DISTRIBUTION OF SPORE AND POLLEN ASSEMBLAGES IN THE LOWER KITTANNING COAL OF WESTERN PENNSYLVANIA

D. HABIB

ABSTRACT. Palynological study of the Lower Kittanning coal seam of western Pennsylvania (Allegheny Series; lower Westphalian D) has revealed an orderly vertical and geographical distribution of spore and pollen assemblages.

Assemblages characterized by *Densosporites* and *Punctatisporites* (*P. obliquus*) occur in the uppermost zones where the seam is directly overlain by marine and restricted-marine faunal facies, respectively, of the Lower Kittanning shale. The greatest vertical variation of assemblages occurs at these localities. Where the seam is in direct contact with the overlying freshwater facies, however, it remains dominated throughout its thickness by assemblages rich in *Lycospora*. Fewer assemblages occur at these localities. Because of the distribution of spore and pollen assemblages in the seam and faunal facies in the overlying shale, a genetic relationship is suggested. New taxa include two genera, *Spackmanites* and *Paleospora*, and thirty-three species.

THE Lower Kittanning coal seam in western Pennsylvania is one of the more readily identifiable and geographically extensive stratigraphic horizons of the Allegheny Series (middle Pennsylvanian age). Because it is easily recognized, variations in the biological, physical, and chemical properties of the seam and surrounding rocks have been investigated. The known variation in these properties has prompted investigation of the seam once again, this time to determine the vertical and geographic distribution of its spore and pollen assemblages. It was assumed at the beginning of this study that if distinctive spore and pollen assemblages at least partially represent *in situ* Lower Kittanning plant communities, then some distributional pattern of their assemblage zones should be discernible, in light of the known distributional pattern of other properties in the seam and juxtaposed rocks.

Methods of study. Vertical columns of the Lower Kittanning seam were collected from 15 localities in the western part of the state (text-fig. 1). A one-inch increment of coal was taken at three-inch levels in sequence in each column from the top downward. Where the bottom-most sample did not coincide with this interval, it was taken as an additional sample. The density of sampling sites was intended to cover a large area while keeping the geographic interval small.

Maceration of the samples consisted of oxidation in nitric acid or Schulze's solution, and subsequent treatment in 8% potassium hydroxide. The spore residue was then mounted on slides in glycerine jelly. Two hundred specimens were counted from each sample (100 per slide). The entire slide was examined at $\times 100$ and/or $\times 450$ magnification, in order to determine the total number of species per sample.

Geological setting. The Kittanning formation comprises the middle third of the Allegheny Series (Westphalian C-D). The formation is defined by three major coal horizons which are separated by two thicker and lithologically more variable detrital units. The lowermost coal seam, the Lower Kittanning, is overlain by the Lower Kittanning

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shale, a unit which separates the seam from the next overlying coal horizon by an interval of from 30 to 50 ft.

On the basis of the distribution of fossil invertebrates in the Lower Kittanning shale, Williams (1959) differentiated facies depicting marine, restricted-marine, and freshwater environments of deposition. In a northwesterly direction across the sedimentary strike of the marine embayment, the fresh-water facies of the Lower Kittanning shale, represented by estherids, changes to restricted-marine (Lingula, Aviculopecten), and marine (Mesolobus, other calcareous brachiopods, gastropods) facies in respective order, before reverting through restricted-marine and fresh-water facies. Geochemical evidence corroborates the delimitation of marine and fresh-water facies. Degens et al. (1957, 1958) distinguished these facies by relative abundance of trace element assemblages. Greater concentrations of boron and rubidium were found in the marine shales, while gallium was found to be more abundant in the fresh-water shales. Williams and Keith (1963) subsequently showed a statistical relationship between the sulphur content of the seam and the facies of the directly overlying rocks (Lower Kittanning shale), the content being higher in the seam where it directly underlies ancient marine sediments. Weber et al. (1964) distinguished fresh-water siderite nodules in the Lower Kittanning shale from marine nodules through distinct differences in their carbon isotope ratios.

Sampling Sites

- Station 1. Section exposed in a limestone quarry, 7 miles west of New Castle, Pennsylvania. The Vanport limestone is mined here and is exposed approximately 40–50 ft. below the Lower Kittanning seam. Marine shale overlies the seam, characterized by Lingula and Mesolobus.
- Station 2. Section exposed in coal strip pit, 1 mile east of West Pittsburg, Pennsylvania. The seam is slightly thicker than that reported for the Lower Kittanning in this area.
- Station 3. Section exposed in a road cut, on the east side of a toll bridge, 1 mile E. of Freedom, Pennsylvania. The marine facies of the Lower Kittanning shale is represented here by Mesolobus. Station 4. Section exposed in a coal strip pit, 5 miles north-west of Harlansburg, Pennsylvania. The
- Lower Kittanning shale is characterized here by sandstone beds occurring 10 ft. above the seam. Station 5. Section exposed in coal strip pit, 4 miles west of Slippery Rock, Pennsylvania. Plant remains prevail in the nonmarine facies of the Lower Kittanning shale. Sandstone beds occur 6 ft. above the
- seam.

 Station 6. Section exposed in road cut 1 mile east of Nectarine, Pennsylvania. Thin irregularly bedded sandstone, with plant remains, lies just above the seam.
- Station 7. Section exposed in strip pit, 1 mile north-north-west of West Freedom, Pennsylvania. The Vanport limestone is exposed approximately 40-50 ft. below the seam. The shale is characterized by interlaminated light and dark layers (varves), with abundant plant fragments.
- Station 8. Type locality of the seam. Section exposed in a railroad cut above west bank of Allegheny River, outside of Kittanning, Pennsylvania. Mesolobus occurs in the shale a few inches above seam. Station 9. Section exposed in strip pit 1 mile east of Turkey City. Pennsylvania. The Vanport limestone
- Station 9. Section exposed in strip pit 1 mile east of Turkey City, Pennsylvania. The Vanport limestone is exposed approximately 25 ft. below the seam.
- Station 10. Section exposed in strip pit, on a hill 2 miles west of U.S. Route 68, and 15 miles south of Clarion, Pennsylvania. Mesolobus abounds in the upper portions of the shale, with Lingula just above the seam. Shale is interlaminated in the lower part.
- Station 11. Section exposed in strip pit 2 miles south of Limestone, Pennsylvania. The shale contains Lingula.
- Station 12. Section exposed in strip pit 1 mile west of Truittsburg, Pennsylvania. The shale contains abundant *Mesolobus* a few inches above the seam. The seam varies within the pit from 64 to 38 ins. in thickness, through a distance of 100 ft.
- Station 13. Section exposed in road cut on north side of creek, just north of Worthville, Pennsylvania.
 Lingula occurs just above the seam, with Mesolobus predominant above.

Station 14. Section exposed in strip pit 0.25 miles north-east of Hamilton, Pennsylvania. Aviculopecten and Lingula are present just above the seam, with Mesolobus and other calcareous brachiopods prevalent above.

Station 15. Section exposed in strip pit 1 mile south of Curwensville, Pennsylvania. Lingula and Aviculopecten occur in the shale.

SYSTEMATIC DESCRIPTIONS

One hundred and forty species of spores and pollen, situated in 59 genera, were recognized. Of these 33 are formally described as new, and 14 are given lettered specific designations due to insufficient number of specimens. Two new genera, *Spackmanites* and *Paleospora*, are proposed. All slides used in this study are stored in the Organic Sediments Laboratory, The Pennsylvania State University. Position of specimens on the slides is indicated by the scale settings of an E. Leitz ortholux microscope, serial no. 448497. All measurements are given with reference to the maximum diameter of specimens. Wherever possible, holotypes were mounted as single grain wax mounts.

Anteturma sporonites (R. Pot.) Ibr. 1933 Genus RETICULATASPORITES Leschik 1955 Reticulatasporites aletoreticulus sp. nov.

Plate 104, fig. 1

Diagnosis. Alete spores; subcircular to circular in outline. Exine covered with concentric reticulation pattern; lacunae largest in centre and become smaller and more lenticular towards margin, as well as more low-lying; muri conversely become wider and more low-lying towards margin, eventually grading into exine. No evidence of tetrad scar. Exine approximately $1.5-2.0~\mu$ thick. Size range (twelve specimens) 53 to 66 μ .

Holotype. Plate 104, fig. 1; $53 \times 55 \mu$; slide LKC-2 (27-28) 1, coordinates 24.3 127.7.

Remarks. Spores of this species are characterized by the marginward diminution of its reticulate pattern. The species was observed only at Station 2, where it is confined to samples containing the *Lycospora-Guthoerlisporites erectus* assemblage. Reticulatasporites aletoreticulus sp. nov. resembles the detached caps of specimens of Vestispora, but could be distinguished in the Lower Kittanning seam by its larger size and ornamentational pattern.

Anteturma sporites H. Pot. 1893
Turma triletes Reinsch 1881
Subturma Azonotriletes Luber 1935
Infraturma Laevigati (Benn. and Kidst.) R. Pot. 1956
Genus leiotriletes Naumova ex Pot. and Kr. 1954

Leiotriletes sp. A

Plate 104, figs. 2, 3

Description. Trilete spores; triangular, with sharply rounded radial corners and concave or slightly convex (due to folding) inter-radial margins. Exine one micron thick or less; essentially levigate. Trilete mark distinct and slightly raised; it extends almost to radial corners; contact area defined by faintly sinuous ('wrinkled') curvaturae which turn

in inter-radially toward juncture of sutures. Two specimens, 41 \times 41 μ , and 36 \times 38 μ (folded).

Remarks. Shape and thickness of spore coat relate the two specimens to Leiotriletes ornatus Naum. and L. tumidus Butt. and Will. They are distinguished, however, by their unique curvaturae. The specimens were observed only at Stations 5 and 7; both are present in zones containing the Thymospora pseudothiesseni assemblage.

Genus CALAMOSPORA S. W. and B. 1944

Calamospora multiplicata sp. nov.

Plate 104, figs. 6, 7

Diagnosis. Trilete spores; roundly elliptical in outline. Exine smooth, one micron thick or less. From 3 to 9 curving, slender folds criss-cross exine in concentric and radial directions; they are typically long and slender. Trilete mark short, extending less than one-half radius; lips very thin and only slightly raised; contact area present, but only slightly darker than remaining exine. Size range (twenty-five specimens) $43-60~\mu$.

Holotype. Plate 104, fig. 6; $55 \times 41 \mu$; slide LKC-10 (13-14) 2, 43.9 113.9.

Remarks. Calamospora multiplicata sp. nov. is present at every locality; it is most common in the *Thymospora pseudothiesseni* and *Lycospora-Guthoerlisporites erectus* assemblages. The species is distinguished from other species of *Calamospora* in the Lower Kittanning seam by its size, roundly elliptical outline, and disposition of folds.

Calamospora elliptica sp. nov.

Plate 104, figs. 9, 10

Diagnosis. Trilete spores; elliptical to subelliptical-elongate in both polar and equatorial views. Exine not over $1.5~\mu$ thick; generally smooth, although the slightly darker contact area may be slightly pitted; contact area not delimited by any specialized curvaturae. Secondary folds always present, usually grouped near margin; relatively long, slender,

EXPLANATION OF PLATE 104

All figures \times 500.

Fig. 1. Reticulatasporites aletoreticulus sp. nov., holotype.

Figs. 2-3. Leiotriletes sp. A.

Figs. 4-5, 8. Calamospora pseudotriangulara sp. nov. 4, Holotype. 5, Proximal polar view with well-developed contact area. 8, Thin dark folds attending the sutures prominent.

Figs. 6-7. Calamospora multiplicata sp. nov. 6, Holotype; slightly corroded but shows short trilete mark and contact area. 7, Specimen with open trilete mark but which shows typical orientation of folds.

Figs. 9-10. Calamospora elliptica sp. nov. 9, Holotype; thick lips border trilete mark. 10, Equatorial view.

Figs. 11-14. Punctatisporites obliquus Kos.; note size variation, and nature of trilete mark.

Figs. 15, 18. Punctatisporites globulosus sp. nov. 15, Holotype; lines of weakness extend longitudinally from sutures on to distal surface. 18, Ruptured specimen, with triangular gap which extends to distal hemisphere.

Figs. 16-17. *Punctatisporites sphaerorigidus* sp. nov. 16, Holotype; thick irregular fold on distal surface. 17, Specimen with T-shaped trilete mark.

and smoothly tapering. Trilete mark distinct, extends about one-half radius bordered by thick, raised lips. Size range (ten specimens) $80-100 \mu$.

Holotype. Plate 104, fig. 9; $85 \times 65 \mu$; slide LKC-10M-4, 37.7 128.5.

Remarks. The elliptical outline, long slender folds, and short thickly bordered trilete mark distinguish this species.

Calamospora pseudotriangulara sp. nov.

Plate 104, figs. 4-5, 8

Diagnosis. Trilete spores; subcircular to triangular in polar view, the outline appearing triangular because of the large folds. Trilete mark distinct, extends from one-half to two-thirds radius; thin but dark and distinct folds border it; contact area present, barely discerned to very distinct. Large sharply tapering folds run peripherally and often, because of their orientation, make the species appear triangular; largest peripheral folds most often occur inter-radially. Exine less than one micron thick, levigate. Size range (twenty specimens) $63-82~\mu$.

Holotype. Plate 104, fig. 4; $75 \times 63 \mu$; slide LKC-8 (36-37) 1, 30-2 127-1.

Remarks. The species is most common in the upper half of zones containing the Lycospora-Guthoerlisporites erectus assemblage. It was not found at Station 13. Calamospora pseudotriangulara sp. nov. is easily distinguished from other related species by its size, triangular outline, thin exine, and long sutures bordered by thin, distinct folds.

Genus PUNCTATISPORITES Ibr. emend. Pot. and Kr. 1954

Punctatisporites obliquus Kosanke

Plate 104, figs. 11-14

Remarks. Because a very close relationship was observed between this species and Laevigatosporites globosus Schem., they were counted together. Except for only a slight difference in size ranges, the two species are very similar, and perhaps should be conspecific. The true nature of the suture in either species is in doubt. Schemel (1951, p. 747) noted the similarity between the species and admitted that if the nature of the suture could not be determined, it would be doubtful to which species and genus the specimens belong.

Punctatisporites sphaerorigidus sp. nov.

Plate 104, figs. 16, 17

Diagnosis. Trilete spores; circular to subcircular in outline, occasionally appearing obliquely compressed, due to the presence of a thick fold. Exine generally smooth, but may be irregularly pitted in localized areas; up to 5–6 μ thick in polar view. Trilete mark distinct and frequently open, extends about one-half radius or less; lips present but only slightly raised; occasionally the trilete mark assumes a T-shape. Single large compression fold, in some specimens accompanied by a smaller fold, usually present, restricted to distal hemisphere. Size range (twenty-five specimens) 75–98 μ .

Holotype. Plate 104, fig. 16; $83 \times 74 \mu$; slide LKC-2 (12-13) 1, 22·1 123·4.

Remarks. The species rarely exceeded one per cent in any sample. It was observed most frequently in zones containing the Punctatisporites obliquus and Thymospora pseudothiesseni assemblages. Punctatisporites sphaerorigidus sp. nov. is distinguished by its size, thick exine, and relatively short trilete mark. It differs from P. obesus (Loose) Pot. & Kr., which also occurs in the seam, by its shorter trilete mark, smaller size, and relatively thicker exine.

Punctatisporites globulosus sp. nov.

Plate 104, figs. 15, 18

Diagnosis. Trilete spores; elliptical to subcircular in outline. Exine covered over its entire surface by dense, very closely spaced punctae; occasionally, probably due to locally unornamented areas, a few low-lying (1 μ or less) rounded protuberances emerge from the spore outline. Trilete mark distinct, and extends over one-half radius; lips distinct, slightly raised; extending radially from the end of each suture is a thin line along which the spores tend to rupture; ruptured specimens collapse usually to more elliptical outline with opened trilete mark forming triangular outline and extending well on to distal hemisphere. Size range (twenty-five specimens) 45–60 μ .

Holotype. Plate 104, fig. 15; $56 \times 53 \mu$; slide LKC-6 (15-16) 1, 20.6 118.0.

Remarks. The species was most frequently encountered in zones containing the Punctatisporites obliquus assemblage, although it rarely exceeded two per cent.

Punctatisporites globulosus sp. nov. differs from other species of Punctatisporites by its lines of weakness along which the specimens tend to rupture.

Punctatisporites ellipticus sp. nov.

Plate 105, fig. 1

Diagnosis. Trilete spores; distinctly elliptical in outline. Exine about one micron thick; ornamented with minute but distinct, equidistant punctae which, as seen on the outline, could also be considered coni. Trilete mark distinct; extends from one-half to two-thirds radius; lips thin and slightly upturned. Size range (fifteen specimens) 55–65 μ .

Holotype. Plate 105, fig. 1; 60×43 μ; slide LKC-2 (12-13) 1, 33 113·6.

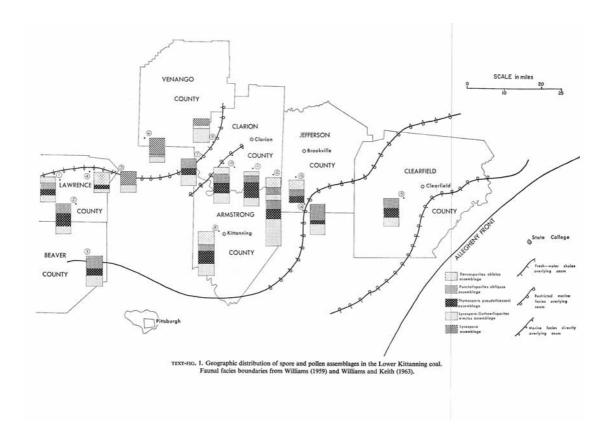
Remarks. This species is similar to *P. globulosus* sp. nov. but differs in its more elliptical outline and trilete mark. It was encountered most frequently in *Punctatisporites obliquus* assemblage zones.

Infraturma APICULATI (Benn. and Kidst.) R. Pot. 1956 Subinfraturma GRANULATI Dyb. and Jach. 1957 Genus GRANISPORITES Dyb. and Jach. 1957

Granisporites medius Dyb. and Jach.

Plate 105, figs. 2-3, 5

Remarks. This species is very similar to those ascribed to Granasporites Alpern, the essential difference being the presence of trilete mark in Granisporites medius. Occasionally, specimens were observed in tetrads (e.g. Pl. 105, fig. 5).



Subinfraturma VERRUCATI Dyb. and Jach. 1957 Genus CONVERRUCOSISPORITES Pot. and Kr. 1954

Converrucosisporites pseudovalvus sp. nov.

Plate 105, figs. 4, 7

Diagnosis. Trilete spores; triangular in polar view, with slightly convex to straight interradial margins and subangular to subrounded radial corners. Exine covered with rounded low-lying (approx. 2 μ high) verrucae which give the margin a roughened appearance; verrucae all about the same size and evenly distributed, tending, however, to become more numerous and slightly larger at radial corners; occasionally verrucae tend to align themselves concentrically. Trilete mark distinct, extends almost completely to radial corners; lips thin and only very slightly raised. Size range (five specimens) 38–50 μ .

Holotype. (Plate 105, fig. 4; $38 \times 38 \mu$; slide LKC-8 (36-37), wax mount 33.

Remarks. Confined to the Lycospora-Guthoerlisporites erectus assemblage zones at Stations 8 and 11. Converrucosisporites pseudovalvus sp. nov. is distinguished from related species by the presence of larger and more numerous verrucae at the radial corners.

Genus schopfites Kosanke 1950

Schopfites grossus sp. nov.

Plate 105, fig. 6

Diagnosis. Trilete spores; outline in polar view usually elliptical, but may be near circular. Exine covered subequatorially and distally by short (to 3 μ) but very wide (up to 10 μ) verrucate processes; it is free of this ornamentation only in a small area of the proximal face, near the trilete mark; wall distinct, 3–6 μ thick. Trilete mark extends over one-half radius; usually closed but may be open, producing an irregular gap. Size range (fifteen specimens) 84–116 μ .

Holotype. Plate 105, fig. 6; $93 \times 70 \mu$; slide LKC-10 (7-8) 2, 34.6 113.2.

Remarks. Although this species was rarely counted, it was observed more regularly in zones of the *Thymospora pseudothiesseni* assemblage.

Genus VERRUCOSISPORITES Ibr. emend. Smith et al. 1964

Verrucosisporites compactus sp. nov.

Plate 105, fig. 8

Diagnosis. Trilete spores; elliptical in both polar and equatorial views. Trilete mark extends from between one-half to two-thirds radius, frequently torn open to form an irregular gap; in some specimens, when not open, obscured by ornamentation; lips very thin and only slightly turned up. Exine covered with relatively large (to 3 μ in width) but low, rounded verrucae with only slightly flattened apices; verrucae closely distributed throughout surface, slightly higher than 1 μ . Size range (nine specimens) 45–53 μ .

Holotype. Plate 105, fig. 8; $48 \times 37 \mu$; slide LKC-12 (5-6) 1, 25-1 129-5.

Remarks. This species was never counted. It differs from the other species of Verrucosisporites by its small size and relatively large verrucae.

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Subinfraturma NODATI Dyb. and Jach. 1957 Genus LOPHOTRILETES Naum. ex Pot. and Kr. 1954

Lophotriletes interruptus sp. nov.

Plate 105, fig. 12

Diagnosis. Trilete spores; triangular in polar view with round to semicircular radial corners and gently to strongly concave inter-radial margins. Exine approximately one micron thick, covered by relatively large (about 3 μ by 3 μ) pointed to rounded coni. Trilete mark extends almost to the margin, usually closed and with thin lips. Size range (ten specimens) 28–38 μ .

Holotype. Plate 105, fig. 12; $28 \times 28 \mu$; slide LKC-4 (18-19) 1, $26 \cdot 2116 \cdot 3$.

Remarks. This species was very rarely encountered.

Genus PLANISPORITES Knox emend. Pot. and Kr. 1954 Planisporites? sp. A

Plate 105, fig. 9

Description. Trilete spore; roundly triangular, with broadly rounded radial corners and gently convex inter-radial margins. Exine slightly more than 1 μ thick, covered over its surface by coni 2.5-3 μ high and wide at their base; the coni number 42 at the margin. Trilete mark thin and very straight, extends almost to the margin; very thin but distinct raised lips attend the sutures. Arcuate thickenings in exine present in proximal hemisphere inter-radial and distinctly convex. Specimen 75×73 μ .

Remarks. The single specimen is very similar to *P. granifer*, differing only in the presence of the arcuate thickenings.

EXPLANATION OF PLATE 105

All figures \times 500.

Fig. 1. Punctatisporites ellipticus sp. nov., holotype.

Figs. 2-3, 5. Granisporites medius Dyb. and Jach. 2, trilete mark present, although indistinct. 3, Two sutures torn, the third indistinct. 5, Tetrad.

Figs. 4, 7. Converrucosisporites pseudovalvus sp. nov. 4, Holotype. 7, Verrucae tend to be concentrically oriented.

Fig. 6. Schopfites grossus sp. nov., holotype.

Fig. 8. Verrucosisporites compactus sp. nov., holotype.

Fig. 9. Planisporites? sp. A; note presence of arcuate ridges.

Figs. 10–11. Acanthotriletes dimorphus sp. nov. 10, Holotype; processes mostly blunted. 11, specimen with mostly spinose ornamentation.

Fig. 12. Lophotriletes interruptus sp. nov., holotype.

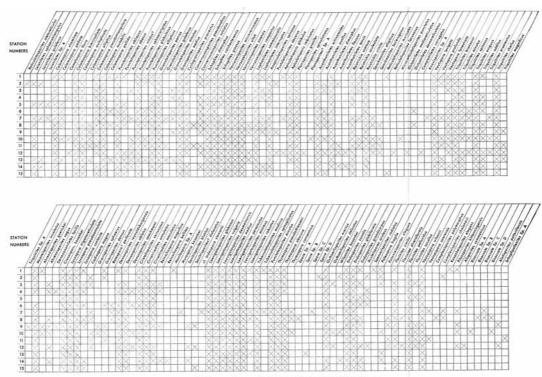
Figs. 13-14. Acanthotriletes flexuus sp. nov. 13, holotype.

Fig. 15. Acanthotriletes tenuis sp. nov., holotype.

Figs. 16, 20. Knoxisporites sp. A. 16, Paired ridges distinct.

Figs. 17-18. Spackmanites ellipticus gen. et sp. nov. 17, holotype. 18, Rudimentary trilete mark can be seen.

Fig. 19. Spackmanites facierugosus (Loose) comb. nov.



TEXT-FIG. 2. Presence of spore and pollen species in the Lower Kittanning coal.

Genus ACANTHOTRILETES Naum. ex Pot. and Kr. 1954

Acanthotriletes dimorphus sp. nov.

Plate 105, figs. 10, 11

Diagrams. Trilete spores; roundly triangular, with broadly rounded radial corners and straight to gently concave (most often) or convex inter-radial margins. Exine $1-2~\mu$ thick, covered with setaceous projections of essentially two types: (1) spine-like, broad-based (to $2~\mu$) projections which taper rapidly to a sharp point, (2) rod-like projections, about 1·5 or $2~\mu$ wide, with rounded or flattened distal ends. Ornamentation usually evenly distributed, with up to 25 projections from the outline; ratio of blunted to spinose projections varies from 1:3 to 3:1. Trilete mark extends more than two-thirds radius; frequently open with upturned lips, occasionally torn. Size range (twenty specimens) $48-65~\mu$.

Holotype. Plate 105, fig. 10; $58 \times 57 \mu$; slide LKC-10 (8-9), wax mount 15.

Remarks. The species is irregularly distributed in the seam although it was found more often in zones containing the *Thymospora pseudothiesseni* and *Lycospora-Guthoerlisporites erectus* assemblages.

Acanthotriletes flexuus sp. nov.

Plate 105, figs. 13, 14

Description: Trilete spores; triangular in outline. Exine less than 1 μ thick, covered with evenly distributed closely packed sharp spines up to 3 μ high; because of the thinness, the exine is almost invariably torn and/or folded. Trilete mark distinct, extends over two-thirds radius, it is attended by very dark thin folds. Size range (eight specimens) $22-32~\mu$.

Holotype. Plate 105, fig. 13; $30 \times 28 \mu$; slide LKC-2 (8-9), 33·6 110·4.

Acanthotriletes tenuis sp. nov.

Plate 105, fig. 15

Diagnosis. Trilete spores; roundly triangular in polar view, with rounded radial corners and straight to convex inter-radial margins. Exine about $1-2~\mu$ thick, sparsely covered by slender, gently tapering spines, never exceeding a height twice their width, and up to $4~\mu$ high; about 15 to 20 spines are present at the outline, although in a few specimens only 8 or 9; the spines tend to group inter-radially at the equator, although they are also present at the radial corners. Trilete mark distinct, extends at least two-thirds radius; lips very thin and ill-defined. Size range (fifteen specimens) 33–41 μ .

Holotype. Plate 105, fig. 15; $33 \times 33 \mu$; slide LKC-12 (8-9) 1, 28·5 126·7.

Remarks. The species was observed from only three localities. It is distinguished mainly by its very sparse, small, gently tapering spines.

Subinfraturma BACULATI Dyb. and Jach. 1957 Genus SPACKMANITES gen. nov.

Type species. S. ellipticus sp. nov.

Diagnosis. Trilete spores; overall outline circular to elliptical. Spore body almost completely obscured by the presence of long, very closely packed rod-shaped or club-shaped baculate processes, each of which is near-straight sided and approximately twice as long as wide; no appreciable thickening of the bacula occurs at the bases; they are evenly distributed over the entire surface of the exine, so much so that they are almost always appressed to one another at the bases; in most cases the bacula are partially fused, either at the base or at the distal ends; bacula usually rounded at the apices, or flat, with indentations. Trilete mark usually short, or may even be represented only by a triangular gap in the exine; usually can be seen only with careful focusing. Size range $30-70~\mu$.

Remarks. Spackmanites is characterized by closely spaced, long bacula which are tightly appressed to each other and even partially fused, the effect of which is to obscure the outline of the spore body. The genus most closely resembles Verrucosisporites and Raistrickia; it differs from the former in the lack of verrucae, and from the latter in the tight packing and partial fusing of the bacula.

Spackmanites ellipticus sp. nov.

Plate 105, figs. 17, 18

Diagnosis. Trilete spores; distinctly elliptical to oval in outline. Exine profusely covered with rod-like bacula which in some cases fuse with each other near their bases; bacula typically smoothly truncated or slightly indented at their distal terminations; many bacula thicken distally, appearing club-shaped in profile. Trilete mark short, with sutures of unequal lengths; frequently torn to form an irregular triangular gap. Size range (twenty specimens) 50–67 μ ; exclusive of ornamentation, 34–49 μ .

Holotype. Plate 105, fig. 17; $60 \times 51 \mu (42 \times 36 \mu)$; slide LKC-12 (63-64), wax mount 39.

Remarks. The truncated and slightly indented bacula, which are partially fused, distinguish this species. It rarely exceeded one per cent in any zone, being found most frequently in those containing the *Lycospora-Guthoerlisporites erectus* assemblage.

Spackmanites facierugosus (Loose) comb. nov.

Plate 105, fig. 19

1934 Reticulatisporites facierugosus Loose, p. 155, pl. 7, fig. 26.

1954 Verrucososporites facierugosus (Loose); Butterworth and Williams, p. 754, pl. 18, fig. 6, text-fig. 1, 3.

Remarks. An excellent description of the species is given in Butterworth and Williams (1954, p. 754). Its more circular outline, less densely packed bacula with rounded apices, separates this species from S. ellipticus. Spackmanites facierugosus is usually restricted to samples of the Lycospora-Guthoerlisporites erectus assemblage. It was rarely counted.

Infraturma MURORNATI Pot. and Kr. 1954 Genus KNOXISPORITES Pot. and Kr. 1954

Knoxisporites sp. A

Plate 105, figs. 16, 20

Description. Trilete spores; outline distinctly polygonal. Exine characterized by thick

ridges, approximately 3 μ wide, paired at polygonal corners but then separate, with each ridge continuing around the peripheral area; exine otherwise about 2 μ thick, levigate. Two specimens described, measure about 75 μ ; similar to *Knoxisporites cinctus* (Lub. and Waltz) Butt. and Will. but differ in size and opening out of paired ridges. Specimens were recovered from the *Lycospora-Guthoerlisporites erectus* assemblage zone at Station 7.

Turma ZONALES (Benn. and Kidst.) R. Pot. 1956 Subturma AURITOTRILETES Pot. and Kr. 1954 Infraturma AURICULATI (Schopf) Pot. and Kr. 1954 Genus TRIOUITRITES Wilson and Coe 1940

Triquitrites cheilus sp. nov.

Plate 106, figs. 1, 2

Diagnosis. Trilete spores; triangular in polar view, with gently to markedly concave inter-radial margins and rounded, extending radial corners. Trilete mark distinct and extends to just short of the corners; it is bordered by wide, thick, and darkened lips (to 7 μ wide) which are raised. At the radial extremities round to flattened valvae are present, which tend to grade in transitionally towards the polar area. Inter-radial margin bordered by a relatively thin (to 2 μ wide), sometimes indistinct, ridge which thickens radially into the valvae. Exine levigate, with tendency to become irregular; approximately 2 μ thick. Size range (fifteen specimens) 45–60 μ .

Holotype. Plate 106, fig. 1; $53 \times 51 \mu$; slide LKC-6 (1-2) 1, 40.6 124.3.

Remarks. The species is ubiquitously distributed, but rarely exceeds one per cent in any assemblage zone.

Triquitrites magnificus sp. nov.

Plate 106, fig. 3

Diagnosis. Trilete spores; isodiametric triangular in polar view. Trilete mark distinct and almost always open; extends almost to radial margins and attended by relatively wide (to 5 μ) lips that are slightly raised. Radial corners consist of flattened or stubby, thick valvae. Ornamentation of rather long digitated, somewhat sinuous baculate processes on an otherwise levigate exine. Projections, usually confined to areas of lips and valvae, about 10–15 μ long and near straight-sided. Size range (seven specimens) 58–78 μ .

Holotype. Plate 106, fig. 3; 75 \times 78 μ ; slide LKC–13 (18–19) 1, 36·0 107·9.

Remarks. This rare species was never counted. *Triquitrites magnificus* sp. nov. differs from *T. cheilus* sp. nov. in the possession of baculate processes, and from other species of *Triquitrites* in the concentration of processes at the lips and valvae.

Triquitrites sp. A

Plate 106, fig. 4

Description. Trilete spore; triangular in polar view, with convex inter-radial margins and angular radial corners. Trilete mark extends almost to radial corners; lips well-defined,

slightly upturned. Radial corners thickened by rectangular to square-shaped valvae which grade in towards the polar area. Ornamentation of scattered lobed cristae, radially disposed; cristae low-lying, wider (to 5μ) than high (to 3μ), they are confined to distal and equatorial areas. Specimen $75 \times 68 \mu$.

Remarks. Triquitrites sp. A resembles T. crassus Kos. but has its ornamentation restricted to the distal and equatorial areas of the exine.

Genus AHRENSISPORITES Pot. and Kr. 1954

Ahrensisporites vagus sp. nov.

Plate 106, fig. 5

Diagnosis. Trilete spores; triangular in polar view, with rounded radial corners and gently concave to convex inter-radial margins. Kyrtome best developed in inter-radial area and can always be traced to radial corners where, however, it is distinguished occasionally only with oil magnification; inner part raised inter-radially to form distinct thickening. Trilete mark distinct, extends approximately three-fourths radius; usually open, with thin lips. Exine smooth to minutely pitted. Size range (twenty specimens) $38-55~\mu$.

Holotype. Plate 106, fig. 5; $49 \times 41 \mu$; slide LKC-12 (8-9), wax mount LK-10.

Remarks. This species is characterized by the indistinct development of the kyrtome at the radial corners. It was commonly encountered in samples of the Densosporites oblatus and Punctatisporites obliquus assemblages, and rare elsewhere.

Subturma ZONOTRILETES Waltz 1935 Infraturma CINGULATI Pot. and Kr. 1954 Genus CRASSISPORA Bhardwaj 1957

Crassispora kosankei (Pot. and Kr.) Bhardwaj

Plate 106, figs. 9-10, 13

Remarks. Some representatives of Crassispora kosankei observed in this study displayed a high degree of crassitudo development. The species was encountered in tetrads in rare instances. It is present at every locality, becoming most abundant in the upper portions of zones containing the Lycospora-Guthoerlisporites erectus assemblage.

Genus LYCOSPORA S. W. and B. 1944

Lycospora contacta sp. nov.

Plate 106, figs. 6, 8

Diagnosis. Trilete spores; roundly triangular to rounded in polar view and hemispherical in equatorial view. Exine approximately 1 μ thick, covered over its surface by very small (probably less than 1 μ) rounded grana. Equatorial crassitudinous thickening, 3–5 μ wide, grades irregularly towards polar area; indents most markedly at radial extension of trilete mark. Trilete mark distinct, straight, passes through indented

crassitudinous thickening to margin; lips thin but distinct, slightly upturned. Size range (twelve specimens) 30–35 μ .

Holotype. Plate 106, fig. 6; $32 \times 32 \mu$; slide LKC-12 (36-37) 1, 31.8 124.4.

Remarks. The species was very rarely counted, but was observed most frequently in samples of the *Thymospora pseudothiesseni* and *Lycospora-Guthoerlisporites erectus* assemblages. *Lycospora contacta* sp. nov. is distinguished by the irregular thickening at the margin which extends towards the polar area at the radial corners.

Genus GRAVISPORITES Bhard. 1954

Gravisporites densus sp. nov.

Plate 106, fig. 11

Diagnosis. Trilete spores; subcircular to oval in polar view, but often triangular and even pentagonal due to folding around the rigid trilete mark. Trilete mark distinct and rigid because of thick, wide (to 5 μ), elevated ridges. Exine usually folds around trilete mark; crassitudo distinct, to 4 μ wide, usually folded; exine 1–2 μ thick, irregularly surfaced with grana of various sizes. Size range (nine specimens) 45–55 μ .

Holotype. Plate 106, fig. 11; $53 \times 48 \mu$; slide LKC-10 (30-31) 2, 39·6 122·6.

Remarks. The species was only very rarely encountered.

Genus ROTASPORA Schemel 1950 Rotaspora? perforata sp. nov.

Plate 106, fig. 7

Diagnosis. Trilete spores; roundly triangular in polar view; outline in some specimens accentuated by protrusion of trilete sutures. Cingulum smooth, but characterized by relatively large perforations aligned along its periphery, forming a peripheral rim. Central body slightly more rounded than cingulum, but still retains triangular outline; appears detached from cingulum, being connected solely by the sutures; ornamentation minutely punctate or scabrate. Trilete mark prominent; raised and extends to outer margin of cingulum. Size range (five specimens) $28-35~\mu$.

Holotype. Plate 106, fig. 7; $28 \times 26 \mu$; slide LKC-7 (9-10) 1, $18 \cdot 0$ 125·0.

Remarks. This species is distinguished by its distinctly perforated cingulum. It is only provisionally assigned to Rotaspora on the basis of the presence of a rim (?) at the outer margin of the cingulum. The actual occurrence of a rim is not firmly established, as it may be the result solely of the marginal alignment of perforations. Were this to be the case, the species would be better assigned to Lycospora.

Genus DENSOSPORITES Berry emend. S. W. and B.

Densosporites oblatus sp. nov.

Plate 106, figs. 12, 14

Diagnosis. Trilete (?) spores; oblate triangular in polar view, the radial corners rounded

but always retaining some angularity. Cingulum occupies from one-third to one-half the area of the proximal surface of the central body, appears bizonate, becoming appreciably darker at its inner margin; ornamented by radiating, prostrate spines up to 5 μ ; spines taper to sharp point; they vary from one or two per specimen to over fifty; in overmacerated specimens, many spines destroyed, leaving radial pits in cingulum. Central body smooth to distinctly punctate; punctae, when they occur, restricted to proximal surface; verrucae, up to 8μ wide, on distal surface. No evidence of trilete mark. Size range (twenty-five specimens) 57-70 μ .

Holotype. Plate 106, fig. 12; $68 \times 66 \mu$; slide LKC-10 (2-3) 1, 16 113·3.

Remarks. This species is very similar to D. sphaerotriangularis Kos., differing only in the presence of tapering prostrate spines and slightly larger size.

Densosporites spackmanii sp. nov.

Plate 106, figs. 15 a, b

Diagnosis. Trilete (?) spores; distinctly triangular in polar view, with a very irregular outline. Cingulum heavily sculptured by irregular flaps which appear imbricate; it is expressed on the outer margin by deeply cut crenulations, the outer portion of which forms a mammoid sculpture; it occupies approximately 30% or more of proximal area of central body. Central body more circular in outline; smooth to punctate on proximal surface, distal surface covered with 15 to 25 large verrucae. Distinct trilete mark lacking, although very faint trace can be seen on several specimens. Size range (nine specimens) $48-63 \mu$.

Holotype. Plate 106, fig. 15; $58 \times 61 \mu$; slide LKC-10 (3-4) 3, 30·8 114·9.

Remarks. The heavily sculptured cingulum and distal verrucae distinguish this species. Only nine specimens were found. Densosporites spackmanii sp. nov. closely resembles

EXPLANATION OF PLATE 106

All figures \times 500.

Figs. 1-4. Triquitrites spp. 1-2. T. cheilus sp. nov. 1, Holotype. 3, T. magnificus sp. nov., holotype. 4, T. sp. A. Distal focus; distinct cristae.

Fig. 5. Ahrensisporites vagus sp. nov., holotype; ill-defined radial extensions of kyrtome.

Figs. 6, 8. Lycospora contacta sp. nov. 6, holotype; polar indentation of crassitudinous margin at radial corners well-expressed.

Fig. 7. Rotaspora? perforata sp. nov., holotype.

Figs. 9-10, 13. Crassispora kosankei (Pot. and Kr.) Bharad. Specimens possess very well-developed crassitudinous thickenings. 9, Polar view; triangular gap. 10, Equatorial view; well-developed crassitudo. 13, Tetrad; area of contact in each specimen, upper specimen in focus.

Fig. 11. Gravisporites densus sp. nov. holotype.

Figs. 12, 14. Densosporites oblatus sp. nov. 12, holotype; prostrate radiating spines and distal verrucae. 14, Verrucae slightly smaller.

Fig. 15. Densosporites spackmanii sp. nov., holotype; a, Proximal focus, structured cingulum, and proximally punctate spore body. b, Distal focus, large verrucae.

Fig. 16. Cristatisporites verrucosus (Dyb. and Jach.) comb. nov.

Fig. 17. Monilospora sp. A; trilete very faint but extends almost to outer margin of spore. Fig. 18. Savitrisporites bluntus sp. nov., holotype.

Fig. 19. Thymospora concentrica sp. nov., holotype.

species of Asperispora Stapl. and Janson. It is provisionally placed in Densosporites, however, because of the distinct verrucae on the distal surface and lack of distinctive sutural ridges.

Genus CRISTATISPORITES Pot. and Kr. 1954

Cristatisporites verrucosus (Dyb. and Jach.) comb. nov.

Plate 106, fig. 16

1957 Densosporites verrucosus Dybova and Jachowicz, p. 166, pl. 50, figs. 1-4.

Remarks. The presence of radially aligned verrucae which are fused at their bases (Potonie and Kremp's 'kammen') warrants the inclusion of this species in Cristatisporites.

Genus MONILOSPORA Hacq. and Barss emend. Staplin 1960

Monilospora sp. A

Plate 106, fig. 17

Description. Trilete spore; roundly triangular in polar view, with convex inter-radial margins and roundly angular radial corners. Capsula, where it projects beyond central body, from 13 to 19 μ wide; it is characterized by a strongly crenulated outer margin, giving the specimen a rather serrated overall outline; it is very thin (less than 1 μ) where it encloses the proximal and distal hemispheres of the central body. Central body roundly triangular, with gently concave inter-radial margins; smooth, and approximately as thick (approx. 2 μ) as the inner margin of the free portion of the capsula. Trilete mark indistinct, but easily seen with careful focusing; extends almost to outer margin of capsula. Specimen $66 \times 56 \ \mu$, central body $39 \times 38 \ \mu$.

Remarks. Single specimen from Station 1.

Genus SAVITRISPORITES Bhardwaj 1956

Remarks. Bhardwaj's diagnosis and schematic illustration (1956, pp. 127-8, text-fig. 3a, b) of Savitrisporites distinguish it as a patellate spore genus. It differs from other patellate genera described here in its slightly thickened angles (Bhardwaj, p. 127).

Savitrisporites bluntus sp. nov.

Plate 106, fig. 18.

Diagnosis. Trilete spores; isodiametric triangular in polar view, with slightly thickened, truncated or rectangular radial corners and straight to gently concave or convex interradial margins. Patella 3–6 μ wide at equator, characterized by a gently crenulated equatorial margin which extends on to the distal surface to form a reticulum in polar view with wide (approx. 3 μ) but ill-defined muri and smaller lacunae. Proximal surface smooth. Trilete mark distinct, extends almost to inner margin of patella; usually open, with thin, raised lips. Size range (fifteen specimens) 30–38 μ .

Holotype. Plate 106, fig. 18; $37 \times 35 \mu$; slide LKC-12 (7-8) 1, 24·2 118·9.

Remarks. This species is distinguished by its blunted isodiametric shape and small size. It was encountered most frequently in zones containing *Thymospora pseudothiesseni* and *Punctatisporites obliquus* assemblages.

Turma MONOLETES Ibr. 1933
Subturma AZONOMONOLETES Luber 1935
Infraturma SCULPTATOMONOLETI Dyb. and Jach. 1957
Genus Tuberculatosporites Imgrund 1952

Tuberculatosporites spinoplicatus sp. nov.

Plate 107, figs. 1-3

Diagnosis. Monolete spores; roundly elliptical to bean-shaped in outline. Exine $1-2~\mu$ thick, somewhat loosely covered with flimsy, usually curved, spinose projections which are best seen at the outline; from 10 to 20 of the processes present at the outline; each process characterized by from 2 to 5 small, radiating folds at its base; processes $2-10~\mu$ long and vary in side view from almost straight-sided with a length of more than twice its width, to relatively short with tapering sides. Monolete mark distinct, almost always open, but may be folded along its entire length; extends almost the entire length of the spore body; lips thin, slightly raised. Size range (twelve specimens) $106-126~\mu$.

Holotype. Plate 107, fig. 1; $119 \times 81 \mu$; slide LKC-1 (6-7), wax mount 31.

Remarks. The presence of radiating small folds at the base of spinose protrusions makes this species unique. Specimens corresponding to this species were observed also in samples from the Cherokee coals of southeastern Kansas.

Genus THYMOSPORA Wilson and Venkatachala 1964

Thymospora concentrica sp. nov.

Plate 106, fig. 19

Diagnosis. Monolete spores; elliptical outline. Exine relatively thick, over 2μ ; ornamented throughout by thick, low-lying (approx. 3μ high) verrucae which commonly fuse into sinuous, elongate vermiculae; in some specimens, the ornamentation is near-concentric. Monolete mark over two-thirds length of spore body; it is usually obscured by ornamentation, but can be observed with careful focusing. Size range (ten specimens) $60-90 \mu$.

Holotype. Plate 106, fig. 19; $61 \times 43 \mu$; slide LKC-8 (24-25) 1, 29.9 117.1.

Remarks. This species is distinguished by its coarse ornamentation and large size.

Spore sp. A
Plate 107, fig. 4

Description. Trilete spore; oval in outline. Crassitudinous thickening at periphery, up to $7~\mu$ wide. Exine otherwise approximately $1{\text -}2~\mu$ thick, covered with very thin, curving, radially branching cristae, which are low-lying (approx. $1~\mu$ high). Very short, irregular trilete mark is present, though indistinct; it is accentuated by a darkened contact area. A relatively large lenticular fold trends the length of the specimen. Size $58 \times 48~\mu$.

Remarks. The presence of a crassitudinous thickening relates this specimen to Crassispora.

Spore sp. B

Plate 107, fig. 5 a, b

Description. Trilete spore; roundly elliptical in polar view. Exine approximately 1 μ thick, covered with sparsely distributed clusters of small hemispherical grana, each cluster of 15 to 25 grana. Triangular-shaped opening, with flaps folded back, indicating a torn trilete mark. Size $76 \times 66 \ \mu$.

Remarks. Specimen is characterized by its clustered grana, and is otherwise very similar to species of Granisporites.

Spore sp. C

Plate 107, fig. 7 a, b

Description. Trilete spore; triangular in polar view, with near straight-sided interradial margins and sharply rounded radial corners. Exine approximately $2.5~\mu$ thick, and characterized by an irregularly serrated equatorial outline; surface irregular but apparently without a distinct ornamentation pattern. On the distal surface, three deep but thin grooves approximately 23 μ long form an incomplete triangle. Width of specimen external to grooves about 12 μ . Trilete mark distinct, slightly wavy, extends almost to the radial margins; lips developed but not prominent. Size $48 \times 41~\mu$.

Remarks. Specimen appears to be unique in its possession of oriented grooves on the distal surface.

Spore sp. D

Plate 107, fig. 6

Description. Trilete spore; roundly triangular, with convex inter-radial margins and broadly angular radial corners. Central body roundly triangular, generally smooth and very thin, probably, less than 1 μ ; eight to ten large (to 5 μ wide) papillate-type thickenings aggregated in proximal polar area. Covering entire central body, except for a torn gap on proximal side, is a capsulate (?) structure; it is covered over its entire surface with short, tapering spines, not over 3 μ high; spines broad-based. Trilete mark extends, on the outer structure, almost to the outer margin of the specimen. Size $51 \times 51 \ \mu$, central body $35 \times 35 \ \mu$.

Remarks. The presence of a capsulate-like thickening relates this specimen closely to Monilospora.

Anteturma Pollenites R. Pot. 1931 Turma SACCITES Erdtman 1947 Subturma MONOSACCITES (Chitaley) Pot. and Kr. 1954 Infraturma TRILETESACCITI Leschik 1955 Subinfraturma INTRORNATI Butt. and Will. 1958 Genus GUTHOERLISPORITES Bhardwaj 1954

Guthoerlisporites erectus sp. nov.

Plate 107, fig. 8

Diagnosis. Monosaccate, trilete pollen grains; overall outline oval to elliptical in proximo-distal and oblique orientations. Central body circular to subcircular, probably

less than 1 μ thick, with a smooth surface; numerous slender folds concentrically disposed about periphery; outline vague. Saccus covers most of proximal surface of central body, thereby leaving only a somewhat indistinct outline of the latter structure; externally levigate and internally moderately reticulate; a darkening of the peripheral region occurs on most specimens. Trilete mark confined to area of central body, thin but straight and distinct; it extends from about one-half the distance to the margin to almost touching it; folds commonly continue the trace of the sutures, to the outline of the central body; lips very thin. Size range (thirty specimens) 60–89 μ ; central body 38–43 μ .

Holotype. Plate 107, fig. 8; $81 \times 69 \mu$; slide LKC-11 (24-25) 2, $21 \cdot 2115 \cdot 2$.

Remarks. This species is distinguished from Guthoerlisporites magnificus, the type species, by its smaller size, and tendency of folds to continue the sutures of the trilete mark to the wall of the central body.

Guthoerlisporites delicatus (Kos.) comb. nov.

Plate 107, fig. 9

1950 Wilsonia delicata Kosanke 1950, pp. 54-55, pl. 14, fig. 4.

1959 Wilsonites delicatus (Kos.); Kosanke, p. 700.

Remarks. Kosanke (1950, p. 54) distinguished Wilsonites partly by its vaguely defined central body being either completely covered or largely covered by the saccus. His illustration of the holotype of this species, as well as all the specimens of it encountered in this study, shows a rather distinct central body. Acknowledging that Wilsonites and Guthoerlisporites are closely related genera, this species is placed in Guthoerlisporites on the basis of its distinct central body.

Subinfraturma extrornati Butt. and Will. 1958 Genus endosporites Wils. and Coe 1940

Endosporites globiformis (Ibr.) S. W. and B.

Plate 107, fig. 10

1932 Sporonites globiformis Ibrahim, p. 447, pl. 14, fig. 5.

1944 Endosporites globiformis (Ibr.) Schopf, Wilson, and Bentall, p. 45.

1940 Endosporites ornatus Wilson and Coe, p. 184, fig. 2.

All figures \times 500.

EXPLANATION OF PLATE 107

Figs. 1-3. Tuberculatosporites spinoplicatus sp. nov. 1, holotype. 2, specimen with somewhat angular outline, due to ornamentation; well-developed radiating folds at bases of spines. 3, three distinct folds radiate from base of a spine.

Figs. 4–7. Unnamed spores. 4, sp. A; contact area present, although ill-defined. 5, sp. B; a, Distal focus; clusters of grana. b, Proximal focus; triangular gap. 6, sp. C. 7, sp. D; a, Proximal focus; slightly undulating trilete mark; b, Distal focus, triangularly oriented grooves prominent.

Fig. 8. Guthoerlisporites erectus sp. nov. holotype.

Fig. 9. Guthoerlisporites delicatus (Kos.) comb. nov.

Fig. 10. Endosporites globiformis (Ibr.) S. W. and B.

Figs. 11-12. Endosporites grandicorpus sp. nov. 11, holotype. 12, distinct apical papillae.

Remarks. Endosporites ornatus is here considered a junior synonym of E. globiformis, primarily on the basis of Chaloner's (1958) description of the microspores in the lycopod cone species Polysporia mirabilis. Although specimens of both species of Sporae dispersae could morphologically be distinguished, they invariably occurred in the same samples, and gradational specimens were observed.

Endosporites grandicorpus sp. nov.

Plate 107, figs. 11, 12

Diagnosis. Monosaccate trilete spores; overall outline roundly triangular in polar view, with distinctly angular radial corners. Central body circular to sub-circular; it occupies most of the area of the specimens, extending seven-tenths the radius or more; less than 1 μ thick; very commonly a number of small, lenticular folds criss-cross its distal hemisphere. Saccus sharply and densely punctate, showing best at the periphery; a distinct limbiate thickening occurs at the periphery, approximately 3–4 μ wide, attached to central body on proximal side. Trilete mark distinct, extends to margin of saccus. Apical papillae located inter-radially on proximal side, a phenomenon common in lycopod microspores. Size range (seven specimens) 65–81 μ ; central body 60–73 μ .

Holotype. Plate 107, fig. 11; $80 \times 72 \mu$; slide LKC-7 (9-10), wax mount 36.

Remarks. This species is distinguished by its relatively large central body, oblate triangular outline, and strongly differentiated limbus. It occurs most frequently in zones containing the *Thymospora pseudothiesseni* assemblage.

Infraturma VESICULOMONORADITI (Pant) Bhardwaj 1956 Genus PALEOSPORA gen. nov.

Type species. Paleospora fragila sp. nov.

Diagnosis. Elliptical to subcircular monosaccate grain with a longitudinal slit. Central body elliptical to circular and occupies an area about one-half or more of the enclosing saccus; in some cases it carries long, thin, concentric folds. Saccus thin, less distinctive than central body and very commonly folded or torn. A longitudinal fissure extends from over one-half to the complete length of the saccus; it forms a line along which entire specimens are commonly folded. An equatorial enclosing flange is the most prominent structure, and appears to hold the shape of the flimsy specimens; it is relatively wider than the saccus. The single described species ranges upward in size from 150 microns.

Remarks. This genus is distinguished from Potonieisporites by its distinct flange, and from Spencerisporites by its longitudinal fissure.

Paleospora fragila sp. nov.

Plate 108, figs. 1, 2

Diagnosis. Monosaccate spores or pollen with a straight longitudinal fissure confined to the area of the saccus; elliptical in outline. Central body more roundly elliptical, $1~\mu$ or less thick; it is enclosed by a closely appressing saccus with which it conforms in

outline. Both saccus and central body appear very flimsy and are almost always folded in several directions; they both appear to be essentially unornamented. Flange in an equatorial zonate structure of about the same thickness (approx. 1 \(\mu \)) throughout its width; it is the most prominent and most highly ornamented structure; the ornamentation consists of very low-lying (approx. 1 μ or less high) irregularly radiating corrugations or cristae, which become more distinctive toward the outer margin. Longitudinal fissure open in all observed specimens, ranging from a thin slit to a wide gap which participates in folds which, when they occur, run the entire length of the body. Size range (twenty-five specimens) 150-195 μ ; saccus 105-140 μ ; flange width 15-25 μ .

Holotype. Plate 108, fig. 1; $161 \times 93 \mu$; slide LKC-2 (21-22) 2, 36.5×115.2 .

Remarks. This species does not appear to be restricted to any particular assemblage zone.

> Genus POTONIEISPORITES Bhardwaj 1954 Potonieisporites elegans (Wils. and Kos.) emend.

> > Plate 108, fig. 3

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

1964 Potonieisporites elegans (Wils. and Kos.); Wilson and Venkatachala, pp. 67-68.

Emended diagnosis. Monosaccate pollen grains; roundly elliptical in overall outline. Central body distinct, elliptical to circular in outline, characterized by prominent crescentic or lenticular folds which commonly transect each other, though on opposite sides of the central body, at angles approaching ninety degrees; the transverse folds, always two, appear confined to the distal hemisphere at or near the juncture of central body and saccus; the longitudinal folds, also two, are present on the proximal (free) hemisphere of the central body and trend along the maximum dimension of the body; ornamentation minutely punctate to granulose. Saccus externally levigate and internally moderately infra-reticulate, attached to central body only on its distal side. Tetrad mark prominent on proximal (free) side of saccus; it is essentially straight longitudinal, but occasionally T-shaped with a much reduced third suture, or even symmetrically (Y-shape) trilete.

EXPLANATION OF PLATE 108

All figures \times 500.

Figs. 1-2. Paleospora fragila gen. et sp. nov. 1, holotype.

Fig. 3. Potonieisporites elegans Wils. and Kos. emend. Monolete mark continued across saccus by folds, optically superimposed on distally attached central body.

Figs. 4-5. Florinites occultus sp. nov. 4, holotype; irregular gap at contact of central body and distal surface of saccus, and radiating folds. 5a, Distal focus, showing contact of central body and saccus; saccus torn around thick central body. 5b, Proximal focus, showing rudimentary trilete mark on

Figs. 6-8. Vesicaspora wilsonii Schemel. 6, Polar view, showing vague central body. 7, Oblique view; continuation of saccus across central body illustrated by folds. 8, Equatorial view, showing orientation of saccus, proximally protruding central body, and tenuitas-like membrane crossing saccus distally.

Fig. 9. Vesicaspora saarensis (Bharad.) comb. nov.

Fig. 10. Complexisporites chalonerii sp. nov. Holotype.

Figs. 11-12. Pityosporites kittanningensis sp. nov. 11, holotype.

Dimensions. (Twenty-five specimens) 135-215 μ ; central body 85-110 μ .

Remarks. This species is formally emended because of the additional information provided by numerous specimens present in the Lower Kittanning seam. These specimens agree in every respect to the species recombined by Wilson and Venkatachala (1964) and have demonstrated that the suture is confined to the saccus on the proximal (free of any contact with the central body) side. In a specimen illustrated in Plate 108, fig. 3, the suture and attendant minor folds pass across the central body and its transverse and longitudinal pairs of folds without disturbing them. This seems possible only when the suture is superimposed on the central body optically from another surface. Because no mention of the actual position of the tetrad suture is given in the generic diagnosis by Bhardwaj (1954, pp. 19–20), this species is retained in *Potonieisporites*.

This species is almost invariably restricted to the bottom-most samples in the Lower Kittanning seam.

Infraturma ALETESACCITI Leschik 1955 Genus FLORINITES S. W. and B. 1944

Florinites occultus sp. nov.

Plate 108, figs. 4, 5 a, b

Diagnosis. Monosaccate pollen grains; roundly elliptical to subcircular outline. Central body circular to oval, very thick and dark, probably over $2.5~\mu$ thick; an irregularly spinose or conate ornamentation is distinct at its outline. Saccus externally levigate and internally coarsely reticulate, reticulation pattern radiating out from area of central body; attached distally to central body, proximal side free; junction with saccus on distal side attended by an irregular gap, exposing central body; in some specimens, it is concentrically torn around the central body, presumably because of the latter structure's thickness. A tetrad scar was observed in only one specimen (Plate 108, fig. 5 a, b), where a short, irregular trilete mark is present on the proximal (free) side of the saccus. Size range (eight specimens) $60-106~\mu$; central body $35-80~\mu$.

Holotype. Plate 108, fig. 5 a, b; $91 \times 76 \mu$; slide LKC-12 (51-52), wax mount 21.

Remarks. This species is distinguished by its thick, dark central body. It occurs most frequently in zones containing the *Lycospora-Guthoerlisporites erectus* assemblage, most usually in the bottom-most samples.

Genus VESICASPORA Schemel emend. Wils. and Venkat. 1963 Vesicaspora wilsonii Schemel emend. Wils. and Venkat. 1963

Plate 108, figs. 6-8

Remarks. Specimens of this species present in the Lower Kittanning coal demonstrate well the morphological reinterpretation by Wilson and Venkatachala (1963).

Vesicaspora saarensis (Bhard.) comb. nov.

Plate 108, fig. 9

1957 Alisporites saarensis Bhardwaj, p. 117, pl. 31, figs. 14-15.

Remarks. The species described by Bhardwaj (1957) as Alisporites saarensis differs from previously described species of Vesicaspora by its slightly darker central body.

Subturma DISACCITES Cookson 1947 Genus COMPLEXISPORITES Jizba 1962 Complexisporites chalonerii sp. nov.

Plate 108, fig. 10

Diagnosis. Striate, capped, bisaccate pollen; roundly elliptical to oval in outline, the width of either saccus never exceeding that of the central body. Central body smooth, not accentuated by an equatorial thickening; subcircular to slightly transversely elongated, outline obscured by attachment folds of sacci. Sacci externally levigate and internally infrareticulate, distally inclined, attached distally to central body near the polar area and proximally in a subequatorial position; distinct folds define their distal attachment to central body. Relatively narrow (approx. 6–8 μ) germinal furrow lies parallel to sacci bases. On the proximal side of the central body, a vaguely defined, but always present, cap is defined by a circular groove; within the cap, from 26 to 35 μ in diameter, is a straight longitudinal fissure, running the length of the cap; it is attended on either side by from one to three less distinct striae; in some specimens the striae could be distinguished only with careful focusing. Size range (six specimens) 63–86 μ .

Holotype. Plate 108, fig. 10; 66×56 μ; slide LKC-7 (18-19) 1, 22·5 114·3.

Remarks. This species is placed in Complexisporites Jizba on the basis of its striated proximal cap. It differs from C. polymorphus, the type species, mainly in the structure of the cap. This species also has sacci which are more distally inclined. It occurs with C. polymorphus in the Lower Kittanning coal, in the lower samples of the Lycospora-Guthoerlisporites erectus assemblage.

Genus PITYOSPORITES Seward emend. Manum 1960

Remarks. Alete, bisaccate grains with distal orientation of sacci are assigned to Pityosporites (Sew.) Manum in this study. These grains are similar to Klausipollenites Jansonius, especially in the crescentic to semicircular outline of the sacci, but can be distinguished from this genus by their distal attachment of sacci closer to the polar area of the central body, and narrower germinal furrow.

Pityosporites kittanningensis sp. nov.

Plate 108, figs. 11, 12

Diagnosis. Alete, bisaccate pollen; central body almost circular, but appears transversely elongated due to the mode of saccus attachment; sacci crescentic, free margin circumscribing more than half the outline of a circle. Central body indistinct, probably not more than 1 μ thick, characterized by subequatorial, convexly crescentic thickenings at proximal bases of sacci; surface smooth to minutely punctate, punctae being observed only with high magnification oil objective. Sacci distally inclined at angles from 20 to 30 degrees, attached proximally to central body in a near equatorial position, and distally in polar area; in smooth continuity with the central body so that in equatorial view they help purvey the 'boomerang' effect typical of the genus; externally levigate and internally infrareticulate; no evidence of a thickening at their outer margin. Germinal furrow relatively thin and only vaguely defined, always present, elongated parallel to

distal attachment of sacci bases. Size range (ten specimens) 60-78 μ ; central body 36-58 μ .

Holotype. Plate 108, fig. 11; $70 \times 47 \mu$; slide LKC-12 (51-52) 1, 26.8 116.0.

Remarks. This species is distinguished from closely allied species by its size and less distinct central body. Almost all specimens were recovered from the lower portions of the Lower Kittanning seam.

Genus ALISPORITES Daugherty emend. Pot. and Kr. 1954

Alisporites symmetricus sp. nov.

Plate 109, figs. 1-3

Diagnosis. Alete, bisaccate pollen; elliptical to elongate-elliptical in polar and equatorial views. Central body indistinct; outline discerned in some specimens only with careful focusing; approximately 1 μ thick, smooth to minutely punctate; greatest diameter along the greatest dimension of the specimens. Sacci attached proximally in subequatorial position and distally nearer the polar area; they appear to be of about the same thickness as the central body and are moderately infrareticulate without any distinct radial orientation. Connecting the two sacci distally is a very thin (probably less than 1 μ) germinal furrow which when observed in equatorial view is always split open, 12–30 μ wide, oriented parallel to the sacci bases; unornamented and much lighter in colour than either central body or sacci. The sacci are not pendant, but are isodiametrically opposed. Size range (eight specimens) 73–91 μ .

Holotype. Plate 109, fig. 1; $81 \times 58 \mu$; slide LKC-12 (63-64), wax mount 39.

Remarks. This species is smaller than most species of Alisporites. It was found only in the lowermost samples of the seam.

Bisaccate sp. A

Plate 109, fig. 4

Description. Fissured, bisaccate pollen grain; elliptical in outline, with the central body at least as wide as the sacci which, in turn, are widest at their bases. Central body 71 μ in diameter, almost circular, although not sharply defined; without appreciably distinct wall, minutely granulose. Sacci externally levigate and internally moderately reticulate, attached distally very close to polar area of central body, and proximally in a subequatorial position; distal attachment marked by distinct primary folds which are convexly lenticular and extend the entire distance of the bases. Relatively narrow germinal furrow, about 7 μ wide, parallel to the primary folds; a narrow but very distinct fold runs almost its entire longest dimension. On the proximal surface of the central body is a very distinct longitudinal fissure 23 μ long, bordered by thick raised lips. Size 91 \times 71 μ .

Remarks. This specimen is distinguished by its large central body and bordered longitudinal fissure.

Bisaccate sp. B

Plate 109, fig. 5 a, b

Description. Two alete, bisaccate pollen grains; elliptical or dumb-bell shaped in outline,

the central body circular with sacci somewhat hemispherical. Central body very vaguely defined, probably very thin and smooth. Sacci attached distally by thickened areas near polar area of central body; attached proximally, although very vaguely, in a subequatorial position; externally levigate and internally incompletely reticulate, the ornamentation appearing more vermiculate or verrucate; the effect of the ornamentation gives the specimens a roughened outline; a darkened peripheral zone occurs at the outline. Relatively wide but thin furrow between sacci bases on distal side. Specimens $64 \times 50 \ \mu$ (Plate 109, fig. 5 a, b) and $61 \times 43 \ \mu$.

Remarks. The two specimens are distinguished by their coarse ornamentation and dumb-bell shape.

Bisaccate sp. C

Plate 109, figs. 6, 7 a, b

Description. Two striate, bisaccate pollen grains; elliptical in polar view, with hemispherical sacci wider than the central body. Sacci attached to indistinct central body in polar area on distal side, and subequatorially on proximal side. On proximal side of central body, well-defined cap distinguished by circular groove; cap striate, six to seven distinct striae, a few split longitudinally for part of their length. Central body roundly elliptical, smooth; sacci externally levigate and internally microreticulate. Relatively narrow germinal furrow parallels the sacci bases. Specimens $89\times62~\mu$ (fig. 6) and $76\times60~\mu$ (fig. 7).

Remarks. The proximally located striate cap relates these specimens to Complexisporites; however, the podocarpitidaceous sacci-central body relationship relate them closely to Striatopodocarpites. Only these two specimens were found, in the lowermost samples containing the Lycospora-Guthoerlisporites erectus assemblage at Stations 7 and 8.

Bisaccate sp. D

Plate 109, figs. 8 a, b and 9

Description. Two striate, bisaccate pollen grains; sacci circumscribe an outline greater than one-half that of a circle, and with a width greater than that of the central body. Central body characterized by thick (to 8 μ wide at outline) sinuous wall; on its proximal side, from two to four relatively wide (approx. 3 μ) but somewhat less sinuous thickenings are separated by striae; usually one or two thickenings are more conspicuous than the others. Sacci externally levigate and internally finely reticulate; long, slender, straight folds radiate out from area of central body, presumably due to thickness of central body; sacci attached distally and proximally to central body in subequatorial positions, being probably only very slightly distally inclined. On the distal surface, a

EXPLANATION OF PLATE 109

All figures \times 500.

Figs. 1-3. Alisporites symmetricus sp. nov. 1, holotype.

Figs. 4-9. Bisaccate spp. 4, Sp. A. 5, Sp. B; a, distal focus; b, proximal focus. 6-7, Sp. C. 8-9, Sp. D. Fig. 10. Schopfipollenites sp. A.

wide unornamented germinal furrow. Specimens, $71 \times 45 \mu$ (fig. 8 a, b) and $80 \times 60 \mu$ (fig. 9).

Remarks. The striate central body and larger sacci relate these specimens closely to Striatopodocarpites.

Turma plicates Naumova emend. R. Pot. 1960 Subturma praecolpates Pot. and Kr. 1954 Genus schopeppol entres Pot. and Kr. 1954

Schopfipollenites sp. A

Plate 109, fig. 10

Description. Monolete, prepollen grain; elongate-elliptical outline. Specimen bordered by thick flange-like structure approximately $8-10~\mu$ wide, thickest nearest the polar area, and thinning rapidly towards the outer margin. Two centrally located thick primary folds extend longitudinally, each $25~\mu$ long; located on the distal surface, they taper in opposite directions, joining with each other at their terminations. Monolete mark slightly bent, extends over two-thirds length. Exine densely but very minutely punctate, probably over $2~\mu$ thick. Specimen $179 \times 109~\mu$.

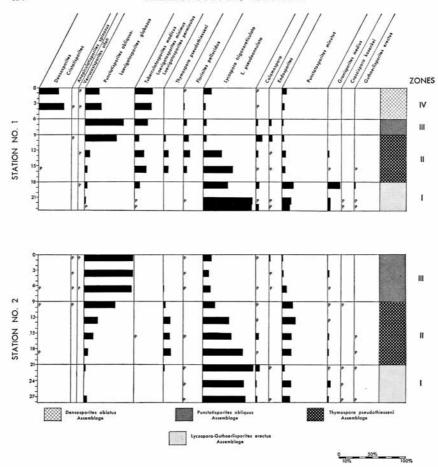
Remarks. This specimen is distinguished by its smaller size, slender elliptical outline, and thick distal folds.

DESCRIPTION OF SPORE AND POLLEN ASSEMBLAGES

The diagnostic characteristics of the five spore and pollen assemblages occurring in the Lower Kittanning coal seam are given in the succeeding numbered paragraphs. Following these are more detailed descriptions and discussions of the assemblages.

- 1. Densosporites oblatus assemblage. Total of all densospores in samples containing this assemblage ranges from 15 % to 47 %. The densospore species include Densosporites oblatus, D. reynoldsburgensis, D. spackmanii, and Cristatisporites verrucosus.
- 2. Punctatisporites obliquus assemblage. Range of Punctatisporites obliquus-Laevigatosporites globosus in incremental samples from 19 % to 90 %. Combined densospore species never exceed 13 % in any sample.
- 3. Thymospora pseudothiessenii assemblage. Range of Thymospora pseudothiesseni in incremental samples from 3.5 % to 24 %. Florinites pellucidus always occurs in its greatest amounts in the assemblage zones.
- 4. Lycospora-Guthoerlisporites erectus assemblage. Lycospora ranges in incremental samples from 30 % to 74 %. Guthoerlisporites erectus occurs in every assemblage zone. Punctatosporites minutus, Granisporites medius, and Crassispora kosankei occur here in greater amounts. There is the greatest diversity of saccate species in the assemblage zones.
- 5. Lycospora assemblage. Lycospora ranges from 40 % to 65 % in incremental samples. Guthoerlisporites erectus is totally lacking.

Bar histogram profiles of the more common species, with the delineated assemblage zones, are presented for most of the investigated localities in text-figs. 3-7.

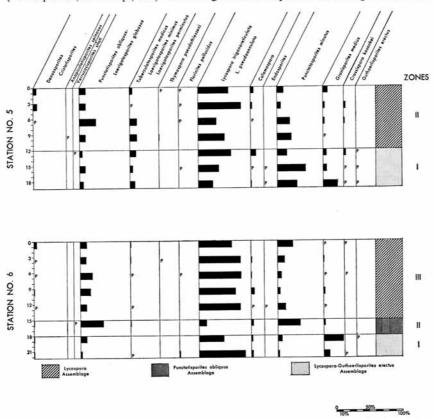


TEXT-FIG. 3. Distribution of spores and pollen in the Lower Kittanning coal at Stations 1 and 2.

The average percentages of species in each assemblage are given in text-fig. 8. Each of the zones is defined solely on the basis of the spore and pollen assemblage occurring in it. Because the increase and decrease of species in the profiles are for the most part gradual, the boundaries of assemblage zones were drawn arbitrarily at the top of the uppermost sample containing the particular assemblage. Because of the sampling interval, it was decided to obtain more than one sample for any particular zone, except where the diagnostic species occurred in numbers well above the required minimum.

Densosporites oblatus assemblage

This assemblage is characterized by the relatively high percentage of densospores (Densosporites, Cristatisporites) which range in their respective assemblage zones from

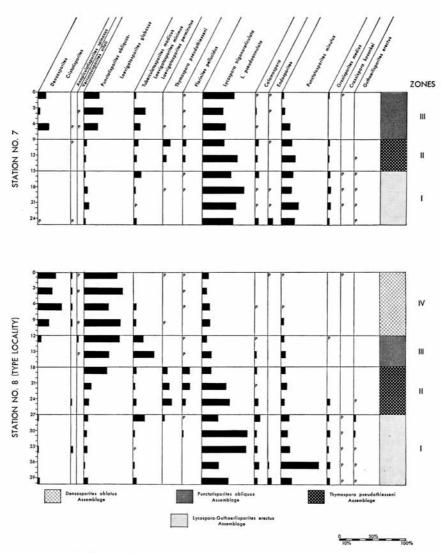


TEXT-FIG. 4. Distribution of spores and pollen in the Lower Kittanning coal at Stations 5 and 6.

20.5 % in Zone III at Station 13 to 41.5 % in Zone IV at Station 10. With one exception, the lowest occurrence in any sample in a zone is 17 %. Punctatisporites obliquus-Laevigatosporites globosus is the most abundant spore species in the assemblage, although the densospores are collectively most abundant at approximately half the localities. Densosporites oblatus sp. nov. accounts for more than half the number of densospores present. Other species included in this group include Densosporites reynoldsburgensis, D. spackmanii sp. nov., and Cristatisporites verrucosus comb. nov. Other species which more frequently occurred in this assemblage include

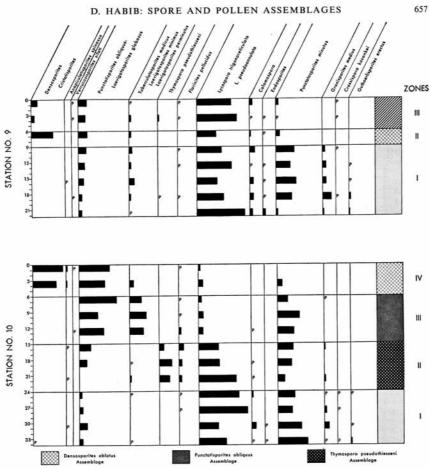


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TEXT-FIG. 5. Distribution of spores and pollen in the Lower Kittanning coal at Stations 7 and 8.

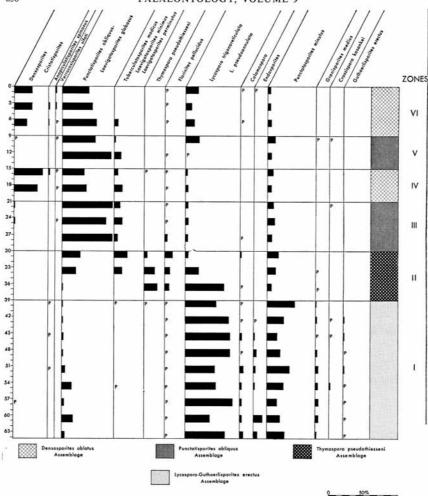




TEXT-FIG. 6. Distribution of spores and pollen in the Lower Kittanning coal at Stations 9 and 10.

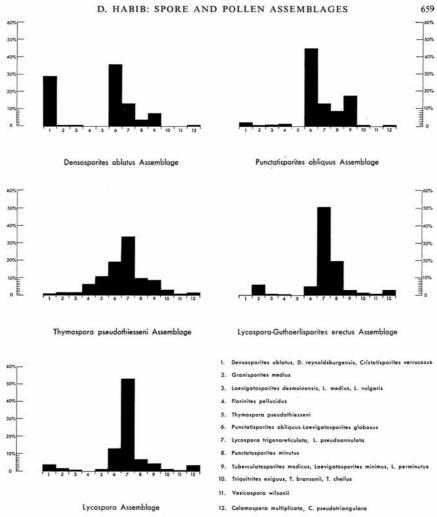
Anapiculatisporites spinosus, Verrucosisporites sifati, Ahrensisporites vagus sp. nov., Acanthotriletes echinatoides, Punctatisporites globulosus sp. nov., and P. ellipticus sp. nov.

The analytical data on the *Densosporites oblatus* assemblage show a relatively small number of species counted and a small number observed per sample. The species ranged from as little as 12 to as many as 22, whereas a range of from 20 to 28 was



TEXT-FIG. 7. Distribution of spores and pollen in the Lower Kittanning coal at Station 12.

observed for the entire population. As many as 38 species were observed in the uppermost zone at Station 4, but this proved to be an exception. The high incidence of mineral matter and occurrence of species not found in other zones containing the *Densosporites oblatus* assemblage suggest their having been contributed from outside the immediate environment.



TEXT-FIG. 8. Average percentages of species in the spore and pollen assemblages. Numbers under histograms refer to listed species.

The rather small number of species comprising the *Densosporites oblatus* assemblage agrees with the data recorded by Smith (1962, pp. 448–9), who reported a low incidence of species in those portions of the seam rich in *Densosporites*. As a result, he concluded (p. 461) that the vegetation was composed of very few species. It seems reasonable to

hypothesize an environment represented by relatively few plant species, either forming dense stands or 'overproducing' microspores to a great extent.

Zones containing the *Densosporites oblatus* assemblage occur at eight of the fifteen localities. They always occur in the upper portions of the seam when present, most frequently occupying the position in contact with the overlying Lower Kittanning shale. Where the assemblage occupies the uppermost zone, the overlying facies is marine or restricted-marine.

Punctatisporites obliquus assemblage

This assemblage is similar to the preceding one, but differs markedly in the reduced occurrence to near-absence of densospores. *P. obliquus–L. globosus* is usually most abundant. At a few localities the lack of densospores is compensated by the large numbers of *Lycospora* and/or small monolete species. *P. obliquus–L. globosus* ranges from a minimum of 24·2 % in Zone II at Station 7 to 77·3 % in Zone III at Station 2. Ten of the thirteen zones containing this assemblage, however, range from 34·5 % to 59 %. Densospores reach above 5 % in only two of the zones. At Station 7, they reach to 13 %, a maximum occurrence which is attended by large numbers of *Lycospora*. Species which are more frequently encountered in this assemblage include *Laevigatosporites perminutus*, *L. minimus*, *Tuberculatosporites modicus*, *Punctatisporites obesus*, *P. sphaerorigidus* sp. nov., *Endosporites zonalis*, *Acanthotriletes echinatoides*, *Ahrensisporites vagus* sp. nov., and *Verrucosisporites sinensis*.

The number of species per 200 spores counted ranges from 16 to 28, while the total number of species observed per sample ranges from 24 to 40. The total number of species per sample always increased in the lower portions of the assemblage zones.

The *Punctatisporites obliquus* assemblage occurs at 12 of the 15 localities. It most usually underlies zones containing the *Densosporites oblatus* assemblage or occurs as the uppermost zone of the seam. In either case, it underlies the Lower Kittanning shale where it contains a marine or restricted-marine facies.

Thymospora pseudothiesseni assemblage

This assemblage is defined by the presence of Thymospora pseudothiesseni, which ranges from 3.5 % to 19 % in its assemblage zones. Although the percentage is not high, this species is virtually absent in samples containing other assemblages, reaching in rare instances, only to as high as 2 %. Concomitant with the increase in T. pseudothiesseni is the relatively sudden jump in Florinites pellucidus, which ranges to 19.5 %. At only two localities, Stations 2 and 4, does this species not rise appreciably. Although it was found in almost every sample of the seam, only seldom did it increase above 2 % in other assemblages. It is within zones containing the T. pseudothiesseni assemblage that P. obliquus-L. globosus becomes replaced in the lower portions in being the most abundant representative. On the average this assemblage is less dominated numerically by a single species than are the other assemblages. Many of the species frequently encountered in lesser proportions in other assemblages consequently are more frequent here. Vesicaspora wilsonii is found in most zones of the seam, but occurs more frequently here, as do species of Calamospora, Laevigatosporites, and Triquitrites. Other species which are regular members of the Thymospora pseudothiesseni assemblage are T. obscura, Schopfites dimorphus, S. colchesterensis, Cirratriradites annulatus, Triquitrites exiguus, Mooreisporites inusitatus, Laevigatosporites vulgaris, L. perminutus, L. minimus, and Tuberculatosporites modicus. The latter three species occur in lesser proportions than in the previously described assemblages. Densospores are present in a few samples.

The number of counted species increases from 19 to 27, while the total number increases from 22 to 51. Most samples contain between 30 and 35 species.

The relatively larger numbers of *Florinites pellucidus*, combined with an increase in number of species per sample and lesser domination by a single species, suggests an environment such as an open herbaceous marsh, which would contain relatively a greater number of spores from surrounding plant communities. Chaloner (1958 b) proposed an 'upland' source for *Florinites*-producing plants, primarily on the results arrived at by Neves (1958). If a rather constant supply of *Florinites* pollen is introduced into the coal swamp from marginal sources, as is evidenced by its low but constant occurrence in almost all samples of the seam, a swamp environment (open marsh) without significant *in situ* spore production by the very nature of its inability to mask (i.e. compare with *Lycospora–Guthoerlisporites erectus* assemblage) would permit the increase in expression of this genus. The high number of species may have been brought in mostly when the environment was covered by the water table, as in floods.

Zones containing this assemblage are present at 12 of the 15 localities. It most frequently occurs in zones in the middle portion of the seam. The assemblage is best developed, i.e. highest percentage of *T. pseudothiesseni* and *F. pellucidus*, usually where the seam underlies ancient 'marine' sediments.

Lycospora-Guthoerlisporites erectus assemblage

This assemblage is characterized by the high percentage of *Lycospora* and low but consistent presence of *Guthoerlisporites*. *Lycospora* is represented by *L. trigonoreticulata* and *L. pseudoannulata* which together range over 45 % in twelve of the fourteen zones the assemblage occurs in. The genus is accompanied in almost every sample of the assemblage by *Guthoerlisporites erectus* sp. nov. Although the species does not occur in appreciable quantity, its near omnipresence serves to distinguish the assemblage. It was only very rarely found in other assemblage zones, and only in the lowermost portions which are directly above the *Lycospora–Guthoerlisporites erectus*. It was not found in any sample from Station 13, where the *Lycospora–Guthoerlisporites erectus* assemblage was not observed. It is in samples of this assemblage that *Punctatosporites minutus* becomes most abundant; in some samples, it replaces *Lycospora* in predominance. It reaches to 56 % of the population in a sample from Zone I at Station 8.

A higher number of species were found to occur regularly in this assemblage, including Granisporites medius, Crassispora kosankei, Endosporites globiformis, species of Calamospora, Florinites similis, Spackmanites ellipticus gen. et sp. nov., S. facierugosus comb. nov., Mooreisporites inusitatus, Vestispora levigata, V. fenestrata, and V. profunda. Other species which are not as widely distributed but still occur most frequently here are Aculeispores aculeus, Cadiospora magna, Complexisporites polymorphus, C. chalonerii sp. nov., Alisporites symmetricus sp. nov., Florinites diversiformis, F. occultus sp. nov., Potonieisporites elegans emend. Pityosporites kittanningensis sp. nov., Guthoerlisporites delicatus comb. nov., Wilsonites kosankei, and Apiculatisporis globulus. Of all these species, G. medius is the most abundant, ranging to 19.5 % in Zone I at Station 6.

This assemblage is characterized by a low number of counted species (16 to 24), but

in contradistinction to the *Densosporites oblatus* assemblage, a rather high number of total species per sample (29 to 38). The low count is obviously due to the great preponderance of lycosporids. Most other species were well below 3 %. That the lycosporid species were produced by arborescent and presumably anemophilous lycopods may have masked the production of other smaller trees or herbaceous plants in the community. The over-all low percentage of gymnospermous pollen, represented, however, by a number of distinctive genera, suggests either long-distance transportation from outside the area of the coal swamp environments, or even *in situ* deposition during the very early stages of peat accumulation. Most of these species are confined to the lower-most samples of the seam.

This assemblage is present at 14 of the 15 studied localities.

Lycospora assemblage

This assemblage is very similar to the last, differing primarily in its total lack of Guthoerlisporites erectus. Lycospora trigonoreticulata and L. pseudoannulata range from 46 to 59.2~%, with Punctatosporites minutus never exceeding 14~% in any zone. The saccate gymnospermous species are notably missing, and Endosporites globiformis was observed in the assemblage only at Station 9. Granisporites medius occurs in larger numbers than in some other assemblages, but reaches only 3~%. Punctatisporites obliquus–Laevigatosporites globosus was recorded at approximately 12~%. The densospores are better represented than in many of the preceding assemblages, extending to 7~% at Station 9.

The Lycospora assemblage contains a low number of counted species (14 to 22), and a total number of 25 to 35 per sample. The low number of species counted is similar to that in the Lycospora-Guthoerlisporites erectus assemblage, which is due here also to the high occurrence of Lycospora species. The additional low number of species per sample, however, is in contrast.

The Lycospora assemblage occurs at 3 of the 15 localities and always occurs in the uppermost zone. It was found only where the seam underlies the non-marine facies of the overlying shale unit.

DISCUSSION

The most typical sequence in which the spore and pollen assemblages of the Lower Kittanning seam occur from the bottom to top is: (1) Lycospora–Guthoerlisporites erectus assemblage; (2) Thymospora pseudothiesseni assemblage; (3) Punctatisporites obliquus assemblage; (4) Densosporites oblatus assemblage. This sequence may be terminated at the top by the Punctatisporites obliquus assemblage. This sequence (1–4 or 1–3) is typical of those localities where the marine and restricted-marine facies lie directly over the seam. It is interrupted, and in one case considerably upset (e.g. Station 9) at the fresh-water localities. There, the Lycospora assemblage occurs in the uppermost zone. The vertical variation in abundance of species is less pronounced, and consequently fewer assemblages are represented. Even those assemblages more typical of other localities which are present (e.g. Thymospora pseudothiesseni and Punctatisporites obliquus assemblages) here appear to be less well-developed, presumably due in large part to the preponderance and masking effect of Lycospora.

CONCLUSIONS

The spatial arrangement of spore and pollen assemblage zones in the Lower Kittanning seam suggests a genetic relationship with the environmental conditions in which the overlying sediments were deposited (text-fig. 1). Their distribution can be compared in part with the Recent pollen deposits of southwestern Florida, only on the basis, however, of their relationship to marine sediments lying directly on buried portions, and distribution of assemblages according to salinity, water table level, and drainage factors (see Spackman, Dolsen, and Riegel 1966; Habib, Riegel, and Spackman 1966). Although both geo-botanical models cannot be considered completely analogous, they offer similar evidence for migration of peat environments and their contained spore and pollen assemblages in response to a transgressing sea.

The salinity factor, resulting from proximity to the sea, seems plausible in attempting to explain the distribution of assemblage zones in the seam. The arborescent lepidodendrids, from which *Lycospora* was disseminated, were presumably less-brackish paralic swamp dwellers which migrated towards the margins of the peat accumulating basin in step with the encroaching more-saline marine waters. Other factors which are also best manifested in selective zones of a coastal swamp are of equal importance, however. The position of the water table, relatively higher towards the centre of a basin, may have had a marked effect on the distribution of the plant communities from which the *Densosporites oblatus* and *Punctatisporites obliquus* assemblages were formed. The margins of the basin would be better drained and hence better able to support the retreating lepidodendrids.

The large number of species and more or less sudden jump in frequency of *Florinites pellucidus* in the *Thymospora pseudothiesseni* assemblage, suggest periods of widespread high water conditions in an open marsh environment. A modern day analogue of this hypothesis can be found in the surface peat deposits of southern Florida, where a relatively large number of pine pollen is present in an environment represented by many marsh plants (Spackman *et al.* 1966, fig. 16). The pollen deposits of this frequently flooded marsh environment are characterized by a large number of plant species.

As the effect of marine transgression became more intensive, the floral environments became more competitive, with an overall decrease in number of species. Here, the number of densospore-producing plants increased, as the water table rose and the area became more brackish. The apparently anomalous presence of the *Densosporites oblatus* assemblage in Zone II at Station 9, and increase in number of densospores at Station 7, may reflect the presence of a tongue of the marine embayment, or more brackish estuary extending northward. In the modern swamps of the Everglades region of southern Florida, the salinity tolerant red mangrove (*Rhizophora mangle L.*) extends up the banks of the lower reaches of the Shark River into areas containing less-brackish waters (Spackman and Dolsen 1962).

That the influence of the subsiding basin was little felt in the initial stages of peat accumulation is attested by the extensive distribution of the Lycospora-Guthoerlisporites erectus and to a lesser degree Thymospora pseudothiesseni assemblages in the lower zones of the seam. Factors introduced with the advent of the marine embayment are recorded as having begun to affect the coal-swamp complex during the time of the Thymospora pseudothiesseni assemblage, although it would have become intensive in the next higher

zones. It is quite possible, of course, that the basin was actively subsiding during the initial stages also, but without presenting evidence into the spore-pollen record.

Immediately prior to, or at the very beginning of, peat formation in the swamp environment, the area was clothed with a gymnospermous (i.e. Alisporites, Pityosporites, Complexisporites, Wilsonites, Guthoerlisporites, and Potonieisporites) and endosporitid—lycopod forest. The gymnospermous genera may instead represent the allochthonous elements of extra-swamp ('highland') plant communities; restricted occurrence to the lowermost portions of the seam appears to obviate this alternative, however.

In Great Britain, Smith (1963, 1964) found no apparent relationship between coal seams containing *Densosporites*-rich assemblages and the facies of the overlying shales. He suggested instead, that the sequence of assemblages culminating in one containing abundant *Densosporites* represent a succession of hydrological units in a stable environment, and that the *Densosporites*-rich assemblage may have formed partially under subaerial conditions. This is difficult to envisage for the Lower Kittanning seam, where in places marine beds rest directly on the coal.

BIOSTRATIGRAPHICAL IMPLICATIONS

The detailed description of spore and pollen assemblages in the coal seams of western Pennsylvania may well lead to a more meaningful biostratigraphical zonation of the Pennsylvanian rocks of the eastern United States, on the basis of paleoecological interpretations. Similarly conducted palynological investigations of several other coal horizons (e.g. Brookville and Lower Clarion seams by Frederiksen 1961; Upper Freeport and Redstone seams, unpublished work by the author) have demonstrated the occurrence of spore and pollen assemblages and/or assemblage sequences unique to each seam. As a result, two broad categories of assemblages could be established, according to the position of the seams in marine and non-marine stratigraphical sections.

This type of palynological investigation also brings to light the significance of the less abundant but nevertheless persistent spore–pollen species, which are of importance for the determination of more accurate stratigraphical ranges.

Acknowledgements. The author is deeply indebted to Dr. William Spackman, Professor of Paleobotany at the Pennsylvania State University, for his supervision of this study. He provided all facilities necessary for its completion. Gratitude is also extended to Dr. William G. Chaloner of University College, London, for his helpful criticisms, and to Dr. Eugene G. Williams of the Pennsylvania State University, for pointing out many of the sampled localities.

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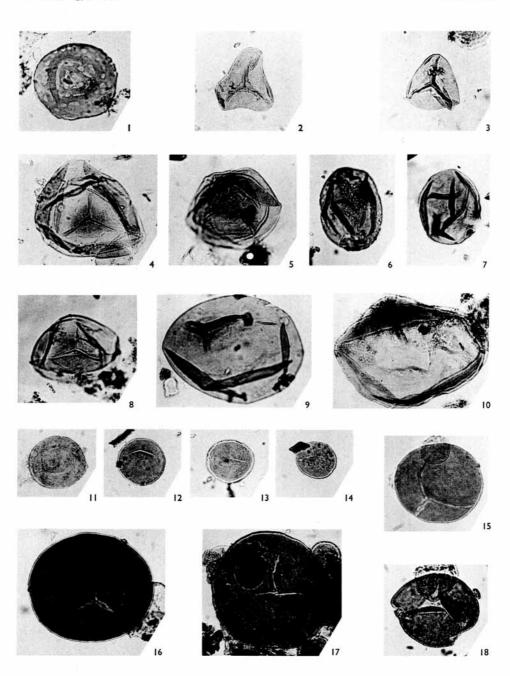
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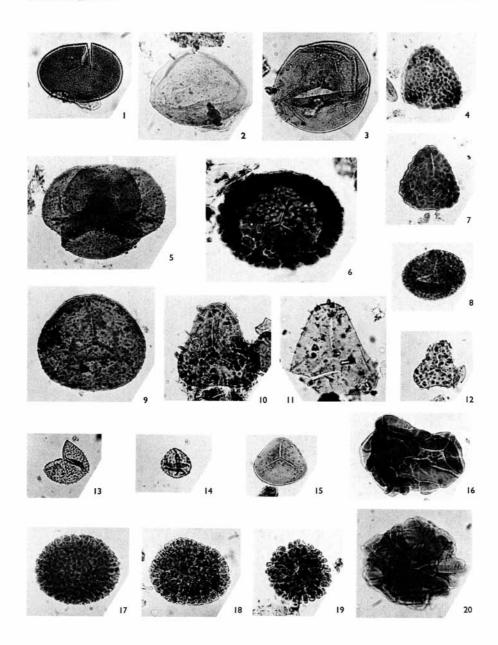
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D. HABIB Department of Geology and Geography, Queens College, Flushing, New York 11367, U.S.A.

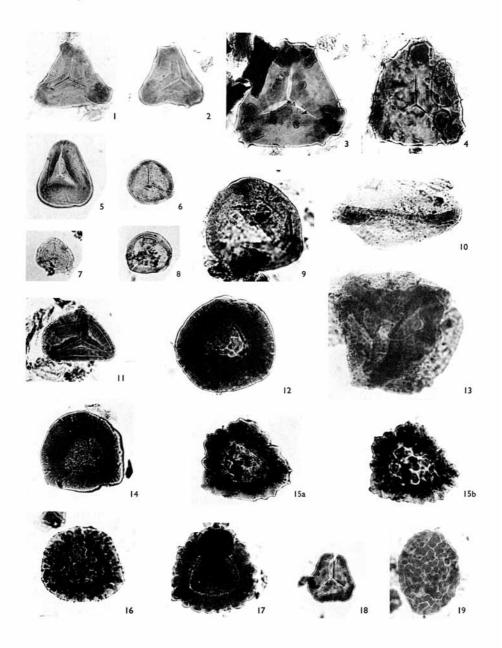
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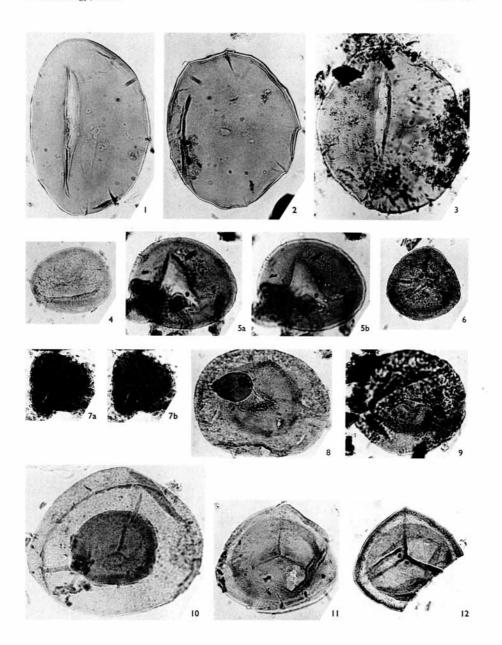
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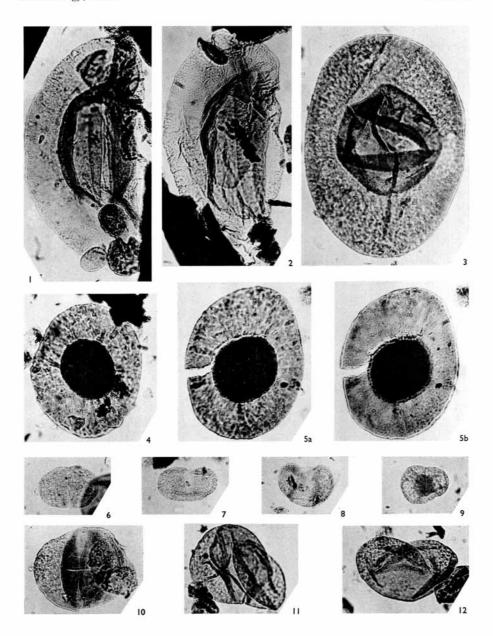
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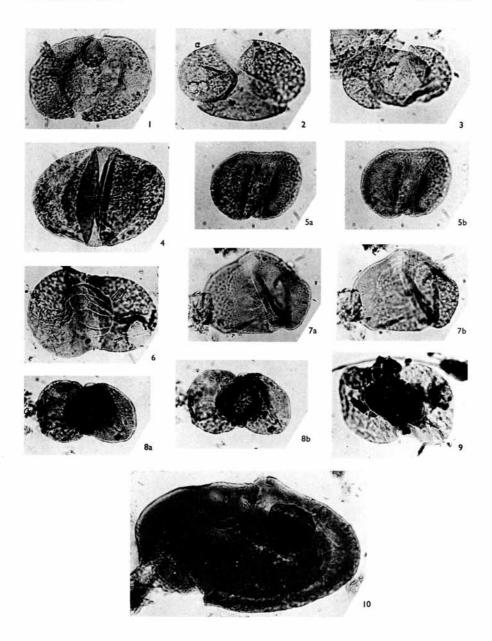
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