NAMURIAN PLANT SPORES FROM THE
SOUTHERN PENNINES, ENGLAND

by R. NEVES

ABSTRACT. Selected fossil spores from coals and carbonaceous shales of Namurian age from the Southern Pennines area of England are described, and their stratigraphic ranges given with reference to the standard sequence of gymnosperm stages. The types of sediment in which the spores are found are recorded, and the apparent association of certain spore types with particular sediments is discussed. Two new series of fossil spores are proposed—Pseudointerites and Membranites; two new genera—Soessia and Hymenospora—and twenty-seven new species are described and illustrated. Disciate pollen grains of the Ptyeisporites-Vesticeps type are recorded for the first time from strata of Namurian age.

The value of fossil plant spores for purposes of coal-seam correlation has been adequately demonstrated by Kosanke (1950), Balme and Butterworth (1952), and Butterworth and Millott (1954 and 1955). These authors were concerned with typical coal-measures sequences in which the coal seams form a prominent lithological constituent. In other sedimentary successions, however, coal seams are often absent or, if present, are of spasmodic occurrence and limited areal extent. Such is the case in the Namurian succession of the Southern Pennines area of England, where carbonaceous shales provide the most readily available source of fossil spores. The spore assemblages obtained from the thin coals are used to supplement the data obtained from studies of the shales.

Hoffmeister, Staplin, and Malloy (1955) and Neves (1958) have already indicated that the types of spores present and their relative abundance differ considerably in coal seams and closely allied carbonaceous shales. Such an occurrence is to be expected, in that the spores obtained from coals will mainly represent a parent vegetation which, although rich in constituent members, is of a somewhat restricted and specialized nature; the vegetation consisting of plants which are adapted to the swamp environment. It is probable, therefore, that certain spore types produced by a vegetation which existed outside the coal swamps will not be represented in the coal-seam assemblages. However, should some of these spores have been carried into the swamp region by wind or water agencies, their presence will be masked to the observer, by the profusion of spore types dispersed more or less in situ from the local swamp vegetation. The allochthonous nature of the shales, on the other hand, implies that the contained fossil spores will be derived from a variety of parent plant associations occupying various ecological stations. The assemblages preserved in shales will be representative of the vegetation which was growing in and around the basin of sedimentation. Consequently the complete microflora and the absolute time ranges of the component forms can only be obtained by an examination of all those sedimentary types which make up the geological succession of the region. In this way the succession of coal swamp vegetations, as represented by the coal seams, will be determined and the characteristics of other contemporaneous vegetation established. The sum total of this combined evidence enables a closer appreciation of the flora to be achieved, and this appears to be an essential criterion in the utilization of microfossil evidence to the problems of stratal subdivision.

In the present paper, certain new spores are described from coals and shales of Namurian age from the Southern Pennines area of England. The stratigraphical occurrences of these spores in this region, together with several already described species, have been recorded and are shown in Table 1. These spores have been selected on account of their value as stratigraphic indicators and represent a small part of the total Namurian microflora. The sequence of goniatite stages, which is used as the basis for Table 1, is that proposed by Bisat (1928, p. 117) and subsequently redefined by Hudson and Cotton (1943, p. 152).

The majority of the samples used during the investigation were collected by the author from outcrop and mine exposures which are described in literature and are listed below. Other samples were kindly provided by Dr. R. M. C. Eagar from the Wigan district in the west of the region. A sketch map of the region (text-fig. 1) indicates sample localities and the outcrop of the Namurian measures.

Stratigraphy and palaeogeography. The Southern Pennines area of the Central Province of England, comprising parts of Yorkshire, Lancashire, Derbyshire, Cheshire, and Staffordshire, was a region of general subsidence throughout Upper Carboniferous
times. The basin of sedimentation was bounded to the south by the land mass of St. George's Land and to the north by the Lake District and Southern Uplands massifs. Within the basin, the areas of maximum subsidence and sedimentation were not constant so that locally non-sequences and even unconformities are present at the base of the Namurian successions.

The stratigraphical succession of the region, based mainly on the genitalic faunas contained in the marine shales, has been thoroughly established through the work of Bisat (1928), Bisat and Hudson (1943), Hudson and Cotton (1943, 1945), Jackson (1927), Hester (1932), Cope (1945), and Trotter (1951). In general, the lower stages of the Namurian, when present, consist of marine, argillaceous deposits interleaved with thin, sandy horizons or crowstones. The younger Namurian measures are characterized by an increased arenaceous component which takes the form of thick, lenticular beds of sandstone and gritstone, such as the Kinderscout Grit series. Observations on current bedding carried out by Gilligan (1920) in the northern areas and the author in the southern parts of the basin indicate that the arenaceous material was derived both from the north and south respectively. Sometimes associated with the sandy horizons are thin coals and bluish grey, non-marine shales, which give rise to a primitive form of rhythmic sedimentation of the coal-measure type in the higher Namurian stages.

List of sample localities and horizons examined. The locality numbers correspond to those used in text

1. Exposure in lane leading to Limekiln Farm, near Congleton, Staffordshire (G.R. SJ. 861591). Astbury Coal, Pendleian stage.
   Grey Non-marine shales.
   Marine shale with *Gastrioceras subereanum*.
   Non-marine shale with *Carbouicola exporrecta*.
   Marine shale with *Gastrioceras cancellatum*.
   Non-marine shale with *Carbouicola exporrecta*.
Marine shale with *Gastroceras umbriense*.
Marine shale with *Gastroceras cancellatum*.
   Horizons: Marine shale with *Gastroceras suberexum*.
   Pot Clay Coal and non-marine roof shales.

Previous palynological literature. Literature dealing with Namurian plant spores is available from several continents. Lubert and Waltz (1938) described Lower Carboniferous assemblages from the Moscow and Karaganda Basins of the U.S.S.R.; Iochenko (1952, 1956, and 1958) published his work on the fossil plant spores from coals of the Donetz and Dnieper Basins; Horst (1955) dealt with the Namurian spores of Upper Silesia and in 1957 Dybova and Jachowicz gave a further account of Upper Carboniferous spores from this region; Artuz (1957, 1959) described the spore assemblages of three coal seams of Namurian and Lower Westphalian A age, from the Zonguldak Coalfield of Turkey. Hoffmeister, Staplin, and Malloy (1955) gave the results of an investigation into the plant spore assemblages contained in coals and shales of Upper Mississippian age from Illinois and Kentucky, U.S.A. In Britain, Millott (1939) considered briefly the fossil spores found in certain coal seams of Namurian age from north Staffordshire; Knox (1942) and Butterworth and Williams (1958) investigated the small spore content of coal seams of Namurian A age in the Limestone Coal Group and the Upper Limestone Group of Scotland. The present author (Neves, 1958) gave a preliminary account of an investigation into the plant spore content of coals and associated carbonaceous shales from the Central Province of England. Most authors, however, have been concerned with the small spore assemblages present in coal seams, with little attention being directed to the spore content of shales. Furthermore, the stratigraphical occurrences of the various spore types are rarely referred directly to the established sequence of goniatite zones.

Maceration techniques. The various methods which have been employed for the isolation of organic remains from coals and shales have been fully described elsewhere by several authors. The technique used throughout the present work relies on Schulze solution to oxidize the humic matter which is in close association with the plant tissues. The oxidized products were then removed in a dilute solution of potassium hydroxide. The mineral matter of the shales is eliminated by digestion in hot hydrofluoric acid following an initial treatment with bromine to break the shale down. The details of the technique are more fully described in Neves (1958).

**SYSTEMATIC PALÆONTOLOGY**

The system proposed by Potonié and Kremp (1954) for the description and classification of the fossil dispersed spores is used in this account. Slight modifications are introduced
where it is considered to be of practical advantage in light of additional information. Two new Series, Pseudoeingulati and Membranati, are erected to accommodate newly described spore types. Two new genera, Secarispores and Hymenospora, are described and illustrated together with new species of the following genera: Leiostroites, Punctatisporites, Acanthotreites, Ibrahimisporites, Neusistrickia, Mooreisporites, Camptotreites, Dictyotreites, Convolisporites, Secarispores, Abrenisporites, Triquinsites, Dansisporites, Knoxispores, Stenozostotreites, Cirratiradiites, Propisporites, and Thollisporites. As a result of observations made during the course of the present investigation, the genus Knoxispores Potonié and Kremp 1954 is here transferred to the Series Cingulati. Details of occurrence are given in Table 1 or in the text.

All slides referred to in the text are lodged in the Micropalaeontology Laboratory, Department of Geology, University of Sheffield.

Division sporites H. Potonié 1893
Group triletes Reinsch 1881
Subgroup azonototreites Luber 1935
Series laevigati (Bennie and Kidston) Potonié 1956
Genus leiostroites (Naumova) Potonié and Kremp 1954
Type species. L. sphaeroconus (Loose) Potonié and Kremp 1954

Leiostroites densus sp. nov.
Plate 30, figs. 1, 2

Holotype. Plate 30, fig. 1.

Type locality. Non-marine roof shales of the Pot Clay Coal, Langsett, Yorkshire (Loc. 16). Yeadonian stage.

Diagnosis. Size range 85–110 μ (fifteen specimens measured), holotype 96 μ; equatorial outline triangular; trilete rays three-quarters radius of the spore; exine dense and thick.

Description. Colour dark brown. Equatorial outline triangular, sides straight to slightly convex, apices broadly rounded. Trilete rays prominent, lips thin, sutures usually closed. Exine thick, laevigate to faintly infrapunctate.

Comparison. The compact triangular shape, longer trilete rays, and the absence of a darkened contact region distinguish these spores from those of the species L. grunds (Kosanke) Bhardwaj 1957.


Genus punctatisporites (Ibrahim) Potonié and Kremp 1954
Type species. P. punctatus Ibrahim 1933

Punctatisporites pseudopunctatus sp. nov.
Plate 30, fig. 3

Holotype. Plate 30, fig. 3.

Type locality. Non-marine shale with Carbonicola exparrecta, Hipper Sick, Derbyshire (Loc. 11). Yeadonian stage.
Diagnosis. Size range 90–120 μ (nineteen specimens measured), holotype 116 μ; equatorial outline subcircular; trilete rays short, approximately half spore radius; exine strongly and densely infrapunctate.

Description. Colour light brown to yellow. Tecta of the tetrad mark tapering, lips often associated with small folds. At the margin of the compressed spores a narrow ‘rim’, 2–3 μ wide, is present. The inner line of the ‘rim’, corresponding to the intine membrane, clearly shows the infra-punctate nature of the exine. Outline smooth. Small secondary folds of the exine occur infrequently.

Comparison. The spores of this species are slightly larger than those of P. aerarius-Butterworth and Williams 1958, and the structure of the exine is much stronger. P. grandis and P. pseudolevatus Hoffmeister, Staplin, and Malloy 1955 differ in possessing a positive surface ornamentation.

Occurrence. Namurian A and C; sometimes common, particularly in marine shales.

*Punctatisporites giganteus* sp. nov.

Plate 30, fig. 4

Holotype. Plate 30, fig. 4.

Type locality. Marine shale with *Eumorphoceras bisulcatum* Girly, Bagnall, Staffordshire (Loc. 2), Arnsbergian stage.

Diagnosis. Size range 150–170 μ (ten specimens measured), holotype 158 μ; equatorial outline subcircular to subtriangular; trilete rays two-thirds to three-quarters radius of the spore; exine keieginate to strongly infrapunctate.

Description. Colour yellow-brown; exine 2–3 μ thick, margin smooth, occasional secondary folds. Trilete rays distinct; lips thin, subparallel to tapering.

Comparison. *P. obesus* (Loose) Potonié and Kremp is smaller.


*Punctatisporites* (*Sinusporites*) *sinnatus* (Artuz) comb. nov.

1958 *Punctatisporites densivacuatus* Neves; p. 6, pl. ii, fig. 7.
1958 *Punctatisporites coroninus* Butterworth and Williams; p. 360, pl. i, fig. 12.

Remarks. *Sinusporites sinnatus* was described by Artuz (1957, p. 254) as possessing a variably thickened exine and a ‘Gurtelzone’. Neves (1958, p. 6) and Butterworth and Williams (1958, p. 360) described this structure as simple exinous folding. The material examined by the current author clearly shows all stages in the development of the pronounced curving fold as seen in the holotype (Artuz 1957, pl. 7, fig. 48), from simple.

**EXPLANATION OF PLATE 30**

All magnifications ×500.

Figs. 1–2. *Leiotrichites densus* sp. nov. Slide ref. s.Z. 1, holotype, 96 μ. 2, 96 μ.

Fig. 3. *Punctatisporites pseudopunctatus* sp. nov., holotype, 116 μ. Slide ref. s.H.

Fig. 4. *Punctatisporites giganteus* sp. nov., holotype, 158 μ. Slide ref. s.B.

Fig. 5. *Acanthotrichites sternidius* sp. nov., holotype, distal surface, 165 μ. Slide ref. 5.26181B.

Figs. 6–7. *Acanthotrichites? pilus* sp. nov. 6, holotype, 69 μ. 7, 84 μ. Slide ref. s.E.
small amplitude folds of the exine. Since these structures are clearly secondary effects it is proposed to transfer the species S. simianus Artuz to the genus Punctatisporites.


Series APICULATI (Bennie and Kidston) Potonié 1956
Genus APICULATISPORIS Potonié and Kremp 1956

_Type species._ A. aculeatus (Ibrahim) Potonié and Kremp 1954

_Apiculatisporis maculosus_ (Knox) Potonié and Kremp 1955

Occurrence. Lower Namurian A, rare. Butterworth and Williams (1958) recorded this species from the Namurian A measures of Scotland.

Genus ACANTHOIRILETES (Naumova) Potonié and Kremp 1954

_Type species._ A. ciliatus (Knox) Potonié and Kremp 1954

_Acanthoiriletes splendidus_ sp. nov.

_Holotype._ Plate 30, fig. 5.
_Type locality._ Marine shale with Anthracoceras paucihorn, Hollywood Dingle, Staffordshire (Loc. 3), Amsbergian stage.

_Diagnosis._ Size range 90–110 μ (ten specimens measured), holotype 105 μ; equatorial outline triangular; trilete rays two-thirds spore radius; exine ornamented with slender, broad-based spines; thirty to fifty spines overtop the equatorial margin.

_Description._ Colour light brown. Equatorial outline triangular, sides concave, apices rounded. Trilete rays with narrow lips, sutures sometimes open. The spines which ornament the exine are 2–10 μ high, and 2–4 μ wide at the base. The spines are not densely spaced and there is room between them for elements of equal size. Exine between spines laevigate.

_Comparison._ These spores are characterized by their large size and the ornament of slender spines. _Acanthoiriletes horridus_ Hacquebard 1957 is larger and possesses stronger more densely spaced spines.


_Acanthoiriletes? pilus_ sp. nov.

_Holotype._ Plate 30, figs. 6, 7.
_Type locality._ Marine shale with Gastroceras cancellatum, Hipper Siek, Derbyshire (Loc. 12), Yeadonian stage.

_Diagnosis._ Size range 50–90 μ (twenty specimens measured), holotype 84 μ; equatorial outline rounded triangular; trilete rays two-thirds to three-quarters radius of the spore; exine densely covered by short, slender, ‘mushroom’-topped pila.
Description. Colour light brown to yellow. Original shape + globular, and the spores are often compressed obliquely with no preferred orientation. Trilete rays straight, tecta slightly tapering, lips thin. Exine 2 µ thick, decorated by closely spaced, discrete pila the tips of which are expanded to a mushroom form; height 2-3 µ, width at base 0.5-1 µ.

Comparison. Acanthotrilites (Azonotrilites) multisetosus (Luber and Waltz) Potonié and Kremp 1955 is superficially similar to A? pilus. However, the spores of the former species are rounded to oval in outline and the ornament consists of essentially parallel-sided spines.

Occurrence. Namurian C; this species has been recorded only from the type horizon.

Acanthotrilites baculatus sp. nov.

Holotype. Plate 31, fig. 1.

Type locality. Marine shale with Hudsomoceras proteus, Congleton Edge ganister quarry, Staffordshire (Loc. 4). Sabdenian stage.

Diagnosis. Size range 34-45 µ (fifteen specimens measured), holotype 34 µ; equatorial outline triangular; trilete rays two-thirds radius of the spores; exine beset with upstanding blunted spines; fifteen to twenty elements occur at the equatorial margin.

Description. Colour pale yellowish-brown. Equatorial outline triangular, sides concave, apices rounded. Rays of the trilete mark simple, often obscured by the ornamentation elements which consist of relatively long, in part parallel sided, and terminally truncate spines; height 4-10 µ, width 1-2/5 µ. The spines are not densely set and between them the exine is lacivigate.

Comparison. Acanthotrilites falcatus has stouter, cone-like spines which are closely spaced; in A. castaneus the spines are uniformly tapering and more densely set.


Genus IBRAHIMISPORES Artuz 1957

Type species. I. microhorridus Artuz 1957

Ibrahimispores brevispinosus sp. nov.

Holotype. Plate 31, fig. 2.

EXPLANATION OF PLATE 31

All magnifications x 500.

Fig. 1. Acanthotrilites baculatus sp. nov., holotype, 34 µ, distal view. Slide ref. 1.302744.

Fig. 2. Ibrahimispores brevispinosus sp. nov., holotype, 80 µ, distal view. Slide ref. s.Y.

Fig. 3. Ibrahimispores magnificus sp. nov., holotype, 81 µ, distal view. Slide ref. s.Ao.

Fig. 4. Neuroastrickia inconstantis sp. nov., holotype, 71 µ, distal view. Slide ref. 1.285759.

Fig. 5. Mooreispores trigilaris sp. nov., holotype, 77 µ, distal view. Slide ref. s.T.

Fig. 6. Mooreispores fastis Neves, distal view, 75 µ.

Fig. 7. Mooreispores bellus sp. nov., holotype, 105 µ, distal view. Slide ref. s.E.

Fig. 8. Mooreispores superfhus sp. nov., holotype, 119 µ, proximo-lateral view focus low on ornament. Slide ref. 3.240769.
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Type locality. Non-marine shales with Carbonicola expursecta, Hipper Sike, Derbyshire (Loc. 11). Yeovilian stage.

Diagnosis. Size range 70–100 µ (fifteen specimens measured), holotype 80 µ; equatorial outline rounded-triangular; exine ornamented with stout, hollow pointed spines which are thickened at the tips.

Description. Colour yellow-brown to brown. Equatorial outline rounded-triangular to subcircular. The rays of the trilete mark are usually associated with dark, flexuous folds of the exine; approximately three-quarters radius of the spores. The ornamentation elements are short, hollow spines, ± uniformly tapering to the sharply pointed, solid tip. Spines 6–10 µ high, 3–5 µ wide at the base and are densely spaced; forty to fifty elements occur at the equatorial outline.

Comparison. I. microborrida Artuz is more circular in outline and the spines appear to be solid and without thickened tips.

Ibrahimisporis magnificus sp. nov.

Plate 31, fig. 3.

Type locality. Non-marine shale with Carbonicola expursecta, Hipper Sike, Derbyshire (Loc. 11). Yeovilian stage.

Diagnosis. Size range 75–90 µ (ten specimens measured), holotype 81 µ; equatorial outline rounded-triangular, sides convex, apices broadly rounded; trilete mark often obscured by dark flexuous folds of the exine. Exine beset with long, hollow pointed spines; fifteen to twenty elements occur at the equatorial margin.

Description. Colour light brown. The large spines which decorate the exine are not densely set and elements of equal size could be placed between them. Spines 15–20 µ high, 3–8 µ wide at the base. The tips of the spines are solid and appear as darker, conical terminations; bifurcation of the spines is infrequently seen. Exine infra-punctate between the spines.

Comparison. I. magnificus is probably closely related to I. brevispinosus. However, on account of the recognizable difference in size and disposition of the ornamentation elements, it proposed as a new species.

Occurrence. Namurian C, rare.

Genus Neoraistrickia Polonié 1956

Type species. N. truncata (Cookson) Polonié

Neoraistrickia inconstans sp. nov.

Plate 31, fig. 4

Type locality. Marine shale with Hudsomoceras proteus, Congleton Edge ganister quarry, Staffordshire (Loc. 4). Sabdenian stage.

Diagnosis. Size range 55–75 µ (twenty specimens measured), holotype 71 µ; equatorial
outline triangular, sides concave to straight, apices rounded. Trilete rays two-thirds spore radius. Distal surface and proximal surface decorated with short baculae.

Description. Colour light brown. Trilete rays distinct, tecta straight, lips thin. Exine laevigate between ornamentation elements. The baculae which are present on the distal surface of the spores are 3–8 μ wide, 2–4 μ wide, parallel-sided elements; interspersed between these are small, blunt conical projections. The ornamentation encroaches on to the proximal surface of the spores, particularly in the region of the spore body apices. Whilst the latter radial regions may be densely ornamented, the inter-radial margin is often devoid of projections.

Comparison. The triangular equatorial outline and the baculose ornamentation are typical of the genus Neoraistriktia.


Genus Mooreisporeites Neves 1958

Type species. M. fastis Neves 1958

Mooreisporeites trigallerus sp. nov.

Plate 31, fig. 5

Holotype. Plate 31, fig. 5.

Type locality. Marine shale with Hudsonoceras protum, Congleton Edge ganister quarry, Staffordshire (Loc. 4). Subenian stage.

Diagnosis. Size range 55–80 μ (thirty specimens measured), holotype 77 μ; equatorial outline triangular; trilete rays short, half radius of the spore; apices of spore body ornamented with short, fused baculae.

Description. Colour light brown, apical ornament darker. Equatorial outline triangular, sides straight, apices expanded due to the projecting baculae. Trilete rays short, lips thin, suture narrow. Exine ornamented overall with small, scattered coni. At the apices of the spore body short baculae are developed, size 8–10 μ high; these elements are often fused laterally in the lower part.

Comparison. Triquartites trisulcis is similar but possesses a narrow equatorial cingulum (Horst 1955, p. 175); Triquartites lucidus Artuz 1957 is slightly larger and the rays of the trilete mark reach the margin of the spore body. Mooreisporeites fastis is characterized by heavy branching baculae both in the apical regions and also on the distal surface of the spores.

Remarks. Mooreisporeites trigallerus sp. nov. should not be placed in the genus Triquartites (Schenck) Potöné and Kremp 1954 since none of the specimens observed possesses the inter-radial, equatorial flange which is present in Triquartites venustus, the type species of the genus.

Occurrence. Namurian A, common at certain horizons.

Mooreisporeites fastis Neves 1958

Plate 31, fig. 6

Occurrence. Spores of this species first appear in the Upper Namurian A assemblages and are to be found in both shale and coal preparations.
Mooreisporetes bellus sp. nov.

Plate 31, fig. 7

Holotype. Plate 31, fig. 7.

Type locality. Baslow Coal, Stone Edge Quarry, Derbyshire (Loc. 9). Marsdenian stage.

Diagnosis. Size range 95–115 μ (fifteen specimens measured), holotype 105 μ; exine decorated with small scattered coni; apical regions with large, irregular patches of thickening and terminal baculae.

Description. Colour light brown, apical thickening dark brown. Trilete rays half radius of the spore body, suture and lips narrow. The large, bifurcating baculae, which project beyond the apical margins of the spores, arise from extensive, irregular patches of distal thickening. The latter often extend polewards on the distal surface. The baculae are 4–8 μ wide, of variable height and with partate terminations.

Comparison. M. bellus is characterized by spores of large size, possessing in the radial positions irregular patches of exinous thickening from which arise the squat baculae seen at the spore margin.

Genus VERRUCOSISPORITES (Ibrahim) Potonié and Kremp

Type species. V. verrucosa Ibrahim 1933

Remarks. The spores of this genus are very rare in the Namurian assemblages of the Central Province of England.

Verrucosisporites morulatus Knox 1950

Remarks. For description see Knox (1950) and Butterworth and Williams (1958 p. 62).

Occurrence. Lower Namurian A, rare. Butterworth and Williams (1958) found this species was confined to the Limestone Coal Group of Scotland.

Series MURORNATI Potonié and Kremp 1954

Genus CAMPTOTRILETES (Namaqua) Potonié and Kremp 1954

Camptotriletes superbus sp. nov.

Plate 31, fig. 8

Holotype. Plate 31, fig. 8.

Type locality. Pot Clay Coal, Holymoorside, Derbyshire (Loc. 13). Yeadonian stage.

Diagnosis. Size 75–125 μ (thirty specimens measured), holotype 119 μ; equatorial outline subcircular; trilete rays long, three-quarters radius of the spore, tecta sharp and tapering. Exine ornamented with irregular, disjointed, subconical ridges.

Description. Colour golden to reddish-brown. Spore margin overtopped by twenty to twenty-five rounded, conical processes. The discontinuous ridges which ornament the surface of the spores are 3–5 μ high and up to 25 μ long; and appear as a verrucose to
conate ornament in which the elements are connected laterally by irregular ridges. The ridges are separated by irregular regions of thinner, laevigate exine.

**Comparison.** The spores of this species are characterized by their large size and the variable nature of the rudimentary cristae.

**Occurrence.** Upper Namurian B-Westphalian A, common in certain coal-seam assemblages.

*Camptotrilites verrucosus* Butterworth and Williams 1958

**Occurrence.** Lower Namurian A, rare. The species was originally described from the Limestone Coal Group of Scotland.

**Genus** *Dictyotrilites* (Naumova) Potonié and Kremp 1954

*Type species.* *D. bifasciatus* (Ibrahim) Potonié and Kremp 1954

*Dictyotrilites tuberosus* sp. nov.

**Holotype.** Plate 32 fig. 1.

**Type locality.** Marine shale with *Hudsoneoceras proteus*, Congleton Edge ganister quarry, Staffordshire (Loc. 4), Subenian stage.

**Diagnosis.** Size range 90–120 μ (ten specimens measured), holotype 120 μ, equatorial outline subcircular to oval; exine decorated with very strong muri which appear as rounded elevations at the spore margin; the muri enclose seven to twelve large lacunae.

**Description.** Colour light brown, muri dark brown. Trilete rays three-quarters spore radius, lips often slightly thickened. The muri of the reticulum are heavy, solid walls, 5–10 μ wide at the base, 5–7 μ high, and rounded conical in profile. The lacunae enclosed by the muri are large and of variable shape.

**Comparison.** *Dictyotrilites* (Azoitotrilites) *subalbumaris* (Luber) Potonié and Kremp 1955 resembles *D. tuberosus* in the nature of the muri, however in the former species, there are many more lacunae present in the reticulum. The muri in *D. tuberosus* show no tendency for the membranous zone at the spore outline, a feature which characterizes the genus *Reticulatisporites*.

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**Explanation of Plate 32**

All magnifications × 500.

Fig. 1. *Dictyotrilites tuberosus* sp. nov., holotype, 120 μ, distal surface, focus low. Slide ref. S.A. 4.

Fig. 2. *Convolutispora* sp. A., distal view, 122 μ.

Fig. 3. *Convolutispora obliqua* sp. nov., holotype, 122 μ, focus low on ornament. Slide ref. 1,295827.

Figs. 4–5. *Convolutispora lamiospora* sp. nov. A, Holotype, 72 μ, distal view. Slide ref. 7,221665. 5, proximo-lateral view, 69 μ.

Figs. 6–7. *Securisporate lobatus* sp. nov. 6, Holotype, 81 μ, proximal view and low focus. Slide ref. 4, 175830. 7, Distal view, 89 μ.

Figs. 8–9. *S. remux* sp. nov. 8, Distal view, 48 μ, 9, Holotype, proximal view, 46 μ. Slide ref. 8,343708.

Fig. 10. *Arenisporites beckettensis* sp. nov., holotype, 56 μ, distal view, low focus. Slide ref. S.Z.

Fig. 11. *Arenisporites guercoceri* var. *ornatus* var. nov., holotype, 66 μ, distal surface. Slide ref. 4,296768.

Fig. 12. *Tigritrites nodosus* sp. nov., holotype, 88 μ. Slide ref. S.A.
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Dictyotriletes varloreticulatus Neves 1958


Genus Convoluitispora Hoffmeister, Staplin and Malloy 1955

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

Convoluitispora sp. A

Plate 32, fig. 2

Description. One specimen only, size 122 μ. Equatorial outline ± circular, margin sinuous to smoothly indented. Trilete rays three-quarters spore radius, sutures thin. Exine with broad anastomosing ridges, 6–10 μ wide, and which form an irregular reticulum when seen in high focus.

Comparison. The organization of the ridges is somewhat similar to that present in C. mellita Hoffmeister, Staplin, and Malloy.


Convoluitispora obliqua sp. nov.

Plate 32, fig. 3

Holotype. Plate 32, fig. 3.

Type locality. Marine shale with Lamathomoceras bisulcatum, Bagnall, Staffordshire (Loc. 2). Arnsbergian stage.

Diagnosis. Size range 100–130 μ (twenty specimens measured), holotype 122 μ; equatorial outline subcircular, spores usually compressed obliquely; exine with an ornament of long, anastomosing ridges, 2–5 μ high, 1–6 μ wide, and up to 25 μ long.

Description. Colour brown. Trilete rays two-thirds to three-quarters radius of the spores, slightly flexuous due to the ornament, suture and limbs narrow. The sinuous, anastomosing ridges appear at the spore margin as subconical processes with rounded or flattened crests. Between the ridges there appear narrow channels of thinner exine. Secondary folds of the exine are infrequently present.

Comparison. C. mellita and C. texellata are smaller, and the ridges in these species are shorter with less tendency for the linear disposition present in C. obliqua. C. flexuosa has flatter, more widely spaced ridges.

Convoluitispora laninosa sp. nov.

Plate 32, figs. 4, 5

Holotype. Pl. 32, fig. 4.

Type locality. Marine shale with Gastricoceras cancellatum, Hipper Sick, Derbyshire (Loc. 12). Yeadonian stage.

Diagnosis. Size range 50–80 μ (twenty specimens measured), holotype 72 μ; equatorial outline subcircular; exine characterized by broad regions of thickening which are sinuous in outline.
Description. Colour brown. Trilete rays hair-like, two-thirds to three-quarters radius of the spores. The exine of these spores bears extensive regions of thickening, between which narrow channels of thin exine are to be found. Locally the patches of thickening break up into broad, flat, ± linear ridges. Thickening 5-20 μ wide, length variable.

Comparison. In all other described species of Convolutispora the linear, sinuous ornamentation ridges predominate.

Occurrence. Namurian B-C, restricted to marine shale assemblages where the species is sometimes fairly common.

Genus Microreticulatisporites (Knox) Potonić and Kremp 1954
Type species: M. locomus (Ibrahim) Knox 1950

Microreticulatisporites concavus Butterworth and Williams 1958

Occurrence. Namurian A, rare and restricted to marine shale assemblages.

Series Pseudocingulati Ser. Nov.

This Series is proposed for those miospores in which the ornamentation of the exo-exine, large warts and lobate outgrowths, extends beyond the line of the spore body membrane (int-exine) in the equatorial region. The compressed spores are consequently characterized by a marked outer marginal rim which is deeply dissected and often discontinuous.

Comparison. Spores of the Series Membranati Ser. Nov. differ in that the exo-exine is membranous and encloses the spore body partially or completely, in the manner of a mantle.

Remarks. The outer zone of these spores is not a true cingulum in the sense of a continuous equatorial structure of the type present in Densosporites, Lycospora, &c. The peripheral zone in the Pseudocingulati arises as a result of the compression of upstanding ornamentation elements which overlap laterally at the spore margin.

Genus Seclarisporites Gen. Nov.

Type species: S. labatus sp. Nov.

Diagnosis. Trilete, iso- or microspores, equatorial outline subcircular, ovate to sub-triangular. The exo-exine is expanded into a series of lobate outgrowths which are of such dimensions as to give rise to an outer zone or pseudo-flange in the compressed spores. The outer zone is not continuous and deep indentations frequently occur between the bulbous lobes. The distal polar region of the spores is covered by an ornament of loosely spaced ridges and warts.

Remarks. The distal ornamentation found in some of these spores closely resembles that seen in spores of the genus Convolutispora Hoffmeister, Staplin, and Malloy 1955. However, the lateral overlap and fusion of the ornamentation elements in the region of
the equator give rise to the discontinuous peripheral rim which characterizes the spores of this genus. With careful focusing, the spore body outline can be distinguished as a sharp line of regular form, lying \( \pm \) concentric with the spore outline (Pl. 32, figs. 6 and 9). Hacquebard and Barss (1957, pl. vi, figs. 11, 12) illustrate Spore Type A, which closely resembles in structural organization spores which are here attributed to the genus *Secarispiorites*.

**Secarispiorites lobatus** sp. nov.

*Plate 32, figs. 6, 7*

*Holotype.* Plate 32, fig. 6.

*Type locality.* Marine shales with *Gastrocoelites cancellatum*, Hipper Sick, Derbyshire (Loc. 12). Yeadonian stage.

*Diagnosis.* Size range 55–85 \( \mu \) (twenty specimens measured) holotype 81 \( \mu \); equatorial outline subcircular, margin lobate and deeply incised; trilete rays thin, reaching to the inner limit of the peripheral zone.

*Description.* Colour medium to dark brown. Equatorial outline of the spore body rounded triangular to subcircular, outer margin of the enclosing rim is \( \pm \) conformable. The *'pseudoflange'* is composed of lobate outgrowths of the exine, which extend 10–18 \( \mu \) beyond the spore body wall. Between the rounded, in part overlapping, lobes the rim is deeply incised. The distal polar region is decorated with rounded thickenings and irregular, linear ridges.

*Comparison.* The spores of this species are characterized by the wide, dissected marginal...
rim. In Secarisporites remotus the rim consists of more widely spaced elements, and the spores are smaller.

_Secarisporites remotus_ sp. nov.

_Plate 32, figs. 8, 9_

_Holotype._ Plate 32, fig. 9.

_Type locality._ Non-marine roof shales of the Pot Clay Coal, Holmwood, Derbyshire (Loc. 14), Yeadonian stage.

_Diagnosis._ Size range 25–50 μ (fifteen specimens measured), holotype 46 μ; equatorial outline triangular, subcircular to ovate; exine ornamented with narrow ridges and small warts; outline of spore with rounded lobes of variable size.

_Description._ Colour brown. Trilete rays thin, reaching to the line of the spore body wall, often obscured by the ornamentation elements. The spore outline is strongly lobate with elements of variable size and lateral continuity, height 2–8 μ and up to 12 μ wide. Over the distal surface of the spores the ornamentation consists of narrow ridges and discrete wart-like thickenings.

_Comparison._ These spores are characterized by their small size, the variable size and often isolated nature of the peripheral lobes.

_Occurrence._ Upper Namurian B–Namurian C, rare.

Division ZONALES (Bennie and Kidston) Potonié 1956
Group AURITO TRILETES Potonié and Kremp 1954
Series AURICULATI (Schopf) Potonié and Kremp 1954
Genus Ahrensiisporites Potonié and Kremp 1954
_Type species._ A. guerickei (Horst) Potonié and Kremp 1954.

_Remarks._ Potonié (1956, p. 16) transferred the genus Ahrensiisporites to the Series Laevigati, Subdivision Azonotrites. Based on observations made during the present study, the current author retains the genus in the original supra-generic position suggested by Potonié and Kremp (1954, p. 155).

_Ahrensiisporites beccleynis_ sp. nov.

_Plate 32, fig. 10_

_Holotype._ Plate 32, fig. 10.

_Type locality._ Non-marine shales with Carbonicola exsorrecta, Hipper Sich, Derbyshire (Loc. 12), Yeadonian stage.

_Diagnosis._ Size range 45–60 μ (twenty specimens measured), holotype 56 μ; equatorial outline triangular, sides straight to slightly concave, apices rounded; kytome built up from a series of small, bluntly conical elements, which also occur scattered in the inter-radial regions.

_Description._ Colour golden-brown to brown. Exine laevigate between the ornamentation elements. Trilete mark simple, rays straight, three-quarters radius of the spores. Small blunted cones are serially arranged on the distal surface of the spores, giving rise to the characteristically dentate kytome. The elements are closely spaced and the bases are fused in part. Scattered cones are found also in the inter-radial regions.
Comparison. The presence of a composite kryptome, constructed from discrete, regularly arranged, small blunted cones, distinguishes the spores of this species. Little morphological variation has been observed in this species group.

Occurrence. Upper Namurian B–Namurian C appears to be more characteristic of non-marine shale assemblages.

*Ahrensisporites guerickei* Horst 1955

*Ahrensisporites guerickei* var. *oratus* nov.

Plate 32, fig. 11

**Holotype.** Plate 32, fig. 11.

**Type locality.** Marine shales with *Eumorphoceras binucleatum*, Bagnall, Staffordshire (Loc. 2), Arnsbergian stage.

**Diagnosis.** Size range 65–80 μ (twenty specimens measured), holotype 77 μ; equatorial outline triangular, sides straight or slightly convex, apices somewhat truncate; kryptome arise from strong folds of the exine of the distal surface; spore body decorated with irregularly, rounded thickenings.

**Description.** Colour yellow-brown, kryptome and exinous thickenings darker. Trilete rays simple, straight, three-quarters spore radius. The exine of the distal surface is ornamented with irregular thickenings of a wart-like nature. The kryptome is a more or less continuous, heavy wall which, when compressed beyond the outline of the spores, appears to be 7–10 μ high.

**Remarks.** A clearly defined group of spores, closely comparable to the holotype of *Ahrensisporites guerickei* figured by Horst (1955, pl. 7, fig. 28), appears in the upper part of the Marsdenian stage (Namurian B) and persists into the Westphalian measures of the English Central province. In addition, a variety of *A. guerickei* (designated above) possessing an ornamentation of irregular exinous thickenings similar to the forms figured by Horst (1955, pl. 7, fig. 61) and Butterworth and Williams (1958, pl. iii, fig. 18) has been found during the current study to persist throughout the Namurian succession from the Arnsbergian stage to the Lower Westphalian horizons.

Genus *Triquirittes* (Wilson and Coe) Potonié and Kremp 1954

*Type species.* *T. arenulatus* Wilson and Coe 1940

*Triquirittes nodosus* sp. nov.

Plate 32, fig. 12 and Plate 33, fig. 1

**Holotype.** Plate 32, fig. 12.

**Type locality.** Non-marine shale with *Carbonicola epoxrecta*, Hipper Sick, Derbyshire (Loc. 12), Yeadonian stage.

**Diagnosis.** Size range 80–95 μ (fifteen specimens measured), holotype 88 μ; equatorial outline triangular, sides straight to slightly convex, apices broadly rounded; valvae broad, protruding slightly at the equatorial margin; distal surface of the spores is ornamented by conical to wart-like elements.
Description. Colour light brown, valvae darker. Trilete rays two-thirds to three-quarters radius of the spores. The valvae are centrifugal thickenings of the exine in the radial positions, projecting 3–5 µ beyond the general equatorial outline. The margins of the valvae are somewhat angular and resemble the upper part of a partially opened fan, arising from the distal surface of the apices. Blunted cones and warts are dispersed randomly over the distal surface of the spores.

Comparison. The spores of this species are distinguished by their large size, the arcuate form of the valvae, and the nature of the distal ornamentation. *Triquirlites verrucosus* Alpern 1938 is smaller and is recorded from much higher horizons.

**Group Zonotriletes** Waltz 1935
**Series Cingulati** Potonié and Klaus 1954
**Genus Densosporites** (Berry) Potonié and Kremp 1954

**Type species.** *D. eovanis* Berry 1937

**Densosporites spinosus** Dybova and Jachowicz 1957

**Occurrence.** Namurian A–B, common in some marine shale and coal seam assemblages.

**Densosporites vulgaris** sp. nov.

Plate 33, fig. 2; text-fig. 3

**Holotype.** Plate 33, fig. 2.

**Type locality.** Pot Clay Coal, Holymoorside, Derbyshire (Loc. 13). Yeadonian stage.

**Diagnosis.** Size range 50–65 µ (twenty-five specimens measured), holotype 59 µ; equatorial outline rounded triangular; trilete rays thin, reaching almost to the spore body wall; contact region thickened; cingulum smooth with slight equatorial taper.

**Description.** Colour light brown to yellowish. Equatorial margin generally smooth, occasionally a few scattered coni may be present. The cingulum has a faint radial, fibrous structure, an ill-defined inner thickened zone and a gradual equatorial taper. Inner thickened zone one-quarter to one-third width of the cingulum and overlapping the spore body margin 2–3 µ, proximally. The proximal polar region bears a thickened contact area, the outer margin of which is concentric with the spore body outline and lies 4–7 µ nearer the proximal pole. The exine of the spore body is laevigate to faintly infra-punctate.

**Remarks.** The spores of this species are characterized by the thickened proximal polar region.

**Genus Knoxosporites** Potonié and Kremp 1954 emend.

**Type species.** *K. lugeni* Potonié and Kremp 1955.

**Emended diagnosis.** Trilete iso- or microspores with an equatorial cingulum which is of more or less uniform thickness throughout its width, possibly tapering slightly in the immediate vicinity of the equator. The distal hemisphere of the spores is characterized by a variable pattern of radial and/or concentric bands of thickening. The equatorial outline of the cingulum is more or less conformable to that of the spore body, only
departing from it locally where the fusion of radial elements and the equatorial girdle produces a swollen node of thickening. Small thickened lobes may project from the cingulum on to the proximal surface of the spore body.

Remarks. From a critical study of author's photographs and descriptions, it becomes apparent that the majority of spores allocated to the genus Knoxisporites Potonié and Kremp 1954 possess an equatorial extension of the exo-exine in the form of a cingulum. In the diagnosis of the type species, K. hageni Potonié and Kremp (1955, p. 116), the authors repeatedly refer to the presence of a cingulum. At the same time, the figure of the holotype (pl. 16, fig. 316) clearly shows the presence of a continuous equatorial girdle or cingulum. Similarly, Hoffmeister, Staplin, and Malloy (1955, p. 391), in considering K. tri radiatus, discuss the structure in terms of 'a central body' and an 'equatorial girdle'. Furthermore, whilst the disposition of the distal thickenings varies considerably in the species groups, the equatorial girdle remains a constant feature. It is not
a question of muri lying parallel with equator, as in Reticulatisporites, but of a definite equatorial structure, as was indeed suggested by Potonié and Kremp (1955) for the type species.

Since the presence of a cingulum has been used by Potonié and Kremp (1954) as the major criterion in the definition of the Series Cingulati, the genus Knoxisporites is here transferred to this Series.

Comparison. Sinozonotriletes is characterized by a triangular equatorial outline. Sinozonotriletes (Naumova) Haequebard 1957 has no thickened bars on the distal surface. Cladotriaspites Haequebard and Barss 1957 possesses a thickened equatorial girdle which partly overlaps the spore body polewards.

Knoxisporites distidius sp. nov.

Plate 33, figs. 4, 6; text-fig. 4

Holotype. Plate 33, fig. 4.

Type locality. Non-marine coal shales of the Pot Clay Coal, Holymoorside, Derbyshire (Loc. 13). Yeadonian stage.

Diagnosis. Size range 50-80 μ (twenty-five specimens measured), holotype 70 μ; equatorial outline somewhat hexagonal, margin slightly irregular; outline of the spore body rounded triangular; distal surface of the spores with a Y-shaped thickening, distal polar region unthickened.

Description. Colour yellow to brown. The hexagonal tendency of the equatorial outline is due to the prolongation of the radial bars of thickening on to the cingulum. Outline of the spore body clearly defined, rounded triangular. Trilete rays three-quarters radius of the spore body, lips thin. Cingulum fleshy, tapering only slightly towards the equatorial margin. The distal surface of the spores bears three radial bars of thickening which are rotated 60° relative to the rays of the trilete mark. The thickened bars unite over the distal surface of the spore body to enclose a circular to triangular region of unthickened exine at the distal pole. Subsidiary bars of thickening often appear proximally in the cingulum, opposite the ends of the trilete rays. Exine laevigate to infra-punctate.

Remarks. The spores of K. distidius are distinguished by the rounded triangular spore body, the slightly discordant fleshy cingulum, and the pattern of distal thickenings.


EXPLANATION OF PLATE 33

All magnifications × 500.

Fig. 1. Triquetrites wodousi sp. nov., 87 μ.

Fig. 2. Deaunotrites vulgaris sp. nov., holotype, 59 μ, proximal view. Slide ref. 9.177820.

Fig. 3. Cirtotriaspites erinatus sp. nov., holotype, 92 μ, distal view, low focus. Slide ref. 8.17.

Figs. 4, 6. Knoxisporites distidius sp. nov. 4, Holotype, 70 μ, distal view, low focus. Slide ref. 4.307719.

6. Distal view, 56 μ.

Fig. 5. K. senudiatus sp. nov., holotype, 88 μ, proximal view, low focus. Slide ref. 8.16.

Figs. 7-8. Sinozonotriletes triangular sp. nov. 7, Holotype, 77 μ, proximal view. Slide ref. 1.361656.

8. Proximal view, 65 μ.

Figs. 9-10. Proginotrites laevigatus sp. nov. 9, Holotype, 77 μ, distal view, low focus. Slide ref. 5.307770, 10, Proximal view, low focus, 101 μ.

Figs. 11-12. Hyemospora pallida sp. nov. 11, Holotype, 87 μ, distal view. Slide ref. 8.319715.

12, 74 μ.
TEXT-FIG. 4. Knoxispores distichus sp. nov. Diagrammatic reconstruction; a, elevation; b, distal polar view.

Knoxispores semiannulatus sp. nov.

Plate 33, fig. 5

*Holotype.* Plate 33, fig. 5.

*Type locality.* Non-marine shales with *Carbonicola exsiccata*, Hipper Sike, Derbyshire (Loc. 12). Yealdomen stage.
Diagnosis. Size range 60–105 μ (twenty specimens measured), holotype 88 μ; equatorial outline of the spore body subcircular; distal surface with tri-radial bars of thickening, rotated 60° relative to the trilete rays of the proximal surface; rays of the trilete mark with prominently thickened lips.

Description. Colour light brown. Outline of the spore body sharp; equatorial girdle is of uniform width. Trilete rays three-quarters radius of the spore body, tecta sharp and straight; lips associated with prominent bands of thickening, 5–7 μ wide, margin away from the suture often slightly undulating. Cingulum 6–14 μ wide. The Y-shaped bars of distal thickening, 6–10 μ wide, often persist into the cingulum. Exine faintly infra-punctate.

Comparison. Knoxisporites triradiatus is very similar, but the spores of that species lack the prominent thickenings which in K. seniradiatus are associated with the trilete rays.

Occurrence. Namurian B–C, rare.

**Genus stenozonotritelles (Naumova)** Hacquebard 1957

_Type species._ *S. conformis* Naumova 1953

*Stenozonotritelles triangularis* sp. nov.

_Holotype._ Plate 33, figs. 7, 8

_Type locality._ Marine shales with _Gastroceras cancellatum_, Hipper Siek, Derbyshire (Loc. 121). Yeadonian stage.

_Diagnosis._ Size range 60–80 μ (twenty-five specimens measured), holotype 77 μ; equatorial outline triangular, sides straight to slightly convex, apices rounded; equatorial girdle narrow, 4–8 μ wide, and smooth.

_Description._ Colour yellowish-brown. Trilete rays three-quarters radius of the spore body, lips often associated with small folds of the exine which taper towards the proximal pole; a darker contact region is often present. The equatorial girdle is of uniform width and possesses little or no equatorial taper. Exine laevigate to slightly infra-punctate.

_Comparison._ _Stenozonotritelles conspersus_ Naumova 1953 is of similar shape but is smaller.

**Genus crassispora** Bhardwaj 1957

_Type species._ *C. ovata* Bhardwaj 1957

*Crassispora kosankeei* (Potonié and Kremp) Bhardwaj 1957

_Occurrence._ Namurian B–Westphalian A, occasionally common in certain coal-seam and non-marine shale assemblages. The first appearance of this species can be correlated accurately with measures of Namurian B age.

_Series zonati_ Potonié and Kremp 1954

**Genus cirratriradites** Wilson and Coe 1940

_Type species._ *C. saturni* (Ibrahim) Schöpf, Wilson and Bentall 1944
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Cirratiradites ornatus sp. nov.

Plate 33, fig. 3

Holotype. Plate 33, fig. 3.
Type locality. Non-marine shale with Carbonicola exorrecosa, Hipper Sick, Derbyshire (Loc. 12), Yeadonian stage.
Diagnosis. Size range 80–110 μ (fifteen specimens measured), holotype 92 μ; equatorial outline rounded triangular; trilette rays are associated with long folds which extend on to the thin, fibrous zona; the whole of the distal surface of the spores is beset with dispersed coni.
Description. Colour light brown, zona pale yellow-brown. Exine of the spore body punctate; decorated on the distal surface with delicate cones and small spines. The zona has a radial fibrous appearance, width 14–20 μ. Where the zona passes over the spore body margin, a darker band, 7–10 μ wide, is present. No foveae are present.
Remarks. C. ornatus is distinguished by its large size, the ornamentation of the distal surface, and the lack of foveae.
Occurrence. Namurian C, present in non-marine shales only, rare.

Series MEMBRANATI SET. NOV.

This series is proposed for those trilette iso- or miospores in which the outer membrane of the exine, the exo-exine, has partially separated from the inner membrane or intine, and projects at the spore margin as a clear, thin membrane. The two membranes may be attached to one another only in the region of the trilette mark, or the exo-exine can be arranged as a series of folds which run over the surface of the spore body membrane.
Remarks. The infra-reticulate structure which characterizes the cavity between the spore body wall and the saccus membrane, in many forms attributed to the Division Saccit, is never present in the Series Membranati.

Genus PROPRIOSPORITES Neves 1958
Type species. P. rugosa Neves 1958

Propriosporites laevigatus sp. nov.

Plate 33, figs. 9, 10

Holotype. Plate 33, fig. 9.
Type locality. Marine shales with Hudanoicerat proteus, Congleton Edge ganister quarry, Staffordshire (Loc. 4), Salidonian stage.
Diagnosis. Size range 70–115 μ (fifteen specimens measured), holotype 77 μ; equatorial outline of the spore body rounded triangular; trilette rays three-quarters radius of the spore body; exo-exine translucent, laevigate and strongly folded over the laevigate spore body.
Description. Colour light brown; exine laevigate. Spore body compact, outline smooth and regular. The outer spore membrane is plicated into a series of sinuous folds which
run over the surface of the spore body. The folds in places lie parallel to the compressed spore margin, where they appear as membranous projections; they may also appear as subconical projections at the spore outline when the fold axis lies at an angle to the outline.

Comparison. The only other described species of this genus, *P. rugosus*, is distinguished by the strong punctuation of the spore body membrane.

Occurrence. Namurian A–B, more typical of the marine shale assemblages.

**Genus hymenospora gen. nov.**

*Text-fig. 5*

Type species. *H. palliata* sp. nov.

**Diagnosis.** Trilet iso- or microspores; equatorial outline circular to subcircular. The exo-exine is attached to the int-exine in the region of the trilet mark. In addition the exo-exine is deeply furrowed, and along the troughs of the furrows the two membranes are still in contact. In the compressed spores the exo-exine projects beyond the body margin as a laevigate, membranous zone.

Remarks. The zonate aspect of these spores is due entirely to the marginal projection of the exo-exine, and the outer zone is not necessarily in the equatorial position relative to the trilet mark, an essential character of the Series Cingulati and Zonati. The outer membrane, although detached for the greater part from the int-exine, is fairly rigid due to the subsidiary lines of adhesion along the furrows in the exo-exine.
Hymenospora palliolata sp. nov.

Plate 33, figs. 11, 12

Holotype. Plate 33, fig. 11.

Type locality. Marine shales with Gastroceras cancellatum, Crowborough Wood, Staffordshire (Loc. 10). Yealdonian stage.

Diagnosis. Size range 70–105 \( \mu \) (twenty specimens measured), holotype 87 \( \mu \); equatorial outline subcircular; trilete rays sharp, three-quarters radius of the spore body; exo-exine laevigate and crenulate.

Description. Colour of spore body light brown, outer membrane pale yellow; exine laevigate. Trilete rays three-quarters spore body radius, tecta tapering, lips thin. The mantle-like outer membrane is wrinkled into a series of narrow linear furrows, along which lines it is attached to the inner membrane. The two membranes are also in contact in the region of the trilete mark. In the compressed spores the exo-exine projects beyond the margin of the spore body as a more or less uniform rim with an outer crenulate border. An original globular form of these spores is indicated by the frequent oblique compression.

Comparison. Knox (1947, pl. 6, fig. 54) illustrates Spore Type 46K from the Limestone Coal Group of Scotland (Namurian A); this form closely resembles Hymenospora palliolata.


Series PATINATI Butterworth and Williams 1958
Genus THOLISPORITES Butterworth and Williams 1958

Type species. T. scoticus Butterworth and Williams 1958

THOLISPORITES biamulatus sp. nov.

Plate 34, fig. 2; text-fig. 6

Holotype. Plate 34, fig. 2.

Type locality. Marine shales with Eumorphoceras bisulcatum Girty, Bagnall, Staffordshire (Loc. 2). Arnsbergian stage.

Diagnosis. Size range 55–90 \( \mu \) (twenty specimens measured), holotype 80 \( \mu \); equatorial outline circular, spores commonly preserved in the lateral position; two raised bands of thickening encircle the spores subequatorially; a large circular patch of thickening is centred on the distal pole.

Description. Colour: thickening dark brown; remainder of the exine pale brown. Exine laevigate to faintly infra-punctate. The spores are usually compressed in the plane of the polar axis, indicating an original spherical to subspherical form. Trilete rays two-thirds radius of the spores. The exine bears two thickened bands, 7–20 \( \mu \) wide, which lie adjacent to the equator, displaced slightly on to the proximal and distal hemispheres. These annular bands are separated by a channel of thinner exine, which appears as a rounded depression at the spore margin. The distal polar region is contained within a broad, circular patch of thickening, up to 45 \( \mu \) in diameter, and which is separated from
the distal annular band by a narrow channel of thinner exine. The margins of all the thickenings are slightly wavy and thickened lenses may be present in the separating channels.

Remarks. These spores are tentatively referred to the genus *Tholisporites* since the thickening of the distal hemisphere is not complete.

**TEXT-FIG. 6. Tholisporites? binaulatus sp. nov. Diagrammatic lateral view.**

**Division Pollenites** R. Potonie 1931
**Group Sacciites** Erdtmann 1947
**Subgroup Monosacciites** (Chita) Potonie and Kremp 1954
**Series Extrornati** Butterworth and Williams 1958
**Genus Remysporites** Butterworth and Williams 1958

*Remysporites magnificus*
Plate 34, fig. 1

**Occurrence.** These distinctive spores are relatively rare in the Namurian measures of Central England, and appear to be restricted to assemblages of Namurian A age. Butterworth and Williams (1958) described this species from the Namurian A of Scotland. Horst (1955) first recorded spores of this type from the Namurian A of Upper Silesia and the Moravian Ostrau.

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**EXPLANATION OF PLATE 34**

All magnifications × 500.

Fig. 1. *Remysporites magnificus* (Horst) Butterworth and Williams 1958, 159 μ.
Fig. 2. *Tholisporites? binaulatus* sp. nov., holotype, 80 μ. Slide ref. 18.263816. Lateral view, common habit.
Fig. 3. Cf. *Pityosporites* sp., distal view, 105 μ.
Fig. 4. *Schopfipollenites elliptoides* (Ibrahim) Potonie and Kremp 1955, 188 μ.
Fig. 5. *Schopfipollenites elliptoides* var. corporeus var. nov., holotype, 168 μ. Slide ref. 4.236800.
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Genus GRANDISPOROA Hoffmeister, Staplin, and Malloy 1955

Type species. *G. spinosa* Hoffmeister, Staplin, and Malloy 1955

*Grandispora spinosa* Hoffmeister, Staplin, and Malloy 1955

Occurrence. Pendleian stage, Namurian A, rare. Hoffmeister, Staplin, and Malloy recorded this species from the Hardinsburg Formation of Illinois and Kentucky, U.S.A.

Series ALITESACCITI Leschik

Genus Florinites Schopf, Wilson, and Bentall 1944

Type species. *F. antiquus* Schopf, in Schopf, Wilson, and Bentall 1944

Remarks. The presence of large numbers of spores of the genus Florinites, particularly the species, *F. elegans*, *F. similis*, *F. visenda*, and *F. pumicosus*, has been found to characterize marine shale assemblages of miospores from the Central Province of England. The presence of these spores in assemblages of Namurian A age represents the earliest known occurrence of these monosaccate grains.

Subgroup DISACCITIS Cookson 1947

Genus Pityosporites (Seward) Potonié and Klaus 1954

Type species. *P. anureticus* Seward


Plate 34, fig. 3

Horizon. Marine shales with *Gastrioceras cancellatum*, Hipper Sick, Derbyshire (Loc. 12). Yeadonian stage, Namurian C.

Occurrence. Disaccate grains of the *Pityosporites–Vesicaspora* type are present as a minor constituent in shale assemblages at several horizons in the Yeadonian stage. This record represents the lowest horizon from which pollen grains of this type have been recorded.

Remarks. The absence of these grains in the coal-seam separations would seem to suggest that the parent plants, presumably Coniferales type, existed outside the coal-swamp regions. They were possibly associated with a marginal area of high land, as was suggested for the South Wales occurrence by Williams (1955, p. 471).

Group PRAECOLPATES Potonié and Kremp 1954

Genus SCHOPFIPOLENITES Potonié and Kremp 1954

Type species. *S. ellipsoide* (Ibrahim) Potonié and Kremp 1955

*Schoepfipollenites ellipsoide* sensu stricto

Plate 34, fig. 4

Occurrence. Plant spores of this species occur in measures of Pendleian age and range spasmodically throughout the Namurian sequence examined, and into the Westphalian.
Schopfipollinutes ellipsoides var. corporeus var. nov.

Plate 34, fig. 5

Holotype. Plate 34, fig. 5.

Type locality, Pot Clay Coal, Consall, north Staffordshire (Loc. 15). Yeomanian stage.

Diagnosis. Size range 145–210 μ (twenty-five specimens measured), holotype 168 μ; equatorial outline oval; proximal surface with a narrow suture, characteristically bent about its middle point; distal surface bears two major longitudinal folds of the exo-exine; the inner spore membrane is preserved as a circular to ovate 'spore body'.

Description. Colour reddish-brown. Equatorial outline of the spore oval, that of the body is usually more circular. Exo-exine laevigate to faintly infra-punctate; spore body laevigate and strongly folded; the folds are arranged approximately transversely and longitudinally tending to form a more or less regular pattern. For the remainder these spores are comparable with Schopfipollinutes ellipsoides Potonié and Kremp (1955, p. 184).

Remarks. Schopf, Wilson, and Bentall (1944, p. 38), in a discussion of the genus Mono-
leles, refer to the 'endosporal membrane', which in certain specimens appeared as a ‘crumpled, translucent sack’. Although the authors gave no illustration, the structure described by them closely resembles that present in S. ellipsoides var. corporeus.

Occurrence. Namurian C; the spores of this variety are not restricted in occurrence to the same assemblages as S. ellipsoides.

DISTRIBUTION OF THE FOSSIL SPORES IN THE SEDIMENTS

Before it is possible to assess the stratigraphical value of the various spore types, it is necessary to consider the distribution of the spores in the different sedimentary types. Several authors (Hoffmeister, Staplin, and Malley 1955; Neves 1958; Staplin 1960) have already drawn attention to the quantitative and qualitative variations in the fossil spore content within a short sequence of sediments.

During the current investigation, similar observations have been made and the association of certain fossil spore species with particular sediments can be readily appreciated from Table 1. Many species have been recorded only from shale preparations and the majority of the newly described species fall into this latter category. For example, spores of the genera Ibreahispores, Propriosporites, and Hymenospora are restricted entirely to these allochthonous deposits. Furthermore, the species Acathoritiles bacalatus, A. splendidus, A.? pilae, Hymenospor apollinata, and Propriosporites rugatus are confined to the marine-shale assemblages. In contrast, other species transgress the 'facies boundaries' and are present in coal, non-marine shale, and marine-shale assemblages. Such species as Punctatisporites sinusus, Campiotritlices superbus, Mooreisporites fuscus, Secu-
risporites lobatus, Abrenisporites guerickei var. ornatus, Crassispora kowalczi, and Remnesporites magnificus could thus prove to be of value for wider correlation. The coal-seam assemblages are generally dominated by spores of the genera Lycospora and

| TABLE 1. Chart showing observed stratigraphical ranges of selected spore species in the Namurian of the Southern Pennines Basin. |
Densosporites which are found in association with Calamospora, Apiculatisporis, Cyclogranisporites, Athrenisporites, and Schulzospora. The marine-shale assemblages from thirty horizons examined have been found to be dominated by saccate spores, principally of the genus Florinites; the remainder of these assemblages is variable in the relative proportions of the various spore types present, although the genera Punctatisporites, Lophotrietes, Raistrickia, Convolisporis, and Auroraspores usually figure prominently.

It would appear probable that the spore assemblages of the coal seams and the marine shales are representative of two completely distinct plant associations. The autochthonous peat deposits, as represented by the coal seams, contain for the greater part the spores of lycopsods, calamites and pteridosperms, &c., which constituted the swamp vegetation. The widespread nature of the marine-shale deposits would necessitate the temporary withdrawal of the latter vegetation and the elimination of extensive coal swamps. Consequently, any vegetation existing on the land areas adjacent to the marine basin would automatically provide the majority of the dispersed spores entombed in the marine muds. An upland flora of the type suggested by Chaloner (1958, p. 261), clothing the St. George's Land mass to the south, forms an attractive hypothesis. The evidence for at least moderate relief in this massif can be seen in the coarse and often pebbly nature of the deltaic deposits which were swept northwards. These deposits now constitute prominent gristone horizons such as the Ashover and Belper grits in Derbyshire, and from which abundant current-direction data are available to indicate their southerly origin.

The intermixing of the two principal spore associations is to be found in the non-marine shales, which often occupy an intermediate stratigraphic position between the coal seam below and the marine shale above. The non-marine shales represent the initial aqueous inundation of the coal swamps and the establishment of mud flats and isolated lagoons within the sedimentary basin. In this way, any masking effect by the products of the swamp vegetation will be reduced, so permitting the spores of a marginal vegetation to play an increasing role in the assemblages. This is substantiated to some extent by the diversity of the spore content of the three sedimentary rock types. The calculated average numbers of genera and species recorded in the various assemblages during the present investigation are as follows:

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<th>Assemblage</th>
<th>Genera</th>
<th>Species</th>
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</thead>
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<tr>
<td>Marine shale</td>
<td>20</td>
<td>32</td>
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<tr>
<td>Non-marine shale</td>
<td>25</td>
<td>45</td>
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<tr>
<td>Coal</td>
<td>18</td>
<td>29</td>
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The wider diversity of morphological types present in the non-marine shale, together with the fact that these assemblages frequently contain many spore species in common with closely associated coals and marine sediments, is considered to indicate the intermixing of the two principal microfloras. Those spores which appear to be confined to the non-marine shale assemblages could be produced by plants capable of colonizing a wet, possibly brackish water environment.

In conclusion, it would appear to be essential to consider the microfloral remains from all sedimentary rock types available in order to achieve a more complete understanding of their distribution and also that of the parent plants. These studies will assist the observer to determine those spores which are sensitive to facies changes and are consequently of restricted value for the purpose of stratal subdivision.
STRATIGRAPHICAL APPLICATIONS

A general scheme for the stratigraphic subdivision of the Upper Carboniferous of the Midlands Coalfields proposed by Butterworth and Millott (1954) was based on the spore content of the coal seams. A sequence of microspore assemblages, S0 to S4 and transition zones, were defined by the occurrence of certain fossil spores with restricted stratigraphic ranges.

The Namurian spore assemblages of the Central Province fall entirely within the S0 assemblage of Butterworth and Millott. However, since the latter authors were dealing only with coal seams, it could be expected that an investigation of the carbonaceous shales would permit a finer accuracy in stratal subdivision. For the purpose of the present account certain useful spores, with restricted or characteristic ranges and those which are of interest on account of their geographical occurrence, have been extracted from the complete assemblages and are listed in Table 1.

Pendleian assemblages. These assemblages are characterized by little diversity in the spore types present, although some spores appear to be restricted to strata of this age in the southern part of the Central Province basin. Such spores are Apiculatisporis maculosus, Verrucosporites morulatus, Camptotriletes verrucosus, and Grandispora spinosa. In addition Avernesisporites guereicki var. ornatus, Reticulatisporites karadanianensis, Schulzea sp. occellata, Auroraspora selsoratus, Microsporites radiatus, &c., are present in these Lower Namurian assemblages. The presence of Floremites elegans, F. similis, and F. viscidus at these horizons represents the first record of these monosaccate grains in Namurian A assemblages. Unfortunately, due to the lack of information concerning the spore content of Lower Carboniferous sediments in this region, it is impossible at the present time to assess any change in the microflora at the base of the Namurian.

Arnbergian assemblages. A wide range of spore types has been obtained from samples of Arnbergian age, and many of the spores appear for the first time in this region. Whilst satisfactory preparations have not been forthcoming from the northern parts, those in the south and west have proved to be closely comparable in content. Convolutisporis is a common constituent, as are Florinites spp., Schulzea, Auroraspora, Callispores, Cyclogranispores, &c. Acanthotriletes splendidus, Proprisporites laviegatus, Hymenospora palliolata, Remispores magnificus, and Tholispores? bialulatus occur together in an association which seems to be diagnostic of this stage. Discerispores and Mooreispores are present in relatively small numbers at these horizons, whilst Alatisporites mahu appears for the first time, although infrequently.

Sabinian assemblages. In many respects these assemblages are comparable with those of the Arnbergian stage. Many species persist into the Sabinian; for example Acanthotriletes basilatus, Sinuosporites trilinatus Artuz, Ibradhini spores microhorridus Artuz, and Proprisporites laviegatus are usually to be found in these two stages, and in certain Sabinian assemblages exhibits a wide diversity of form. At the same time several new spore types appear, including Secarispores lobatus, Knoxispores dissidius, Reinschspora spectosa, and an undescribed species of Grandispora. Tholispores? bialulatus has not been recorded in these assemblages.

Kinderscoutian assemblages. These assemblages have been found to be relatively im-
poverished in the constituent spore types present, a feature which may be related to the widespread arenaceous facies which occurs throughout the region during this stage. In the lower horizons, the assemblages are closely comparable with those of the Sahdenian. _Densosporites spinatus_ is often quite common in these separations and forms approaching _Cristatisporites indignabunda_ represent a similar form in which the ornamentation of the flange (laterally fused spines) becomes more strongly developed. A few spore types appear for the first time and the two species _Crassispora kosaneki_ and _Knoxisporites seniradiatus_ are quite distinctive.

**Marsdenian assemblages.** Many spores make an initial appearance in the Marsdenian and persist through into the Westphalian assemblages. The former assemblages are easily distinguished, therefore, from those of the Namurian A and lower Namurian B. _Apiculatisporis_ is present and is characterized by a considerable variety of morphological types, of which _A. setulosa_ and _A. latigranifer_ are quite distinctive and become fairly common in the overlying Yeadonian stage. _Mooreispores bella_, _Campotrilites superbus_, and _Ailrenisporites beeleynensis_ are completely new types and become established forms in the Yeadonian assemblages. The genera _Arnatisporis_ Dybova and _Jachowicz_ and _Mooreispores_ occur commonly in the coal-seam assemblages of this stage.

**Yeadonian assemblages.** The Westphalian aspect of the spore assemblages, initiated in the Marsdenian stage, is developed further in the spore floras above the _Gastrioceras cancellatum_ marine band. The latter horizon has been found to contain a rich and varied association of spore types in the several localities from which the shales have been examined. The related occurrence of _Acanthotrilletes? pilus_, _Ibrahimispores magnificus_, _I. brevispinosus_, _Knoxisporites dissilius_, and _K. seniradiatus_ in an assemblage dominated by _Florinites_ appears to be typical of this horizon throughout the basin. In contrast, the overlying marine shales containing _Gastrioceras cambriense_ have yielded very poor spore assemblages from the four localities at which they were sampled. The succeeding sequence of sandstones, shales, and coals is characterized by a wide variety of spore types and the succession is distinguished by a specific morphological variation pattern shown by spores of the genus _Ailrenisporites_. The non-marine shales with _Carbamicola exorrecta_ contain a diverse assemblage of fossil spores in the extreme east of the region and extending to the extreme west, in the Wigan district. The occurrence of the alga, _Botryococcus brasili_, is a persistent feature of these shales.

The coal-seam and associated non-marine roof shales, found immediately below the _Gastrioceras suberenatum_ marine band, marks the first occasion on which the entire basin was colonized by a swamp vegetation. Based on the study of the fossil spore content of the coal seam it would appear that the vegetation was relatively uniform over the whole region. The assemblage is usually dominated by spores of the genus _Lyospora_, although locally the general _Calamospora_ and _Densosporites_ assume the dominant role. The Yeadonian assemblages as a whole are characterized by the following species in particular: _Campotrilites superbus_, _Dictyotrilites varioreticulatus_, _Ailrenisporites guerickei_ sensu stricto, _Densosporites vulgaris_, _Cirratiradles ornatus_, _Propriisporites rugosus_, _Schopfipollenites ellipsoides var. corporeus_. _Crassispora kosaneki_ is sometimes a common constituent of both non-marine shale and coal-seam assemblages, whilst the presence of discate pollen grains in the shales is of particular interest on account of their possible Coniferalean affinity.
Lower Westphalian A assemblages. Lying between the marine horizons of *Gastrioceras subrenatum* and *G. histrii* is a variable series of coal seams, sandstones, and shales which contain a microflora closely comparable in broad aspect to that of the Yeadonian stage of the Namurian. Immediately below the higher marine horizon, the Alton or Crabtree coal seam is persistent across the basin. Samples from this seam are characterized by an abundance of the species *Anulatisporites anulatus* and *Densoisporites spp.* In addition, typical spores of the genus *Triquitrites* appear strongly for the first time in the succession.

Conclusions. The observed stratigraphic ranges of the fossil spores shown on Table 1 implies a characteristic ‘drift’ in the content of the spore assemblages from older to younger horizons. On account of this distribution pattern, spore assemblages from random samples of coal or shale from the Namurian succession of the Central Province Basin can be dated in relation to the sequence of goniastite stages. Furthermore, when the ranges of these spores are considered in conjunction with more complete assemblage data, the recognition of specific horizons is possible, as for example in the Yeadonian stage. Further investigation into the distribution of fossil spores in this type of succession could lead to an independent system of stratigraphic subdivision, providing sufficient attention is paid to the facies characteristics of the various spore types.

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R. NEVES: NAMURIAN PLANT SPORES 279


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