WESTPHALIAN D MEGASPORES FROM THE FOREST OF DEAN COALFIELD, ENGLAND

by EDWIN SPINNER

ABSTRACT. A first description is given of Westphalian D dispersed megaspores in Britain. Among the seventeen species recorded five are new: *Setosisporites pilatus*, *Lagenicula verrurugosa*, *L. perverrucata*, *L.? verrucata*, *L. irregularis*. The species are assigned to nine genera as defined by Potonié and Kremp (1954). The genus *Zonalesporites* (Ibrahim) Potonié and Kremp is redefined to include *Superbisporites*, *Rotatisporites*, and *Radiatisporites* as defined by Potonié and Kremp (1954). A list of additional macro-plant species from the Coal Measures concerned is also given.

DURING the last thirty years several studies have been carried out on Carboniferous megaspores in Europe and North America. European workers, particularly Zerndt (1930–38) and Dijkstra (1946–56), have demonstrated the value of megaspores in the broad zonation and correlation of coal basins and in the correlation of individual seams within a basin. Similar studies on the Mississippian and Pennsylvanian of North America were carried out by Schopf (1938), Arnold (1950), and Winslow (1959). These studies have resulted in the recognition and description of a large number of megaspore species from rocks ranging in age from Dinantian to Stephanian.

In Britain the study of dispersed Carboniferous megaspores has been largely neglected since the early work of Bennie and Kidston (1886) on megaspores from the Carboniferous of Scotland. A number of papers by Slater, Evans, and Eddy (1930–32) described megaspores in thin sections from some coal seams from the Yorkshire coalfield and indicated the use of these fossils in correlation between the Yorkshire and Lancashire coalfields. Since this work was based on thin sections only, much of the detail of shape and ornament of the spores could not be observed.

Techniques devised by Schulze (1855) and Zetzsche and Kälin (1932) for the extraction of spores from unweathered coals were applied by Zerndt and Dijkstra and rapidly led to greater possibilities for the taxonomic study of megaspores and their application to stratigraphical correlation.

The present investigation has followed these techniques and constitutes a systematic account of the megaspores and of their stratigraphic distribution in a British coalfield. Thirteen coal seams and associated shales have been examined from the Forest of Dean. All these samples yielded well-preserved megaspores. Approximately 1,000 megaspores were examined in detail. Amongst these occur twelve previously known species, all of which had not been recorded before from the Westphalian D of Britain. Eight new species have also been recognized, five of which are described in the present paper. The remaining new species will be described in the future, when more complete information becomes available. The descriptions are based on an examination by means of transmitted and reflected light.

GENERAL GEOLOGY OF THE COALFIELD

The Forest of Dean coalfield is a small, broadly triangular shaped area situated in Gloucestershire between the Severn and Wye valleys. The coalfield is some thirty square

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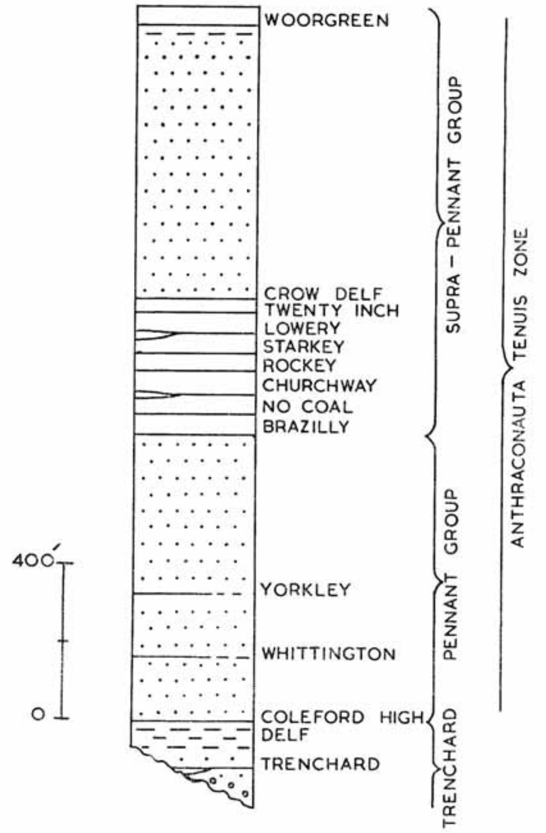
miles in extent and forms an outlier of high country surrounded by rocks of Lower Carboniferous and Devonian ages. To the west and south lie the larger coalfields of South Wales and Bristol/Somerset.

Within the Forest of Dean the Coal Measures are restricted to Upper Westphalian



TEXT-FIG. 1. Coal Measures succession in the Forest of Dean (after L. R. Moore 1954, p. 127, fig. 7).

age and rest with marked unconformity upon Lower Carboniferous and Old Red Sandstone. The Coal Measures are completely exposed and are approximately 2,000 to 2,300 feet in total thickness. The succession is generally subdivided into three lithological formations (text-fig. 1). Since these formations have already been described in detail by Trotter (1942) and Moore (1954), only a summary is given here. The lower or Trenchard formation, between 50 and 400 feet thick (Trotter, 1942, p. 28), consists of conglomerates, grits, sandstones, and shales. It contains a single coal seam, the Trenchard seam, which is well developed in the south-western part of the coalfield, but deteriorates northwards and splits into two leats, known as the Lower and Upper Trenchard seams. These coals have not yet been proved in the eastern part of the coalfield. The succeeding Pennant formation extends from the Coleford High Delf seam to the base of the Brazilly seam and consists of 800 feet of massive felspathic sandstones with intervening thin shale horizons containing coal seams. The highest subdivision or Supra-Pennant formation is some 1,100 feet thick and contains most of the workable coal seams found in the Forest of Dean. Within this formation two further subdivisions have been recognized, viz., a lower division from the Brazilly seam to the top of the Crow Delf seam, consisting mainly of shales and thin sandstones, and an upper division containing massive sandstones and thin coals (i.e. including the Woorgreen coals).

Structurally, the Forest of Dean coalfield is represented by a north–south elongated basin formed by small anticlinal and synclinal folds (Trotter 1942, pp. 3–8).

MACROPALAEONTOLOGICAL EVIDENCE FOR AGE OF COAL MEASURES

The lowest recorded evidence is that from the roof shales of the Coleford High Delf seam (Trotter 1942, p. 38) which included a number of non-marine lamellibranchs forming an *Anthraconauta tenuis-phillipsi* assemblage. After a re-examination of the fauna, Calver (in Welch, Trotter, *et al.* 1961, p. 90) considered that the horizon should be placed in the *Anthraconauta tenuis* zone of the upper Coal Measures (as redefined by Stubblefield and Trotter 1957, p. 3).

The first detailed examination of the plant macrofossils of the coalfield was carried out by Arber (1912), who concluded that the assemblages obtained from the different seams were practically the same. He assigned them to the 'Upper Coal Measures' which may be broadly equivalent to high Westphalian. However, Crookall (1930, p. 225) after a re-examination of Arber's material regarded only the Woorgreen coals as belonging to the Upper Coal Measures, the remainder of the sequence being referred to the Staffordian. In a later paper by Crookall (1955, table A, p. 2) the Upper Coal Measures and the Staffordian were approximately equated with Westphalian D and upper Westphalian C respectively.

Moore (1947, p. 291) pointed out that the floras of some of the coal seams in the Forest of Dean were indicative of floral zone H of Dix (1934), i.e. Westphalian D. A list of plant species collected from the Forest of Dean and considered to be diagnostic of Westphalian D is given by Welch, Trotter, *et al.* (1961, p. 90).

More plant fossils were found during the collection of material for the present investigation, in company with R. H. Wagner, who has kindly identified the species quoted below. The fossils are grouped according to the colliery tips on which they were found.

Northern United colliery tip (Coleford High Delf seam): *Neuropteris ovata* Hoffmann, *Lobatopteris vestita* (Lesquereux) Wagner, *Pecopteris dentata* Brongniart, *Sphenophyllum* cf. *emarginatum* Brongniart, *Asterophyllites equisetiformis* (Schlotheim), *Lepidophloios laricinus* Sternberg, *Lepidophyllum sp.*

Steam Mills colliery tip (Brazilly seam): *Neuropteris flexuosa* Sternberg, *N. scheuchzeri* Hoffmann, *Odontopteris lindleyana* Sternberg, *Sphenopteris neuropteroides*

(Boulay) Zeiller, *Lobatopteris vestita* (Lesquereux) Wagner, *Sphenophyllum sp. Lepidodendron sp.* Lightmoor colliery tip (composite tip of seams from No Coal to Twenty Inch): *Neuropteris ovata* Hoffmann, *Polymorphopteris polymorpha* (Brongniart) Wagner, *Pecopteris unita* (Brongniart), *P. hemitelioides* Brongniart, *Sphenophyllum* cf. *cuneifolium* Sternberg.

New Fancy Colliery tip (composite tip of seams from Churchway to Crow Delf): *Neuropteris flexuosa* Sternberg, *N.* cf. *flexuosa* Sternberg, *N. scheuchzeri* Hoffmann, *Alethopteris ambigua* Lesquereux *pars* D. White emend, *Pseudomariopteris ribeyroni* (Zeiller) Danzé-Corsin, *Sphenopteris neuropteroides* (Boulay), *Lobatopteris vestita* (Lesquereux) Wagner, *Pecopteris cisti* Brongniart, *Sphenophyllum emarginatum* Brongniart, *Annularia stellata* (Schlotheim), *Asterophyllites equisetiformis* (Schlotheim), *Calamites suckowi* Brongniart, *Lepidodendron* cf. *wortheni* Lesquereux.

Wagner considers the evidence from the New Fancy colliery tip to be particularly significant, since it contains elements not previously mentioned from the Forest of Dean. The most important is *Pseudomariopteris ribeyroni*, a well-known Stephanian element in Western European floras. However, Bell (1938) recorded this species from strata of approximate Westphalian D age in Nova Scotia, Canada. Judging from the present assemblage it also appears to occur in high Westphalian D rocks of the British Isles. *Alethopteris ambigua* was originally figured from the New Fancy colliery as *Alethopteris davreuxi?* Brongniart by Arber (1912, pl. 11, fig. 8). *Lobatopteris vestita* has been usually recorded from Britain under the name of *Pecopteris miltoni* (Artis). Although well known in North America, *L. vestita* has only been encountered sporadically in Western Europe, apart from the British Isles. *Alethopteris ambigua* Lesquereux (= *Alethopteris friedeli* P. Bertrand) seems equally well represented in Europe and North America.

The sum total of plants encountered in the Forest of Dean strongly suggest a Westphalian D age for the measures from the Coleford High Delf seam upwards. Both *Neuropteris ovata* and *Lobatopteris vestita* are considered to indicate at least Westphalian D.

No macrofossils have yet been found in the Trenchard formation, the age of which is uncertain. On the unpublished micropalaeontological evidence of Williams (1956) as quoted by Butterworth and Millott (1960, p. 159), it appears that the Trenchard coal could be referred to either the highest Westphalian C or the Westphalian D.

TECHNIQUES OF STUDY OF MICROFOSSILS

Most of the material used was obtained from channel samples cut in the coal seams worked from small adits. Associated shales were also collected. Where seams were sampled at outcrop, the identification was based on the Geological Survey 6 inch to 1 mile maps of the area. Supplementary samples were also taken from tips, if definite knowledge of the seams worked was available at the Gaveller's office. Samples from the Howle Hill outlier (see Trotter 1942, p. 3, fig. 1) were also examined. The microfossils obtained from these samples are referred to under 'Occurrence' as ? Trenchard (Howle Hill).

Approximately 10 grams of coal were taken at a time and broken into small pieces approximately 5 mm. in diameter. The coal was then placed in a glass flask and treated with Schulze's solution for a period of time which varied between twelve and forty-eight hours. After decantation of the Schulze's solution and washing with distilled water, a weak solution (5 per cent.) of potassium hydroxide was added. The samples were repeatedly washed with water in a sieve (mesh size 180 μ) until the water ran clear. The time necessary for acid and alkali treatment varied for each sample and was only obtained by experimentation and careful observation of the state of the sample during the process. The mineral matter in shale samples was removed by treatment with hydrocloric and hydrofluoric acids before the oxidation of the remaining organic material.

The residue obtained by sieving was immersed in water in a small sorting tray and examined under a stereoscopic microscope (magnifications $\times 35$ and $\times 70$) and the megaspores picked off with a fine brush and steel needle and stored temporarily in distilled water in corked glass tubes. A little acid was added to prevent any mould developing.

Specimens were examined with both transmitted and reflected light. In general the greatest detail was obtained by using transmitted light, especially on the thinner walled lageniculate forms. The large thick walled forms were studied more successfully by reflected light, since the body colour of some specimens was too dark for transmitted light study. The transparency of the spore coat was frequently improved by further treatment with concentrated nitric acid or a sodium hypochlorite solution (30–50 per cent.). The latter was found to be the quicker method, but careful attention was necessary in order to prevent specimens from being destroyed. Specimens placed in such a solution soon lost their dark colour and if the solution was not neutralized by the addition of sodium sulphide the spores disintegrated after a short time. The large thick walled spores, e.g. *Laevigatisporites*, were successfully bleached by this method, but became very fragile and were difficult to mount after such treatment. Consequently, most of the large spores were placed on thin pieces of glass in cardboard single cell slides with cellulose covers and allowed to dry, before examination by reflected light (magnification $\times 70$ and $\times 200$). Some thin-walled forms were also treated in the same manner, but the majority were mounted in glycerine jelly on glass slides, the coverslips being sealed with beeswax. These were examined under transmitted light (magnification $\times 100$ and $\times 450$). Photographs were taken with a Zeiss 35 mm. attachment camera using transmitted and oblique reflected light. All the illustrated specimens are lodged in the permanent collections of the Micropalaeontology Laboratory, Department of Geology, University of Sheffield.

Classification. Because of the dispersed nature and the uncertain botanical affinities of many spores, the artificial classification based on spore morphology as proposed by Potonié and Kremp (1954) is used. Slight modifications on this classification are proposed, where this is considered advisable in the light of the present investigation. Four new species of *Lagenicula* (Zerndt) Potonié and Kremp and one new species of *Setosisporites* (Ibrahim) Potonié and Kremp are described, and the genus *Zonalesporites* (Ibrahim) Potonié and Kremp is redefined. The descriptive terms are mainly used in accordance with the recommendations made by the Commission Internationale de Microflore du Paléozoïque (C.I.M.P., 1961, Krefeld).

SYSTEMATIC DESCRIPTIONS

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch) Potonié and Kremp 1954
Subturma AZONOTRILETES Luber 1935
Infraturma LAEVIGATI (Bennie and Kidston) Potonié 1956
Genus LAEVIGATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. Laevigatisporites primus (Wicher)

Laevigatisporites glabratus (Zerndt) Potonié and Kremp *sensu* Dijkstra

Plate 14, figs. 1, 2

1930 *Triletes glabratus* Zerndt, pp. 43–45, pl. 1, figs. 1–3.
1933 *Laevigati-sporites reinschi* Ibrahim, p. 18, pl. 4, fig. 28.
1934 *Sporites primus* Wicher, p. 169.
1946 *Triletes glabratus* Dijkstra, pp. 26–28, pl. 1, figs. 28–40.
1955 *Laevigatisporites glabratus* Potonié and Kremp, p. 53, pl. 1, figs. 4–8.
1955 *Laevigatisporites reinschi* Potonié and Kremp, p. 55, pl. 2, figs. 9–10.
1955 *Laevigatisporites primus* Potonié and Kremp, p. 55, pl. 1, fig. 2.
1958 *Laevigatisporites glabratus* Piérart, p. 40, pl. 1, figs. 1–2.
1959 *Triletes glabratus* Winslow, p. 28, pl. 6, figs. 7–10.
1959 *Laevigatisporites glabratus* Danzé and Vigreux, p. 132.

Remarks. Considerable variation in size, haptotypic structures, and thickness of the spore wall occurs within this species. Two main types seem to be present, (1) a large relatively thin-walled spore, circular in outline with almost suppressed curvaturae and laesurae, (2) a smaller thicker-walled form, rounded triangular in outline with prominent contact faces, curvaturae, and triradiate ridges extending from the laesurae. However, many specimens were found in the same assemblage linking both types. Some specimens could be assigned to *L. primus*, *L. reinschi*, or *L. glabratus* as described by Potonié and Kremp (1955, pp. 51–56), but the majority have characteristics common to more than one of the above species. In view of this wide variation in size range (max. diam. 800–2400 μ) and limited morphological features the group has been referred here to one 'broad' species, i.e. *sensu* Dijkstra (Schopf 1949, p. 509). Piérart (1958, p. 34) has been followed in retaining the generic name *Laevigatisporites*.

Affinities. Bocheński (1936, p. 225; 1939, p. 5, pl. 5, figs. 30–32, pl. 7, figs. 42–45) demonstrated similar variation in size of this type of megaspore in the cone species *Sigillariostrobus czarnockii*. *Laevigatisporites* type megaspores have also been recorded from *Mazocarpon oedipternum* Schopf (1941) and *Sigillariostrobus gothani* Bode (1928), as stated by Chaloner (1953*b*, p. 887).

Stratigraphic range. Namurian–Stephanian (Dijkstra 1946).

Occurrence. ? Trenchard (Howle Hill), Lowery (loc. 26), Twenty Inch (loc. 28, 29) seams.

Infraturma APICULATI (Bennie and Kidston) Potonié and Kremp 1956
Genus TUBERCULATISPORITES (Ibrahim) Potonié and Kremp 1954

Tuberculatisporites brevispiculus (Schopf) Potonié and Kremp 1955

Plate 14, figs. 3–5

1938 *Triletes brevispiculus* Schopf, p. 26, pl. 1, figs. 13*a–r*, pl. 2, fig. 6, pl. 3, figs. 1–4.
1946 *Triletes mamillarius* Dijkstra *pars*, *non* Bartlett, p. 28 (synonymy).
1955 *Tuberculatisporites brevispiculus* Potonié and Kremp, p. 90.
1957 *Tuberculatisporites brevispiculus* Bhardwaj, p. 91, pl. 24, figs. 14–16.
1959 *Triletes mamillarius* Winslow *pars*, *non* Bartlett, p. 29.
non 1955 *Tuberculatisporites brevispiculus* in Horst, p. 163.

Remarks. Dijkstra (1946, p. 28) considered this species as a synonym of '*Triletes*' *mamillarius* Bartlett and maintained that the variation in size of ornament was so great that only one species could be satisfactorily defined. Evidence obtained by Bocheński (1939, p. 21, pl. 4, figs. 16–26) and Chaloner (1953*b*, p. 882, pl. 22, figs. 1–3) of *Tuberculatisporites* type spores in Sigillarian cones partly supports Dijkstra's interpretation. However, neither author found spores with sculptural elements of the small size found in *T. brevispiculus*. Moreover, Arnold (1961, p. 250) has re-examined Bartlett's type material of *T. mamillarius* and concluded that it is distinct from *T. brevispiculus*. All the specimens from the Forest of Dean agree closely with Schopf's original description. Horst (1955, p. 163) described specimens characterized by sculptural elements 15 to 30 μ high, 40 to 65 μ in diameter as *T. brevispiculus*. None of these were figured; but judging from the dimensions of the cone-shaped elements, it is doubtful that they belong to *T. brevispiculus*.

Affinities. Sigillariaceae.

Stratigraphic distribution. U.S.A.: Herrin (No. 6) Coal, Carbondale series, Pennsylvanian, Illinois (Schopf 1938). Europe: Saar and Ruhr coalfields, lower Westphalian D (Bhardwaj 1957*b*).

Occurrence. Trenchard (loc. 1–3), Coleford High Delf (loc. 6), Yorkley (loc. 15), Woorgreen (loc. 31) seams.

Subturma LAGENOTRILETES Potonié and Kremp (1954) emend. Bhardwaj 1957
Infraturma GULATI Bhardwaj 1957
Genus SETOSISPORITES (Ibrahim) Potonié and Kremp 1956

Type species. *Setosisporites hirsutus* (Loose) Ibrahim 1933

Setosisporites pilatus sp. nov.

Plate 14, fig. 6; Plate 15, figs. 1, 2

Holotype. Slide FD/12, Crow Delf coal, Collingwood level. Plate 15, fig. 1.

Diagnosis. Trilete megaspores, circular to oval outline, maximum diameter 450 to 700 μ. Laesurae expanded at proximal pole to form small apical prominence, 60 to 100 μ diameter. Small club-shaped pilae and baculae 10 to 15 μ long, 2 to 6 μ wide, cover the distal surface. Contact faces are distinct, laevigate, occupying up to three-quarters of the proximal surface of the compressed spore. Spore wall is approximately 20 μ thick.

Description

Size and Shape. Small trilete megaspores, circular to oval in outline, maximum diameter varies between 450 and 700 μ, mean 530 μ (twelve specimens measured in glycerine jelly). Oblique polar compressions are most common, lateral compressions rare. The spore body was originally more or less spherical in shape.

Haptotypic structures. Tetrad mark is represented by laesurae, equal to three-quarters of the spore radius in length, 20 to 25 μ wide. Near the proximal pole, the laesurae are abruptly expanded to form a blunt pyramidal prominence, varying between 60 and 100 μ in maximum diameter. There is no appreciable expansion of the contact faces involved in the formation of this structure. The contact faces are distinct, laevigate, locally thickened near the proximal pole, and occupy half to three-quarters of the proximal surface of the compressed spore. The abrupt change of ornament from the laevigate contact faces to the pilate elements of the distal suface and the relatively thinner exine of the contact faces determines the position of the curvaturae.

Exine Structure and Sculpture. The spore body, excluding the contact faces, is covered with a combination of pilate and baculate elements, densely developed in places (approximately 5 μ apart), but elsewhere more widely dispersed (15 to 25 μ). The elements vary between 10 and 15 μ in overall length, 3 to 6 μ in width. They are pilate in the sense that

TEXT-FIG. 2. Diagram to illustrate variation in ornament of *Setosisporites pilatus* sp. nov., × 2,000; drawn from holotype slide FD/12.

some are composed of a distinct 'head' and 'stalk' whilst in others a smooth transition exists between the smaller basal diameter and the apical diameter, thus forming what might be described as 'club-shaped' baculae. The 'stalks' are approximately 1 μ long up to 5 μ wide, with straight or slightly concave sides bearing spherical heads, 3 to 6 μ in diameter. The heads are terminated by small cone-like structures, approximately 2 μ high. Some of the baculae have typically straight, parallel sides. There is no noticeable segregation of the two types of ornament on the spore body except in the region of the curvaturae, where a dense development of small baculae predominates. The spore wall is approximately 20 μ thick, as measured in optical section, and appears to have a rather complex infrastructure. Under reflected light the spore appears yellow-brown in colour. In places the exine of the contact faces appears darker (i.e. thickened), but these areas are not prominently elevated above the spore wall. The pilate-baculate ornamentation gives the sporea a matted or hairy appearance.

Comparison. S. pseudotenuispinosus Piérart (1958) is similar in size to *S. pilatus* but has a larger apical prominence (80 to 200 μ wide, 80 to 150 μ high) and a different type of distal ornamentation consisting of small granules up to 5 μ in diameter. *S. hirsutus* var. *brevispinosus* (Zerndt) Potonié and Kremp (1955) also has smaller sculptural elements (tubercles, 6 μ long) than *S. pilatus*. The contact faces in *S. pilatus* are also laevigate, not ornamented as in *S. hirsutus* var. *brevispinosus*, and although the contact faces are locally thickened, no prominent radial folds are developed as in *S. hirsutus* var. *brevispinosus*. *S. globosus* (Arnold) Potonié and Kremp (1955) and the varieties of *S. globosus* described by Winslow (1959), can all be distinguished from *S. pilatus* by the larger sculptural elements on the distal surface and the small elements on the contact faces. Also, *S. globosus* var. B Winslow has an equatorial flange structure and a larger apical prominence than *S. pilatus*. *S. hirsutus* (Loose) Ibrahim (1933) is slightly larger than *S. pilatus* and has longer sculptural elements, up to 200 μ long. *S. praetextus* (Zerndt) Potonié and Kremp is larger (600 to 1,800 μ) than *S. pilatus* and has longer (200 to 300 μ) bifurcating sculptural elements usually restricted to a zone around the equator. The apical prominence in *S. praetextus* is also much larger than in *S. pilatus*.

Remarks. This species is placed in the genus *Setosisporites* on the basis of the spherical shape of the spore body, the small apical prominence formed by the proximal part of the laesurae, the smooth contact faces, and the 'hairy' appearance of the spore coat.

Due to the breaking of some of the sculptural elements the spore coat may sometimes appear verrucose.

Affinities. *S. pilatus* type spores have not been described from any known cone species. According to Potonié (1962), *Setosisporites* type spores have been found in cones belonging to the Bothrodendraceae.

Occurrence. Crow Delf Coal (loc. 30).

Genus LAGENOISPORITES Potonié and Kremp 1954

Type species. *Lagenoisporites rugosus* (Loose) Potonié and Kremp 1954

Remarks. The differences between *Lagenoisporites* and *Lagenicula* are not very clear. According to Potonié and Kremp (1954, p. 151), *Lagenoisporites* has a more or less smooth exine and, in any case, does not show a distinct ornamentation as in *Lagenicula* and *Setosisporites*. However, the distinctiveness of an ornamentation can be affected by the size of the sculptural elements, the state of preservation, and laboratory treatment. Insufficient oxidation may cause the ornament to be obscured, while over-oxidation can cause breakage or removal of part of the ornament. The method of examination is also important, since a small ornament may be less distinct under reflected light than it is under transmitted light. Moreover, Chaloner (1953*c*, p. 284, text-fig. 20) has found both smooth and ornamented lageniculate megaspores in the same fructifications (i.e. *Lepidostrobus rusellianus* Binney, *L. olryi* Zeiller). It therefore seems that the difference between the two genera as at present described is inadequate and, in fact, Bhardwaj and Kremp (1955, p. 43, pl. 4, figs. 2, 3), have assigned species with a distinct ornamentation

EXPLANATION OF PLATE 14

All figures × 50, under reflected light, unless otherwise stated.

Figs. 1–2. *Laevigatisporites glabratus* (Zernit) Potonié and Kremp *sensu* Dijkstra. Lowery seam (loc. 26), FD/1, FD/2.

Figs. 3–5. *Tuberculatisporites brevispiculus* (Schopf) Potonié and Kremp. 3, mature form, Trenchard seam (loc. 2), FD/3. 4, sculptural elements ×400, transmitted light, Trenchard seam (loc. 2), FD/4. 5, abortive form, Woorgreen seam (loc. 31), FD/5.

Fig. 6. *Setosisporites pilatus* sp. nov. Crow Delf seam (loc. 30), transmitted light, FD/6.

Fig. 7. *Lagenoisporites rugosus* (Loose) Potonié and Kremp; lateral compression, transmitted light; Trenchard seam (loc. 2), FD/7.

Figs. 8–9. *Lagenicula verrurugosa* sp. nov. 8, holotype ×80, transmitted light, Trenchard seam (loc. 2), FD/8. 9, Exine ornamentation ×500, transmitted light, FD/8.

Figs. 10–12. *Triangulatisporites regalis* (Ibrahim) Potonié and Kremp. 10, central body after removal of outer reticulate layer, exposing commissures and triangular inner membrane, trasmitted light, ×60, Whittington seam (loc. 12), FD/9. 11, proximal surface, polar view, Coleford High Delf seam (loc. 6), FD/10. 12, lateral compression, transmitted light, Crow Delf seam (loc. 30), FD/11.

to *Lagenoisporites*. *Lagenoisporites* is regarded here as a generic group for lageniculate spores with an apical prominence formed by the expansion of laesurae and parts of the contact faces, and a laevigate spore exine.

Lagenoisporites rugosus (Loose) Potonié and Kremp 1954

Plate 14, fig. 7

1932 *Sporonites rugosus* Loose, p. 452, fig. 59.
1955 *Lagenoisporites rugosus* Potonié and Kremp, p. 122, pl. 4, fig. 22.
1958 *Lagenoisporites rugosus* Piérart, p. 40, pl. 3, fig. 11; pl. 10, figs. 1–4.
1959 *Triletes rugosus* Winslow *pars*, pp. 22–24, pl. 3, figs. 4–6.

Remarks. Dijkstra (1946, p. 48; 1955*b*, p. 10; 1956*b*, p. 259) described a small, thick-walled ornamented 'immature' form within this species. However, the work by Chaloner (1953*c*, pp. 272–86) and Felix (1954, pp. 357–60) on *L. rugosus* type spores from *Lepidostrobus* cones does not support this interpretation.

Stratigraphic distribution. Europe: Westphalian A–Stephanian (Dijkstra 1955 *a*, *b*, 1956 *b*). U.S.A.: Pennsylvanian, Michigan (Arnold 1950), Illinois (Schopf 1938; Winslow 1959).

Occurrence. Trenchard to Woorgreen (No. 2) seams.

Genus LAGENICULA (Bennie and Kidston) Potonié and Kremp 1954

Type species. *Lagenicula horrida* Zerndt 1934.

Remarks. Bharadwaj and Venkatachala (1962, p. 25) proposed a new genus *Rostratispora*, based on megaspores obtained from the Lower Carboniferous of Spitsbergen. This genus is, according to its authors, distinguished from *Lagenicula* by its verrucose ornament and small apical prominence. However, Potonié and Kremp (1954, p. 151) in their emendation of *Lagenicula* made some provision for lageniculate forms with a verrucose ornament by describing the exine as being closely covered with warts (verrucae) on which strong, pointed spines or hairs could stand or occur. The other main difference between *Rostratispora* and *Lagenicula* would appear to be in the ratio of size (height) of apical prominence to spore body. The only species of *Rostratispora* described (*R. iucundus* Bharadwaj and Venkatachala 1962) shows a preferred lateral direction of compression, which indicates a larger polar axis, as occurs in *Lagenicula*. The two genera are therefore very similar and it seems that *Rostratispora* falls within the range of variability admitted for *Lagenicula* as defined by Potonié and Kremp 1954.

Lagenicula verrurugosa sp. nov.

Plate 14, figs. 8, 9; Plate 15, fig. 3

? 1955 *Triletes rugosus* Dijkstra *pars*, p. 10, pl. 2, figs. 19, 20.

Holotype. Slide FD/8, Trenchard seam, Mapleford Colliery. The species name refers to the characteristic ornament on the distal surface. Plate 14, fig. 8.

Diagnosis. Flask-shaped trilete megaspores, 500 to 900 μ maximum diameter, including apical prominence. Apical prominence varies from 160 to 280 μ in height, 200 to 320 μ in width. Contact faces distinct, occupying half the proximal surface of compressed spore, arcuate ridges low, 30 μ wide. Distal surface covered with verrucae and rugulae, up to 30 μ in diameter, height less than half diameter. Spore wall ?foveolate, 25 μ thick.

Description

Size and Shape. Medium-sized trilete megaspores varying between 500 and 900 μ in maximum diameter (including apical prominence), mean 655 μ (32 specimens measured in glycerine jelly). Polar compressions are circular to oval in outline, lateral compressions flask-shaped, the apical prominence forming the 'neck' of the flask. Spore body was originally spherical in shape.

Haptotypic structures. Tetrad mark is represented by an apical prominence formed by the laesurae and the apical parts of the contact faces. Laesurae are equal in length to one-third to one-half of the radius of the spore body; they are 30 μ to 40 μ high and wide at the junction with the curvaturae and gradually increase in height (up to 100 μ) at the proximal pole. Near the proximal pole the laesurae are often contorted. The apical prominence is 160 to 280 μ high (measured from curvaturae to apex on lateral compressions) and 200 to 320 μ wide. Contact faces are distinct; they occupy approximately half the proximal surface of the compressed spore and are delimited by low arcuate ridges, up to 30 μ wide.

Exine Structure and Sculpture. Small densely placed verrucae, circular in outline, up to 10 μ in diameter, occur on the apical prominence. The arcuate ridges are usually ornamented with larger verrucae, 20 to 40 μ in diameter, up to 20 μ high. A combination of densely developed verrucae and rugulae covers the distal surface. These elements are elongate, irregular to circular in outline, up to 30 μ in diameter, and up to 10 μ high. Spore wall is approximately 25 μ thick, ?foveolate (fovea 1 μ in diameter). Under reflected light the spore appears yellow-brown in colour, glossy, and 'granulose'.

Comparison. *Lagenoisporites rugosus* (Loose) Potonié and Kremp is larger (300 to 1,170 μ) than *L. verrurugosa* and lacks the ornament on the distal surface. *L. irregularis* sp. nov. is larger than *L. verrurugosa* in overall size (700 to 1,210 μ), and has the distal surface covered with large irregular thickenings 35 to 70 μ wide, 10 μ high, and a thinner spore wall (10 to 15 μ). *L. verrucata* sp. nov. is similar in size to *L. verrurugosa* but has large verrucae, 40 to 70 μ diameter, 20 to 30 μ high, developed on the curvaturae and distal surface. The apical prominence is smaller (up to 150 μ high). *L. perverrucata* sp. nov. is larger (300 to 1,100 μ) than *L. verrurugosa* and has a coarser ornamentation, with verrucae 20 to 35 μ high. *Rostratispora iucundus* Bharadwaj and Venkatachala 1962 is similar in shape and ornamentation to *L. verrurugosa*, but is much smaller (300 to 500 μ) in spore size and in the size of the apical prominence (50 to 80 μ).

Remarks. Dijkstra (1946, p. 48; 1955*b*, p. 259) described some specimens as 'immature' forms of '*Triletes rugosus*' which are similar to *L. verrurugosa*. His description and illustrations are based on reflected light only and it is difficult to compare with the greater detail shown by transmitted light. Three slides containing specimens of *L. verrurugosa* after being examined by transmitted light were dismantled, washed and re-examined by reflected light. They appeared very similar to the illustrations of Dijkstra (1955*b*, pl. 2, figs. 19, 20). However, Dijkstra's evidence for immaturity is not very convincing (see remarks in *Lagenoisporites rugosus* above).

Stratigraphic Distribution. ? Sfaia, Egypt, Upper Westphalian C, Dijkstra (1955*b*).

Occurrence. Trenchard (loc. 2, 3), Colefield High Delf (loc. 6, 8, 9, 11), Brazilly (loc. 17, 18), Rockey (loc. 23), Starkey (loc. 24, 25), Lowery (loc. 26, 27), Twenty Inch (loc. 28), and Woorgreen (No. 2) (loc. 31) coal seams.

Lagenicula perverrucata sp. nov.

Plate 15, figs. 4, 5

Holotype. Slide no. FD/16, ? Trenchard seam (Howle Hill); Plate 15, fig. 4.

Diagnosis. Flask-shaped trilete megaspores, varying between 500 and 1,100 μ in maximum diameter. The contact faces and laesurae form a large apical prominence equal in height to approximately one-third polar axis, slightly constricted at the base, often ruptured to form spoon-shaped segments. Large verrucae, 20 to 70μ in diameter, height equal to half diameter, cover spore body and lower part of the apical prominence. Verrucae are polygonal in outline and dome-shaped in lateral view. Spore wall is 20 to 30 μ thick.

Description

Size and shape. Medium to large size trilete megaspores, which are flask-shaped due to the development of a large apical prominence. The maximum diameter of the compressed spore varies between 500 and 1,100 μ (mean 750 μ, as measured on nineteen specimens in glycerine jelly). Lateral compressions are most common; the polar axis being longer than the equatorial axis.

Haptotypic Structures. The tetrad mark is represented by the large apical prominence formed by the expansion of the greater part of the contact faces and the laesurae. In lateral compressions, the apical prominence is oval in outline and varies between 175 and 400 μ in height and width. The height of the apical prominence is approximately equal to one-third of the length of the polar axis and the maximum width occurs just above the slight basal constriction. The apical prominence is commonly found ruptured, forming spoon-shaped flaps. Originally, the apical prominence was more or less bluntly pyramidal in shape. Most of the details of the laesurae, contact faces, and curvaturae are obscured by the dense verrucose ornament of the exine. On some specimens the low arcuate thickenings of the curvaturae can be distinguished (under transmitted light) just below the constriction at the base of the apical prominence.

Exine Structure and Sculpture. Large, closely-spaced verrucae cover the spore body and lower part of the apical prominence. The verrucae are polygonal at the base, appearing dome-shaped where they project from the spore margin. They are up to 30 μ high and vary between 20 and 70 μ in diameter, generally more than 30 μ. The height usually equals approximately half the diameter. Narrow grooves (*c.* 1 μ wide) run radially from the centres of the verrucae towards the margins (as visible under oil immersion × 1,000). The distance between two adjoining verrucae is usually less than the diameter of an individual verruca. On the basal part of the apical prominence the verrucae are smaller than elsewhere (approximately 30 μ). The upper part of the apical prominence is smooth, but scattered verrucae may occur. The spore wall (? foveolate) varies between 20 and 30 μ in thickness.

Comparison. Lagenicula perverrucata differs from *Lagenicula angulata* Zerndt (1937) in lacking the horn-shaped protuberances formed at the junction of the laesurae and curvaturae. The ornament of *L. perverrucata* is larger (30 to 70 μ) than in *L. angulata* (25 μ length, 10 to 15 μ diameter). *Lagenicula agnina* Zerndt (1937*a*) has an ornamentation similar to that of *L. perverrucata*, but possesses smooth contact faces and a thicker spore wall (80 to 120 μ). '*Triletes*' *furcatus* Dijkstra (1956*a*) is similar in size and thickness of the spore wall to *L. perverrucata*, but the sculptural elements of *T. furcatus* are more conical, and there is a marked difference in size between those on the distal surface (30 to 70 μ long, 20 μ diameter) and on the contact faces (3 to 5 μ diameter, 7 μ long). *Lagenicula splendida* Zerndt (1937*a*) is larger and has more conical elements than those of *L. perverrucata*. *L. verrucata* sp. nov. is smaller in overall size (370 to 585 μ) and in the size of the apical prominence (150 μ) than *L. perverrucata* and has prominently ornamented curvaturae and distinct contact faces. *L. irregularis* sp. nov. is similar in size and shape to *L. perverrucata*, but the shape of the ornament is different, with verrucae 35 to 70 μ in diameter, but only 10 μ high. In *L. perverrucata* the height of the verrucae is approximately half the diameter.

Remarks. L. perverrucata is somewhat atypical of the genus in that the contact faces are not very distinct from the remainder of the spore body.

Occurrence. ? Trenchard (Howle Hill) (loc. 4), and Woorgreen (No. 2) (loc. 31) seams.

Lagenicula? verrucata sp. nov.

Plate 15, figs. 8, 9

Holotype. Slide FD/20, Trenchard seam, Mapleford Colliery; Plate 15, fig. 8.

Diagnosis. Small trilete megaspores varying between 370 and 585 μ in maximum diameter. Prominent curvaturae are marked by strongly developed verrucae (40 to 70 μ diameter), which also characterize the distal surface. A small apical prominence may be formed by the laesurae and apical parts of the contact faces. Spore wall is approximately 20 μ thick.

Description

Size and Shape. Small trilete megaspores varying between 370 and 585 μ in maximum diameter (mean 500 μ, nine specimens measured in glycerine jelly), more or less circular in equatorial outline. Lateral compressions are slightly flask-shaped. Most specimens are

EXPLANATION OF PLATE 15

All specimens with transmitted light.

Figs. 1–2. *Setosisporites pilatus* sp. nov. 1, Holotype, ×100; Crow Delf seam (loc. 30), FD/12. 2, Apical prominence of FD/12, ×250.

Figs. 3–9. *Lagenicula* spp. 3, *L. verrurugosa* sp. nov.; lateral compression ×50, Trenchard seam (loc. 2), FD/13. 4–5. *L. perverrucata* sp. nov. 4, Holotype, ×50; lateral compression, Trenchard seam (loc. 3), FD/14. 5, Sculptural elements of FD/14, ×500. 6–7. *L. irregularis* sp. nov. 6, Holotype, ×50; lateral compression, Trenchard seam (loc. 2), FD/15. 7, Sculptural elements of FD/15, ×500. 8–9. *L.? verrucata* sp. nov. 8, Holotype, ×100; Trenchard seam (loc. 2), FD/16. 9, Tetrad scar of FD/16, ×250.

Fig. 10. *Triangularisporites regalis* (Ibrahim) Potonié and Kremp, distal reticulation, ×500; Coleford High Delf seam (loc. 8), FD/17.

compressed slightly oblique to the polar axis. Originally, the spore was spherical to slightly flask-shaped, the polar axis being only slightly larger than the equatorial axis.

Haptotypic Structure. The tetrad mark is represented by laesurae equalling approximately half the radius of the spore body in length. At the junction with the curvaturae, laesurae are 30 to 50 μ high, increasing gradually up to 80 μ at the proximal pole. The contact faces are distinct, occupying up to half the proximal surface of the compressed spore. The apical parts of the contact faces are slightly thickened and, together with the laesurae, form a small bluntly pyramidal prominence, 100 to 150 μ high. The curvaturae form low but prominent arcuate ridges, ornamented with large verrucae and/or pila.

Exine Structure and Sculpture. Large verrucae are present on the distal surface, curvaturae and sometimes the laesurae. They are most densely developed on the curvaturae, being more scattered on the distal surface; diameters vary between 40 and 90 μ, height up to 30 μ. The height of an individual element is less than half the diameter. Circular to slightly irregular in outline, as seen from above, the verrucae have a low dome-shaped outline with a slightly wrinkled surface in lateral view. Pila may occur intermingled with the verrucae. The spherical heads of the pila vary between 20 and 35 μ in diameter. They are borne by a short stalk, 8 to 10 μ high, approximately 5 μ wide. Smaller verrucae (5 to 20 μ diameter, up to 10 μ high) may occur between the larger elements and on the thickened apical parts of the contact faces. The spore wall (? foveolate) is approximately 20 μ thick, as measured in optical section.

Comparison. *Lagenicula? verrucata* sp. nov. can be distinguished by its small size and the large verrucate thickenings on the curvaturae and distal surface. These characteristics clearly set it apart from all other species of *Lagenicula* that have so far been described.

Remarks. This species combines some characteristics of both *Lagenicula* and *Rostratispora* Bharadwaj and Venkatachala (1962). The raised laesurae are often folded at the proximal pole and the thickened apical parts of the contact faces (Pl. 15, fig. 9) indicate the presence of a low pyramidal prominence. The species is atypical of *Lagenicula* in the small size of this structure. Oblique compressions are most common, the polar axis being only slightly longer than the equatorial axis. In *Lagenicula*, lateral compressions are common as a result of the longer polar axis of the spore.

This species resembles *Rostratispora* in its verrucose ornament and small apical prominence. However, in view of the close similarity between *Lagenicula* and *Rostratispora* as defined at present, this species has been tentatively assigned to the older genus *Lagenicula* until more evidence is available.

Occurrence. Trenchard seam (loc. 2).

Lagenicula irregularis sp. nov.

Plate 15, figs. 6, 7

Holotype. Slide FD/18, Trenchard seam, Mapleford colliery. Plate 15, fig. 6.

Diagnosis. Flask-shaped trilete megaspores, size range 700 to 1,210 μ. Apical prominence formed by the laesurae and apical parts of the contact faces, height 180 to 300 μ. Contact faces occupy less than half the proximal surface of the compressed spore, and are ornamented with verrucae 20 μ in diameter, up to 15 μ high. Arcuate ridges are not developed. Distal surface covered with large lens-shaped thickenings (verrucae), irregular in outline. Spore wall is 10 to 15 μ thick. It has a complex structure.

Description

Size and Shape. Medium-sized trilete megaspores, flask-shaped, varying between 7C0 and 1,210 μ in maximum diameter, including apical prominence, mean 966 μ (after 15 specimens in glycerine jelly). Lateral compressions are the most common. Originally the spore body was more or less spherical in shape; the apical prominence forming the 'neck' of the flask.

Haptotypic Structures. The tetrad mark is represented by laesurae less than half the spore radius in length. The laesurae and most of the contact faces are expanded to form an apical prominence, elliptical in outline in lateral compressions, 180 to 300 μ high (as measured from curvaturae to apex). Small verrucae, up to 20 μ in diameter and height, may occur on the apical prominence. The contact faces are not very distinct and occupy less than half the proximal surface of the compressed spore. No arcuate ridges are developed, but the exine may be thickened opposite the laesurae, i.e. curvaturae imperfectae. The contact faces are distinguished by the absence of the large verrucate ornament which characterizes the distal surface.

Exine Structure and Sculpture. The distal surface is covered by large verrucae, 35 to 70 μ in diameter, rarely more than 10 μ high (5 to 15 μ). In polar view, the verrucae are irregular to circular in outline; narrow lens-shaped where they project from the spore margin. Often the verrucae are joined to form rugulae or large, irregular, thickened areas. The spore wall is 10 to 15 μ thick, as measured in optical section, with a complex structure.

Comparison. L. irregularis can be distinguished from *L. perverrucata* sp. nov. by its irregularly shaped verrucae, since these show a ratio of height to diameter which is greater (1:4 to 1:7) than that of *L. perverrucata* (1:2). The spore wall in *L. perverrucata* is thicker than in *L. irregularis* (30 to 33 μ). *Lagenoisporites rugosus* (Loose) Potonié and Kremp can be distinguished from *L. irregularis* by its smooth distal surface. *L.? verrucata* sp. nov. is smaller in size (370 to 585 μ) than *L. irregularis* and has distinctly ornamented curvaturae.

Occurrence. Trenchard seam (loc. 2), Brazilly seam (locs. 17, 18).

Turma ZONALES (Bennie and Kidston) Potonié 1956
Subturma AURITOTRILETES Potonié and Kremp 1954
Infraturma AURICULATI (Schopf) Potonié and Kremp 1956
Genus VALVISISPORITES (Ibrahim) Potonié and Kremp 1954

Valvisisporites auritus (Zerndt) Potonié and Kremp 1956 *sensu* Bhardwaj 1957

Plate 17, figs. 6, 7

1930 *Triletes auritus* Zerndt, p. 46, pl. 1, figs. 4–5.
1957 *Valvisisporites auritus* Bhardwaj, p. 98, pl. 26, figs. 10–13.
1959 *Valvisisporites auritus* Kalibová, p. 431, pl. 11, figs. 1–4.

Stratigraphic Distribution. Westphalian D–Stephanian (Bhardwaj 1957*a*).

Occurrence. Coleford High Delf (loc. 6, 7, 8, 10, 11), Lowery (loc. 26, 27), Twenty Inch (loc. 28), Crow Delf (loc. 30) seams.

Valvisisporites nigrozonales (Stach and Zerndt) Potonié and Kremp 1956

Plate 17, figs. 8, 9

1931 *Triletes nigrozonales* Stach and Zerndt, p. 1123, pl. 2, figs. 26–27.
1956 *Valvisisporites nigrozonales* Potonié and Kremp, p. 96, pl. 5, figs. 35–37 (part I).
1957 *Valvisisporites nigrozonales* Bhardwaj, p. 98.
1958 *Valvisisporites nigrozonales* Piérart, p. 50, pl. 2, figs. 1–4.
1959 *Valvisisporites nigrozonales* Danzé and Vigreux, p. 134.

Remarks. The megaspores described here as *V. nigrozonales* are similar in size (560 to 900 μ) to those described by Potonié and Kremp, but have no clearly granular sculpture. However, this might be due to preservation. Under transmitted light the spore wall appears to have a complex structure (? infrareticulate). A thin folded inner membrane may also be seen in some specimens.

Affinities. The megaspore illustrated by Chaloner (1958, p. 31, fig. 5) from *Polysporia mirabilis* Newberry is similar to *V. nigrozonales*. Chaloner compared with *V. auritus sensu lato.*

Stratigraphic Distribution. Lower Westphalian B–Westphalian D (Potonié and Kremp).

Occurrence. Trenchard (loc. 2, 3), Coleford High Delf (loc. 8, 11), Woorgreen No. 2 seams.

Valvisisporites sofiaense (Schopf, Wilson, and Bentall) Bhardwaj 1957

Plate 16, fig. 4

1932 *Triletes auritus* III Maslankiewiczowa, p. 161, figs. 37–38.
1944 *Triletes sofiaense* Schopf, Wilson, and Bentall, p. 25.
1946 *Triletes auritus* Dijkstra *pars*, p. 31 (synonomy).
1951 *Triletes auritus* Kalibová *pars*, p. 14.
1957 *Valvisisporites sofiaensis* Bhardwaj, p. 101.

Description. Spores similar in size (1,100 to 1,300 μ) to *V. auritus* (Zerndt) Bhardwaj. The laesurae are straight to slightly sinuous, up to 100 μ high, 75 to 120 μ wide at the proximal pole, gradually decreasing in height and width towards the auriculae. They extend on to the base of the auriculae. Distal surface, contact faces, and laesurae are covered with a coarse reticulum of muri (12 to 25 μ wide), surrounding lumina, which are up to 50 μ in diameter, circular to polygonal in outline.

Remarks. Bhardwaj (1957*a*, p. 101) and Kalibová (1959, p. 434) referred to this species as '*Valvisisporites sofiaensis* (S. W. and B.) POT. and KR.' However, no direct reference to this species seems to occur in Potonié and Kremp 1954, 1955, 1956, which were the papers quoted by both Bhardwaj and Kalibová. Both Potonié and Bharadwaj (pers. communications, November 1963) have agreed that the combination in Bhardwaj 1957*a*, p. 101 was in error. The combination has therefore been credited here to Bhardwaj, not Potonié and Kremp.

Stratigraphic Distribution. Maslankiewiczowa (1932, p. 161) first described this species from the Laziska series in Poland, upper Westphalian B (Schopf, Wilson, and Bentall 1944, p. 25). Bhardwaj (1957*a*, p. 101) stated that '*V. sofiaensis* is reported from the Stephanian' but did not mention a locality.

Occurrence. Twenty Inch (loc. 28) and Crow Delf (loc. 30) seams.

Subturma ZONOTRILETES Waltz 1935
Infraturma ZONATI Potonié and Kremp 1954
Genus TRIANGULATISPORITES Potonié and Kremp 1954

Triangulatisporites regalis (Ibrahim) Potonié and Kremp 1956

Plate 14, figs. 10–12; Plate 15, fig. 10

Description

Size and Shape. Trilete megaspores with a distinct spherical central body, surrounded by an equatorial flange or zona, which is widest opposite the laesurae; hence the triangular outline of the spore. Maximum diameter of the spore (including zona), measured from one radial extremity to the opposite margin of the zona, varies between 600 and 1,040 μ (mean 752 μ, 35 specimens measured in glycerine jelly). The central body varies between 430 μ and 650 μ in diameter (mean 525 μ). Both lateral and polar compressions occur, polar being the most common.

Haptotypic Structures. Tetrad mark on complete specimens represented by prominent triradiate ridges, wavy in outline, 50 to 70 μ high, extending to the margin of the zona. On denuded specimens (i.e. where the outer reticulate layer of exine has been removed), the laesurae are up to two-thirds the spore body radius in length. The commissures are distinct, with low marginal thickenings. On the contact faces low narrow irregular ridges occur. Some of these appear to coalesce with the triradiate ridges. Towards the spore body margin, outside the contact faces, these ridges form a reticulum (lumina 20 to 30 μ diameter, muri 5 to 12 μ wide). No arcuate ridges are present, but the contact faces are more or less delimited by the reticulum occurring on the remainder of the spore body. The lumina become wider on the distal surface of the spore.

Exine Structure and Sculpture. The outer reticulate layer of the exine is extended to form a zona, 100 to 215 μ wide radially, 80 to 120 μ interradially. The meshes are most distinct on the distal surface and consist of irregular polygonal to circular lumina, 40 to 80 μ in diameter (mainly 50 to 60 μ), surrounded by narrow muri, 5 to 15 μ high. Near the spore body margin the lumina are radially elongate, with the muri extending on to the zona. The latter may appear pleated or reticulate. The central body is smooth to finely granular on removal of the reticulate outer layer. The wall of the central body is 15 to 30 μ thick. Within the body a thin folded membrane, rounded triangular in outline, appears to be attached to the laesurae.

EXPLANATION OF PLATE 16

All figures × 50, reflected light illumination unless otherwise stated.

Figs. 1–3. *Zonalesporites brasserti* (Stach and Zerndt) Potonie and Kremp. 1, Oblique lateral compression; roof-shale Yorkley seam (loc. 15), FD/18. 2, Detail of zona, transmitted light × 100; roof-shale Yorkley seam (loc. 15), FD/19. 3, Proximal view, polar compression; roof-shale Yorkley seam (loc. 15), FD/18.

Fig. 4. *Valvisisporites sofiaense* (Schopf, Wilson and Bentall) Bhardwaj 1957, lateral compression: Twenty Inch seam (loc. 28), FD/20.

Figs. 5–9. *Cystosporites* spp. 5–6, *C. giganteus* (Zerndt) Schopf. 5, Part of mature specimen with two adhering abortive spores, transmitted light; Lowery seam (loc. 26), FD/21. 6, Abortive specimen, transmitted light: Trenchard seam (loc. 1), FD/22. 7–9. *C. varius* (Wicher) Dijkstra, ? abortive specimens; Trenchard seam (loc. 1), FD/23.

Comparison. T. triangulatus (Zerndt) Potonié and Kremp is smaller in overall size than *T. regalis*. Also the meshes of its distal reticulum are smaller, with the lumina up to 60 μ in diameter, separated by muri 15 to 20 μ wide. *T. zonatus* (Ibrahim) Potonié and Kremp differs from *T. regalis* in its smaller size (400 to 500 μ, Potonié and Kremp 1956, p. 131) and the presence of smaller meshes forming the distal reticulum. *Zerndtisporites laxomarginalis* (Zerndt) Bhardwaj is similar in shape to *T. regalis*, but the triradiate ridges do not extend on to the zona and there is no distal reticulum.

Remarks. The size range of the specimens described here is greater than that of the specimens described by Potonié and Kremp (1956, p. 129). This may be due to differences in mounting media used (see Winslow 1959, p. 14; Pant and Srivastava 1962), and is not considered to be of any taxonomic significance. No papillate ornament as mentioned by Winslow (1959, p. 38) was observed on the folded membrane within the central body. The outer reticulate layer is characterized by narrow muri (5 to 15 μ wide), surrounding large circular to polygonal lumina (40 to 80 μ diameter).

Megaspores from *Selaginellites crassicinctus* Hoskins and Abbott 1956 (assigned by those authors to *Triletes triangulatus* Zerndt) are similar to *T. regalis* in overall size (710 to 935 μ), diameter of central body (380 to 450 μ), and size of distal reticulations (30 to 80 μ). However, its equatorial flange is stated to be 100 μ thick and, although the megaspores are not compressed (petrifaction), it is questionable whether a compressed flange would become thin and membranous as in *Triangulatisporites*. Megaspores from *Selaginellites suissei* Zeiller, as described by Chaloner (1954*a*, p. 82), are smaller (450 to 520 μ) and agree more closely with *T. triangulatus* (Zerndt) Potonié and Kremp.

Stratigraphic Distribution. As many workers include this species within *Triletes triangulatus* Zerndt, its stratigraphic range is uncertain. According to Potonié and Kremp (1956, p. 129), it occurs in Upper Westphalian B of the Ruhr; and in Herrin (No. 6) Coal, Illinois, Lower Westphalian D (after Schopf, 1938).

Occurrence. Trenchard (loc. 1, 2), Coleford High Delf (loc. 6–11), Whittington (loc. 12), Lowery (loc. 26), Twenty Inch (loc. 28), and Woorgreen (No. 2) (loc. 31) seams.

Genus ZONALESPORITES (Ibrahim) Potonié and Kremp emend.

Type species. Zonalesporites brasserti (Stach and Zerndt) Potonié and Kremp 1956.

1954 *Radiatisporites* Potonié and Kremp, 1954, p. 163, pl. 14, fig. 13.
1954 *Rotatisporites* Potonié and Kremp, 1954, p. 163, pl. 15, fig. 65.
1954 *Superbisporites* Potonié and Kremp, 1954, p. 164, pl. 15, fig. 64.

Emended diagnosis. Trilete megaspores, circular or oval to rounded triangular in equatorial outline and consisting of a distinct spore body with a surrounding equatorial to subequatorial structure. Laesurae are distinct, wavy or straight in outline and extend to the spore body margin. Generally, the laesurae are higher at the radial extremities than they are at the proximal pole. Contact faces occupy most of the proximal surface of the spore body. They are either laevigate or ornamented with small verrucae, spinae, or baculae. The equatorial structure consists of numerous fimbria which are either single or bifurcating and coalescing, and sometimes separated by fovea of varying size. The distal surface of the spore body may be laevigate or covered with elements similar to those forming the equatorial structure.

Comparison. *Triangulatisporites* Potonié and Kremp 1954 is similar to *Zonalesporites* in that an equatorial structure is present. However, this structure or zona is smaller, more coherent and continuous than in *Zonalesporites*. No individual elements can be distinguished within the zona which appears to be formed by a radial extension of the reticulate outer layer of the spore wall.

Remarks. The genera *Zonalesporites* (Ibrahim), *Superbisporites*, *Rotatisporites*, and *Radiatisporites*, as described by Potonié and Kremp (1954), have been distinguished mainly on differences in the number and degree of coalescence and bifurcation of the elements forming the equatorial structure. These differences are small and do not seem to warrant the retention of four generic names. A similar recommendation was made by a subcommittee of the Commission Internationale de Microflore du Paléozoïque (at Krefeld 1961), but no formal emendation was proposed.

Zonalesporites brasserti (Stach and Zerndt) Potonié and Kremp

Plate 16, figs. 1–3

1931 *Triletes brasserti* Stach and Zerndt, p. 1123, figs. 16, 18–31.
1955 *Triletes brasserti* forma 2. Dijkstra, p. 334, pl. 38, fig. 15; pl. 39, fig. 23; pl. 41, fig. 27.
1956 *Zonalesporites brasserti* Potonié and Kremp, p. 122, pl. 7, figs. 52–56.
1958 *Zonalesporites brasserti* Piérart, p. 57, pl. 10, figs. 17a, b; pl. 11, figs. 1, 2.
1959 *Triletes brasserti* Winslow, p. 35, pl. 9, figs. 3–10.

Remarks. Under transmitted light the equatorial structure can be seen to consist of several (? 6) layers of fimbria, varying in length, densely placed, and fused laterally except for their distal extremities. The outermost layer form the 'bar-like' processes (Winslow, p. 36) projecting at the margin. Small oval dissections (*c*. 30 μ diameter) may occur near the margin of the equatorial structure, which thickens towards the spore body and has a fine structure. In some broken specimens a thin membrane occurs within the spore body.

Stratigraphic Distribution. Namurian B–Westphalian C (Potonié and Kremp 1956, p. 122).
Occurrence. Roof shale of Yorkley coal seam (loc. 14, 15).

Zonalesporites dentatus (Zerndt) comb. nov.

Plate 17, figs. 1, 2

1938 *Triletes dentatus* Zerndt, pp. 22–27.
1952 *Triletes dentatus* Dijkstra, p. 166, pl. 5, figs. 1, 2, 6.
1956 *Superbisporites dentatus* Potonié and Kremp, p. 135.
1958 *Superbisporites dentatus* Piérart, p. 59, pl. 4, figs. 1–7; pl. 5, figs. 1–6.
1959 *Superbisporites dentatus* Danzé and Vigreux, p. 137.

Diagnosis. See Dijkstra 1952*c*, p. 166.

Remarks. Specimens were found with characters common to both '*Triletes dentatus*' Zerndt and '*Triletes ramosus*' Arnold, which partly supports Dijkstra's view (1952*c*, p. 167) that the two species are essentially the same. Maximum diameter of spore body varies between 750 and 2,000 μ (mean 1,150 μ, after twenty-five specimens measured in water). Laesurae are 125 to 250 μ high, 60 μ broad at the base. They become membraneous towards the vertex. The details of the equatorial structure are best seen under transmitted light. The fimbria forming the equatorial structure are 400 μ or more long, 10 to 25 μ wide, coalescing and bifurcating to form a continuous marginal rim. Small dissections occurring between fimbria give a fenestrate appearance. The rim of the flange is characterized by small protrusions 8 to 25 μ long, 12 to 25 μ wide with small cone-like terminations, 2 to 6 μ in diameter. The size of the spore body, the height of the laesurae and the width of the flange are similar to those of the specimens described as '*Triletes ramosus*' by Winslow (p. 33) and do not coincide entirely with those of '*Triletes dentatus*' Dijkstra (1952*c*, p. 166). This may be due in part to the state of the specimens when measured. Dijkstra's measurements are based on dry specimens, Winslow's on specimens mounted in Canada Balsam. Winslow (p. 144) recorded a 19 per cent. difference in size between specimens that were measured in water, allowed to dry, and then remeasured. However, the processes on the rim of the equatorial structure are more similar to those of *Superbisporites dentatus* (Piérart 1958, p. 61) than those described by Arnold (1950, p. 72, pl. 3, fig. 2) and Winslow (p. 33, pl. 8, figs. 3–6) for '*Triletes ramosus*'. The age of the specimens described here (Trenchard Seam, Westphalian C–D) lies within the known stratigraphic range of *Z. dentatus* in Europe.

Occurrence. Small coal seam in Trenchard measures, Cinderford (loc. 5).

Zonalesporites rotatus (Bartlett) comb. nov.

Plate 17, figs. 3–5

1929 *Triletes rotatus* Bartlett, p. 21, pls. 9–12.
1954 *Rotatisporites rotatus* Potonié and Kremp, p. 163.
1956 *Rotatisporites rotatus* Potonié and Kremp, p. 135.
1959 *Triletes rotatus* Winslow, p. 32, pl. 8, figs. 1, 2.
1961 *Triletes rotatus* Arnold, p. 249.

Description. See Bartlett, 1929*a*, p. 21; Dijkstra 1952*c*, p. 166.

Remarks. This species has not previously been recorded in rocks younger than Westphalian B (Dijkstra 1952*c*, p. 166). It seems more generally characteristic of Namurian strata. The marginal rim of the equatorial structure of specimens recorded here as *Z. rotatus* differs from the descriptions given by Zerndt (1937*a*, p. 9) and Dijkstra (1952*c*, p. 166) for specimens from the Namurian. The width of the rim is 30 to 60 μ, approximately twice that of the Namurian forms (15 to 30 μ) (Dijkstra, 1952*c*) and the projections from the rim are smaller, 10 to 20 μ high, and more scattered. Zerndt (p. 9) described the processes as cylindrical and dentate, 12 to 60 μ high (usually 30 μ). These differences may in future warrant specific or varietal differentiation, but an insufficient number of specimens with well preserved equatorial structure has been found at the present time to justify this move.

Stratigraphic Distribution. Lower Pennsylvanian, U.S.A. (Bartlett 1929, Cross 1947, Winslow 1959), ? Dinantian–Namurian C, Europe (Dijkstra 1952*c*), Westphalian B, Limburg, Belgium–Netherlands (Dijkstra 1955, Piérart 1955).

Occurrence. Roof shale of Yorkley coal seam (loc. 14, 15).

Turma CYSTITES Potonié and Kremp 1954
Genus CYSTOSPORITES Schopf 1938

Cystosporites giganteus (Zerndt) Schopf 1938

Plate 16, figs. 5, 6

1930 *Triletes giganteus* Zerndt, pp. 71–79, pls. 9–11.
1950 *Cystosporites giganteus* Arnold, p. 87, figs. 157–160.
1951 *Cystosporites giganteus* Kalibová, p. 27, pl. 4, figs. 4–5.
1955 *Cystosporites giganteus* Dijkstra, p. 339, *pars*, pl. 44, figs. 48–50.
1956 *Cystosporites giganteus* Potonié and Kremp, p. 150, pl. 10, figs. 76–79.
1958 *Cystosporites giganteus* Piérart, p. 62, pl. 3, fig. 7, pl. 10, figs. 14–15.
1959 *Cystosporites giganteus* Winslow, p. 52, pl. 11, fig. 9, pl. 12, figs. 1–4.

Remarks. Of the fertile form, only five specimens were found intact. These varied between 3,000 and 4,000 μ in maximum diameter. Dijkstra (1946, p. 57) gave a range in maximum size of 3,500 to 11,000 μ. No apical prominence, as described by Chaloner (1954*b*, p. 30), was observed, the laesurae being relatively short in length (up to 200 μ), usually concealed by adhering abortive forms. The proximal part of the spore wall is thicker (20 μ) than the remainder and appears finely vermiculate to granulate under transmitted light. The medial and distal portions of the spore wall are thinner, more translucent, and consist of fibrils, 6 μ wide, which coalesce and bifurcate to form the meshwork that characterizes this genus.

Affinities. *Lepidocarpaceae* (Potonié 1962, p. 132).

Stratigraphic Distribution. Europe, ? Dinantian–Westphalian D (Dijkstra 1946); U.S.A., Mississippian, Michigan, Indiana, Pennsylvania, (Chaloner 1954); Illinois (Winslow 1959); Pennsylvanian, Michigan (Arnold 1950), Illinois (Winslow 1959).

Occurrence. Trenchard (loc. 1–4) and Woorgreen (No. 2) (loc. 31) seams.

Cystosporites varius (Wicher) Dijkstra 1946

Plate 16, figs. 7–9

1934 *Sporites varius* Wicher, pp. 1973, 1974, pl. 8, figs. 3–4.
1950 *Cystosporites varius* Arnold, pp. 88–91, pls. 16–17.
1951 *Cystosporites varius* Kalibová, p. 28, pl. 2, figs. 1–6.
1956 *Cystosporites varius* Potonié and Kremp, p. 152, pl. 10, figs. 80–84.
1958 *Cystosporites varius* Piérart, p. 61, pl. 3, fig. 8.
1959 *Cystosporites varius* Winslow, p. 51, pl. 12, figs. 5–8.
1959 *Cystosporites varius* Danzé and Vigreux, p. 137.

Remarks. Specimens found varied between 700 to 1,500 μ in maximum diameter. They are intermediate in size between the fertile and abortive forms as described by Dijkstra

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EXPLANATION OF PLATE 17

All specimens × 50 under reflected light.

Figs. 1–5. *Zonalesporites* spp. 1–2, *Z. dentatus* (Zerndt) comb. nov. 1, Proximal surface; Trenchard seam (loc. 5), FD/24. 2, Distal surface; Trenchard seam (loc. 5), FD/25. 3–5. *Z. rotatus* (Bartlett) comb. nov. 3, Proximal view of spore body with flange removed; roof-shale Yorkley seam (loc. 15), FD/26. 4, Proximal view of entire spore, oblique compression; roof-shale Yorkley seam (loc. 15), FD/26. 5, Distal view of spore with almost entire flange; roof-shale Yorkley seam (loc. 15), FD/26.

Figs. 6–9. *Valvisisporites* spp. 6–7, *V. auritus* (Zerndt) Bhardwaj. 6, Proximal view; Coleford High Delf seam (loc. 7), FD/27. 7, Lateral compression; Coleford High Delf seam (loc. 8), FD/27. 8–9. *V. nigrozonales* (Stach and Zerndt) Potonié and Kremp. 8, Proximal surface showing narrow laesurae and small auriculae; Woorgreen seam (loc. 31), FD/28. 9, Distal surface; Woorgreen seam (loc. 31), FD/28.

(1946, p. 58) and Potonié and Kremp (1956, p. 152). The spore wall is smooth to finely granulose, no reticulate ornamentation being present as in *C. breretonensis* Schopf (Winslow 1959, pp. 50–51).

Affinities. Lepidocarpaceae. *C. varius* type spores have been obtained from *Lepidocarpon bohdanowiczii* (Bocheński) Potonié 1962.

Stratigraphic Range. Europe, Westphalian A–Stephanian (Dijkstra 1946, 1955*a*); N. America, Lower Pennsylvanian, Michigan (Arnold 1950); Illinois (Winslow 1959).

Occurrence. Trenchard to Woorgreen (no. 2) seams.

MEGASPORE EVIDENCE FOR AGE OF COAL MEASURES

The occurrence of *Valvisisporites* (Zerndt) Potonié and Kremp 1956 *sensu* Bhardwaj 1957 in the Coleford High Delf and seams above it confirms the Westphalian D age of the measures as suggested by non-marine lamellibranch and macrofloral evidence. Sen (1964, p. 99) has recently recorded *Triletes auritus* Zerndt from the Westphalian A–B of the Ayrshire Coalfield. No description, remarks, or illustrations of the species were given by this author, who followed Dijkstra's (1946) 'broad' interpretation of megaspore species. Dijkstra (1946, pp. 31–33) distinguished *Triletes auritus* Zerndt and *Triletes auritus* Zerndt var. *grandis* Zerndt. Since *V. auritus* (Zerndt) Potonié and Kremp *sensu* Bhardwaj is equated to *T. auritus* Zerndt var. *grandis* Zerndt it seems unlikely that the species *T. auritus* referred to by Sen is the same species as recorded here.

An abundance of *Tuberculatisporites brevispiculus* (Schopf) Potonié and Kremp, and *Zonalesporites dentatus* (Zerndt) comb. nov. suggests a lower Westphalian D or possibly highest Westphalian C age for the Trenchard measures. Such an age is also supported by the absence of *Setosisporites praetextus* (Zerndt) Potonié and Kremp, *S. hirsutus* (Loose) Ibrahim, *Lagenicula horrida* Zerndt, and *L. subpilosa* (Ibrahim) Potonié and Kremp, species which are common in Westphalian assemblages up to middle Westphalian C (Dijkstra 1955*b*, p. 6).

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LIST OF LOCALITIES

The map references given below are based upon the $2\frac{1}{2}$ inch to 1 mile topographical maps of the Ordnance Survey of Great Britain. The localities refer to coal samples unless otherwise stated.

Trenchard seam. 1, Edenwall, Coleford, opencast site, SO.51/582103. 2, Mapleford colliery, SO.50/595078. 3, Old Ten Acre and Norchard levels, tips, SO.60/634050. 4, Howle Hill near Ross-on-Wye, outcrop and tips, SO62/200611. 5, Morse Lane, Drybrook, near Cinderford, SO.61/641176.

Coleford High Delf seam. 6, Berry Hill, Coleford, opencast site, SO.51/573118. 7, Edenwall, Coleford, opencast site, SO.51/585104. 8, Wells level, Coleford, SO.51/568134. 9, Hillersland colliery, near Coleford, SO.51/569140. 10, Bream's cove colliery, Bream, SO.60/611047. 11, Northern United colliery, Cinderford, SO.61/637150.

Whittington seam. 12, Parking Hill No. 3 Level, Bream, SO.60/616047. 13, Pillowell, opencast site, SO. 60/631062.

Yorkley seam. 14, Worcester Lodge, near Coleford, coal and roof-shales, SO.51/596115. 15, New road level, Cannop, coal and roof-shales, SO.61/603115. 16, Hamiltons level, Cannop, SO.61/607125.

Brazilly seam. 17, Steam mills, Cinderford, tips, coal, and shales, SO.61/607125. 18, Outcrop near Swan Inn, Brierley, SO.61/626151.

No Coal seam. 19, Outcrop near Cannop colliery, SO.61/611128. 20, Outcrop near Cannop ponds, coal and shales, SO.61/611107. 21, Nine wells near Blakeney, SO.60/611082.

Churchway seam. 22, Outcrop near weir, Cannop ponds, SO.61/612107.

Rockey seam. 23, Outcrop near Cannop colliery, SO.61/611128.

Starkey seam. 24, Oaken hill railway cutting, near Parkend, coal and shale, SO.60/631079. 25, Outcrop near Cannop colliery, SO.61/611129.

Lowery seam. 26, Adit near Lightmoor colliery, coal and roof-shales, SO.61/641109. 27, Outcrop near Cannop colliery, SO.61/611129.

Twenty Inch seam. 28, Morgan's adit near Swan Inn, Brierley, coal and roof-shales, SO.61/627152. 29, Delves inclosure, Brierley, SO.61/642124.

Crow Delf seam. 30, Collingwood level, Nelson green, tip, SO.61/152632.

Woorgreen seam. 31, Adit, near Dilke hospital, Cinderford, SO.61/644155.

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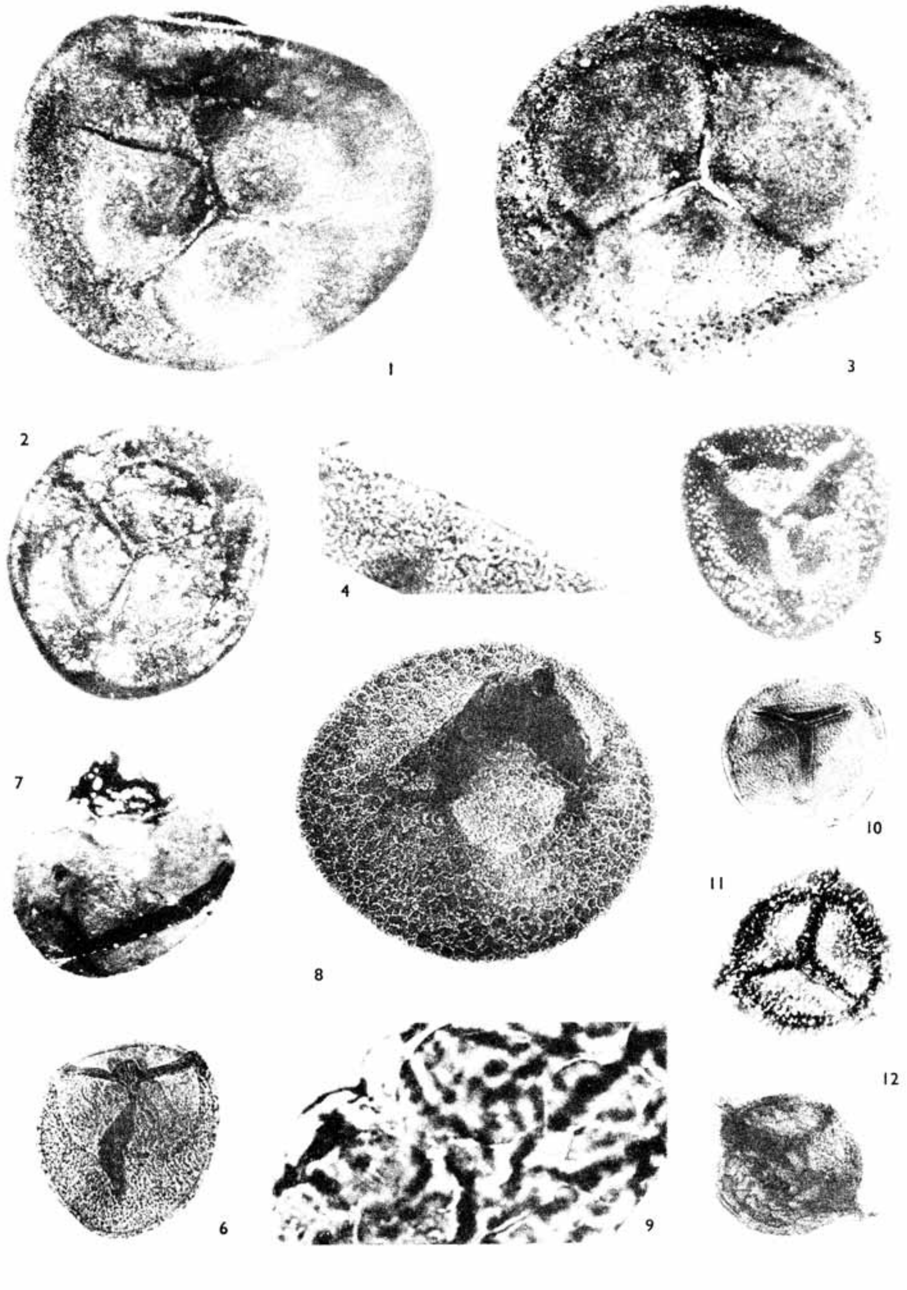
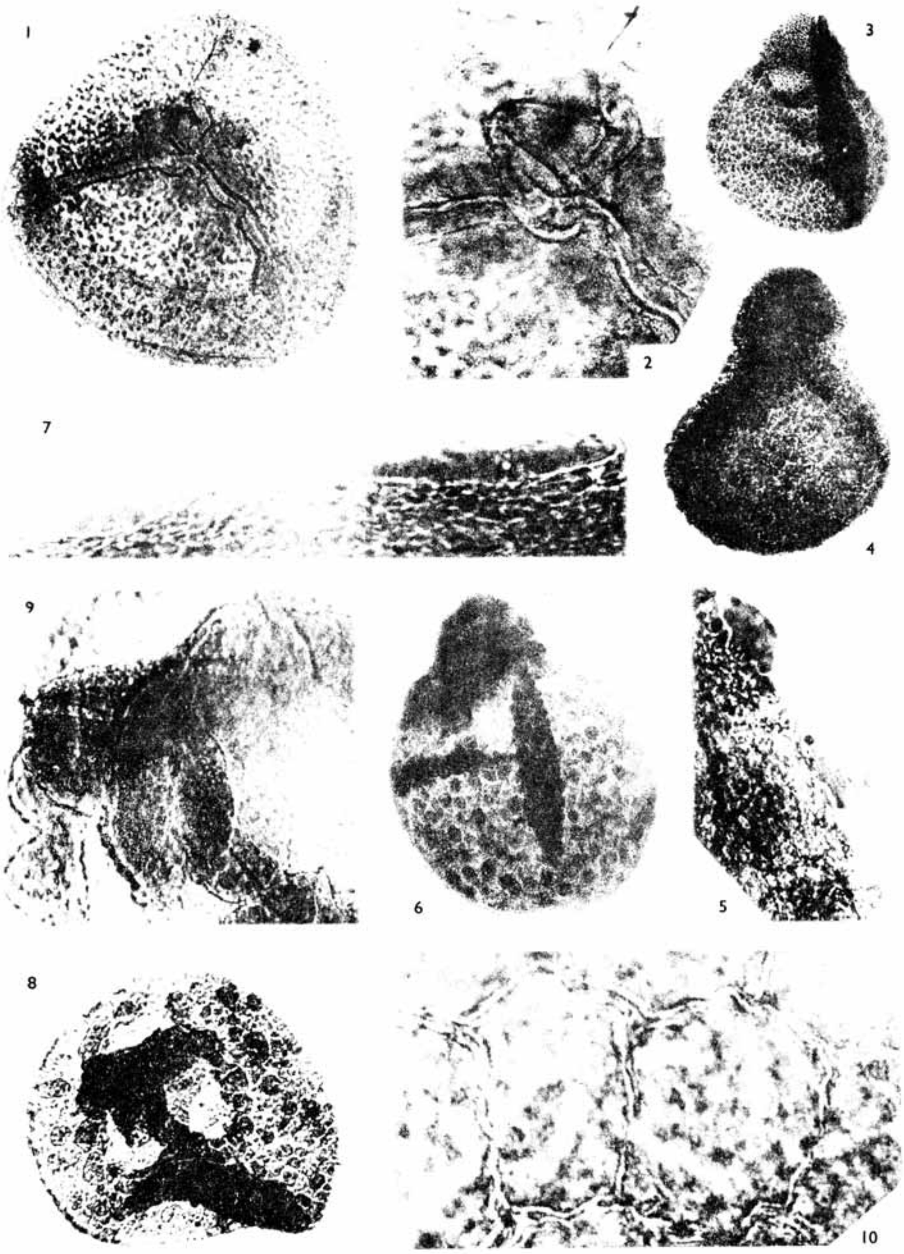


SPINNER, Westphalian D megaspores



SPINNER, Westphalian D megaspores

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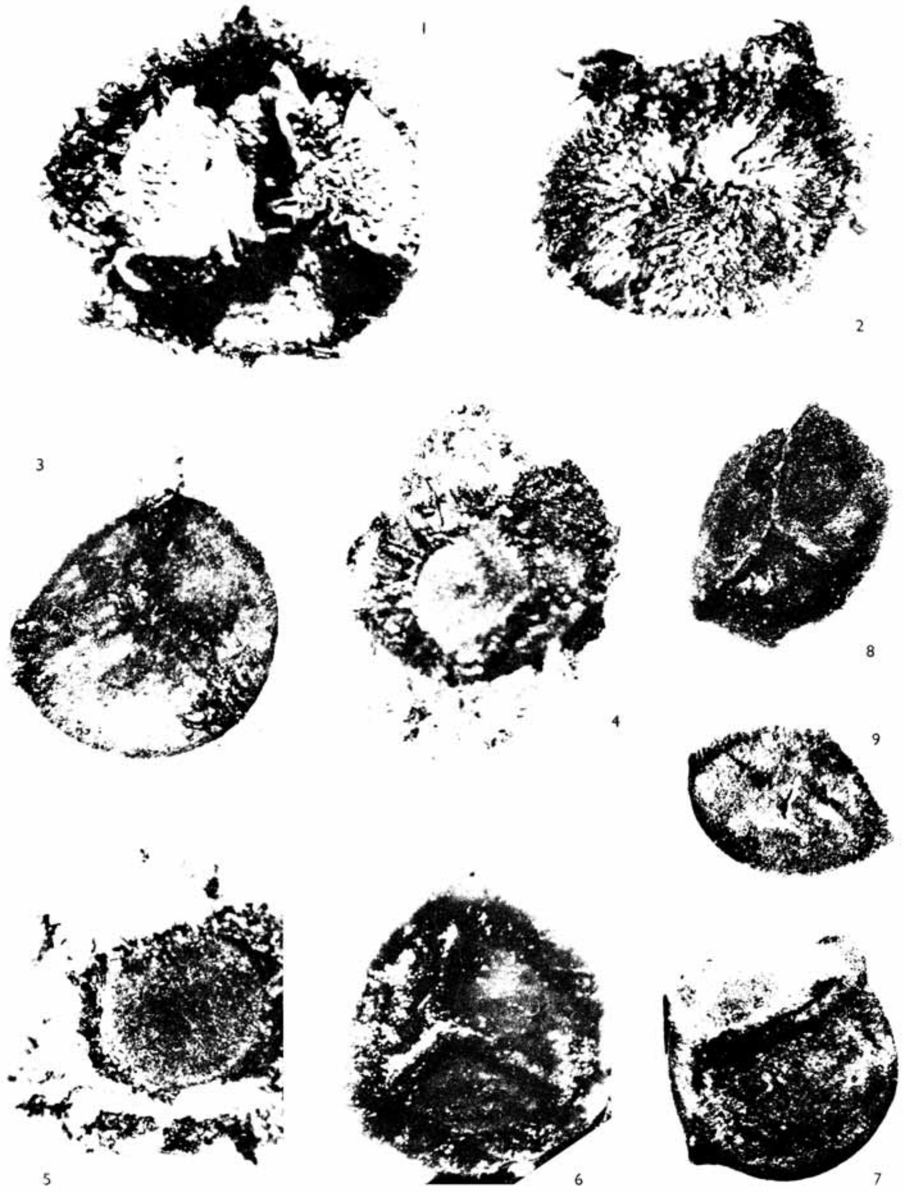

SPINNER, Westphalian D megaspores