OKLAHOMA GEOLOGICAL SURVEY

CARL C. BRANSON, DIRECTOR

Circular 32

PLANT MICROFOSSILS OF THE CROWEBURG CO.

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Illustrations

PENNSYLVANIAN PLANT MICROFOSSILS OF THE CROWEBURG COAL IN OKLAHOMA*

L. R. WILSON[1] AND W. S. HOFFMEISTER[2]

ABSTRACT

Fossil spores and leaf cuticles of the Croweburg coal of Pennsylvanian (Desmoinesian) age from nine localities in northeastern Oklahoma are described and statistically treated for stratigraphic correlation. The spore assemblage consists of 13 genera and 48 species. One new genus, nine new species and four leaf cuticle types are described. The microfossil flora is similar at all localities in composition and relative abundance. It differs markedly from the underlying Bluejacket coal spore assemblage, and from the overlying Iron Post coal spore assemblage. The Croweburg microfossil flora appears to be correlative with the Colchester coal of Illinois. Spore associations in the bottom, middle, and top third of the seams are designated by those genera or species which reach their greatest abundance in those levels. These abundances suggest that the Croweburg floral succession began with the *Cirratriradites* and *Triquitrites* maxima, changed to a *Laevigato-sporites* maximum association in the middle third of the seam, and finally in the top third, *Calamospora, Endosporites* and *Florinites* attained their maxima. Calculated measurements based on Carbon 14 studies of peat and reduction of vegetable matter to bituminous coal suggest that approximately 20,000 years were required for the deposition of the Croweburg coal seam.

INTRODUCTION

The Croweburg coal is widely exposed in northeastern Oklahoma and contains a wealth of fossil plant spores and plant cuticles that are easily separated from the matrices. Analyses of the spore and cuticular fossils indicate that stratigraphic and paleoecological data of value in the resolution of Pennsylvanian problems is procurable from these fossils.

The present study was begun in 1952 with the following as objectives: (1) a detailed description of recognizable plant microfossils of the Croweburg coal over the Oklahoma exposure area; (2) a population study of the spores and plant cuticles to discover what changes, locally and areally, occurred in such floral composition of Oklahoma during deposition in the Croweburg coal swamps; (3) the establishment of spore and cuticle histograms useful in the stratigraphic recognition of equivalent and different coal seams.

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The objectives have been realized and the results are described in this report.

In geological studies fossil spores were seen early in coal, though not recognized as to their true significance. Witham (1833) may have been the first to publish an illustration of a coal showing fossil spores. Attempts were made by Thiessen and Wilson (1924) in America and Slater (1931) in Great Britain to use spores in thin section preparations as stratigraphic indices. Though their respective works showed some positive results, the thin section method is limited in its usefulness because only a single section or view is possible. This limitation frequently prevents accurate identification, and limits the value of spores in coal analyses. Raistrick published a paper in 1933 describing the results of maceration studies of British coals. In this paper he set forth a method of separating spores from their matrices and of graphically presenting his spore population studies as histograms. Raistrick's methods are essentially those used in the present study. The construction of channel sample histograms for the correlation of coals has not been widely practiced outside of Great Britain though they have been found useful for all but the thickest coal seams.

Methods of designating various species of fossil spores have differed considerably as spore and pollen paleontology developed. Raistrick and Simpson (1933) utilized a system of letters and figures to designate various species of spores. Six loose morphological groups were recognized by them and designated as group A, group B, etc. Specific types were indicated as A_1, A_2, etc. The German students previous to 1933 referred the smaller fossil spores to the genus *Sporites*. Species were designated by a trivial name in the manner of approved botanical taxonomic procedure. Ibrahim (1933), recognizing the need for subdividing the form genus *Sporites* into smaller entities, proposed a classification of Paleozoic spores which was based primarily on spore germinal apparatus. Three main groups were recognized as follows: (1) spores without a germinal apparatus (*aletes*), (2) spores with a three-rayed germinal apparatus (*triletes*), and (3) spores with a single straight germinal apparatus (*monoletes*). These groups might be considered as equivalent to some taxonomic rank above generic status, but the names do not infer any phylogenetic relationship. Genera within the groups were established on exine ornamentation, such as granulation, punctation, reticulation, etc. Within each of the three germinal apparatus groups, types of ornament were designated by name and identified to group by a letter ending as, for example: *Granulato-sporites* (*alete* form), *Granulata-sporites* (*monolete* form), *and Granulati-sporites* (*trilete* form). Ibrahim's system of classification, though a real advance over earlier systems, has serious limitations since generic emphasis is on spore coat ornamentation, and obviously related spore species will occur in different genera. Recognizing these difficulties, Schopf, Wilson and Bentall (1944) attempted to resolve the problems and establish a sound classification. Megaspores were separated from the smaller microspores and isospores, and genera were recognized where distinctive morphological structures appeared constant. The two most generalized genera (*Punctati-sporites* and *Granulati-sporites*) have been the object of revision by Knox (1950) who has constructed several new genera based on exine structure. The results of this study are not generally acceptable on taxonomic and morphological grounds. Potonié and Kremp (1945) described several new genera, the names of which may be interpreted as replacing some of the names used in this paper. Until further explanation is available, those changes are not recognized as desirable.

The most comprehensive Paleozoic spore investigation in the United States to date is that of Kosanke (1950). In that publication five new genera and one hundred new species are described from the coal of Illinois. The stratigraphic range of the spores and the spore floras of the various Illinois coals are described, and that paper has been the best reference in the present study.

The writers wish to express their appreciation to Dr. Carl C. Branson for aid given in the securing of suitable coals for study and for reading and criticizing the manuscript. Mrs. Carolyn Wagner and Miss Madge Heard prepared the coals for study. The photographs were taken and processed by Mrs. Betty Fingerhut. Dale Radford and John Fisher gave invaluable aid in the preparation of the illustrations. The writers also wish to thank The Carter Oil Company for permission to publish this report on the investigation.

PREPARATION METHODS

All samples examined were collected either from the coal faces or were secured by widely picking a representative sample from the mine dump. In the latter case, these were from the Concharty Mountain and Stewart Mines. Samples taken from the coal faces were channel samples divided to represent equally the top, middle, and bottom portions of the seam. These samples were processed by the approximately a 50 gram sample; (2) mix sample with approximately 20 grams of powdered $KClO_3$ and cover with twice as much HNO_3 following schedule: (1) Pulverize, mix coal, and divide to obtain by volume; (3) when reaction stops apply heat and boil for five minutes; (4) add water and centrifuge sample; repeat centrifuging two or more times; (5) cover residue with NH_3OH for three hours; (6) repeat step 4; (7) place residue in copper beaker, add HF acid, and boil five minutes; (8) add water while sample is hot; (9) centrifuge and wash several times; (10) study or make permanent microscope slides. Permanent microscope slides are made using either glycerine jelly or Diaphane as mounting media. Slide numbers refer to collection number and do not necessarily correspond to the location numbers illustrated in Fig. 2. The following list is an index to the mine location.

WH1 —McNabb Mine (Fig. 2 location No. 4)

WH2 —Sequoyah Mine (Fig. 2 location No. 6)

WH3 —Fisher Mine (Fig. 2 location No. 3)

WH4 —Brady Mine (Fig. 2 location No. 5)

WH5 —Ashley Property (Fig. 2 location No. 7)

WH6 —Stewart Mine (Fig. 2 location No. 8)

WH7 —Omer Williams Mine (Fig. 2 location No. 9)

WH11—Concharty Mt. Mine (Fig. 2 location No. 2)

WH12—Sam Crabtree Mine (Fig. 2 location No. 1)

STRATIGRAPHY

The following information concerning the stratigraphy of the Croweburg coal seam has been kindly supplied by Dr. Carl C. Branson, State Geologist of Oklahoma.

"The Croweburg coal bed lies in a cyclothem in the upper part of the Senora formation in Oklahoma. In Kansas, the seam is in the Cherokee shale formation of U. S. Geological Survey terminology. The coal was given a distinctive name, Croweburg, by geologists of the Kansas State Geological Survey, and the name was published by Pierce and Courtier (1937, p. 74). The bed has been called Fireclay bed, Huntsinger bed, Mud seam, and other names in Kansas. In Oklahoma, the coal is called the Broken Arrow coal, the Henryetta coal, and it is possible that the Senora coal is the same bed. Representatives of the Missouri, Oklahoma, Kansas and Nebraska geological surveys agreed at a conference held in Nevada, Missouri, to use the name Croweburg in those states (Searight and others, 1953, p. 2748).

The Senora formation is the upper unit of the Cabaniss group of Oakes (1953, p. 1525). This group, together with the Marmaton group above and the Krebs group below, constitute the Des Moines series in most of Oklahoma. The area from which samples were collected lies in the platform facies of the Senora. The sediments are markedly cyclical, and in Oklahoma and nearby parts of Kansas 12 cycles of deposition, each with a coal bed, are recognized. These are (modified from Branson 1954, p. 5):

Cyclothems of Abernathy	Coal Cycles	
Mulky	Mulky coal cycle	Excello shale (black, fissle, phosphatic shale)
		(Mulky coal (Kansas and Missouri)
		(underclay
		(
		(Breezy Hill limestone
		(
		(Kinnison shale, limestone at base in Craig Co.
unrecognized	Lagonda coal cycle	(Iron Post coal
		(Lagonda shale and sandstone (upper part)
		(sandy limestone (Craig Co.)
Bevier	Bevier coal cycle	(Bevier coal
		(underclay
		(shale and sandstone
Bevier ?		Limestone (thin and local)
Ardmore	Verdigris coal cycle	(Wheeler coal
		(Verdigris limestone
		(black fissile shale, phosphatic nodules
		(shale and sandstone (north of Arkansas River)
Croweburg	Croweburg coal cycle	(Croweburg coal
		(underclay
		(McNabb limestone (Wagoner and Rogers Cos.
		(
		(shale
Coalville (?)	unnamed coal cycle	(Sequoyah coal (local name)
		(shale and sandstone
		(
		(limestone or clay-ironstone (Kansas and northern Craig Co.)
Fleming	Fleming coal cycle	(Fleming coal
		(shale
		(limestone or clay-ironstone

unrecognized	Robinson Branch coal cycle	((Robinson Branch coal (Kansas and Missouri) (shale, sandstone ((Russell Creek limestone
Mineral	Mineral coal cycle	(Mineral coal (Craig Co. only in Okla.) (shale and sandstone
Scammon	Scammon coal cycle	(Scammon coal (Kansas and Mo.) ((Chelsea sandstone
Pilot		(possibly another coal zone) (shale ((Tiawah limestone ((black fissile shale, phosphatic
	Tebo coal cycle	(Tebo coal ((shale ((sandstone ((dark shale
unrecognized		((black fissile shale, pea-sized phosphatic nodules
	Unnamed coal cycle	((coal ((shale ((sandstone

base of Senora formation

The units termed coal cycles above are considered formations by some geologists. The top of a coal is selected at the top of each unit because only such units can be mapped readily. Cyclothems are quite different units, each including a non-marine sequence, a coal, and a marine sequence.

The basinal facies lies mainly south of the Arkansas River Valley, but platform conditions extended southward at certain times. Several coal beds and limestones can be traced into the basin sequence, the Croweburg and Verdigris among them. The Henryetta coal of Okmulgee County is Croweburg, and it is possible that the coal recently found in central-eastern Hughes County is also Croweburg. The 'Senora lime' of that area is believed to be Verdigris.

The Croweburg coal lies below the Verdigris limestone and can be unmistakably identified by the association, and the distinctive black fissile shale with phosphatic concretions at the base of the limestone is a further aid in identification. In Kansas, the Verdigris limestone is 11 feet above the coal, in southern Craig Co., 43 feet, in Rogers Co., 30 feet, in Concharty Mountain, 11 feet. The coal bed averages 12 inches thick in Missouri and Kansas, 16 inches in Craig County, 20 inches in Rogers and Wagoner Counties. The Henryetta coal is as much as 40 inches thick at places, and has an average thickness of about 30 inches."

COLLECTIONS

Nine exposures of the Croweburg coal in Oklahoma were examined for plant microfossils. The outcrops included extend from sec. 26-16N-14E northeast to sec. 33-26N-18E, a distance of approximately 70 miles, and occur in Okmulgee, Wagoner, Rogers, and Craig Counties. Brief lithologic descriptions of the sections where the coals were collected follow:

Locality No. 1, Sam Crabtree Mine, N. C. sec. 26-16N-14E, Okmulgee County, Oklahoma.

Gray shale	5′ 0″
Gray compact limestone	1′ 2″
Black fissile shale with concretions up to 18" diameter, abundant brachiopods	8′ 0″
Croweburg coal	1′ 6″
Dark gray clay	1′ 0″
Total Section Measured	16′ 8″

Locality No. 2, Concharty Mt. Mine, sec. 6-16N-15E, Wagoner County, Oklahoma.

Gray massive limestone (Verdigris)	2′ 7″
Dark gray hard shale	2′ 2″
Layer of hard concretions up to 13″ in diameter	0′ 10″
Black carbonaceous shale with concretions	1′ 10″
Croweburg coal	Float
Total Section Measured	7′ 5″

Locality No. 3, Fisher Mine, sec. 8-18N-15E, Wagoner County, Oklahoma.

Gray shale	4′ 0″
Croweburg coal	1′ 9″
Black coaly shale	0′ 3″
Gray shale	2′ 0″
Total Section Measured	8′

Locality No. 4, McNabb Mine, NE 1/4 sec. 33-20N-15E, Rogers County, Oklahoma.

Gray massive limestone (Verdigris)	3′ 0″
Gray "rotten" limestone	0′ 6″
Black blocky shale	4′ 0″
Gray limestone with brachiopods	1′ 2″
Gray shale, conchoidal fracture, bands of concretions and thin chert layers	8′ 0″
Croweburg coal	1′ 6″
Gray shale	3′ 4″
Total Section Measured	33′ 6″

Locality No. 5, Brady Mine sec. 3-20N-15E, Rogers County, Oklahoma.

Compact gray massive limestone (Verdigris)	2′	6″
Gray "rotten" limestone	0′	4.5″
Carbonaceous gray fissile shale	0′	9″
Buff shale	0′	7″
Covered	20′	±
Layer of ironstone concretions	0′	4″
Gray conchoidal shale	16′	1″
Indurated shale with concretions	0′	1.5″
Hard gray conchoidal shale	5′	8″
Croweburg coal	1′	10″
Gray clayey shale	1′	0″+—
Total Section Measured	49′	3″

Locality No. 6 Sequoyah Mine, sec. 14-22N-16E, Rogers County, Oklahoma.

Buff sandstone	12′	0″
Gray sandy shale	8′	0″
Gray shale, with plant fossils	1′	0″
Croweburg coal	1′	6″
Gray shale	2′	0″
Total Section Measured	24′	6″

Locality No. 7, Ashley Property, sec. 9-23N-17E, Rogers County, Oklahoma.

Gray hard limestone (Verdigris?)		
Dark gray carbonaceous shale	1′	8″
Covered	50′±	0″
Gray conchoidal shale with concretions	6′	0″
Croweburg coal	1′	8″
Gray shale	1′	0″±
Total Section Measured	60′	4″

Locality No. 8, Stewart Mine, sec. 30-25N-18E, Craig County, Oklahoma.

Gray massive limestone	3′	
Gray to buff shale with large concretions	15′	±
Croweburg coal	Float	
Total Section Measured	18′	

Locality No. 9, Omer Williams Mine, sec. 33-26N-18E, Craig County, Oklahoma.

Quaternary clay	9′	0″
Gray hard conchoidal shale with concretions	15′	0″
Croweburg coal	1′	1″
Gray clay	1′	0″
Total Section Measured	26′	1″

PALEONTOLOGY

The spore flora of the Croweburg coal consists of 13 genera and 48 recognized species. One new genus and nine new species are described. The Croweburg spore flora is one of the richest described from Paleozoic coals. Leaf cuticles are abundant and have been grouped into four types for statistical analysis. These may actually represent numerous species or in some instances parts of the same plant species.

Genus *CALAMOSPORA,* S. W. B., 1944

CALAMOSPORA HARTUNGIANA Schopf, 1944

Plate I, fig. 3

This species was found at all nine Croweburg coal localities studied and in all but two of twenty-four samples. Its greatest abundance occurs in the Crabtree Mine where it constitutes 4.6 percent of the total spore flora. The lowest frequency is found in the Fisher and McNabb Mines where it constitutes 1 percent of the total spore flora. In the composite spore histogram *C. hartungiana* makes up 2.3 percent of the flora. Kosanke (1950) records this species in Illinois as occurring almost continuously from the Murphysboro coal in the Tradewater group to the top of the Pennsylvanian section. Schemel (1951) records it from the Mystic and Marshall coals in Iowa. Figured specimen: Slide No. 3, WH1A McNabb Mine.

C. STRAMINEA Wilson and Kosanke, 1944

Plate I, fig. 5

Observed only at the four northern Croweburg coal locations described in this report. This species is a minor element of the coal and constitutes 1.5 percent of the spore flora at the Williams Mine and 0.3 percent in the Croweburg composite spore histogram. This species was originally described from Iowa coal of nearly equivalent age to that in Oklahoma. In Illinois (Kosanke, 1950) it was observed only in the Tradewater coals, which may be somewhat older age than the Croweburg. Figured specimen: Slide No. 4, WH6, Stewart Mine.

C. FLEXILIS Kosanke, 1950

Plate I, fig. 2

This is an uncommon species found in the Croweburg coal at the Omer Williams Mine, Craig County. It is not abundant enough to have been observed during the spore population count. In Illinois it is found in the Tradewater and Carbondale groups, extending above into the Harrisburg coal (Kosanke, 1950). Figured specimen: Slide No. 6, WH7, Williams Mine.

C. BREVIRADIATA Kosanke, 1950

Plate I, fig. 1

This species has been observed in the Croweburg coal at the Stewart Mine, Craig County; also in the Mystic and Marshall coals of Iowa (Schemel, 1951), and in Illinois (Kosanke, 1950) it occurs in the upper Tradewater group through the Carbondale and as high as the La Salle coal in the McLeansboro group. Figured specimen: Slide No. 15, WH6, Stewart Mine.

C. DECORA sp. nov.

Plate I, fig. 4

Spherical; diameter 60 to 70 microns; wall 2 microns thick; coarsely punctate, translucent, colorless to yellow; trilete rays 25 to 27 microns long, simple, lips not developed; contact area not modified; compression folds common, taper-pointed.

Holotype: Slide No. 4, WH11. Croweburg coal, Concharty Mt. Mine, Rogers County, Oklahoma. Diameter: 62.5 by 68.7 microns.

This species occurs infrequently at the four northern locations studied but only once did it appear in a spore population count. This occurrence is at the Concharty Mt. Mine. The coarsely punctate wall, proportionally long, trilete rays and lack of development in the contact area are distinctive features of *C. decora.*

Genus *CIRRATRIRADITES* Wilson and Coe, 1940

CIRRATRIRADITES CRASSUS sp. nov.

Plate II, fig. 6

Oblate, subtriangular; overall diameter 80 to 95 microns; spore body 86 to 77 microns; flange width 6 to 7.7 microns; trilete sutures bordered by broad, raised, involuted thickenings 3 to 4.8 microns wide, extend to outer edge of equatorial flange; wall 2 microns thick, punctate to punctate-reticulate; translucent, dark brown; flange width nearly uniform, outer edge roughly crenulate, translucent, colorless.

Holotype: Slide No. 2, WH3B, Croweburg coal, Fisher Mine, Wagoner County, Oklahoma. Diameter: 84 by 90 microns.

Cirratriradites crassus occurs infrequently in the Croweburg coal and appears to be somewhat more abundant at the southern locations. The wide ridges bordering the trilete rays distinguish this species from others now described.

C. INTERMEDIUS sp. nov.

Plate II, fig. 9 (holotype)

Oblate, subtriangular; overall diameter 40 to 50 microns; spore body 35 to 37 microns; flange width 3.5 to 6.5 microns; trilete sutures bordered by narrow raised thickenings, 1.0 to 1.2 microns wide, extend to inner edge of equatorial flange; wall 2 microns thick, coarsely granulose, translucent, brown; flange width slightly greater between rays, outer edge slightly crenulate, inner edge translucent, colorless.

Holotype: Slide No. 1, WH3B, Croweburg coal, Fisher Mine, Wagoner County, Oklahoma. Diameter: 47.6 by 48.8 microns. Occurs frequently in all Croweburg coal examined. The greatest abundance observed is in the Concharty Mt. Coal Mine where it is represented by 5.5 percent in the spore frequency count. In the composite spore histogram its frequency percentage is 1.3.

C. PUNCTATUS (Kosanke, 1950) Hoffmeister, Staplin, Malloy, 1955.

Plate II, fig 7

Lycospora punctata Kosanke 1950, p. 45, Plate 10, fig. 3

Cirratriradites punctatus is the most abundant spore in the Croweburg coal. In the composite spore population count this species comprises 42.1 percent of the total. Its greatest abundance occurs at the Fisher Mine where it is 47.5 percent. The number of specimens in any Croweburg coal sample is usually large, but the greatest abundance occurs in the lower and middle portions of the seam. This differential distribution is indicative of plant succession within the coal swamps of Croweburg time. Figured specimen: Slide No. 6 WH7 (fig. 7), Williams Mine, and Slide No. 1 WH3B (fig. 8), Fisher Mine.

Genus *ENDOSPORITES* Wilson and Coe, 1944

ENDOSPORITES ORNATUS Wilson and Coe, 1944

Plate IV, figs. 1 to 4

This species is the fourth most abundant spore type in the Croweburg coal. Its frequency in the composite spore histogram is 2.8 percent but varies from 1.3 to 8.3 percent among the nine localities studied. Generally, the greatest abundance within the Croweburg coal is near the top of the seam. In Illinois, *E. ornatus* is reported from the Tradewater, Carbondale and lower McLeansboro coals (Kosanke, 1950). Figured specimen: Slide No. 9, WH2C (fig. 1), Sequoyah Mine; Slides Nos. 6, 7, WH1D (figs. 2, 4), McNabb Mine; and Slide No. 12 WH5C (fig. 3), Ashley Property.

Genus *FLORINITES* S. W. B., 1944

FLORINITES ANTIQUUS Schopf, 1944

Plate IV, figs. 8 to 10

Occurs in all samples of Croweburg coal and is the third most abundant fossil spore. Its frequency ranges from 4 to 17 percent of the various Croweburg spore populations and in the composite population histogram it constitutes 9.8 percent of the whole. *Florinites antiquus* was described from an Iowa coal of upper Tradewater and lower Allegheny age. It has been recorded by Kosanke (1950) from the Reynoldsburg coal (Caseyville) through the Carlinville coal (McLeansboro) of Illinois. Within the Croweburg coal seam, it is most frequent in the uppermost levels and in certain shales above the coal. Slides Nos. 9 (fig. 8), 19 (fig. 9), 4 (fig. 10) WH1A, McNabb Mine.

F. PARVUS sp. nov.

Plate IV, fig 11 (holotype); fig. 12

Annulate bladder broadly elliptical, central body more spherical; trilete obscure, vestigial; overall length 50 to 58 microns, width 40 to 45 microns; central body diameter 18 to 23 microns; bladder wall 1.5 to 2 microns thick, exterior granular, interior reticulate, translucent, colorless; central body wall 1.0-1.5 microns thick, granular or levigate, translucent, colorless.

Holotype: Slide No. 5, WH7, Croweburg coal, Omer Williams Mine, Craig County, Oklahoma. Length 58.6 microns, width 42.5 microns, central body 18.7 by 22.8 microns. Slide No. 7, WH7 (fig. 12), Williams Mine.

Occurs infrequently and many specimen are poorly preserved. When first noticed the fossils were thought to be immature specimens of *F. antiquus,* but the size range is consistently nearly 20 microns less than *F. antiquus,* the structural condition of the spores indicates maturity, and the two forms do not always occur in the same samples.

Genus *GRANULATI-SPORITES* (Ibrahim, 1933) emend. S. W. B., 1944.

GRANULATI-SPORITES ADNATUS (?) Kosanke, 1950

Plate II, fig. 2

Occurrence occasional in the Croweburg coal, originally described from the No. 8 coal, McLeansboro group, of Illinois (Kosanke, 1950). The diagnostic feature of this species according to Kosanke is a developed contact area. Such a development is only slight in the specimens of the Croweburg coal and these may subsequently prove to represent a new species. Its much higher stratigraphic position in Illinois than in Oklahoma also suggests that these fossils are of an undescribed species. Figured specimen: Slide No. 2, WH7, Williams Mine.

GRANULATI-SPORITES VERRUCOSUS (Wilson and Coe) S. W. B., 1944.

Plate II, fig. 4

Triquitrites verrucosus Wilson and Coe, 1940, p. 185, fig. 10

Occurs at all Croweburg coal locations. With the next species, the two constitute 1.0 percent of the composite spore population histogram. It was first described from the Desmoinesian stage of Iowa and also reported by Kosanke (1950) as occurring in the Tradewater, Carbondale, and lower part of the McLeansboro of Illinois. Figured specimen: Slide No. 22, WH5C, Ashley Property.

G. GRANULARIS Kosanke, 1950

Plate II, fig. 5

Widely distributed and at all locations examined but infrequent and sporadic. Kosanke (1950) records it from the upper part of the Carbondale and lower portion of the McLeansboro rocks of Illinois. Figured specimen: Slide No. 6, WH1A, McNabb Mine.

G. DELTIFORMIS S. W. B., 1944

Plate II, fig. 3

Triquitrites deltoides Wilson and Coe, 1940, p. 185, fig. 9 (since *G. deltoides of* Ibrahim, 1933, prevents the transfer of *T. deltoides* to *Granulati-sporites* as a new combination, S. W. B. (1944) proposed *G. deltiformis* as a new name).

Frequent at several localities and constitutes 1 percent of the spore population at the Ashley Property locality. Recorded only from the Carbondale coal of Illinois (Kosanke, 1950). Figured specimen: Slide No. 5, WH7, Williams Mine.

G. PIROFORMIS Loose, 1934

Plate II, fig. 1

Specimens identified as this species are rare and sporadic in the Croweburg coal. It is not recorded by Kosanke (1950) from Illinois coals. Figured specimen: Slide No. 24, WH1A, McNabb Mine.

Genus *LAEVIGATO-SPORITES* (Ibrahim, 1933), emend. S. W. B., 1944.

LAEVIGATO-SPORITES DESMOINENSIS (Wilson and Coe) S. W. B., 1944.

Plate II, fig. 15

Phaseolites desmoinensis Wilson and Coe, 1940, p. 183, fig. 4

Found at all Croweburg coal localities studied and comprises 4.5 percent of the composite spore population. This species was originally described from the Desmoinesian stage of Iowa and since has been found by Kosanke (1950) to range almost continuously from the top coal of the Caseyville group to the Woodbury (?) coal near the top of the McLeansboro group. Ibrahim (1933) in Europe described *L. vulgaris* and three forms, i. e., *minor, major,* and *maximus.* These forms are undoubtedly very closely related to *L. desmoinensis* and to other described American forms, however, slight morphological differences seem evident. Therefore, it appears desirable at this time to recognize the American names as designating different species than those described by Ibrahim. Figured specimen: Slide No. 5, WH5C, Ashley Property.

L. MINUTUS (Ibrahim) S. W. B. 1944

Plate II, fig. 12

Punctati-sporites minutus Ibrahim, 1933, p. 40, pl. 5, fig. 33.

This species is the second most abundant spore in the Croweburg coal. In the composite population count, it constitutes 32.5 percent of the fossils. Kosanke (1950) records this species from the bottom coal of the Tradewater group to the top coal of the McLeansboro group. Figured specimen: Slide No. 12, WH6, Stewart Mine.

Laevigato-sporites minutus is most abundant in the lower levels of the Croweburg coal where it is the dominant fossil. At many places toward the middle and top of the seam it is replaced in importance by *Cirratriradites* and in some samples *Florinites.*

L. GLOBUS Schemel, 1951

Plate II, fig. 11

A fairly common fossil at all studied Croweburg localities, especially in the lower portions of the seam. The greatest abundance was found at the Crabtree Mine where 3.6 percent of the spore population is of this species. The composite of all Croweburg samples is 2.1 percent. This species was not recognized at the time of Kosanke's 1950 publication and some of the specimens identified as *L. punctatus* from Illinois may actually be *L. globus*. Certainly the two species are closely related if not identical, the difference representing extreme ranges in the species morphology. Figured specimen: Slide No. 10, WH6, Stewart Mine.

L. MINIMUS (Wilson and Coe) S. W. B., 1950

Plate II, fig. 13

Phaseolites minimus Wilson and Coe, 1940, p. 18, fig. 5

Infrequent and found sporadically in the lower samples at several localities. Reported from the Tradewater, Carbondale, and McLeansboro groups of Illinois (Kosanke, 1950). Occurred in the spore population counts only once and constitutes 0.05 percent of the composite spore count. Figured specimen: Slide No. 2, WH7, Williams Mine.

L. OVALIS (?) Kosanke, 1950

Plate II, fig. 14

The spores identified as *L. ovalis* in the Croweburg coals probably should be described as distinct since the size range is rather definitely restricted within 45 to 55 microns in length and 25 to 35 microns in width. The size range given by Kosanke (1950) is 45 to 65 microns for length. The monolete suture, like in *L. ovalis,* is approximately one-half the length of the spore. Figured specimen: Slide No. 5, WH5C, Ashley Property.

The Croweburg form is infrequent and found normally in the lower levels of the seam. In Illinois it occurs in most of the Pennsylvanian coals studied by Kosanke (1950).

Genus *LYCOSPORA* S. W. B., 1944

LYCOSPORA BREVIJUGA Kosanke, 1950

Plate II, fig. 10

Occurs generally but not abundantly in the Croweburg coal. Variation in specimens identified as *L. brevijuga is* great. It is reported from the Tradewater and Carbondale coals in Illinois (Kosanke, 1950). It did not appear in the Croweburg population counts; consequently no index of frequency is given in the composite spore histogram. Figured Specimen: Slide No. 26, WH1D, McNabb Mine.

Genus *PUNCTATI-SPORITES* Ibrahim, 1933, emend. S. W. B., 1944

PUNCTATI-SPORITES TRIANGULARIS Kosanke, 1950

Plate I, fig. 7

Infrequent in the Croweburg coal in Oklahoma. Recorded by Kosanke (1950) from the Carbondale and lower McLeansboro coals of Illinois. Figured specimen: Slide No. 2, WH1A, McNabb Mine.

P. SULCATUS Wilson and Kosanke, 1944

Plate I, fig. 11

Occasionally found in the upper levels of the Croweburg coal. Kosanke (1950) records it from the Tradewater and McLeansboro coals of Illinois. Figured specimen: Slide No. 12 WH6, Stewart Mine.

P. ORBICULARIS Kosanke, 1950

Plate I, fig. 10

This fossil is consistently in the lower size range given for *P. orbicularis* by Kosanke (1950); consequently, it might be a different species. However, for the present it is not so treated. Figured specimen: Slide No. 8, WH7, Williams Mine.

Occurs at all Croweburg localities except in the Crabtree Mine. The greatest abundance is 3 percent in the Fisher Mine and the average abundance for the nine localities studied is 1.2 percent. In Illinois this species is recorded by Kosanke (1950) only from the McLeansboro coals. Figured specimen: Slide No. 8, WH7, Williams Mine.

P. LATIGRANIFER Kosanke, 1950

Plate I, fig. 8

Rare, found only in the Croweburg coal of the Ashley Property. In Illinois, Kosanke (1950) indicates this species is restricted to the McLeansboro coals. Figured specimen: Slide No. 27, WH5C, Ashley Property.

P. OBLIQUUS Kosanke, 1950

Plate I, fig. 9

Found occasionally in the lower portion of the Croweburg coal. Reported from the Tradewater, Carbondale, and McLeansboro coals by Kosanke (1950) and from the Mystic and Marshall (Desmoinesian) coals of Iowa by Schemel (1951). Figured specimen: Slide No. 9, WH1A, McNabb Mine.

P. DENTATUS sp. nov.

Plate I, fig. 12 (holotype)

Spores radial; trilete; spherical; diameter 4 to 58 microns; trilete rays simple, 18 to 21 microns long, bordered by serrated ridges 2.5 to 3.5 microns high; wall 1.5 to 2 microns thick, brown, translucent, ornamented by scattered sharp pointed spines, 1 to 2.5 microns long.

Holotype: Slide No. 8, WH4C, Croweburg coal, Brady Mine, Verdigris, Rogers County, Oklahoma. Diameter 51 to 48 microns.

Observed at all Croweburg localities except the Williams Mine. It reaches it greatest abundance, 2.5 percent at Concharty Mt. Mine, and constitutes 0.7 percent of the composite spore population.

Genus *RAISTRICKIA* S. W. B., 1944

RAISTRICKIA ACULEOLATA Wilson and Kosanke, 1944

Plate I, fig. 15

Found occasionally in the Croweburg coal. It was originally described from a Desmoinesian coal in Iowa and is reported by Kosanke (1950) from Tradewater and Carbondale coals of Illinois. Figured specimen: Slide No. 4, WH7, Williams Mine.

R. CRINITA Kosanke, 1950

Plate I, figs. 13 and 14

Occurs generally throughout the samples studied but does not appear in all of the population counts. Its greatest abundance is in the Stewart Mine where it constitutes 1.6 percent of the spores. The average is 0.4 percent for all of the Croweburg spore population. In Illinois, it has been reported by Kosanke (1950) from the upper Tradewater, Carbondale, and lower McLeansboro coals. Figured specimens: Slides Nos. 4, WH7 (fig. 13), Williams Mine, and No. 13, WH6 (fig. 14), Stewart Mine.

R. CROCEA Kosanke, 1950

Plate I, figs. 20 and 21

Observed only in the lower portion of the Croweburg coal at the McNabb Mine. Kosanke (1950) records it from the Carbondale of Illinois. Figured specimens: Slide Nos. 1 (fig. 20) and 3 (fig. 21), WH1A, McNabb Mine.

R. GROVENSIS Schopf, 1944

Plate I, fig. 16

Occurrence is general in the Croweburg coal but its greatest abundance is only 0.6 percent at any location. The composite population is 0.2 percent. The occurrence of *R. grovensis* in Illinois is reported as restricted to the Carbondale coals (Kosanke, 1950). Figured specimen: Slide No. 167, WH2C, Sequoyah Mine.

R. PRISCA Kosanke, 1950

Plate I, fig. 17

Observed as an occasional fossil in the lower portion of the McNabb Mine, Rogers County. It is reported from the Caseyville and lower Tradewater coals of Illinois (Kosanke, 1950). Figured specimen: Slide No. 3, WH1A, McNabb Mine.

R. SOLARIA sp. nov.

Plate I, figs. 18 (holotype) and 19

Spores radial, trilete; spherical, diameter 51 to 63.5 microns; trilete rays obscured by processes, where visible, simple, 19-21 microns long; processes simple to tripartite, crowded, 7 to 12 microns long, 2 to 6 microns wide, tapering to point or tubular; wall translucent, amber to brown.

Holotype: Slide No. 10, WH1A, Croweburg coal, McNabb Mine, Catoosa, Rogers County, Oklahoma. Diameter 58 microns, processes 7 to 10.5 microns long, 2 to 6 microns wide. Figured specimen: Slide No. 2, WH1A (fig. 19), McNabb Mine.

Generally distributed but not abundant and did not occur in the population counts. Fig. 18, the holotype, illustrates the most frequent aspect of this species and Fig. 19 appears to represent the extreme range of form.

Genus *SCHOPFITES* Kosanke, 1950

SCHOPFITES COLCHESTERENSIS Kosanke, 1950

Plate I, fig. 6

Occasional in the Stewart Mine of the Croweburg seam; Kosanke (1950) has reported this species and *S. dimorphus* only from the Colchester coal of the Carbondale group in Illinois. Figured specimen: Slide No. 16, WH6, Stewart Mine.

Genus *TRIQUITRITES* Wilson and Coe, 1940

TRIQUITRITES ARCULATUS Wilson and Coe, 1940

Plate III, fig. 20

Infrequent but generally distributed in the Croweburg seam. Originally described from the Des Moines series of Iowa. Reported from the coals of the Tradewater and Carbondale groups of Illinois (Kosanke, 1950). Figured specimen: Slide No. 10, WH6, Stewart Mine.

T. CRASSUS Kosanke, 1950

Plate III, figs. 17, 18, and 19

Frequent at all Croweburg localities studied but did not appear in all the spore population counts. Greatest abundance 1.5 percent at the Sequoyah Mine and 0.5 percent in the composite population average. Reported by Kosanke (1950) from the Tradewater, Carbondale, and McLeansboro coals. Figured specimens: Slides Nos. 27, WH1A (fig. 17), McNabb Mine; 13, WH6 (fig. 18), Stewart Mine; 5, WH3B (fig. 19), Fisher Mine.

T. DISCOIDEUS Kosanke, 1950

Plate III, fig. 14

Rare; found only in the Stewart Mine, Craig County, Oklahoma. In Illinois it is reported from the Tradewater, Carbondale and McLeansboro coals (Kosanke, 1950). Figured specimen: Slide No. 10, WH6, Stewart Mine.

T. EXIGUUS Wilson and Kosanke, 1944

Plate III, fig. 23

Occasional in the lower portion of the Williams Mine and observed in coal from the Stewart Mine. Described originally from a Desmoinesian coal of Iowa, also reported in the Mystic and Marshall coals, by Schemel (1951). Kosanke (1950) has observed it in the Tradewater and Carbondale coals of Illinois. Figured specimen: Slide No. 1, WH3B, Fisher Mine.

T. INUSITATUS Kosanke, 1950

Plate III, fig. 21

Rare in the lower portion of the Croweburg seam at the Williams Mine. Reported from the upper Tradewater and lower Carbondale coals of Illinois by Kosanke (1950). Figured specimen: Slide No. 8, WH7, Williams Mine.

T. ADDITUS sp. nov.

Plate III, figs. 6 (holotype) to 9

Spores radial, trilete; triangular-oblate; diameter 35 to 45 microns long, lips thickened; arcuate thickening present, usually associated with or obscured by tubular or lobed projections, 9 to 10 microns long and 2.5 to 9 microns wide, developed on either or both surfaces; distal surface frequently with partial secondary wall layers; wall levigate between processes, translucent, amber to brown.

Holotype: Slide No. 14, WH5C, Croweburg coal, Brady Mine, Rogers County, Oklahoma. Diameter, 37.5 microns. Figured specimens: Slide No. 5, WH5C (fig. 7), Ashley Property; Slide No. 4, WH7 (fig. 8), Williams Mine; Slide No. 12A, WH6 (fig. 9), Stewart Mine.

This species is generally distributed throughout the Croweburg seam but is not abundant. It does not appear in the population counts. Great variation of form occurs as illustrated in Figs. 6 through 10. It is quite possible that more than one natural species is included here, but the transition from one form to the next appears gradual and complete.

T. BRANSONII sp. nov.

Plate III, figs. 1 (holotype) to 5

Spores radial, trilete; triangular-oblate; diameter 30 to 42 microns; arcuate thickenings distinct, most specimens broadly oval to angular, darker color than spore body, shape and size variable on some specimens, height 4.5 to 7.0 microns, width 9 to 16.5 microns;

wall 1-1.5 microns thick, translucent, amber color, levigate; rays distinct, normally extending to equator, lips slightly raised.

Holotype: Slide No. 12A, WH6, Croweburg coal, Stewart Mine, Craig County, Oklahoma. Dimensions, 35 to 37.5 microns. Figured specimens: Slide No. 40, WH1A (fig. 2), McNabb Mine; Slide No. 6, WH5C (fig. 3), Ashley Property; Slide No. 9, WH1A (fig. 4), McNabb Mine; Slide No. 9, WH5C (fig. 5) Ashley Property.

This species slightly resembles *T. pulvinatus* Kosanke, 1950, but is distinguished from it by its smaller size. It occurs abundantly in all Croweburg coals examined, being most abundant in the Williams Mine where it constitutes 3.5 percent of the spore population. In the composite population it is 1.9 percent of the histogram.

T. DIVIDUUS sp. nov.

Plate III, figs. 10 (holotype) and 11

Spores radial, trilete; triangular-oblate, corners flat or round; diameter 40 to 49 microns; trilete rays simple, 18 to 20 microns long, lips slightly raised; arcuate areas with or without thickenings; arcuate processes when present not restricted to equator, slightly lobed, projecting 2 to 4 microns beyond equator; width usually equal to width of arcuate area; equatorial wall 2 to 2.5 microns thick; proximal and distal walls levigate or with few verrucose thickenings in commissural area; translucent, amber to brown, arcuate areas darker when thickenings are present.

Holotype: Slide No. 2, WH1, Croweburg coal, McNabb Mine, Catoosa, Rogers County, Oklahoma. Dimensions, 42 by 44 microns. Figured specimen: Slide No. 163, WH2C (fig. 11), Sequoyah Mine.

Common in all Croweburg coals examined and constitutes 0.5 percent of the composite spore population count. Variation in arcuate form is common, frequently one corner will be flat and the other two rounded or slightly pointed. Thickening in the arcuate area is also variable, ranging from none to one or two microns.

T. PRAETEXTUS sp. nov.

Plate III, figs. 15 (holotype) and 16

Spores radial, trilete; triangular-oblate; diameter exclusive of arcuate processes 35 to 48 microns; trilete rays simple, 18 to 19 microns long; arcuate processes equatorial in position, tubular to triangular, entire or shallowly lobed, height 10 to 12 microns, width 18 to 23 microns at base; equatorial wall 3 to 5 microns thick; wall levigate, translucent, brown, arcuate areas darker color.

Holotype: Slide No. 8, WH1A, Croweburg coal, McNabb Mine, Rogers County, Oklahoma. Diameter 37.5 microns, arcuate processes 9 to 11 microns high, 18.5 to 23 wide; overall dimensions 51 by 56 microns. Figured specimen: Slide No. 13, WH5C (fig. 16), Ashley Property.

Distribution general though not abundant. Variation in form consists mostly in size and shape of the arcuate appendages.

T. TUMULUS sp. nov.

Plate III, figs. 12 (holotype) and 13

Spores radial, trilete; triangular-pyramidal; diameter exclusive of arcuate processes 35 to 40 microns, total diameter, 40 to 48 microns, trilete rays simple, usually curved, 16 to 19 microns long, lips slightly raised; arcuate processes variable, pointed to scalloped, equatorial wrinkle ridges or thickenings on proximal and distal surfaces, 4 to 9 microns high; equatorial wall 2 to 4.5 microns thick, translucent, amber to brown, ridges darker.

Holotype: Slide No. 21, WH1A, Croweburg coal, McNabb Mine, Catoosa, Rogers County, Oklahoma. Diameter exclusive of processes 39 microns, total diameter 46.5 microns.

This species is characterized by the pyramidal shape, surface ridges and wrinkled appearance. It is fairly abundant in the lower portion of the coal at the McNabb Mine, but rare elsewhere.

TRIQUITRITES sp.

Plate III, fig. 23

Spore radial, trilete; triangular-oblate; diameter exclusive of arcuate processes 35 to 37 microns, total 42 by 48; trilete rays simple, curved, 16 to 20 microns long, bordered by thickened margin 7 to 9 microns wide and extending to arcuate areas, 16 to 23 microns wide; arcuate processes equatorial, lobed, circular or irregular, varying from none to several, 4 to 12 microns high and 4 to 14 microns wide; equatorial wall 2 to 3 microns thick; proximal and distal walls levigate, translucent, brown, arcuate and commissural areas darker color.

Specimen: Slide No. 1, WH3B, Croweburg coal, Fisher Mine, Broken Arrow, Wagoner County, Oklahoma. Diameter exclusive of processes 35 to 37 microns, total diameter 42 by 48 microns.

A single specimen of this form was found during the investigation and though the specimen may represent simply an anomalous individual, it is being recorded in case it appears in other coals and becomes a useful stratigraphic species.

Genus *VESTISPORA* Wilson and Hoffmeister, gen. nov.

Spores radial, trilete; spherical but usually flattened by compression; total diameter 64 to 96 microns, diameter of central body 32 to 35; trilete mark simple, straight, 18-20 microns long, external or peripheral bladder; central body inserted on peripheral bladder approximately below trilete area, circular ridge present at contact; distal side of central body apparently not attached; central body levigate or granular; reticulations on peripheral bladder equiangular to linear, presenting the appearance of circular ridges near edges; walls thin 1.5 to 2 microns thick, translucent, amber to brown.

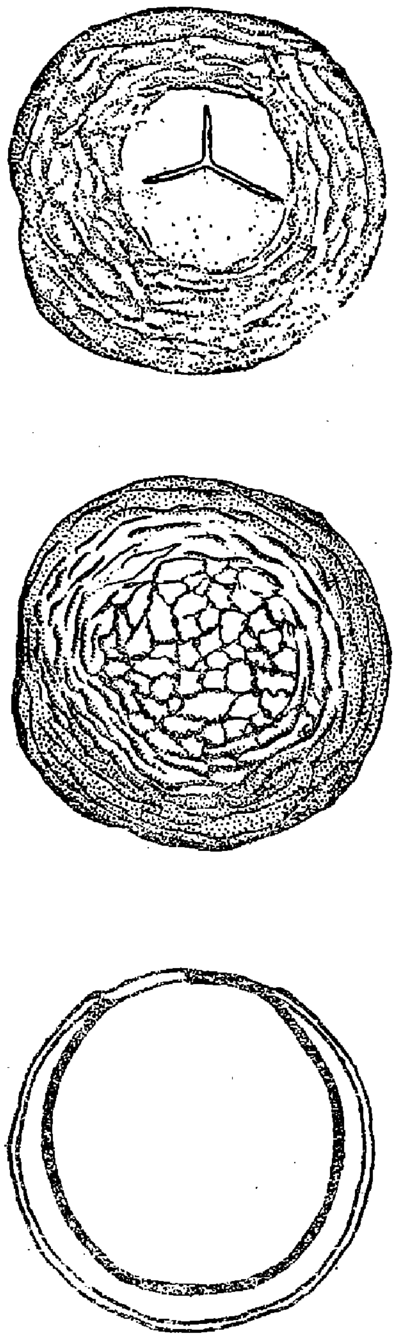
VESTISPORA PROFUNDA sp. nov.

Plate II, figs. 16 and 17 (Genoholotype, proximal and distal views), 18, and 19, also text fig. 1

Description of species as above for genus.

Genoholotype: Slide No. 5, WH7, Croweburg coal, Ashley Property, North Bushyhead, Rogers County, Oklahoma. Diameter: total 70.2 microns, central body 35 microns. Figured specimens: Slides Nos. 1 (fig. 19), 6 (fig. 18), WH5C, Ashley Property.

Vestispora profunda is not a common spore in any of the Croweburg coals. It has been most frequently observed in the Ashley Property coal at The North Bushyhead. The circular ridges near the periphery and angular reticulation at the center of the spore on the distal surface make it easily recognizable. The trilete mark is clearly apparent on the central body. The circular transverse shape and definite trilete mark development suggest closer affinity with *Endosporites* and *Wilsonia* than with *Florinites*.



A. PROXIMAL VIEW OF HOLOTYPE

B. DISTAL VIEW OF HOLOTYPE

C. INTERPRETED POLAR SECTION VIEW OF HOLOTYPE

SKETCHES OF <u>VESTISPORA PROFUNDA</u>

Fig. 1

Genus *WILSONIA* Kosanke, 1950

WILSONIA VESICATA Kosanke, 1950

Plate IV, figs. 5 to 7

Generally distributed throughout the Croweburg seam but most abundant in the upper portion, Kosanke (1950) reports it from the McLeansboro coals.

PLANT CUTICLES

CUTICLE TYPE A. Plate V, figs. 5 and 6

Cells compact, oblong; length 39 to 58 microns, width 5 to 18 microns; walls simple, uniform thickness, 1 to 2 microns, translucent; stomatal structures poorly preserved, usually represented by oval voids, en echelon arrangement.

This cuticle is the most abundant type in the Croweburg coal, usually comprising 40 to 55 percent of the tissue fragments. The average frequency is 48 percent. Figured specimens: Slides Nos. 6, WH5C and 8, WH5C, Ashley Property.

Similar cuticles have been described by Seward and Sahni, and by Francis and Wheeler (Francis, pp. 101-108) which are assigned to the genus *Cordaites.*

CUTICLE TYPE B. Plate V, figs. 1 and 2

Membranous or film-like, structureless; less than one micron thick; transparent; usually folded; abundantly perforated by circular holes, 5 to 6 microns diameter, irregular arrangement, may or may not have morphological significance.

Twenty to thirty percent of the cuticle fragments are of this type. In the composite histogram it represents 25 percent of the cuticles. Figured specimens: Slides Nos. 5, WH5C and 4, Ashley Property.

CUTICLE TYPE C. Plate V, fig. 4

Cells compact, short rectangular, square, infrequently hexagonal, length 15 to 21 microns, width 8 to 16 microns; walls thickened, especially above and slightly convexed, 2 to 3 microns thick, translucent to opaque; stomatal structures not observed.

Constitutes 16 percent of the composite cuticle population and ranges from 12 to 22 percent at the various Croweburg localities.

Type C is a distinctive and easily recognized cuticle which should become a useful fossil for correlation. Figured specimen: Slide No. 2, WH5C, Ashley Property.

CUTICLE TYPE D. Plate V, fig. 3

Cells compact, most species are hexagonal, infrequently rectangular, net-like arrangement; dimensions 35 to 62 microns; walls thin, simple, 1.5 to 2.5 microns thick, transparent to translucent; stomatal structures not observed.

Uniformly distributed in the Croweburg coals, constitute 11 percent of the composite histogram. Figured specimen: Slide No. 3, WH5C, Ashley Property.

DISCUSSION

The principles of stratigraphic paleontology are well demonstrated in the Croweburg coal and since that coal extends across northeastern Oklahoma (Fig. 2), Kansas, and Missouri, and appears to have equivalents toward the northeast in Illinois, Indiana and Kentucky, it is an important horizon in the Pennsylvanian system. Its stratigraphic position is within the Cabaniss group of the Desmoinesian stage, Middle Pennsylvanian series. According to Branson (1954A) the position of the Croweburg coal below the Verdigris limestone makes it easily recognizable.

The plant microfossils within the coal consist of spores and plant cuticles. Forty-eight species of spores and four types of plant cuticles have been distinguished, described and illustrated. The spores indicate that the flora of the Croweburg swamps consisted of ferns, lycopods, calamarians, and gymnosperms typical of Pennsylvanian time.

The general aspect of the Croweburg spore assemblage is similar to that of the late Desmoinesian coals of Iowa reported by Wilson and Coe (1940), Wilson and Kosanke (1944) and Schemel (1951). In Illinois, a closely related flora is reported by Kosanke (1950) from the lower Carbondale coals, which are in strata equivalent to the Desmoinesian of Iowa and Oklahoma. As in other middle Pennsylvanian spore assemblages, the presence of the genus *Laevigato-sporites* and the absence of the genus *Denso-sporites* was

PLANT MICROPALEONTOLOGY OF THE CROWEBURG COAL IN OKLAHOMA

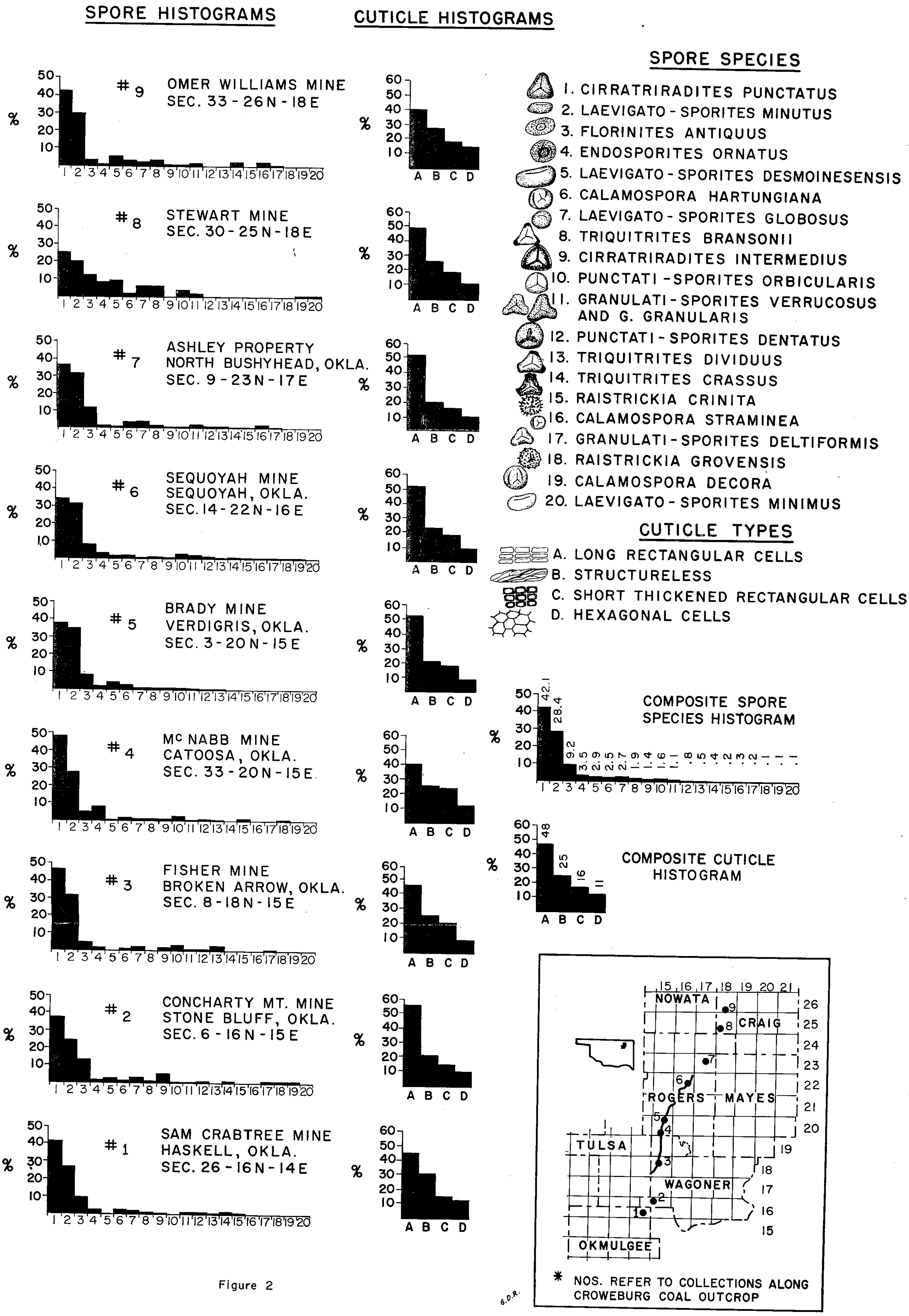


Figure 2

noted. This is characteristic of coal spore assemblages of the upper part of the Desmoinesian stage. The most prolific genus is *Cirratriradites* and is followed by the genera *Laevigato-sporites, Florinites, Endosporites, Calamospora* and *Punctati-sporites* in order of abundance. The new spore genus, *Vestispora,* and nine new species distinguish the Croweburg coal from all others which have received examination. Whether this indicates that the Croweburg coal is not correlative with the more northern coal, or that an element of geographic distribution and regional ecology enters the problem, is not yet discernible. Further studies will have a bearing on this problem.

Raistrick and Simpson (1933) were probably the first to make wide use of plant spores and histograms in the correlation of coal seams when they investigated the spores of the Northumberland coals. In the United States, Kosanke (1950) successfully used spores for correlating the coals of Illinois.

The ecological approach to spore and pollen problems in ancient sediments is a relatively new technique which may be patterned after Pleistocene paleoecological methods. Studies of the plant microfossils taken from a peat deposit show changes in the regional pollen flora as samples from different levels of the peat are examined. Such succession is also observable through a coal seam. Microfossils from a channel sample of coal, for example from the lower 6 inches, the middle 6 inches, and the upper 6 inches of an 18-inch coal seam show floristic changes as in the recent peats. The changes have been found consistent in the same coal seam at localities miles apart and indicate that plant succession occurred in the Paleozoic swamps as in those of recent time. For correlation of coals, plant microfossils can thus be used with assurance. However, caution must be exercised in order that complete sections be studied and that no part of the successional series be omitted.

Histograms depicting spore population abundance in complete channel samples were constructed from counts of 200 specimens of 20 important species. A histogram was made of the spore assemblage at each of the nine localities and the histograms are remarkably similar (shown in Fig. 2). It was believed that histograms made of the four cuticle types might be of interest and might show similar populations at various collection areas. Counts of 1000 cuticle specimens of 100 microns or more were made at each locality and the results are shown in Fig. 2. Cuticle types are remarkably consistent in the localities studied. Although this method of correlation is probably not as conclusive as that with plant spores, it does constitute a method for simple and quick comparison of the residues. It should not be used as a substitute for spore and pollen studies but rather as an additional tool to confirm the correlations by them.

Table I gives the channel sample percentages of 20 spore species noted at the nine studied Croweburg coal localities. Included in the table is a composite percentage of the spore species from the nine localities. Because of their rare occurrences 28 of the 48 species in the total flora are not included in the table.

When the Croweburg seam was found to possess uniform spore histograms across its areal distribution, an investigation of the spores in the overlying and underlying seams was made. Shown in Fig. 3 are histograms of eight spore genera from the Croweburg coal, the overlying Iron Post coal and the underlying Bluejacket coal. The Bluejacket coal can be separated readily from the two overlying coals by the presence of the genus *Denso-sporites*. The Croweburg coal differs from the Iron Post coal in that the genus *Cirratriradites* is abundant, constituting approximately 42 percent of the spore assemblage and is absent in the Iron Post coal. Other differences in spore genera population can be seen by the marked dissimilarities of the three histograms. The spore genera of the Iron Post and Croweburg coals are more nearly alike than they are with those of the Bluejacket coal. Because of the evident dissimilarity between the Bluejacket and the upper two coals, the boundary between the Middle Pennsylvanian and the Lower Pennsylvanian may occur near this level. The genus *Denso-sporites* appears to be mostly confined to the Upper Mississippian and Lower Pennsylvanian sediments.

An attempt has also been made to relate the Croweburg coal with the equivalent or nearly correlative coal in the Illinois series described by Kosanke (1950). When spores of *Schopfites colchesterensis* were observed in the Croweburg coal it was noted that this species is reported only from the Colchester coal in Illinois. Further paleontological comparisons with the Colchester coal, and two other Illinois coals, the Greenbush, which lies below the Colchester, and the Summum, which lies above the Colchester, are given in Tables II and III.

TABLE I. SUMMARY OF SPORE PERCENTAGES AT NINE CROWEBURG COAL SEAM LOCATIONS

SPORE SPECIES	Crabtree Mine	Concharty Mt. Mine	Fisher Mine	McNabb Mine	Brady Mine	Sequoyah Mine	Ashley Property	Stewart Mine	Williams Mine	Composite
1. Cirratriradites punctatus	45.6	38.5	47.5	48.3	38.0	35.0	39.0	25.0	43.0	42.1
2. Laevigato-sporites minutus	28.0	25.0	33.0	28.6	36.0	32.0	32.0	21.0	30.5	28.4
3. Florinites antiquus	10.6	14.5	5.0	5.6	10.5	9.0	12.0	13.0	4.0	9.2
4. Endosporites cherokeensis	3.0	2.0	2.0	8.3	2.0	4.5	1.3	9.0	1.0	3.5
5. Laevigato-sporites desmoinensis	0.0	3.0	0.0	0.3	5.0	2.5	1.0	10.0	6.0	2.9
6. Calamospora hartungiana	4.6	2.0	1.0	1.0	2.5	2.5	3.3	2.0	3.5	2.5
7. Laevigato-sporites globus	3.6	3.0	2.0	1.0	1.5	1.0	3.6	6.0	3.0	2.9
8. Triquitrites bransonii	2.0	1.0	0.0	1.0	1.0	1.5	1.3	6.0	3.5	1.9
9. Cirratriradites intermedius	0.3	5.5	2.0	1.0	1.0	1.5	0.3	1.0	0.5	1.4
10. Punctati-sporites orbicularis	0.0	1.0	3.0	2.0	1.0	3.0	0.3	4.0	0.5	1.6
11. Granulati-sporites verrucosus and G. granularis	0.6	0.5	0.5	0.3	1.0	2.5	2.0	2.0	1.0	1.1
12. Punctati-sporites dentatus	0.6	2.5	0.5	0.6	0.5	1.5	1.0	0.0	0.0	0.8
13. Triquitrites dividuus	0.3	0.0	3.0	0.3	0.5	0.5	1.0	0.0	0.0	0.5
14. Triquitrites crassus	0.6	0.5	0.0	0.0	0.0	1.5	0.3	0.0	1.5	0.4
15. Raistrickia crinita	0.0	0.0	0.0	1.0	0.0	0.5	0.3	0.0	0.0	0.2
16. Calamospora straminea	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	1.5	0.3
17. Granulati-sporites deltiformis	0.0	0.5	0.5	0.0	0.0	0.5	0.3	0.0	0.5	0.2
18. Raistrickia grovensis	0.0	0.5	0.0	0.6	0.0	0.5	0.0	0.0	0.0	0.1
19. Calamospora decora	0.0	0.5	0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.1
20. Laevigato-sporites minimus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.1

TABLE II
COMPARISON OF SPORE FLORAS IN THREE ILLINOIS COALS AND THE CROWEBURG COAL OF OKLAHOMA

Spore Species in Coals of Illinois and Oklahoma	ILLINOIS			OKLAHOMA
	GROUPS			
	Tradewater	Carbondale		Cabaniss
SPECIES	Greenbush Coal	Colchester Coal	Summum Coal	Croweburg Coal
Calamospora decora				X
Cirratriradites crassus				X
C. intermedius				X
C. pseudoannulatus				X
Florinites parvus				X
Granulati-sporites adnatus				X
G. deltiformis				X
G. granularis				X
G. piroformis				X
G. verrucosus				X
Laevigato-sporites globus				X
Punctati-sporites dentatus				X
P. latigranifer				X
P. orbicularis				X
P. sulcatus				X
P. triangularis				X
Raistrickia prisca				X
R. solaria				X
Triquitrites additus				X
T. bransonii				X
T. discoideus				X
T. dividuus				X
T. praetextus				X
T. tumulus				X
Vestispora profunda				X
Wilsonia vesicata				X
Endosporites ornatus		X	X	X
Punctati-sporites obliquus		X	X	X
Raistrickia crinita		X	X	X
R. crocea		X	X	X
Triquitrites exiguus		X	X	X
Calamospora breviradiata	X	X	X	X
Cirratriradites punctatus	X	X	X	X
Florinites antiquus	X	X	X	X
Laevigato-sporites desmoinensis	X	X	X	X
L. minimus	X	X	X	X
L. minutus	X	X	X	X
Calamospora hartungiana	X	X		X
Laevigato-sporites ovalis	X	X		X
Triquitrites arculatus	X	X		X
T. inusitatus	X	X		X
Calamospora flexilis		X		X
Lycospora brevijuga		X		X
Raistrickia aculeata		X		X
R. grovensis		X		X
Schopfites colchesterensis		X		X
Triquitrites crassus		X		X

TABLE II (Continued)
COMPARISON OF SPORE FLORAS IN THREE ILLINOIS COALS AND THE CROWEBURG COAL OF OKLAHOMA

Spore Species in Coals of Illinois and Oklahoma	ILLINOIS			OKLAHOMA
	GROUPS			
	Tradewater	Carbondale		Cabaniss
SPECIES	Greenbush Coal	Colchester Coal	Summum Coal	Croweburg Coal
Calamospora straminea	X			X
Cirratriradites annulatus		X	X	
C. annuliformis		X	X	
Granulati-sporites convexus		X	X	
Punctati-sporites quaesitus			X	
Laevigato-sporites pseudothiessenii	X	X	X	
L. punctatus	X	X	X	
Lycospora granulata	X	X	X	
Punctati-sporites verrucifer	X	X	X	
Alati-sporites trialatus		X		
Triquitrites pulvinatus	X	X	X	
Punctati-sporites fenestratus	X		X	
Granulati-sporites pallidus		X		
G. spinosus		X		
Punctati-sporites quasiarcuatus		X		
P. reticuloides		X		
Raistrickia irregularis		X		
R. pilosa		X		
R. rubida		X		
Schopfites dimorphus		X		
"Spherites" sp.		X		
Alati-sporites hexalatus	X	X		
Laevigato-sporites robustus	X	X		
Punctati-sporites foveatus	X			
Cirratriradites maculatus	X			
Denso-sporites sphaerotriangularis	X			
Granulati-sporites aculeolatus	X			
Laevigato-sporites vulgaris	X			
Punctati-sporites firmus	X			
Triquitrites protensus	X			

TABLE III
SUMMARY OF SPORE DISTRIBUTION IN THREE ILLINOIS COALS AND THE CROWEBURG COAL

Comparison	Tradewater	Carbondale		Cabaniss
	Greenbush	Colchester	Summum	Croweburg
Species reported	26	43	22	48
Restricted species	6	10	0	26
Species and percentage in common with Croweburg	11 (23%)	21 (43.7%)	11 (23%)	—
Species restricted to Croweburg and other	1	6	0	—

It would seem from the data given in Tables II and III that the closest correlation of the Croweburg coal with the Illinois sequence is the Colchester coal, which lies at the base of the Carbondale group, and is considered equivalent to the middle part of the Desmoinesian series of Oklahoma where the Croweburg coal occurs. The type locality of the Colchester coal, according to Kosanke (1950), is at Colchester, Illinois, which is approximately 300 miles from the town of Croweburg, Kansas, the type locality of the Croweburg coal.

Paleoecology

Few Paleozoic coal studies of a successional nature have been published although the opportunity is as available as with the Pleistocene peats. The wide occurrence of the Croweburg coal seam made a paleogeographic and paleoecologic investigation especially desirable. Therefore, collections were made which would permit a comparison of the spore and cuticle floras in the bottom, middle and top thirds of the seam. The samples from these segments were processed separately and examined to determine their floristic content. Eight of the most abundant spore species were graphed and found to agree in stratigraphic sequence of species and abundance at the seven localities studied. At two of the nine localities, the Concharty Mt. and Stewart Mines, it was not possible to obtain channel samples. At these, three samples consisting each of several pounds of random coal fragments were secured and processed. Their histograms (Fig. 2) agree closely with those of adjacent localities and indicate that it is possible to obtain useable stratigraphic information from the random sampling of tipple piles. However, such technique is not a desirable practice.

The variations in spore percentages at the seven locations where channel samples were obtained showed successional sequences which are illustrated in Fig. 3.

COMPARISON OF SPORE GENERA IN THREE OKLAHOMA COALS

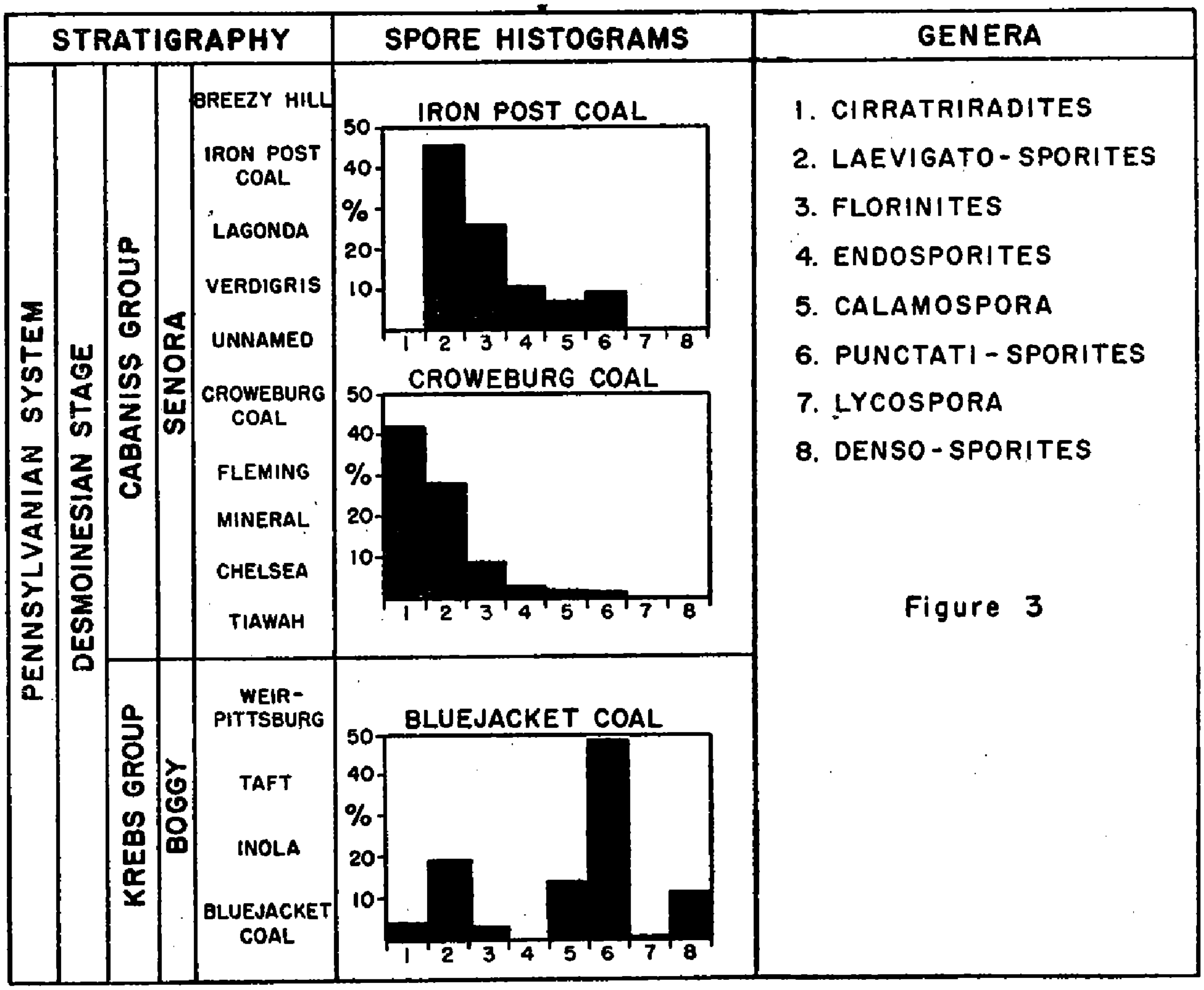


Figure 3

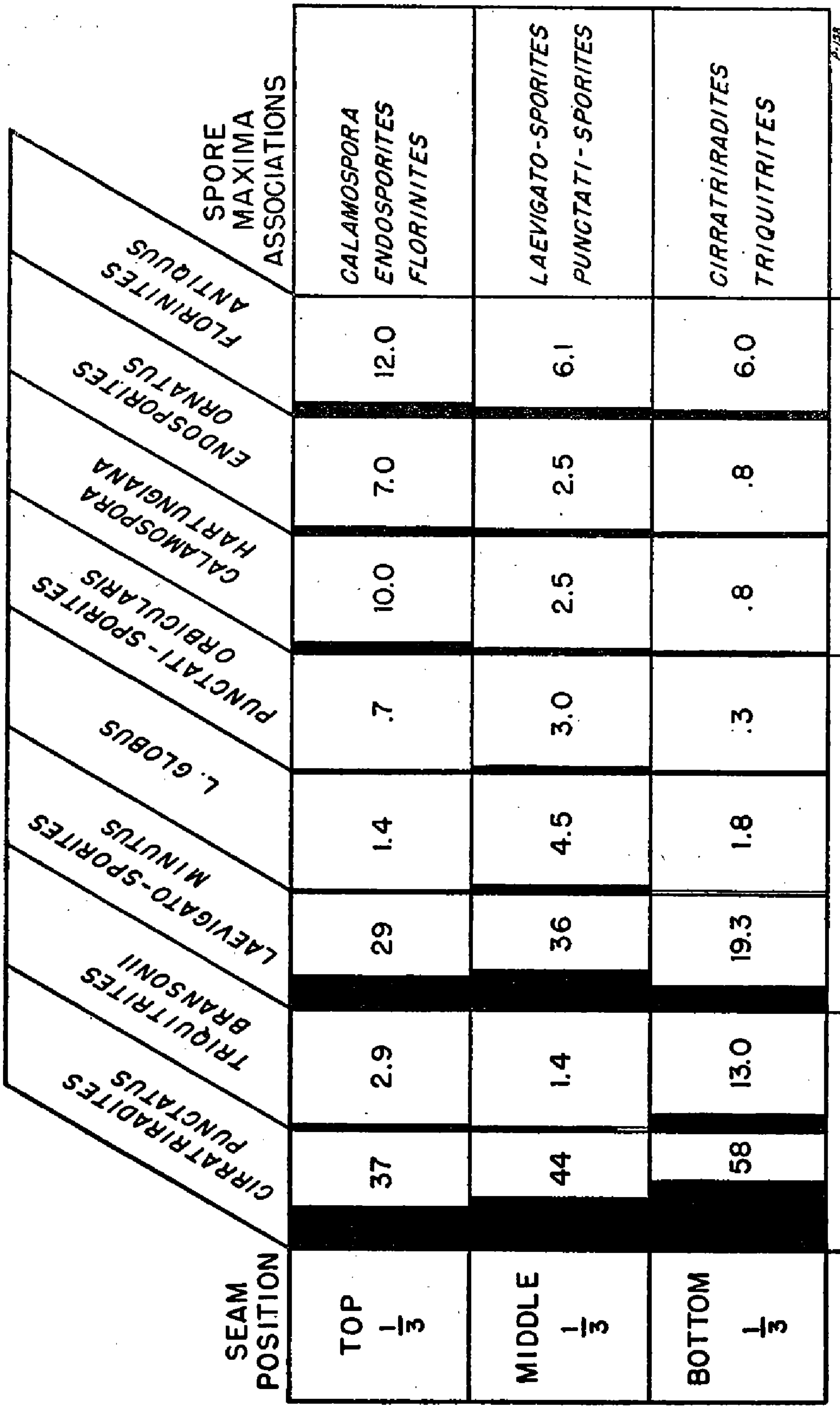

SPORE MAXIMA ASSOCIATIONS
CALAMOSPORA
ENDOSPORITES
FLORINITES
LAEVIGATO-SPORITES
PUNCTATI-SPORITES
CIRRATRIRADITES
TRIQUITRITES
FLORINITES ANTIQUUS
ENDOSPORITES ORNATUS
CALAMOSPORA HARTUNGIANA
PUNCTATI-SPORITES ORBICULARIS
L. GLOBUS
LAEVIGATO-SPORITES MINUTUS
TRIQUITRITES BRANSONII
CIRRATRIRADITES PUNCTATUS
SEAM POSITION
TOP 1/3
MIDDLE 1/3
BOTTOM 1/3
12.0
7.0
10.0
.7
1.4
29
2.9
37
6.1
2.5
2.5
3.0
4.5
36
1.4
44
6.0
.8
.8
.3
1.8
19.3
13.0
58
TYPE 3
TYPE 2
TYPE 1

Figure 4

At present, the phylogenetic affinities of the spores are not well known and only a few may be assigned tentatively to plant groups. The spores of the genus *Cirratriradites* appear to be mostly from lycopods; *Triquitrites,* fern spores, *Laevigato-sporites,* ferns and some other elements; *Punctati-sporites,* ferns and lycopods; *Calamospora,* possibly, calamarians; and *Endosporites* and its close morphological associates *Florinites, Wilsonia,* and *Vestispora* appear to be cordaitean pollens. If these conclusions are valid it is possible to construct some concept of the floristic nature and plant succession during the sedimentation of Paleozoic coal swamps. When the ecological significance of the spores is better understood, it should be possible to postulate a reconstructed environment and interpolate conditions which may have definite bearing upon applied geology.

For the present, two types of spore abundances are utilized in the Croweburg paleoecological studies. These are the statistically dominant and subdominant species. The first constitute 15 percent of more of a population and the second usually from approximately 2.5 to 15 percent. Those species with fewer fossils may be called auxiliary species after the practice of Raistrick (1935). The choosing of these percentages is admittedly somewhat arbitrary, but they have some demonstrative support from modern pollen-rain studies. Such an example may be observed within a region of mixed oak forest adjacent to one of pine. The number of oak pollen collected from moss polsters in the mixed oak forest may be only a few percent of the total pollen assemblage. Pine frequently is over-represented because of its great pollen production and great preservation properties. Comparable conditions could have existed in the ancient swamps and should be taken into consideration. In many peat deposits of northern United States, the stratigraphic levels representing the climatic optimum of several thousand years ago are often recognized by a small percentage of oak and hickory pollen in a dominance of pine pollen. If the same principles operated in the past, then it is important to consider these species with comparatively small numbers of spores.

In the Croweburg coal, three types of successional histogram curves have been recognized. These are (1) species having their greatest abundance in the bottom one-third of the seam, (2) species having their greatest abundance in the middle one-third of the seam, and (3) species having their greatest abundance in the top one-third of the seam. The first type of curve is represented by *Cirratriradites punctatus* and *Triquitrites bransonii,* the second by *Laevigato-sporites minutus, L. globus* and *Punctati-sporites orbicularis,* and the third by *Calamospora hartungiana, Endosporites ornatus,* and *Florinites antiquus.* These curves are shown in Fig. 4.

The species listed above occur in all portions of the seam but their varying abundance suggests definite trends which may be interpreted as suggesting the order of plant succession during Croweburg time. These vegetational changes may have been in part local, as observed in modern bog plant communities where ecological control is an immediate feature, or the changes in vegetation may have been extensive, controlled by climatic change comparable to that which caused mass migration of plants in Pleistocene time. Regional topography also may have been very important. Evolution of plants during Croweburg time may have played some part in the appearance of minor elements in the spore assemblage, but at present no evidence is apparent. It is doubtful if the time interval of Croweburg coal deposition was sufficiently long to permit any appreciable plant evolution. Ashley (1907), discussing the maximum rate of deposition of coal, postulated the formation for seven feet of bituminous coal in the Pittsburgh seam as 2,100 years, or one foot of coal in 300 years. That time estimate appears much too short. The maximum observed thickness of the Croweburg coal is one foot, ten inches, which, on applying Ashley's age measurements, would be approximately 550 years for the deposition of the seam. With the recent development of the carbon 14 technique it is possible to calculate more accurately the rate of peat deposition. However, so many variables enter into the problem that generalized calculations are at best mere approximations. An examination of peat deposits lying upon the Cary (Wisconsin) drift indicates that they average approximately twenty feet in thickness. These deposits began accumulation at about the time of the Two Creeks Forest Bed origin (Wilson, 1932) and have continued to the present. Carbon 14 measurements indicate that the forest bed is approximately 11,000 years old. The average radiocarbon date for Two Creeks Forest Bed wood is reported by Suess (1954) as 11,370± 100 years. If the 20 foot peats are compared with Renault's (Twenhofel, p. 428, 1939) calculations that raw peat is reduced to 1/17 to 1/20 its thickness when converted to bituminous coal, then the peats in Wisconsin would be compressed into approximately one foot of coal, and would have a deposition value of 916 years for one inch of coal. Since the observed maximum thickness of the Croweburg seam is one foot, ten inches, the calculated years of its deposition will be of the order of 20,000 years and the Pittsburgh coal bed deposition 77,000 years instead of 2,100 years given by Ashley (1907). If the above estimate of years for the Croweburg swamp development is reasonably correct, little or no evolutionary effect should be recognized in the spore flora. Spore and pollen form appears to be conservative and their evolution is slow, consequently, spore form changes should not be recognizable within the estimated years of Croweburg swamp time.

To designate the paleoecological stages within the Croweburg seam two or three of the spore species have been used as floristic indices after the practice of recent plant ecology. However, rather than recognizing the two or three most abundant species, at each level, the most abundant species of each type of curve is used. In this manner the level of maximum abundance of a species is stratigraphically emphasized rather than spore dominance in the level. This designation is here referred to as spore associations. A criticism that such procedure does not describe the abundant species at each level may be warranted, but the advantage of depicting minor elements and their position of greatest abundance appears important in the present investigation. Further studies will evaluate the method. Successional histograms should be included in all paleoecological projects and reference to them will clearly indicate the relation of the spore flora at all segment levels in a coal seam.

Kosanke (1950) has noted within the Colchester coal seam of Illinois a spore succession strikingly similar to that in the Croweburg seam. His list of genera describing the spore flora in the bottom one-third of the seam is almost identical with that of the Croweburg. He observes that the greater abundance of *Schopfites* occurs in the lower one-third of the Colchester coal, it is rare in the middle, and absent from the top one-third. Unfortunately, this fossil occurred only in the random fragment collection of the Stewart Mine, consequently it is not possible to determine its stratigraphic abundance within the Croweburg coal.

If preservation is good in a coal swamp, plant cuticles should be a better index to the vegetation growing at a locality than the spores since cuticles appear to represent foliar tissues dropped from plants in the immediate vicinity whereas the spore flora also represents a wind borne element. The cuticles of the Croweburg seam may represent a number of natural species or they may be largely from one species. No attempt was made to search the coarser fraction of the coal macerations for larger and more complete tissues to resolve this question. There was observed, however, some relationship between cuticle *Types A* and *C*. To some large fragments of *Type C* are attached tissues slightly resembling *Type A* cuticle, however, the identification is not conclusive.

The slides used in the spore analyses were also used for the cuticle study. A marked similarity between cuticle histograms is apparent (Fig. 2) and suggests that they may be very useful in correlation studies. When the various segments of the Croweburg coal seam were compared for possible stratigraphic succession of cuticles, it was found that they differed little in percentage from bottom to top. This uniformity might suggest that relatively little change took place in the general composition of the swamp flora, and that a greater number of spores came from a regional source by wind transport than usually assumed.

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PLATE I

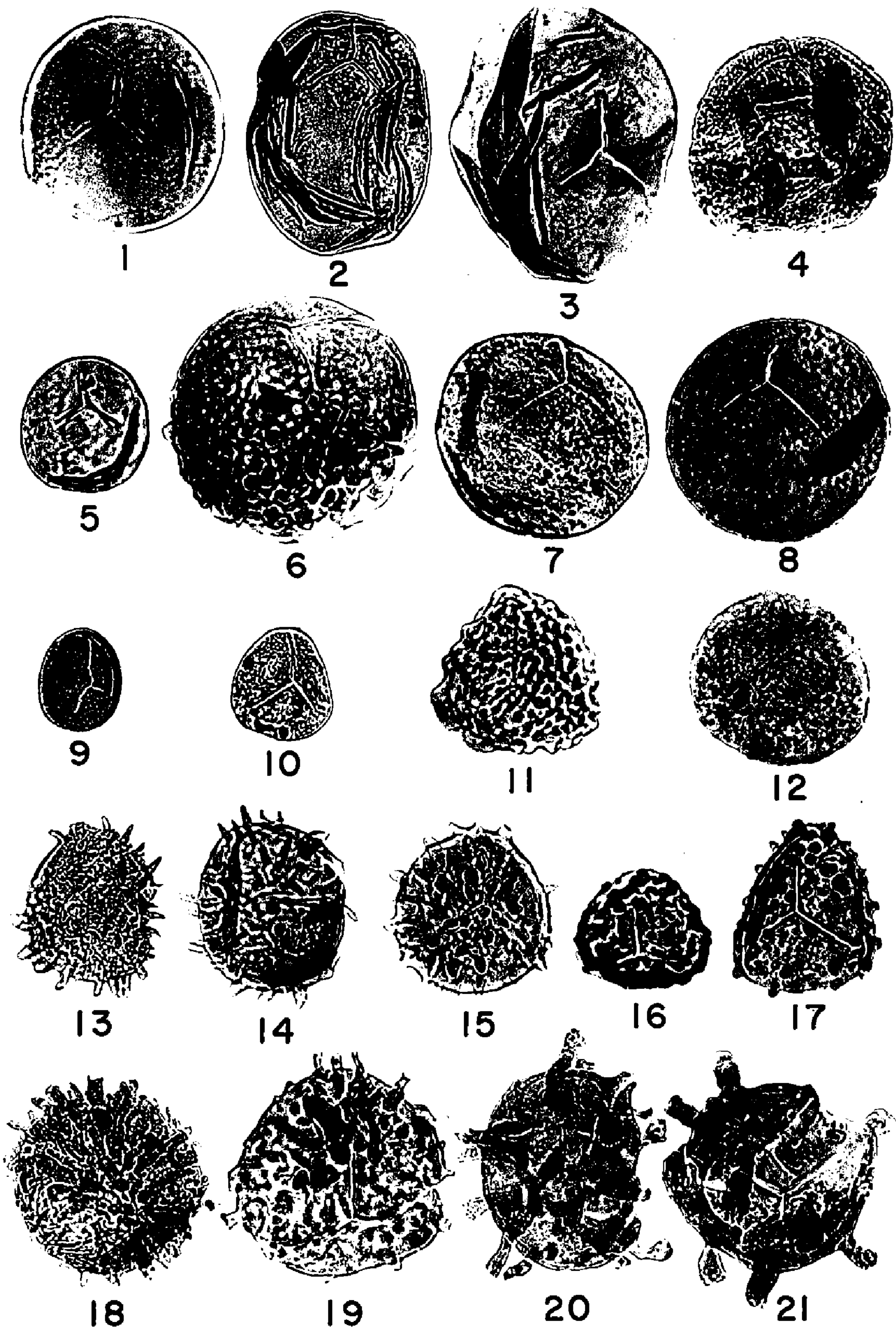
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PLATE II

Page

Fig. 1—*Granulati-sporites piroformis* Loose, 31 by 35 microns, Slide No. 24, WH1A. 17

Fig. 2—*Granulati-sporites adnatus* (?) Kosanke, 38 by 38 microns, Slide No. 2, WH7. 16

Fig. 3—*Granulati-sporites deltiformis* S. W. B., 25.7 microns, Slide No. 5, WH7. 17

Fig. 4—*Granulati-sporites verrucosus* Wilson and Coe, 25 by 27 microns, Slide No. 22, WH5C. 17

Fig. 5—*Granulati-sporites granularis* Kosanke, 38 by 38 microns, Slide No. 6, WH1A. 17

Fig. 6—*Cirratriradites crassus* sp. nov. (Holotype), 84 by 90 microns, Slide No. 2, WH3B. 14

Fig. 7—*Cirratriradites punctatus* (Kosanke 1950) H. S. M., 37 by 37 microns, Slide No. 6, WH7. 15

Fig. 8—*Cirratriradites punctatus* (Kosanke 1950) H. S. M., 32 by 48.8 microns, Slide No. 1, WH3B. 15

Fig. 9—*Cirratriradites intermedius* sp. nov. (Holotype), 47.6 by 48.8 microns, Slide No. 1, WH3B. 14

Fig. 10—*Lycospora brevijuga* Kosanke, 33 by 35 microns, Slide No. 26, WH1D....19

Fig. 11—*Laevigato-sporites globus* Schemel, 33 by 33 microns, Slide No. 10, WH6. 18

Fig. 12—*Laevigato-sporites minutus* (Ibrahim) S. W. B., 19 by 29 microns, Slide No. 12, WH6. 18

Fig. 13—*Laevigato-sporites minimus* (Wilson and Coe) S. W. B., 14.5 by 22.5 microns, Slide No. 2, WH7. 19

Fig. 14—*Laevigato-sporites ovalis* Kosanke, 32 by 46 microns, Slide No. 5, WH5C. 19

Fig. 15—*Laevigato-sporites desmoinensis* (Wilson and Coe) S. W. B., 50 by 71 microns, Slide No. 5, WH5C. 18

Fig. 16—*Vestispora profunda* sp. nov. (Genoholotype), proximal surface, 70.2 microns, Slide No. 5, WH7. 27

Fig. 17—*Vestispora profunda* sp. nov. (Genoholotype), distal surface, 70.2 microns, Slide No. 5, WH7. 27

Fig. 18—*Vestispora profunda* sp. nov., proximal surface, 71 microns, Slide No. 6, WH5C. 27

Fig. 19—*Vestispora profunda* sp. nov., 96 microns, Slide No. 1, WH5C. 27

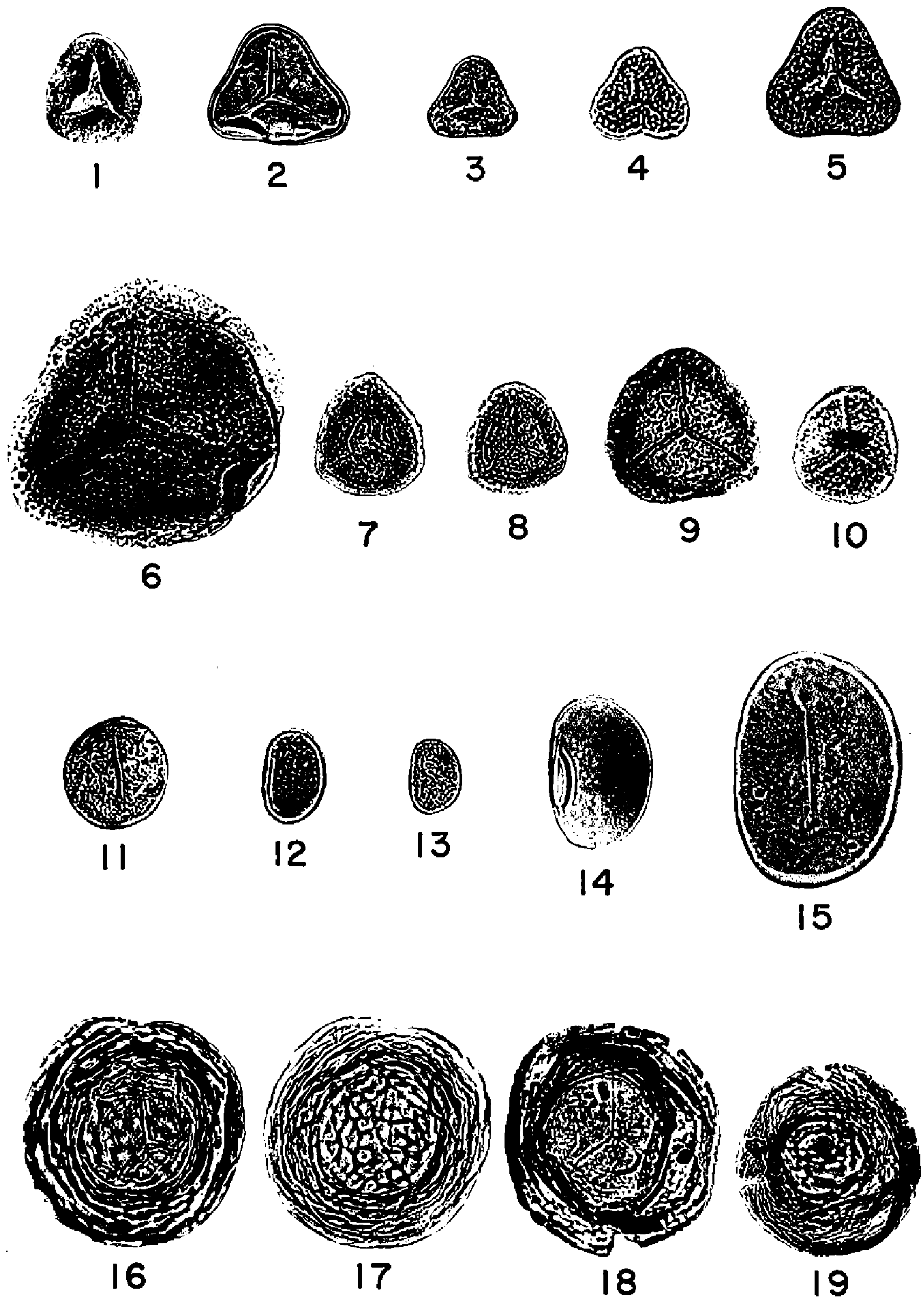
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PLATE III

Fig. 1—*Triquitrites bransonii* sp. nov. (holotype), 37.5 by 35 microns, Slide No. 12A, WH6. 24

Fig. 2—*Triquitrites bransonii* sp. nov., 35 microns, Slide No. 40, WH1A. 24

Fig. 3—*Triquitrites bransonii* sp. nov., 37.5 by 39 microns, Slide No. 6, WH5C. 24

Fig. 4—*Triquitrites bransonii* sp. nov., 35 by 37.5 microns, Slide No. 9, WH1A. 24

Fig. 5—*Triquitrites bransonii* sp. nov., 33 by 35 microns, Slide No. 9, WH5C. 24

Fig. 6—*Triquitrites additus* sp. nov. (holotype), 44 by 49 microns, Slide No. 14, WH5C. 24

Fig. 7—*Triquitrites additus* sp. nov., 40 by 43.5 microns, Slide No. 5, WH5C. 24

Fig. 8—*Triquitrites additus* sp. nov., 39.5 by 42.5 microns, Slide No. 4, WH7, bottom 6″ of coal. 24

Fig. 9—*Triquitrites additus* sp. nov., 44.5 by 45 microns, Slide No. 12A, WH6....24

Fig. 10—*Triquitrites dividuus* sp. nov. (holotype), 39.6 microns, Slide No. 2, WH1A. 25

Fig. 11—*Triquitrites dividuus* sp. nov., 44 by 45 microns, Slide No. 163, WH2C....25

Fig. 12—*Triquitrites tumulus* sp. nov. (holotype), 49.5 microns, Slide No. 21, WH1A. 26

Fig. 13—*Triquitrites tumulus* sp. nov., 49.5 microns, Slide No. 21, WH1A. 26

Fig. 14—*Triquitrites discoideus* Kosanke, 61.5 by 62 microns, Slide No. 10, WH6. 23

Fig. 15—*Triquitrites praetextus* sp. nov. (Holotype), 50 by 56 microns, Slide No. 8, WH1A. 25

Fig. 16—*Triquitrites praetextus* sp. nov., 50 by 52.5 microns, Slide No. 13, WH5C. 25

Fig. 17—*Triquitrites crassus* Kosanke, 1950, 59.4 microns, Slide No. 27, WH1A....23

Fig. 18—*Triquitrites crassus* Kosanke, 1950, 53.7 microns, Slide No. 13, WH6, spl. B. 23

Fig. 19—*Triquitrites crassus* Kosanke, 1950, 50 by 56 microns, Slide No. 5, WH3B. 23

Fig. 20—*Triquitrites arculatus* Wilson and Coe, 1940, 45 by 48 microns, Slide No. 10, WH6, spl. 3. 23

Fig. 21—*Triquitrites inusitatus* Kosanke, 1950, 41 by 43 microns, Slide No. 8, WH7, bottom 6″ of coal. 24

Fig. 22—*Triquitrites exiguus* Wilson and Kosanke, 1944, 23.5 microns, Slide No. 7, WH7, bottom 6″ of coal. 23

Fig. 23—*Triquitrites* sp., 42 by 50 microns, Slide No. 1, WH3B. 26

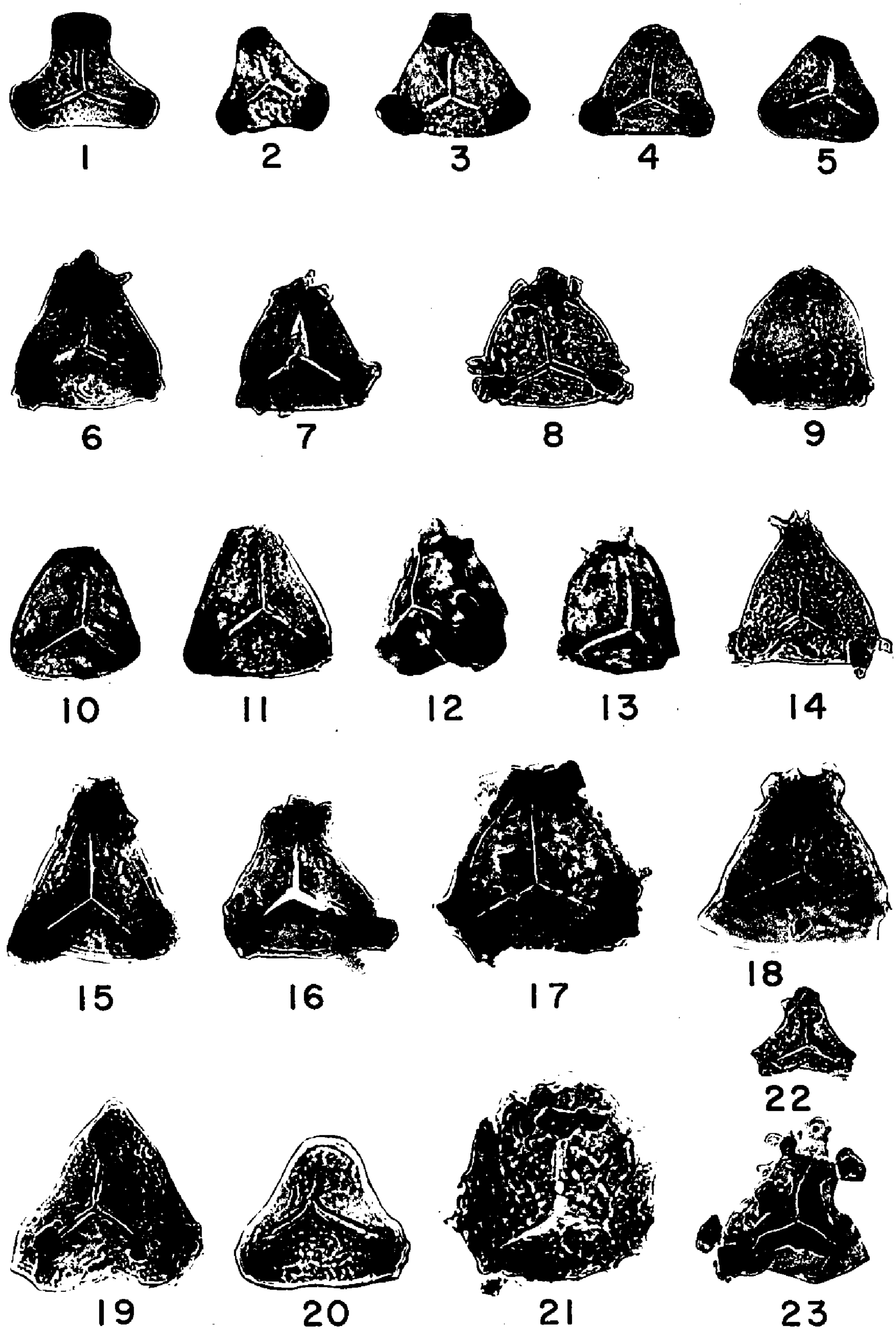
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PLATE IV

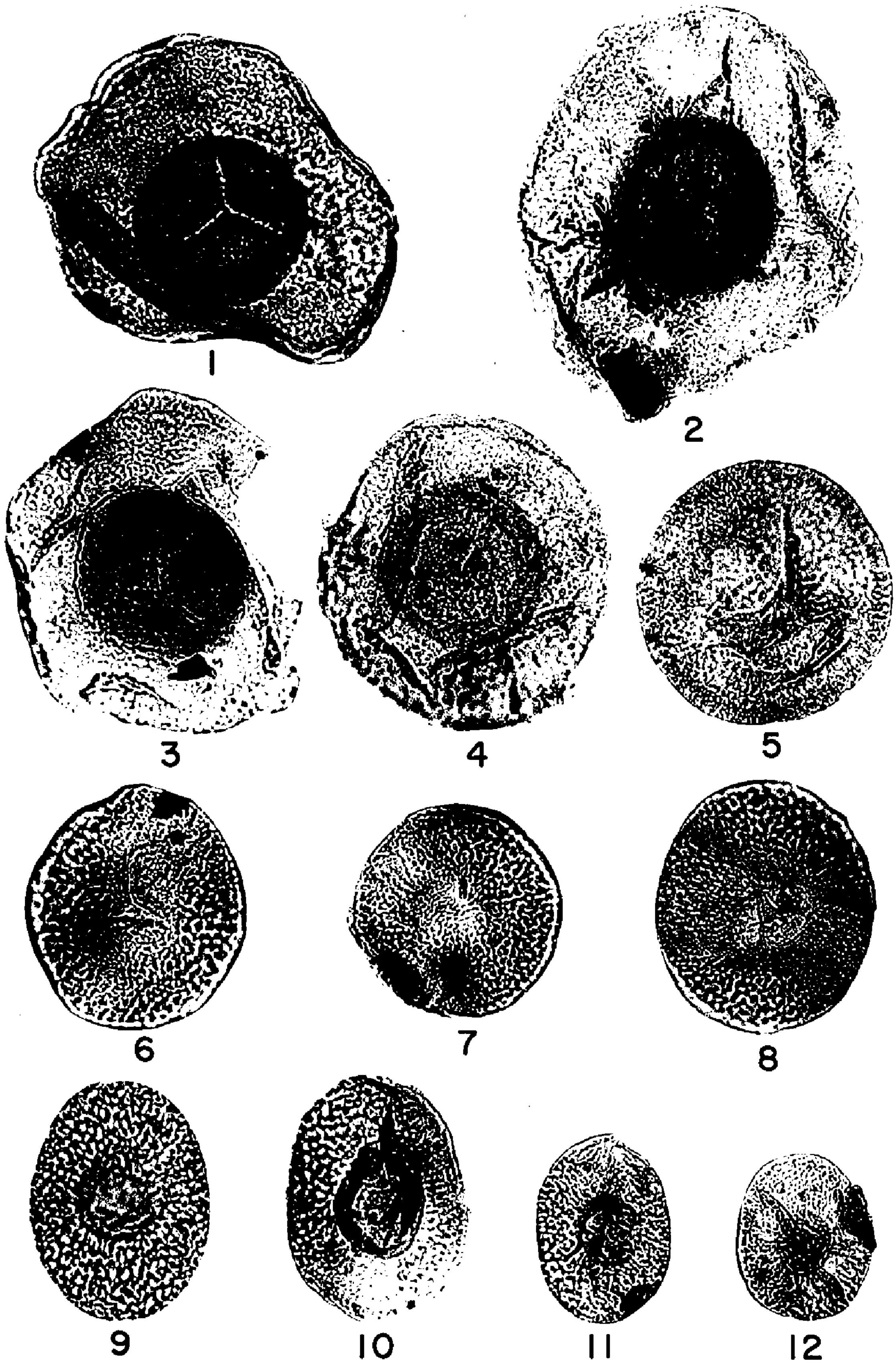
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PLATE V

Fig. 1—Cuticle type B, Slide No. 5, WH5C. 29

Fig. 2—Cuticle type B, Slide No. 4, WH5C. 29

Fig. 3—Cuticle type D, Slide No. 3, WH5C. 30

Fig. 4—Cuticle type C, Slide No. 2, WH5C. 29

Fig. 5—Cuticle type A, Slide No. 6, WH5C. 29

Fig. 6—Cuticle type A, Slide No. 8, WH5C. 29

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