5, fig. 8)

1934 Reticulatisporites aureus Loose, p. 155, pl. 7, fig. 24.
1950 Planisporites aureus (Loose) Knox, p. 315.
1955 Cyclogranisporites aureus (Loose) Potonié and Kremp, p. 61, pl. 13, figs. 184-186.

Occurrence—Rare to infrequent, widely distributed throughout the Florinites and Densosporites-Crassispora intervals; virtually absent from the Lyceospora interval.

Cyclogranisporites cf. leopoldi (Kremp) Potonié and Kremp 1955
(Plate 5, fig. 2)

1952 Granulatisporites leopoldi Kremp, p. 348, pl. 156, figs. 15, 16.
1954 Cyclogranisporites leopoldi (Kremp) Potonié and Kremp, p.126, pl. 20, fig. 103.

Discussion—The grana of specimens designated C. cf. leopoldi are larger and more conspicuous than those of specimens illustrated by Potonié and Kremp (1955). Although the combination C. leopoldi was first proposed by Potonié and Kremp in 1954, Kremp and Ames (1959) considered the name to be inadequately validated until Potonié and Kremp's (1955) publication.

Cyclogranisporites microgranus Bharadwaj 1957
(Plate 5, fig. 6)

1957a Cyclogranisporites microgranus Bharadwaj, p. 84, pl. 22, figs. 29-32.

Occurrence—Rare.

Cyclogranisporites minutus Bharadwaj 1957
(Plate 5, fig. 1)

1957a Cyclogranisporites minutus Bharadwaj, p. 83, pl. 22, fig. 22-23.

Discussion—C. minutus is distinguished from the similar-sized C. leopoldi by possession of finer, more closely spaced grana.

Occurrence—Rare to frequent in the Florinites interval, generally frequent in the Densosporites-Crassispora interval, virtually absent from the Lyceospora interval.

Cyclogranisporites orbicularis (Kosanke) Potonié and Kremp 1955
(Plate 5, fig. 5)

1950 Punctatisporites orbicularis Kosanke, p. 16, pl. 2, fig. 9.
1955 Cyclogranisporites orbicularis (Kosanke) Potonié and Kremp, p. 60.

Occurrence—Rare.

Cyclogranisporites parvus Bharadwaj 1957
(Plate 5, figs. 3, 4)

1957a Cyclogranisporites parvus Bharadwaj, p. 85, pl. 23, figs. 7, 8.

Discussion—C. parvus is similar in character of ornament to C. minutus, but is commonly somewhat larger and possesses a more or less symmetrical trilete mark with a pronounced darkened contact area.

Occurrence—Rare, but widely distributed in the Florinites and Densosporites-Crassispora intervals.

Cyclogranisporites sp. 1
(Plate 5, fig. 7)

Description—Miospore radial, trilete, apparently spherical in original shape. Laesurae about 1/3 of spore radius, may be asymmetrical, with distinct lips. Exine relatively thin, evenly ornamented with low grana, approximately 1 micron in height, often elliptical in outline, long axis as much as 2 microns, densely packed with bases not quite touching. Crescentic compression folds commonly arranged along equator. Size of illustrated specimen 53.0 microns maximum diameter.

Discussion—The relatively large oval or elliptical grana approach the size and shape of verrucae, making this spore appear transitional between Cyclogranisporites and Verrucosisporites. The character
of the compression folding resembles that of C. provectus (Kosanke) Potonié and Kremp 1955, but the granulose sculpture of the latter species is much finer.

Occurrence — Rare, Densosporites - Crassispora interval.

Genus GRANULATISPORITES (Ibrahim) Potonié and Kremp 1954

_Type species—G. granulatus Ibrahim 1933._

_Affinity—Spores assignable to Granulatisporites have been isolated from Paleozoic and Mesozoic fern fossils (Mamay, 1950; Harris, 1961; Grauvogel-Stamm and Doubinger, 1975; Good, 1979). One species, _G. frustulentus_ (Balme and Hassell) Playford 1971, described from the Australian Lower Carboniferous, is considered a “lycosporoid” element of the spore flora._

_Discussion—This species appears essentially laevigate at lower magnifications, and was interpreted as having a fine granulose infrasculpture by Potonié and Kremp (1955). Smith and Butterworth (1967) noted that examination at higher power under oil immersion revealed the outer surface of the spore to be granulose. The similar species _L. adnatus_ (Kosanke) Potonié and Kremp 1955 is described as finely granulose in the region of the trilete mark; distinction of the two species is very difficult in practice, and they should perhaps be regarded as conspecific. Nearly all forms encountered in CP-19-4 possess granule visible at the margin, and they are therefore assigned to _G. adnata_. Other finely granulose species of similar size include _G. granulatus_ Kosanke 1950, _G. microgranifer_ Ibrahim 1933 and _G. piroformis_ Loose 1934; all these, however, appear distinctly granulose even at lower magnifications._

Occurrence—Rare, but widely distributed in the _Florinites_ and _Densosporites-Crassispora_ intervals; virtually absent from the _Lycosporina_ interval.

Genus LOPHOTRILETES (Naumova) Potonié and Kremp 1954

_Type species—L. gibbosus (Ibrahim) Potonié and Kremp 1954._

_Affinity—Miospores assignable to Lophotriletes have been isolated from fern sporangia (Remy and Remy, 1957; Taylor and Eggert, 1969; Good, 1979)._
1950 *Granulatisporites commissuralis* Kosanke, p. 20, pl. 3, fig. 1.

1955 *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp, p. 73, pl. 14, figs. 222, 223.

non 1960 *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp 1955; Imgrund, p. 164, pl. 15, figs. 66-68.

1965a *Lophisporites commissuralis* (Kosanke) Laveine, p. 133.

**Occurrence**—Rare, widely distributed in the Florinites and Densosporites-Crassispora intervals.

*Lophotriletes confertus* sp. nov.

(Plate 6, figs. 9-13)

**Diagnosis**—Miospores radial, trilet, triangular in equatorial outline, usually in good proximal-distal orientation; interradial margins straight to convex. Laesurae reaching approximately ⅓ of spore radius, often somewhat obscured by ornamentation of exine, with slight, indistinct lips. Exine thick and dark, ornamented on both hemispheres with coarse coni having fused bases. Coni 2-5 microns in height, equal or broader at bases, reduced near or arranged concentrically along trilet mark; 18-25 coni are usually visible at margin. Fusing of bases may make coni appear elongate or irregular in outline.

**Size**—(16 specimens) 38-51 microns maximum diameter.

**Discussion**—This species is assigned to *Lophotriletes* due to the distinctly conate appearance of the ornament at the margin. The fusing of elements at their bases gives *L. confertus* a somewhat different appearance than most other species of the genus. It most closely resembles *L. insignitus* (Ibrahim) Potonié and Kremp 1955, in which the coni are of similar size and number, but are separated at their bases, and *L. ibrahimii* (Peppers) Pi-Radondy and Doubinger 1968, which has concave interradial margins and only occasional fusing of bases of elements.

**Derivation**—The specific nomen refers to the crowded (confertus) nature of the ornament.

**Occurrence**—Rare, observed primarily in the Florinites interval.

*Holotype*—Plate 6, fig. 9, slide 2J2 coordinates 127.5-41, 43.3 microns maximum diameter.

*Paratype*—Plate 6, fig. 10, slide 1D5 coordinates 121.5-60.

*Paratype*—Plate 6, fig. 11, slide 2J6 coordinates 128-29, 50.2 microns.

*Paratype*—Plate 6, fig. 12, slide 2F2 coordinates 132-55, 47.9 microns.

*Paratype*—Plate 6, fig. 13, slide 1Y1 coordinates 122-36, 48.5 microns.

*Lophotriletes copiosus* Peppers 1970

(Plate 6, figs. 6, 7)

1970 *Lophotriletes copiosus* Peppers, p. 97, pl. 5, figs. 25, 26.

**Occurrence**—Rare, Florinites interval.

*Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp 1955

(Plate 6, fig. 5)

1933 *Verrucosi-sporites gibbosus* Ibrahim, p. 25, pl. 6, fig. 49.

1938 *Azonotriletes gibbosus* (Ibrahim) Luber in Luber and Walz, pl. 7, fig. 91.

1944 *Granulatisporites gibbosus* (Ibrahim) Schopf, Wilso and Bentall, p. 33.

1950 *Verrucos-sporites gibbosus* (Ibrahim) Knox, p. 317, pl 17, fig. 232.


1955 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp, p. 74, pl. 14, figs. 220, 221.

non 1958 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp

Guen nel, p. 62, pl. 3, fig. 3.

1965a *Lophisporites gibbosus* (Ibrahim) Laveine, p. 133.

**Discussion**—As for several of the species designated as type species of Potonié and Kremp's (1954) new genera, the specific name was not validated until 1955 (Kremp and Ames, 1959).

**Occurrence**—Rare.

*Lophotriletes granoornatus* Artüz 1957

(Plate 5, figs. 24, 25)

1957 *Lophotriletes granoornatus* Artüz, p. 244, pl. 2, fig. 13.

**Discussion**—Assignment of miospores to *L. granoornatus* follows the practice of Peppers (1970), who noted that the photograph and drawing of the type specimen of Artüz (1957) are dissimilar. Specimens illustrated on plate 5 of this report closely resemble those illustrated by Peppers (1970, pl. 5, figs. 18, 23). Artüz characterized the ornament as consisting of grana; if this is correct, the species probably should be re-assigned to *Granulatisporites*, but the type material should be re-examined before any such emendation is made.

**Occurrence**—Rare.

*Lophotriletes ibrahimii* (Peppers) Pi-Radondy and Doubinger 1968

(Plate 5, fig. 26)

1964 *Granulatisporites ibrahimii* Peppers, p. 20, pl. 2, figs. 9, 10.

1968 *Lophotriletes ibrahimii* (Peppers) Pi-Radondy and Doubinger, p. 412-414, pl. 1, fig. 2.

**Discussion**—Traverse, Ames and Spackman (1973) altered the spelling of the specific nomen from *ibrahimii* to *ibrahimi* as an orthographic correction.

**Occurrence**—Rare.

*Lophotriletes microsaeotosus* (Loose) Potonié and Kremp 1955

(Plate 5, fig. 23)

1932 *Sporonites microsaeotosus* Loose in Potonié, Ibrahim and Loose, p. 450, pl. 18, fig. 40.


1934 *Setosisporites microsaeotosus* (Loose) Loose, p. 148.

1944 *Granulatisporites microsaeotosus* (Loose) Schopf, Wilso and Bentall, p. 33.

1950 *Spinoso-sporites microsaeotosus* (Loose) Knox, p. 314, pl. 17, fig. 203.


1958 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp 1954; Guennel, p. 62, pl. 3, fig. 3.

non 1955 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp, p. 74, pl. 14, figs. 220, 221.

1960 *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp
Discussion—Acanthotriletes aculeolatus (Kosanke) Potonié and Kremp 1955 is similar to L. microsaetosus; the former species is slightly larger and more distinctly spined. Forms intermediate to the two species were observed occasionally in CP-19-4, and distinction was sometimes difficult. It is possible that the two species are end-members of a continuum, but a formal study of the morphologic variation of a large number of specimens would be necessary to resolve the matter.

Occurrence—Rare, Florinites and Densospores-Crassispora intervals.

Lophotriletes mosaicus Potonié and Kremp 1955
(Plate 6, fig. 4)
1955 Lophotriletes mosaicus Potonié and Kremp, p. 75, pl. 14, figs. 227, 228.
1965a Lophisporites mosaicus (Potonie and Kremp) Laveine, p. 133.

Occurrence—Rare.

Lophotriletes rarispinosus Peppers 1970
(Plate 5, figs. 20, 21)
1970 Lophotriletes rarispinosus Peppers, p. 96, text-fig. 17, pl. 5, figs. 20-22.

Occurrence—Rare, lower portion of the Florinites interval.

Lophotriletes cf. tuberifer (Imgrund) Potonié and Kremp 1955
(Plate 6, figs. 1-3)
1955 Lophotriletes tuberifer (Imgrund) Potonié and Kremp, p. 73.
1960 Lophotriletes tuberifer (Imgrund) Potonié and Kremp 1955; Imgrund p. 163, pl. 14, fig. 42.

Discussion—This species was first described by Imgrund (1952) in his thesis, which has not been available to this writer. Specimens designated L. cf. tuberifer in this report display similar ornamentation to the holotype illustrated by Imgrund (1960), but were usually smaller than the quoted size range (44-70 microns).

Occurrence—Rare.

Lophotriletes sp. 1
(Plate 6, fig. 8)

Description—Miospore radial, trilete, triangular in equatorial outline, straight interradial margins, broadly rounded angles. Laesurae approximately ½ of spore radius, straight, with indistinct lips. Ornament of rounded coni 1-3 microns in height and basal width, regularly distributed on both hemispheres, reduced in size near trilete mark on proximal surface. Space between coni about equal to basal width of coni. About 30 coni project from margin. Size of illustrated specimen 34.8 microns maximum diameter.

Discussion—L. sp. 2 is a distinctive, easily recognized form which does not strongly resemble previously described species of the genus.

Occurrence—Rare.

Genus WALTZISPORA Staplin 1960

Type species—W. lobophora (Waltz) Staplin 1960.

Affinity—Unknown.

Waltzispora sagittata Playford 1962
(Plate 6, fig: 4)

non 1955 Granulatisporites politus Hoffmeister, Staplin and Malloy, p. 369, pl. 36, fig. 13.
1960 Leiotriletes politus (Hoffmeister, Staplin and Malloy) Love, pi. 1, fig. 1.
1962 Waltzispora sagittata Playford, p. 582-583, text-fig. 5c, pl. 79, fig. 12.

Discussion—The occurrence of W. sagittata at the stratigraphic horizon represented by the miospore assemblage of CP-19-4 is unusual, as the genus has been reported previously only from Mississippian and lower Pennsylvanian strata. Only two specimens were observed, and the possibility of reworking from older deposits must be considered; other species of Waltzispora (e.g., W. prisca (Kosanke) Sullivan 1964 and W. polita (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967 occur in appreciable numbers in Iowa coals not greatly older than CP-19-4.

There is no physical evidence of reworking in CP-19-4.

Occurrence—Rare.

Genus ANAPICULATISPORITES (Potonie and Kremp) Smith and Butterworth 1967

Type species—A. isselburgensis Potonié and Kremp 1954.

Affinity—Unknown.

Anapiculatisporites spinosus (Kosanke) Potonié and Kremp 1955
(Plate 6, figs. 17, 18)
1950 Granulatisporites politus Hoffmeister, p. 22, pl. 3, fig. 7.
1955 Anapiculatisporites spinosus (Kosanke) Potonié and Kremp, p. 82, pl. 14, figs. 253-255.
non 1967 Granulatisporites spinosus Kosanke 1950; Felix and Burbridge, p. 364, pl. 34, fig. 10.

Occurrence—Rare, but widely distributed in the Florinites and Densospores-Crassispora intervals.
Genus ANAPLANISPORITES Jansonius 1962

Type species—A. telephorus Klaus 1960.

Affinity—Unknown.

Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967

(Plate 6, figs. 19, 20)

1955 Punctatisporites? baccatus Hoffmeister, Staplin and Malloy, p. 392, pl. 36, fig. 2.

1958 Apiculatisporites baccatus (Hoffmeister, Staplin and Malloy) Butterworth and Williams, p. 363, pl. 1, fig. 25.

1967 Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth, p. 166, pl. 7, figs. 1-5.

Occurrence—Rare.

Genus APICULATISPORIS Potonie and Kremp 1956

Type species—A. aculeatus (Ibrahim) Smith and Butterworth 1967.

Discussion—The generic name was altered from Apiculatisporites without emendation by Potonie and Kremp (1956), when the former name was found to be a junior homonym of the megaspore genus Apiculati-sporites Bennie and Kidston 1886.

Affinity—Unknown.

Apiculatisporis abditus (Loose) Potonie and Kremp 1955

(Plate 7, fig. 8)

1932 Sporonites abditus Loose in Potonie, Ibrahim and Loose, p. 451, pl. 19, fig. 53.

1934 Verrucos-isporites abditus Loose, p. 154.


1955 Apiculatisporis abditus (Loose) Potonie and Kremp, p. 78, pl. 14, figs. 237-239.

1962 Apiculatisporis abditus (Loose) Pierart, tabl. 2.

Occurrence—Rare, but widely distributed in CP-19-4.

Apiculatisporis aculeatus (Ibrahim) Smith and Butterworth 1967

(Plate 7, figs. 1-3)

1933 Apiculati-sporites aculeatus Ibrahim, ib. 23, pl. 6, fig. 57.


1950 Spinoso-sporites aculeatus (Ibrahim) Knox, p. 313.


1965 Apiculatisporis aculeatus (Ibrahim) Potonie and Kremp, p. 94.

1967 Apiculatisporis aculeatus (Ibrahim) Smith and Butterworth, p. 170, pl. 7, figs. 12, 13.

Discussion—Smith and Butterworth (1967) described A. aculeatus as having a round to rounded triangular equatorial outline. Miospores assigned to this species observed in CP-19-4 invariably displayed sphaerotriangular outlines. The ornament of A. aculeatus is similar to that of Lophotriletes pseudaculeatus Potonie and Kremp 1955, but the latter species is more distinctly triangular.

Occurrence—Rare, observed primarily in the

Florinites and Densosporites-Crassispore intervals.

Apiculatisporis irregularis (Kosanke) Potonie and Kremp 1955

(Plate 8, fig. 7)

1950 Raistrickia irregularis Kosanke, p. 47-48, pl. 11, fig. 5.

1955 Apiculatisporis irregularis (Kosanke) Potonie and Kremp, p. 77.

1956 Apiculatisporis irregularis (Kosanke) Potonie and Kremp, p. 94.

non 1967 Apiculatisporis irregularis (Alpern) Smith and Butterworth, p. 171-172, pl. 7, figs. 18-19.


Discussion—As noted by Peppers (1970), Apiculatisporis (Raistrickia) irregularis resembles A. abditus, the two species differing chiefly in the relative length of spines on the distal hemisphere. A. irregularis is distinguished by possessing spines that are longer than they are broad; the spines of A. abditus are shorter and may appear to fuse at their bases.

Occurrence—Rare.

Apiculatisporis latigranijer (Loose) Potonie and Kremp 1955

(Plate 7, fig. 6)

1932 Sporonites latigranijer Loose in Potonie, Ibrahim and Loose, p. 452, pl. 19, fig. 54.

1934 Granulati-sporites latigranijer Loose, p. 147.

1944 Punctati-sporites latigranijer (Loose) Schopf, Wilson and Bentall, p. 31.


1955 Apiculatisporis latigranijer (Loose) Potonie and Kremp, p. 79, pl. 14, figs. 244, 245.

1960 Apiculatisporis latigranijer (Loose) Imgrund, p. 164-165, pl. 14, figs. 43-45.

Occurrence—Rare.

Apiculatisporis saetiger (Peppers) Peppers and Ravn comb. nov.

(Plate 7, figs. 4, 5)

1964 Punctatisporites saetiger Peppers, p. 30, pl. 4, figs. 1, 2.

Discussion—This species is reassigned to Apiculatisporis on the basis of the spinose sculpture. The suture is trilete, although one ray typically is shortened and sometimes virtually absent. The reassignment is made with some uncertainty. A. saetiger usually is oval in shape and may appear monolete, simulating species of the genera Laevigatosporites Ibrahim 1933 and Punctatosporites Ibrahim 1933. The sculpture of specimens observed in CP-19-4 was fine and closely-spaced, though it has been observed to vary considerably in other coals.

Occurrence—Rare.

Apiculatisporis variocomeus Sullivan 1964

(Plate 7, fig. 7)

1964 Apiculatisporis variocomeus Sullivan, p. 363-364, pl. 58, figs. 4-8.

Occurrence—Rare, observed only in CP-19-5.

Apiculatisporis sp. 1

(Plate 7, fig. 9)
Description—Miospore radial, trilete, circular in equatorial outline. Laesurae ¾ of spore radius with pronounced lips 2-3 microns in width. Sculpture consists of loosely arranged small spinae 2 microns or less in height and basal width. Exine rather thin, folding frequent. Size of illustrated specimen 45.6 microns maximum diameter.

Discussion—The pronounced lips and thin exine distinguish A. sp. 1 from other species of similar size.

Occurrence—Rare.

Genus APICULATASPORITES (Ibrahim) Smith and Butterworth 1967

Type species—A. spinulistratus (Loose) Ibrahim 1933.

Discussion—As emended by Smith and Butterworth (1967), genus Apiculatasporites accommodates spores with a finer grade of conate ornament than those assigned to Apiculatisporis. The ornament of the type species, A. spinulistratus, is cited as about 1-2.5 microns in height, which is similar to that of some species of Apiculatisporis, e.g., A. latigranifer. The distinction between the two genera is questionable, and it may be desirable upon examination of the original material to transfer A. spinulistratus to Apiculatisporis; such a reassignment would serve to eliminate the unfortunate confusion between the similar generic names.

Affinity—?Filicales (Potonie, 1962).

Apiculatasporites spinulistratus (Loose) Ibrahim 1933

—Rare. (Plate 7, figs. 10, 11)

1932 Spororites spinulistratus Loose in Potonie, Ibrahim and Loose, p. 450, pl. 18, fig. 47.
1933 Apiculatisporites spinulistratus (Loose) Ibrahim, p. 37.
1934 Apiculatisporites globosus Loose, p. 152, pl. 7, fig. 14.
1944 Punctatisporites spinulistratus (Loose) Schopf, Wilson and Bentall, p. 31.
1950 Spinososporites spinulistratus (Loose) Knox, p. 314.

Occurrence—Rare.

Genus ACANTHOTHRILETES (Naumova) Potonie and Kremp 1954

Type species—A. ciliatus (Knox) Potonie and Kremp 1954.

Affinity—Spores assignable to Acanthotriletes have been recovered from fern fructifications (Remy and Remy, 1957; Good, 1979).

Acanthotriletes aculeolatus (Kosanke) Potonie and Kremp 1955

—Rare. (Plate 7, fig. 14)

1950 Granulatisporites aculeolatus Kosanke, p. 22, pl. 3, fig. 8.
1955 Acanthotriletes aculeolatus (Kosanke) Potonie and Kremp, p. 84.

Occurrence—Rare.

Acanthotriletes echinatus (Knox) Potonie and Kremp 1955

—Rare. (Plate 7, fig. 12)

1950 Spinososporites echinatus Knox, p. 313, pl. 17, fig. 208.
1955 Acanthotriletes echinatus (Knox) Potonie and Kremp, p. 84.
non 1955 Acanthotriletes echinatus Hoffmeister, Staplin and Malloy, p. 379, pl. 38, figs. 1, 2.

Occurrence—Rare, but widely distributed in the Florinites interval; rare elsewhere in CP-19-4.

Acanthotriletes cf. falcatus (Knox) Potonie and Kremp 1955

—Rare. (Plate 7, fig. 15)

1950 Spinososporites falcatus Knox, p. 313, pl. 17, fig. 205.
1955 Acanthotriletes falcatus (Knox) Potonie and Kremp, p. 84.

Discussion—The ornament of A. cf. falcatus is more widely distributed than that of the specimens illustrated by Smith and Butterworth (1967).

Occurrence—Rare.

Acanthotriletes triquetus Smith and Butterworth 1967

—Rare. (Plate 7, fig. 13)

1967 Acanthotriletes triquetus Smith and Butterworth, p. 179, pl. 8, figs. 13, 14.
1967 Granulatisporites spinosus Kosanke 1950; Felix and Burbidge, p. 364, pl. 54, fig. 10.
non 1950 Granulatisporites (Anapiculatisporites) spinosus Kosanke, p. 22, pl. 3, fig. 7.

Occurrence—Rare to infrequent in the Florinites and Densosporites-Crassispora intervals; virtually absent from the Lycospora interval.

Genus RAISTRICKIA (Schopf, Wilson and Bentall) Potonie and Kremp 1954

Type species—R. grovensis Schoop, in Schoop, Wilson and Bentall, 1944.

Affinity—Filices (Radforth, 1938, 1939; Mamay, 1950; Remy and Remy, 1955a; Phillips and Andrews, 1965; Grauvogel-Stamm and Dobinger, 1975).

Rai trickia crocea Kosanke 1950

—Rare. (Plate 8, fig. 5)

1950 Raitrickia crocea Kosanke, p. 47, pl. 11, fig. 6

Discussion—R. crocea closely resembles R. saetosa (Loose) Schoop, Wilson and Bentall 1944, and the two species are considered synonymous by Smith and Butterworth (1967). The bacula of specimens observed in CP-19-4 appear longer and somewhat thinner than those illustrated by Smith and Butterworth, and more like those of R. crocea as illustrated by Kosanke (1950).

Occurrence—R. crocea is the most commonly observed species of the genus in CP-19-4; in numbers it is usually rare, but is found in most samples in the Florinites and Densosporites-Crassispora intervals.

Rai trickia lacerata Peppers 1970

—Rare. (Plate 8, fig. 3)


Occurrence—Rare.

Rai trickia lowellensis Peppers 1970

—Rare. (Plate 8, figs. 4, 6)

1970 Raitrickia lowellensis Peppers, p. 105, pl. 8, figs. 3, 4.
Occurrence—Rare.

Raistrickia cf. macro Bharadwaj 1957
(Plate 8, fig. 8)

1957a Raistrickia macro Bharadwaj, p. 89, pl. 23, fig. 23.

Discussion—R. cf. macro differs from the type description of Bharadwaj (1957a) in displaying only a very indistinct negative reticulum.

Raistrickia pilosa Kosanke 1950
(Plate 8, fig. 2)

1950 Raistrickia pilosa Kosanke, p. 48, pl. 11, fig. 4.

Occurrence—Rare.

Raistrickia protensa Kosanke 1950
(Plate 8, fig. 1)

1950 Raistrickia protensa Kosanke, p. 46, pl. 11, figs. 1-3.

Genus SPACKMANITES Habib 1966

Type species—S. ellipticus Habib 1966.

Affinity—Unknown.

Spackmanites facierugosus (Loose) Habib 1966
(Plate 8, figs. 9-11)

1954 Verrucosospores facierugosus (Loose) Butterworth and Williams, p. 754, pl. 18, fig. 6.

1966 Spackmanites facierugosus (Loose) Habib, p. 638, pl. 105, fig. 19.

1967 Verrucosospores facierugosus (Loose) Habib, p. 638, pl. 105, fig. 19.

1967 unidentified 16239; Barss, pl. 23, fig. 4.

1967 unidentified 16398; Barss, p. 29, fig. 19.

1967 Verrucosospores facierugosus (Loose) Butterworth and Williams 1954; Barss, pl. 8, fig. 7.

1970 Spackmanites cf. facierugosus (Loose) Habib; Peppers, p. 109, pl. 8, figs. 17-20.

1979 Verrucosospores facierugosus (Loose) Butterworth and Williams 1954; Ettensohn and Peppers, p. 1, fig. 11.

Discussion—A question exists concerning the synonymy of this species as given by Habib (1966). It is uncertain that the specimen illustrated in a line-drawing by Loose (1934) is actually the same taxon as that designated by Habib (1966). Habib provided no formal diagnosis for S. facierugosus beyond that of the genus itself; Peppers (1970) did provide a detailed description and noted the difficulty of interpreting Loose’s (1934) illustration. A species that appears to be distinctly different from S. facierugosus has been illustrated as Verrucosospores facierugosus (Loose) Butterworth and Williams 1954 by Barss (1967, pl. 8, fig. 7) and as Verrucosospores (sic?) facierugosus (Loose) Butterworth and Williams 1954 by Ettensohn and Peppers (1979, pl. 1, fig. 11). Barss (1967) also illustrated specimens regarded as unassigned which appear to correspond to S. facierugosus (pl. 23, fig. 4, pl. 29, fig. 19) and clearly differ from his illustrated specimen of V. facierugosus.

S. facierugosus as illustrated by Habib (1966) and described (as S. cf. facierugosus by Peppers, 1970) is a distinctive, easily recognized and stratigraphically useful species despite its muddled synonymy. Distinction between S. facierugosus and the type species, S. ellipticus Habib 1966, is questionable. A complete range of variation between the two forms was observed in the study of CP-19-4; the majority of specimens closely resembled those illustrated by Peppers (1970, pl. 8, figs. 17-20) and therefore are designated S. facierugosus in this report. If synonymy exists between S. facierugosus and S. ellipticus, it might be preferable to employ the latter name and to reject synonymy with Reticulati-sporites facierugosus Loose 1934. Verrucosisporites pseudobaculatus Laveine 1965 is similar to S. facierugosus and may be synonymous.

Raistrickia macro Bharadwaj 1957
(Plate 8, fig. 23)

1950 Raistrickia macro Bharadwaj, p. 48, pl. 11, fig. 4.

Affinity—Unknown.

C. florida Hoffmeister, Staplin and Malloy 1955

Type species—C. florida Hoffmeister, Staplin and Malloy 1955.

Affinity—Smith and Butterworth (1967) suggested that spores from a fern fructification (Senftenbergia) described by Radforth (1938) were assignable to Convolutispora; Potonie (1962) assigned the same spores to genus Camptotriletes (Naumova) Potonie and Kremp 1954. Jennings and Eggert (1977) also reported spores corresponding to Convolutispora in situ from Senftenbergia. Cridland (1966) illustrated spores from a fern sporangium which closely resemble certain larger species of Convolutispora.

Convolutispora cerina sp. nov.
(Plate 8, figs. 12-15)

1964 Convolutispora sp. 2 Peppers, p. 17, pl. 1, fig. 17.

Diagnosis—Miospores radial, trilete, circular to subcircular in equatorial outline, usually in good proximal-distal orientation. Exine rather thick, approximately 3 microns, often appearing as a zona in compression. Proximal surface laevigate, distal surface ornamented by low, irregular, flat convolute ridges, width 3-6 microns, height 1-2 microns. Slight indentation of spore margin related to distal sculpture is sometimes visible at the angles.

Size—(10 specimens) 36-50 microns maximum diameter.

Discussion—Although it is not considered a diagnostic feature, specimens of C. cerina observed in CP-19-4 did not accept staining as readily as most other miospores, and were conspicuous by their waxy yellowish appearance. The spore designated Convolutispora sp. 2 by Peppers (1964) appears virtually identical. C. laminosa Neves 1961 and C. superficialis Felix and Burbridge 1967 resemble C. cerina, but both the former species are larger and bear less distinct ornamentation than C. cerina.

Derivation—The specific nomen refers to the waxy yellow (cerina) appearance of the spore in stained preparations.

Occurrence—Rare.
Holotype—Plate 8, fig. 12, slide 3M6 coordinates 130-71.5, 44.5 microns maximum diameter.
Paratype—Plate 8, fig. 13, slide 3M6 coordinates 134-31.5, 43.9 microns.
Paratype—Plate 8, fig. 14, slide 1Y1 coordinates 122.5-36, 46.2 microns.
Paratype—Plate 8, fig. 15, slide 1Y1 coordinates 126.5-35, 45.6 microns.

*Convolutispora?* sp. 1

*Description*—Miospore circular in outline, exine thick and dark, bearing a uniform, vaguely convolute sculpture. No suture has been observed. Size of illustrated specimen 34.2 microns maximum diameter.

*Discussion*—Due to the irregularity of the sculpture and the apparent absence of any laesurae, the assignment of this species to *Convolutispora* is tentative. It resembles C. sp. 1 of Peppers (1970, p. 108, pl. 8, fig. 15), but the latter shows a definite trilete mark.

*Occurrence*—Rare.

Genus *MICRORETICULATISPORITES* (Knox)

*Potonie* and *Kremp* 1954

*Type species*—*M. lacunosus* (Ibrahim) Knox 1950.

*Affinity*—Filicales. *Potonie* (1962) considered spores from an Iowa fern fructification described by *Mamay* (1950) to be assignable to *Microreticulatisporites*.

*Microreticulatisporites harrisonii* Peppers 1970

(Plate 9, fig. 10)

1970 *Microreticulatisporites harrisonii* Peppers, p. 110, pl. 9, fig. 1.

*Occurrence*—Rare.

*Microreticulatisporites nobilis* (Wicher) Knox 1950

(Plate 9, figs. 11, 12)

1934 *Sporites nobilis* Wicher, p. 186, pl. 8, fig. 30.

*Occurrence*—Rare to infrequent, widely distributed in the *Florinites* and *Densosporites-Crassispora* intervals, rare in the *Lycospora* interval.

*Microreticulatisporites* sp. 1

(Plate 9, fig. 15)

*Description*—Miospore radial, trilete, triangular in equatorial outline, interradial margins slightly convex, angles moderately rounded. Laesurae straight, ½ of spore radius. Exine thick and dark, uniformly and coarsely microreticulate. Lacunae generally circular, about 2 microns wide, separated by rounded muri 4-6 microns wide. Muri appear sometimes as verrucate ridges, especially at margin. Size of illustrated specimen 41.0 microns maximum diameter.

*Discussion*—The ornament of M. sp. 1 resembles that of *M. sulcatus* (Wilson and Kosanke) Smith and Butterworth 1967, but is coarser. *M. sp. 1* could be assigned possibly to genus *Convurucosisporites* *Potonie* and *Kremp* 1954.

*Occurrence*—Rare.

Genus *DICTYOTRILETES* (Naumova) Smith and Butterworth 1967

*Type species*—*D. bireticulatus* (Ibrahim) Smith and Butterworth 1967.

*Affinity*—Unknown; listed as questionably filicinean by *Potonie* and *Kremp* (1954). Spores with a reticulate ornament assignable possibly to *Dictyotriletes* or to *Reticulatisporites* (Ibrahim) Neves 1964 were recovered by *Mamay* (1954b) from a fructification, but *Smith* and *Butterworth* (1967) stated that the taxonomic affinity of the plant fossil was uncertain. *Millay* (1979) isolated monolete reticulate spores from a species of the marattialean fern *Scolecopteris* which resemble the species *D. castaneaeformis*. These spores appear to be variants of the genus *Thymospora* *Wilson* and *Venkatachala* 1963 (see Discussion of *D. castaneaeformis*).

*Dictyotriletes bireticulatus* (Ibrahim) Smith and Butterworth 1967

(Plate 9, fig. 6)

1933 *Reticulatis-sporites bireticulatus* Ibrahim, p. 35, pl. 1, fig. 1.
1934 *Reticulatis-sporites bireticulatus* Ibrahim; Loose, pl. 7, fig. 28.
1950 *Reticulatisporites mediareticulatus* Ibrahim; Knox, p. 323, pl. 18, fig. 253.
1952 *Reticulatisporites mediareticulatus* Ibrahim; Balme, p. 176, text-fig. 1c.
1952 *Reticulatis-sporites cf. mediareticulatus* Ibrahim; Balme and *Butterworth*, pl. 48, figs. 4a, 4b.
1954 *Dictyotriletes bireticulatus* (Ibrahim) *Potonie* and *Kremp*, p. 108.
1954 *Reticulatis-sporites cf. mediareticulatus* Ibrahim; *Butterworth* and *Millott*, p. 21, fig. 8b.
1956 *Reticulatisporites mediareticulatus* Ibrahim; *Butterworth* and *Millott*, text-fig. 3B.
1964 *Dictyotriletes bireticulatus* (Ibrahim) *Levet-Carette*, p. 271, pl. 10, fig. 17.

*Occurrence*—Rare; observed in the *Florinites* and *Lycospora* intervals, not encountered in the *Densosporites-Crassispora* interval.

*Dictyotriletes castaneaeformis* (Horst) *Sullivan* 1964

(Plate 9, figs. 2-4)

1943 *Aletes castaneaeformis* Horst, p. 124, fig. 82.
1955 *Reticulatisporites castaneaeformis* (Horst) *Potonie* and *Kremp*, p. 169.

*Discussion*—The assignment of this species to *Dictyotriletes* was made on the basis of ornament, and the nature of the suture is in doubt. *Smith* and *Butterworth* (1967) described *D. castaneaeformis* as apparently alete, and considered it synonymous with *D. clatriformis* (Artüz) Sullivan 1964. *D. clatriformis* is indistinctly trilete, whereas *D. castaneaeformis* is generally oval in shape, and some specimens (e.g., pl. 9, fig. 3) display what appears to be a monolete laesura. It is possible that this form species accommodates spores of various unknown plant affinities, but no reliable basis seems to

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exist for subdivision into separate species.

Occurrence—Rare.

**Dictyotriletes densoreticulatus** Potonie and Kremp 1955

(Plate 9, fig. 7)

1955 *Dictyotriletes densoreticulatus* Potonie and Kremp, p. 109, pl. 16, fig. 313.

Occurrence—Rare.

**Dictyotriletes distortus** Peppers 1970

(Plate 9, fig. 9)

1970 *Dictyotriletes distortus* Peppers, p. 112, pl. 9, figs. 9-11.

Occurrence—Rare.

**Densosporites-Crassispora interval.**

**Dictyotriletes reticulocingulum** (Loose) Smith and Butterworth 1967

(Plate 9, figs. 5, 8)

1932 *Sporonites reticulocingulum* Loose in Potonie', Ibrahim and Loose, p. 450, pl. 18, fig. 41.

1934 *Reticulati-sporites reticulocingulum* Loose, p. 156.

1944 *Punctati-sporites reticulocingulum* (Loose) Schopf, Wilson and Bentall, p. 31.


1967 *Dictyotriletes reticulocingulum* (Loose) Smith and Butterworth, p. 198, pl. 11, figs. 27-29.

Discussion—Smith and Butterworth (1967) noted a great deal of variation in the relative coarseness of the reticulate ornament of specimens they assigned to this species. Specimens observed in CP-19-4 and other Iowa coals tend to display a consistent fine reticulum with little variation between proximal and distal surfaces, resembling the specimen illustrated on plate 11, fig. 27 of Smith and Butterworth (1967). Peppers (1970) made a similar observation concerning specimens encountered in Illinois Basin coals. As the holotype (Smith and Butterworth, 1967) appears to be rather finely reticulate, the assignment of specimens in CP-19-4 to *D. reticulocingulum* is appropriate.

Occurrence—Infrequent in a narrow horizon of the lower Florinites interval, rarely observed elsewhere.

Genus CAMPTOTRILETES (Naumova) Potonie and Kremp 1954

**Type species**—*C. corrugatus* (Ibrahim) Potonie and Kremp 1954.

Affinity—Filices; Mamay (1950) isolated spores assignable to *Camptotriletes* from fern fructifications.

**Camptotriletes bucculentus** (Loose) Potonie and Kremp 1955

(Plate 9, fig. 13)

1934 *Verrucosi-sporites bucculentus* Loose, p. 154, pl. 7, fig. 15.


1955 *Camptotriletes bucculentus* (Loose) Potonie and Kremp, p. 104, pl. 16, figs. 287, 288.

Occurrence—Rare.

**Camptotriletes cf. corrugatus** (Ibrahim) Potonie and Kremp 1954

(Plate 9, fig. 14)

1933 *Reticulati-sporites corrugatus* Ibrahim, p. 35, pl. 5, fig. 41.


1954 *Camptotriletes corrugatus* (Ibrahim) Potonie and Kremp, p. 104, pl. 16, figs. 289, 290.

Discussion—The semi-reticulate ornament of spores designated *C. cf. corrugatus* appears somewhat coarser than that of the type illustrations in Potonie and Kremp (1954, pl. 16, figs. 289, 290).

Occurrence—Rare.

Genus LATIPULVINITES Peppers 1964

**Type species**—*L. kosankii* Peppers 1964.

Affinity—Unknown.

**Latipulvinites kosankii** Peppers 1964

(Plate 9, fig. 16)


Discussion—*L. kosankii* bears a superficial resemblance to species of the genus *Ahrensisporites* Potonie and Kremp 1954, but the triradiate ridges of *L. kosankii* are located on the proximal surface, as opposed to the kyrto mes of *Ahrensisporites*, which are located on the distal surface. *Concavisporites lunzensis* (Klaus) Chaloner 1969, from the Triassic of Austria, closely resembles *L. kosankii*.

Occurrence—Rare.

Genus AHRENSISPORITES Potonie and Kremp 1954

**Type species**—*A. guerickei* (Horst) Potonie and Kremp 1954.

Affinity—Unknown.

**Ahrensisporites guerickei** (Horst) Potonie and Kremp 1954

(Plate 9, fig. 17)

1943 *Triletes guerickei* Horst, pi. 7, figs. 58, 59, 61-64.


Occurrence—Rare.

Genus STELLISPORITES Alpern 1958

**Type species**—*S. inflatus* Alpern 1958.

Affinity—Unknown.

**Stellisporites inflatus** Alpern 1958

(Plate 10, fig. 1)

1958 *Stellisporites inflatus* Alpern, p. 78, pl. 1, fig. 14.

Discussion—*S. inflatus* Alpern, 1958.

Genus TANTILLUS Felix and Burbridge 1967

**Type species**—*T. triquetrus* Felix and Burbridge 1967.

Affinity—Unknown.
Tantillus triquetrus Felix and Burbridge 1967
(Plate 10, figs. 2-8)

1967 Tantillus triquetrus Felix and Burbridge, p. 383-384, pl. 65, figs. 4, 5.

Discussion—The ornamentation of T. triquetrus is described by Felix and Burbridge (1967) as laevigate to minutely granulose. Forms observed in Iowa coals range from laevigate (plate 10, fig. 2) to distinctly granulose (plate 10, figs. 3, 4) to minutely spinose (plate 10, figs. 7, 8). This variability or ornament suggests that further speciation of the genus may be useful, but too few specimens have been observed during the present study to establish reliable categories for morphologic types.

Occurrence—Rare, but widely distributed in the Florinites and Densosporites-Crassispora intervals.

Genus TRIQUITRITES (Wilson and Coe)

Type species—T. arculatus Wilson and Coe 1940.

Affinity—Schopf, Wilson and Bellant (1944) suggested a filicinean affinity for this genus, but no miospores corresponding to Triquitrites appear to have been described from fructifications of known affinity. Moore (1946) illustrated spores resembling Triquitrites from a reproductive structure of unknown paleobotanical relationship.

Triquitrites additus Wilson and Hoffmeister 1956
(Plate 10, figs. 11, 15)

1956 Triquitrites additus Wilson and Hoffmeister, p. 24, pl. 3, figs. 6-9.

Occurrence—Rare to infrequent in the Densosporites-Crassispora interval, virtually absent elsewhere in CP-19-4.

Triquitrites bransonii Wilson and Hoffmeister 1956
(Plate 10, figs. 13, 14)

1956 Triquitrites bransonii Wilson and Hoffmeister, p. 24-25, pl. 3, figs. 1-5.

Discussion—T. bransonii, T. protensus Kosanke 1950 and T. pulvinatus Kosanke 1950 are very similar, and distinctions between them often are made with some hesitancy. Among specimens observed in CP-19-4, a range of variation existed between forms assignable to T. bransonii and T. protensus. Both species are provided systematic treatment and illustrated in this report, but they are considered together in the data (see Appendix II).

Occurrence—Infrequent to occasionally frequent in the Densosporites-Crassispora interval, rarely observed elsewhere.

Triquitrites crassus Kosanke 1950
(Plate 10, fig. 18)

1950 Triquitrites crassus Kosanke, p. 38, pl. 8, fig. 6.

Occurrence—Rare, lower levels of the Florinites interval.

Triquitrites exiguis Wilson and Kosanke 1944
(Plate 10, fig. 10)

1944 Triquitrites exiguis Wilson and Kosanke, p. 332, fig. 2.

Discussion—T. exiguis resembles T. protensus but is smaller. In practice, specimens smaller than 30 microns in maximum diameter are assigned to T. exiguis; forms 30 microns or larger are assigned to T. protensus.

Occurrence—Rare to infrequent in the Densosporites-Crassispora interval, rare in the Florinites interval, and virtually absent from the Lycospora interval.

Triquitrites minutus Alpern 1958
(Plate 10, fig. 9)

1958 Triquitrites minutus Alpern, p. 77, pl. 1, figs. 9, 10.

Discussion—T. minutus is similar to T. exiguis in size, but displays only rudimentary, inconspicuous thickenings at the angles.

Occurrence—Rare, observed primarily in the Florinites interval.

Triquitrites protensus Kosanke 1950
(Plate 10, fig. 12)

1950 Triquitrites protensus Kosanke, p. 40, pl. 8, fig. 2.

Occurrence—See T. bransonii.

Triquitrites sculptilis (Balme) Smith and Butterworth 1967

1952 Triquitrites sculptilis Balme, p. 181, text-fig. 1g.
1957b Triquitrites coesfeldensis Bharadwaj, p. 123, pl. 25, figs. 66, 67.
1958 Triquitrites bucculentus Guennel, p. 73, pl. 5, figs. 1, 2.
1965a Triquisporites sculptilis (Balme) Laveine, p. 134, pl. 10, fig. 42.
1967 Triquisporites sculptilis (Balme) Smith and Butterworth, p. 204, pl. 12, figs. 10-15.

Discussion—Gupta (1970) proposed synonymy of T. sculptilis Balme 1952 with T. trigonus (Ibrahim) Gupta 1969, but his synonymy did not take into account the emendation of T. sculptilis by Smith and Butterworth (1967). The relationship of T. sculptilis as illustrated both by Balme (1952) and Smith and Butterworth (1967) with the description and illustration of Reticulatisporites trigonus Ibrahim 1933 is unclear, and it is considered advisable to retain T. sculptilis as a valid name.

Occurrence—Infrequent to frequent in the Densosporites-Crassispora interval, rare in the Florinites interval, virtually absent from the Lycospora interval.

Triquitrites subspinosus Peppers 1970
(Plate 10, fig. 17)

1970 Triquitrites subspinosus Peppers, p. 118, pl. 11, figs. 8, 9.

Occurrence—Rare.

Genus INDOSPORA Bharadwaj 1960

Type species—I. clara Bharadwaj 1960.

Affinity—Unknown.

Indospora boleta Peppers 1970
(Plate 11, fig. 2)

1970 Indospora boletus Peppers, p. 118, pl. 11, figs. 12, 13.
**Discussion**—Specimens of *I. boleta* observed in CP-19-4 were slightly smaller than those noted by Peppers (1970), but the character of the ornamentation corresponds closely to the type description. The spelling of the specific nomen is altered from *boletus* to *boleta* to bring it into orthographic agreement with the generic nomen.

**Occurrence**—Rare.

**Genus ZOSTEROSPORITES** Kosanke 1973

**Type species**—*Z. triangularis* Kosanke 1973.

**Affinity**—Unknown.

*Zosterosporites triangularis* Kosanke 1973

(Plate 10, figs. 19, 20)

1973 *Zosterosporites triangularis* Kosanke, p. 11, text-fig. 5, pi. 1, figs. 1-6.

**Discussion**—The spore figured by Alpern (1959) as indeterminate no. 368 appears to be *Z. triangularis*. *Ahrensisporites aspersus* Gupta 1969 resembles *Z. triangularis*, but is somewhat larger and possesses distinct kyriomes instead of a beltlike thickening near the equator. *Z. triangularis* appears to have a relatively restricted stratigraphic range in the lower Cherokee coals of Iowa and is particularly characteristic of the seam represented by CP-19-4.

**Occurrence**—Rare, observed primarily in the Florinites interval.

**Genus SIMOZONOTRILETES** (Naumova) Potonie' and Kremp 1954

**Type species**—*S. intortus* (Waltz) Potonie' and Kremp 1954.

**Affinity**—Unknown.

*Simozonotriletes intortus* (Waltz) Potonie' and Kremp 1954

(Plate 12, fig. 6)

1938 *Zonotriletes intortus* Waltz in Luber and Waltz, pi. 2, fig. 24.


1957a *Simozonotriletes priscus* Dybová and Jachowicz, p. 152, pl. 41, figs. 1, 2.

1962 *Murospora intorta* (Waltz) Playford, p. 609, pl. 86, figs. 12, 13.

**Occurrence**—Rare.

**Genus KNOXISPORITES** (Potonie' and Kremp) Neves and Playford 1961

**Type species**—*K. hageni* Potonie' and Kremp 1954.

**Affinity**—Unknown.

*Knoxisporites stephanephorus* Love 1960

(Plate 10, fig. 22)

1960 *Knoxisporites stephanephorus* Love, p. 118, text-fig. 8, pl. II, figs. 1, 2.

**Discussion**—*K. stephanephorus* is very similar to, and possibly synonymous with *K. rotatus* Hoffmeister, Staplin and Malloy 1955 and *K. glomus* Shwartsman in Inosova, Krusina and Shwartsman, 1976. The three species were described originally from widely separated stratigraphic horizons, and similar forms have been noted from the Upper Mississippian to the Lower Permian (Bless, Loboziaik and Streel, 1977). *K. ruhlandi* Doubinger and Rauscher 1966 displays a distal ornament similar to that of *K. stephanephorus*, but the equatorial outline of the former species is sphaerotriangular rather than circular.

**Occurrence**—Rare.

*Knoxisporites triradiatus* Hoffmeister, Staplin and Malloy 1955

(Plate 10, fig. 23)

1955 *Knoxisporites triradiatus* Hoffmeister, Staplin and Malloy, p. 391, pl. 37, figs. 11-12.

**Genus RETICULATISPORITES** (Ibrahim) Neves 1964(a)

**Type species**—*R. reticulatus* (Ibrahim) Ibrahim 1935.

**Affinity**—Sphenopsid (Andrews and Agashe, 1963).

*Reticulatisporites reticulatus* (Ibrahim) Ibrahim 1933

(Plate 10, fig. 21)

1932 *Sporonites reticulatus* Ibrahim in Potonie', Ibrahim and Loose, p. 447, pl. 14, fig. 3.

1933 *Reticulatisporites reticulatus* (Ibrahim) Ibrahim, p. 33, pl. 1, fig. 3.

1938 *Azoneotrites reticulatus* (Ibrahim) Luber in Luber and Waltz, pl. 7, fig. 99.

**Occurrence**—Rare.

**Genus REINSCHOSPORA** Schopf, Wilson and Bentall 1944

**Type species**—*R. speciosa* (Loose) Schopf, Wilson and Bentall 1944.

**Affinity**—Unknown.

*Reinschospora speciosa* (Loose) Schopf, Wilson and Bentall 1944

(Plate 11, fig. 1)

1934 *Alatisporites speciosus* Loose, p. 151, pi. 7, fig. 1.

1944 *Reinschospora bellius* Bentall in Schopf, Wilson and Bentall, p. 53, fig. 2.

1944 *Reinschospora speciosa* (Loose) Schopf, Wilson and Bentall, p. 53.

**Discussion**—*R. magnifica* Kosanke 1950 is similar and may be synonymous. *R. punctata* Kosanke 1950 is distinguished from *R. speciosa* by possession of a distinctly punctate ornament; Urban (1971) observed that the corona is an equatorial extension of an exoexine separation over the entire spore body and noted a punctate ornament of the exoexine in some specimens ascribed to *R. speciosa*.

**Occurrence**—Rare.

*Reinschospora triangularis* (Kosanke) emend.

(Plate 11, figs. 3-6)

1950 *Reinschospora triangularis* Kosanke, p. 43, pl. 9, figs. 6, 7.

1957 *Reinschospora fimbriata* Artúz, p. 255, pl. 7, fig. 50.

1965a *Reinschisporites triangularis* (Kosanke) Lavelle, p. 134, pl. 10, fig. 40.
Diagnosis (emended from description of Kosanke, 1950, p. 43)—Miospores radial, trilete, triangular in outline exclusive of corona. Margin between radii slightly convex, corners opposite radii pointed, rarely folded. Spore coat laevigate, may appear slightly granulose (?) infrasculpture under oil immersion objective. Equatorial portion of spore ornamented with a corona of bifurcating spines often with rounded or bulbous tips. Spines near angles extend 5 to 6 microns beyond spore wall; spines midway between angles approximately twice as long. All spines appear to originate well within the spore wall. A quasi-trilete fringe of similar but smaller spines occurs opposite the laserae on the distal surface. Outline of spore including corona is subospherial. Spores may bear subtriangular groups of minute papillae or grana, 6-20 in number, on the proximal surface near the angles; papillae about 1 micron in width and height. Distal surface occasionally ornamented with coarse cone-shaped spines, ranging from scattered individuals to a moderately crowded spine sculpture covering most of the distal surface. Spines 2-4 microns in width and height, both dimensions approximately equal on any given spine. Trilete rays, lips and commissure distinct, extending nearly to angles.

Size—Kosanke’s (1950) size range of 66-79 microns maximum diameter downward to include spores as small as 50 microns in maximum diameter.

Discussion—During the study of CP-19-4 and other Iowa coals, the writer observed spores bearing groups of papillae or grana near the angles and coarse cone-shaped distal spines, but in other respects corresponding to R. triangularis Kosanke 1950. After study of Kosanke’s holotype, it was considered more appropriate to emend the diagnosis to include such forms rather than to erect a new species. The newly-included characteristics may be present in the Iowa material due to preservational fortuitu. The distal spines, in particular, appear to exist in a complete range of variation from none (plate 11, fig. 2), similar to the holotype (Kosanke, 1950), to many (plate 11, fig. 3).

Occurrence—Rare. Observed only in a narrow horizon in the Florinites interval.

Genus CUNEISPORITES gen. nov.

Type species—C. rigidus sp. nov.

Diagnosis—Miospores radial, trilete, strongly triangular to wedge-shaped in proximal-distal orientation. Sides straight to slightly convex, angles narrowly rounded. Exine thick and dark, thicker at equator and angles, reinforcing triangular shape upon compression. Often slightly elongated in one direction, producing bilaterally symmetrical wedge-shaped outline. Compression folds parallel to equator, especially on distal surface, give the impression of a zona. Trilete rays straight, extending nearly to equator.

Discussion—The relatively uniform equatorial thickening of the exine, which is not a flange or separate zonal structure from the main spore body, serves to distinguish Cuneisporites from other strongly triangular genera. It most closely resembles Zosterosporites, but the latter genus possess a beltlike equatorial thickening much more distinct than the thickening of Cuneisporites.

Derivation—The generic nomen refers to the wedge-shaped (cuneus) aspect of the miospore in polar compression.

Affinity—Unknown.

Cuneisporites rigidus sp. nov.
(Plate 11, figs. 7-9)

Diagnosis—Miospores conforming to the characteristics of the genus. Normally in good proximal-distal orientation. Both proximal and distal surfaces evenly ornamented with closely spaced fine grana less than 1 micron in breadth and height, scarcely visible at margin. Laserae bearing narrow but distinct lips. Thickness of exine at equator between rays about 3 microns, may be slightly thicker at angles. Compression folds often produce appearance of a triangular zona congruent to the equator. Spores commonly dark, making features difficult to discern.

Size—(12 specimens) 40-50 microns maximum diameter.

Discussion—C. rigidus resembles Stenozonotriletes infirmus Naumova 1953 (p. 74, pi. 11, fig. 4). The genus Stenozonotriletes has been emended (Hacquebard, 1957; Potonić, 1958) to apply only to spores with a distinct cingulum; Smith and Butterworth (1967) noted that care must be taken to distinguish a true cingulum from the marginal rim of thick-walled spores in compression, a feature displayed by Cuneisporites. C. rigidus also resembles Gravisporites densus Habib 1966, but the latter displays conspicuous thickening along the trilete rays. The status of the genus Gravisporites Bharadwaj 1954 is in question; Smith and Butterworth (1967) considered it synonymous with Cadiospora Kosanke 1950, and neither C. rigidus nor Habib’s (1966) species correspond properly to Cadiospora.

Derivation—The specific nomen of C. rigidus is derived from the apparent rigidity of the spore margin and angles, resulting in the strong triangularity of the spore upon compression.

Occurrence—Rare.

Holotype—Plate 11, fig. 8, slide 2H2 coordinates 128-55.5, 47.3 microns maximum diameter.
Paratype—Plate 11, fig. 7, slide CP-10-49 slide B-9 coordinates 127-69.5, 45.6 microns.
Paratype—Plate 11, fig. 9, slide 2H3 coordinates 125-40, 41.0 microns.

Genus TETANISPORITES gen. nov.

Type species—T. granulatus sp. nov.

Diagnosis—Miospores radial, trilete, subtriangular in equatorial outline. Laserae straight, extending to angles, commissure narrow, bordered by a raised, thickened area of uniform width which serves to reinforce the proximal surface of the spore during compression, producing compression folds or wrinkles on the distal surface transverse to the laserae midway between the pole and the angles. Compression folds occasionally

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absent, but usually one or more of the angles bears such a transverse fold; folds often give the spore a semi-hexagonal outline.

**Discussion**—The characteristic thickened region bordering the laesae is similar to that observed in *Cadiospora*, but the latter genus possesses faint curvaturae (Smith and Butterworth, 1967) and a circular outline.

**Derivation**—The generic nomen refers to the stiffened (tetanus) thick border along the laesae which produces the characteristic folding on compression.

**Affinity**—Unknown.

*Tetanisporites granulatus* sp. nov.  
(Plate 11, figs. 10-12)

**Diagnosis**—Miospores conforming to the characteristics of the genus. Both proximal and distal surfaces evenly ornamented with closely spaced fine grana about 1 micron in breadth and height, producing a serrated margin. Ridge along laesae up to 8 microns in width and 2 microns in height. Usually in good proximal-distal orientation. Exine thick (3 microns or greater) and dark, often rendering observation of morphologic features difficult.

**Size**—(23 specimens) 36-51 microns maximum diameter.

**Discussion**—Although *T. granulatus* is the sole species of the genus described at present, miospores with an essentially laevigate exine having characteristics typical of *Tetanisporites* have been observed in certain Iowa coals (not in CP-19-4).

**Derivation**—The specific nomen refers to the granulose ornament.

**Occurrence**—Rare.

**Holotype**—Plate 11, fig. 11, slide 1C1 coordinates 119-58, 49.6 microns maximum diameter.

**Paratype**—Plate 11, fig. 10, slide 6V3 coordinates 134.5-51, 45.6 microns.

**Paratype**—Plate 11, fig. 12, coal CP-10-7 slide 12 coordinates 119-58, 49.6 microns.

**Genus SAVITRISPORITES** Bharadwaj 1955

**Type species**—*S. triangularis* Bharadwaj 1955.

**Affinity**—Filicales. Spores corresponding to *Savitrisporites* were recovered from a fern fructification of the genus *Derflation* (Butterworth, 1939).

*Savitrisporites nux* (Butterworth and Williams)  
Smith and Butterworth 1967  
(Plate 12, fig. 2)

1958 *Callisporites nux* Butterworth and Williams, p. 377, pl. 3 figs. 24-25.

1964 *Savitrisporites nux* (Butterworth and Williams) Sullivan, p. 373, pl. 60, figs. 1-5.

1964 *Converticulosporites idiili* Ibrahim-Okay and Artuz, p. 272-273, text-fig. 1, pl. 1, fig. 4.

1967 *Savitrisporites nux* (Butterworth and Williams) Smith and Butterworth, p. 223-225, pl.15, figs. 1-3.

**Occurrence**—Rare.

*Savitrisporites* sp. 1  
(Plate 12, fig. 3)

**Description**—Miospores radial, trilete, broadly sphaerotriangular in equatorial outline. Often obliquely compressed, suggesting that the original shape was somewhat hemispherical. Ornament of low, irregular ridges or broad, partly fused verrucae as large as 5 microns in width at base. Ridges on proximal surface indistinctly aligned parallel to laesae; laesae reaching nearly to equator. One rather conspicuous ridge usually runs along equator on proximal surface, appearing as a reduced cingulum. Exine relatively thick. Size of illustrated specimen 54.7 microns maximum diameter.

**Discussion**—The alignment of ornament congruent to the laesae on the proximal surface is typical of the genus, but the ornament is less conspicuous than in other species. The equatorial outline of *S. sp. 1* is more rounded than most other species.

**Occurrence**—Rare.

**Genus GRUMOSISPORITES** Smith and Butterworth 1967

**Type species**—*Grumosisporites rufus* (Butterworth and Williams) Smith and Butterworth 1967.

**Affinity**—Unknown.

*Grumosisporites (?) rufus* (Butterworth and Williams),  
Smith and Butterworth 1967  
(Plate 12, fig. 1)

1958 *Verrucosporites rufus* Butterworth and Williams, p. 363, pl. 1, figs. 44, 45.


1970 *Grumosisporites cf. rufus* (Butterworth and Williams) Smith and Butterworth 1967; Peppers, p. 119, pl. 11, fig. 15.

**Discussion**—The exine separation characterizing genus *Grumosisporites* is very indistinctly developed in *G. rufus*. Specimens observed in CP-19-4 did not reveal exine separation clearly, and therefore assigned questionably to the genus, even though other characters such as size, shape and ornament correspond to *G. rufus*.

**Occurrence**—Rare.

**Genus CRISTATISPORITES** (Potonie' and Kremp)  
Butterworth, Jansonius, Smith and Staplin 1964

**Type species**—*C. indignabundus* (Loose) Staplin and Jansonius 1964.

**Affinity**—Lycopsid (Chaloner, 1962).

*Cristatisporites indignabundus* (Loose) Staplin and Jansonius 1964  
(Plate 12, fig. 1)


1958 *Verrucosporites indignabundus* (Loose) Staplin and Jansonius, p. 166.

1954 *Cristatisporites indignabundus* (Loose) Potonie and Kremp, p. 142.

1964 *Cristatisporites indignabundus* (Loose) Staplin and Jansonius, p. 108-109, text-fig. 2c, pl. 19, figs. 7-9, 12, 14, 20.

1965b *Demisporites indignabundus* (Loose) Laveine, p. 133.
Discussion—C. indignabundus is highly variable in ornamentation. An inconveniently large number of species of Cristatisporites have been erected, many distinguished by subtle, narrowly circumscribed morphologic features that paleobotanical studies (e.g., Leisman, 1970) indicate may be individual variations of phylogenetically identical spores. Specimens observed in CP-19-4 correspond closely to the descriptions and illustrations of C. indignabundus reported by previous workers.

Occurrence—Rare.

Genus RADIIZONATES Staplin and Jansonius 1964

Type species—R. aligerens (Knox) Staplin and Jansonius 1964.


Radiizonates cf. difformis (Kosanke) Staplin and Jansonius 1964

(Plate 12, figs. 7, 8)

1950 Cirratriradites difformis Kosanke, p. 35, pl. 7, fig. 3.
1957a Cingulizonates asteroides Dybová and Jachowicz, p. 173-174, pl. 54, figs. 1-4.
1957a Cingulizonates karezewskii Dybová and Jachowicz, p. 175-176, pl. 56, figs. 1-4.
1964 Radiizonates difformis (Kosanke) Staplin and Jansonius, p. 106.

Discussion—Spores designated R. cf. difformis differ from the type description in being somewhat smaller, and occasionally displaying less distinct ribbing in the flange.

Occurrence—Rare.

Genus CINGULIZONATES (Dybová and Jachowicz)

Butterworth, Jansonius, Smith and Staplin 1964

Type species—C. bialatus (Waltz) Smith and Butterworth 1967.

Affinity—Lycopsid (Chaloner, 1958a).

Cingulizonates loricatus (Loose) Butterworth and Smith in Butterworth et al., 1964

(Plate 13, fig. 13)

1932 Sporones loricatus Loose in Potonic, Ibrahim and Loose, p. 450, pl. 18, fig. 42.
1934 Zonales-sporites loricatus Loose, p. 151.
1964a Denisporites loricatus (Loose) Agrali, p. 13.
1964 Cingulizonates loricatus (Loose) Butterworth and Smith, in Butterworth et al., p. 1053, pl. 2, fig. 4.

Discussion—Smith and Butterworth (1967) noted the essential similarity between C. loricatus and C. bialatus. In British coals, the two species have distinct stratigraphic ranges. The genus does not appear to have been reported previously from Midcontinent North American coals, and the specimens encountered in CP-19-4 are assigned to C. loricatus due to its occurrence in equivalent Westphalian strata in Britain (Smith and Butterworth, 1967; Clayton et al., 1977). C. loricatus has also been observed in abundance in Lower Pennsylvanian coals of eastern Iowa.

Occurrence—Rare.

Genus CRASSISPORA (Bharadwaj) Sullivan 1964

Type species—C. kosankei (Potonie and Kremp) Smith and Butterworth 1967.

Affinity—Miospores of genus Crassispora have been isolated from reproductive cones of the lycopsid family Sigillariaceae (Retschlag and Remy, 1954; Courvoisier and Phillips, 1975). Spores resembling Crassispora also have been recovered from the sphenopsid cone Calamostachys (Abbott, 1968).

Crassispora annulata sp. nov.

(Plate 12, figs. 11-15)

1964 Crassispora plicata Peppers (in part), p. 17, pl. 2, fig. 2.
non 1964 Crassispora plicata Peppers (in part), p. 17, pl. 1, fig. 18.
1964 Crassispora kosankei (Potonie and Kremp) Bharadwaj; Sullivan, pl. 60, fig. 14.

Diagnosis—Miospores radial, trilete, roundly triangular in equatorial outline, normally in good proximal-distal orientation. Laesurae faint, difficult to observe, extend nearly to angles. Spores display a distinct separation of the intine, resulting in a uniform ring-like sub-equatorial structure or "annulus". The separation of exine layers appears to be confined to the equatorial region of the spore, as the intine is not folded and the zone of separation around the equator is relatively uniform in width on any individual specimen. The width of the zone of exine separation varies from 3 to 8 microns between specimens. Exine thin, 2 microns or less, and crescentic compression folds commonly cross the polar areas of the spore, obscuring the laesurae; margin usually not folded. Faint apical papillae are present. External sculpture varies from finely to coarsely granulose, and is confined to the distal hemisphere and equatorial margin.

Size—(30 specimens) 36-55 microns maximum diameter.

Discussion—C. plicata Peppers 1964 as described is now considered synonymous with C. kosankei by Peppers (personal communication 1976). Examination of the type specimens of C. plicata, however, revealed that the second paratype (Peppers, 1964, pl. 2, fig. 2) corresponds to C. annulata sp. nov. Sullivan (1964, pl. 60, fig. 14) illustrated a similar specimen, and considered it a variant of C. kosankei. C. annulata sp. nov. is erected therefore with some hesitancy: the decision to create a new species is based on the absence of forms intermediate between C. annulata and C. kosankei in CP-19-4, and observations on other Iowa coals that suggest the possibility of distinct stratigraphic ranges for the two forms. As the holotype of C. plicata does correspond to C. kosankei, it is considered advisable in the interest of clarity to propose the new name C. annulata, based on characteristics other than those cited by Peppers (1964) in his description of C. plicata, rather than to attempt to emend the diagnosis of C. plicata and conserve the name. An emendation would create a confusing and potentially ambiguous circumstance concerning types.

C. annulata differs from C. kosankei in displaying distinct exine separation; C. kosankei has an equatorial
Crassitude not present in *C. annulata*, and the character of compression folds in the two species also tends to differ, with folds most often arranged around the equator of *C. kosankei*, but most often transecting polar regions of *C. annulata*. *C. annulata* is also consistently somewhat smaller than *C. kosankei*, although the size ranges of the species overlap.

**Derivation**—The specific nomen refers to the annular structure formed by the internal membrane.

**Occurrence**—Rare to infrequent, observed principally in segments 6 and 7 of the Densosporites-Crassispora interval.

*Holotype*—Plate 12, fig. 11, slide 6V3 coordinates 131.5-48.5, 49.6 microns maximum diameter.

*Paratype*—Plate 12, fig. 12, slide 6R6 coordinates 128-63, 50.1 microns.

*Paratype*—Plate 12, fig. 13, slide 7M3 coordinates 128-53.5, 42.8 microns.

*Paratype*—Plate 12, fig. 14, slide 7D2 coordinates 133-56, 38.8 microns.

*Paratype*—Plate 12, fig. 15, slide 6H4 coordinates 123-41.5, 46.7 microns.

*Crassispora kosankei* (Potonie and Kremp)

Smith and Butterworth 1967

(Plate 12, figs. 9, 10)

1955 *Planisporites kosankei* Potonie and Kremp, p. 71, pl. 13, figs. 208-213.

1957a *Planisporites ovalis* Bharadwaj, p. 86, pl. 23, figs. 9, 10.

1957b *Crassispora ovalis* Bharadwaj, p. 126, pl. 25, figs. 73-76.

1957b *Crassispora kosankei* (Potonie and Kremp) Bharadwaj, p. 127.

1957 *Apiculatisporites apiculatus* (Ibrahim) Dybová and Jachowicz (non sensu Ibrahim) p. 87, pl. 15, figs. 1-4.

1964 *Crassispora plicata* Peppers (in part), p. 17, pl. 1, fig. 18, pl. 2, fig. 1.

1964 *Crassispora plicata* Peppers (in part), p. 17, pl. 2, fig. 2.

1967 *Crassispora kosankei* (Potonie and Kremp) Bharadwaj, p. 234, pl. 19, figs. 2-4.

**Discussion**—See Discussion of *C. annulata* sp. nov.

**Occurrence**—Characteristic species of the Densosporites-Crassispora interval, where it is often abundant and occasionally dominant; rare in the Florinites and Lycospora intervals.

**Genus CAPPASPORITES Urban 1966**

_Type species_—*C. distortus* Urban 1966.

**Affinity**—Miospores of genus Cappasporites have been isolated from the lycopod cone *Achlamydocarpon* (Courvoisier and Phillips, 1975; Leisman and Phillips, 1979).

*Cappasporites distortus* Urban 1966

(Plate 13, figs. 1, 2)


1966 *Crannisporites medius* Dybová and Jachowicz 1957; Habib, p. 634, pl.105, figs. 2, 3, 5.

1970 *Crassispora plicata?* Peppers 1964; Peppers, pl. 11, fig. 19.

**Discussion**—Apiculatisporis irregularis (Alpern) Smith and Butterworth 1967 displays an ornament similar to that of *C. distortus*, but the grana are arranged in loose groups or patches and appear to occur on both distal and proximal surfaces; grana of *C. distortus* are more random in distribution and are confined to the distal surface. *A. irregularis* (Alpern) Smith and Butterworth 1967 is a junior homonym of *A. irregularis* (Kosanke) Potonie and Kremp 1955.

**Occurrence**—Common to occasionally abundant throughout CP-19-4, although somewhat reduced in numbers in the Densosporites-Crassispora interval.

**Genus DENSOSPORITES (Berry) Butterworth, Jansonius, Smith and Staplin 1964**

_Type species_—*D. covensis* Berry 1937.

**Affinity**—Miospores assignable to Densosporites have been described from minute lycopod cones, probably related to herbaceous plants (Chaloner, 1958a; Bharadwaj, 1958; Leisman, 1970).

*Densosporites anulatus* (Loose) Smith and Butterworth 1967

(Plate 13, figs. 3-5)

1932 *Sporonites anulatus* Loose in Potonie, Ibrahim and Loose, p. 45, pl. 18, fig. 44.


1944 *Densosporites anulatus* (Loose) Schoof, Wilson and Bentall, p. 40.

1950 *Denso-sporites reynoldsburgensis* Kosanke, p. 33, pl. 6, figs. 9-11.

1956 *Anulatisporites anulatus* (Loose) Potonie and Kremp, p. 112, pl. 17, figs. 365-372.

1967 *Densosporites anulatus* (Loose) Smith and Butterworth, p. 239, pl. 19, figs. 5, 6.

**Occurrence**—Rare.

*Densosporites irregularis* Hacquebard and Barss 1957

(Plate 13, fig. 9)

1957 *Denso-sporites irregularis* Hacquebard and Barss, p. 31, pl. 4, figs. 11-14.

**Discussion**—*D. cavus* Urban 1971 (p. 118, pl. 26, figs. 10-12, pl. 27, figs. 1-5) displays similar “excavations” around the cingulum, but has small coni on the distal surface, and is smaller than *D. irregularis*.

**Occurrence**—Rare.

*Densosporites sphaerotriangularis* Kosanke 1950

(Plate 13, figs. 7, 8)

1950 *Densosporites sphaerotriangularis* Kosanke, p. 33-34, pl. 6, fig. 7.


**Occurrence**—Characteristic of the Densosporites-Crassispora interval, where it ranges from common to dominant. Rare in the Florinites interval and lower levels of the Lycospora interval, but becomes frequent to common in the uppermost levels of the seam.

*Densosporites spinifer* Hoffmeister, Staplin and Malloy 1955

(Plate 13, figs. 10-12)
Discussion—D. spinifer was first described from the Mississippian and is given a range of Viséan to Namurian (Upper Mississippian equivalent) by Smith and Butterworth (1967) in Britain. Miospores assigned to this species in CP-19-4 correspond closely to the description of Hoffmeister, Staplin and Malloy (1955).

Occurrence—Rare, Densosporites-Crassispora interval.

**Densosporites triangularis** Kosanke 1950

(Plate 13, fig. 6)

1950 Densosporites triangularis Kosanke, p. 34, pl. 7, fig. 1.
1958 Densosporites spongeous Butterworth and Williams, p. 380, pl. 3, figs. 40, 41.
1966 Densosporites oblatus Habib, p. 641-642, pl. 106, figs. 12, 14.

Occurrence—Rare, Florinites interval.

Genus Lycospora (Schopf, Wilson and Bentall) Potoniéand Kremp 1954

Type species—L. micropapillata (Wilson and Coe) Schopf, Wilson and Bentall 1944.

Discussion—A great many species of Lycospora have been described, and paleobotanical studies of spores from reproductive structures have indicated that many are superfluous (Balbach, 1966). In an attempt to bring order to the genus, Somers (1971) revised Lycospora, synonymizing many species into a few broadly defined form categories. This revision has been employed variously by subsequent authors, and the utility of certain synonyms has been questioned (e.g., Coquel, 1973). The revision is not followed in this report.


**Lycospora granulata** Kosanke 1950

(Plate 13, fig. 15)

1950 Lycospora granulata Kosanke, p. 45, pl. 10, figs. 4, 6.
1957a Lycospora denticulata Bharadwaj, p. 103, pl. 27, fig. 9.
1957a Lycospora triangularis Bharadwaj, p. 103, pl. 27, figs. 13, 14.

Discussion—Miospores assignable to L. granulata under Kosanke's (1950) description exhibit variable coarseness and density of granulose ornament, a characteristic noted by other workers (e.g., Smith and Butterworth, 1967).

Occurrence—L. granulata is infrequent to frequent through the Florinites and Densosporites-Crassispora intervals, but becomes the dominant miospore species above segment 9, marking the base of the Lycospora interval. L. granulata consistently constitutes 50% or more of the miospore population in segments 10 and 11.

**Lycospora micropapillata** (Wilson and Coe) Schopf, Wilson and Bentall 1944

(Plate 13, fig. 14)

1940 Cirratriradites micropapillatus Wilson and Coe, p. 184, fig. 6.
1944 Lycospora micropapillata (Wilson and Coe) Schopf, Wilson and Bentall, p. 54.

Discussion—The original diagnosis of this species is inadequate and was not emended by Schopf, Wilson and Bentall (1944) when reassigned as the type species of Lycospora. Wilson (1958, pl. 1, fig. 6) noted that the original size measurements of the species were in error and provided the first photographic illustration of it. Specimens observed in CP-19-4 are therefore assigned with some hesitancy to L. micropapillata primarily on the basis of comparison with Wilson's (1958) illustration.

Occurrence—Rare to infrequent in the Lycospora interval, rare in the Florinites and Densosporites-Crassispora intervals.

**Lycospora pellucida** (Wicher) Schopf, Wilson and Bentall 1944

(Plate 13, fig. 16)

1934 Sporites pellucidus Wicher, p. 186, pl. 8, fig. 29.
1944 Lycospora pellucida (Wicher) Schopf, Wilson and Bentall, p. 54.
1950 Lycospora punctata Kosanke, p. 45, pl. 10, fig. 7.
1950 Lycospora pseudoannulata Kosanke, p. 45, pl. 10, fig. 3.
1955 Cirratriradites uber Hofmeister, Staplin and Malloy, p. 383, pl. 36, fig. 24.
1957a Lycospora microgranulata Bharadwaj, p. 104, pl. 27, fig. 18.
1957 Lycospora tenuireticulata Artüz, p. 250, pl. 5, fig. 32.
1957 Lycospora uzunmehmedi Artüz, p. 250, pl. 5, fig. 33.
1960 Lycospora uber (Hofmeister, Staplin and Malloy) Staplin, p. 20, figs. 13, 17, 18, 20.
1964 Lycosisporites pellucidus (Wicher) Levet-Carette, p. 272, pl. 10, fig. 24.

Discussion—The likelihood of synonymy of L. punctata and L. pseudoannulata with L. pellucida has been suggested by previous workers (Smith and Picart, in Pierart et al., 1964; Smith and Butterworth, 1967; Peppers, 1970). L. uber, L. microgranulata and L. uzunmehmedi are also considered synonymous with L. pellucida in this report. Somers (1971) considered L. pellucida to be synonymous with L. pusilla (Ibrahim) Schopf, Wilson and Bentall 1944, but this view is not followed here.

Occurrence—Common to occasionally dominant through the Florinites interval, infrequent to common in the lower portion of the Densosporites-Crassispora interval, rising to dominance with a peak of abundance of more than 50% in the upper portion of the interval; rare to infrequent throughout the Lycospora interval.

**Lycospora rotunda** Bharadwaj 1957

(Plate 13, figs. 19, 20)

1957a Lycospora rotunda Bharadwaj, p. 103, pl. 27, figs. 10-12.
1957 Lycospora nitida Artüz, p. 250, pl. 5, fig. 34.
1957 Lycospora paulula Artüz, p. 250, pl. 5, fig. 35.

Occurrence—Rare.

Lycospora cf. L. torquifer (Loose) Potonie and Kremp 1956

1932 Sporonites torquifer Loose in Potonie, Ibrahim and Loose, p. 450, pl. 18, fig. 43.
1956 Lycospora torquifer (Loose) Potonie and Kremp, p. 104, pl. 17, fig. 355-359.

Discussion—Pierart (1964) excluded L. torquifer from the genus Lycospora after an examination of photographs of the holotype indicated that it did not possess a cingulum. Potonie and Kremp (1956), in reassigning the species to Lycospora, illustrated four additional specimens which are definitely cingulate. Specimens observed in CP-19-4 closely resemble these specimens and have a granulose ornament intermediate in coarseness between L. granulata and L. rotunda. Peppers (1970) recognized similar spores as L. cf. torquifer.

Occurrence—Rare, but widely distributed throughout CP-19-4.

Cirratriradites reticulatus sp. nov.
(Plate 14, figs. 4-6)

Diagnosis—Miospores radial, trilete, sphaerotriangular to nearly circular in equatorial outline, usually in good proximal-distal orientation. Finely serrate equatorial flange, very thin, diaphanous and nearly transparent in outer region, slightly thicker near conjunction with spore body; fine radial striations occur in thicker portion of flange. Flange 5-10 microns wide, slightly wider at angles. Laesurae raised, narrow and slightly sinuose, reaching to angles, often indistinct, obscured by distal ornament. Proximal surface nearly laevigate to finely punctate (?infraosculature), exine thin; distal surface of spore body covered with well-developed reticulum of irregularly polygonal lumina. Muri 1-2 microns wide, about 1 micron in height, tending to merge near edge of spore body. Over most of the distal surface, lumina are relatively equal in size, 2-8 microns in maximum dimension. Spore body seldom folded, but flange often possesses minor folds.

Size—(10 specimens) 42-54 microns maximum diameter including flange.

Discussion—No distal fovea has been observed. C. reticulatus is distinguished from other species of the genus by its strongly developed distal reticulum. C. saturni has a finer, less conspicuous reticulate sculpture, but is usually larger, has a more substantial flange, and normally bears a distal fovea.

Derivation—The specific nomen refers to the reticulate distal ornament.

Occurrence—Rare, observed only in coaly shale unit, CP-19-5.

Holotype—Plate 14, fig. 4, CP-19-5 slide Y-4 coordinates 124.5-33, 52.4 microns maximum diameter including flange.

Paratype—Plate 14, fig. 5, CP-19-5 slide A-3 coordinates 128-61, 49.6 microns.

Paratype—Plate 14, fig. 6, CP-19-5 slide X-5 coordinates 137.5-34.5, 51.3 microns.

Cirratriradites saturni (Ibrahim) Schopf, Wilson and Bentall 1944
(Plate 14, fig. 3)

1932 Sporonites saturni Ibrahim in Potonie, Ibrahim and Loose, p. 448, pl. 15, fig. 14.
1933 Zonales-sporites saturni Ibrahim, p. 30, pl. 2, fig. 14.
1938 Zonotriletes saturni (Ibrahim) Luber in Luber and Waltz, p. 8, fig. 102.
1944 Cirratriradiles saturni (Ibrahim) Schopf, Wilson and Bentall, p. 44.
1965a Cirratrisporites saturni (Ibrahim) Laveine, p. 134.

Discussion — Wilson (1966) indicated that C. saturni differs from C. maculatus in possession of a reticulate sculpture on the spore body and radial striations in the flange.

Occurrence — Rare.

Genus ENDOSPORITES Wilson and Coe 1940

Type species — E. ornatus Wilson and Coe 1940.

Discussion — As noted by Smith and Butterworth (1967), the generic diagnosis of Wilson and Coe (1940) has become inadequate for separation of pseudosaccate spore genera, and is in need of emendation based on study of type materials. Although not noted by Wilson and Coe (1940), most subsequent studies have considered possession of a limbus to be a generic character for Endosporites, distinguishing it from such genera as Florinites Schopf in Schopf, Wilson and Bentall 1944 and Wilsonites (Kosanke) Kosanke 1959.

Affinity — Spores of genus Endosporites have been described as microspores from the cone of a heterosporous arborescent lycopod (Chaloner, 1953b, 1958b; Brack and Taylor, 1972). Recent study of the cone genus (Polysporia), however, suggests an herbaceous rather than an arborescent habit (DiMichele, Mahaffy and Phillips, in press).

Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944

(Plate 14, fig. 7)

1932 Sporonites globiformis Ibrahim in Potonie, Ibrahim and Loose, p. 447, pl. 14, fig. 5.
1933 Zonales-sporites globiformis Ibrahim, p. 28, pl. 1, fig. 5.
1938 Zonotriletes globiformis (Ibrahim) Luber in Luber and Waltz, pl. 8, fig. 103, pl. B, fig. 30.
1944 Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall, p. 45.
1965a Endopollenites globiformis (Ibrahim) Laveine, p. 136.

Discussion — Distinction between E. globiformis and E. zonalis (Loose) Knox 1950 is made on the basis of the ratio of body radius to pseudosaccus radius; E. globiformis has a body radius smaller than the width of the pseudosaccus, where E. zonalis has a body radius greater than that of the pseudosaccus. E. zonalis commonly, though not always, also display a faint zonate structure around the margin of the spore body, which may reflect some exine separation. Smith and Butterworth (1967) noted the existence of several similar and possibly synonymous species, including E. ornatus, the type species, which is described as having a body-to-pseudosaccus ratio intermediate between E. globiformis and E. zonalis.

Occurrence — Common to abundant in the Florinites interval, infrequent or rare in the Densosporites-Crassiospora interval, frequent to common in the Lycospora interval. The overall frequency curve of E. globiformis is similar to that of Florinites mediapudens (Loose) Potonie and Kremp 1956, suggesting a possible paleoecologic similarity in the two saccate species.

Endosporites staplinii Gupta and Boozer 1969

(Plate 14, figs. 9-11)

1960 Endosporites? parvus Staplin, p. 33, pl. 7, figs. 8, 12.
1958 Endosporites parvus Guennel, p. 50-51, text-fig. 11, pl. 1, figs. 16, 17.
1969 Endosporites staplinii Gupta and Boozer, p. 78.
1976 Endosporites cf. micromanifestus Hacquebard 1957; Tillement, Peniguel and Guillemin, p. 438, pl. 1, fig. 27.

Discussion — The spelling of the specific name is altered from staplini to staplinii as an orthographic correction without emendation.

E. egemeni (Agrali) Loboziak 1971 resembles E. staplinii, but the inadequacy of the original description of E. egemeni (Agrali, 1964b), which was not expanded in Loboziak's (1971) reassignment, makes comparison difficult and suggests that E. egemeni would best be regarded as a nomen nudum. E. egemeni is given a size range slightly larger than that of E. staplinii (24-35 microns: Staplin, 1960), and the former was described from strata younger than that characterized by reported occurrences of E. staplinii. Neither Agrali (1964b) nor Loboziak (1971) suggested synonymy of E. egemeni with E.? parvus Staplin 1960.

Occurrence — Rare, observed primarily in the Florinites interval.

Endosporites zonalis (Loose) Knox 1950

(Plate 14, fig. 8)

1934 Zonales-sporites zonalis Loose, p. 148, pl. 7, fig. 5.
1944 Cirratriradiles zonalis (Loose) Schopf, Wilson and Bentall, p. 44.
1950 Endosporites zonalis (Loose) Knox, p. 332.
1965a Endopollenites zonalis (Loose) Laveine, p. 136.

Occurrence — Rare to infrequent throughout CP-19-4; less abundant than E. globiformis.

Genus ALATISPORITES (Ibrahim) Smith and Butterworth 1967

Type species — A. pustulatus (Ibrahim) Ibrahim 1933.

Affinity — Unknown. Spores of Alatisporites have been isolated from a fructification of uncertain paleobotanical relationship (Courvoisier and Phillips, 1975).

Alatisporites hoffmeisterii Morgan 1955

(Plate 15, figs. 1, 2)


Occurrence — Rare, observed most often in the Florinites interval.

Alatisporites pustulatus (Ibrahim) Ibrahim 1933

(Plate 14, figs. 12, 13)

1932 Sporonites pustulatus Ibrahim in Potonie, Ibrahim and Loose, p. 448, pl. 14, fig. 12.
1933 Alatis-sporites pustulatus (Ibrahim) Ibrahim, p. 32, pl. 1, fig. 12.
Discussion—A. trialatus Kosanke 1950 is similar to A. pustulatus, but the latter species is ornamented on the proximal surface of the spore body by small, sinuose folds of the pseudosaccus, while the former is relatively smooth.

Occurrence—Rare, except for a narrow horizon in the Florinites interval where it is frequent.

Genus LAEVI GATOSPORITES Ibrahim 1933

Type species—L. vulgaris (Ibrahim) Ibrahim 1933.

Discussion—Several other genera of small monolete spores have been erected, notably Punctatosporites Ibrahim 1933, Lateosporites Potonié and Kremp 1954 and Speciososporites Potonié and Kremp 1954, which are distinguished from Laevigatosporites on the basis of characters which may be subject to considerable variation or which may be difficult to determine with consistency. Small monolete spores observed in CP-19-4 having little or no exine ornament were assigned entirely to Laevigatosporites, although certain of the other genera could have been employed in individual instances. These alternative assignments are noted where appropriate in the individual species synonymies.

Affinity—Laevigatosporites is a highly generalized form taxon containing mio-spores of both sphenopsid and fern affinities. Species larger than about 35 microns in length have been isolated only from sphenopsid fructifications (Reed, 1938; Andrews and Mamay, 1951; Leisman and Graves, 1964). In CP-19-4, species larger than 35 microns include L. medius, L. ovalis, L. desmoinensis, L. striatus, L. cf. dunkardensis, L. vulgaris and L. cf. vulgaris. Small monolete spores assignable to Laevigatosporites have been isolated from both ferns (Mamay, 1950; Ewart, 1961) and sphenopsids (Baxter, 1950; Andrews and Mamay, 1951). The smaller species in CP-19-4 include L. globosus and L. minutus; they are considered to have marattialean fern affinities, although a degree of uncertainty exists.

Laevigatosporites desmoinensis (Wilson and Coe)
Schopf, Wilson and Bentall 1944
(Plate 15, fig. 11)

1940 Phaseolites desmoinensis Wilson and Coe, p. 182, pl. 1, fig. 4.

Discussion—In this report, distinction between L. medius, L. ovalis, L. desmoinensis and L. vulgaris is made arbitrarily on the basis of length. The size range of L. desmoinensis was cited originally as 60-75 microns (Wilson and Coe, 1940), and is employed for L. desmoinensis here. Smith and Butterworth (1967) considered L. desmoinensis to be synonymous with L. vulgaris. In CP-19-4, however, a bimodal size distribution of larger forms of Laevigatosporites was observed. Few specimens occurred with lengths of 70-80 microns, and a 75-micron boundary was employed for separation of the smaller L. desmoinensis from the larger L. vulgaris. L. vulgaris is commonly thinner than L. desmoinensis and often possesses minor compression folds near the ends of the laesura; L. desmoinensis rarely displays folds.

Occurrence—Rare to infrequent throughout CP-19-4.

Laevigatosporites cf. dunkardensis Clendening 1970
(Plate 15, fig. 14)

1968 Laevigatosporites plicatus Kar, p. 120-121, pl. 1, figs. 28, 29.

Discussion—L. dunkardensis overlaps the size ranges of L. desmoinensis and L. vulgaris but is distinguished from these latter species by its extremely thin, much-folded Calamospora-like exine. Specimens observed in CP-19-4, designated L. cf. dunkardensis, displayed a more distinct, raised laesura than specimens of L. dunkardensis described by Clendening (1969).

Occurrence—Rare, observed primarily in lower levels of the Florinites interval.

Laevigatosporites globosus Schopf 1951
(Plate 15, figs. 4-6)

1951 Laevigatosporites globosus Schopf, p. 746-747, fig. 2.
1956 Lateosporites globosus (Schopf) Potonié and Kremp, p. 140.

Discussion—Spores assigned to L. globosus in CP-19-4 displayed ornamentation ranging from punctate to laevigate to granulose, as illustrated in plate 15, figs. 4-6. See also Discussion of Punctatosporites obliquus.

Occurrence—Common in lower levels of Florinites interval, rare to infrequent above segment 1.

Laevigatosporites medius Kosanke 1950
(Plate 15, figs. 8, 9)

1934 Laevigatosporites minor Loose (in part), p. 158, pl. 7, fig. 12.
1950 Laevigatosporites medius Kosanke, p. 29, pl. 16, fig. 2.

Discussion—L. medius is considered here to have a length ranging from 32-45 microns.

Occurrence—Rare, but widely distributed throughout CP-19-4.

Laevigatosporites minutus (Ibrahim) Schopf, Wilson and Bentall 1944
(Plate 15, fig. 3)

1933 Punctatosporites minutus Ibrahim, p. 40, pl. 5, fig. 33.

Discussion—Forms smaller than 32 microns in length are assigned here to L. minutus. The relations of this species with L. minimus (Wilson and Coe) Schopf, Wilson and Bentall 1944 and L. perminutus Alpern 1959 are unclear. The exine of L. minutus commonly appears infrapunctate.

Occurrence—Common to abundant throughout CP-19-4.

Laevigatosporites ovalis Kosanke 1950
(Plate 15, fig. 10)

1934 Laevigatosporites ovalis Loose (in part), p. 158, pl. 7, fig. 12.
1950 Laevigatosporites ovalis Kosanke, p. 29-30, pl. 5, fig. 7.
Discussion—L. ovalis is considered to have a length ranging from 45-60 microns. Most specimens were somewhat wider in relation to their length than were specimens of L. desmoinei s. 

Occurrence—Common to abundant in the Florinites and Densosporites-Crassispora intervals, frequent to common in the Lycospora interval.

_Laevigatosporites striatus_ Alperrn 1959

(Plate 15, figs. 12, 13)

1959 _Laevigatosporites striatus_ Alperrn, p. 153, pl. 11, figs. 267, 268.

Discussion—The arcuate striations of _L. striatus_ appear to result from compression of a group of spores against one another, followed by separation of individual spores, possibly during maceration. Several masses of these spores were observed in CP-19-4. In the absence of striations, the spores would correspond to _L. ovalis_. Both _L. ovalis_ and _L. striatus_ did not accept safranin stain readily, suggesting similarity in exine characteristics. Despite these implications of potential synonymy of _L. striatus_ with _L. ovalis_, it is possible that the deposition of spores of _L. striatus_ in masses may be due to their production by a plant phylelogenetically distinct from that which produced _L. ovalis_ spores. The distribution of _L. striatus_ in CP-19-4 does not mimic that of _L. ovalis_, and study of other Iowa coals indicates that differences exist against one another, followed by separation of individual specimens of _T. striatus_, _cf._ _L. striatus_.

Densosporites-Crassispora interval; seldom observed elsewhere in CP-19-4.

_Laevigatosporites vulgaris_ (Ibrahim) Ibrahim 1933

(Plate 15, fig. 15)

1932 _Sporonites vulgaris_ Ibrahim in Potonić, Ibrahim and Loose, p. 448, pl. 15, fig. 16.

1933 _Laevigatosporites vulgaris_ (Ibrahim) Ibrahim, p. 39, pl. 2, fig. 16.

Discussion—In practice, forms of _Laevigatosporites_ ranging from 75 to 100 microns in length, having a laesura of 1⁄2 to more than 1⁄4 of the spore length, and displaying a relatively thin, but not diaphanous and heavily folded exine, are assigned to _L. vulgaris_. Specimens larger than 100 microns in length are assigned to _L. maximus_ (Loose) Potonić and Kremp 1956, 54; specimens fitting this description were encountered in CP-19-4, although the species has been observed in other Iowa coals. _L. dunkardensis_ can be of similar size to _L. vulgaris_, but the former species has an extremely thin exine, which is almost always heavily folded. A miospore designated _L._ _cf._ _vulgaris_ is described following.

Occurrence — Rare.

_Laevigatosporites_ _cf._ _vulgaris_ (Ibrahim) Ibrahim 1933

(Plate 15, fig. 16)

Description—Similar to _L. vulgaris_ in length, but with a considerably thicker exine and more oval shape. Laesura normally about 1⁄2 of spore length.

Occurrence — Rare.

Genus _THYMOSPORA_ Wilson and Venkatachala 1963(a)


_Affinity—_ Marattiales (Millay, 1979).

_Thymospora_ _cf._ _pseudothiessenii_ (Kosanke) Wilson and Venkatachala 1963

(Plate 16, figs. 2-4)

1950 _Laevigatosporites pseudothiessenii_ Kosanke, p. 30, pl. 5, fig. 10.

1956 _Verrucososporites pseudothiessenii_ (Kosanke) Potonić and Kremp, p. 144.


Discussion—Miospores designated _T._ _cf._ _pseudothiessenii_ display a greater variety of ornament than normal for _T. pseudothiessenii_.

Occurrence — Rare, Florinites interval.

Genus _TORISPORA_ (Balme) Doubinger and Horst 1961

_Type species—_ _T. securis_ Balme 1952.

_Affinity—_ Investigations of _Torispora_ have established that it represents the outermost cells of a sporangial mass in which the inner cells correspond to certain species of _Laevigatosporites_ and _Thymospora_ (Horst, 1957; Guennel and Neavel, 1961; Artüz, 1962). Spores corresponding to _Torispora_ have been isolated from fern fructifications, along with smaller forms of _Laevigatosporites_ (Laveine, 1969, 1970). Stach (1975) suggested a pteridospermous affinity, but this has not been substantiated and seems unlikely.

_Torispora securis_ Balme 1952

(Plate 16, fig. 1)

1952 _Torispora securis_ Balme, p. 183, text-fig. 3a-3d.

1957a _Torispora recta_ Dybová and Jachowicz, p. 197, pl. 66, figs. 1-4.

1957a _Torispora undulata_ Dybová and Jachowicz, p. 197, pl. 67, figs. 1-4.

1957a _Torispora speciosa_ Dybová and Jachowicz, p. 198, pl. 68, figs. 1-4.

Discussion—Alperrn (1958, 1959) and Alperrn, Doubing and Horst (1965) have erected a number of species of _Torispora_ differentiated by ornamentation. Smith and Butterworth (1967) suggested relationships between the species of _Torispora_ and various other monolete species of similar ornamentation. Specimens observed in CP-19-4 were uniformly of fine granulose ornamentation, and all were assigned to _T. securis_; _Laevigatosporites globosus_ displays similar ornament.

Occurrence — Rare to infrequent throughout CP-19-4.

Genus _TUBERCULATOSPORITES_ Imgrund 1960

_Type species—_ _T. anicystoides_ Imgrund 1960.

_Affinity—_ Unknown.

_Tuberculatosporites robustus_ (Kosanke) Peppers 1970

(Plate 16, figs. 5, 6)
Genus VESTISPORA (Wilson and Hoffmeister) Wilson and Venkatachala 1963(b)

Type species—\textit{V. profunda} Wilson and Hoffmeister 1956.

Affinity—Mamay (1954a) described spores assignable to \textit{Vestispora} from Iowa sphenopsid cone. Similar spores have been isolated from a variety of sphenopsid-related fructifications (Levittan and Barghorn, 1948; W. Remy, 1955; R. Remy, 1959; Brush and Barghoorn, 1964). See also Discussion of genus \textit{Elaterites}.

\textit{Vestispora fenestrata} (Kosanke and Brokaw) Spode, in Smith and Butterworth, 1967

(Plate 17, figs. 2, 3)


1954 \textit{Microreticulatosporites fenestratus} (Kosanke and Brokaw) Butterworth and Williams, p. 755, pl. 17, figs. 1-3, text-fig. 1, fig. 2.

1955 \textit{Foveolatosporites fenestratus} (Kosanke and Brokaw) Bharadwaj, p. 126, pl. 1, fig. 4.


1965b \textit{Vestisporites fenestralus} (Kosanke and Brokaw) Laveine, p. 2556, pl. 1, figs. 9, 24.

1967 \textit{Vestispora fenestrata} (Kosanke and Brokaw) Spode, in Smith and Butterworth, p. 296, pl. 25, figs. 3-6.

Discussion—\textit{V. velensis} (Bharadwaj) Wilson and Venkatachala 1963 is similar to \textit{V. fenestrata} and possibly synonymous.

Occurrence—Rare.

\textit{Vestispora laevigata} Wilson and Venkatachala 1963

(Plate 16, figs. 7-9)

1963b \textit{Vestispora laevigata} Wilson and Venkatachala, p. 98, pl. 1, figs. 8-11.

1965b \textit{Vestisporites laevigatus} (Wilson and Venkatachala) Laveine, p. 2556, pl. 1, fig. 10.

Occurrence—Rare to infrequent throughout CP-19-4.

\textit{Vestispora luminata} sp. nov.

(Plate 17, figs. 4-10)

Diagnosis—Miospores radial, trilete, spherical, bearing operculate exoexine with strongly developed reticulum. Muri about 3 microns in width, 2-3 microns in height, lumina 3-6 microns in diameter, oval to polygonal in outline. Lumina of operculum tend to be somewhat more round in outline. Inner body thin; both body and trilette rays very difficult to observe in most specimens owing to density of exoexine ornament.

Size—(21 specimens) 78-111 microns maximum diameter.

Discussion—\textit{V. luminata} most closely resembles \textit{V. fenestrata}, differing from the latter in the greater size and commonly polygonal outline of the lumina. \textit{V. pseudoreticulata} Spode (in Smith and Butterworth, 1967) possesses a secondary reticulum which, in the most distinct specimens, may have a similar aspect to the reticulum of \textit{V. luminata}, but \textit{V. pseudoreticulata} also displays a coarse primary reticum not seen in \textit{V. luminata}. A spore described by Ibrahim (1953) as \textit{Reticulata-sporites spongiosus} bears some resemblance to \textit{V. luminata}, but it is unclear from the description and illustration whether this spore could be assigned to \textit{Vestispora}.

Derivation—The specific nomen refers to the distinctive lumina.

Occurrence—Rare, observed most often in the \textit{Densosporites-Crassispora} interval.

Holotype—Plate 17, fig. 4, slide 5Z6 coordinates 123-51.5, 96.6 microns maximum diameter.

Paratype—Plate 17, fig. 6, slide 6Z6 coordinates 128-50, 93.7 microns.

Paratype—Plate 17, fig. 7, slide 6H2 coordinates 131.5-43.5, 88.0 microns.

Paratype—Plate 17, fig. 8, slide 6V1 coordinates 125-49, 92.3 microns.

Paratype—Plate 17, fig. 9, slide 6Z5 coordinates 125-58.5, 102.2 microns.

Paratype—Plate 17, fig. 10, slide 6H3 coordinates 118.5-56, 99.4 microns.

\textit{Vestispora pseudoreticulata} Spode in Smith and Butterworth, 1967

(Plate 16, figs. 10, 11)

1964b \textit{Vestispora pseudoreticulata} Spode, in Neves, p. 1233, pl. 3, figs. 1, 2.

1965b \textit{Vestisporites pseudoreticulatus} (Spode) Laveine, p. 2556, pl. 1, figs. 6, 18.

1967 \textit{Vestispora pseudoreticulata} Spode, in Smith and Butterworth, p. 298-299, pl. 25, figs. 13, 14.

Discussion—The name \textit{V. pseudoreticulata} Spode was first cited by Neves (1964b), who provided illustrations but no taxonomic information. The name appears to have been validated by subsequent description in Smith and Butterworth (1967).

Occurrence—Rare, \textit{Florinites} interval.

\textit{Vestispora cf. reticulata} (Laveine) Loboziak 1971

(Plate 16, fig. 12)

1965b \textit{Vestisporites reticulatus} Laveine, p. 2558, pl. 1, fig. 21.

1971 \textit{Vestispora reticulata} (Laveine) Loboziak, p. 81, pl. 12, fig. 8.

Discussion—\textit{V. reticulata} is distinguished from other species of the genus by its rather uniform reticulum of elongate lumina and strongly developed curved muri. The species does not display a secondary reticulum and the ornament is more regular than that of \textit{V. irregularis}. Specimens observed in CP-19-4 are designated \textit{V. cf. reticulata} because they appear to have a somewhat finer reticum than that of the holotype.

Occurrence—Rare, \textit{Florinites} interval.

\textit{Vestispora sp. 1}

(Plate 17, fig. 1)

Description—Miospore radial, trilette, originally spherical, with operculate exoexine. Ornament of
relatively indistinct round indentations or shallow lumina 2-4 microns wide, most strongly developed along margin of operculum. Large areas of exoexine may be essentially laevigate and grade into areas of indentation. Size of illustrated specimen 72.4 microns maximum diameter.

Discussion—The indistinctness and irregular distribution of indentations distinguishes *V*. sp. 1 from other species. Some specimens bear extremely shallow variant of *Densosporites-Crassispora* interval.

Genus *AUMANCISPORITES* Alpem 1958

**Type species**—*A. striatus* Alpem 1958.

**Affinity**—Unknown.

*Aumancisporites striatus* Alpem 1958

(Plate 18, figs. 1-3)

1958 *Aumancisporites striatus* Alpem, p. 84-86, pl. 2, figs. 53-54.

**Occurrence**—Rare, lower levels of the *Florinites* interval.

Genus *THYSANITES* gen. nov.

**Type species**—*T. densus* sp. nov.

**Diagnosis**—Miospores radial, trilete, with a distinct central body and a thin equatorial flange which is often crenulate and expanded at the angles. Flange much narrower than width of spore body, attached near or along the equator. Outline of spore body and outline of flange both sphaerotriangular. Laesurae straight, raised, about ½ of radius of spore body.

Discussion—Genus *Thysanites* superficially resembles the genera *Diaphanospora* (Balme and Hassell) Evans 1970 and *Hymenospora* Neves 1961, but these latter genera display perisporia which enclose the spore body rather than an equatorially attached flange.

**Derivation**—The generic nomen refers to the fringelike (*thysanus*) appearance of the flange.

**Affinity**—Unknown.

*Thysanites densus* sp. nov.

(Plate 18, figs. 4-9)

**Diagnosis**—Miospores conforming to the characteristics of the genus. Nearly always in good proximal-distal orientation. Spore body very thick and dark, tending to obscure laesurae. Flange width along interradial side ranges from about one-fourth to less than one-eighth the diameter of the spore body. Flange usually widened, often folded at angles, very finely granulose or puncate.

**Size**—(13 specimens) 24-36 microns maximum diameter of central body, 36-50 microns maximum diameter including flange.

**Derivation**—The specific nomen refers to the thick (*densus*) exine of the spore body.

**Occurrence**—Rare, observed most often in lower levels of the *Florinites* interval.

Holotype—Plate 18, fig. 6, side 1X5 coordinates 119-60, 30.2 microns maximum diameter of spore body exclusive of flange.

Paratype—Plate 18, figs. 4, 5, slide 1C1 coordinates 132-45, 31.4 microns.

Paratype—Plate 18, fig. 7, slide 1Z5 coordinates 122-64, 34.2 microns.

Paratype—Plate 18, figs. 8, 9, slide 6Z6 coordinates 124-61, 30.2 microns.

Genus *COLATISPORITES* W illiams in Neves et al., 1973

**Type species**—*C. decorus* (Bharadwaj and Venkatachala) Williams in Neves et al., 1973.

**Affinity**—Unknown.

*Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves et al., 1973

(Plate 1, figs. 16-18)

1961 *Tholisporites decorus* Bharadwaj and Venkatachala, p. 39, pl. 10, figs. 142-146.

1973 *Colatisporites decorus* (Bharadwaj and Venkatachala) Williams, in Neves et al., p. 41, pl. 2, figs. 11-13, pl. 4, fig. 19.

**Occurrence**—Rare, observed most often in the *Florinites* interval.

Genus *HYMENOSPORA* Neves 1961

**Type species**—*H. palliolata* Neves 1961.

**Discussion**—A number of similar perisporate genera have been described, many from the Mesozoic; the genera *Hymenospora* and *Diaphanospora* Balme and Hassell 1962 were described from rocks of Paleozoic age, and the originally Mesozoic genus *Perotrilites* (Erdtman) ex Couper 1953 also has been employed in some Paleozoic studies (e.g., Hughes and Playford, 1961; Varma, 1969; Peppers, 1970). Peppers (1970) discussed the essential morphologic similarity among these genera. Evans (1970) re-evaluated the type material of various species of several perisporate genera, and emended the diagnoses of *Perotrilites* and *Diaphanospora*, restricting the former to zonate rather than perisporate miospores. The relationship of *Hymenospora* to the other genera was not discussed by Evans (1970); his emendation of *Diaphanospora* stressed the tenuous nature of the perispore, which appears to contrast with that of *Hymenospora*, in which the perispore often is thick enough to obscure details of the central body. Hymenospora also differs in manner of attachment of perispore to central body (Neves, 1961). These distinctions appear to function adequately to separate species observed in the study of Iowa coal microfloras, although intermediate forms may occur in other areas or at other stratigraphic intervals. The taxonomy of cavate spores in general remains difficult and in need of further study.

**Affinity**—Unknown.

*Hymenospora multirugosa* Peppers 1970

(Plate 18, fig. 10)
1970 *Hymenospora multirugosa* Peppers, p. 129, pl.13, figs. 8, 9.

**Occurrence**—Rare.

**Genus** DIAPHANOSPORA (Balme and Hassell) Evans 1970

**Type species**—*D. riciniata* (Balme and Hassell) Evans 1970.

**Affinity**—Unknown. Good (1976) suggested a calamitean affinity for at least some perisporate miospores of genus *Perotrilites*, which, as originally defined, would correspond to *Diaphanospora*. A review of specimens observed in this study and reported in previous work, however, demonstrates a lack of morphologic similarity between the most common types of Paleozoic calamitean spores (*Calamospora*) and the central bodies of species of *Diaphanospora*. Perisporate spores may have developed in a number of plant groups.

*Diaphanospora parvigracila* (Peppers) comb. nov.

(Plate 18, fig. 11)

1970 *Perotrilites* (sic) *parvigracilus* Peppers, p. 128, pl. 13, figs. 5-7.

**Discussion**—Evans' (1970) emendation of genus *Perotrilites* excluded truly perisporate species, requiring reassignment of *P. parvigracilus* to another genus. *Diaphanospora* is described as having a thin perispore, which is characteristic also of this species. The name *Hymenospora parvigracilis* has been employed by Gupta (1977), apparently in reference to the same species; no validly published taxonomic reassignment appears to exist for this combination, although several papers in press were cited by Gupta (1977) as containing his formal taxonomic information.

**Occurrence**—Rare.

*Diaphanospora* sp. 1

(Plate 18, fig. 12)

**Description**—Miospore radial, trilete, sphaerotriangular in equatorial outline. Spore body covered by a profusely wrinkled, moderately thin perispore which extends up to 8 microns from the margin of the spore body at irregularly distributed points; elsewhere the perispore appears to fit closely about the spore body. Laesurae distinct, extending about ¾ of the distance to the spore body margin. Spore body relatively thick, details difficult to discern because of the perisporial covering. Size of illustrated specimen 58.2 microns, maximum diameter of spore body exclusive of perispore.

**Discussion**—*D. sp. 1* differs from *D. parvigracila* in displaying a sphaerotriangular outline of the spore body and radially symmetrical laesurae. The perispore of *D. sp. 1* is somewhat thicker and more profusely wrinkled than that of *D. parvigracila*, and *D. sp. 1* is larger than *D. parvigracila*.

**Occurrence**—Rare.

**Genus** FLORINITES Schopf in Schopf, Wilson and Bentall 1944

**Type species**—*F. mediapudens* (Loose) Potonie and Kremp 1956.

**Affinity**—Cycadofilicales, Cordaitales, Coniferales (Potonie, 1962). The presence of a distinctly infrareticulate saccus or sacci is considered an indication of gymnospermous pollen or prepollen. Pollen grains corresponding to *Florinites* have been described from cordaita (Delevoryas, 1953; Wilson, 1960; Brush and Barghoorn, 1962; Potonie, 1969; Millay and Taylor, 1974, 1976) and pteridosperm (Long, 1977b) fructifications.

*Florinites mediapudens* (Loose) Potonie and Kremp 1956

(Plate 19, figs. 1, 2)

1934 *Reticulato-sporites mediapudens* Loose, p. 158, pl. 7, fig. 8.

1940 *Endosporites pellucidus* Wilson and Coe, p. 184, pl. 1, fig. 3.

1944 *Florinites antiquus* Schopf in Schopf, Wilson and Bentall, p. 58-59, fig. 4.

1956 *Florinites mediapudens* (Loose) Potonie and Kremp, p. 169, pl. 21, figs. 468-471.

1957a *Florinites circularis* Bharadwaj, p. 116, pl. 30, fig. 17, 18.

1957a *Endosporites mediapudens* (Loose) Dybová and Jakchowicz, p. 207, pl. 71, fig. 4.

1958 *Florinites pellucidus* (Wilson and Coe) Wilson, p. 99, pl. 1, fig. 3.

1965a *Florinipollenites mediapudens* (Loose) Laveine, p. 135.


**Discussion**—Employment of the name *F. mediapudens* in this report follows the practice of Smith and Butterworth (1967), who suggested the synonymy of *F. pellucidus*; *F. antiquus* was previously considered a junior synonym of *F. pellucidus* by Wilson (1963b). Miospores resembling those designated *F.* cf. *florini* in Smith and Butterworth (1967) were also observed in CP-19-4 and are included in *F. mediapudens* in this report. Several other species, including *F. parvus* Wilson and Hoffmeister 1956, *F. ovalis* Bharadwaj 1957 and *F. junior* Potonie and Kremp 1956, are similar to *F. mediapudens*. Forms resembling these species were observed occasionally in CP-19-4, but distinction between them and specimens of *F. mediapudens* could not be made with certainty, and all such specimens are included in *F. mediapudens*. It is likely that these morphologically generalized pollen grains represent a number of gymnospermous plants of varied phylogenetic relationships. Correlation of palynological and paleobotanical data for coals of a stratigraphic horizon similar to that of CP-19-4 suggests that cordaites were the dominant *Florinites*-producing plants in the coal swamps (Phillips, Peppers, Avcin and Laughnan, 1975).

**Occurrence**—*F. mediapudens* is the most abundant gymnosperm-related miospore in CP-19-4. It occurs in virtually every level of the seam, is common to abundant throughout the *Florinites* interval, infrequent to frequent in the *Densosporites-Crassispora* interval, and frequent to common through the *Lycospora* interval.
Florinites millotti Butterworth and Williams 1954
(Plate 19, fig. 3)

1954 Florinites millotti Butterworth and Williams, p. 760, text-fig. 1, 8, pl. 18, figs. 7, 8.
1966 Florinipollenites millotti (Butterworth and Williams) Coquel, p. 21, pl. 2, fig. 14, 15.

Occurrence—Frequent to common throughout the Florinites interval, rare to infrequent through the rest of the seam.

Florinites occul tus Habib 1966
(Plate 19, fig. 4)

1966 Florinites occul tus Habib, p. 649, pl. 108, figs. 4, 5a, 5b.

Occurrence—Rare, Florinites interval.

Florinites visendus (Ibrahim) Schopf, Wilson and Bentall 1944
(Plate 20, fig. 1)

1932 Sporonites volans Loose in Potonie, Ibrahim and Loose, p. 451, pl. 18, fig. 6.
1933 Reticulatisporites visendus Ibrahim, p. 39, pl. 8, fig. 66.
1944 Florinites (?) visendus (Ibrahim) Schopf, Wilson and Bentall, p. 60.
1966 Florinipollenites visendus (Ibrahim) Coquel, p. 28, pl. 2, fig. 16.

Occurrence—Rare.

Florinites cf. volans (Loose) Potonie and Kremp 1956
(Plate 19, figs. 5, 6)

1932 Sporonites volans Loose in Potonie, Ibrahim and Loose, p. 451, pl. 18, fig. 6.
1933 Reticulatisporites visendus Ibrahim, p. 39, pl. 8, fig. 66.
1944 Endosporites volans (Loose) Schopf, Wilson and Bentall, p. 46.
1956 Florinites volans (Loose) Potonie and Kremp, p. 170, pl. 21, fig. 462.
1966 Guthoerlisporites volans (Loose) Coquel, p. 21, pl. 2, fig. 21.
1971 Guthoerlisporites volans (Loose) Lobeziaik, p. 87, pl. 13, fig. 11.

Discussion—Miospores designated F. cf. volans resemble closely certain species ascribed to the genus Guthoerlisporites Bharadwaj 1954. Guthoerlisporites theoretically is distinguished from Florinites by possession of a central body free from the saccus on the proximal surface. Observations by Peppers (1970) cast doubt on this interpretation, which is in any event difficult to apply in practice. Nygreen and Bourn (1967) have described complete morphological transitions in a late Pennsylvanian shale among miospores assignable to Potoniesporites Bharadwaj 1954 and three other genera, including Guthoerlisporites. Most species assigned to Guthoerlisporites are circular in outline, rather than elliptical, which is common for species of Florinites. Specimens observed in CP-19-4 tended to be circular, but were not exclusively so; the central body is more distinct than that of Wilsonites (Kosanke) Kosanke 1959, and the size range is somewhat smaller than that of F. volans proper. The assignment of F. cf. volans is made primarily as a matter of convenience, as no existing designation appears to be entirely satisfactory.

Occurrence—Rare to infrequent, Florinites interval.

Genus POTONIEISPORITES Bharadwaj 1954

Type species—P. novicus Bharadwaj 1954.
Affinity—Morphologically gymnospermous, but not specifically known.

Potoniesporites elegans (Wilson and Kosanke) Habib 1966
(Plate 20, fig. 9)

1944 Florinites elegans Wilson and Kosanke, p. 330, fig. 3.

Occurrence—Rare, observed most often in the Florinites interval.

Potoniesporites solidus sp. nov.
(Plate 19, figs. 7-9)

Discussion—Monosaccate pollen grains with a large, thick elliptical central body free from the saccus on the proximal surface. Straight monolete suture on proximal surface of central body less than ¼ the length of the central body; laesura surrounded by a slightly thickened area which is difficult to observe on most specimens owing to the overall thickness of the central body. Central body granulose to punctate, seldom folded. Bladder attachment overlaps about ¼ the diameter of the central body on the proximal surface, and is not usually crenulate; nature of bladder attachment, if any, on the distal surface is unclear. Central body occupies ½ to more than ⅝ of the length of the saccus and more than ¼ of the width of the saccus. Saccus coarsely infrareticulate, often slightly constricted medially, which may be a feature of miospore compression.

Size—(10 specimens) 99-127 microns maximum dimension.

Diagnosis—Monosaccate pollen grains with a large, thick elliptical central body free from the saccus on the proximal surface. Straight monolete suture on proximal surface of central body less than ¼ the length of the central body; laesura surrounded by a slightly thickened area which is difficult to observe on most specimens owing to the overall thickness of the central body. Central body granulose to punctate, seldom folded. Bladder attachment overlaps about ¼ the diameter of the central body on the proximal surface, and is not usually crenulate; nature of bladder attachment, if any, on the distal surface is unclear. Central body occupies ½ to more than ⅝ of the length of the saccus and more than ¼ of the width of the saccus. Saccus coarsely infrareticulate, often slightly constricted medially, which may be a feature of miospore compression.

Size—(10 specimens) 99-127 microns maximum dimension.

Discussion—This species is assigned to Potoniesporites on the basis of the apparent attachment of the saccus to the proximal surface of the central body, and the monolete suture. It differs from other species of the genus by possession of the large, thick and normally unfolded central body and by the shortness and un'flexed nature of the suture.

Derivation—The specific nomen refers to the thick (solidus) nature of the central body.

Occurrence—Rare, lower levels of the Florinites interval.

Holotype—Plate 19, fig. 7, slide 1Z3 coordinates 121-64, 120.7 microns, maximum dimension.
Paratype—Plate 19, fig. 8, CP-19-5 slide Z-7 coordinates 127-38, 120.7 microns.
Paratype—Plate 19, fig. 9, slide 11Y coordinates 132-38.5, 105.1 microns.

Genus COSTATASCYCLUS (Felix and Burbridge) Urban 1971

Type species—C. crenatus (Felix and Burbridge) Urban 1971.
Affinity—Morphologically gymnospermous, but not specifically known.
Costatoscyclus crenatus (Felix and Burbridge) Urban 1971
(Plate 20, fig. 2)
1967 Costatoscyclus crenatus (Felix and Burbridge, p. 411, pl. 64, fig. 6).
1971 Costatoscyclus crenatus (Felix and Burbridge) Urban, p. 114-115, pl. 25, figs. 4-9.

Occurrence—Rare, Florinites interval.

Genus WILSONITES (Kosanke) Kosanke 1959
Type species—W. vesicatus (Kosanke) Kosanke 1959.
Affinity—Pteridosperm (Remy, 1954).

Discussion—Guennel (1958) assigned this species to Endosporites due to some uncertainties which existed at the time concerning the status of Wilsonia (Wilsonites). The transfer to Wilsonites is made without descriptive emendation.

Occurrence—Rare, Florinites interval.

Wilsonites circularis (Guennel) Peppers and Ravn comb. nov.
(Plate 20, fig. 3)
1958 Endosporites circularis Guennel, p. 51, text-fig. 12, plate 1, figs. 18, 19.

Discussion—Guennel (1958) assigned this species to Endosporites due to some uncertainties which existed at the time concerning the status of Wilsonia (Wilsonites). The transfer to Wilsonites is made without descriptive emendation.

Occurrence—Rare, Florinites interval.

Wilsonites delicatus (Kosanke) Kosanke 1959
(Plate 20, fig. 5)
1950 Wilsonia delicata Kosanke, p. 54-55, pl. 14, fig. 4.
1959 Wilsonites delicatus (Kosanke) Kosanke, p. 700.
1966 Guthoerlisporites delicatus (Kosanke) Habib, p. 646, pl. 107, fig. 9.

Occurrence—Rare to infrequent, Florinites interval.

Wilsonites vesicatus (Kosanke) Kosanke 1959
(Plate 20, fig. 4)
1950 Wilsonia vesicatus Kosanke, p. 54, pl. 14, figs. 1-3.
1957b Guthoerlisporites velesensis Bharadwaj, p. 130, pl. 26, fig. 120.
1959 Wilsonites vesicatus (Kosanke) Kosanke, p. 700.

Occurrence—Rare to infrequent, Florinites interval, rare in the Densosporites-Crassisporea intervals.

Genus PITYOSPORITES (Seward) Manum 1960
Type species—P. antarcticus Seward 1914.
Affinity—Potonie (1962) suggested an affinity with pteridosperms but disagreement with this view has been expressed (Manum, 1960). Certain species (e.g., P. westphalensis Williams 1955) display a striking similarity to many modern coniferous pollen grains.

Pityosporites westphalensis Williams 1955
(Plate 20, fig. 8)
1955 Pityosporites westphalensis Williams, p. 467, text-figs. 1, 2, pl. 6, figs. 1-6.

Occurrence—Rare to infrequent in the Florinites and Densosporites-Crassisporea intervals, virtually absent from the Lycospora interval.

Genus PLATYSACCUS (Naumova) Potonie and Klaus 1954
Type species—P. papilionis Potonie and Klaus 1954.
Affinity—Morphologically gymnospermous, but not specifically known.

Platysaccus saarensis (Bharadwaj) Jizba 1962
(Plate 20, figs. 6, 7)
1957a Alisporites saarensis Bharadwaj, p. 117-118, pl. 31, figs. 14, 15.
1962 Platysaccus saarensis (Bharadwaj) Jizba, p. 885, pl. 124, figs. 59-61.

Occurrence—Rare, but widely distributed in the Florinites and Densosporites-Crassisporea intervals.

Genus ILLINITES (Kosanke) Helby 1966
Type species—I. unicus (Kosanke) Helby 1966.
Discussion—Helby (1966) regarded Kosankeisporites elegans (Kosanke) Bharadwaj 1955 and Complexisporites polymorphus Jizba 1962 as synonymous with Illinites unicus Kosanke 1950. Although not specifically designated so by Helby, this synonymy appears to constitute a de facto emendation of both the genus Illinites and the species I. unicus, and is designated as such in this report. The formal synonymy is listed in full under the species I. unicus.

Affinity—Pteridosperm (Remy, 1954).

Illinites unicus (Kosanke) Helby 1966
(Plate 21, fig. 5)
1950 Illinites unicus Kosanke, p. 51-52, pl. 1, figs. 3, 4.
1950 Illinites elegans Kosanke, p. 52, pl. 1, figs. 1, 2.
1955 Kosankeisporites elegans (Kosanke) Bharadwaj, p. 137, pl. 2, figs. 16-17.
1970 Kosankeisporites elegans (Kosanke) Peppers, p. 133-134, text-fig. 29, pl. 14, figs. 6-8.
1962 Complexisporites polymorphus Jizba, p. 869, pl. 121, figs. 1-14.
1966 Illinites unicus (Kosanke) Helby, p. 680-681, pl. 8, figs. 9-18, pl. 9, fig. 1, figs. 3, 4.

Discussion—Helby's (1966) observations concerning the variability of ornamentation of the central body of I. unicus are supported by the variable nature of the morphology of these miospores in CP-19-4 and other Iowa coals.

Occurrence—Rare.

Genus PSEUDOILLINITES gen. nov.
Type species—P. diversiformis (Kosanke) comb. nov. emend.

Diagnosis—Bilateral, monosaccate, monolete prepollen or pollen grains. Central body normally extending nearly the full width of the saccus, resulting in the appearance of a bisaccate grain. Central body characterized by two strongly developed crescentic compression folds at right angles to the long axis of the saccus, usually producing a more or less hexagonal outline for the central body. Proximal surface of central body free from saccus. Saccus oval, width approximately 1/2 of length; extensions of saccus from central body in long dimension approximately 1/2 the width of the central
body. Saccus coarsely infrareticulate, reticulations becoming somewhat finer near juncture with central body.

Discussion—Genus *Pseudoillinites* is proposed to accommodate monosaccate prepollen or pollen grains in which the central body is so expanded as to approach bisecting the saccus into separate laterally attached saccs. The type species originally was assigned to genus *Florinites*, but the relationship of the central body to the saccus, both in general appearance and manner of attachment, is not typical of *Florinites*. The pseudobisaccate appearance of the genus also serves to differentiate it from *Potonieisporites*, in which the characteristics of body attachment to saccus are similar.

Derivation—The generic nomen refers to the similarity of general appearance of the genus to the bisaccate genus *Illinites*.

Affinity—Morphologically gymnospermous, but not specifically known.

*Pseudoillinites diversiformis* (Kosanke)

(comb. nov. emend.

(Plate 21, figs. 9-11)

1950 *Florinites diversiformis* Kosanke, p. 49, pl. 12, fig. 5.

non 1976 *Florinites cf. diversiformis* Kosanke 1950; Tillement, Peniguel and Guillemin, p. 439, pl. 1, fig. 29.

Diagnosis—Miospores conforming to the characteristics of the genus. Central body thick and dark, laevigate or nearly so. Laesa about \(\frac{1}{2}\) the length of the central body, terminations commonly obscured by compression folds.

Discussion—Occasional specimens of *P. diversiformis* develop fortuitous folding of the central body in addition to the two well-developed lateral compression folds. In such specimens, the central body is less regularly hexagonal in outline and may not bisect the saccus as completely as that of normal specimens. This latter condition appears to be true of the holotype (Kosanke, 1950, pl. 12, fig. 5). Study of both the holotype and material from the holotype maceration indicates that most specimens display the characteristics described in the generic and specific diagnoses of this report and that the holotype is an unusual specimen.

Occurrence—Rare, to occasionally infrequent, *Florinites* interval.

Genus PEPPERSITES gen. nov.

Type species—*P. ellipticus* sp. nov.

Diagnosis—Bilateral, monosaccate, monolete prepollen or pollen grains. Central body oval to elliptical in outline, proximal surface free from saccus. Saccus relatively small in relation to central body, appressed to central body in short dimension, slightly expanded in long dimension, finely infrareticulate. Saccus attached to central body near equator on proximal surface; nature of attachment to distal surface uncertain.

Discussion—Genus *Peppersites* is distinguished from other monosaccate genera by the relatively large size of the central body in relation to the saccus. The genus superficially resembles *Schulzospora* Kosanke 1950, but the latter genus is clearly trilete and bears a granulose saccus.

Derivation—The generic nomen is proposed in honor of Dr. Russel A. Peppers of the Illinois Geological Survey.

Affinity—Morphologically gymnospermous, but not specifically known.

*Peppersites ellipticus* sp. nov.

(Plate 21, figs. 1-4)

Diagnosis—Miospores conforming to the characteristics of the genus. Central body thick and dark, laevigate to faintly punctate or granulose. Laesa approximately \(\frac{1}{2}\) the length of the central body, with slightly thickened lips; laesa sometimes obscured by thickness of central body. Central body seldom folded. Maximum extension of saccus from central body in long dimension normally less than \(\frac{1}{4}\) the maximum dimension of the central body. Saccus very finely infrareticulate, often displaying slightly crenulated margin.

Size—(10 specimens) 51-74 microns maximum dimension.

Discussion—The specific nomen refers to the elliptical outline of the central body.

Occurrence—Rare, *Florinites* interval.

Holotype—Plate 21, fig. 1, slide 1Z3 coordinates 121-53.5, 51.3 microns maximum dimension including saccus.

Paratype—Plate 21, fig. 2, slide 1C4 coordinates 130.5-62, 61.0 microns.

Paratype—Plate 21, fig. 3, slide 1Y3 coordinates 127.5-35, 65.6 microns.

Paratype—Plate 21, fig. 4, slide 1Y4 coordinates 119-72.5, 53.6 microns.

Genus WAPELLITES gen. nov.

Type species—*W. variabilis* sp. nov.

Diagnosis—Bilateral, monosaccate prepollen or pollen grains with an apparently alete, dark, elliptical to nearly circular central body. Saccus infrareticulate, constricted medially, greatly expanded in long dimension of grain. Extent of constriction of saccus ranges from specimens which are clearly monosaccate to those in which the saccus is so appressed to the central body in the short dimension as to give the grain the appearance of being bisaccate. Central body appears to be attached to the saccus both proximally and distally; radiating crenulations of the saccus extending approximately \(\frac{1}{2}\) the radius of the central body occur on the proximal(?) surface, but are not always visible due to characteristics of the central body.

Discussion—Genus *Wapellites* most closely resembles genus *Costatascyclus* in overall characteristics, particularly in the nature of the attachment of the central body to the saccus and the radiating crenulations of the saccus in the region of the central body. In the latter genus, however, the saccus is not so conspicuously constricted around the central body, and folds of the saccus occur on the face of the central body (Urban, 1971). *Costatascyclus* is monolete, whereas *Wapellites* appears to be alete; minor marks have been observed on
the central bodies of some specimens which resemble faint trilette laesurae, but these may be fortuitous wrinkles or folds. Genus *Rhizosporaspora* Wilson 1962 resembles *Wapellites* in general appearance, but is definitely bisaccate.

**Derivation**—The generic nomen is derived from Wapello County, Iowa, the site of the Iowa Geological Survey core hole CP-19.

**Affinity**—Morphologically gymnospermous, but not specifically known.

*Wapellites variabilis* sp. nov.

(Plate 22, figs. 1-3)

**Diagnosis**—Miospores corresponding to the characteristics of the genus. Central body laevigate, very thick and dark, with thickness of the exine (4 or more microns) giving the appearance of a "zona" in compression. Longitudinal expansions of the saccus semi-circular in outline; maximum width of saccus ½ to ¾ maximum diameter of the central body. Internal reticulations of saccus grade from very fine near the central body to moderately coarse away from it.

**Size**—(10 specimens) 72-99 microns maximum dimension.

**Derivation**—The specific nomen refers to the variability in the appearance of the saccus from clearly monosaccate to pseudo-bisaccate.

**Occurrence**—Rare, lower levels of the *Florinites* interval.

Holotype—Plate 22, fig. 1, slide 1Z3 coordinates 125.5-47, 98.0 microns maximum dimension including saccus.

Paratype—Plate 22, fig. 2, slide 1Z3 coordinates 131-38, 92.7 microns.

Paratype—Plate 22, fig. 3, slide 1Z3 coordinates 119-42, 95.5 microns.

Genus **PHILLIPSITES** gen. nov.

**Type species**— *P. tenuis* sp. nov.

**Diagnosis**—Bilateral, bisaccate prepollen or pollen grains. Central body elongate, more or less rectangular in outline, with sacci attached at either end of central body in long dimension; sacci sometimes slightly inclined toward distal (?) surface of central body. Line of attachment between sacci and central body relatively straight; little or no constriction of outline of grain occurs at the points of attachment of sacci to central body. Sacci relatively small in relation to central body, width of sacci about ½ the length of the central body. Sacci display internal reticulation of variable coarseness. Central body laevigate to faintly punctate or granulose, thickest near sacci, thinning toward middle, but without clearly developed sulcus. Overall outline of grain including sacci elliptical.

**Discussion**—Genus *Phillipsites* differs from other bisaccate genera in having a large central body thinning toward the middle, and relatively small sacci attached in an unconstricted manner. It is most similar to *Pityosporites*, but the latter has relatively larger sacci constricted at the points of attachment, and displays a well-developed distal sulcus.

**Derivation**—The generic nomen is proposed in honor of Dr. Tom L. Phillips of the Department of Botany, University of Illinois.

**Affinity**—Morphologically gymnospermous, but not specifically known.

*Phillipsites tenuis* sp. nov.

(Plate 21, figs. 6-8)

**Diagnosis**—Miospores conforming to the characteristics of the genus. Central body very thin toward middle, often torn open or highly folded. Lines of attachment of sacci to central body appear thickened; sacci do not overlap central body on compression.

**Size**—(21 specimens) 92-139 microns maximum dimension.

**Derivation**—The specific nomen refers to the thin (tenuis) nature of the central body.

**Occurrence**—Rare, but widely distributed throughout the *Florinites* interval.

Holotype—Plate 21, fig. 6, slide 1Z6 coordinates 127-43.5, 115.0 microns maximum dimension including sacci.

Paratype—Plate 21, fig. 7, slide 1D3 coordinates 122-71.5, 87.5 microns.

Paratype—Plate 21, fig. 8, slide 1X4 coordinates 123.5-46.5, 99.4 microns.

Saccate grain no. 1

(Plate 21, fig. 12)

**Description**—Miospore radial, trilette, with a closely appressed, crenulated saccus. Outline of spore body circular, laesurae short, relatively indistinct. Saccus punctate or possibly very finely infrareticulate appears to be attached to spore body on both proximal and distal surface. Saccus extends irregularly from equator of spore body to a maximum distance of 8 microns. Size of illustrated specimen 57.0 microns, spore body exclusive of saccus.

**Discussion**—Saccate grain no. 1 resembles certain specimens of perispore-bearing genera, such as *Diaphanospora*, but the outer "membrane" appears more like a true saccus than a perispore.

**Occurrence**—Rare.

Genus **SCHOPFHIPOLLENITES** Potonie and Kremp 1954

**Type species**— *S. ellipsoides* (Ibrahim) Potonie and Kremp 1954.

**Discussion**—Pollen grains corresponding to *Schopfpollenites* were first described under the name *Monoletes* by Ibrahim (1933). Potonie (1960) considered the name *Monoletes* to be invalid, and most subsequent investigators (e.g., Smith and Butterworth, 1967) have recognized *Schopfpollenites* as the proper generic name. Nevertheless, the name *Monoletes* continues to be employed, particularly in an informal sense.

**Affinity**—Pollen grains corresponding to *Schopfpollenites* have been correlated with a variety of Medullosan pteridospore fructifications (Florin, 1937; Schopf, 1938; Delevoryas, 1964; Eggert and Kryder, 1969; Leisman and Peters, 1970; Taylor, 1971; Stidd,

Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954
(Plate 22, figs. 6, 7)

1932 Sporonites ellipsoides Ibrahim in Potonié, Ibrahim and Loose, p. 449, pl. 17, fig. 29.
1933 Laevigato-sporites ellipsoides Ibrahim, p. 40, pl. 4, fig. 29.
1934 Punctato-sporites ellipsoides (Ibrahim), Loose, p. 158, pl. 7, fig. 35.
1934 Sporites ellipsoides (Ibrahim) Wicher, p. 185.
1938 Monoletes ellipsoides (Ibrahim) Schopf, p. 45, pl. 1, fig. 14 and pl. 6, figs. 5, 6.

Description—Bilateral, monolete pollen grains corresponding in general aspect to S. ellipsoides, but displaying a conspicuous, regularly wrinkled surface. Size of illustrated specimen 242.9 microns maximum dimension.

Discussion—As pointed out by Winslow (1959) and Smith and Butterworth (1967), distinction of species of Schopfipollenites on a morphologic basis is often problematical. It is therefore possible that S. sp. 1 may represent a variant of S. ellipsoides.

Occurrence—Rarely observed in CP-19-4, but subject to the same quantitative bias as S. ellipsoides.

Genus TRIHYPHAECITES Peppers 1970

Type species—T. triangulatus Peppers 1970.


Trihyphaecites triangulatus Peppers 1970
(Plate 22, figs. 4, 5)


Occurrence—Rare, but widely distributed in the Florinites and Densosporites-Crassispora intervals.

APPENDIX I

PREPARATION TECHNIQUES

Chemical preparation and slide mounting techniques described here are presently in use by the Iowa Geological Survey Coal Division, and were adapted from those in use at the Illinois Geological Survey, (Peppers, 1970). Thorough discussions of various preparation techniques and theoretical considerations may be found in Brown (1960), Gray (1965) and Andersen (1965).

The following chemical preparation schedule was followed in the preparation of samples from CP-19-4:
1. Approximately 5-gm samples, crushed with mortar and pestle until the largest fragments are of medium sand size.
2. Maceration for two days in Schulze solution (1 part saturated solution potassium chlorate, 2 parts concentrated nitric acid).
3. 3 water washes (centrifuging and decanting supernatant liquid).
4. 10-15 minute treatment with 10% solution of potassium hydroxide, followed by sufficient water washes to clarify supernatant liquid, removing humic acids.
5. 24-hour treatment with cold 48% hydrofluoric acid, followed by 4 water washes.
6. Sieve with fine jet of water through 250-micron screen.
7. Centrifuge for 45 seconds, to settle out palynomorphs and leave ultra-fine debris in suspension.
8. 50% ethanol–50% water wash, followed by 2 washes in 95% ethanol. (Peppers [1970] recommended further treatment with absolute ethanol, but this was found not to be necessary.)
9. Staining with 5-10 ml concentrated ethanol solution of either basic fuchsine or safranin 0 stains. The major purpose of stains is to enhance visibility of fine detail, and for photography. Both fuchsine and safranin are adequate, but safranin was found to be superior to fuchsine, and has since become the standard stain used in palynological preparations at the Iowa Geological Survey.
10. 50% ethanol–50% xylene wash, followed by one straight xylene wash. Samples are now ready for slide preparation.

SLIDE MOUNTING MEDIA AND TECHNIQUES

It is normally desirable to employ uniform techniques and media in slide preparation, to facilitate comparison of samples. This is particularly important in regard to measuring the sizes of miospores, as some mounting media (e.g., glycerine jelly) are known to cause appreciable swelling of spore exines (Smith and Butterworth, 1967). At the outset of this project, however, several mounting techniques were tried as experiments, although those media known to cause changes in spore sizes were not tried. Three co-soluble resins were employed: Piccolyte, Permount, and Canada Balsam. All three have similar refractive indices and are
soluble in xylene. Piccolyte and Permount have a higher percent volatile base than does Canada Balsam, and shrinkage of these mountants under the slide cover glasses was an occasional problem. Another experiment allowing a smear of piccolyte to dry on a slide, and affixing a cover glass later with another medium was tried, and produced fairly good results, although spores sometimes tended to aggregate during drying of the smear.

The most satisfactory medium was determined to be Canada Balsam, and it is presently the standard palynological mountant used in Iowa Geological Survey palynological preparations. Slides are prepared by placing a drop of Canada Balsam on the microscope slide, securing a portion of sample with a teasing needle and mixing with the Canada Balsam to a desirable concentration. A cover slip is placed on the mixture, and gentle, but firm pressure is applied with a soft-pointed applicator (preferably wooden) to spread the mixture to the edges of the cover glass. Slides are placed in a low-temperature oven (105-110° F) for 4-10 days.

Many other workers have employed water-miscible mountants with success, but these have not been used at the Iowa Geological Survey, as their preparations appear to be at least as complex as the use of resin media (Wilson, 1959). Andersen (1965) criticized the use of Canada Balsam because of its high refractive index, but this objection is overcome by staining of samples.

Due to employment of three separate media for slides in this study, a check was made on the relative sizes of representative abundant spore taxa in each of the mountants. No significant difference in spore sizes was found, probably due to the chemical similarity and co-solubility of the resins.

Following slide-making, samples were prepared for storage by returning to an ethanol base by washing twice with 95% ethanol, rinsing with a spray-jet of ethanol into a storage vial, centrifuging and decanting the supernatant ethanol, and adding sufficient glycerine to equal twice the residue volume. The ethanol remaining in the residue mixes with the glycerine, and serves to retard potential bacterial or algal growth while the sample is in storage. Should additional slides be needed later, the glycerine can be removed by washing with ethanol, and the normal mounting procedure may be followed, including staining (re-staining is necessary due to the removal of stain by previous ethanol washes during storage).

APPENDIX II
DATA

Data presented here are the result of population counts of miospores at 86 levels within seam CP-19-4. 250 identifiable miospores were counted at each level. Numbers for each taxon listed indicate the number of individual specimens of each taxon identified during the population count. Taxa encountered during scanning of slides following completion of the population count are represented by “X”. Percentages of occurrence of individual taxa are calculated readily by multiplying the data figure by .4. See also Method.
<table>
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<tr>
<th>LOPHOTRILETES GIBOSUS</th>
<th>L. GRANOORNATUS</th>
<th>L. IBERIAE</th>
<th>L. MICROSAEUS</th>
<th>L. MOSAICA</th>
<th>L. PARSIPHO</th>
<th>L. CF. TUBERIFER</th>
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<td>L. PROTEUS</td>
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<td>CONVOLUTISPORAS CERNA</td>
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<td>CAMPTOTRILETES BUCCELLATUS</td>
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<td>TORSOSPORIA SECURIS</td>
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<td>VESTnymospora Fexestrata</td>
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REFERENCES CITED


PLATES

Figures are magnified 750X except as noted otherwise. Specimens are from coal CP-19-4 except as noted. Many specimens, particularly those with fine sculpture patterns, were photographed using Nomarski interference-contrast illumination, which produces the effect of a scanning light and greatly enhances resolution of surface detail. Occasionally two views of a given specimen are illustrated, one with normal transmitted light, one with Nomarski illumination; in such instances the Nomarski view is designated by (N). Dimensions of specimens in microns refer to the maximum diameter unless specified otherwise. Coordinates refer to the mechanical stage of the Leitz Wetzlar microscope, serial number 826091, at the University of Iowa Department of Geology.
PLATE 1

FIGURE

1. *Leiotriletes guennelii* nom. nov; slide DB1Y coordinates 121-62.5, 23.9 microns.
3. *Leiotriletes sphaerotriangulus* (Loose) Potonie and Kremp 1955; slide 1C4 coordinates 127-36, 42.8 microns.
4. *Leiotriletes levis* (Kosanke) Potonie and Kremp 1955; slide 1Y5 coordinates 118.5-44, 32.5 microns.
5. *Leiotriletes*, sp. 1; slide 1Y3 coordinates 132.5-70, 32.5 microns.
6. *Leiotriletes* sp. 2; slide 6T1 coordinates 127-49, 31.9 microns.
8. *Leiotriletes levis* (Kosanke) Potonie and Kremp 1955; slide 1X6 coordinates 125.5-59, 41.8 microns.
9. *Leiotriletes* sp. 3; slide 1Y6 coordinates 121-69, 55.5 microns.
10. *Punctatisporites minutus* (Kosanke) Peppers 1964; slide 1W1 coordinates 119-71.5, 28.5 microns.
11. *Punctatisporites minutus* (Kosanke) Peppers 1964; slide 2J3 coordinates 125-43.5, 34.2 microns.
12. *Punctatisporites nitidus* Hoffmeister, Staplin and Malloy 1955; slide 3A2 coordinates 135.5-55, 35.3 microns.
17. *Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves et al., 1973; slide 1C2 coordinates 119.5-47.5, 47.3 microns.
PLATE 2

FIGURE

2. *Punctatisporiles kankakeensis* Peppers 1970; slide 5A9 coordinates 120-66, 68.7 microns.
3. *Punctatisporiles* sp. 1; slide 7B3 coordinates 125-60, 43.3 microns.
6. *Phyllothecotriletes* sp. 1; slide 5A3 coordinates 133-32.5, 102.2 microns (300X).
PLATE 3

FIGURE

1. *Calamospora straminea* Wilson and Kosanke 1944; slide 1W2 coordinates 120.5-65, 35.9 microns.
2. *Calamospora breviradiata* Kosanke 1950; slide 1Z3 coordinates 121-49, 50.7 microns.
3. *Calamospora liquida* Kosanke 1950; slide 1C4 coordinates 124-56.5, 61.6 microns.
4. *Calamospora* cf. *mutabilis* (Loose) Schopf, Wilson and Bentall 1944; slide 5A6 coordinates 118.5-63, 110.8 microns (300X).
5. *Calamospora hartungiana* Schopf in Schopf, Wilson and Bentall 1944; slide 1C2 coordinates 123.5-39, 76.7 microns (300X).
7. *Calamospora* cf. *pedata* Kosanke 1950; slide 6Z2 coordinates 133-56.6, 92.3 microns (300X).
8. *Calamospora nebulosa* sp. nov.; paratype, slide 6Z2 coordinates 125-45, 72.4 microns (300X).
9. *Calamospora nebulosa* sp. nov.; holotype, slide 6Z4 coordinates 139-35, 85.2 microns (300X).
10. *Calamospora nebulosa* sp. nov.; paratype, slide 6Z1 coordinates 123.5-54.5, 94.1 microns (300X).
11. *Calamospora nebulosa* sp. nov.; paratype, slide 1B4 coordinates 121.5-49.5, 83.8 microns (300X).
12. *Calamospora nebulosa* sp. nov.; paratype, slide 6Z4 coordinates 130-32.5, 87.0 microns (300X).
PLATE 4

FIGURE

1. *Elaterites trifrons* Wilson 1943; slide DB1Y coordinates 124-52, 62.7 microns, spore body excluding perispore.
2. *Adelisporites multiplicatus* sp. nov.; holotype, slide 1C2 coordinates 136.5-60, 26.8 microns.
4. *Adelisporites multiplicatus* sp. nov.; paratype, CP-19-5 slide Z-7 coordinates 128-51, 23.9 microns.
5. *Adelisporites multiplicatus* sp. nov.; paratype, slide 1C3 coordinates 137.5-45.5, 26.2 microns.
6. *Adelisporites multiplicatus* sp. nov.; paratype, slide 5H2 coordinates 120-52.5, 23.4 microns.
8. *Verrucosisporites verrucosus* (Ibrahim) Ibrahim 1933; slide DB1Y coordinates 129-57.5, 72.5 microns.
9. *Verrucosisporites microtuberosus* (Loose) Smith and Butterworth 1967; slide 1C4 coordinates 129-46.5, 90.0 microns (300X).
10. *Verrucosisporites sifati* (Ibrahim) Smith and Butterworth 1967; slide 7M1 coordinates 123-38.5, 110.8 microns (300X).
12. same as fig. 11 (N).
14. same as fig. 13 (N).
PLATE 5

FIGURE

1. Cyclogranisporites minutus Bharadwaj 1957; slide 1X2 coordinates 128-41.5, 28.5 microns.
2. Cyclogranisporites cf. leopoldi (Kremp) Potonie and Kremp 1955; slide 1Y4 coordinates 139-70, 33.1 microns.
3. Cyclogranisporites parvus Bharadwaj 1957; slide 1Y6 coordinates 125-50, 31.4 microns.
4. Cyclogranisporites parvus Bharadwaj 1957; slide 6Z1 coordinates 133.5-55 41.0 microns.
5. Cyclogranisporites orbicularis (Kosanke) Potonie and Kremp 1955; slide 1B8 coordinates 132.49, 39.3 microns.
6. Cyclogranisporites microgranus Bharadwaj 1957; slide 1Y3 coordinates 124-40.5, 45.0 microns.
7. Cyclogranisporites sp. 1; slide 6Z4 coordinates 132-57, 53.0 microns.
8. Cyclogranisporites aureus (Loose) Potonie and Kremp 1955; slide 5Z2 coordinates 130-65.5, 80.9 microns (300X).
9. Granulatisporites microgranifer Ibrahim 1933; slide 1Z6 coordinates 133.5-39.5, 21.7 microns.
10. Granulatisporites microgranifer Ibrahim 1933; slide 1C4 coordinates 122.5-57, 22.8 microns.
11. Granulatisporites granularis Kosanke 1950; slide 1Z6 coordinates 129.5-47, 25.1 microns.
15. Granulatisporites granulatus Ibrahim 1933; slide 1X6 coordinates 130.5-66, 21.6 microns.
16. Granulatisporites granulatus Ibrahim 1933; slide 1C6 coordinates 119.5-71.5, 28.5 microns.
17. Granulatisporites parvus (Ibrahim) Potonie and Kremp 1955; slide 1Z3 coordinates 124-51.5, 36.5 microns.
20. Lophotriletes rarispinosus Peppers 1970; slide 1C4 coordinates 127-43, 22.8 microns.
21. Lophotriletes rarispinosus Peppers 1970; slide 1C1 coordinates 139-57, 26.2 microns.
22. Lophotriletes commissuralis (Kosanke) Potonie and Kremp 1955; slide 1C6 coordinates 124.5-63, 28.5 microns.
23. Lophotriletes microsaetosus (Loose) Potonie and Kremp 1955; slide DB1Y coordinates 126-61.5, 28.5 microns exclusive of ornament.
24. Lophotriletes granoornatus Artüz 1957; slide 1C4 coordinates 129.5-42, 30.8 microns.
PLATE 6

FIGURE

1. Lophotriletes cf. tuberifer (Imgrund) Potonie and Kremp 1955; slide 1Z1 coordinates 118.5-49.5, 31.4 microns.
3. Lophotriletes cf. tuberifer (Imgrund) Potonie and Kremp 1955; slide 1X5 coordinates 123-41, 44.5 microns.
4. Lophotriletes mosaicus Potonie and Kremp 1955; slide 1Z3 coordinates 137-38, 31.9 microns.
5. Lophotriletes gibbosus (Ibrahim) Potonie and Kremp 1955; slide 1D6 coordinates 137-40, 43.9 microns.
7. Lophotriletes copiosisus Peppers 1970; slide 1C1 coordinates 138.5-45, 39.9 microns.
8. Lophotriletes sp. 1; slide 6T1 coordinates 122.5-64.5, 38.4 microns.
9. Lophotriletes confertus sp. nov.; holotype, slide 2J2 coordinates 127.5-41, 43.3 microns.
10. Lophotriletes confertus sp. nov.; paratype, slide 1D5 coordinates 121.5-60, 41.7 microns.
11. Lophotriletes confertus sp. nov.; paratype, slide 2J6 coordinates 128-29, 50.2 microns.
12. Lophotriletes confertus sp. nov.; paratype, slide 2P2 coordinates 132-55, 47.9 microns.
13. Lophotriletes confertus sp. nov.; paratype, slide 1Y1 coordinates 122-36, 48.5 microns.
14. Lophotriletes sp. 2; slide 6Z2 coordinates 124-36.5, 34.8 microns.
15. same as fig. 14 (N).
17. Anapiculatisporites spinosus (Kosanke) Potonie and Kremp 1955; slide 1W2 coordinates 129-72.5, 24.5 microns.
18. Anapiculatisporites spinosus (Kosanke) Potonie and Kremp 1955; slide 1Y2 coordinates 127-54.5, 22.8 microns.
19. Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967; slide 5A2 coordinates 133-61.5, 26.2 microns.
20. Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967; slide 1Y4 coordinates 123.5-60, 26.2 microns.
PLATE 7

FIGURE

1. *Apiculatisporis aculeatus* (Ibrahim) Smith and Butterworth 1967; slide 1W1 coordinates 122-72, 37.1 microns.
2. *Apiculatisporis aculeatus* (Ibrahim) Smith and Butterworth 1967; slide 5Z1 coordinates 135-63, 33.1 microns.
3. *Apiculatisporis aculeatus* (Ibrahim) Smith and Butterworth 1967; slide 2J3 coordinates 120-40, 44.5 microns.
5. *Apiculatisporis saetiger* (Peppers) Peppers and Ravn comb. nov.; slide DB1Z coordinates 122.5-56, 22.8 microns.
6. *Apiculatisporis latigranifer* (Loose) Potonié and Kremp 1955; slide 1Y6 coordinates 123-38, 68.4 microns (300X).
7. *Apiculatisporis variocornus* Sullivan 1964; CP-19-5 slide Z-7 coordinates 127.5-44, 68.2 microns exclusive of ornament (300X).
8. *Apiculatisporis abditus* (Loose) Potonié and Kremp 1956; slide 3A4 coordinates 132.5-31, 68.4 microns.
9. *Apiculatisporis* sp. 1; slide 1X1 coordinates 127-40, 45.6 microns.
10. *Apiculatasporites spinulistratus* (Loose) Ibrahim 1933; slide 6V4 coordinates 122-61.5, 48.5 microns.
11. *Apiculatasporites spinulistratus* (Loose) Ibrahim 1933; slide 7R3 coordinates 131-42, 62.7 microns.
12. *Acanthotriletes echinatus* (Knox) Potonié and Kremp 1955; slide 1Z2 coordinates 139-69.5, 25.7 microns.
15. *Acanthotriletes cf. falcatus* (Knox) Potonié and Kremp 1955; slide 2H4 coordinates 124-30.5, 45.6 microns exclusive of ornament.
PLATE 8

FIGURE

1. *Raistrickia protensa* Kosanke 1950; slide 2J3 coordinates 136.5-50, 46.2 microns, exclusive of ornament.
4. *Raistrickia lowellensis* Peppers 1970; slide 6Z1 coordinates 134.5-56.5, 39.9 microns exclusive of ornament.
5. *Raistrickia crocea* Kosanke 1950; slide 5A4 coordinates 134.5-61.5, 61.6 microns exclusive of ornament.
7. *Apiculatisporis irregularis* (Kosanke) Potonie' and Kremp 1955; slide 3A4 coordinates 125.5-44.5, 57.0 microns exclusive of ornament.
10. same as fig. 9 (N).
11. *Spackmanites facierugosus* (Loose) Habib 1966: slide 3Z5 coordinates 132.5-64, 46.7 microns.
12. *Convolutispora cerina* sp. nov.; holotype, slide 3M6 coordinates 130-71.5, 44.5 microns.
13. *Convolutispora cerina* sp. nov.; paratype, slide 3M6 coordinates 134-31.5, 43.9 microns.
14. *Convolutispora cerina* sp. nov.; paratype, slide 1Y1 coordinates 122.5-36, 46.2 microns.
15. *Convolutispora cerina* sp. nov.; paratype, slide 1Y1 coordinates 126.5-35, 45.6 microns.
PLATE 9

FIGURE

1. Convolutispora(?) sp. 1; slide 5A7 coordinates 122-54.5, 34.2 microns.
4. Dictyotriletes castaneaeformis (Horst) Sullivan 1964; slide DB1Z coordinates 125-60.5, 31.4 microns.
5. Dictyotriletes reticulocingulum (Loose) Smith and Butterworth 1967; slide 1Z1 coordinates 120-48, 41.6 microns.
6. Dictyotriletes bireticulatus (Ibrahim) Potonie and Kremp 1954; slide 1Y1 coordinates 139.5-50.5, 53.6 microns.
7. Dictyotriletes densoreticulatus Potonie and Kremp 1955; slide 1Z5 coordinates 118.5-40, 61.0 microns.
8. Dictyotriletes reticulocingulum (Loose) Smith and Butterworth 1967; slide 6H4 coordinates 127-44.5, 43.9 microns.
10. Microreticulatisporites harrisonii Peppers 1970; slide 1C4 coordinates 121-51.5, 32.5 microns.
11. Microreticulatisporites nobilis (Wicher) Knox 1950; slide 6V4 coordinates 119.5-52.5, 34.2 microns.
13. Camptotriletes bucculentus (Loose) Potonie and Kremp 1955; slide 5A9 coordinates 126.5-55, 40.6 microns.
15. Microreticulatisporites sp. 1; slide 1D6 coordinates 122-44, 41.0 microns.
16. Latipulvinites kosankii Peppers 1964; slide 1Y5 coordinates 119.5-71, 34.8 microns.
17. Ahrensisporites guerickei (Horst) Potonie and Kremp 1954; slide 5Z1 coordinates 133.5-45, 37.1 microns exclusive of kyrtomes.
PLATE 10

FIGURE

1. Stellisporites inflatus Alpera 1958; slide 5A1 coordinates 122.5-63.5, 26.2 microns.
2. Tantillus triquetrus Felix and Burbridge 1967; slide 6Z1 coordinates 131-64, 19.9 microns.
4. Tantillus triquetrus Felix and Burbridge 1967; CP-27-7 slide 1 coordinates 130-45, 25.7 microns.
5. Tantillus triquetrus Felix and Burbridge 1967; slide DB1Z coordinates 137.5-56.5, 16.0 microns.
7. Tantillus triquetrus Felix and Burbridge 1967; slide 5A1 coordinates 127-61.5, 22.6 microns.
8. same as fig. 7 (N).
11. Triquitrites additus Wilson and Hoffmeister 1956; slide 5Z3 coordinates 139-41, 31.9 microns.
12. Triquitrites protensus Kosanke 1950; slide 6Z6 coordinates 130-46, 34.2 microns.
15. Triquitrites additus Wilson and Hoffmeister 1956; slide 5A3 coordinates 124-60, 35.3 microns.
16. Triquitrites sculptilis (Balme) Smith and Butterworth 1967; slide 6Z4 coordinates 136-54, 34.8 microns.
18. Triquitrites crassus Kosanke 1950; CP-19-5 slide A-4 coordinates 126.5-33, 45.6 microns.
21. Reticulatisporites reticulatus (Ibrahim) Ibrahim 1933; slide 6Z1 coordinates 126-56, 75.4 microns (300X).
22. Knaxisporites stephanephorus Love 1960; slide 6R2 coordinates 133-42, 41.6 microns.
23. Knaxisporites triradiatus Hoffmeister, Staplin and Molloy 1955; slide 5A1 coordinates 127-66.5, 63.9 microns.
PLATE II

FIGURE

1. Reinschospora speciosa (Loose) Schopf, Wilson and Bentall 1944; slide 5A3 coordinates 132-38, 51.1 microns exclusive of ornament.
2. Indospora boleta Peppers 1970; slide 6T2 coordinates 129-59, 22.2 microns exclusive of ornament.
3. Reinschospora triangularis (Kosanke) emend.; slide 1Z3 coordinates 134.5-61, 57.0 microns exclusive of ornament.
4. Reinschospora triangularis (Kosanke) emend.; slide 1Z2 coordinates 127.5-49, 55.6 microns exclusive of ornament.
5. Reinschospora triangularis (Kosanke) emend.; slide 1Z12 coordinates 133-60, 55.3 microns exclusive of ornament.
6. Reinschospora triangularis (Kosanke) emend.; slide DB1Z coordinates 132-70, 59.9 microns exclusive of ornament.
7. Cuneisporites rigidus sp. nov.; paratype, CP-10-49 slide B-9 coordinates 127-69.5, 45.6 microns.
8. Cuneisporites rigidus sp. nov.; holotype, slide 2H2 coordinates 128-55.5 47.3 microns.
9. Cuneisporites rigidus sp. nov.; paratype, slide 2H3 coordinates 125-40, 41.0 microns.
10. Tetanisporites granulatus sp. nov.; paratype, slide 6V3 coordinates 134.5-51, 45.6 microns.
11. Tetanisporites granulatus sp. nov.; holotype, slide 1C1 coordinates 132-60.5, 50.7 microns.
12. Tetanisporites granulatus sp. nov.; paratype, CP-10-7 slide 12 coordinates 119-58, 49.6 microns.
FIGURE
2. *Savitrisporites nux* (Butterworth and Williams) Smith and Butterworth 1967; slide 4A3 coordinates 125-36, 47.7 microns.
3. *Savitrisporites* sp. 1; slide 6R2 coordinates 119.5-65, 54.7 microns.
4. *Cristatisporites indignabundus* (Loose) Staplin and Jansonius 1964; slide 5A6 coordinates 130-52, 48.6 microns.
5. same as fig. 4 (N).
11. *Crassispora annulata* sp. nov.; holotype, slide 6V3 coordinates 131.5-48.5, 49.6 microns.
12. *Crassispora annulata* sp. nov.; paratype, slide 6R6 coordinates 128-63, 50.1 microns.
13. *Crassispora annulata* sp. nov.; paratype, slide 7M3 coordinates 128-53.5, 42.8 microns.
14. *Crassispora annulata* sp. nov.; paratype, slide 7D2 coordinates 133-56, 38.8 microns.
15. *Crassispora annulata* sp. nov.; paratype, slide 6H4 coordinates 123-41.5, 46.7 microns.
PLATE 13

FIGURE

1. *Cappasporites distortus* Urban 1966; slide 1B8 coordinates 138-62, 53.0 microns.
2. *Cappasporites distortus* Urban 1966; slide 5A4 coordinates 134-63, 55.9 microns.
3. *Densosporites anulatus* (Loose) Smith and Butterworth 1967; slide 2A2 coordinates 122-47.5, 27.4 microns.
4. *Densosporites anulatus* (Loose) Smith and Butterworth 1967; slide 3U5 coordinates 121-52.5, 27.9 microns.
6. *Densosporites triangularis* Kosanke 1950; slide 1X2 coordinates 126.5-57.5, 48.5 microns.
7. *Densosporites sphaerotriangularis* Kosanke 1950; slide 6Z1 coordinates 125.5-57, 39.3 microns.
8. *Densosporites sphaerotriangularis* Kosanke 1950; slide 6Z6 coordinates 132-49.5, 40.5 microns.
9. *Densosporites irregularis* Hacquebard and Bars 1957; slide 3Z2 coordinates 130.5-65.6, 49.6 microns.
10. *Densosporites spinifer* Hoffmeister, Staplin and Malloy 1955; slide 6Z4 coordinates 130-33, 35.9 microns exclusive of spines.
12. *Densosporites spinifer* Hoffmeister, Staplin and Malloy 1955; slide 6V4 coordinates 128.5-54, 33.6 microns exclusive of spines.
13. *Cingulizonales loricatus* (Loose) Butterworth and Smith in Butterworth *et al.*, 1964; slide 6T3 coordinates 120.5-50, 37.6 microns.
15. *Lycospora granulata* Kosanke 1950; slide 1Z4 coordinates 123.5-70, 29.6 microns.
16. *Lycospora pellucida* (Wicher) Schopf, Wilson and Bentall 1944; slide 2H6 coordinates 121.5-64, 36.5 microns.
17. *Lycospora* *c.l.* *torquifer* (Loose) Potonić and Kremp 1956; slide 1Y1 coordinates 122.5-68, 34.8 microns.
18. *Lycospora* *c.f.* *L. torquifer* (Loose) Potonić and Kremp 1956; slide DB1Z coordinates 136-62, 31.9 microns.
1. Cirratriradites maculatus Wilson and Coe 1940; slide 1Z1 coordinates 122-58.5, 75.3 microns (300X).
2. Cirratriradites annuliformis Kosanke 1950; slide 6H2 coordinates 130-73, 59.3 microns.
3. Cirratriradites saturni (Ibrahim) Schopf, Wilson and Bentall 1944; slide 4M4 coordinates 120-47.5, 65.3 microns (300X).
4. Cirratriradites reticulatus sp. nov.; holotype, CP-19-5 slide Y-4 coordinates 124.5-33, 52.4 microns.
5. Cirratriradites reticulatus sp. nov.; paratype, CP-19-5 slide A-3 coordinates 128-61, 49.6 microns.
7. Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944; slide 1Z2 coordinates 121-43.5, 92.9 microns (300X).
8. Endosporites zonalis (Loose) Knox 1950; slide 1Z4 coordinates 131-48, 85.2 microns (300X).
9. Endosporites staplinii Gupta and Boozer 1969; slide 2H6 coordinates 119-33, 33.1 microns.
11. Endosporites staplinii Gupta and Boozer 1969; FITZ II slide 23 coordinates 126-57.5, 35.3 microns.
12. Alatisporites pustulatus (Ibrahim) Ibrahim 1933; slide 3A2 coordinates 121-58, 90.0 microns (300X).
13. Alatisporites pustulatus (Ibrahim) Ibrahim 1933; slide 1Z4 coordinates 122-51, 86.8 microns (300X).
PLATE 15

FIGURE

1. *Alatisporites hoffmeisteri* Morgan 1955; slide 1Y4 coordinates 126.5-46, 55.4 microns exclusive of bladders (300X).
2. same as fig. 1 (N).
5. *Laevigatosporites globosus* Schemel 1951; slide 1Z2 coordinates 125.5-42.5, 30.2 microns.
6. *Laevigatosporites globosus* Schemel 1951; slide DB1Z coordinates 126.5-60.5, 31.4 microns.
7. *Punctatisporites obliquus* Kosanke 1950; slide 1C1 coordinates 119.5-65.5, 33.1 microns.
9. *Laevigatosporites medius* Kosanke 1950; slide 1X1 coordinates 123.5-53.5, 35.9 microns.
10. *Laevigatosporites ovalis* Kosanke 1950; slide 6R6 coordinates 120-65.5, 47.3 microns.
11. *Laevigatosporites desmoinensis* (Wilson and Coe) Schopf, Wilson and Bentall 1944; slide 1Z1 coordinates 130-74, 63.3 microns.
13. *Laevigatosporites striatus* Alpem 1959; slide 5A2 coordinates 130.5-64, 51.9 microns.
15. *Laevigatosporites vulgaris* (Ibrahim) Ibrahim 1933; slide 6Z3 coordinates 130.5-32.5, 84.4 microns.
PLATE 16

FIGURE

1. Torispora securis Balme 1952; slide 6Z6 coordinates 125-56.5, 34.2 microns.
3. Thymospora cf. pseudiothiessenii (Kosanke) Wilson and Venkatachala 1963; slide 1X4 coordinates 121-45, 27.9 microns.
4. Thymospora cf. pseudiothiessenii (Kosanke) Wilson and Venkatachala 1963; slide 1Y4 coordinates 122-64, 22.8 microns.
5. Tuberculatosporites robustus (Kosanke) Peppers 1970; slide 1C1 coordinates 124-62, 73.8 microns (300X).
6. Tuberculatosporites robustus (Kosanke) Peppers 1970; slide 1C6 coordinates 137-55, 105.1 microns (300X).
7. Vestipora laevigata Wilson and Venkatachala 1963; slide 3Z6 coordinates 130.5-39, 78.1 microns (300X).
8. Vestiispora laevigata Wilson and Venkatachala 1963; slide 1W1 coordinates 125.5-60, 63.8 microns.
9. Vestiispora laevigata Wilson and Venkatachala 1963; slide DB1Z coordinates 134-58, 68.0 microns.
10. Vestiispora pseudoreticulata Spode in Smith and Butterworth, 1967; slide 1C1 coordinates 124-66, 73.8 microns.
11. Vestiispora pseudoreticulata Spode in Smith and Butterworth, 1967; slide 1D4 coordinates 123.5-63.5, 65.3 microns.
PLATE 17

FIGURE

1. *Vestispora* sp. 1; slide 5A6 coordinates 132-32, 72.4 microns (300X).
2. *Vestispora fenestrata* (Kosanke and Brokaw) Spode in Smith and Butterworth 1967; slide 6Z1 coordinates 133.5-55.5, 62.1 microns.
4. *Vestispora luminata* sp. nov.; holotype, slide 5Z6 coordinates 123-51.5, 96.6 microns (300X).
5. *Vestispora luminata* sp. nov.; detached operculum, slide 6Z2 coordinates 133.5-46.5, 43.9 microns.
6. *Vestispora luminata* sp. nov.; paratype, slide 6Z6 coordinates 128-50, 93.7 microns (300X).
7. *Vestispora luminata* sp. nov.; paratype, slide 6H2 coordinates 131.5-43.5, 88.0 microns (300X).
8. *Vestispora luminata* sp. nov.; paratype, slide 6V1 coordinates 125-49, 92.3 microns (300X).
9. *Vestispora luminata* sp. nov.; paratype, slide 6Z5 coordinates 125-58.5, 102.2 microns (300X).
10. *Vestispora luminata* sp. nov.; paratype, slide 6H3 coordinates 118.5-56, 99.4 microns (300X).
1. *Aumancisporites striatus* Alpern 1958; slide 1C6 coordinates 139-64, 54.2 microns.
2. *Aumancisporites striatus* Alpern 1958; slide 1C2 coordinates 134-61, 62.7 microns.
3. *Aumancisporites striatus* Alpern 1958; slide 1Y4 coordinates 133-66, 43.9 microns.
4. *Thysanites densus* sp. nov.; paratype, slide 1C1 coordinates 132-45, 31.4 microns, spore body exclusive of flange.
5. same as fig. 4 (N).
6. *Thysanites densus* sp. nov.; holotype, slide 1X5 coordinates 119.5-60, 30.2 microns, spore body exclusive of flange.
7. *Thysanites densus* sp. nov.; paratype, slide 1Z5 coordinates 122-64, 34.2 microns, spore body exclusive of flange.
8. *Thysanites densus* sp. nov.; paratype, slide 6Z6 coordinates 124-61, 30.2 microns, spore body exclusive of flange.
9. same as fig. 8 (N).
10. *Hymenospora multirugosa* Peppers 1970; slide 1C2 coordinates 128.5-56, 45.6 microns.
12. *Diaphanospora* sp. 1; slide 7M1 coordinates 121.5-51, 58.2 microns, spore body exclusive of perispore.
PLATE 19

FIGURE

1. *Florinites mediapudens* (Loose) Potonić and Kremp 1956; slide 1Z2 coordinates 128-46, 75.3 microns (300X).
2. *Florinites mediapudens* (Loose) Potonić and Kremp 1956; slide 3A2 coordinates 134-44, 79.5 microns (300X).
3. *Florinites millotti* Butterworth and Williams 1954; slide 1C2 coordinates 129-57, 42.2 microns.
4. *Florinites occultus* Habib 1966; slide 1Z6 coordinates 134-58, 67.6 microns.
5. *Florinites cf. volans* (Loose) Potonić and Kremp 1956; slide 1D3 coordinates 131-61, 75.3 microns (300X).
7. *Potonieisporites solidus* sp. nov.; holotype, slide 1Z3 coordinates 121-64, 120.7 microns (300X).
8. *Potonieisporites solidus* sp. nov.; paratype, CP-19-5 slide Z-7 coordinates 127-39, 120.7 microns (300X).
9. *Potonieisporites solidus* sp. nov.; paratype, slide 1Y5 coordinates 132-38.5, 105.1 microns (300X).
1. *Florinites visendus* (Ibrahim) Schopf, Wilson and Bentall 1944; slide 5A6 coordinates 127.5-46.5, 147.7 microns (300X).
2. *Costatascyclus crenatus* (Felix and Burbridge) Urban 1971; slide 1W2 coordinates 125-38, 153.3 microns (300X).
3. *Wilsonites circularis* (Guennel) Peppers and Ravn comb. nov.; slide 1Y6 coordinates 134-43.5, 45.6 microns.
4. *Wilsonites vesicatus* (Kosanke) Kosanke 1959; slide 1X2 coordinates 119-55, 70.1 microns.
5. *Wilsonites delicatus* (Kosanke) Kosanke 1959; slide 1Z4 coordinates 123-54.5, 86.6 microns (300X).
8. *Pityosporites westphalensis* Williams 1955; slide 2L1 coordinates 133-47.5, 52.4 microns.
PLATE 21

FIGURE
1. *Peppersites ellipticus* sp. nov.; holotype, slide 1Z3 coordinates 121-53.5, 51.3 microns.
2. *Peppersites ellipticus* sp. nov.; paratype, slide 1C4 coordinates 130.5-62, 61.0 microns.
3. *Peppersites ellipticus* sp. nov.; paratype, slide 1Y3 coordinates 127.5-35, 65.6 microns.
4. *Peppersites ellipticus* sp. nov.; paratype, slide 1Y4 coordinates 119-72.5, 53.6 microns.
5. *Illinites unicus* (Kosanke) Helby 1966; slide 7Y1 coordinates 127-41.5, 47.7 microns.
6. *Phillipsites tenuis* sp. nov.; holotype, slide 1Z6 coordinates 127-43.5, 115.0 microns (300X).
7. *Phillipsites tenuis* sp. nov.; paratype, slide 1D3 coordinates 122-71.5, 87.5 microns (300X).
8. *Phillipsites tenuis* sp. nov.; paratype, slide 1X4 coordinates 123.5-46.5, 99.4 microns (300X).
9. *Pseudoillinites diversiformis* (Kosanke) comb. nov.; slide 1Z4 coordinates 124-61, 102.3 microns (300X).
10. *Pseudoillinites diversiformis* (Kosanke) comb. nov.; slide 1Z2 coordinates 134-45, 109.3 microns (300X).
11. *Pseudoillinites diversiformis* (Kosanke) comb. nov.; slide 1Y5 coordinates 125-39, 100.8 microns (300X).
12. Saccate grain no. 1; slide 2H6 coordinates 124-60, 57.0 microns, spore body exclusive of saccus.
PLATE 22

FIGURE

1. *Wapellites variabilis* sp. nov.; holotype, slide 1Z3 coordinates 125.5-47, 98.0 microns (300X).
2. *Wapellites variabilis* sp. nov.; paratype, slide 1Z3 coordinates 131-38, 92.7 microns (300X).
3. *Wapellites variabilis* sp. nov.; paratype, slide 1Z3 coordinates 119-42, 95.5 microns (300X).
5. *Trihyphaecites triangulatus* Peppers 1970; slide 1Y3 coordinates 122.5-39.5, 34.2 microns maximum dimension of central body.
7. same as fig. 6 (N).
8. *Schopfipollenites* sp. 1; slide 8Z1 coordinates 127-55.5, 242.9 microns (240X).
9. same as fig. 8 (N).
10. detail, fig. 9 (750X).