THE SILESIAN SUB-SYSTEM IN WARWICKSHIRE, SOME ASPECTS OF ITS PALYNOLOGY, SEDIMENTOLOGY AND STRATIGRAPHY

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IAIN MACFIE FULTON
Doctor of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM
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CHAPTER 6

PALYNOLOGY

The broad objective of this part of the study was to examine the palynology of both the four leaves of the Thick Coal at Longmeadow Wood borehole, and their intervening and under and overlying siliciclastic beds. Initially the most effective maceration technique for removal of the miospores from the coal was determined. Following this the leaves of coal were divided into subsections on a lithological basis and samples taken for maceration. All siliciclastic subsections were macerated. In both cases slides were made from each sample to allow an examination of the miospores present. One hundred and twenty seven miospore species (species) were identified and 19 new forms described. They were presented in a systematic way so that comparison could be made with species described by other authors. Special emphasis in this section was placed on a study of the species of Densosporites found within the Thick Coal.

Following this the distribution of the relative percentages for each species in each of the leaves of the Thick Coal were plotted and subjected to statistical analysis. The distribution of seven of these species were used to divide each leaf palynologically, and based on this and sedimentological data from this and other localities a palaeoecological interpretation of the Thick Coal was made. Finally the species likely to be most useful in correlation of the leaves of the Thick Coal were identified.

6.1 PRACTICAL TECHNIQUES

6.1.1 Sample Collection

Following from section 5.1.1 the coal cores were divided into beds of different lithofacies and a sample about 30mm x 30mm in cross section extracted from each bed. Each sample is termed a subsection and was placed in a self sealing plastic bag.

6.1.2 Mechanical Preparation

Materials needed:- hammer, splitter, pestle and mortar, self sealing plastic bag.

Each sample of coal was broken down with a hammer to less than $5mm^3$. From this 25g. were separated using a splitter, retaining the remainder for possible future use. If the sample was believed to contain silicate it went straight to chemical preparation. Coal samples were placed in a mortar and crushed with a tapping motion of the pestle until fine enough to pass through a 36 B.S. (0.42mm) mesh sieve. After each sample had been mechanically prepared, all the articles used during the preparation were cleaned thoroughly with a brush and hot water and then dried.

If a composite sample consisting of several subsections was required, then different weights of each subsection sample, relating to their thickness, were combined to form the composite sample.

6.1.3 Chemical preparation

6.1.3.1 Removal of carbonates and silicates

Materials needed;-

Fume cupboard with lime tank, samples crushed to $-5mm^3$, 250ml. polythene jars with pierced lids, stirring rods, dilute hydrochloric acid, 40% hydrofluoric acid and distilled water.

10g. of sample which were believed to contain silicate were placed in a 250ml. polythene jar and covered with dilute hydrochloric acid to remove any carbonates that may be present. After effervescence ceased the hydrochloric acid was removed by decantation and 30ml. of 40% hydrofluoric acid was added to the jar and left for 9 days at room temperature, stirring several times each day. The solution was then decanted off into a lime tank and the residue washed five or six times with distilled water.

6.1.3.2 Maceration

Materials needed:-

Fume cupboard, samples, 100ml. beakers, 500ml. beakers, watchglasses, sintered glass funnels - porosity 3, 1 litre Buchner flasks, rubber air bulb, 30ml. glass vials, fuming nitric acid, concentrated nitric acid, 1:1 dilute nitric acid, chromic acid, mould inhibitor, and distilled water.

1g. of coal, previously crushed to pass a 36 B.S. mesh sieve or the residue from previously prepared sample believed to contain silicates, was placed in a 100ml. beaker. To this was added 50ml. of fuming nitric acid (see section 6.1.4) and the beaker covered with a watchglass. All were then placed in a fume cupboard for 12 hours (see section 6.1.4) whilst oxidation released the spores from the sample.

When this had taken place the contents of the beaker were transferred to a sintered glass funnel previously placed in a 1 litre Buchner flask. Filtration then took place with addition of fuming nitric acid until the filtrate was colourless. The residue was then washed twice with 50ml. of concentrated nitric acid and once with 50ml. of 1:1 dilute nitric acid. The final part of filtration consisted of washing the residue several times with distilled water. At this stage air was blown back through the filter with a rubber air bulb to check that it had not become blocked by small particles. The gradual reduction in concentration of acid prevented flocculation of the particles which would increase filtration time. The residue was then washed out of the funnel with distilled water into a labelled 30ml. glass vial and a few drops of mould inhibitor added. After the residue had settled for a few days its thickness was measured.

All articles used during maceration were cleaned throughly with hot water and dried. The sintered glass funnel was cleaned with chromic acid (made of up 50g. of sodium dichromate dissolved in 50ml. of distilled water, to which 2 litres of concentrated sulphuric acid was added).

6.1.4 <u>Determination of the most effective maceration technique</u>

The factors most likely to cause variation in length of time of maceration are differences in rank or subsequent physical and chemical weathering, as this means that the sample may already have undergone some oxidation. For this reason it was necessary to discover the most effective maceration technique for each sample or group of samples.

The two parameters which were most easily varied during maceration, were the strength of acid and the time the sample was immersed in the acid. Four coal samples were taken from a variety of sites including the Thick Coal at Catchems Corner borehole, Longmeadow Wood borehole and one sample from 30m. above the Thick Coal in Daw Mill surface drift. They were prepared as described in the previous sections and each sample divided into two, providing two sets of four samples. 1g. from each of the four samples of the first set were placed in separate beakers and 25ml. of concentrated nitric acid followed by 25ml. of fuming nitric acid was added. After 2 hours, 6 hours, 14 hours and 24 hours samples were taken, filtered, and inspected microscopically. In all cases very little of the coal had broken down so that only a few miospores were released. 1g. from each of the four samples of the second set were placed in separate beakers and 50ml. of fuming nitric acid was added. After 2 hours, 4 hours, 8 hours, 12 hours, 16 hours and 24 hours samples were taken, filtered and inspected microscopically. After 2 and 4 hours not much coal had broken down, but the breakdown progressively increased until after 12 hours all the coal had broken down. Examination of miospores with thin exines showed that quite a lot of colour was retained after 12 hours, but that the colour progressively decreased until after 24 hours it was believed there was a possibility of some chemical disintegration. For these reasons maceration of 1g. of coal with 50ml. of fuming nitric acid for 12 hours, was chosen as the most effective maceration technique.

6.1.5 Preparation of permanent miospore residue mounts

Materials required:-

Spore residue in a 30ml. glass vial filled with distilled water, 10ml. glass jar, Finne pipette, coverslips 22 x 40mm, slides, cellosize solution, Elvacite, xylene, methylated spirits and labels. The glass vial containing the spore residue was shaken gently for 30 sec. and then allowed to settle for 15 sec. to allow large woody fragments to drop to the bottom. A Finne pipette was introduced into the vial with its end near the bottom and a sample of 0.3ml. taken whilst withdrawing the pipette from the vial. This was placed into a 10ml. glass jar, followed by 1.5ml. of a 2% aqueous solution of hydroxethyl cellulose solution. (This was made up of 2g. of cellosize with 2 drops of methylated spirit dissolved in 100ml. of hot water and then filtered with fast filter paper). Using a pipette the sample was mixed throughly and evenly distributed on the surface of 3 coverslips. These were allowed to dry in a dust free atmosphere at room temperature. To each coverslip several drops of Elvacite in xylene was added, and the coverslip gently lowered onto a clean glass slide. (The Elvacite solution was made by adding 70 cc. of Analytical Grade Xylene to 40g. of crushed Elvacite powder whilst stirring. Stirring was continued, using a magnetic bead so as to avoid producing bubbles, until the Elvacite was completely dissolved). The slides were left to set for 24 hours at room temperature. Any excess Elvacite was removed using xylene. After labelling the slide was ready for use.

The advantages of these mounting media over others are that the cellosize prevents clumping, dries to a thin film so that all miospores are in the same plane of focus, and the Elvacite does not require high setting temperatures and gives a clear permanent mount.

6.1.6 Microscopy

Two of the three slides prepared for each subsection or composite sample were horizontally traversed at a magnification of 600 times using a Watson Microsystem 70 microscope. Generally at least 500 miospores were counted as they passed between either end of a calibrated scale and the horizontal distance travelled during scanning was recorded. Each slide was then scanned at a lower magnification for additional taxa not seen on the initial scan. Photographs were taken with a Zeiss Photomicroscope II and the stage coordinates for the photographed miospores relate to that microscope.

6.1.7 Use of the computer in assembling miospore data

Once the logging of the slides was completed, it was felt that the use of a computer would ease in the manipulation of the data produced. In this way the time taken to produce the results was reduced and the accuracy achieved during calculation was increased.

However, the only computer to which there was easy access was a Commodore Pet 8032 expanded to give a 96k memory which was a little small for the task and had a limited range of programmes. A commercial programme entitled Visicalc produced by Visicorp was used, and by dividing the manipulations into suitable size batches it was hoped to achieve the desired objectives.

6.1.7.1 Creation of the miospore count (mc) table
(Appendix 'C')

Because of the way the spread sheet was laid out it was decided to place the subsection numbers horizontally along the top, so that each column represented a subsection from a leaf at a given location and each horizontal row represented a property of that subsection. The first property fed in was thickness (cm) followed below by the second digit of the lithofacies number, macrolithotype percentages, physical and chemical properties, thickness of residue left after maceration (Tr)mm, horizontal distance travelled during counting (Hd)cm, the number of miospore species recognised during counting and scanning, and finally the number of miospores for each species recognised (Nm).

These figures were fed into alternate columns until 13 of the latter were filled (any more and after the manipulations listed below the computer would run out of memory). A formula was placed at the bottom of the column to calculate the total number of miospores counted (Tm) viz. Tm = Nm1 + Nms where s = number of miospore species.

Each of these columns was saved as separate Data interchange format (Dif) files labelled 'mc' according to their subsection number. This process was continued until all of the subsections required had been counted and stored. They were then recalled to form the 'miospore count' table.

6.1.7.2 Creation of the miospore species relative percentage distribution table (Appendix 'D')

The 'mc' Dif files were recalled into a table in which formulae have previously been inserted, to convert the 'mc' files to percentage (per) files.

In the space opposite 'thickness of residue left after maceration' a formula was inserted to convert this figure to 'volume of residue left after maceration' (Vr) cu. cm. viz.

$$Vr = \frac{Tr \times \text{area cross section of vial(mm)}}{1000}$$

i.e.

$$Vr = \frac{Tr \times \pi\ 12.5^2}{1000} \text{ cu.cm.}$$

In the space opposite 'Horizontal distance travelled during counting' a formula was inserted to convert this figure to 'Total number of miospores/g coal' (Tmgc) viz.

$$Tmgc = \frac{\left(\frac{Tm}{Hd} \times Wt\right) \times 3 \times Lc \times 2C \times V}{S}$$

where

Tm = Total number of miospores counted

Hd = Horizontal distance travelled during counting (cm.)

Wt = Width of traverse (0.00159cm.)

Lc = Length of coverslip (4.0cm.)

Wc = Width of coverslip (2.2cm.)

V = Original volume of water plus residue from 1g. of macerated coal (30ml.)

S = Sample volume of original volume distributed between 3 coverslips (0.3ml.)

In the space below this a formula was inserted to calculate the number of species/500 miospores counted (Ns 500) viz.

$$Ns500 = \frac{Ns}{Tm} \times 500$$

In the spaces opposite the 'Number of miospores for each species recognised' a formula was inserted to convert these to 'Relative percentage of each miospore species' (Ms%) viz.

$$Ms\% = \frac{Nm}{Tm} \times 100$$

Each of the columns was saved as a separate Dif file labelled 'per' according to its subsection number. This process continued until all of the 'mc' files had been converted to 'per' files and stored. They were then recalled to form the miospore species relative percentage distribution table.

6.2 SYSTEMATICS

The objectives of the systematic description of miospores within this study are to provide a framework for their identification, and to facilitate comparison with those recognised by other workers. Nomenclature for miospores within this section is based upon the rules of priority and typification laid down in the International Code of Botanical Nomenclature (1961). The systematics are not treated taxonomically, because differences in morphology provide a basis for distinguishing between species, and so are independant of the principles of evolution and phylogenetic relationships. Terminology used in the description of miospore morphology in this study is based on Smith and Butterworth (1967) and Grebe (1971).

6.2.1. Nomenclature of miospore species and genera

The formal treatment of miospore species and genera (synonymy, type locality, diagnosis, description, remarks and comparison) is the same as that in Smith and Butterworth (1967) unless otherwise stated. Considerable use is made of Nader's (1983) systematics, because the coals from which the miospores were derived are the same age. Comparison of the miospores is important because those of Nader (1983) came from the Northumberland Coalfield which possibly had a different palaeoecological setting. Relative abundance and prevalence of species are indicated under the heading of occurrence.

The characteristics listed in the paragraph above refer to miospores found in the four leaves of the Thick Coal (and the high silicate subsections associated with them) at Longmeadow Wood borehole which are of Westphalian B age. Categories of abundance used in this study have been modified from Smith and Butterworth (1967) as follows:-

Percentages	Categories of Abundance: Used in this study	Categories of Abundance: Smith and Butterworth (1967)
Greater than 29.9	Very abundant	Abundant
10-29.9	Abundant	
5.00-9.99	Very Common	Very Common
2.00-4.99	Common	Common
1.00-1.99	Frequent	Frequent
0.500-0.999	Occasional	
Present-0.499	Infrequent	Infrequent
Only one specimen seen	Present	

For each species under the heading of 'Occurrence' the range of categories of abundance are given (as above) for each leaf of coal. This is followed by the category of prevalence (vertical distribution, (see below) for each leaf of coal.

Approximate number of subsections per leaf in which the species has been found	Category of Prevalence used in this study
Greater than 2/3	Throughout
1/3 - 2/3	Intermittent
Less than 1/3	Rare

Following this the range of categories of abundance for each siliciclastic bed is given.

Species are illustrated on plates (Appendix 'E'). Photographs are taken of specimens derived from the Thick Coal at Longmeadow Wood borehole unless otherwise stated. They illustrate typical specimens, although where a range of morphological characteristics is present in one species this is also illustrated. The names of the species are given, together with (in order) their sample, slide and specimen numbers, their location using a Zeiss stage and their photograph number. Normally slides are inserted into the stage with the label at the right hand side; when the label has been inserted on the left hand side an asterisk precedes the location co-ordinates. All specimens have been magnified X500 unless otherwise stated.

6.2.2. Suprageneric systematics

Many suprageneric classification systems of miospores have been proposed. They began in Britain as a simple grouping of miospores with similar morphological characteristics (Raistrick and Simpson 1933) and grew rapidly abroad with some authors placing emphasis on the use of one character only at each systematic level (Naumova 1939, Dettmann 1963) whilst others used a variety (Potonie and Kremp 1954, 1955, 1956a and b). The latter authors have produced probably the best known system, which has been subsequently revised and amplified by many authors (Potonie 1956, 1958, 1960, 1970, 1975; Dettman 1963; Neves and Owens 1966; Smith and Butterworth 1967). Most of the genera found in the present study occur in the suprageneric classification of Smith and Butterworth (1967) and for this reason it is used by the author. Those genera not recorded by Smith and Butterworth (1967) are

Table 6.1 Scheme for the suprageneric classification of miospores (from Smith and Butterworth 1967) inserted in the appropriate places, together with any new suprageneric grouping proposed by the respective authors.

A summary of suprageneric classification is given in Table 6.1. The two major categories distinguishing spores from pollen are Sporites (Potonie 1893) and Pollenites (Potonie 1931). These are divided into major categories called anteturma (Potonie 1956) and four other ranks of classification are used: turma, suprasubturma, subturma, infraturma and subinfraturma.

Anteturma Sporites is divided into four turmae based on the presence/absence, and type of dehiscence mark following three authors - Triletes (Dettman 1963 following Reinsch), Monoletes and Aletes (Ibrahim 1933) and Hilates (Dettman 1963). There are eight suprasubturmae based on differences in wall stratification originally described by Potonie and Kremp (1955, 1956) and expanded by Dettmann (1963), together with contributions from Richardson (1965) and Smith and Butterworth (1967). There are eight subturmae based on difference in equatorial features using the work of Luber (1935), Luber and Schopf in Dettmann (1963), and Smith and Butterworth (1967). Sculpture and equatorial thickening and/or extension provide the basis for sixteen infraturma using the work of many authors and one infraturma has been divided into four subinfraturmae by Smith and Butterworth (1967) on the basis of differences in sculpture.

Anteturma Pollenites is divided into two turmae Saccites (Erdtman 1947) and Plicates (Plicata-Naumova 1937, 1939; Potonie 1960) on the basis of the presence or absence of a longitudinal furrow. Turma Saccites is divided into two subturmae on the number of bladders present either one - Monosaccites (Chitaley) Potonie and Kremp 1954

Table 6.1.A Known plant affinities of miospores found in this study
(Classification after Taylor 1981)

PLANT MEGAFOSSILS				MIOSPORES in this study	
Phylum	Class	Order	Examples of Genus/ Species	Genus	Species
TRIMEROPHYTOPHTA		Psilotales	Pertica	Apiculiretusispora	
LYCOPHYTA		Lepidodendrales	Lepidodendron	Apiculatisporis	irregularis
		Sellaginellales	Selaginella canonbiensis	Cingulizonates	
		"	Selaginella suessi; fraiponti	Cirratriradites	
		Lepiododendrales	Sigillaria (Mazocarpon)	Crassispora	kosankei
		"	Sporangiostrobus	Cristatisporites	
		Sellaginellales	Selaginella canonbiensis	Densosporites	
		Lepidodendrales	Polysporia mirabilis	Endosporites	globiformis
		"	Paralycopodites	Lycospora	micropapillata
		Lepidodendrales	Lepidophloios harcourti	Lycospora	pellucida
		" "	Lepidophloios) halli) Lepidodendron) hicki)	Lycospora	pusilla
		"	Sigillariostrobus	Planisporites	
		"	Sporangiostrobus	Radiizonates	
		Protolepidodendrales	Spencerites	Spencerisporites	
SPHENOPHYTA		Sphenophyllales	Eviostachya	Acanthotriletes	(pars)
		"	Bowmanites	Calamospora	(pars)
		Equisetales	Calamostachys Palaeostachya	" "	
			Calamostachys	Crassispora	(pars)
		Sphenophyllales	Bowmanites bifurcatus	Laevigatosporites	All species
		Equisitales	Asterophyllites multifolia	"	"
		Sphenophyllales	Sphenophyllum dawsoni	Reticulatisporites	(pars)
		Sphenophyllales	Sphenophyllo-stachys sp	Vestispora	
PTERIDOPHYTA	?	?	?	Acanthotriletes	(pars)
	Filiopsida	Filicales	?	Apiculatasporites	
	"	Marattiales	Scolopteris	Calamospora	
	"	Filicales		Camptotriletes	
	"	"	Senftenbergia	Convolutispora	(pars)
	Coenopteridopsida	Zygopteridales	Bisaltheca kansana	Convolutispora	(pars)
	Filicopsida	Marattiales	Asterotheca miltoni	Cyclogranisporites	minutus

Table 6.1A (Cont) Known plant affinities of miospores found in this study (Classification after Taylor 1981)

PLANT MEGAFOSSILS				MIOSPORES in this study	
Phylum	Class	Order	Examples of Genus/ Species	Genus	Species
PTERIDOPHYTA cont ...	Coenopteridopsida "	Zygopteridales "	Bisaltheca musata Cornyopteris scottii	Cyclogranisporites	(pars)
	Filicopsida	Marattiales	Acitheca	Cyclogranisporites	(pars)
	"	"	Scolopteris	Dictyotriletes	castaneaeformis
		Filicales	Sermaya biseriata	Granulatispoites	(pars)
	"	"	Botryopteris antiqua	"	"
	"	"	Oligocarpia	Leiotriletes	
	Coenopteridopsida	?	?	"	
			Sphyroteris cf. boenishi	Lophotriletes	
	Filicopsida	Filicales	Botryopsis forensis, globosa	Punctatispories	(pars)
	"	Marattiales	Asterotheca scolecopteris	"	
	Coenopteridopsa	Zygopteridales	Bisaltheca musata	"	
	"	"	Pecopteris cf. platoni	Punctatosporites	
	"	Filicales	Senftenbergia plumosa	Raistrickia	
	"	"	Ankyopteris brongniartii	"	
		"	Anachopteris	"	
	"	"	Senftenbergia	Savitrisporites	
	"	"	Botryopteris	Triquitrites	
	Filicopsida	Marattiales	Pecopteris hemitelioides	Verrucosisporites	
	Coenopteridopsa	Zygopteridales	Biscaltheca musata	"	
	"	"	Cornyopteris scottii	"	
	"	"	Zygopteris	"	
	Filicopsida	Filicales	Botryopsis forensis	"	
PTERIDOSPERMO-PHYTA			Staphylotheca kilpatrickensis	Convolutispora	(pars)
		Lyginopteridales	Crossotheca schatzalerensis	Cyclogranisporites	(pars)
		"	Crossotheca crepini	Granulatisporites	(pars)
		"	Crossotheca crepini; sagittata schatzalerensis	Punctatisporites	(pars)
		Medullosales	Linopteris subbrongniartii	"	"

Table 6.1A (Cont) Known plant affinities of miospores found in this study (Classification after Taylor 1981)

PLANT MEGAFOSSILS				MIOSPORES in this study	
Phylum	Class	Order	Examples of Genus/ Species	Genus	Species
PTERIDOSPERMO -PHYTA cont ...		"	Aulotheca elongata, hemingwayi	Schopfipollenites	
			Whittleseya elegans	"	
			Goldenbergia glomerata	"	
			Halletheca	"	
			Dolerotheca	"	
			Rhetinotheca	"	
			Schopfitheca	"	
CONIFEROPHYTA	Cordaitopsida	Cordaitales	Coraitanthus gemmifer, scholeri saportianus	Florinites	
	Coniferopsida	Voltziales	Lebachia piniformis, hypnoides	Potonieisporites	
			Walchianthus crassus	"	

(pars) means that the miospore species occurs in more than one phylum or two - Disaccites Cookson (1947); the former being divided into three infraturmae.

In recent years papers produced by several American authors have not used suprageneric classification following objections raised by Schopf (1969). He believed that "taxonomic assignment should be a means of indicating an author's evaluation of phyletic affinity". At the moment the relationships between miospores and their parent plants is under investigation with a varying amount of success (Table 6.1A). Schopf (1969) also considers that forms which in any way significant botanically should be emphasised within any classification. Form genera, defined by morphology and for which there are no known botanical affinities, are not assignable to a family (Lanjouw 1966). However, Potonie (1956, 1958, 1960) devised a classification using turmae as indicators of rank which Schopf (1969) suggests are "parataxa". These have never been sanctioned by the botanical code, and duplicate and conflict with corresponding and well established botanical nomenclature (Schopf 1969). This has resulted in some American authors rejecting suprageneric classification and either arranging miospore genera alphabetically (Urban 1971) or ordering them in a similar way to Smith and Butterworth (1967) for convenience of comparison with other literature (Peppers 1970, Ravn 1979, Ravn and Fitzgerald 1982).

6.2.3. Systematic Descriptions of Miospores

Anteturma SPORITES Potonie 1893

Turma TRILETES (Reinsch) Dettman 1963

Suprasubturma ACAVATITRILETES Dettman 1963

Subturma AZONOTRILETES (Luber) Dettman 1963

Infraturma LAEVIGATI (Bennie and Kidston) Potonie 1956

Genus LEIOTRILETES (Naumova) Potonie and Kremp 1954

Leiotriletes adnatus (Kosanke) Potonie and Kremp 1955

1950 Granulati-sporites adnatus Kosanke, p.20, pl.3, Fig. 9.

1955 Leiotriletes adnatus (Kosanke) Potonie and Kremp

Holotype. Kosanke 1950, pl.3, Fig.2, Maceration 573, slide 8.

Type locality. Coal 20 feet below the Carlinville limestone (No.8 coal), Macoupin County Illinois, USA.

Diagnosis. (Kosanke 1950, p.20).

Size in micrometres. Holotype 35 x 36; 32 - 39, Schulze and 10% KOH (Kosanke 1950).

Leiotriletes cf. adnatus (Kosanke) Potonie and Kremp 1955

Plate 1, Figs. 1, 2.

1983 Leiotriletes cf. adantus (Kosanke) Potonie and Kremp in Nader, p.35, pl.1, fig 1 - 5 and 7.

Size in micrometres. 24(26) 33 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B (ii) 18 (4) 29 (5 specimens) fum. HNO_3 Leaf 3, Thick Coal, Longmeadow Wood borehole Warwickshire, England; Westphalian B.

Description. Amb triangular, sides straight to slightly convex or concave, with rounded angles. Laesurae simple straight 2/3 - 3/4 spore radius, slight thickening along the edge of the commissure, often open. Prominent contact area extending 2/3 length of the laesurae. Exine laevigate to occasionally scabrate on proximal surface only, thin, approximately 1 micrometre with few folds.

Remarks. Leiotriletes cf. adnatus differs from the type in its smaller size and its straight to slightly convex or concave sides.

Comparison. Differs from Leiotriletes levis (Kosanke) Potonie and

Kremp 1955 in smaller size and straighter sides and from Leiotriletes sp.A which consistently has strongly concave sides.

Occurrence. Present to infrequent rarely in Leaves 2 and 4, occasional rarely in Leaf 3. Occasional between Leaves 3 and 4. Present below the Thick Coal.

Leiotriletes guennelii Ravn 1979

Plate 1, figs. 3,4.

1958 Leiotriletes parvus Guennel, p.57, text - fig.14, pl.2, fig. 7, 8.

Non 1953 Leiotriletes parvus Naumova, p.44, pl.5, fig. 10.

Non 1958 Leiotriletes parvus Nilsson, p.30, pl.1, fig. 1.

1967 Leiotriletes parvus Guennel, in smith and Butterworth p.122, pl.1, figs. 3, 4.

1979 Leiotriletes guennelii Ravn, p.20, pl.1, fig. 1.

Holotype. (Smith and Butterworth 1967, p.122).

Type locality. (Smith and Butterworth 1967, p.122).

Diagnosis. (Ravn 1979, p.20).

Size in micrometres. (i) Holotype 22; 16(20)28, Schulze)Guennel 1958) (ii) 23(27)29 fum. HNO_3 (Nader 1983), Northumberland, England; Westphalian B, (iii) 18(21)26 (20 specimens) fum. HNO_3, Leaf 3, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides concave rarely convex, angles well rounded. Laesurae straight, 1/2 - 3/4 spore radius. Exine laevigate, moderately thin approximately 1-1.5 micrometres, seldom folded, or occasionally in gulagerous compression.

Remarks. (See discussion Ravn 1979, p.20).

Comparison. (See discussion Ravn 1979, p.20 and Smith and Butterworth 1967, p.122).

Occurrence. Infrequent to common intermittently in Leaves 1 and 3, present to very abundant intermittently in Leaf 2, present to common throughout Leaf 4. Occasional below the Thick Coal, and between Leaves 1 and 2 and Leaves 2 and 3, present between Leaves 3 and 4, infrequent above the Thick Coal.

Leiotriletes levis (Kosanke) Potonie and Kremp 1955.

Plate 1, figs. 5, 6.

1950 *Granulati-sporites levis* Kosanke, p.21, pl.3, fig. 5

1955 *Leiotriletes levis* (Kosanke) Potonie and Kremp, p.38.

1966 *Ahrensisporites vagus* Habib, p.640, pl.106, fig. 5.

1979 *Leiotriletes levis* (Kosanke) Potonie and Kremp, in Ravn, p.21, pl.1, figs. 4, 8.

Holotype. Kosanke 1950, pl.3, fig. 5, Maceration 500B slide 2.

Type locality. Central pipe line - Liddle No. 1 (Friendsville Coal), Wabsash County, Illinois, USA, Upper McLeansboro Group.

Diagnosis. (Kosanke 1950, p.21).

Size in micrometres. (i) Holotype 48 x 50, Schulze and 10% KOH, (Kosanke 1950), (ii) 35(36)41, fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B.

Description. (Nader 1983) "Amb triangular, sides slightly concave to convex with well rounded angles. Laesurae simple straight to slightly fluxose, 1/2 - 3/4 spore radius. Contact area extending to end of laesurae. Exine laevigate, moderately thick 1 - 2 micrometres with no folding".

Occurrence. Occasional rarely in Leaf 1, present rarely in Leaf 2, infrequent to occasional rarely in Leaf 4. Present below the Thick Coal.

Leiotriletes priddyi (Berry) Potonie and Kremp 1955

Leiotriletes cf. priddyi (Berry) Potonie and Kremp 1555

in Smith and Butterworth 1967

Plate 1, figs. 7-9.

1967 Leiotriletes cf. priddyi (Berry) Potonie and Kremp 1955 in Smith and Butterworth, p.123, pl.1, figs. 5, 6.

Occurrence. Present to infrequent rarely in Leaf 1, present to frequent intermittently in Leaf 2, rarely in Leaf 3, present to common rarely in Leaf 4. Frequent to abundant below the Thick Coal, occasional to frequent between Leaves 1 and 2, frequent between Leaves 2 and 3, infrequent between 3 and 4 and above the Thick Coal.

Leiotriletes sphaerotriangulus (Loose) Potonie and Kremp 1955,

Plate 1, figs. 10-13.

Occurrence. Present rarely in Leaf 1. Present below the Thick Coal.

Leotriletes sp.A

Plate 1, figs. 14, 15.

Size in micrometres. 18, 23, 24 (3 specimens) fum. HNO_3 Leaf 1 Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides concave, angles well rounded. Laesurae simple, straight 3/4 spore radius, with a well defined contact area, extending 3/4 the length of the laesurae. Exine laevigate, thin, approximately 1 micrometre, no folds.

Comparison. L. guennelii Ravn (1979) is of similar size and shape but lacks a contact area. In photographs of L. guennelii taken by Ravn (1979) and Nader (1983) an incipient darkened area around the laesurae is visible. The contact area of L. sp.A is much more clearly defined. Leiotriletes sp.1 Ravn)1979) resembles L. sp.A but is larger.

Occurrence. Present to occasional rarely in Leaf 1. Present between leaves 1 and 2.

Genus PUNCTATISPORITES (Ibrahim) Potonie and Kremp 1954

Punctatisporites edgarensis Peppers 1970

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

Holotype. Peppers 1970, pl.1, fig. 16, maceration 1402 D, slide 21, co-ordinates, 138.5 x 55.7.

Type locality. Lowel Coal, No. 5, Illinois, Pennsylvanian.

Size in micrometres. (i) Holotype 121.9 x 113.8; 90 (130.7) 152,8 (21 specimens) Schulze and KOH (Peppers 1970).

Punctatisporites cf. edgarensis Peppers 1970, in Ravn 1979

Plate 1, figs. 16-19.

1979 Punctatisporites cf. edgarensis (Peppers) Ravn pl.2, fig. 8.

Size in micrometres. (i) 132.1 Schulze and KOH (Ravn 1979) (ii) 74(84)96 fum.HNO_3 (Nader 1983), Northumberland, England; Westphalian A and B (iii) 40(68)95 (20 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. (Nader 1983) "Amb rounded triangles with undulating margin. Laesurae simple straight, 1/2 - 3/4 of spore radius, sometimes open. The distal surface bears conspicuous, sharply bounded low vermiform ridges, mainly around the spore margin, while on the proximal surface the number of those structures is reduced and they sometimes tend to merge with the rest of the spore coat. Exine otherwise laevigate, 4 - 8 micrometres thick".

Remarks. The specimens described by Nader (1983) and those seen in the present study are smaller than those described by Ravn (1979) perhaps because of the different method of preparation.

Comparison. Differs from the type possessing distinct and well defined ridges on the distal surface. P. sinuatus (Artuz) Neves 1961 has a more rounded shape and is not so strongly folded as P. cf. edgarensis, although one of the specimens figured by Smith and Butterworth 1967, pl.2, fig. 2 may have distal ridges, but this is unclear because the view is of the proximal surface.

Occurrence. Present rarely in Leaves 1 - 3. Infrequent below the Thick Coal.

Punctatisporites obesus (Loose) Potonie and Kremp, 1955

Plate 3, figs. 1-3.

Remarks. Specimens as small as 76 micrometres have been observed in this study.

Occurrence. Present to infrequent rarely in Leaves 1 - 3. Common beneath the Thick Coal, present between Leaves 1 and 2, occasional between Leaves 3 and 4.

Punctatisporites punctatus Ibrahim 1932

Plate 4, figs. 4-6.

Remarks. Specimens included in this species ranged in size from 32-84 micrometres, which is larger than the range given by Smith and Butterworth (1967) 59-89 micrometres and Nader (1983) 49-75 micrometres. The exine is also thicker (1-3 micrometres) in some specimens than in the original diagnosis (1-2 micrometres).

Comparison. See Smith and Butterworth 1967; also differs from P minutus (Kosanke 1950) because of its larger size.

Occurrence. Present to infrequent intermittently in all leaves, occasional at the base of Leaf 2 and in Leaves 3 and 4. Common below the Thick Coal, occasional to very common between Leaves 1 and 2, infrequent between Leaves 3 and 4, occasional above the Thick Coal.

Punctatisporites sp.A

Plate 2, figs. 7-9.

Size in micrometres. Minimum 42 x 51, maximum 59 x 71, average 50 (9 specimens) 40% HF and fum. HNO_3, interseam parting between Leaves 3 and 4, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to elongate rounded triangular, margin smooth. Laesurae simple, straight with one angle 90° or less, the other two angles are obtuse. The length of the laesurae can vary in individual specimens and between specimens from 1/2 - 4/5 spore radius. Exine 1-2 micrometres thick, laevigate, with or without one compression fold.

Remarks. The range of exine thickness and length of laesurae are shown in the photographs.

Comparison. The angles between the laesurae distinguish this from other species of Punctatisporites. P. sp.A (Nader 1983) is similar but has a thicker exine (2-3 micrometres).

Occurrence. Present rarely in Leaves 1, 2 and 3. Present between Leaves 1 and 2; infrequent between Leaves 3 and 4.

Genus CALAMOSPORA Schopf Wilson and Bentall 1944

Calamospora breviradiata Kosanke 1950

Plate 2, figs. 10, 11.

Comparison. Three species of Calamospora with contact areas are recognised in this study on the basis mainly of size following Smith and Butterworth 1967 viz. C. parva Guennel 1958 smaller than 45 micrometres, C. cf. breviradiata Kosanke 1950 in Smith and Butterworth 1967 44-55 micrometres, and C. breviradiata 55-75 micrometres. A fourth species C. hartungiana (Schopf) Schopf, Wilson and Bentall

(1944) 74(81)103 found by Nader (1983) was not seen in this study. A fifth species with a contact area C. cf. laevigata (Ibrahim) Schopf, Wilson and Bentall in Smith and Butterworth 1967 is larger than C. hartungiana and is also recognised by its thicker exine.

Occurrence. Present to frequent intermittently in Leaves 1 and 4, present to occasional rarely in Leaf 2, present rarely in Leaf 3. Present above and below the Thick Coal.

Calamospora cf. breviradiata Kosanke 1950 in Smith and Butterworth 1967

Plate 2, figs. 12-14.

1967 Calamospora cf. breviradiata Kosanke in Smith and Butterworth Pl.2, figs. 5, 6.

Comparison. C. parva is smaller and usually has simple laesurae.

Occurrence. Present to very common throughout Leaf 1, intermittently in Leaf 2, infrequent to frequent rarely in Leaf 3, occasional to common throughout Leaf 4. Present below the Thick Coal, present to frequent between Leaves 1 and 2, occasional above the Thick Coal.

Calamospora laevigata (Ibrahim) Schopf, Wilson and Bentall

Calamospora cf. laevigata (Ibrahim) Schopf, Wilson and Bentall 1944, in Smith and Butterworth 1967.

Plate 3, figs. 1-3.

1967 Calamospora cf. laevigata (Ibrahim) Schopf, Wilson and Bentall 1944 in Smith and Butterworth, pl.2, figs. 10, 11.

Occurrence. Present rarely in all leaves. Present below the Thick Coal and between Leaves 1 and 2, and Leaves 2 and 3.

Calamospora microrugosa (Ibrahim), Schopf, Wilson and Bentall 1944

Plate 3, figs. 4-6

Remarks. A faint darkened area between the rays of the laesurae is occasionally present.

Comparison. Two species of Calamospora without contact areas are recognised mainly on the basis of size viz. those smaller than 75 micrometres are C. pallida (Loose) Schopf, Wilson and Bentall 1944 and those larger than 75 micrometres C. microrugosa, following Smith and Butterworth (1967). C. liquida Kosanke 1950, differs from C. microrugosa only in possessing longer laesurae (Smith and Butterworth 1967), and it may be synonymous with C. microrugosa.

Occurrence. Present rarely in Leaf 1, present to frequent intermittently in Leaf 2, and present rarely in Leaves 3 and 4. Common below the Thick Coal and present between Leaves 3 and 4.

Calamospora nebulosa Ravn 1979

Plate 3, figs. 7-10.

1979 Calamospora nebulosa Ravn, p.24, Pl.3, figs. 8 -12.

Holotype. Ravn 1979, Pl.3, fig. 9, slide 6Z4 co-ordinates 139, 35.

Type locality. CP-19-4 Seam, Cherokee Group, Wapello County, Iowa, USA.

Diagnosis. (Ravn 1979, p.24)

Size in micrometers. (i) Holotype 85.2, 63-94 Schulze, 10% KOH and 48% HF (Ravn 1979) (ii) 56(77)89.5, fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B (iii) 42(68)85 (20 specimens) fum. HNO_3, leaf 4, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Remarks. Specimens as small as 42 micrometres in size have been observed in this study. The size of the distally thickened area ia variable and not always well defined.

Comparison. Differs from other species in its thicker exine (2-2.5 micrometres) and in possessing a distal thickening.

Occurrence. Present to occasional rarely Leaves 1-3, present to frequent rarely in Leaf 4. Present below the Thick Coal, occasional between Leaves 1 and 2.

Calamospora pallida (Loose) Schopf, Wilson and Bentall 1944

Plate 3, figs. 11-13

Occurrence. Present to frequent rarely in Leaves 1 and 3, present to common intermittently in Leaf 2, occasional rarely in Leaf 4. Occasional to common below the Thick Coal, occasional to frequent between Leaves 1 and 2, frequent between Leaves 3 and 4, present above the Thick Coal.

Calamospora parva Guennel 1958

Plate 3, figs. 14-17.

Occurrence. Present to very common intermittently in Leaf 1 and throughout the base of Leaf 2, infrequent to common throughout Leaf 3 and present to frequent intermittently in Leaf 4. Present to common below the Thick Coal, common between Leaves 1 and 2, and Leaves 3 and 4, frequent between Leaves 2 and 3, present above the Thick Coal.

Calamospora pedata Kosanke 1950

Plate 4, figs. 1-3.

Size in micrometres, (i) Holotype 70.3 x 44.1, 41-75 Schulze and 10% KOH (Kosanke 1950) (ii) 38(49)72, fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B.

Remarks. Some specimens have darkened contract areas.

Comparison. C. pedata is distinguished from other species of Calamospora previously described by its thicker exine and presence of a single fold producing an elliptical outline.

Occurrence. Present to frequent rarely in all leaves. Present to frequent below the Thick Coal, present between Leaves 2 and 3.

Calamospora cf. pedata Kosanke 1950, in Ravn 1979

Plate 4, figs. 4-7.

1979 Calamospora cf. pedata (Kosanke) Ravn Pl.3, figs. 6, 7.

Size in micrometres. (i) 61, 92 Schulze, 10% KOH and 48% HF (Ravn 1979) (ii) 32 (55) 80 fum. HNO_3, (Nader 1983) Northumberland, England; Westphalian B.

Description (Nader 1983) "Amb lenticular due to compression. Laesurae, ridged raised with distinct lips, sometimes of unequal length, 1/4 of spore radius. Exine yellowish brown, laevigate moderately thick, a faint contact area is present and a single major broad well developed compression fold".

Remarks Some specimens observed had longer laesurae than those mentioned by Ravn (1979) and Nader (1983).

Comparison. Ravn (1979) distinguishes this from the type because of its short, raised laesurae with distinct lips, together with a contact area.

Occurrence. Present to frequent intermittently in Leaves 1 and 4, present to occasional intermittently in Leaf 2, infrequent rarely in Leaf 3. Occasional to frequent between Leaves 1 and 2, occasional between Leaves 3 and 4 and above the Thick Coal.

Calamospora straminea Wilson and Kosanke 1944

Plate 4, figs. 8, 9.

Remarks. The spores examined in this study have a thick exine similar to that observed by Smith and Butterworth (1967) and recognition of this species is based on specimens having one or two marginal folds at the most.

Occurrence. Present to infrequent rarely in Leaf 1, present to frequent intermittently in Leaf 2, present to occasional rarely in Leaves 3 and 4. Occasional below the Thick Coal, and between Leaves 1 and 2.

Genus ADELISPORITES RAVN 1979

Type species. A. multiplicatus Ravn 1979.

Diagnosis. (Ravn 1979 p.25).

Comparison. Distinguished from Calamospora by its characteristic folding resulting in a more or less hexagonal equatorial outline.

Adelisporites multiplicatus Ravn 1979

Plate 4, fig. 10.

1979 Adelisporites multiplicatus Ravn, p.25, pl. 4, figs 2-6.

Holotype. Ravn 1979, pl.4, fig.2, slide $1C_2$ co-ordinates 136.5 x 60.

Type locality. Seam CP-19-4, Cherokee Group, Wapello County, Iowa, U.S.A.

Diagnosis. (Ravn. 1979 p.25).

Size in micrometres. 21-34 Schulze, 10% KOH,, and 48% HF (Ravn 1979).

Occurrence. Present to infrequent rarely in Leaves 1 and 4, and intermittently in Leaf 2. Present beneath the Thick Coal and present to infrequent between Leaves 1 and 2.

Infraturma APICULATI (Bennie and Kidston) Potonie 1956

Subinfraturma GRANULATI Dybova and Jachowicz 1957

Genus GRANULATISPORITES (Ibrahim) Potonie and Kremp 1954

Granulatisporites adnatoides (Potonie and Kremp) Smith and Butterworth 1967

Plate 4, figs. 11-14

Size in micrometres. (i) Holotype 36, 30 -40 Schulze (Potonie and Kremp 1955) (ii) 27(31)38 fum. HNO_3 (Smith and Butterworth 1967) Yorkshire, England; Westphalian B, (iii) 24(30)40 (20 specimens) Leaf 4,, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, angles broad, inter-radial margins straight to slightly convex. Laesurae simple, straight, often open,, 2/3 to 3/4 spore radius. A contact area is present extending nearly to the ends of the laesurae. Exine thin, occasionally folded with an ornament of closely spaced, but sometimes irregularly distributed, very fine grana.

Remarks. Smith and Butterworth (1967) noted that the exine possesses a finely granulate ornament, although on some specimens observed in this study the grana are unevenly distributed. L. adnatus (Kosanke 1950) was described by Potonie and Kremp (1955) as finely granulose in the region of the tetrad mark and on this basis would, like similar specimens observed in this study be assigned to G. adnatoides. Ravn (1979) made G. parvigranulatus Staplin 1960 and G. tenuis Peppers 1964 synonymous with G.adnatoides.

Comparison. This is the most finely ornamented of the species of Granulatisporites recognised in this study. G.parvus (Ibrahim) Potonie and Kremp 1955 is larger and has slightly coarser and more evenly distributed ornament. G.cf.parvus (Ibrahim) Potonie and Kremp (1955) illustrated in Peppers 1970 appears very similar to G. adnatoides. G.microgranifer (Ibrahim 1933 has concave sides and the faint contact area is not always visible.

Occurrence. Absent in Leaf 1, present to frequent rarely in Leaf 2, present to abundant throughout Leaf 4. Occasional to frequent below the Thick Coal, present between Leaves 3 and 4 and above the Thick Coal.

Granulatisporites granulatus Ibrahim 1933

Plate 4, figs. 15-17

Remarks. The grana range in size from 0.5 - 1.5 micrometres and are fairly evenly distrubuted. Several specimens with convex sides were observed. Ravn (1979) made Granitriletes granifer (Ibrahim) Dybova and Jachowicz 1957a synonymous with G.granulatus.

Comparison. This is the most coarsely ornamented of the species of Granulatisporites recognised in this study. Both G.microgranifer Ibrahim 1933 and G.minutus Potonie and Kremp 1955 have a smaller average size, and smaller size of ornament.

Occurrence. Present to occasional intermittently in Leaf 1 and rarely in Leaf 2. Present to frequent rarly in Leaf 3 and present to occasional rarely in Leaf 4. Common below the Thick Coal, present between Leaves 1 and 2 and Leaves 3 and 4.

Granulatisporites microgranifer Ibrahim 1933

Plate 4, figs. 18-21.

Comparison. Distinguished from G. adnatoides (Potonie and Kremp) Smith and Butterworth 1967 by its concave sides and from all other species of Granulatisporites by its fine grade of ornament.

Occurrence. Present to very common often in Leaves 1 and 2, frequent to common often in Leaf 3, occasional to common often in Leaf 1. Frequent to common below the Thick Coal, common to very common between Leaves 1 and 2, occasional between Leaves 2 and 3, infrequent above the Thick Coal.

Granulatisporites minutus Potonie and Kremp 1955

Plate 4, figs. 22, 23.

Remarks. The grana range in size from 0.5 to 1 micrometre and are irregularly distributed.

Comparison. Distinguished from *G.granulatus* Ibrahim 1933 by its slightly finer and more unevenly distributed ornament, and from other species by its coarser grade of ornament.

Occurrence. Infrequent to common often in Leaf 1 and intermittently in Leaf 2, present to frequent rarely in Leaf 3 and intermittently in Leaf 4. Occasional to frequent below the Thick Coal, and between Leaves 1 and 2, occasional between Leaves 3 and 4.

Genus CYCLOGRANISPORITES Potonie and Kremp 1954

Cyclogranisporites aureus (Loose) Potonie and Kremp 1955

Plate 4, figs. 24-27.

Comparison. This is the largest species (greater than 55 micrometres) recognised in this study, and possesses the coarsest and most regularly distributed grana.

Occurrence. Generally from present to infrequent rarely in most leaves, frequent rarely in Leaf 1, present only in Leaf 4. Occasional beneath the Thick Coal.

Cyclogranisporites minutus Bharadwaj 1957a

Plate 4, figs. 28-30.

Diagnosis. (Bharadwaj 1957a, p.38)

Comparison. Distinguished from *C.* cf.*minutus* Bharadwaj 1957a in Smith and Butterworth 1967 which is larger (40-55 micrometres) and *C.* cf.*pressoides* Potonie and Kremp 1955 which is considerably smaller.

Occurrence. Occasional rarely in Leaf 1, present to occasional intermittently in Leaf 2, and present rarely in Leaves 3 and 4. Present below the Thick Coal.

Cyclogranisporites cf. minutus Bharadwaj 1957a in Smith and Butterworth 1967

Plate 4, figs. 31-32.

1967 Cyclogranisporites cf. minutus Smith and Butterworth p.143, pl.4, figs. 4-7.

Comparison. Distinguished from other species by its size range (40-55 micrometres).

Occurrence. Infrequent to occasional rarely in Leaf 1 and present to occasional rarely in Leaf 2. Present to common below the Thick Coal, occasional to frequent between Leaves 1 and 2, occasional between Leaves 2 and 3, infrequent between Leaves 3 and 4.

Cyclogranisporites pressoides Potonie and Kremp 1955

1955 Cyclogranisporites pressoides Potonie and Kremp, p.62, pl.13, figs 187-190.

non 1956 Lycospora (Cyclogranisporites) pressoides (Potonie and Kremp) Bharadwaj p.127, p.25, figs. 89-92.

Holotype. Potonie and Kremp 1955, p.62, pl.13, fig.187.

Type locality. Baldur seam, Brassert Colliery, Ruhr Coalfield, Germany; Westphalian C.

Diagnosis. (Potonie and Kremp 1955)

Remarks. Spores figured by Bharadwaj (1957b) as Lycospora pressoides differ from the type in their strongly ridged laesurae and equatorial cingulum or curvaturae.

Size in micrometres. Holotype 21, 20-25, Schulze and KOH (Potonie and Kremp 1955).

Cyclogranisporites cf. pressoides Potonie and Kremp 1955

Plate 5, figs. 1-6.

Size in micrometres. 13(16)18 (20 specimens) fum.HNO_3, Leaf 2 Thick Coal, Warwickshire, England; Westphalian B.

Description. Amb circular or oval when folded, modified by the ornament. Laesurae simple, straight, between 2/5 - 1/2 spore radius, often two of the rays are open and the other hidden. Grana 0.5 - 1 micrometre in height and diameter, evenly cover the exine, with not enough space to fit in further elements; 30-40 project from the equator. Exine 1 micrometre thick often with a single fold.

Remarks. Differs from the type in being smaller and possessing shorter laesurae.

Comparison. Distinguished from other species of Cyclogranisporites by its smaller size. Apiculatisporis saetiger (Peppers) Peppers and Ravn in Ravn (1979), originally Punctatisporites saetiger (Peppers 1964), appears similar in size, distribution and size of ornament and reduction of one of the trilete rays, although usually in C. cf. pressoides the two rays remaining form an acute angle and another difference is that A. saetiger is usually oval.

Occurrence. Present to occasional rarely in Leaf 1, frequent to very common toward the top of Leaf 2, infrequent to frequent in Leaf 3, absent in Leaf 4. Present between Leaves 1 and 2 and Leaves 3 and 4.

Cyclogranisporites sp.A

Plate 5, figs. 7-9

Size in micrometres. 34(50)59 (8 specimens) fum. HNO_3, Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular or sharply lenticular when folded; margin minutely notched. Laesurae ridged, with distinct lips 1.5 - 2 micrometres wide, generally straight, sometimes curved when folded, 1/2 - 2/3 spore radius. Exine 1 - 1.5 micrometres thick, covered by evenly distributed closely space grana 0.5-1 micrometres in diameter. Commonly a single fold is present.

Comparison. Distinguished from other species in this study because of its raised laesurae and the nature of its folding. C.densus Bharadwaj 1957a has simple laesurae.

Occurrence. Present rarely in Leaves 1 and 2.

Genus APICULIRETUSISPORA Streel 1964

Type species. A.brandtii Streel 1964

Diagnosis. (Streel 1967, p.32 translated from Streel 1964, p.240)

Comparison. Differs from Cyclogranisporites, and Stenozonotriletes in the distinct curvaturae and reduced sculpture in the contact area. Retusotriletes is completely smooth.

Apiculiretusispora sp.A.

Plate 5, figs. 10-12.

Size in micrometres. (i) 20(22)24 (5 specimens) fum. HNO_3 Leaves 1 and 2, Thick Coal, Warwickshire, England; Westphalian B.

Description. Amb circular, to oval margin barely modified. Laesurae straight with narrow raised lips, extending almost to the equator. The ends of the laesurae are connected by curvaturae. Proximally laevigate, distally ornamented by slightly irregularly distributed minute grana about 0.5 micrometres in diameter and height. The thickness of the exine at the equator is 1 - 1.5 micrometres, sometimes folded.

Comparison. Distinguished from other species of Apiculiretusispora encountered in this study by its fine grade of ornament. A. sp.A and A. sp.B (Nader 1983) are larger and have thicker exines at the equator.

Occurrence. Present rarely in leaves 1, 2 and 4, present to infrequent rarely in Leaf 3. Present below the Thick Coal.

Apiculiretusispora sp.B

Plate 5, figs. 13-16

Size in micrometres. 13(16)19 (20 specimens) fum. HNO_3, Leaf 4, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular, rarely rounded triangular. Laesurae simple, straight, usually open, 1/3 to 2/3 spore radius, often the laesurae are of different lengths; ends of laesurae connected by narrow curvaturae which are usually coincident with the equator. Contact faces laevigate, distal surface ornamented with spinae up to 1.5 micrometres high with pointed apices and small coni generally 1 micrometre in height and diameter, fairly closely spaced with about 20 - 25 elements projecting from the margin. Thickness of exine about 1 micrometre.

Comparison. The spinose ornament distinguishes this species of Apiculiretusispora from others of the genus encountered in this study.

Occurrence. Present rarely in Leaves 1, 2 and 3 present to frequent intermittently in Leaf 4. Infrequent above the Thick Coal.

Apiculiretusispora sp.C

Plate 5, figs. 17-21.

Size in micrometres. 16(18)22 (5 specimens) fum. HNO_3, Leaf 1, Thick Coal, Longmeadow borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to rounded triangular. Laesurae ridged, about 1 micrometre wide, flexuose extending to the equator; ends of the laesurae connected by curvaturae. Contact faces laevigate, distal surface ornamented with coni and bacula up to 2 micrometres in height and diameter but variable in size on individual specimens, sometimes with pointed apices, although the larger elements may have rounded apices. Elements are fairly closely spaced about between 15-25 projecting from the margin. Thickness of the exine at the equator 1 - 2 micrometres, generally without folds.

Comparison. The lack of spinae, larger coni and bacula and greater thickness at the equator distinguish *A.*sp.C from *A.*sp.B.

Occurrence. Present to occasional rarely in Leaf 1.

Subinfraturma VERRUCATI Dybova and Jachowicz 1957a

Genus CONVERRUCOSISPORITES Potonia and Kremp 1954

Converrucosisporites armatus (Dybova and Jachowicz) Smith and Butterworth 1967

Plate 5 figs. 22-24.

Remarks. Specimens in this study range up to 46 micrometres in size, sometimes the margins are convex, and the exine is between 1.5-2 micrometres thick.

Occurrence. Occasional rarely in Leaf 1, present rarely in Leaves 2 and 3. Present below the Thick Coal and between Leaves 1 and 2.

Genus VERRUCOSISPORITES (Ibrahim)

Smith and Butterworth 1967

Verrucosisporites donarii Potonie and Kremp 1955

Plate 5, figs. 25-29.

Remarks. Specimens observed in this study ranged from 33-77 micrometres in size, and the ornament consists of both verrucae and rugulae.

Occurrence. Present rarely in Leaf 1 and present to infrequent rarely in Leaves 2, 3 and 4. Infrequent below the Thick Coal, present to occasional betweeen Leaves 1 and 2, present between Leaves 3 and 4.

Verrucosisporites microtuberosus (Loose) Smith and Butterworth 1967

Plate 5, figs. 30-33.

Remarks. Smith *et al*, (1964) made *Microreticulatisporites verus* Potonie and Kremp 1955 synonymous with *V. microtuberosus*. Ravn (1979) made *Cyclogransporites pergranulus* Alpern 1959 synonymous with *V. microtuberosus*.

Comparison. *V.donarii* Protonie and Kremp 1955 is often smaller, and *V.microtuberosus* differs from this species and *V.verrucosus* (Ibrahim) 1933 in possessing an ornament of small more closely packed verrucae and an absence of rugulae.

Occurrence. Present to occasional intermittently throughout all leaves, but frequent rarely in Leaf 4 and common rarely in Leaves 2 and 3. Occasional to common beneath the Thick Coal, occasional to frequent between Leaves 1 and 2, frequent between Leaves 2 and 3, present between Leaves 3 and 4.

Verrucosisporites sifati (Ibrahim) Smith and Butterworth 1967

Plate 6, figs. 1-5.

Remarks. Rugulae are sometimes present.

Comparison. The broad, low, well rounded and loosely packed verrucae distinguish this species from *V.donarii* Potonie and Kremp 1955 and *V.verrucosus* (Ibrahim) Ibrahim 1933.

Occurrence. Occasional rarely in Leaf 1 present to occasional rarely in Leaves 1 and 4, present to frequent intermittently in Leaf 3. Present to common below the Thick Coal, present between Leaves 1 and 2, and Leaves 3 and 4, frequent between Leaves 2 and 3.

Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933

Plate 6, figs. 6-8.

Remarks. Often rugulae are present. The verrucae are mostly between 1-1.5 micrometres high. The exine is between 1.5-2 micrometres thick.

Comparison. V. donarii Potonie and Kremp 1955 can be distinguished from V. verrucosus by its closely psaced and mostly rounded verrucae, a larger number of which project from the margin and the lack of folding.

Occurrence. Present to infrequent rarely in Leaf 1, present rarely in Leaf 2, present to occasional rarely in Leaf 3, present to infrequent rarely in Leaf 4. Occastional below the Thick Coal and between Leaves 2 and 3.

Verrucosisporites sp.A

Plate 6, figs. 9-12.

Size in micrometres. 71(83)92 (15 specimens) fum. HNO_3, and 40% HF and fum.HNO_3, high silicate subsections beneath the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to circular, rarely rounded triangular, with crenulate margin. Laesurae simple, straight, approximately 1/2 spore radius. Exine ornamented with a mixture of rugulae and verrucae with rounded or flat apices. Verrucae vary from less than 1 to 3 micrometres in diameter whilst rugulae are generally 1.5 micrometres wide and up to 8 micrometres long. The height of the ornament is generally 1-1.5 micrometres. Size of ornament varies within individual specimens and the distributions of ornament varies between individuals from very closely spaced to irregularly distributed with enough space for further elements. Often the rugulae are arranged polygonally, with a few verrucae in the centre of the polygon. Exine is between 3-5 micrometres thick, sometimes with one fold which follows the margin.

Comparison. Distinguished from other species by the thickness of the exine. Both V.donarii and V.microtuberosus Potonie and Kremp 1955 have a closer spaced ornament, the former has few verrucae with flat topped apices, the latter is more folded. V.verrucosus Ibrahim 1933 is smaller and more folded. V. sp.A Nader 1983 is larger 79(94)106 micrometres and has a darkened contact area.

Occurrence. Present to infrequent rarely in Leaves 1 and 2, present rarely in Leaf 3, present to frequent rarely in Leaf 4. Present above and below the Thick Coal, and between Leaves 1 and 2, frequent between Leaves 2 and 3 and occasional between Leaves 3 and 4.

Subinfraturma NODATI Dybova and Jachowicz 1957a

Genus LOPHOTRILETES (Naumova) Potonie and Kremp 1954

Lophotriletes commisuralis (Kosanke) Potonie and Kremp 1955

Plate 6, figs. 13-15.

Size in micrometres. (i) Holotype 29.5 x 26; 25 - 34 Schulze and 10% KOH (Kosanke 1950) (ii) 24(29)35 Schulze and 5% KOH (Smith and Butterworth 1967) Forest of Wyre Coalfield, England; Westphalian D. (iii) 21(24)27 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B. (iv) 21(24)26 (20 specimens) fum. HNO_3, Leaf 4, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, angles rounded sides concave. Laesurae simple straight (curved when compressed) 3/4 of spore radius, sometimes extending nearly to the margin. Exine slightly less than 1, to 1.5 micrometres thick, with an ornament of loosely spaced coni with room for further elements. Coni vary in size on individual specimens from 0.75 - 1.5 micrometres in width but are generally about 1 micrometre high, and clearly modify the margin. Often with one or more folds.

Comparison. Distinguished from other species of *Lophotriletes* by its finer grade of ornament.

Remarks. Specimens photographed in this study and by Smith and Butterworth (1967) show the loosely spaced ornament.

Occurrence. Present to frequent throughout Leaves 1 to 3, present to very common throughout Leaf 4. Occasional to frequent below the Thick Coal, occasional between Leaves 1 and 2, frequent between Leaves 2 and 3 infrequent between Leaves 3 and 4 and above the Thick Coal.

Lophotriletes granoornatus Artuz 1957

Size in micrometres. (i) Holotype 37, 35-41, method of maceration not known (Artuz 1957) (ii) 27(35)44 fum. HNO_3 (Smith and Butterworth 1967) Yorkshire Coalfield, England; Westphalian B.

Lophotriletes cf. *granoonatus* Artuz 1957 in Peppers 1970

Plate 5, figs. 16-19.

1970 *Lophotriletes* cf. *granoornatus* Artuz in Peppers pl.5, figs. 18, 23.

1983 *Lophotriletes granoornatus* Artuz in Nader pl.8, figs. 5-9 and 23.

Size in micrometres. (i) 34(43)53 Schulze and 5% KOH (Peppers 1970) (ii) 35(39)45 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B. (iii) 25(37)44 fum. HNO_3 (20 specimens) Leaves 2 and 4, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, with broad rounded angles, sides convex, one occasionally straight. Laesurae simple, straight, often unequal in length ranging from 1/3 - 2/3 spore radius. Slightly darkened contact area extends the length of the laesurae. Ornament of coni 0.5 to 2 micrometres wide (most 1 - 1.5 micrometres) generally 1 micrometre high, but up to 2 micrometres, varying on individual specimens, irregularly distributed with large areas with little or no ornament. Exine 1 - 2 micrometres thick often with one fold only.

Remarks. Specimens assigned to L. cf. granoornatus generally have convex sides which is the same as the photograph in Artuz (1957, pl.2, fig.13a). There also appears to be a contact area on the photograph. These two features together with the ornament described by Peppers (1970) and shown in pl.5, figs. 18 and 23 make the specimens described in this study very similar to L. cf. granoornatus Peppers 1970. Nader (1983) found that his specimens of L. granoornatus Artuz 1957 consistently had straight to slightly convex sides, but made L. cf. granoornatus Peppers 1970 synonymous with it.

Comparison. The consistent convexity of the sides distinguish L. cf. granoornatus from the type, and this together with the thickness of exine distinguish L. cf. granoornatus from other species of Lophotriletes encountered in this study.

Occurrence. Present to occasional intermittently in Leaf 1, present to frequent intermittently in Leaf 2, present to infrequent intermittently in Leaf 3 and infrequent to frequent intermittently in Leaf 4. Occasional to frequent below the Thick Coal, present to occasional between Leaves 1 and 2, occasional between Leaves 2 and 3 and Leaves 3 and 4.

Lophotriletes microsaetosus (Loose) Potonie and Kremp 1955
Lophotriletes cf. microsaetosus (Loose) Potonie and Kremp 1955 in Smith and Butterworth 1967
Plate 6, figs. 20-23.

1967 Lophotriletes cf. microsaetosus (Loose) Potonie and Kremp 1955 in Smith and Butterworth, p.158, pl.6, figs. 10, 11.

Size in micrometres. (i) 21(25)32 fum. HNO_3 (Smith and Butterworth

1967) Ayrshire Coalfield, Scotland, Wesphalian B, (ii) 16(20)24 fum. HNO_3 (Smith and Butterworth 1967) Somerset Coalfield, England; Westphalian D, (iii) 18(23)27 fum. HNO_3 (20 specimens) Leaf 4, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, angles rounded, sides concave rarely straight. Laesurae simple, straight, often with a slight thickening along the edge, 1/2 - 2/3 spore radius. Ornament consists mainly of coni generally 2 micrometres high and wide although rarely they can be up to 2 micrometres high and 3 micrometres wide. Other more spine-like coni up to 2 micrometres high and about 1 micrometre wide are often present between the larger elements. Size and shape of ornament varies on individual specimens from fairly closely to irregularly distributed. Exine less than 1 micrometre to 1.5 micrometres thick, often with one fold.

Comparison. Differs from L. commisuralis (Kosanke) Potonie and Kremp 1955 in its larger size of ornament. Ravn (1979) noted the similarity between L.microsaetosus and Acanthotriletes aculeolatus (Kosanke) Potonie and Kremp 1955, and although some specimens in this study had more spinose coni than others, they always had several broad coni.

Occurrence Present to common throughout Leaves 1 and 2, present to frequent throughout Leaf 3 and occasional to very common in Leaf 4. Occasional to frequent beneath the Thick Coal, occasional between Leaves 2 and 3, infrequent between Leaves 3 and 4 and above the Thick Coal.

Genus WALTZISPORA Staplin 1960

Waltzispora prisca (Kosanke) Sullivan 1964

Plate 6, figs. 24-26.

1950 Triqutrites prisca Kosanke, p.39, pl.9, fig. 4.

1964 Walzispora prisca (Kosanke), Sullivan, pl.57, fig.24.

Holotype. Kosanke 1950, pl.8, fig.4, maceration 587, slide 13.

Type locality. Battery Rock coal bed, Hardin County Illinois, USA.

Diagnosis. (Kosanke 1950, p.39-40).

Size in micrometres. Holotype 404, 36-45 Schulze and 10% KOH (Kosanke 1950) (ii) 35(37)42 fum. HNO_3. (Nader 1983), Northumberland, England; Westphalian B.

Remarks. Sullivan (1964) transferred this species to Walzispora and noted that it had an ornament of grana probably all on the distal surface. The grana are up to 0.5 micrometres in diameter and irregularly distributed. There is a faint narrow contact area present. The exine is between 1-2 micrometres thick.

Comparison. W. planiangulata (Sullivan 1964 pl.57, figs. 25-30) has a similar size range to W. prisca, but the former has a coarser ornament.

Occurrence. Present rarely in Leaves 1, 2 and 3, present to infrequent rarely in Leaf 4. Frequent beneath the Thick Coal, occasional between Leaves 1 and 2.

Waltzispora sp.A

Plate 6, fig. 27.

Size in micrometres. 28, (1 specimen) fum. HNO_3 Leaf 1, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, interradial margins concave, angles blunt but slightly rounded, Laesurae simple, straight, about 2/3 spore radius. Exine laevigate, between 1-1.5 micrometres thick.

Comparison. The angularity of the junction between the radial and interradial margin is less distinctive than W. sagitta Playford 1962 and both this latter species and W. polita (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967 have a more angular radial margin.

Occurrence. Present rarely in Leaf 1.

Genus ANAPICULATISPORITES (Potonie and Kremp) Smith and Butterworth 1967

Anapiculatisporites minor (Butterworth and Williams) Smith and Butterworth 1967

Plate 7, figs. 1, 2.

Remarks. The spinae vary between 1-2 micrometres in height, and between 0.75-1.5 micrometres in diameter, although they are usually 1 micrometre in diameter.

Occurrence. Generally occasional to common throughout all leaves, very common rarely in Leaf 1. Present to frequent below the Thick Coal, infrequent to occasional between Leaves 1 and 2, frequent above the Thick Coal.

Anapiculatisporites sp.A

Plate 7, figs. 3-5.

Size in micrometres. 20(22)24 (6 specimens) fum. HNO_3, Leaves 1 and 4, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides straight to slightly convex or concave, with narrow angles equal in height and diameter from 1-2 micrometres with sharp pointed apices, between 15-45 elements in total. Ornament restricted to the distal surface with very few elements projecting from the margin. Exine thin, less than 1.0 micrometre with frequent folding.

Comparison. The ornament on A. minor is smaller in diameter and more densely packed with a corresponding larger number of elements.

Occurrence. Present rarely in Leaves 1, 2 and 3, present to infrequent rarely in Leaf 1.

Genus ANAPLANISPORITES Jansonius 1962

Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy)

Smith and Butterworth 1967

Plate 7, figs. 6-10.

Occurrence. Present to frequent intermittently in Leaf 1, present to very common intermittently in Leaf 2, present rarely in Leaf 3, present to common intermittently in Leaf 4.

Anaplanisporites sp.A

Plate 7, figs. 11, 12.

Size in micrometres. 38, 53 (2 specimens) fum. HNO_3, Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular or rounded triangular. Distal surface rounded in equatorial view, proximal surface flattened. Laesurae not seen clearly, simple straight. Ornament made up of verrucae between 2-6 micrometres wide and 1-2.5 micrometres high, very widely spaced, about 15 elements in total. Ornament restricted to the distal surface, proximal surface laevigate. Exine 1-1.5 micrometres thick with only one fold.

Comparison. Lophotriletes fulvus Ishchenko 1958 is similar but larger (size range 50-65 micrometres) and no mention is made of lack of proximal ornament. A sp.A. (Nader) is smaller and the ornament consists of galea.

Occurrence. Present rarely in Leaf 2.

Genus PUSTULATISPORITES Potonie and Kremp 1954

Pustulatisporites pustulatus Potonie and Kremp 1954

Plate 7, figs. 13-15.

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some specimens and coni have blunt apices and resemble bacula.

Comparison. A. cf. latigranifer is larger (55-90 micrometres) than A. aculeatus (32-58 micrometres) with longer laesurae and is more circular in shape.

Occurrence. Present to occasional intermittently in Leaves 1 and 3, present to frequent throughout Leaf 2, present to common rarely at the top of Leaf 4. Occasional to frequent beneath the Thick Coal, and between Leaves 1 and 2, occasional between Leaves 2 and 3 and Leaves 3 and 4.

Apiculatisporis irregularis (Alpern) Smith and Butterworth 1967

Plate 7, figs. 22-25.

Remarks. Where laesurae are discernable they appear to be variable in length. A. irregularis sometimes occurs in tetrads (Plate 7, fig. 23). Although the ornament is very patchy it may be reduced proximally.

Comparison. Cappasporites distortus Urban 1966 displays a similar ornament to A. irregularis but it is confined to the distal surface. Ravn et al. (in press) consider the two species to be conspecific, and have proposed that they be assigned to Granasporites irregularis Alpern 1959. The sparsity and irregular distribution of ornament distinguish this species from others of the genus encountered in this study.

Occurrence. Present to very abundant throughout Leaf 1, present to common throughout Leaf 2, occasional to very common throughout Leaf 3, present to occasional intermittently in Leaf 4. Present below the Thick Coal, occasional to requent between Leaves 1 and

2, absent between Leaves 2 and 3, common between Leaves 3 and 4 and occasional above the Thick Coal.

Apiculatisporis latigranifer (Loose) Potonie and Kremp 1955

Apiculatisporis cf. *latigranifer* (Loose) Potonie and Kremp

1955 in Smith and Butterworth 1967.

Plate 7, figs. 26, 27.

1967 *Apiculatisporis* cf. *latigranifer* (Loose) Potonie and Kremp in Smith and butterworth p.172, pl.7, figs. 20, 21.

Remarks. Sometimes a darkened contact area is present and occasionally a single fold.

Comparison. The variety of shape and size of coni and their loosely spaced distribution, distinguish *A.* cf. *latigranifer* from other species of *Apiculatisporis.*

Occurrence. Present to occasional rarely in Leaf 2, present rarely in Leaf 3. Absent in siliciclastic subsections.

Apiculatisporis spinosaetosus (Loose) Smith and Butterworth 1967

Plate 7, figs. 28-30.

Remarks. The laesurae vary in size from 1/3 to 2/3 spore radius. Ornament consists of pointed coni of varying size, verucae and bacula with only slightly converging sides and apices which may be truncate, rounded or partate. Ornament often reduced proximally. Exine 1.5-2 micrometres thick.

Comparison. *A.* *spinosaetosus* is distinguished from other species of *Apiculatisporis* by the combination of widely differing ornament.

Raistrickia fulva has a more coarse ornament and the ornament of *R. irregularis* Kosanke 1950 is larger.

Occurrence. Present to frequent throughout Leaves 1 and 2, present to common throughout Leaf 3, and present to occasional intermittently in Leaf 4. Present to occasional below the Thick Coal, occasional between Leaves 1 and 2, present between Leaves 2 and 3, and frequent between Leaves 3 and 4.

Genus PLANISPORITES (Knox) Potonie 1960

Remarks. Although the generic diagnosis states (Potonie and Kremp 1954, p.129, emend. Potonie 1960, p.39, translation) '... completely covered by small coni of approximately equal size ...' the species *P. granifer* has an ornament of different size coni and verrucae.

Planisporites granifer (Ibrahim) Knox 1950

Plate 8, figs. 1-4.

Remarks. Most of the specimens observed in this study have a contact area and are less than 70 micrometres in diameter as shown in Smith and Butterworth (1967) Plate 8, figs. 1-3.

Comparison. The triangular shape of *P. granifer* distinguishes it from *A.* cf. *latigranifer* (Loose) Potonie and Kremp 1955 which has a similar ornament although the latter does not possess verrucae.

Occurrence. Present to occasional rarely in Leaves 1, 2 and 3, present rarely in Leaf. Occastional to frequent below the Thick Coal, present to occasional between Leaves 1 and 2, and infrequent between Leaves 3 and 4.

Genus APICULATASPORITES (Ibrahim) Smith and Butterworth 1967

Apiculatasporites spinulistratus (Loose) Ibrahim 1933

Plate 8, figs. 5-7.

Remarks. A faint contact area extending the length of the laesurae is usually present.

Comparison. The uniform small size and distribution of the ornament differentiates this species from Apiculatisporis cf. latigranifer (Loose) Potonie and Kremp 1955. Ravn (1979) suggested that A. spinulistratus be transferred to the genus Apiculatisporis because the basis of finer grade of ornament for separating Apiculatisporis and Apiculatasporites was questionable, and it would eliminate confusion between similar generic names.

Occurrence. Present to occasional intermittently in Leaves 1 and 3, present to frequent intermittently in Leaves 2 and 4. Present to occasional below the Thick Coal, present to frequent between Leaves 1 and 2 and present between Leaves 2 and 3.

Genus ACANTHOTRILETES (Naumova) Potonie and Kremp 1954

Acanthotriletes echinatus (Knox) Potonie and Kremp 1955

Plate 8, figs. 8-11.

1950 Spinoso-sporites echinatus Knox, p.313, pl.17, fig. 208.

1955 Acanothotriletes echinatus (Knox) Potonie and Kremp p.84. Non

1955 Acanthotriletes echinatus Hoffmeister, Staplin and Malloy, p.379, pl.38, figs. 1, 2.

Size in micrometres. (i) Neotype 26 fum. HNO_3 (Smith and Butterworth 1967), (ii) 12(20)28 fum. HNO_3 type locality, (Smith and Butterworth 1967), (iii) 19(25)30 fum. HNO_3 (20 specimens) Leaf 4 (iv) 16(25)37 fum. HNO_3 (20 specimens) seatearth below the Thick Coal, (iii) and (iv) from Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Remarks. Maximum and mean sizes are larger than those quoted by Smith and Butterworth (1967). Spines are sometimes up to 1.5 micrometres in basal diameter.

Comparison. The greater length of spinae, and more circular shape distinguish *A. echinatus* from *A. triquetrus* Smith and Butterworth (1967).

Occurrence. Present to frequent intermittently in Leaves 1 and 3, present to frequent intermittently in Leaf 2, present to very common in Leaf 4. Occasional to very common below the Thick Coal, frequent between Leaves 1 and 2, occasional between Leaves 2 and 3 and present between Leaves 3 and 4 and above the Thick Coal.

Acanthotriletes triquetrus Smith and Butterworth 1967

Plate 8, figs. 12-15.

Occurrence. Present to common rarely in Leaf 1, throughout Leaf 4, present to frequent rarely in Leaf 2, occasional rarely in Leaf 3. Occasional to frequent beneath the Thick Coal, present between Leaves 3 and 4 and occasional above the Thick Coal.

Genus IBRAHIMISPORES Artuz 1957

Type species. *I. microhorridus* Artuz 1957

Diagnosis. (Artuz 1957 p. 246)

Comparison. Distinguished from *Apiculatisporis* and *Acanthotriletes* by the length and the nature of the thorn like spines, which are sometimes curved and have thickned tips.

Ibrahimispores sp.A

Plate 8, figs. 16-18.

Size in micrometres. 58 and 61 x 43 (2 specimens) fum. HNO_3 Leaf 2 Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to rounded triangular. Laesurae indistinct simple, straight about 3/4 spore radius. Exine covered in closely spaced spinae with expanded bases which often join with adjacent spinae giving a cuspate outline; about 35 elements projecting from the equator. Spinae are thin walled, possibly hollow, up to 8 micrometres high and 9.5 micrometres in diameter, with pointed apices which are thickened and sometimes falcate. Exine fairly thick, with a poorly defined thickened area about 5.5 micrometres wide around the margin.

Comparison. Both *I. microhorridus* Artuz 1957 and *I. brevispinosus* Neves 1961 are larger (92-110 and 70-100 micrometres respectively) and have a slightly coarser ornament.

Occurrence. Present rarely in Leaf 2.

Subinfraturma BACULATI (Dybova and Jachowicz 1957a

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

Raistrickia firma (Loose) Smith 1971

Plate 8, figs. 19-22.

1934 *Verrucosi-sporites firmus* Loose p.154, pl.7, fig. 30

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

1955 *Verrucosisporites firmus* (Loose Potonie and Kremp, p.67, pl.13, figs. 203, 204.

1971 *Raistrickia firma* (Loose) Smith, p.81

Holotype. Potonie and Kremp 1955, pl. 13, fig. 203, after Loose, 1934, pl. 7, fig. 30, Preparation III $18a_2$ (m/U1).

Type Locality. Bismark seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. (Potonie and Kremp 1955, p.67).

Size in micrometres. (i) Holotype 60; 60-70 Schulze (Potonie and Kremp 1955) (ii) 33(41)45 fum. HNO_3, (Nader 1983) Northumberland England; Westphalian A and B. (iii) 36(39)44 (8 specimens), fum.

HNO_3, Leaves 1 and 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to oval. Laesurae sometimes obscured by the ornament, simple, straight 1/2-3/4 spore radius. Both the proximal and distal surfaces are covered in bacula, either with sub-parallel sides and rounded apices up to 3 micrometres in height and diameter, or pilate expanding from the base in a mushroom shaped structure up to 3 micrometres high and 4.5 micrometres wide. The elements are closely spaced and in some cases the bases may be fused, with 25-35 projecting from the margin. Exine thin rarely folded.

Remarks. Smith (1971) after re-examination of spores from the type material of the Bismark seam decided that baculate processes dominated the ornament and for this reason transferred the species to Raistrickia. The expanded and rounded apices of the bacula resemble verrucae which may have led to confusion in the past. Specimens found in this study are smaller than those in Potonie and Kremp (1955). The sizes given above include ornament.

Comparison. Differs from other species of Raistrickia in the shape of the bacula and in the large number of elements projecting from the margin.

Occurrence. Present rarely in Leaf 1, present to infrequent rarely in Leaf 2, infrequent rarely in Leaf 4. Present below the Thick Coal.

Raistrickia fulva Artuz 1957

Raistrickia cf. fulva

Plate 8, figs. 23-26

Size in micrometres. (i) 34(40)46 (20 specimens) fum. HNO_3 subsection below the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to triangular. Laesurae rarely seen, simple, straight, 2/3-3/4 spore radius. Ornament composed mainly of verrucae, variable in size on individual specimens from 1.5 micrometres high by 3 micrometres in diameter, to 2.5 micrometres high by 6.5 micrometres in diameter, generally with only slightly converging sides and slightly rounded apices. Bacula also exist of equal height (2.5 micrometres) and diameter and coni with rounded apices varying in size from 1.5-3 micrometres in diameter and 1-1.5 micrometres high. Ornament is loosely spaced but occasionally some of the elements are fused at their bases. Number of elements projecting from the margin varies between 8-18. Exine varies between 1-2.5 micrometres thick with occasional folds.

Remarks. The majority of elements which ornament the specimens of R. fulva described by Smith and Butterworth (1967) are similar to those seen on R. cf. fulva in this study with bases wider than their heights. These are described as verrucae in this study.

Comparison. R. fulva is more circular in shape and has a thicker exine. R. cf. fulva differs from other species of Raistrickia and Apiculatisporis spinosaetosus (Loose) Smith and Butterworth (1967) in possessing a much broader ornament. In Camptotriletes bucculentus (Loose) Potonie and Kremp 1955 ridges are present as well as coni, verrucae and fimbriate baculae.

Occurrence. Present to frequent rarely in Leaf 4. Present to frequent below the Thick Coal and present between Leaves 1 and 2.

Raistrickia lowellensis Peppers 1970

1970 Raistrickia lowellensis Peppers, p.105, pl.8, figs. 3, 4.

Holotype. Peppers 1970, pl.8, fig.3, maceration 1384-N, slide 11.

Type locality. Lowell coal, Carbondale Formation, Illinois, USA.

Diagnosis. (see Peppers 1970, p.105, 106).

Size in micrometres. Holotype 47 x 44, 33(46)50 Schulze and 5% KOH (Peppers 1970).

Raistrickia cf. lowellensis Peppers 1970

Plate 8, figs. 27-30.

Size in micrometres. 38(47)64 (20 specimens) fum. HNO_3, all leaves, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to oval. Laesurae simple, straight 2/3 to 3/4 of spore radius. The distal surface is covered with fairly loosely spaced bacula which vary in shape and size on individual specimens, up to 12 micrometres in height and 5 micrometres in diameter. The majority are fan shaped with fimbriate apices which occasionally branch, but elements with parallel sides and flat apices also occur. On the proximal surface the elements are reduced in size and number, with between 10 to 25 elements projecting from the margin. A faint contact area is sometimes visible. Exine between 1-1.5 micrometres thick often with a single fold or broken.

Remarks. Differs from the type in the reduction of ornament on the proximal surface, some specimens possess slightly longer elements and the exine is slightly thicker. A specimen of R. lowellensis photographed by Ravn (1979 pl.8, fig.6) appears to show a reduction of the ornament on the proximal surface.

Comparison. R. crocea and R. protensa Kosanke 1950 are larger with longer bacula and thicker exines. R. superba (Ibrahim) Schopf, Wilson and Bentall 1944 lacks fan shaped projections. These last three species do not have a reduced ornament on the proximal surface. R. irregularis Kosanke 1950 has bacula which have rounded or blunt apices. R. cf. lowellensis resembles R. sp.A Nader (1983).

Occurrence. Present to frequent throughout the lower half of Leaf 1 and the whole of Leaf 3, present to occasional intermittently in Leaf 2 and present rarely in the top half of Leaf 1 and the whole of Leaf 4. Infrequent to common below the Thick Coal, occasional between Leaves 1 and 2 and Leaves 3 and 4, frequent between Leaves 2 and 3, and infrequent above the Thick Coal.

Raistrickia pilosa Kosanke 1950

Plate 9, figs. 1-3.

1950 Raistrickia pilosa Kosanke, p.45 pl.11, fig.4.

Holotype. Kosanke 1950, pl.11, fig.4, Preparation 544, slide 2.

Type locality. No.7 coal bed, Fulton County, Illinois.

Size in micrometres. (i) Holotype 39.9 x 40.3 37-43 Schulze and 10% KOH (Kosanke 1950) (ii) 32(36)40 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B.

Remarks. Laesurae simple, straight 2/3 to 3/4 spore radius but usually concealed by ornament. Generally the bacula are unbranched, sometimes narrow gently toward the top, and have flat or partate apices. Between 7-20 elements project from the margin. The exine varies in thickness from 1.5-2.5 micrometres.

Comparison. Differs from other species of Raistrickia by its smaller size and relatively long bacula, some of which are over 10 micrometres in length.

Occurrence. Present rarely in Leaf 1, present to infrequent rarely in Leaf 2 and infrequent rarely in Leaf 4. Occasional to common beneath the Thick Coal, present between Leaves 1 and 2, and Leaves 3 and 4.

Raistrickia saetosa (Loose) Schopf, Wilson and Bentall 1944

Plate 9, figs. 4-7.

Remarks. The majority of baculae are between 5-12 micrometres long and 4 micrometres wide. The exine is between 1.5-2.5 micrometres thick.

Comparison. The size and shape of the bacula together with their similarity on any one individual and the low numbers of fimbriate bacula separate this species from other species of Raistrickia. R. saetosa also has a thicker exine than R. cf. lowellensis.

Occurrence. Present rarely in Leaves 1 and 4, and present to infrequent rarely in Leaves 2 and 3. Frequent below the Thick Coal, and present between Leaves 1 and 2 and Leaves 3 and 4.

Raistrickia solaria Wilson and Hoffmeister 1956

Plate 9, figs. 8, 9.

1956 Raistrickia solaria Wilson and Hoffmeister, p.22, pl.1, figs. 18, 19.

Holotype. Wilson and Hoffmeister 1956, pl.1, fig.18, slide No.10, WHIA.

Type locality. Croweburg coal, McNabb Mine, Catoosa, Rogers County, Oklahoma, USA.

Diagnosis. (Wilson and Hoffmeister 1956, p.22).

Size in micrometres. (i) Holotype 58, 51-63.5 Schulze and 10% KOH (Wilson and Hoffmeister 1956) (ii) 40, 48, 54, fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B (iii) 46(51)56 (5 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to oval. Laesurae simple, straight, 3/4 spore radius, sometimes extending to the margin. Ornament consists of closely spaced bacula, generally with sides which converge slowly, with rounded, truncated or serrated apices. The bacula are between 4-11 micrometres high and 4-6 micrometres in diameter. Number of elements projecting from the margin is between 18-28. Exine 1.5-2.5 micrometres thick.

Comparison. The closely spaced, broader bacula distinguish this species from *R. saetosa* (Loose) Schopf, Wilson and Bentall 1944.

Occurrence. Present rarely in Leaf 2.

Genus SPACKMANITES Habib 1966

Type Species. *S. ellipticus* Habib 1966

Diagnosis. Habib 1966, p.638.

Comparison. This genus closely resembles *Verrucosisporites* and *Raistrickia*; it differs from the former in the lack of verrucae, and the latter in the tight packing and partial fusing of the bacula.

Spackmanites ellipticus Habib 1966

Plate 9, figs. 10-13.

Holotype. Habib 1966, pl.105, fig.17, slide LKC-12(63-64), wax mount 39.

Type locality. Lower Kittanning coal, Western Pennsylvania (Allegheny Series, Lower Westphalian D).

Diagnosis. (Habib 1966, p.638).

Size in micrometres. (i) Holotype 60 x 51 (42 x 36 excluding ornament) 50-67, Schulze and 8% KOH, (Habib 1966) (ii) 29(35)41 (12 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb generally oval, sometimes circular. Laesurae not seen clearly in any specimen. Exine covered with closely spaced, radially arranged, rod shaped bacula, expanding slightly and evenly from the base and terminating with a undulating or flat apex. Usually most of the bacula are fused together although this varies between specimens, fusing taking place from the base or near the top. Because of this, when the bacula are viewed end on a reticulate pattern is created in the centre of the specimen (the size of the 'luminae' and 'muri' varying according to the size of the bacula). The size of bacula are consistent within specimens but varies between them from 1.5-3.5 micrometres wide and 3 to 6.5 micrometres high. Exine 1.5 micrometres thick, unfolded.

Remarks. The specimens found in this study are smaller than those seen by Habib (1966) but most of this is probably due to the different maceration technique as shown by Butterworth and Williams (1954).

Comparison. Although Habib (1966) makes a distinction between *S. ellipticus* and *S. facierugosus* (Loose) Habib 1966 on the basis of the latter's circular outline and loosely packed bacula with rounded apices, a range of variation between the two was observed in this study. However none was as loosely packed as those specimens of *S. facierugosus* illustrated by Butterworth and Williams (1954, fig.1, 3), or Peppers (1970 pl.8, fig.18). A similar range of ornament was observed by Ravn (1979) - see his discussion. *Raistrickia firma* (Loose) Smith 1971 differs in having shorter, mushroom shaped, unfused bacula.

Occurrence. Present to occasional rarely in Leaves 1 and 4, present rarely in Leaves 2 and 3.

Infraturma MURONATI Potonie and Kremp 1954

Genus CONVULUTISPORA Hoffmeister, Staplin and Malloy 1955

Convolutispora sp.A

Plate 9, figs. 14, 15.

Size in micrometres. 39(44)50 (6 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire England; Westphalian B.

Description. Amb oval to circular, margin undulating, and notched, with ornament projecting up to 2 micrometres from the surface. Laesurae simple straight between 2/3 to 4/5 spore radius. Ornament of low rugulae generally 4 micrometres wide, but longer because many of them are joined. Spaces between rugulae are irregular and elongate from 0.5-1 micrometre wide. Exine 3-4 micrometres thick including ornament.

Comparison. Convolutispora sp.C is smaller, and the rugulae are higher and more continuous. Convolutispora sp.B and sp.D have a finer grade of ornament. In Convolutispora cerina Ravn (1979) the ornament is restricted to the distal surface, and the ornament in Convolutispora sp.2 Peppers (1970) is greater in height, but otherwise both species appear similar to C. sp.A.

Occurrence. Present rarely in all leaves. Absent in siliciclastic subsections.

Convolutispora sp.B.

Plate 9, figs. 16, 17.

Size in micrometres. 32(39)46 (7 specimens) fum. HNO_3 Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb generally oval, sometimes circular. Margin notched with ornament projecting up to 1 micrometre from the surface. Laesurae rarely visible, simple, straight between 2-3/4 spore radius. Ornament of rugulae and verrucae which are occasionally joined and are generally 1-2 micrometres wide separated by vermiculi 1-1.5 micrometres wide up to 3.5 micrometres long. Exine thickness difficult to estimate because of the ornament, 2-2.5 micrometres including ornament.

Comparison. Convolutispora sp.D has a finer grade of ornament and laesurae of variable length. The ornament in C. fromensis Balme and Hassel 1962 and C. venusta projects further from the margin and C. venusta is larger than C. sp.B. Two photographs of C. sp.A (Nader 1983, plate 11, figs. 17, 18 resemble C. sp.B.

Occurrence. Present rarely in Leaves 2 and 4. Present below the Thick Coal.

Convolutispora sp.C

Plate 9, figs. 18-23.

Size in micrometres. 22(32)38 (10 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular, margin smooth to undulating, sometimes projecting up to 2 micrometres. Laesurae rarely visible, about 3/4 spore radius. Ornament of rugulae mostly joined together, leaving small oval foveolae and elongate vermiculi generally about 1.5 micrometres wide. Occasional verrucae occur between the rugulae. The ornament is much reduced or may be absent on the proximal surface. Exine viewed from proximal surface between 1-1.5 micrometres thick.

Comparison. C. cerina Ravn (1979) is larger and the rugulae do not project as far from the margin as C. sp.B. C.sp.A is larger, has a thicker exine and the rugulae are smaller in height and width.

Occurrence. Present rarely in Leaves 1, 2 and 4. Present below the Thick Coal.

Convolutispora sp.D

Plate 9, figs.24-26

Size in micrometers. 37(45)54 (5 specimens) fum. HNO_3, Leaves 1 and 4, Thick Coal, Longmeadow Wood borehole, Warwickshire england; Westphalian B.

Description. Amb circular, margin barely modified (minutely crenulated). Laesurae simple, straight, 1/2 to 2/3 spore radius, one ray sometimes larger extending up to 3/4 spore radius. Ornament of low muri generally 1.5 micrometres wide but up to 6 micrometres long, with a majority of foveolae and occasional vermiculi both irregularly distributed. Foveolae if circular 0.5-1 micrometres in diameter, if oval up to 1.5 micrometres long. Vermiculi up to 5 micrometres long. Exine sometimes thickned in a zone up to 2 micrometres wide along each side of the commissure. Thickness of the exine 2-3 micrometres.

Comparison. *C. cerebra* Butterworth and Williams 1958 is larger 55(72)83 with a thicker exine (5-9 micrometres including muri). Apart from a slightly thinner exine (1-1.5 micrometres thick). Two photographs of *C.* sp.A (Nader 1983, plate 11, figs. 19, 20) resemble *C.* sp.D.

Occurrence. Present rarely in Leaves 1 and 4. Absent in high silicate subsections.

Genus MICRORETICULATISPORITES (Knox) Potonie and Kremp 1954

Microreticulatisporites harrisoni Peppers 1970

Plate 9, figs. 27-29.

1970 *Microreticulatisporites harrisoni* Peppers, pl.9, fig.1.

Remarks. The muri are up to 1.5 micrometres in width.

Comparison. This is the only species of Microreticulatisporites with concave sides seen in this study. M.concavus Butterworth and Williams 1958 has larger lumina and wider muri.

Occurrence. Present to occasional intermittently in Leaf 1, present to frequent intermittently in Leaves 2 and 4, present to infrequent rarely in Leaf 3. Occasional beneath the Thick Coal, infrequent between Leaves 1 and 2 and present between Leaves 3 and 4.

Microreticulatisporites nobilis (Wicher) Knox 1950

Plate 9, figs. 30, 31.

Occurrence. Present rarely in Leaves 1 and 4. Absent in siliciclastic subsections. This is a zonal index species used with Florinites junior by Clayton et al. to define the Westphalian B and the lower part of Westphalian C.

Genus SECARISPORITES Neves 1961

Type species. S.lobatus Neves 1961.

Diagnosis. (Neves 1961 p.260).

Comparison. Secarisporites is characterised by the lateral overlap and fusion of lobate ornament in the equatorial region, which gives rise to a discontinuous rim, and distinguishes it from the genus Convolutispora Hoffmeister Staplin and Malloy 1955.

Secarisporites remotus Neves 1961

Plate 10, figs. 1-3.

1961 Secarisporites remotus Neves, p.262, pl.32, figs. 8-9.

Holotype. Neves 1961, pl.32, fig.9.

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

Diagnosis. (Neves 1961).

Size in micrometres. (i) Holotype 46, 35-50 Schulze and KOH (Neves 1961), (ii) 35(40)51 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B.

Description. (Neves 1961)

Remarks. The number of elements projecting from the margin varies between 8 - 14. The exine is approximately 2 micrometres thick.

Comparison. Convolutispora florida Hoffmeister Staplin and Malloy 1955 is similar although more elements which are smaller project from the margin and they are more flattened rather than lobate. Although no mention is made of it the ornamentation appears to be reduced on the proximal surface in Hoffmeister Staplin and Malloy (1955 Pl.38 fig.5).

Occurrence. Present to infrequent rarely in Leaf 1, present rarely in Leaves 2, 3 and 4. Present below the Thick Coal, and between Leaves 2 and 3.

Genus DICTYOTRILETES (Naumova) Smith and Butterworth 1967

Dictyotriletes bireticulatus (Ibrahim) Smith and Butterworth 1967

Plate 10, figs. 4-6.

Comparison. Differs from D.falsus Potonie and Kremp 1955 and D. reticulocingulum (Loose) Smith and Butterworth 1967 in possession of a laevigate proximal surface.

Occurrence. Present to common intermittently in Leaves 1 and 2, present to very common intermittently in Leaf 3, present to abundant intermittently in Leaf 4. Present below the Thick Coal, between Leaves 1 and 2 and Leaves 3 and 4. Occasional between Leaves 2 and 3 and frequent above the Thick Coal.

Dictyotriletes castaneaeformis (Horst) Sullivan 1964

Plate 10, figs. 7-11.

Remarks. Ravn and Fitzgerald (1982) believe that D.castaneaeformis is monolete (see also Ravn 1979) whilst D.clatriformis (Artuz) Sullivan 1964 is trilete. Both elongate and circular forms were seen in this study although sutures were either not present or indistinct.

Occurrence. Present to occasional rarely in Leaf 2, present rarely in Leaves 3 and 4. Present beneath the Thick Coal and between Leaves 1 and 2, occasional between Leaves 2 and 3.

Dictyotriletes falsus Potonie and Kremp 1955

Plate 10, figs. 12-14.

Remarks. Although there is variation in shape and size of lumina on each individual, there is often more variation between individuals; some of which may have larger lumina ranging in size between 4 - 10 micrometres whereas in others the range may be between 2 - 6 micrometres.

Comparison D.reticulocingulum (Loose) Smith and Butterworth (1967) has thinner muri and a more varied size of luminae.

Occurrence. Present to infrequent rarely in Leaf 1, present rarely in Leaves 2, 3 and 4. Infrequent below the Thick coal and present between Leaves 1 and 2.

Dictyotriletes muricatus (Kosanke) Smith and Butterworth 1967

Plate 10, figs. 15-17.

Occurrence. Present to frequent rarely in Leaf 1, and present to occasional rarely in Leaf 2. Frequent below the Thick Coal, present between Leaves 1 and 2.

Dictyotriletes reticulocingulum (Loose) Smith and

Butterworth 1967

Plate 10, figs. 18-22.

Remarks. There appears to be a considerable range in width and distribution of muri, which may suggest the presence of more than one species.

Occurrence. Present to occasional rarely in Leaf 1, present rarely in Leaves 2, 3 and 4. Present beneath the Thick Coal, between Leaves 1 and 2 and above the Thick Coal.

Genus CAMPTOTRILETES (Naumova) Potonie and Kremp 1954

Camptotriletes bucculentus (Loose) Potonie and Kremp 1955

Plate 10, figs. 23-27.

Size in micrometres. (i) Holotype 47.5 (ii) 45-75 Schulze (Potonie and Kremp 1955) (iii) 50(56)67 fum. HNO_3 (Smith and Butterworth 1967) various localities; Westphalian A and B (iv) 40(47)59 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B (v) 31(45)61 (15 specimens) fum. HNO_3. various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Remarks. The low ridges are generally 2 micrometres high, but often coni and fimbriate low bacula are found on top of them, making them up to 3.5 micrometres high. The striae are up to 8 micrometres long. Exine between 1.5 - 2.5 micrometres thick. Specimens smaller than those previously encountered have been found in this study.

Occurrence. Present to occasional intermittently in Leaves 1 and 2, present intermittently in Leaf 3, present to infrequent rarely in Leaf 4. Present to common beneath the Thick Coal, present to occasional between Leaves 1 and 2 and infrequent between Leaves 3 and 4.

Camptotriletes corrugatus (Ibrahim) Potonie and Kremp 1954

Plate 10, figs. 28, 29.

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

1944 Punctati-sporites corrugatus (Ibrahim) Schopf, Wilson and Bentall p.30.

1950 Microreticulati-sporites corrugatus (Ibrahim) Knox pl.5 VIII, fig. 238.

1954 Camptotriletes corrugatus (Ibrahim) Potonie and Kremp, p.104, pl.16, figs. 281, 290.

Holotype. Potonie and Kremp 1955, pl.16, fig.239, after Ibrahim 1933, pl.5, fig.41, Preparation B31, 6_5 (or).

Type locality. Bismark seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. (Potonie and Kremp 1955, p.104)

Size in micrometres. (i) Holotype 46, Schulze and KOH (ii) 40-50 Schulze (Potonie and Kremp 1955) (iii) 40(46.3)52 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B (iv) 37(48)61 (6 specimens) fum. HNO_3, Leaves 1 and 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb rounded triangular, rarely triagular or circular. Laesurae simple straight 2/3 to 3/4 spore radius. Exine covered with well spaced low ridges and verrucae, arrete shaped in cross section, generally 1 micrometre but up to 2 micrometres high. The ridges anastomose, and are joined in such a way as to form an imperfect reticulation, with lumina of varying size on any individual; but greater variability between individuals. Lumina range in size generally from 2 to 8 micrometres, although the maximum size is difficult to determine because some of the lumina are incomplete. The ridges are generally between 1-1.5 micrometres wide but up to 3 micrometres on larger specimens. Sculptural elements are reduced on the proximal surface. Exine 1 - 2 micrometres thick, rarely folded.

Comparison. The sculptural elements on C. bucculentus (Loose) Potonie and Kremp 1955 are more varied, project further from the margin and do not form a reticulate pattern.

Occurrence. Present rarely in Leaf 1, present to infrequent rarely in Leaf 2. Present below the Thick Coal, occasional between Leaves 1 and 2.

Camptotriletes sp.A

Plate 11, figs. 1-4.

Size in micrometres. 34(38)43 (15 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides straight to slightly convex, angles well rounded. Laesurae simple, straight, sometimes of unequal length, with one ray longer or shorter than the others; 1/2 - 3/4 spore radius. Ornament of small scattered coni approximately 1 micrometre high and wide and low ridges 1 micrometre in height and generally 3 - 4 micrometres long, although they can be up to 6.5 micrometres long. Sculptural elements are loosely and irregularly spaced and barely modify the margin. A faint contact area is sometimes present. Exine 1 - 1.5 micrometres thick with folds very rare.

Comparison C.bucculentus (Loose) Potonie and Kremp 1955 is larger and the ornament is coarser and more varied. In C. corrugatus

(Ibrahim) Potonie and Kremp 1954 the ornament forms an imperfect reticulate pattern. Lophotriletes cf. granoornatus Artuz in Peppers 1970 is similar but the coni are larger and it does not possess ridges. C. sp.A is very similar to C. sp.A Nader 1983.

Occurrence. Present to occasional intermittently in Leaf 1 and rarely in Leaf 2, present rarely in Leaf 4. Present between Leaves 1 and 2.

Subturma ZONOTRILETES Waltz 1935

Infraturma AURICULATI (Schopf) Dettmann 1963

Genus AHRENSISPORITES Potonie and Kremp 1954

Ahrensisporites guerickei (Horst) Potonie and Kremp 1954

Plate 11, figs. 5-8.

Remarks. Kyrtomes are very prominent, continuous ridges 5 - 10 micrometres in width and height usually undulating. Exine 1.5 - 2 micrometres thick.

Comparison. The more continuous, wider, undulating kyrtomes distinguish A.guerickei from Triquitrites protensus Kosanke 1950 which can also be smaller.

Occurrence. Present to occasional rarely in Leaf 1, present rarely in Leaves 2, 3 and 4. Present to occasional below the Thick Coal, infrequent to occasional between Leaves 1 and 2.

Genus TRIQUITRITES (Wilson and Coe) Potonie and Kremp 1954

Triquitrites protensus Kosanke 1950

Plate 11, figs. 9-12.

Size in micrometres. (i) Holotype 38 x 36.5; 33.5-39 Schulze and 10% KOH (Kosanke 1950) (ii) 32(39)48 fum. HNO_3 (Nader 1983)

Northumberland, England; Westphalian B (iii) 34(40)48 (10 specimens) fum. HNO_3. Leaf 1, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides straight to slightly convex, angles rounded, truncate or undulating. Laesarae straight, simple, extending nearly to inner margin of radial crassitude, usually open. Development of radial crassitude variable in length and height on any individual, generally 3.5 - 6.5 micrometres in height (radial length) extending onto the distal surface in the form of arcuate ridges. These ridges are usually variable in prominence decreasing in height poleward; although occasionally forming a faint kyrotome, they more usually occur as a loop-like structure. Exine 1-2 micrometres thick, laevigate or occasionally with rare verrucae, compression folds absent.

Remarks. Specimens described in this study have a size range extending from that given by Kosanke (1950) i.e. 33.5-39 micrometres to the one given by Smith and Butterworth (1967) i.e. 38-51 micrometres for T.protensus. According to Smith and Butterworth (1967) this species, despite possessing distal arcuate ridges, belongs to Triquitrites due to the presence of radial crassitudes.

Occurrence. Present to common intermittently in Leaf 1, present rarely in Leaves 2, 3 and 4. Present below the Thick Coal, and occasional between Leaves 1 and 2.

Triquitrites tribullatus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 11, figs. 13, 14.

Occurrence. Present to infrequent rarely in Leaf 1, present to common rarely in Leaf 2, present rarely in Leaf 3. Present between Leaves 2 and 3.

Genus TANTILLUS Felix and Burbridge 1967

Type species. T.triquetrus Felix and Burbridge 1967

Diagnosis. (Felix and Burbridge 1967, p.383)

Comparison. Distinguished by its triangular distal thickening which is more concave than the spore body and usually truncated at the apices.

Tantillus triquetrus Felix and Burbridge

1967

Plate 11, figs. 15-18.

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

Holotype. Felix and Burbridge 1967, pl.65, figs. 4,5, slide 03V16-11(6). Location 40.8 x 110.1.

Type locality. Springer Formation, Southern Oklahoma, U.S.A. Mississippian/Pennsylvanian.

Diagnosis. (Felix and Burbridge 1967 p.383).

Size in micrometres. (i) Holotype 18 x 18, 16.5 - 25, Schulze and KOH (Felix and Burbridge 1967) (ii) 26.5(27)32 fum. HNO_3, (Nader 1983) Northumberland, England; Westphalian A and B. (iii) 16(22)37 (15 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides slightly concave or convex, angles rounded sometimes expanded. Laesurae simple, slightly flexuose, extending 3/4 spore radius, usually obscured by the distal thickening. Distal thickening consists of a triangular area located centrally, which may expand at one or more ot its apices to form a T-shaped structure, this expansion is equal to the width of the body. Exine laevigate to granulate (average diameter 1 - 1.5 micrometres) to minutely spinose, 1 - 1.5 micrometres thick.

Remarks. The size range is larger than that given by Felix and Burbridge 1967. This together with the size variation in ornament may lead to further speciation of the genus as suggested by Ravn (1979).

Occurrence. Present to infrequent rarely in Leaves 1 and 4, present rarely in Leaves 2 and 3. Infrequent below the Thick Coal, present between Leaves 1 and 2 and above the Thick Coal.

Infraturma TRICASSATI Dettmann 1963

Genus REINSCHOSPORA Schopf, Wilson and Bentall 1944

Reinschospora speciosa (Loose) Schopf, Wilson and Bentall 1944

Plate 11, figs. 19, 20.

Occurrence. Present rarely in Leaves 1, 2 and 3, present to infrequent rarely in Leaf 4. Present beneath the Thick Coal.

Reinschospora triangularis Kosanke 1950

Plate 11, fig. 21.

Occurrence. Present rarely in Leaf 2.

Infraturma CINGULATI (Potonie and Klaus) Dettman 1963

Genus KNOXISPORITES (Potonie and Kremp) Neves and Playford 1961

Knoxisporites triradiatus Hoffmeister, Staplin and Malloy 1955

Plate 11, figs. 22, 23.

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

Holotype. Hoffmeister, Staplin and Malloy 1955, pl.37, fig. 12, slide 6, ser. 18, 939.

Type locality. Shale at 2087ft Carter No. 3 borehole (TCQ-82) Webster County, Kentucky, U.S.A; Hardinsburg Formation, Chester Series.

Diagnosis. (Hoffmeister, Staplin and Malloy 1955, p.391).

Size in micrometres. (i) Holotype 80 x 86, HF (Hoffmeister, Staplin and Malloy 1955) (ii) 48(56)64 fum. HNO_3, (Nader 1983) Northumberland, England; Westphalian B (iii) 42(49)58, HF and fum. HNO_3, immediately below the Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to rectangular, rarely rounded triangular, margin smooth. Laesurae straight, extending to inner margin of the cingulum, usually accompanied by lips up to 1.5 micrometres wide, and bifurcating into two short branches near the margin (Plate 11, fig. 22). Equatorial thickening (cingulum) is of similar size on individual specimens but ranges between 2.5-7 (average 4.8) micrometres. On the distal surface are three muri between 4-10 micrometres wide radiating from the distal pole, and joining the cingulum in the interradial areas. The muri are often folded. Exine laevigate, occasionally folded.

Remarks. The specimens in this study are smaller than the holotype.

Comparison. K.hageni Potonie and Kremp 1954 possesses 3 muri on the distal surface, which form a triangle with apices towards the interradial areas of the margin, and enclose a circular unthickened area at the proximal pole.

Occurrence. Present rarely in Leaves 1 and 2. Present to frequent below the Thick Coal.

Genus RETICULATISPORITES (Ibrahim) Neves 1964

Reticulatisporites polygonalis (Ibrahim)

Smith and Butterworth 1967

Plate 11, figs. 24-26.

Occurrence. Present rarely in Leaf 1, present rarely in Leaf 2. Present between Leaves 1 and 2.

Reticulatisporites reticulatus (Ibrahim) Ibrahim 1933

Plate 11, figs. 27-29.

Occurrence. Present rarely in Leaves 1, 2 and 3. Present to occasional below the Thick Coal, occasional between Leaves 1 and 2 and Leaves 3 and 4, present between Leaves 2 and 3. This is a zonal index species used with Raistrickia fulva by Clayton et al. (1977) to define the Namurian C.

Genus SAVITRISPORITES Bharadwaj 1955

Savitrisporites concavus. Marshall and Smith 1965

Plate 12, figs. 1-4.

1965 Savitrisporites concavus Marshall and Smith, p.661,

pl.99, figs. 9-12.

Holotype. Marshall and Smith 1964, pl.99, fig.9, Preparation T78/1.

Type locality. Non-coaly seatearth of Swallow Wood seam, Elsecar Main Colliery, Yorkshire; Lower Westphalian B.

Diagnosis. (Marshall and Smith 1965)

Size in micrometres. (i) Holotype 43, 29(34)43 Schulze and 5% KOH (Marshall and Smith 1964) (ii) 24(28)37 (15 specimens) fum. HNO_3 Leaf 2, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, often elongated, sides slightly to strongly convex, angles pointed to narrowly rounded, margin smooth to slightly crenulate. Laesurae simply, straight, reaching inner margin of cingulum, suture often open. Cingulum present with a sharply defined inner margin, slightly uneven in width on any one individual from 2.5 - 4.5 micrometres. Ornament variable between specimens although some is always present. On the distal surface, including the cingulum, these may be both ridges up to 5 micrometres wide, of variable length and verrucae up to 3.5 micrometres in width and height. On the proximal surface are ridges of irregular width bordering the commissure, giving it an undulating edge.

Rarely foveolae occur, encircling the body poleward of the cingulum (Plate 12, Fig. 3). Exine about 1 micrometre thick.

Remarks. The specimens in this study are slightly smaller than those of Marshall and Smith 1965 which may be explained by the method of maceration.

Comparison. S.nux (Butterworth and Williams) Sullivan 1964 is larger and typically convex, S.asperatus Sullivan 1964 is of comparable size, but its sides are less concave, it is more heavily ornamented and the exine is thicker. S.triangularis Bharadwaj 1955 is larger, has straight sides, and possesses a heavier distal ornament. Murospora kosankei Somers 1972 lacks ridges bordering the commisure and the distal surface is not so heavily ornamented.

Occurrence. Present rarely in Leaf 1, present to occasional rarely in Leaf 2, present intermittently in Leaf 3 and present rarely in Leaf 4. Present to frequent below the Thick Coal and present between Leaves 2 and 3.

Savitrisporites nux (Butterworth and Williams)

Sullivan 1964

Plate 12, figs. 5-7.

Occurrence. Present to occasional rarely in Leaf 1, present to infrequent rarely in Leaves 2 and 3, present rarely in Leaf 4. Present to very common below the Thick Coal, occasional between Leaves 1 and 2, present between Leaves 2 and 3 and infrequent between Leaves 3 and 4.

Savitrisporites sp.A

Plate 12, figs. 8, 9.

Size in micrometres. 31(41)43 (3 specimens) fum. HNO_3, Leaf 1 and 3, Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B.

Description. Amb triangular, sides straight, rarely slightly convex or concave, angles pointed well formed. Laesurae simple, straight extending nearly to the inner margin of cingulum. Cingulum 3 - 4.5 micrometres wide. Distal ornament of small coni, variable in size on any one individual, up to 1 micrometre high and 1.5 micrometres in diameter, fairly closely spaced without room for further elements. On the proximal surface low ridges are sometimes developed which may be associated with the laesurae, giving the sutures the appearance of having lips. Exine thickened distally in the central area, so that a thinner zone of exoexine about 1.5 micrometres wide exists between it and the cingulum. Marginal compression folds sometimes present.

Comparison. Gravisporties densus Habib 1966 has more pronounced folds around the laesurae, an ornament of grana and is larger i.e. 45-55 micrometres. Cuneisporites rigidus Ravn 1979 does not possess a cingulum, there is no distal thickening and the ornament consists of grana. Savitrisporites triangulus Bharadwaj 1955 is larger and has a much coarser ornament of coni.

Occurrence Present rarely in Leaves 1 and 3. Absent in siliciclastic subsections.

Suprasubturma LAMINATITRILETES Smith and Butterworth 1967

Subturma AZONOLAMINATITRILETES Smith and Butterworth 1967

Infraturma TUBERCULORNATI Smith and Butterworth 1967

Genus GRUMOSISPORITES Smith and Butterworth 1967

Grumosisporites varioreticulatus (Neves) Smith and Butterworth 1967

Plate 12, figs. 10, 11.

Ocvcurrence. Present rarely in Leaves 1 and 2. Absent in siliciclastic subsections. This is a zonal index species used with *Crassispora kosankei* by Clayton *et al.*(1977) to define the Namurian B.

Genus DIAPHANOSPORA (Balme and Hassel) Evans 1970

Type species. *D.riciniata* Balme and Hassel 1962

Diagnosis. (Evans 1970, p.68 amended from Balme and Hassel 1962)

Remarks. Balme and Hassel (1962) erected the genus *Diaphanospora* to accommodate spores of similar morphology to *Perotrilites* Couper 1953 but which were considerably older, although some species of Lower Carboniferous age have been assigned to *Perotrilites* (see discussion in Peppers 1970 and Ravn 1979). Evans in his emendation of *Diaphanospora* stressed the tenuous nature of the outer membrane and did not use the term perispore. The use of the term perispore when describing fossil material is not recommended following Grebe

(1971). In this study the term exoexine is used to describe the outer membrane, whilst the term intexine is used to describe the coat of the spore body. As mentioned by several authors (Peppers 1970, Ravn 1979, Ravn and Fitzgerald 1982) the taxonomy of cavate spores of this type (including Hymenospora) is difficult and in need of further study.

Comparison. Differs from Hymenospora in possessing a thinner, membranous, hyaline exoexine and in the manner of attachment of exoexine to intexine.

Diaphanospora parvigracila (Peppers) Ravn 1979

Plate 12, figs. 12-15.

1970 Perotriletes parvigracilus Peppers, p.128, pl.13, figs. 5-7.

1979 Diaphanospora parvigracila (Peppers) Ravn, p.48, pl.18, fig. 11).

Holotype. Peppers 1970, pl.13, fig. 5. Preparation 1133-E, slide 37, co-ordinates 130.1 x 42.2.

Type locality. Uncorrelated coal beds between Colchester (No. 2) and Cardiff Coals, Carbondale Formation, Illinois, U.S.A; Pennsylvanian.

Diagnosis. (Peppers 1970 p. 128).

Size in micrometres. (i) Holotype 45.8 x 40.6, 42.5 - 52.3 Schulze and 5% KOH (Peppers 1970) (ii) Body 29(35.2)43, overall dimensions 39(42.1)48 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A and B. (iii) Body diameter, average 22(34)49, overall dimensions average 26(38)51 (6 specimens) fum. HNO_3 Leaves 1 and 2 and immediately below the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to rounded triangular, margin smooth. Exine differentiated into two layers. Intexine 1 - 1.5 micrometres thick. Laesurae distinct, simple, straight, all variable in length on any one individual from 1/2 to nearly full spore radius. Often one angle between two of the laesurae is much smaller than the others. The commissure is usually closed and accompanied by narrow lips less than 1 micrometre wide. Exoexine is less than 0.5 micrometres thick, translucent, usually extending less than 1 micrometre beyond the margin of the intexine, rarely up to 3 micrometres. The exoexine is frequently folded distally with few folds proximally. Ornament of the exoexine is confined to a few scattered grana, that of the intexine cannot be determined because it is obscured by the exoexine. Compression folds rare.

Remarks. Most of the specimens observed in this study are smaller than those previously observed, the intexine is slightly thinner, and generally the laesurae are of different length with a smaller angle between two of them.

Comparison. D.sp.A is more heavily ornamented with grana, has a much greater number of larger folds, a slightly thicker intexine and the exoexine generally extends further beyond the margin of the intexine.

Occurrence. Present rarely in Leaves 1 and 2. Present below the Thick Coal.

Diaphanospora sp.A

Plate 12, figs. 16-20

Size in micrometres. Body diameter average 36(41)48, overall diameter average 41(46)54 (8 specimens) fum. HNO_3, Leaves 1 and 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to rounded triangular margin crenulate. Exine differentiated into two layers. Intexine usually 2-4 micrometres thick, rarely up to 6 micrometres. Exoexine is less than 0.5 micrometres thick, translucent extending up to 2.5 micrometres beyond the margin of the intexine. Laesurae distinct simple, straight, sometimes variable in length on any one individual from 1/3 to 3/4 spore radius often with associated folds. Often one angle between two of the laesurae is much larger or smaller than the others. The commissure is usually open and rarely accompanied by narrow lips. The exoexine is heavily folded distally with fewer folds proximally and it forms the crenulate margin of the spore. Ornament of the exoexine consists of fairly closely spaced grana about 1 micrometre in height and diameter, that of the intexine cannot be determined because it is obscured by the exoexine. Compression folds rare.

Comparison. Dsp.1 Ravn (1979) is larger, the exoexine extends further beyond the margin of the intexine and the laesurae are of equal length. D.sp.1 Ravn and Fitzgerald (1982) is laevigate distally and more rounded triangular in shape. D. sp. B Nader (1983) is slightly smaller, not so heavily ornamented, and the exoexine does not extend very far from the margin of the intexine.

Occurrence. Present rarely in Leaves 1 and 2. Present below the Thick Coal.

Genus HYMENOSPORA Neves 1961

Type species. H. palliolata Neves 1961

Diagnosis. (Neves 1961 p.270) "Trilete iso-or microspores; equatorial outline circular to subcircular. The exo-exine is attached to the int-exine in the region of the trilete mark. In addition the exoexine 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."

Comparison. The more rigid exoexine distinguishes species of Hymenospora from those of Diaphanospora.

Hymenospora multirugosa Peppers 1970

Plate 12, figs. 21-25.

1970 Hymenospora multirugosa Peppers, p.120, pl.13, figs. 8, 9.

Holotype. Peppers 1970, pl.13, fig. 8. Preparation 1384-U, slide 12, co-ordinates 125.6 x 43.1.

Type locality. Danville (No. 7) Coal, Carbondale Formation, Illinois Basin; Pennsylvanian.

Diagnosis. (Peppers 1970. p.129).

Size in micrometres. (i) Holotype body 29.3 x 32.5, overall size 35.1 x 39.0, maximum diameter - body 32.5(33.5)39 - overall dimensions 35.8(42)45.8, Schulze and 5% KOH (Peppers 1970) (ii) body 21(25)30.5, overall dimensions 25.5(29.1)36 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A. (iii) maximum diameter body 21(25)34 overall dimensions 26(31)44 (12 specimens) fum. HNO_3 Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to circular or rounded triangular, margin smooth to gently undulating. Exine clearly differentiated into intexine and exoexine. Intexine 1 - 1.5 micrometres thick, about

5/6 the radius of the exoexine, with laesurae simple, straight, 3/4 spore radius, often open. Occasionally narrow lips are present. Ornament of the intexine cannot be determined with certainty because it is concealed by the exoexine. Exoexine about 1 micrometre thick, with common folds in the polar areas especially on the distal surface. They become fewer toward the margin so that it is smooth. Ornament of grana about 0.5 micrometres in diameter, closely spaced in the polar area but some present near the margin. Compression folds rare.

Remarks. Neves (1961) in his diagnosis of the genus concentrates on the furrows which are long, extending beyond the margin of the spore body. Peppers (1970) in his diagnosis of *H. multirugosa* makes no reference to furrows and none were seen in the present study. Also Peppers considers the outer membrane to be a perispore, although Neves in his diagnosis of the genus *Hymenospora* regards it as an exoexine. Some of the specimens observed in this study were smaller than those previously observed by the authors mentioned above.

Comparison. *H.paucirugosa* Peppers 1970 is larger and in both this species and *H.cf.paucirugosa* the spore body is indistinct. *H.caperata* Felix and Burbridge 1967 has a smaller body and a greater number of folds. (For comparison of species of *Diaphanospora* with *Hymenospora* see Peppers 1970 p.129).

Occurrence. present to occasional rarely in Leaves 1 and 2, present rarely in Leaves 3 and 4. Occasional below the Thick Coal.

Hymenospora paucirugosa Peppers 1970

1970 *Hymenospora paucirugosa* Peppers, pl.30, p.13, figs. 10-13.

Holotype. Peppers 1970, pl.13, fig. 10. Preparation 954-Ee, slide 18, co-ordinates 137.6 x 36.3.

Type locality. Colchester (No.2) Coal, Carbondale Formation, Illinois Basin, Pennsylvanian.

Diagnosis. (abbreviated from Peppers 1970 p.130) Amb circular, rounded triangular to elliptical often folded. The spores are divided into a perispore 1 micrometre or less thick, which is closely attached, especially on the proximal surface to an indistinct body. Larger specimens seldom display any evidence of a body. The laesurae are distinct and variable extending 3/4 to nearly full radius of the body, often one ray is shorter than the others and the ends may bifurate. The commissure may be bordered by lips about 2 micrometres wide. The body is probably laevigate; the perispore is externally laevigate but finely infrapunctate to infrareticulate. The central portions of the proximal and more especially the distal sides are set with small anastamosing folds.

Size in micrometres. (i) Holotype body 54.0 x 54.0, overall size 62.1 x 65.0, overall size range, maximum diameter 55.3(67.3)82.6 Schulze and 5% KOH (Peppers 1970).

Hymenospora cf.paucirugosa

Plate 12, figs. 26-28.

Size in micrometres. Maximum diameter - intexine 34(41)51, - overall dimension 39(46)54 (16 specimens) fum. HNO_3 Leaves 1 and 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb circular to rounded triangular rarely elliptical. Exine indistinctly differentiated into intexine and exoexine.

Intexine probably 1 micrometre or less thick, about 9/10 the radius of the exoexine. Laesurae are simple, straight, extending 1/2 to 3/4 radius of the exoexine although one may be shorter than the others. Often they are obscured by folds. Ornament of the intexine cannot be determined with certainty because it is concealed by the exoexine. Eoexine about 1 micrometre thick with common folds in the polar area (especially on the distal surface) becoming fewer toward the margin. Ornament of grana about 0.5 micrometres in diameter, loosely scattered over the surface of the exoexine, but more closely spaced toward the centre. Compression folds common.

Comparison. *H.paucirugosa* Peppers 1970 is larger although this may be due to the different method of maceration.

Occurrence. Present to occasional rarely in Leaf 1, present rarely in Leaves 2 and 3. Present below the Thick Coal and occasional between Leaves 1 and 2.

Subturma ZONOLAMINATITRILETES Smith and Butterworth 1967

Infraturma CRASSATI (Bharadwaj and Venkatachala) Smith and Butterworth 1967.

Genus CRASSISPORA (Bharadwaj) Sullivan 1964

Crassispora kosankei (Potonie and Kremp) Smith and Butterworth 1967

Plate 12, figs. 29-31.

Remarks. Ravn (1979) made *C.plicata* Peppers 1970 in part synonymous with *C.kosankei* but excluded another part because it was conspecific with *C.annulata* Ravn 1979.

Occurrence. Present to very common throughout leaves 1 and 4, present to abundant throughout Leaves 2 and 3. Infrequent to frequent below the Thick Coal, frequent between Leaves 1 and 2, common between Leaves 3 and 4 and abundant above the Thick Coal. Used by Clayton *et al.* (1977) as a zonal index species with *Grumosisporites varioreticulatus* for the Namurian B of Western Europe.

Infraturma CINGULICAVATI Smith and Butterworth 1967

Genus SIMOZONOTRILETES (Naumova) Potonie and Kremp 1954

Simozonotriletes intortus (Waltz) Potonie and Kremp 1954

Plate 13, figs. 1-3.

Remarks. Sullivan (1958) described nine different varieties of the species on the basis of modifications in sculpture. These modifications were not considered enough to define new species. In this work the following varieties have been observed, *S. intortus* var. *concavus*, *S. intortus* var. *intortus* and *S. intortus* var. *polymorphosus*.

Occurrence. Present to infrequent rarely in Leaf 1, and present rarely in Leaf 2. Present between Leaves 1 and 2 and Leaves 3 and 4.

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

Type species. *D. convensis* Berry 1937

Diagnosis. (Smith and Butterworth 1967, p.238, from Butterworth, Jansonius, Smith and Staplin in Staplin and Jansonius 1964 p.101).

Comparison. *Cingulizonates* (Dybova and Jachowicz) Butterworth *et al.* 1964 is distinguished by the presence of a cuesta, although certain laevigate individuals of *D. sphaerotriangularis* are similar. *Radiizonates* Staplin and Jansonius 1964 possesses radial plications on the cingulum.

Cristatisporities (Potonie and Kremp) Butterworth *et al.* 1964 is distinguished by its more prominent ornament which occurs as cristae on the cingulum, ornament which is undifferentiated between the central area and cingulum on the distal surface, and its irregular outline; certain individuals of a population of D. cf. duriti (Plate 13, fig. 19) resemble certain individuals in a population of C. connexus.

Tholisporites Butterworth and Williams 1958 is distinguished by the presence of a patina, but certain individuals in a population of D. cf. anulatus (Plate 13, fig. 7) and D. cf. triangularis (Plate 14 fig. 22) have much thicker exoexines in the distal polar area.

Lycospora (Schopf, Wilson and Bentall) Somers 1972 is distinguished by its cunieform cingulum which does not extend far equatorially, but certain individuals in a population of D. gracilis have a similarly narrow cingulum (Plate 13, fig. 24, 25).

Asperispora Staplin and Jansonius 1964 is distinguished by its indistinct intexine, distinct sutural ridges, distal setose coni or verrucae and small width of cingulum, some individuals in a population of D. cf. duriti resemble this description.

Murospora Somers 1952 is distinguished in patellate forms by a thickened exoexine in the central distal area, whilst in capsulate forms the proximal central area is also thickened; certain individuals in a population of D. cf. anulatus resemble this genus.

Cincturasporites Hacquebard and Barss 1957 is distinguished by its thick exoexine, abrupt thickening of the cingulum (which is smaller in radius than the central area) and distinct laesurae.

Labiadensites Hacquebard and Barss 1957 is distinguished by laesurae with prominent lips and its much larger size.

Tendosporites Hacquebard and Barss 1957 is distinguished by a wedge shaped elongate cingulum that tapers to a thin edge at the equator.

Monilospora Hacquebard and Barss 1957 is distinguished by cusp shaped depressions on the outer half of the cingulum and a crenulate margin.

Tumulispora and Clivosispora Staplin and Jansonius 1964 are both distinguished by a thick exoexine which bears large bosses or various arrangements of warts.

Minimasporites Jachowicz 1972 is distinguished by an increase in thickness of the exoexine in the central area between the laesurae, although certain individuals in a population of D. cf. anulatus (Plate 13, fig. 9) resemble this description.

Remarks. Although the genus Densosporites was first validly proposed by Berry in 1937 the existence of thick walled spores with a thin central area had already been noted by Reinsch (1884). The description and illustration of the type species D. covensis Berry 1937 would today be considered inadequate and the type slide has been destroyed. Spores within the genus were "characterised by a thick opaque wall, thickness about 1/3 diameter of the spore, central portion clear, no triradiate split". Emendation of the genus by Schopf, Wilson and Bentall (1944) included forms now assigned to Cristatisporites and Cingulizonates; Potonie and Kremp (1954) excluded unornamented species (including the type species D. covensis), which they assigned to the genus Anulatisporites; Staplin and Jansonius (1964) noted the difference between laesurae and sutural ridges, and the emended diagnosis of Butterworth et al. in Staplin and Jansonius (1964) - see above, forms the basis for recognising the genus Densosporites in this work. Unfortunately in their emendation no mention is made of the increased thickness of the zona, as the term had been previously described (p.98) as being either light or dark, the latter not necessarily a function of thickness. This was clarified by Smith and Butterworth (1967), who made the term zona used in the emendation synonymous with cingulum as defined on p.115-116. The genus Anulatisporites is no longer required, as forms within this genus now fall within the genus Densosporites.

The terms used in the description of the genus generally follow Grebe (1971). The existence of an inner layer (intexine) was discovered by Stach and Zerndt (1931) and it is separated from the outer layer (exoexine) which means that densospores are cavate. This particular form of cavate is termed camerate, as the separation is not accompanied by a columellate infrastructure. This morphological arrangement was demonstrated by Smith (1960) by means of thin sections and specimens with the exoexine partially destroyed. On examination of a slide containing densospores the proximal polar part of the exoexine is often missing. A number of terms have been applied to the equatorial thickening of the exoexine. Staplin and Jansonius (1964) used the term zona to describe "a relatively wide rim extending beyond the margin of the intexine including equatorial centrifugal extensions in excess of the normal exoexinal thickness". In this study the term cingulum will be used as defined by Smith and Butterworth (1967) - "a thickening of the exine or exoexine more or less confined to the equator ... in cross section the outer edge of the cingulum may be rounded or cunieform". It is thus distinguished from other types of equatorial extension viz. crassitude - a localised thickening of the exine usually rounded in cross-section as in Knoxisporites, or with a gradational inner margin as in

Crassispora; or the opposite viz. zona - an equatorial membraneous extension of the exine or exoexine which is thickened very little at the base as in Cirratriradiates. The width of the cingulum is measured from the poleward edge of the exoexinal thickening to the equator, and the total width of cingulum is divided by the total spore diameter and expressed as a percentage.

Different species display a wide variety of sculpture although generally they are laevigate proximally, and distally sometimes the ornament on the cingulum differs slightly from the ornament on the central distal area.

Two of the problems which impede the differentiation of species of Densosporites are poor preservation and the gradation of morphological characteristics. Difference in sculpture is the chief means of distinguishing the species and the fact that there are gradations in this and other morphological characteristics between species of Densosporites make this task formidable. Corrosion of individual species as a consequence of either chemical or bacteriological action may result in the formation of vacuoles or pits. The genera characterised by these i.e. Hymenozonotrileles Naumova 1953 and Vallatisporites Hacquebard 1957 have been excluded from the comparison of genera, as the vacuoles may be secondary, and to compare them it would be necessary to examine the type material. Individuals with vacuoles have been found from all of the Densosporites species recognised in this study, and this is also the case for individuals of other species e.g. Savitrisporites concavus (Plate 12 fig. 3) and Laevigatisporites minor (Plate 17, fig. 16). Species of Densosporites in which vacuoles form part of the diagnosis have also been excluded from comparison in this study for the same reason as the genera above. These include D. ruhus Kosanke 1950, Anulatisporites bacatus, A. coronarius, A. coronatus and A. sacculatus Dybova and Jachowicz 1957, D. variabilis (Waltz) Potonie and Kremp 1956, D. formosus Artuz 1957, D. irregularis Hacquebard and Barss 1957 and D. cavus Urban 1971.

Densosporites anulatus (Loose) Smith and Butterworth 1967

Remarks. The mean cingulum width given by Smith and Butterworth (1967) is between 29-43% of the mean spore diameter.

Densosporites cf. anulatus

Plate 13, figs. 4.14.

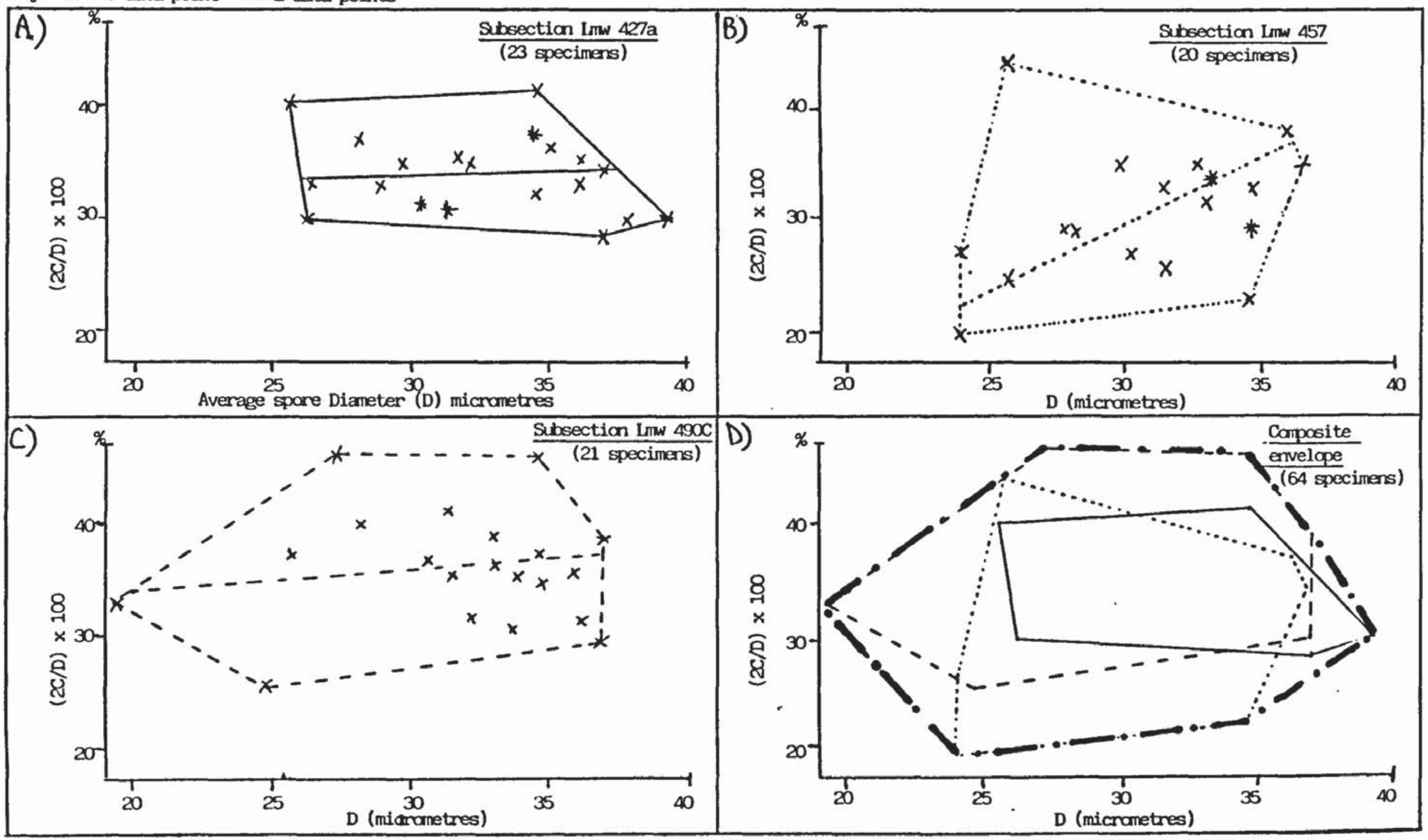
Size in micrometres.

	Average Spore Diameter(D)	Average Cingulum Width (C)	2C x 100 / D
(i)	25.6(32.4)39.2 (23 specimens)	4.0(5.5)7.2 fum.HNO_3 Leaf 4	30(34)42
(ii)	24.0(30.9)36.4 (20 specimens)	2.4(4.6)6.8 fum.HNO_3 Leaf 2	20(30)44
(iii)	19.2(31.8)36.8 (21 specimens)	3.2(5.8)8.0 fum.HNO_3 Leaf 1	26(36)46

(i) to (iii) from the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B. The three populations examined demonstrate a close relationship in cingulum width : diameter % and spore diameter (Fig. 6.1.A-C), so that the composite confining envelope is not much bigger than the individual component populations (Fig. 6.1.D).

Fig 6.1 Densosporites cf. anulatus: Analysis of 2 x Cingulum (C) width/ av. Diameter (D) % plotted against average diameter for populations in 3 subsections, showing confining envelope and line of best fit for the data points

Key: x = 1 data point * = 2 data points



Description. Amb polygonal, circular, oval or rounded triangular. Margin smooth, occasionally some specimens have coni projecting from it. Laesurae generally indistinct except where central body is thicker, sometimes ridged, straight or slightly flexuose extending to, or just beyond the inner margin of the cingulum. Intexine thin laevigate. Central area of exoexine usually thin but occasionally thickened both proximally and distally, sometimes between the laesurae; laevigate. Cingulum narrow, generally uniform in width, mean between 30-36% of spore diameter, only tapering slightly in thickness towards the equator: proximally and distally laevigate, but occasionally the distal surface may possess rare grana, or coni up to 1-5 micrometres high and wide with rounded apices, or verrucae up to 1 micrometre high and 3 micrometres wide with flattened apices.

Comparison. D. anulatus (Loose) Smith and Butterworth 1967 whose populations were taken from Westphalian A or older strata, is completely laevigate, no mention is made of thickening of the exoexine in the central area and the cingulum width is larger. D. gracilis Smith and Butterworth 1967 differs in possessing abundant ornament on both the central body and cingulum. D. cf. triangularis is larger with a wider cingulum (Fig. 6.7) D. simplex Staplin 1960 is minutely granulose distally on the cingulum and has prominent raised lips. Minimasporites minimus Jachowicz 1972 has a thickened exoexine in the central area and some specimens of D. cf. anulatus resemble this description. (Plate 13, fig. 9).

Occurrence. Present to common intermittently towards the top of Leaf 1, present to very abundant especially towards the top of Leaf 2, present to very common throughout Leaf 3 and at the top of Leaf 4. Infrequent to frequent below the Thick Coal, frequent to abundant between Leaves 1 and 2, common between Leaves 2 and 3, and frequent above the Thick Coal.

Densosporites duriti Potonie and Kremp 1956

1956 Densosporites duriti Potonie and Kremp p.117, pl.18, figs. 383, 384.

Holotype. Potonie and Kremp 1956 pl. 18, fig. 383.

Type locality. Zollverein seam, Friederich Heinrich Mine, Ruhr, Germany; Essener Schichten, Westphalian B.

Diagnosis. (from Potonie and Kremp 1956 p.117, abbreviated translation) Amb irregularly triangular to subtriangular, margin smooth, occasionally modified by ornament. Laesurae unclear. Cingulum of uniform width, not divided into a light and dark zone; ornamented loosely with blunt coni and ? verrucae (hockern). About 15-20 coni occur in the central area.

Size in micrometres. Holotype 68, 45-70 Schulze and KOH (Potonie and Kremp 1956).

Densosporites cf. duriti

Plate 13, figs. 15-23.

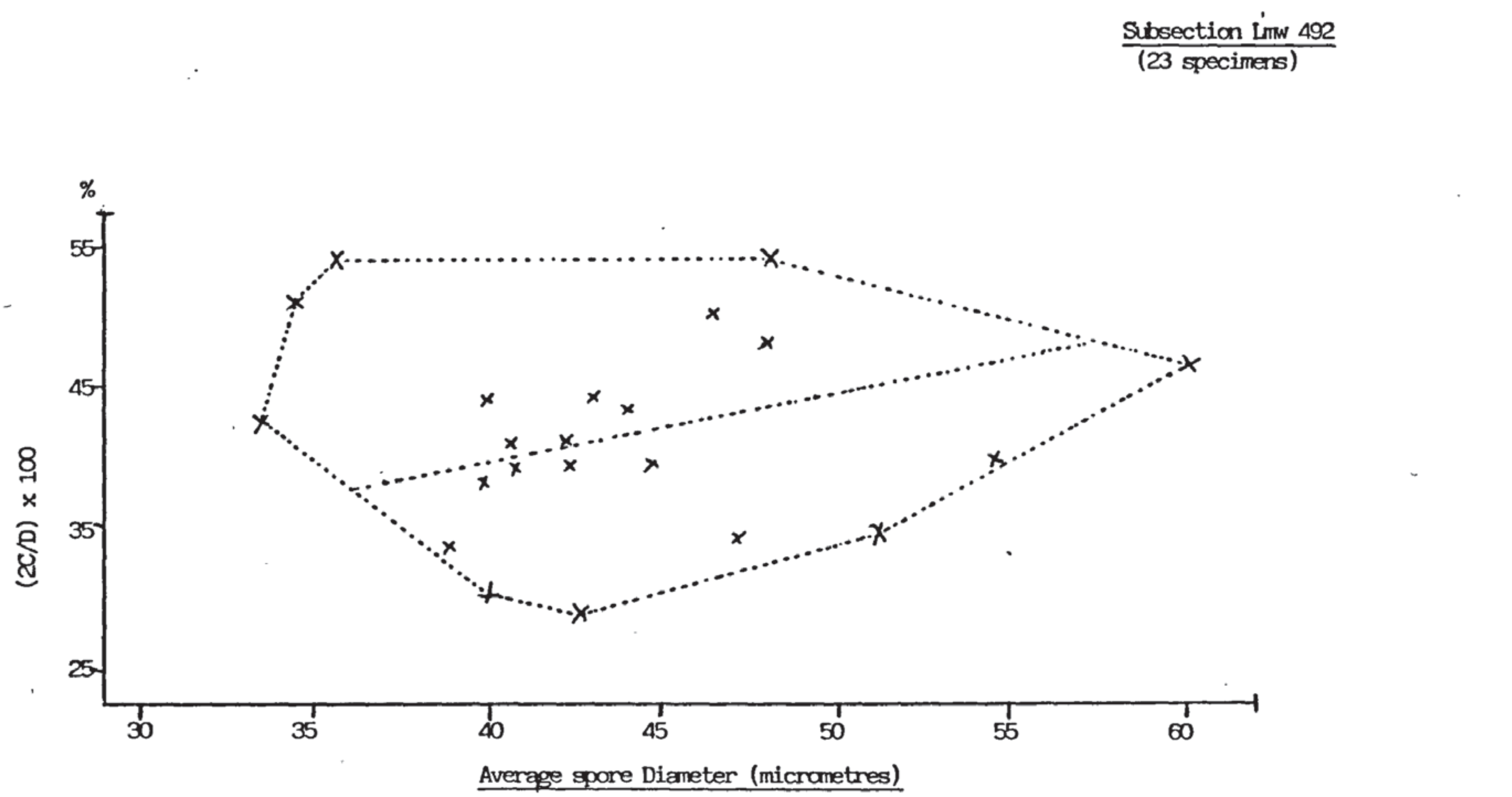
Size in micrometres.

Average Spore Diameter(D)	Average Cingulum Width (C)	$\frac{2C}{D}$x100
33.6(43.7)60.0	6.0(9.0)14.0	29(41)54 (22 specimens)

fum.HNO_3 Leaf 1, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B. (See also Figs. 6.2 and 6.7).

Description. Amb rounded triangular to oval or circular, rarely polygonal. Margin variably modified either by large scallop shaped

Fig. 6.2 Densosporites cf. duriti : Analysis of 2 x Cingulum (C) width/av. Diameter (D) % plotted against average diameter for population subsection Lmw 492, showing confining envelope and line of best fit for data points



curves up to 8 micrometres wide and 5 micrometres high with a cone at the apex, or often smaller scallops, or sometimes modified only by small coni. Laesurae vary from simple to ridged and straight to slightly flexuose, extending up to halfway across the cingulum. Intexine thin, laevigate. Central area of exoexine thin, proximally laevigate, distally with loosely scattered coni up to 2 micrometres high and 2.5 micrometres wide with rounded or pointed apices, occasionally pilate or galeate. Usually there are small coni up to 1.5 micrometres high and wide with pointed apices, although often the ornament on individual specimens is of similar size. Cingulum varies in width, mean 42% spore diameter, varying between tapering gently to only tapering slightly in thickness towards the equator: proximally laevigate; distally with the same ornament as the central area together with poorly defined ridges on some specimens. The exoexine of the central area is thicker distally than proximally.

Remarks. Specimens show a wide variety of shape, equatorial modification and ornament, although sharp coni appear to characterise the species. It may be significant that where more than 1 specimen was found Cristatisporites connexus also occurred within that population.

Comparison. D. duriti Potonie and Kremp 1956 differs in being larger, and the ornament is larger and more blunt. D, cf. duriti is distinguished from D. sphaerotriangularis Kosanke 1950 either by the lack of a divided cingulum, or modification of the margin. It is also slightly larger with the cingulum forming a smaller % of the spore diameter (Fig. 6.7). It is distinguished from D. gracilis Smith and Butterworth 1967 by its larger size and the cingulum forming a larger % of the spore diameter (Fig. 6.7). The smaller size, lack of joined verrucae and the cingulum forming a smaller % of the spore diameter distinguish it from Cristatisporites connexus Potonie and Kremp 1955. D. spinosus Dybova and Jachowicz 1957 resembles those specimens which have mostly small pointed coni. D. spackmanii Habib 1966 differs in possessing large distal verrucae which modify the outline more than D. cf. duriti. D. regalis (Bharadwaj and Venkatachala) Smith and Butterworth 1967 and D. aseki Potonie and Kremp 1956 are larger. D. goniacanthus Dybova and Jachowicz 1957a resembles some of the less sculptured forms. D. glandulosus Kosanke 1950 is smaller with a more strongly divided cingulum, but the ornament resembles that found on some of the specimens of D. cf. duriti.

Occurrence. Present to very common intermittently towards the top of Leaf 1, present rarely in Leaf 2, frequent to common rarely in Leaf 3, present rarely in Leaf 4. Present to occasional below the Thick Coal and present between Leaves 1 and 2.

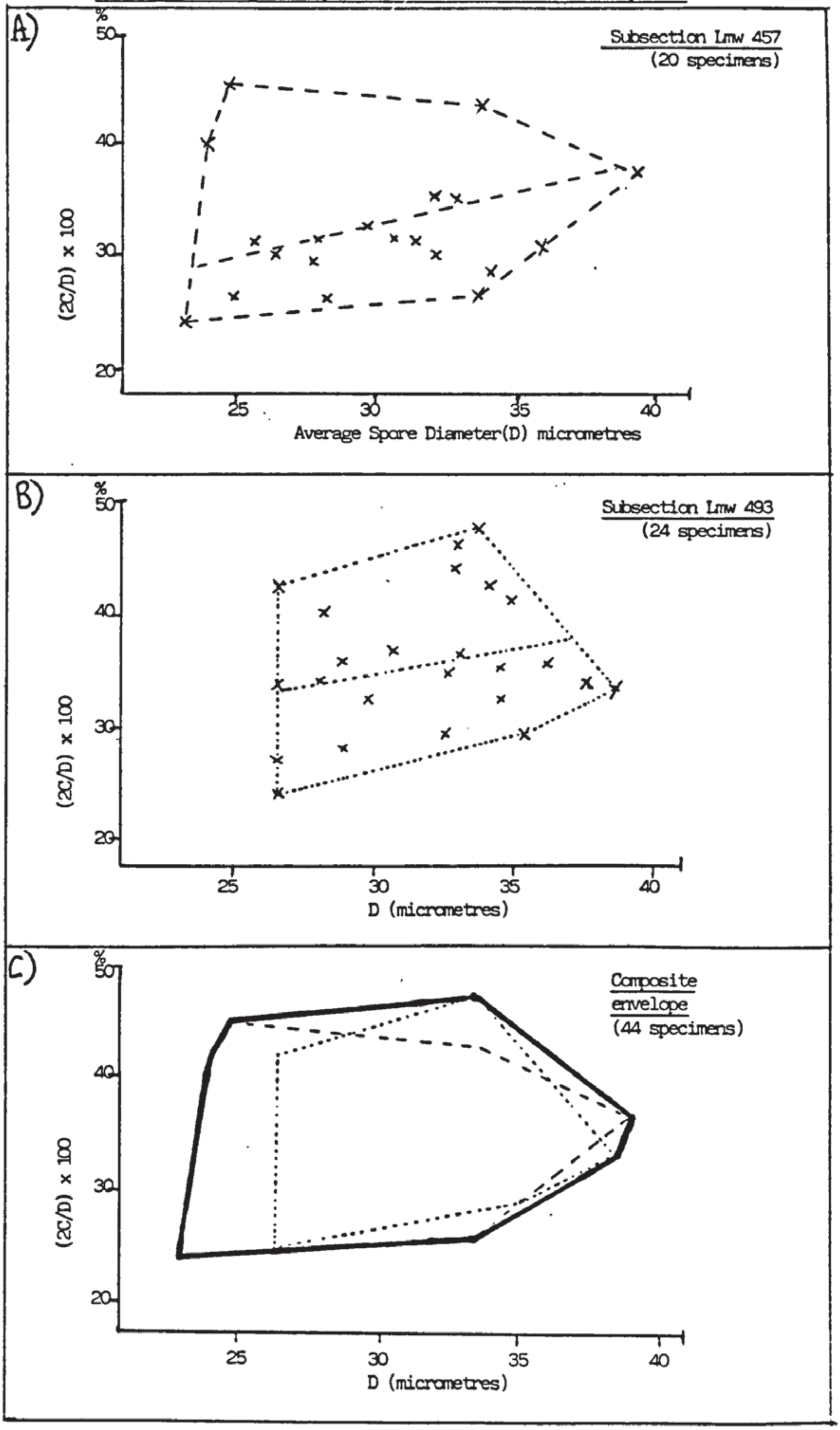
Densosporites gracilis Smith and Butterworth 1967

Plate 13, figs. 24-30.

Size in micrometres.

	Average Spore Diameter(D)	Average Cingulum Width (C)	$\frac{2C}{D}$x100	
(i)	Holotype 35, - 27(35)42	4(6)10		fum.HNO_3 (Smith and Butterworth 1967) Dicky Gobbler seam, Derbys, England; Westphalian B.

Fig. 6.3 Densosporites gracilis : Analysis of 2 x Cingulum (C) width/av. diameter (D) % plotted against average diameter for populations in 2 subsections showing confining envelope and line of best fit for data points



(ii)	28(34)38	5(6)8		fum.HNO_3 (Smith and Butterworth 1967) Barncraig Seam, Michael Colliery, East Fife Coalfield, Scotland; Westphalian B
(iii)	23.2(29.8)39.2	2.8(4.8)7.2	24(32)45	(20 specimens) fum.HNO_3 Leaf 2
(iv)	26.4(31.7)37.6	3.2(5.7)7.6	27(36)46	(24 specimens) fum.HNO_3 Leaf 1

Both (iii) and (iv) from the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B. The two populations examined demonstrate a close relationship in cingulum width : diameter % and spore diameter (Fig. 6.3.A,B) so that the composite confining envelope is not much larger than the individual component populations (Fig. 6.3.C).

Description. Amb rounded triangular, occasionally oval, circular or polygonal. Margin usually modified either by small indentations or occasionally by cones, rarely smooth. Laesurae not usually visible, straight, sometimes ridged, usually extending onto the cingulum. Intexine thin laevigate. Central area of exoexine thin, laevigate or finely granulate proximally, mostly apiculate distally. This ornament is fairly loosely spaced and varies between specimens, from coni 1-1.5 micrometres high and wide with pointed apices to a mixture of these elements with coni 1 micrometre high and 2 micrometres wide with blunt apices. Occasionally small spinae up to 1 micrometre high are present, loosely and irregularly scattered. Cingulum narrow, generally uniform in width, mean between 32-36% of total diameter tapering gradually in thickness towards the equator: usually laevigate proximally; apiculate distally with similar elements to those found in the central area, but often specimens have larger coni up to 4 micrometres high and 5 micrometres wide with pointed apices, widening at the base and sometimes joined to other coni. The larger elements are close together with smaller elements loosely and irregularly scattered. The exoexine of the central area is thicker distally than proximally.

Remarks. The laesurae where visible appear to be straight and not flexuose and the mean cingulum width given by Smith and Butterworth 1967 is between 34-35% of the mean spore diameter.

Comparison. *D. gracilis* is distinguished from *D. sphaerotriangularis* Kosanke 1950 by its smaller size, narrow cingulum (Fig. 6.3.8) and smaller pointed ornament. *D.* cf. *anulatus* differs in being less ornamented. *D. lori* Bharadwaj 1957a has a wider bizonate cingulum although some specimens seen in this study resemble this description. *D. microcarbonicus* (Artuz) Somers 1972 may be synonymous with *D. gracilis*, because although the ornament in pl. V, fig. 31b (drawing of photograph by Artuz) is described by Artuz 1957 as punctate, that shown in pl. V figs. 31a (photograph) is noticeably coarser and resembles small cones.

Occurrence. Present to common rarely in Leaf 1, present to very abundant especially towards the top of Leaf 1, occasionally to very common throughout Leaf 3, present to very common towards the top of Leaf 4. Present to frequent below the Thick Coal, occasional to common between Leaves 1 and 2, frequent between Leaves 2 and 3, infrequent above the Thick Coal.

Densosporites granulosus Kosanke 1950

1950 *Denso-sporites granulosus*, Kosanke, p.32, pl.6, fig. 8.

Holotype. Kosanke 1950, pl.6, fig. 8, maceration 625-A, slide 6.

Type locality. Willis Coal Bed, Gallatin County, Illinios, USA.

Diagnosis. (abbreviated from Kosanke 1950) Amb circular, laesurae indistinct sometimes extending onto equatorial portion. Proximal surface covered in small blunt granulose structures. Equatorial portion of spore coat is over 40% of the diameter.

Size in micrometres. Holotype 52.5 x 48.3, 45-56 Schulze and 10% KOH (Kosanke 1950).

Densosporites cf. granulosus

Plate 14, figs. 1-10.

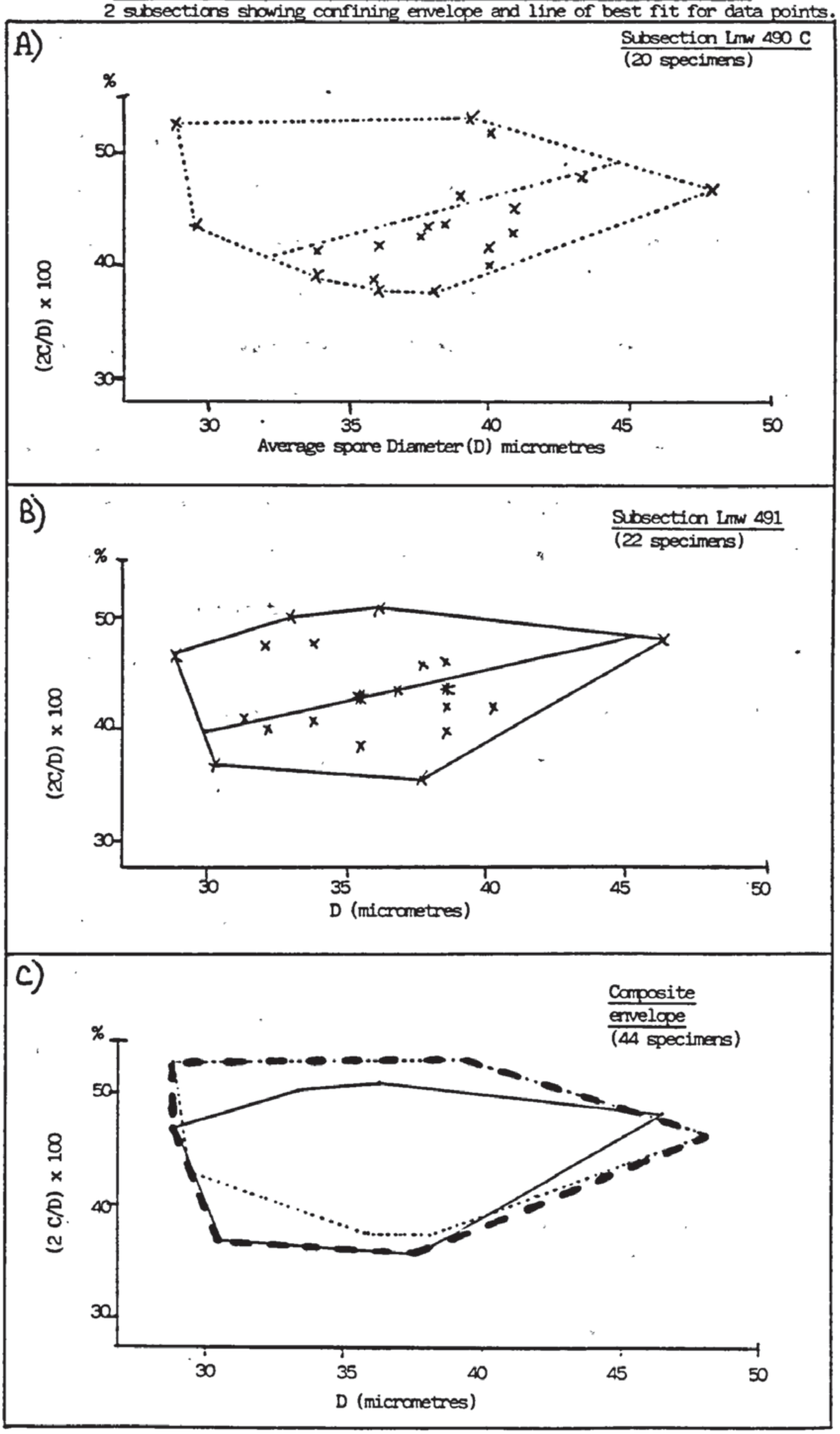
Size in micrometres.

	Average Spore Diameter(D)	Average Cingulum Width (C)	$\frac{2C \times 100}{D}$	
(i)	28.8(35.7)46.4	11.2(15.6)22.4	36(44)51	(22 specimens) fum. HNO_3 Leaf 1
(ii)	28.8(37.7)48	12.8(16.6)20.8	38(44)53	(20 specimens) fum. HNO_3 Leaf 1

(ii) and (iii) from the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B. The two populations examined demonstrate a close relationship in cingulum width : diameter % and spore diameter (Fig. 6.4.A,B) so that the composite confining envelope is not much larger than the individual component populations (Fig. 6.4.C).

Description. Amb rounded triangular to circular, oval or rarely polygonal, margin smooth to minutely indented. Laesurae rarely visible, indistinct, simple, straight often open, extending from just onto the cingulum to near the equator. Intexine thin laevigate. Central area of exoexine thin, proximally laevigate, distally ornamented with grana or minute coni with rounded apices up to but generally less than 1 micrometre high and wide, closely spaced with just enough space for further elements. Rarely there may also be minute spinae. Cingulum generally uniform in width, mean 44% of total diameter, tapering gradually in thickness towards the equator, sometimes poorly divided into an inner thickned and outer thinner

Fig. 6.4 Densosporites cf. granulosus : Analysis of 2 x Cingulum (C) width/ av. Diameter (D) % , plotted against average diameter for populations 2 subsections showing confining envelope and line of best fit for data points.



part: proximally laevigate; distally the ornament is similar to the central area, but with occasional coni up to 1.5 micrometres high and wide.

Comparison. D. granulosus Kosanke 1950 is slightly larger and the grana occur on the proximal surface. D. cf. graulosus is distinguished from other species in this study by its consistent ornament of grana and minute blunt coni. D. microsilvanus Artuz 1957 and D. sp. Artuz 1963 are both larger (former 45-52, latter 40-55 micrometres) and have wider cinguli (former 50%, latter 60% spore radius). D. granulatus Dybova and Jachowicz 1957 is slightly larger (mean 45 micrometres). D. hispidus Felix and Burbridge 1967 differs in that the distal ornament is composed of grana in the central area and bristle like spinae on the cingulum about 1 micrometre in length.

Occurrence. Present to very abundant towards the top of Leaf 1, present to infrequent rarely in Leaf 2, present rarely in Leaf 3. Infrequent to occasional below the Thick Coal, frequent between Leaves 1 and 2.

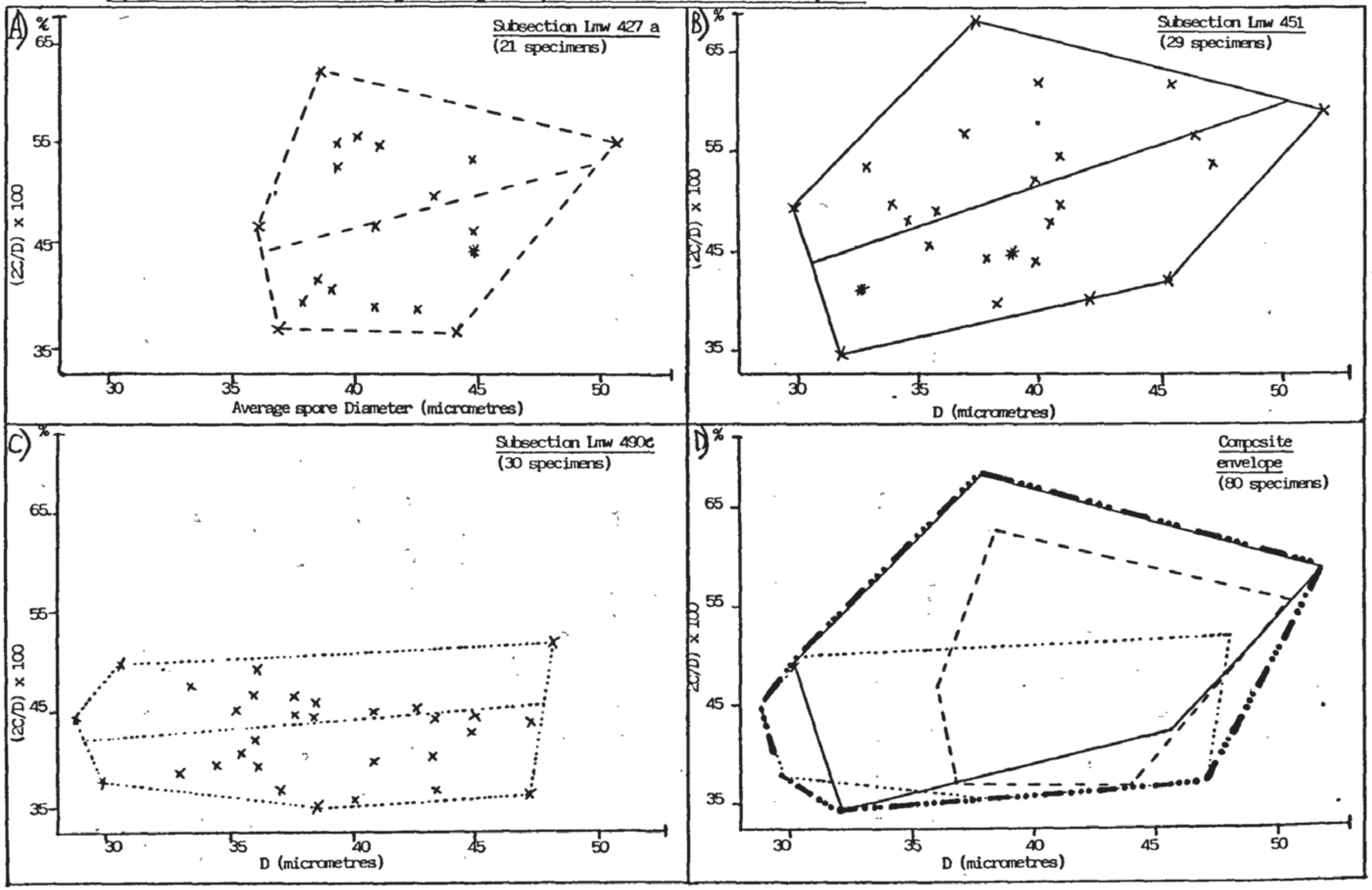
Densosporites sphaerotriangularis Kosanke 1950

Plate 14, figs. 11-20.

Size in micrometres.

	Average Spore Diameter(D)	Average Cingulum Width(C)	$\frac{2C\times100}{D}$	
(i)	Holotype 50.4x48.3 46-59			Schulze and 10% KOH (Kosanke 1950) Illinois, USA; Tradewater Group
(ii)	39(47)60	7.5(11)17		fum.HNO_3, Somerset, England; Westphalian D or Stephanian A
(iii)	26(50)59	5(12)18		fum. HNO_3, East Fife, Scotland; Upper Westphalian B

Fig. 6.5 Densosporites sphaerotriangularis: Analysis of 2 x Cingulum (C) width/av. Diameter (D) % plotted against average diameter (D) for populations in 3 subsections showing confining envelope and line of best fit for data points



(vi) 40(47)61	8(12)17		fum. HNO_3, Durham, England; Lower Westphalian B
(v) 38(47)59	8(12)16		fum. HNO_3, Warks, England; Upper Westphalian A
(vi) 36.0(41.1)50.4	6.8(9.9)14.0	36(48)63	(21 specimens) fum. HNO_3, Leaf 4.
(iix)33.6(40.6)48	6.8(9.1)12.8	37(45)58	(20 specimens) fum. HNO_3, Leaf 1

(ii) to (v) from Smith and Butterworth (1967)

(vi) to (viii) from the Thick Coal, Longmeadow Wood Borehole, Warwickshire, England; Westphalian B. The three populations examined demonstrate a close relationship in cingulum width : diameter % and spore diameter (Fig. 6.5.A-C) so that the composite confining envelope is not much larger than the individual component populations (Fig. 6.5.D).

Description. Amb rounded triangular to circular, occasionally oval or polygonal; margin smooth or slightly undulating. Laesurae with narrow ridges, flexuose, generally extending halfway across the cingulum, rarely extending either only to the inner margin of the cingulum or to the equator. Intexine thin laevigate. Central area of exoexine thin; proximally laevigate or finely granulate, distally with loosely scattered verrucae up to 2 micrometres high and 6 micrometres wide and coni generally 2.0 micrometres high and 3 micrometres wide with blunt apices. Cingulum irregular in width, mean between 45-57% of spore diameter, often divided into an inner thicker part and an outer thinner part or gradually tapering in thickness towards the equator; proximally laevigate; distally with the same loosely spaced ornament as the central area, although the verrucae may be larger - up to 5 micrometres high and 11 micrometres long and there may be small pointed coni about 1 micrometre high and wide, very loosely scattered. The exoexine in the central area is slightly thicker distally than proximally.

Remarks. The mean size range is slightly smaller than those given in Smith and Butterworth (1967) and the ornament of coni and verrucae appears restricted to the distal surface. The mean cingulum width given by Smith and Butterworth (1967) is between 47-52% of the mean spore diameter. The ornament on the photograph of Kosanke 1950 pl.6, fig. 7, and the description of an ornament of papillations similar to those seen in this study, seems at variance with the ornament on the photographs of Ravn (1979 pl.13, figs, 7, 8) and Ravn and Fitzgerald (1982 pl.9, figs. 3, 4,) which more resemble specimens of D. cf. duriti seen in this study.

Comparison. The divided cingulum, prominent rounded cones and verrucae, and slightly smaller size (Fig. 6.7) distinguish D. sphaerotriangularis from D. cf. triangularis and D. cf. duriti. D. brevispinosus Hoffmeister Staplin and Malloy 1955 has an ornament of widely scattered spinae, and appears in cingulum and ornament to occupy a position midway between D. sphaerotriangularis and D. cf. triangularis. D. dissimilis Felix and Burbidge 1967 differs in having blunt spines proximally and distally on the cingulum although some specimens of D. sphaerotriangulous observed in this study resemble it. D. crassigranifer Artuz 1957 appears to resemble D. sphaerotriangularis.

Occurrence. Present to very abundant especially towards the top of Leaf 1, present to very abundant especially towards the top of Leaf 2, occasional to very abundant throughout Leaf 3, present to abundant especially towards the top of Leaf 4. Frequent to common below the Thick Coal, common to very common between Leaves 1 and 2, occasional between Leaves 2 and 3, common above the Thick Coal.

Densosporites triangularis Kosanke 1950

Remarks. The mean cingulum width given by Smith and Butterworth (1967) is between 47-49% of the mean spore diameter. They only recorded D. triangularis from the Visean and Namurian but Ravn (1979) has found it in strata probably equivalent in age to Westphalian B/C.

Densosporites cf. triangularis

Plate 14, figs. 21-27.

Size in micrometres

	Average Spore Diameter(D)	Average Cingulum Width (C)	$\frac{2C\times100}{D}$	
(i)	30.4(41.8)55.2	6.4(9.8)12.8	35(47)58	(26 specimens) fum. HNO_3, Leaf 4
(ii)	32.0(38.6)47.5	8(9.5)12.0	40(49)59	(26 specimens) fum. HNO_3, Leaf 2
(iii)	32.0(40.8)55.2	6.4(9.4)14.4	36(46)58	(22 specimens) fum. HNO_3, Leaf 2

(i) to (iii) from the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B. The three populations examined demonstrate a close relationship in cingulum width : diameter % and spore diameter (Fig. 6.6.A-C), so that the composite confining envelope is not much bigger than the individual component populations (Fig. 6.6.D).

Description. Amb polygonal or rounded triangular, occasionally circular or oval; margin smooth or minutely modified with rare coni. Laesurae simple or ridged, slightly flexuose, extending up to, or just onto the cingulum. Intexine thin, laevigate. Central area of exoexine generally thin but occasionally thickened both proximally and distally; laevigate generally, but one or two small coni may be present and often many vacuoles are present giving rise to a foveolate

Fig.6.6 Densosporites cf. triangularis: Analysis of 2 x Cingulum (C) width/ av. Diameter (D) %, plotted against average diameter for populations in 3 subsections showing confining envelope and line of best fit for data points.

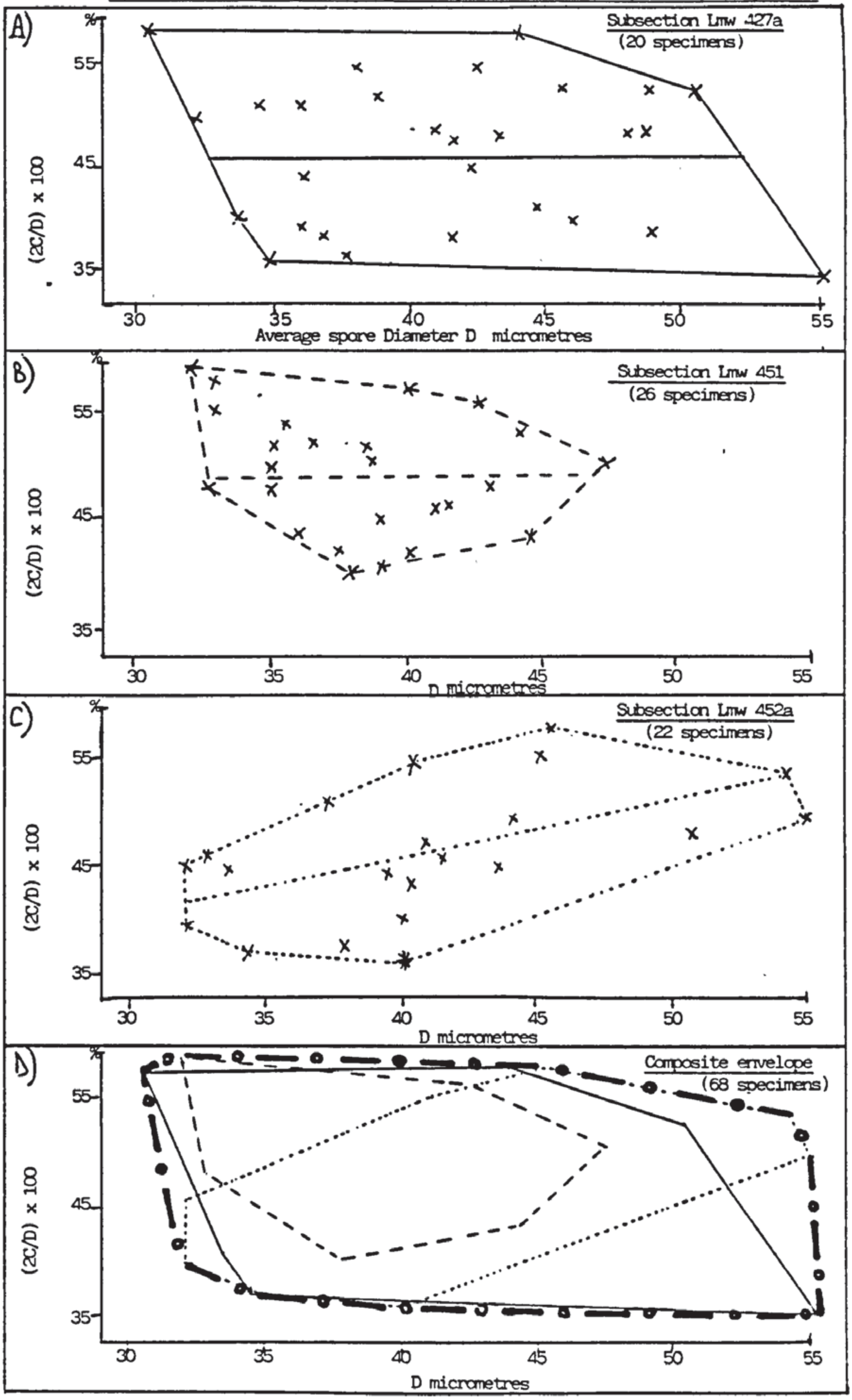
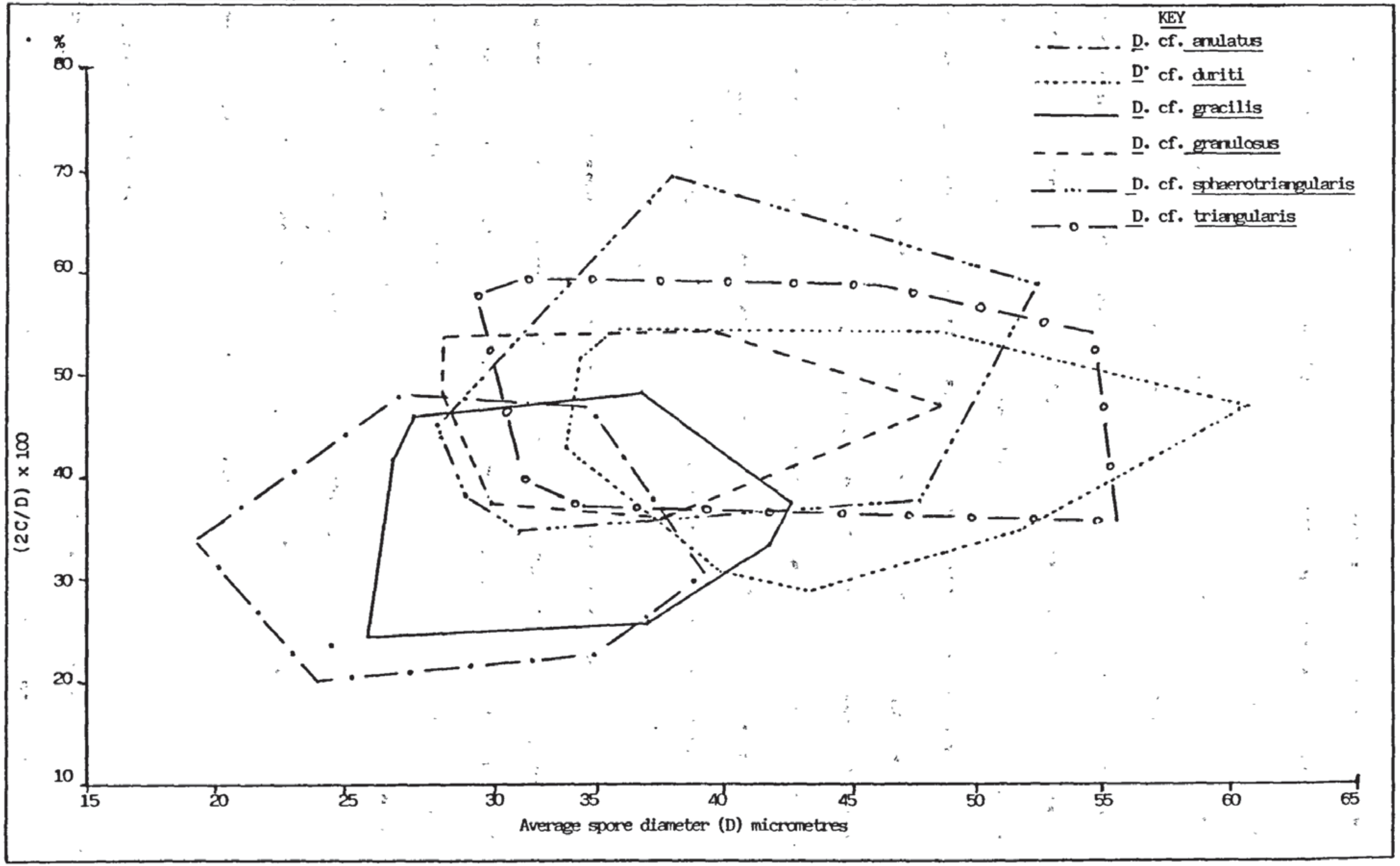


Fig. 6.7 Composite confining envelopes for the six species of Densosporites recognised in this study



ornament. Cingulum irregular in width, mean between 46-49% of spore diameter, only tapering slightly in thickness towards the equator: laevigate proximally and distally, but sometimes scattered minute coni up to 1 micrometre high and wide with pointed apices occur on the distal surface, rarely coni up to 3 micrometres high and wide with rounded apices occur loosely scattered on the distal surface.

Comparison. D. triangularis Kosanke 1950 differs in being larger (52-65 micrometres Kosanke 1950, 40(51)50 and 41(47)54 micrometres Smith and Butterworth 1967), generally more triangular in shape and the central area is granulose to vermiculate - foveolate. D. cuneicinctus Hoffmeister, Staplin and Malloy 1955 is also larger and more triangular in shape. D. oblatus Habib 1966 usually has a bizonate cingulum and verrucae up to 8 micrometres wide on the distal surface. D. brevispinosus Hoffmeister Staplin and Malloy 1955 also has a bizonate cingulum. D. pseudonnulatus Butterworth and Williams 1958 has a graulate central area.

Occurrence. Present to abundant especially towards the top of Leaf 1, present to abundant especially towards the top of Leaf 2, present to abundant intermittently in Leaf 3, present to abundant especially towards the top of Leaf 4. Occasional to frequent below the Thick Coal, common to abundant between Leaves 1 and 2, very common between Leaves 2 and 3, common above the Thick Coal.

Genus LYCOSPORA (Schopf, Wilson and Bentall) Somers 1972

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

Diagnosis. (Somers 1972 p.55)

Remarks. Somers (1972) reduced the number of species belonging to this genus. Initially she divided species within the genus into five groups according to size and width of equatorial extension, and also ornament, using the oldest specific name for each viz. L. brevis Bharadwaj 1957, L. pusilla (Ibrahim) Somers 1972, L. pellucida (Wicher) Schopf, Wilson and Bentall 1944, L. rotunda (Bharadwaj) Somers 1972 and L. noctuina Butterworth and Williams 1958.

Thirty one species were re-examined and described, and many more species designated Lycospora by a variety of authors were also studied. Following this only four species were recognised and a list of synonomies and provisional and probable synonomies given for each one. Some of the species were further divided into "varieties" and "tendencies" as follows:- (See Somers 1972 p.65-75).

I. Punctate or granulate

1. Lycospora orbicula (Potonie and Kremp) Smith and Butterworth 1967 with a very narrow cingulum (equal or less than 1 micrometre) and no zona.

2. Lycospora pusilla (Ibrahim) Somers 1972 with a clearly defined cingulum. This species was divided into two "tendencies", "tendency A" with a faint, reduced zona i.e. cingulum and zona / total radius is low, and "tendency B" with a clearly defined, well developed zona i.e. cingulum and zona / total radius is high. This "tendency" was further divided into "tendency B_1", in which the cingulum and central area are laevigate or punctate and "tendency B_2" in which the cingulum and central area are granulate.

II. Verrucate or rugulate

3. Lycospora rotunda (Bharadwaj) Somers 1972, ornamented with verrucae and with a clearly lobed margin.

4. Lycospora noctuina var. noctuina Butterworth and Williams 1958, ornamented with irregularly distributed verrucae and rugulae and

laevigate zona; and L. noctuina var. reticulata Kruszewska 1963, with rugulae arranged in a pseudoreticulum.

In this study L. noctuina was not recognised, but it was possible to distinguish consistently, populations of five species of Lycospora. Only L. rotunda completely accorded with the diagnoses and synonomies given by Somers (1972), L. ?rugosa (Schemel) Smith and Butterworth 1967 was separable from L. orbicula, and L. pellucida was separable from L. pusilla.

Lycospora orbicula (Potonie and Kremp) Smith and Butterworth 1967

Plate 14, figs. 28-30.

1955 Cyclogranisporites orbiculus Potonie and Kremp, p.63, pl.13, figs. 177-183.

1967 Lycospora orbicula (Potonie and Kremp) Smith and Butterworth, p.249, pl.20, figs. 16-19.

1972 Lycospora orbicula (Potonie and Kremp) Smith and Butterworth, in Somers (in part) p.71, pl.1, fig. 4; pl.11, fig.2, pl.XIV, figs. 1-20.

Occurrence. Occasional to very common especially towards the base of Leaf 1, infrequent to abundant especially towards the base of Leaf 2, present to very common throughout Leaf 3, present to abundant throughout Leaf 4. Present to occasional below the Thick Coal, occasional between Leaves 1 and 2, frequent between Leaves 2 and 3, and Leaves 3 and 4, common above the Thick Coal.

Lycospora pellucida (Wicher) Schopf, Wilson and Bentall 1944

Plate 15, figs. 1-40.

1934 Sporites pellucidus Wicher, p.186, pl.8, fig.29.

1944 Lycospora pellucidus (Wicher) Schopf, Wilson and Bentall, p.54.

1950 Lycospora punctata Kosanke, p.45, pl.10, fig.7.

1950 Lycospora pseudoannulata Kosanke, p.45, pl.10, fig.3.

1955 Cirratriradiates uber Hoffmeister, Staplin and Malloy, p.383, pl.36, fig.24

1957a Lycospora microgranulata Bharadwaj, p.104, pl.27, fig.18.

1957 Lycospora tenuireticulata Artuz, p.250, pl.5, fig.32.

1957 Lycospora uzunmehmedi Artuz, p.250, pl.5, fig.33.

1960 Lycospora uber (Hoffmeister, Staplin and Malloy) Staplin, p.20, pl.4, figs. 13, 17, 18, 20.

1967 Lycospora pellucida (Wicher) Schopf, Wilson and Bentall in Smith and Butterworth, pl.20, figs. 7-9.

1972 Lycospora pusilla "tendence B_1" (Ibrahim) Somers, p.66-70, pl.XII, fig.17.

1972 Lycospora pusilla "tendence B_2" (Ibrahim) Somers, p.66-70, pl.XII, fig.7.

1979 Lycospora pellucida (Wicher) Schopf, Wilson and Bentall in Ravn pl.13, fig.16.

Remarks. Specimens which appear to be punctate as well as those which are granulate are included in L. pellucida in this study. L. uber, (following Staplin 1960) and L. punctata and L. pseudoannulata (following Smith and Butterworth 1967) were made synonymous by Ravn (1979). He also made L. microgranulata, Bharadwaj 1957a, L. teniureticulata and L. uzunmehmedi Artuz 1957 synonymous with L. pellucida. Photographs and descriptions given in the original publications, for all of the species listed in the synonomy, have been examined and accord with the specimens observed in this study.

Occurrence. Present to very common throughout Leaves 1 to 3, present to frequent throughout Leaf 4. Present to very common below the Thick Coal, common to very common between Leaves 1 and 2, abundant between Leaves 2 and 3, very common between Leaves 3 and 4 and above the Thick Coal.

Lycospora pusilla (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 15, figs.5-10.

1932 Sporonites pusillus Ibrahim in Potonie, Ibrahim and Loose, p.448, pl.15, fig.19.

1933 Zonales-sporites pusillus Ibrahim, p.32, pl.2, fig.20.

1938 Zonotriletes pusillus (Ibrahim); Waltz in Luber and Waltz, pl.13, fig.33 and pl.8, fig.105.

1944 Lycospora pusillus (Ibrahim), Schopf, Wilson and Bentall, p.54.

1950 Lycospora granulata Kosanke, p.45, pl.10, figs. 4, 6.

1957a Lycospora denticulata Bharadwaj, p.103, pl.27, fig.9.

1957a Lycospora triangulata Bharadwaj, p.103, pl.27, figs.13, 14.

1957b Lycospora subjuga Bharadwaj, p.127, pl.25, figs. 84-86.

1967 Lycospora pusilla (Ibrahim) Schopf, Wilson and Bentall in Smith and Butterworth, p.251, pl.20, figs. 10-12.

1972 Lycospora pusilla "tendence A" Somers, p.66-70, pl.X, fig.2.

1979 Lycospora granulata Kosanke in Ravn, pl.13, fig.15.

Remarks. L. pusilla shows a range of size of grana from less than 0.5 micrometres to 1 micrometre. L. granulata Kosanke 1950, L. denticulata Bharadwaj 1957a L. triangulata Bharadwaj 1957a and L. subjuga Bharadwaj 1957b were made provisionally synonymous with L. pusilla by Somers (1972). L. denticulata and L. triangulata were made synonymous with L. granulata by Ravn (1979). Photographs and descriptions given in the original publications, for all of the species listed in the synonymy, have been examined and accord with specimens observed in this study.

Comparison. Smith and Butterworth (1967) considered that there was insufficient difference between *L. pusilla* and *L. brevijuga* Kosanke 1950, *L. micropapillata* (Wilson and Coe) Schopf, Wilson and Bentall 1944 and *L. parva* Kosanke 1950 to justify the status of species.

Occurrence. Occasional to very abundant throughout but especially towards the base of Leaf 1, present to very abundant throughout but especially towards the base of Leaf 2, common to abundant throughout Leaf 3, frequent to very abundant throughout but especially towards the base of Leaf 4. Common to very common below the Thick Coal, common to abundant between Leaves 1 and 2, common between Leaves 2 and 3, abundant between Leaves 3 and 4, very abundant above the Thick Coal. This is a zonal index species used by Clayton *et al.* (1977) to zone the Visean V1-2.

Lycospora rotunda (Bharadwaj) Somers 1972

Plate 15, figs. 11-16.

1956 *Lycospora torquifer* (Loose) Potonie and Kremp, p.104, pl.17, figs. 356-359 (not the holotype fig.355).

1956 *Lycospora granulata* (Kosanke) Potonie and Kremp, p.102, pl.17, figs. 339-340.

1957a *Lycospora rotunda* Bharadwaj, p.103, pl.27, figs.10-12.

1967 *Lycospora ?granulata* Kosanke in Smith and Butterworth, p.247, pl.20, figs.1-3.

1972 *Lycospora rotunda* (Bharadwaj) Somers, p.73, pl.1, figs.34-38, and pl.XV.

1979 *Lycospora rotunda* Bharadwaj in Ravn pl.13, figs.19, 20.

1979 Lycospora L. cf. torquifer (Loose) Potonie and Kremp in Ravn, pl.13, figs.17-18.

Holotype. Bharadwaj 1957a, pl.27, fig.10 Preparation SI. No. 7325/11 Geologisches Landesmat fur Nordreheim, Westfalen, Krefeld.

CIMP Type. Somers 1972, pl.XV, fig.4. Preparation 125(3)2, Iniex, Liege.

Type locality. Constanze Seam, mine Gottelborn, Saar Basin; Westphalian D.

CIMP locality. Couche 16, siege de Houthalen, bassin de Campine, Belgium; Zone de Genk, Westphalian A.

Diagnosis. Emendation in Somers 1972, p.73.

Size in micrometres. (i) Holotype ? ;29-37 (Bharadwaj 1957a). (ii) CIMP type 33; 24-37 (Somers 1972). (iii) 27(32)37 fum. HNO_3 (Smith and Butterworth 1967). Yorkshire Coalfield; Westphalian B. (iv) 29(33)39 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B. (v) 20(26)31 (20 specimens) fum. HNO_3, Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb rounded triangular, angles pointed or rounded, margin lobate. Laesurae with narrow lips about 1 micrometre in height and width, flexuose, often extending to amb. Cingulum generally between 1.5 to 2 micrometres wide, zona 1.5-3 micrometres wide, the division between the inner thickened zone and flange not always clear. Distal surface ornamented with grana and verrucae with rounded apices, varying in size from 1.5-2.5 micrometres in width, about 1.5 micrometres high. Spacing varies between very loosely spaced to irregularly closely spaced. Proximal surface finely granulate. Exine thin, occasionally folded.

Remarks. Smith and Butterworth (1967) noted that the ornament of their specimens of L. granulata Kosanke 1950 was coarser than that given by

Kosanke and because of this used the name L. ?granulata; the only distinction they made between this and L. rotunda was in shape. Somers (1972) made L. granulata (Kosanke) sensu Potonie and Kremp 1956 and L. torquifer (Loose) Potonie and Kremp 1956 synonymous with L. rotunda; whilst noting that the holotype of L. torquifer illustrated by Potonie and Kremp did not belong to the genus Lycospora but the three other specimens illustrated did. L. cf. torquifer Ravn 1979 was made synonymous by him with L. torquifer, and he noted that the size of ornament of this species was intermediate between L. granulata Kosanke 1950 and L. rotunda. Photographs and descriptions given in the original publications for all of the species listed in the synonomy have been examined and accord with specimens observed in this study.

Comparison. The coarseness of ornament (1.5-2.5 micrometres) distinguishes L. rotunda from L. pusilla (ornament less than 0.5 micrometres to 1.0 micrometre) and L. pellucida (ornament of puncti and grana up to 1.0 micrometre). Ravn (1979) made L. nitida and L. paulula Artuz 1957 synonymous with L. rotunda, but this practice is not followed here as Somers (1972) made these species synonymous with L. noctuina.

Occurrence. Present to abundant throughout Leaf 1, present to very abundant intermittently in Leaf 2, infrequent to very abundant throughout Leaf 3, and infrequent to abundant throughout Leaf 4. Present to common below the Thick Coal, common between Leaves 1 and 2 and Leaves 3 and 4, and occasional above the Thick Coal.

Lycospora rugosa Schemel 1951

Plate 15, figs. 17-20.

1951 Lycospora rugosa Schemel, p.747, text fig.4.

1967 Lycospora ?rugosa Schemel in Smith and Butterworth, p.252, pl.20, figs. 13-15.

1972 Lycospora orbicula (Potonie and Kremp) Smith and Butterworth in Somers (in part) p.71, pl.I, fig.7.

Remarks. The size of the grana ranges from very fine (less than 0.5 micrometres) to just less than 1 micrometre and barely modify the margin.

Occurrence. Present to occasional intermittently in Leaf 1, present to frequent rarely in Leaves 2 and 4, intermittently in Leaf 3. Present below the Thick Coal, occasional to frequent between Leaves 1 and 2 and frequent above the Thick Coal.

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

Cristatisporites connexus Potonie and Kremp 1955

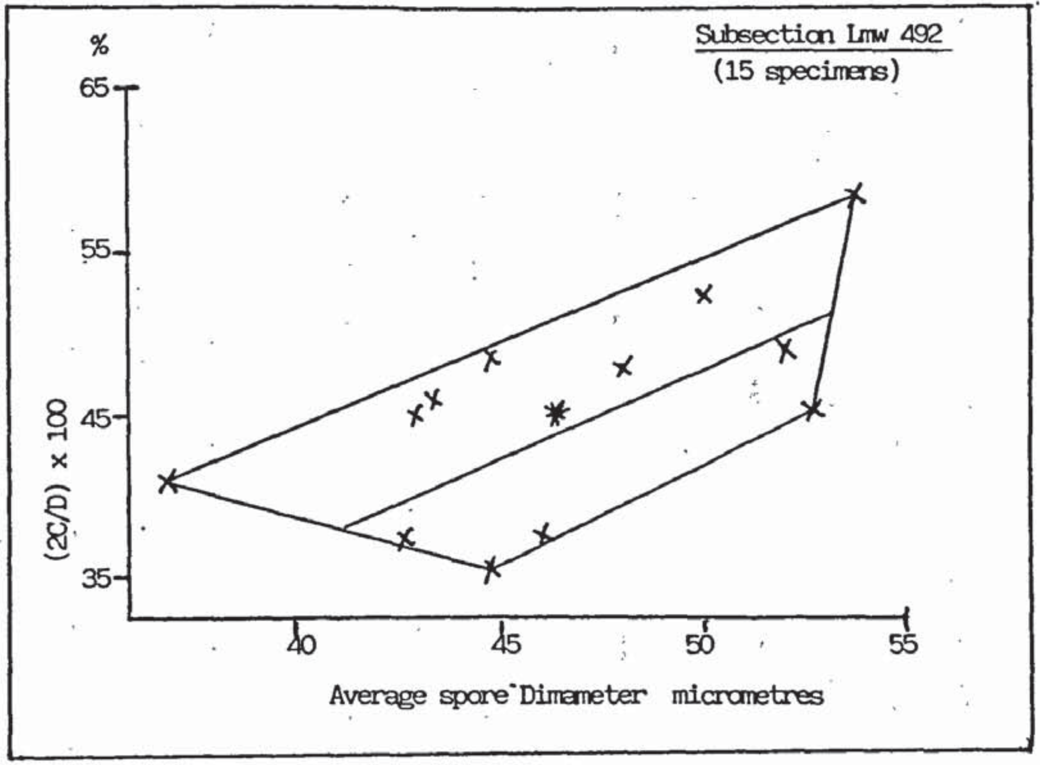
Plate 15, figs. 21-25.

Size in micrometres.

	Average spore diameter(D)	Average cingulum width (C)	
(i)	Holotype 56 45-70		Schulze Potonie and Kremp 1955
(ii)	41(54)66		fum.HNO_3 Lothians Coalfield Scotland, Lower Westphalian B
(iii)	51(58)67		Schulze and 5% KOH, Lancashire England, Lower Westphalian B
(iv)	37(47)59		fum. HNO_3 Warwickshire Coalfield, England; Upper Westphalian A.

$$\frac{2C \times 100}{D}$$

Fig.6.8 Cristatisporites connexus : Analysis of 2 x Cingulum (C) width/av. Diameter (D) % plotted against average diameter for a population in subsection 492 showing confining envelope and line of best fit for data points



(v)36.8(46.7)53.6   7.7(10.5)15.2 36(45)59 (15 specimens) fum. HNO_3
Leaf 1, Thick Coal,
Longmeadow Wood
borehole,
Warwickshire England;
Westphalian B

(ii) to (iv) from Smith and Butterworth (1967). (See also Fig. 6.8).

Description. Amb circular to rounded triangular, rarely polygonal, margin modified by 21-45 elements. Laesurae usually not visible, extending to the inner margin of the cingulum or just onto it, slightly flexuose. Intexine and visible. Central area of exine thin, proximally granulate, distally with verrucae up to 5 micrometres in height and width joined at the base (cristae), often with small coni or spinae on them, closely spaced. Cingulum varies in width, not always well defined, mean 45% spore diameter, tapering in thickness towards the margin; proximally granulate; distally with the same ornament as the central area, but more closely spaced along the inner margin of the cingulum and arranged in ridges, more scattered towards the margin. The exoexine of the central area is thicker distally than proximally.

Comparison. The coarser verrucate ornament and larger size distinguish C. connexus from other species of Cristatisporites.

Occurrence Present to abundant intermittently in Leaf 1, present rarely in Leaf 2, occasional rarely in Leaf 3, infrequent rarely in Leaf 4. Occasional below the Thick Coal, present between Leaves 3 and 4.

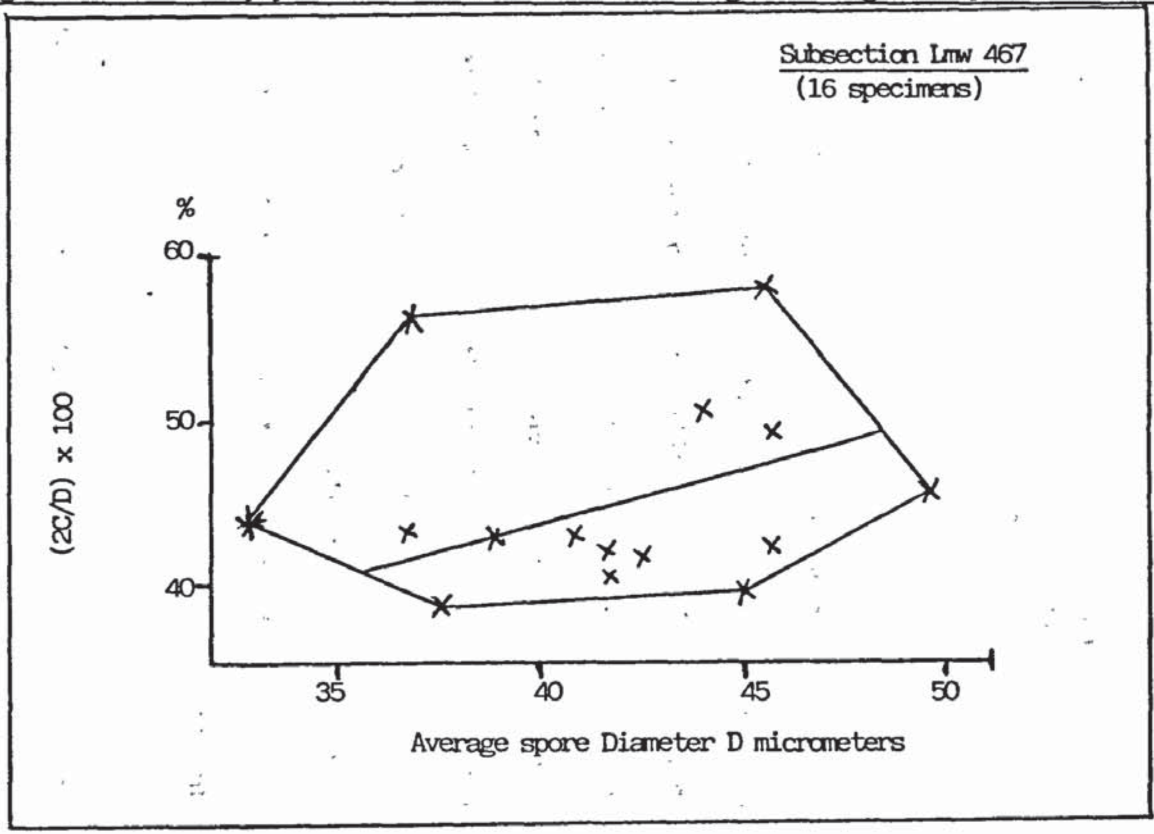
Cristatisporites indignabundus (Loose) Staplin and Jansonius 1964

Plate 15, figs. 26-28.

Size in micrometres.

Average spore diameter(D)	Average cingulum width (C)	$\frac{2C \times 100}{D}$

Fig. 6.9 Cristatisporites indignabundus : Analysis of 2 x Cingulum (C) width/av. Diameter (D) % plotted against average diameter for a population in subsection 467 showing confining envelope and line of best fit for data points



(i) Holotype 52.5 50-80			Schulze Potonie and Kremp 1955
(ii) 42(53)52.5			fum. HNO_3: Cannock Coalfield, England; Upper Westphalian B
(iii) 41(51)58			fum. HNO_3 Coalbrookdale Coalfield England; Upper Westphalian B
(iv) 44(52)61			fum. HNO_3: Yorkshire, England; Westphalian B
(v) 32.8(41.0)45.2	8.0(9.3)13.2	39(45)58	(15 specimens) fum. HNO_3', Leaf 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B

(ii) to (iv) from Smith and Butterworth 1967. (See also Fig. 6.3.10).

Description. Amb circular to rounded triangular, margin modified by between 29-53 elements. Laesurae not usually visible, extending onto the cingulum. Intexine not visible. Central area of exoexine thin, proximally punctate or finely granulate, distally ornamented with cristae, coni and verrucae sometimes joined at the base, the largest ornament up to 7 micrometres wide, closely spaced. Cingulum varies in width mean 45% spore diameter often clearly divided into an inner thickened zone and outer thinner zone: proximally a ring of spinae up to 3 micrometres long and 1 micrometre in diameter surround the central area; distally with the same ornament as the central area, except that the elements are more fused and the setose tips can clearly be seen.

Occurrence. Present to frequent intermittently towards the top of Leaf 1, present to common rarely in Leaf 2, and intermittently in Leaf 3, present to infrequent rarely in Leaf 4. Present to infrequent below the Thick Coal, present between Leaves 1 and 2, and Leaves 2 and 3.

Genus CIRRATRIRADIATES Wilson and Coe 1940

Cirratriradiates saturni (Ibrahim) Schopf, Wilson and

Bentall 1944

Plate 15, figs. 29-32.

Occurrence. Present to occasional intermittently in Leaf 1, present to frequent intermittently in Leaf 2, present to common throughout Leaves 3 and 4. Present beneath the Thick Coal, present to occasional between Leaves 1 and 2, present between Leaves 2 and 3 and Leaves 3 and 4 and occasional above the Thick Coal. Used by Clayton et al. (1977) as a zonal index species with Triquitrites sinani for the lowest part of the Westphalian A.

Genus CINGULIZONATES (Dybova and Jachowicz)

Butterworth Jansonius, Smith and Staplin 1964

Cingulizonates loricatus (Loose) Butterworth and

Smith in Butterworth et al. 1964

Plate 15, figs. 33-37.

Occurrence. Present to common rarely in Leaf 1, present to abundant intermittently in Leaf 2, and Leaf 3, present to infrequent in Leaf 4. Present to very common below the Thick Coal, present to common between Leaves 1 and 2, occasional between Leaves 2 and 3, common between Leaves 3 and 4.

Genus RADIIZONATES Staplin and Jansonius 1964

Radiizonates striatus (Knox) Staplin and Jansonius 1964

Radiizonates cf. striatus (Knox) Staplin and Jansonius 1964

Plate 16, figs. 1-3.

1967 Radiizonates cf. striatus (Knox) Staplin and Jansonius in Smith and Butterworth, p.266, pl.20, figs.20, 21

Size in micrometres. (i) Diameter 30(37.5)45, cingulum 1.5(5.5)8.5, zona 1.5(4)8.5, fum. HNO_3 (Smith and Butterworth 1967) East Fife, Scotland; Lower Westphalian B (ii) Diameter 26(32.4)40, cingulum

3.2(4.9)6.4, zona 1.6(2.9)4.8 (20 specimens) fum. HNO_3, Leaf 3, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb sub-circular to rounded triangular. Laesurae usually indistinct, slightly raised, extending to inner margin of cingulum. Intexine faint, laevigate. The inner cingulum is equal in width or larger than the outer zona, and has radial costae which usually extend onto the zona. Central part of exoexine thin, usually laevigate, distally rarely granulate, or with a few scattered verrucae.

Occurrence. Present to occasional rarely in Leaf 1, present to frequent rarely in Leaf 2 and occasional to very common intermittently in Leaf 3. Occasional to frequent below the Thick Coal, common to very common between Leaves 1 and 2 and common between Leaves 2 and 3.

Radiizonates tenuis (Loose) Butterworth and Smith

(in Butterworth et al. 1964)

Plate 16, figs. 4-8.

Occurrence. Present to abundant intermittently in Leaf 1, present to common rarely in Leaf 2, present to occasional rarely in Leaf 3, present to very common rarely in Leaf 4. Present to occasional below the Thick Coal, present between Leaves 1 and 2.

Suprasubturma PSEUDOSACCITRILETES Richardson 1965

Infraturma MONOPSEUDOSACCATI Smith and Butterworth 1967

Genus SPENCERISPORITES Chaloner 1951

Spencerisporites radiatus (Ibrahim) Felix and Parks 1959

Plate 16, figs.9, 10.

Occurrence. Present rarely in Leaves 1 and 3, present to infrequent rarely in Leaf 2. Present between Leaves 1 and 2.

Genus ENDOSPORITES Wilson and Coe 1940

Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 16, figs. 11-13.

Comparison. The distinction between E. globiformis and E. zonalis (Loose) Knox 1950 is made on the basis of the ratio of the body to pseudosaccus dimension. Following smith and Butterworth (1967) an arbitrary ratio of 50% is used to distinguish between E. zonalis which has a larger and E. globiformis which has a smaller ratio than 50%.

Occurrence. Present to common rarely in Leaf 1, intermittently in Leaf 2, present to frequent rarely in Leaf 3, infrequent rarely in Leaf 4. Present to frequent between Leaves 1 and 2, occasional between Leaves 3 and 4, common above the Thick Coal.

Endosporites zonalis (Loose) Knox 1950

Plate 16, figs.14-17.

Occurrence. Present to common intermittently in Leaves 1, 2 and 3, infrequent rarely in Leaf 3. Present below the Thick Coal, present to common between Leaves 1 and 2, common above the Thick Coal.

Genus RETISPORA Staplin 1960

Type Species. R. florida Staplin 1960

Diagnosis. (Staplin 1960 p.32)

Comparison. Distinguished from Endosporites Wilson and Coe 1940 by the presence of a distal reticulate ornament on the exoexine.

Retispora staplinii (Gupta and Boozer) Ravn and Fitzgerald 1982

Plate 17, figs. 1-50.

1960 Endosporites ?parvus Staplin, p.33, pl.7, figs.8, 12.

non 1958 Endosporites parvus Guennel, p.50-51, text fig.11, pl.1, figs.16,17.

1969 Endosporites staplinii Gupta and Boozer p.78.

1976 Endosporites cf. micromanifestus (Hacquebard 1957); Tillement Peniguel and Guillemin, p.438, pl.1, fig.27.

1979 Endosporites staplinii Gupta and Boozer 1969; Ravn p.43, pl.14, figs. 9-11.

1982 Retispora staplinii (Gupta and Boozer) Ravn and Fitzgerald p.143, pl.10, figs.1-8.

Holotype. Staplin 1960, pl.7, fig.9, sample Imp. 1707, 1-49.4 x 116.5.

Type Locality. Golata formation, West-Central alberta, Canada.

Size in micrometres. (i) Holotype exoexine 33, intexine 17, exoexine range 24-35, intexine 16-20, HF, schulze and 5% K_2CO_3 (Staplin 1960); Golata FM, Chesterian, Mississipian. (ii) exoexine 32 (36.5)39, intexine 22(23.7)25.5 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B (iii) exoexine 26(32)40, intexine 18(21)27 (20 specimens) fum. HNO_3, Leaf 1, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb of pseudosaccus rounded triangular to circular, margin irregular, crenulate. Leasurae raised, often flexuose, approximately equal to the radius of the central body, although often they continue to the margin of the pseudosaccus.Intexine forming the central body is about 1 micrometre thick, circular in outline although it may be modified by small folds. It is finely granulate and attached proximally to the exoexine, about 1/2 to 5/6 spore radius. Exoexine forms a thin pseudosaccus which has a few folds on the proximal surface and is ornamented on the distal surface with irregular, discontinuous muri about 1 micrometre in width and less than 1 micrometre in height. The muri form a very imperfect reticulation, which is best developed in the polar area where lumina vary in diameter from 2-7 micrometres; towards the margin the lumina are larger and more imperfect. Limbus sometimes present up to 1 micrometre wide.

Remarks. Ravn and Fitzgerald (1982) found muri up to 4 micrometres in width which is much greater than those found in the present study.

Comparison. Both *R. florida* Staplin 1960 and *R. lepidophyta* (Kedo) Playford 1976 have a more regular, distinct distal reticulate ornament.

Occurrence. Common to abundant rarely in Leaf 1, present in Leaf 3. Frequent between Leaves 1 and 2.

Infraturma POLYPSEUDOSACCATI Smith and Butterworth 1967

Alatisporites pustulatus (Ibrahim) Ibrahim 1933

Plate 17, figs.6,7.

Occurrence. Present to infrequent rarely in Leaf 1, present rarely in Leaves 2, 3 and 4. Not seen in siliciclastic subsections.

Turma MONOLETES Ibrahim 1933

Suprasubturma ACAVOMONOLETES Dettmann 1963

Subturma AZONOMONLETES Luber 1935

Infratuoma LAEVIGATOMONOLETES Dybova and Jachowicz 1957a

Genus LAEVIGATOSPORITES Ibrahim 1933

Laevigatosporites dunkardensis Clendening 1970

1969 *Laevigatosporites plicatus* Clendening, p.263, pl.3, figs.1-7.

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

1970 *Laevigatosporites dunkardensis* Clendening, p.788.

Holotype. Clendening 1969, pl.3, fig.1, Maceration 3709, slide 1.

Type Locality. Washington Formation, Dunkard coal, Monongalia County, West Virginia, Pennsylvanian.

Diagnosis. (Clendening 1969).

Size of micrometres. (i) Holotype 80.5 x 53.7, length 46-95, width 30-60 Schulze and 10% KOH (Clendening 1969) (ii) 48(68.3)112 fum. HNO_3(Nader 1983) Northumberland, England; Westphalian B.

Laevigatosporites cf. dunkardensis

Plate 17, figs.8-11.

Size in micrometres. 30(50)74 (20 specimens) fum.HNO_3, Leaf 1, Thick Coal, Longmeadow Wood borehole, Warwickshire, England, Westphalian B.

Description. Amb oval, usually irregular due to folding, margin smooth. Laesurae simple, straight, 1/2-3/4 of spore radius, although often hidden by folds. Exine laevigate, thin, with many folds which have no specific orientation relative to the long axis of the spore.

Remarks. L. dunkardensis is larger.

Comparison. L. cf.dunkardensis is distinguished from other species of the genus by its heavy folding.

Occurrence. Occasional to common throughout Leaf 1, infrequent to very common throughout Leaf 2, infrequent to abundant throughout Leaf 3, present to common throughout Leaf 4. Frequent to common below the Thick Coal, very common to abundant between Leaves 1 and 2, abundant between Leaves 2 and 3, very common between Leaves 3 and 4 and occasional above the Thick Coal.

Laevigatosporites minor Loose 1934

Plate 17, figs.12-16.

Comparison. A size boundary of 35-65 micrometres is employed in this study to distinguish this species from L. minimus, which is smaller than 35 micrometres and L. vulgaris which is larger than 65 micrometres, following Smith and Butterworth 1967.

Occurrence. Frequent to abundant throughout Leaf 1, occasional to very abundant throughout Leaf 2, very common to abundant in Leaf 3, common to abundant throughout Leaf 4. Frequent to common below the Thick

Coal, very common to abundant between Leaves 1 and 2, very common between Leaves 2 and 3, abundant between Leaves 3 and 4, common above the Thick Coal.

Laevigatorsporites vulgaris (Ibrahim) Ibrahim 1933

Plate 17, figs.17-19.

Remarks. Although some specimens are folded (Plate 17, fig.18) the majority have relatively few folds.

Occurrence. Present to frequent intermittently in Leaf 1, present to occasional rarely in Leaf 2, present rarely in Leaf 3, present to infrequent rarely in Leaf 4. Occasional between Leaves 1 and 2, infrequent between Leaves 3 and 4.

Infraturma SCULPTATOMONOLETES Dybova and Jachowicz 1957a

Genus PUNCTATOSPORITES Ibrahim 1933

Punctatosporites minutus Ibrahim 1933

Plate 17, figs.20-25.

Size in micrometres. (i) Holotype 25.5 Schulze and KOH (ii) 21-28 Schulze (Potonie and Kremp 1956) (iii) 21(25)30 Schulze and KOH (Smith and Butterworth 1967) Lancashire, England; Westphalian B (iv) 16(25.7)35 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian B (v) 12.8 (18.2)24.8 (20 specimens) fum. HNO_3 Leaf 1 (vi) 18.4(22)26.4 (20 specimens) fum. HNO_3, Leaf 2. (v) and (vi) from the Thick Coal Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to subcircular, circular in polar view margin barely modified. Laesurae distinct, simple or slightly ridged, slightly curved, 1/2-3/4 spore length, sometimes showing an incipient trilete condition. Sometimes the laesurae is not visible if the spore is viewed from the distal surface. Ornament of very fine grana about

0.5 micrometres in diameter, varying from loosely to closely spaced on different individuals. Exine between 0.5-1 micrometre thick, with some specimens possessing one or two secondary folds.

Comparison. Fabasporites pallidus Sullivan 1964 is alete and slightly smaller (13-23 micrometres).

Occurrence. Present to common intermittently in leaf 1, occasional to abundant intermittently in Leaf 2, present to abundant intermittently in Leaf 3, present to abundant throughout Leaf 4. Occasional below the Thick Coal, infrequent to frequent between Leaves 1 and 2, occasional between Leaves 2 and 3, common between Leaves 3 and 4.

Turma HILATES Dettmann 1963

Suprasubturma CAVATIHILATES Smith and Butterworth 1967

Subturma AZONOCAVATIHILATES Smith and Butterworth 1967

Infraturma EPITYGMATI Spode in Smith and Butterworth 1967

Genus VESTISPORA (Wilson and Hoffmeister) Wilson and Venkatachala 1963.

Vestispora costata (Balme) Spode in Smith and Butterworth 1967

Plate 17, figs.26-28.

Remarks. Laesurae simple, straight, about 1/2 spore radius.Muri about 2 micrometres wide and 1 micrometre high which are rarely branched and separated by up to 12 micrometres.

Comparison. Distinguished from other species in this study by its unmodified costae which are only rarely branched.

Occurrence. Present rarely in Leaf 1, present to common intermittently in the bottom half of Leaf 2, present rarely in Leaf 3, present to infrequent rarely in Leaf 4. Present between Leaves 3 and 4.

Vestispora laevigata Wilson and Venkatachala 1963

Plate 18, figs., 1, 2.

Remarks. The laesurae in this study extend from 3/4 to full intexine radius and may be enclosed in folds. Both intexine and exoexine may be folded.

Comparison. Distinguished from other species of the genus by its almost laevigate exoexine.

Occurrence. Infrequent rarely in Leaf 2.

Vestispora pseudoreticulata Spode in Smith and Butterworth 1967

Plate 18, figs.3-5.

Remarks. Primary muri are 2-3 micrometres wide and about 2 micrometres high, enclosing large polygonal lumina up to 12 micrometres in diameter. The carinae are up to 2 micrometres wide and 1 micrometre high and enclose lumina 2-3 micrometres in diameter. Exine 1-1.5 micrometres thick.

Comparison. Distinguished from other species of Vestispora seen in this study by the well developed secondary reticulum.

Occurrence. Present to occasional rarely in Leaf 1, present to frequent intermittently in Leaf 2, present rarely in Leaf 3, present to infrequent rarely in Leaf 4. Frequent above the Thick Coal.

Vestispora tortuosa (Balme) Spode in Smith and Butterworth 1967

Plate 18, figs.6-8.

Remarks. Primary muri are 1.5-3 micrometres wide and about 1 micrometre high, occasionally branching and enclosing large polygonal luninae. The carinae are up to 2 micrometres wide and up to 3 micrometres long so that they do not form a secondary reticulum. Exoexine about 1.5 micrometres thick.

Comparison. Distinguished from V. pseudoreticulata which has a strong secondary reticulum and from V. costata which is not carinate.

Occurrence. Present to infrequent intermittently in Leaf 1, present to frequent rarely in Leaf 2, present rarely in Leaf 3. Not observed in siliciclastic subsections.

Turma ALETES Ibrahim 1933

Subturma AZONALETES (Luber) Potonie and Kremp 1954

Genus FABASPORITES Sullivan 1964

Fabasporites exilis Clendening 1967

1967 Fabasporites exilis p.316, pl.1, figs.7,8.

Holotype. Clendening 1967, pl.1, fig.7, maceration 3500, slide 20.

Type Locality. Little Washington coal, Washington County, U.S.A; Pennsylvanian.

Diagnosis. (Clendening 1967, p.316).

Size in micrometres. (i) 21(25)30 Schulze and 10% KOH (Clendening 1967)

Fabasporites cf. exilis

Plate 18, figs.9-12.

Size in micrometres. (i) 11(17)22 (20 specimens) fum. HNO_3, Leaf 1 (ii) 11(20)28 (20 specimens) fum. HNO_3, Leaf 4; both from the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to circular, margin usually unmodified. Exine about 1/2 micrometre thick usually laevigate but may be ornamented with loosely spaced fina grana. A single major compression fold, usually parallel to the long axis simulates the appearance of a monolete suture because it is often accompanied by a lighter thinner zone along part of the length of the fold. This major fold may be hidden by the large number of secondary folds which may be present.

Comparison. F. exilis is slightly larger and laevigate to punctate. F. pallidus Sullivan 1964 is often bean shaped with only occasional crescentic folds and although essentially laevigate may possess dome shaped granules. F. molestus and F. parvus Clendening 1967 are both smaller and laevigate and the latter has a thicker exine.

Occurrence. Occasional to very abundant throughout the lower half of Leaf 1, present to very abundant throughout Leaf 2, frequent to abundant throughout Leaf 3, occasional to very abundant throughout Leaf 4. Present below the Thick Coal, occasional to common between Leaves 1 and 2, abundant between Leaves 2 and 3 and Leaves 3 and 4, common above the Thick Coal.

Fabasporites parvus Clendening 1967

Plate 18, fig.13-16.

1967 Fabasporites parvus, p.317, pl1, figs.9,10.

Holotype. Clendening 1967, pl.1, fig.9, maceration 3500, slide 20.

Type Locality. Little Washington coal, Washington County, USA; Pennsylvanian.

Diagnosis. (Clendening 1967, p.317).

Size in micrometres. (i) 12(15)18 Schulze and 10% KOH (Clendening 1967) (ii) 8(15.1)18.4 (20 specimens) fum. HNO_3, Leaf 1, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B

Description. Amb oval to elliptical, margin usually unmodified. Exine between 1-1.5 micrometres thick, usually laevigate, although on some specimens loosely spaced very fine grana may be present. A single major compression fold usually parallel to the long axis simulates the appearance of a monolete suture. Sometimes the spore is folded parallel to the long axis giving an elliptical shape; often other secondary folds are present.

Comparison. The specimens described as F. pallidus by Nader (1983) appear similar to this species but are larger, 16(23)33 micrometres.

Occurrence. Occasional to very common intermittently in Leaf 1, present to common intermittently in Leaf 2, infrequent to common intermittently in Leaf 3, present to common throughout Leaf 1. Occasional below the Thick Coal, present to frequent between Leaves 1 and 2, occasional between Leaves 2 and 3, frequent between Leaves 3 and 4.

Anteturma POLLENITES Potonie 1931

Turma SACCITES Erdtman 1947

Subturma MONOSACCITES (Chitaley) Potonie and Kremp 1954

Infraturma ARADIATES Bharadwaj 1957a

Genus FLORINITES Schopf, Wilson and Bentall 1944

Florinites florina Imgrund 1960

Florinites ct. florini Imgrund 1960

Plate 18, figs.17-20.

1967 Florinites cf. florina Imgrund 1960 in Smith and Butterworth, p.302, pl.26, figs.3-5.

Comparison. F. cf. florini, unlike F. mediapudens (Loose) Potonie and Kremp 1954 which it closely resembles, lacks a distinct body. Two other species of Florinites which lack a distinct body are separated from F. cf. florini using the criterion of size following Smith and Butterworth 1967. An arbitrary size limit of 50 micrometres is used to differentiate F. millotti Butterworth and Williams 1954 (size range, saccus max. length 32(37)48 micrometres) from F. cf. florini (size range, saccus max. length 50(66)79 micrometres), whilst F. pumicosus (Ibrahim) Schopf,Wilson and Bentall 1944 is larger (size range, saccus max. length 77(93)117 micrometres). Sizes from Smith and Butterworth (1967). Wilsonites cf. delicatus Kosanke 1950 is slightly larger and consistently possesses an indistinct body with a trilete mark.

Occurrence. Present to occasional rarely in Leaf 1, present to frequent rarely in Leaf 2, present to infrequent rarely in Leaf 3, infrequent to frequent rarely in Leaf 4. Very common to abundant below the Thick Coal, present to frequent between Leaves 1 and 2, present between Leaves 2 and 3, occasional between Leaves 3 and 4, frequent above the Thick Coal.

Florinites mediapudens (Loose) Schopf, wilson and Bentall 1944

Plate 18, figs.21-24.

Remarks. When folding of the body is less intense a vestigial trilete mark may be observed often with one ray longer than the others (Plate 18, fig.23), or an apparent monolete suture. The body is randomly folded and thicker than the saccus.

Comparison. F. similis Kosanke 1950 is larger (saccus max. length 112-161 micrometres Smith and Butterworth 1967, 88(111)137 micrometres Nader 1983) and has a thicker body than F. mediapudens (saccus max.length 50(58)72 micrometres Smith and Butterworth 1967) and F. triletus Kosanke 1950 has a thicker body with a distinct trilete mark. It is possible that certain specimens may possess some of the characteristics of the genus Potonieisporites viz. elliptical shape of amb, crescentic folds of the body at right angles to one another, variable germinal aperture, much thicker body than saccus; although not all of these characteristics are ever present in one specimen (Plate 18, fig.23).

Occurrence. Present to very common throughout Leaf 1, intermittently in Leaf 2, present to common throughout Leaves 3 and 4. Present to common below the Thick Coal present to occasional between Leaves 1 and 2, occasional between leaves 3 and 4 present above the Thick Coal.

Florinites millotti Butterworth and Williams 1954

Plate 18, figs.1,2.

Remarks. The muri are about 1 micrometre wide enclosing lumina generally less than 1 micrometre in diameter.

Occurrence. Present to occasional rarely in Leaves 1 and 2 present rarely in Leaf 4. Present to occasional below the Thick Coal.

Florinites pumicosus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 19, figs.3,4.

Comparison. F. visendus (Ibrahim) Schopf, Wilson and Bentall 1944 is larger (saccus max. length 122(151)186 micrometres) than F. pumicosus (saccus max. length 77(93)117 micrometres). Sizes from Smith and Butterworth (1967).

Occurrence. Occasional rarely in Leaf 1, present to infrequent rarely in Leaf 2. Occasional to frequent below the Thick Coal, infrequent between Leaves 3 and 4, present above the Thick Coal.

Florinites similis Kosanke 1950

Plate 19, figs.5,6.

Remarks. Peppers (1970) after remacerating the sample from which the holotype was taken found specimens with the same characteristics as the holotype, but with a clear trilete mark. Several of the specimens observed in this study exhibit this feature, often with one laesura longer or shorter than the others (Plate 19, fig.6). The body is laevigate to finely granulate. Compression folds affecting body and saccus are common.

Comparison. Smith and Butterworth (1967) believe examination of specimens from the type locality may show that F. similis is synonymous with F. volans (Loose) Potonie and Kremp 1956. According to Peppers (1970) Guthoerlisporites magnificus Bharadwaj 1954 is morphologically similar to F. similis.

Occurrence. Present rarely in Leaf 1, present to occasional rarely in Leaf 2, present rarely in Leaf 3, present to infrequent rarely in Leaf 4. Occasional to frequent below the Thick Coal.

Florinites triletus Kosanke 1950

Plate 19, figs.7-9.

Holotype. Kosanke 1950, pl.12, fig.3, maceration 574, slide 3.

Type Locality. Shoal Creek coal bed McLeansboro Group, Bond County, Illinois, USA, Pennsylvanian.

Diagnosis. (Kosanke 1950 p.50).

Size in micrometres. (i) Holotype saccus 52.9 x 65.1, 49-69, body 33.6 x 27.3, 25-36 Schulze and 10% KOH (Kosanke 1950) (ii) Saccus max. 56(64.5)77, min. 35(54.8)72; body max. 24(35.6)51, min. 24(31)41.5 fum. HNO_3 (Nader 1983) Northumberland, England; Westphalian A-B (iii) Saccus max. 44.8(49.6)54.4, min. 35.2(38.4)41.6; body max. 25.6(28)32, min. 24(27.7)30.4 (5 specimens) fum. HNO_3, various leaves, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval to circular margin smooth or minutely indented. Body sharply defined, slightly oval to circular, forming 55-65% of the saccus along the major axis of the saccus. Body much thicker (1-2 micrometres) than the saccus, rarely folded, finely granulate. Laesurae distinct on the proximal surface of the body, sometimes varying in length on individual specimens from 2.5-6.4 micrometres long. Saccus laevigate externally, but with infrareticulate sculpture, sometimes with slightly darker margin. Muri slightly less than 1 micrometre wide, enclosing lumina which increase in size towards the equator to a maximum of 2.5 micrometres in diameter. Distal furrow rarely visible.

Comparison. F. triletus is distinguished from other species of Florinites seen in this study by the clearly visible trilete mark and thick body. F. similis is larger, has a variably developed trilete mark and is often more folded. F. cf. volans Ravn 1979 appears similar to F. triletus but is larger.

Occurrence. Present to infrequent rarely in Leaf 1, present rarely in Leaf 2, present to occasional rarely in Leaf 4. Present below the Thick Coal.

Florinites visendus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 19, figs.10-12.

Occurrence. Present rarely in Leaf 2. Not observed in siliciclastic subsections.

Infraturma TRIRADITES (Pant) Bharadwaj 1955

Genus WILSONITES Kosanke 1959

Wilsonites delicatus Kosanke 1950

Wilsonites cf. delicatus Kosanke 1950

Plate 20, figs.1-3.

1967 Wilsonites cf. delicatus Kosanke in Smith and Butterworth, p.308, pl.24, figs. 41, 42.

Remarks. Specimens with a saccus as small as 56 micrometres have been observed in this study which is smaller than the size range 68(90)12.4 quoted by Smith and Butterworth (1967). The laesurae vary in length from 2/3 to almost the entire body radius.

Occurrence. Present to infrequent rarely in Leaf 2, present rarely in Leaves 3 and 4. Occasional to common below the Thick Coal.

Infratuma VESICULOMONORADITI (Pant) Bharadwaj 1956

Genus POTONIEISPORITES Bharadwaj 1954

Type species. P. novicus Bharadwaj 1954

Diagnosis. (Bharadwaj 1954, p.520)

Comparison. Differs from species of Florinites in possessing a consistently oval or elliptical outline, characteristic crescentic folding of the body, and in usually possessing a monolete suture.

Potonieisporites elegans (Wilson and Kosanke) Habib 1966

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

1964 Potonieisporites elegans (Wilson and Kosanke) Wilson and Venkatachala, p.67 and 68, figs.1, 2.

1966 Potonieisporites elegans (Wilson and Kosanke) Habib, p.648, 649, pl.108, fig.3.

Holotype. Wilson and Kosanke, fig.3, 1944.

Type Locality. Angus Coal Mine, Iowa, Des Moines Series.

Diagnosis. (See diagnosis in Habib 1966, p.648, emended from Wilson and Kosanke 1944, p.330).

Size in micrometres. (i) 135-215, central body 85-110,Schulze and 8% KOH (Habib 1966) (ii) 100 x 137 to 145 x 200, body 70 x 72 to 102 x 108, Schulze and KOH (Felix and Burbridge 1967) (iii) 95(118)144, body 55(70)82, fum. HNO_3 (Nader 1983).

Potonieisporites cf. elegans

Plate 20, figs.4,5.

Size in micrometres. Saccus max. 67(87)99, min. 59(63)69, body max. 41(50)66, min.22(32)43 (5 specimens) fum. HNO_3, Leaves 1 and 2, Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Monosaccate, monolete to trilete, amb elliptical to oval in outline, margin smooth, central body sharply defined circular to oval in shape. The maximum length of the central body is usually along the same axis as the maximum length of the saccus and occupies about 2/3 its length. It is characterised by a pair of crescentic folds parallel or at right angles to the length of the body and other crescentic folds more or less at right angles to the first folds. Itmay be laevigate to punctate. The suture is typically monolete extending between 1/3 to 2/3 across the body, sometimes with a medial deflection halfway along its length. At this point commonly a short vestigial third ray may be present making the suture trilete. Saccus extends about 1/4 the diameter onto the central body on the proximal surface, and is externally laevigate and internally irregularly reticulate with lamina between 1.5-3 micrometres in size.

Comparison. Differs from P. elegans (Wilson and Kosanke) Habib 1966 in being smaller in size. Potonieisporites sp. A Nader 1983 is smaller in size (saccus 45(66)87 micrometres).

Occurrence. Present rarely in Leaves 2 and 3. Absent in siliciclastic subsections.

Genus COSTATASCYCLUS (Felix and Burbridge) Urban 1971

Type species. C. crenatus Felix and Burbridge 1967.

Diagnosis. (Urban 1971, p.114, emended from Felix and Burbridge 1967, p.411).

Comparison. Differs from species of Florinites and Potonieisporites in possessing a very thick body on the distal surface of which are radiating ribs and in the mode of compression which may cause the spores to appear bisaccate.

Costatascyclus crenatus (Felix and Burbridge) Urban 1971

Plate 20, figs.6-8.

1967 Costatascyclus crenatus, Felix and Burbridge, p.411, pl.64, fig.6.

1971 Costatascyclus crenatus (Felix and Burbridge) Urban, p.114-115, pl.25, figs.4-9.

Holotype. Felix and Burbridge 1967, pl.64, figs. 5, 6, slide 03V16-11(5).

Type Locality. Springer Formation, Southern Oklahoma, USA Mississipian/Pennsylvanian.

Diagnosis. (See diagnosis in Urban 1971, p.114-115 emended from Felix and Burbridge 1967, p.411).

Size in micrometres. (i) Saccus 77 x 125 to 110 x 165, body 54 x 72 to 60 x 84 (ii) Saccus max. length 141(130)128, min. length 111(89)80, body max. length 61(56)51, min. length 48(45)44 (3 specimens) fum. HNO_3, Leaf 2, Thick Coal, Warwickshire, England; Westphalian B.

Description. Monosaccate, monolete, amb oval with an indentation on one side, margin smooth, central body sharply defined oval to circular in shape. The body occupies about 2/5 the length of the saccus, with its long axis parallel to the major axis of the saccus, about 3 micrometres thick. It usually has one fold and is apparently laevigate. The suture is about 1/4 the length of the body, orientated parallel to the major axis, and has a medial deflection halfway along its length. The saccus is closely attached to the proximal surface of the central body, but folded into four or five major areas and further folded to give a verrucate appearance (referred to as botryoidal by Urbabn 1971). It is attached to the central portion of the body on the distal surface. From the point of attachment extending for 1/4 the radius of the body are between 20 to 30 radiating ribs formed by the folding of the saccus as it expands outwards. The saccus is externally laevigate and infrareticulate and possesses several long radial folds.

Remarks. The indentation in the amb gives the spore a bisaccate appearance.

Comparison. *Florinites similis* Kosanke 1950 occasionally has a trilete mark and lacks the radiating ribs.

Occurrence. Present rarely in Leaf 2. Absent in high silicate subsections.

Subturma DISSACITES Cookson 1947

Genus PITYOSPORITES (Seward) Maneum 1960

Pityosporites kittanningensis Habib 1966

1966 Pityosporites kittanningensis Habib, p.650, pl.108, figs.11, 12.

Holotype. Habib 1966, pl.108, fig.11,slide LKC-12 (51-52)1, 26.8 x 116.0.

Type Locality. Lower Kittanning seam, Western Pennsylvania, USA; Allegheny Series, Lower Westphalian D.

Diagnosis. (Habib 1966, p.650).

Size in micrometres. (i) Holotype 70 x 47, 60-78, central body 36-58 Schulze and 8% KOH (Habib 1966).

Pityosporites cf. kittanningensis

Plate 21, figs.1,2.

Size of micrometres. Maximum length of grain 109, 128; depth of grain 73, 84, depth of sacci 73, 82, width of body 32-38 (2 specimens) fum. HNO_3, Leaf 2 Thick Coal, Longmeadow Wood borehole, Warwickshire, England, Westphalian B.

Description. Alete bisaccate grain; central body almost circular, sacci elliptical in lateral view. Central body indistinct about 1 micrometre thick, punctate. Two sacci are attached distally to the body in the polar area and proximally to the body near the equator, each inclined between 35-55 degrees from the proximal-distal axis. They are of similar size and externally laevigate and internally infrareticulate. There appear to be both primary muri about 1 micrometre wide enclosing lumina up to 6 micrometres in diameter, and secondary muri less than 1 micrometre wide enclosing lumina about 1 micrometre in diameter. A poorly defined furrow is present distally between the two sacci.

Comparison. Both P. westphalensis Williams 1955 (length of grain 38.7(47)50.8 micrometres) and P. kittanningensis Habib 1966 (60-78) micrometres) are smaller than P. cf. kittanningensis. The size range of P. zapfei Potonie and Klaus 1954 (70-120 micrometres) is comparable with P. cf. kittanningensis, but in the idealised drawings (figs. 9,10) and photographs (pld.10, figs.9,10) the central body is much larger than the sacci.

Occurrence. Present rarely in Leaf 2.

Pityosporites westphalensis Williams 1955

Plate 21, figs.3-5.

Remarks. Muri are slightly less than 1 micrometre thick and enclose lumina 1-2 micrometres in diameter.

Occurrence. Present to frequent intermittently in Leaf 1, present to common rarely in Leaf 2, present intermittently in Leaf 3, present rarely in Leaf 4. Infrequent to occasional below the Thick Coal, frequent between Leaves 1 and 2.

Turma PLICATES (PLICATA Naumova 1937, 1939) Potonie 1960

Subturma PRAECOLPATES Potonie and Kremp 1954

Genus SCHOPFIPOLLENITES Potonie and Kremp 1954

Schopfipollenites ellipsoides var. corporeus Neves 1961

Plate 21, figs.6,7.

occurrence. Infrequent rarely in Leaf 1, present rarely in Leaf 2. Occasional below the Thick Coal.

INCERTAE SEDIS

Spore Type A

Plate 21, figs.8-16.

Size in micrometres. 20.8(24.6)30.4 HF and fum. HNO_3, seatearth immediately below the Thick Coal, Longmeadow Wood borehole, Warwickshire, England; Westphalian B.

Description. Amb oval, often circular, rarely polygonal, margin barely modified by the ornament. Trilete, laesurae straight, simple, usually open, often indistinct or torn, extending between 1/3-2/3 spore radius, sometimes of unequal length. Ornament of costae about 0.3 micrometres wide and high, separated by about 1 micrometre, rarely branching, appear generally sub-parallel to the margin. Costae vary in clarity between specimens and are often reduced proximally. Exine between 1-1.5 micrometres thick.

Comparison. The ornament appears similar to the genus Vestispora although no central body is visible.

Occurrence. Present rarely below the Thick Coal.

6.3 DISTRIBUTION OF MIOSPORES IN THE THICK COAL AT LONGMEADOW WOOD BOREHOLE

The Thick Coal at Longmeadow Wood borehole comprises four leaves of coal separated by siliciclastic interleaf partings (Fig.5.45). Division of the Thick Coal at this location into 116 subsections (samples) was by recognition of lithofacies (see principally section 5.3.10). All the subsections (5) making up the interleaf partings (3) and the siliciclastic subsections above the Thick Coal (1) and some of those below the Thick Coal (4) were counted for their miospore content. Of the 104 coal subsections making up the four leaves 83 subsections were counted for their miospore content, in such a way that in only two cases were uncounted subsections next to each other (Appendix 'C'). It was hoped that the choice of subsections would adequately cover different lithofacies, chemical analyses, and miospore assemblages.

The basic data files were compiled using the method shown in section 6.1.7.1. for all of the subsections counted at Longmeadow Wood Borehole and the miospore count table was constructed (Appendix 'C'). For purposes of comparison with other authors the miospore species relative percentage distribution table was produced (Appendix 'D').

6.3.1 Analysis of the miospore species relative percentage distribution table (Appendix 'D')

Because percentage distribution of miospore species is the basis for the analysis of miospore data used by many palynologists, most of the work in this study is carried out using data from Appendix 'D'.

A vast amount of data is contained in Appendix 'D'. In order to identify the most potentially useful miospore species (species) a statistical analysis concerning their prevalence and abundance in

TABLE 6.2 The 57 most prevalent species within coal subsections

		Number of coal subsections in which the species occurs
1	Lycospora pusilla	82
1	Laevigatosporites minor	82
3	Lycospora pellucida	80
4	Laevigatosporites cf. dunkardensis	79
4	Fabasporites cf. exilis	79
6	Crassispora kosankei	72
6	Florinites mediapudens	72
8	Anapiculatisporites minor	71
9	Granulatisporites microgranifer	66
9	Lycospora rotunda	66
11	Lycospora orbicula	63
12	Calamospora cf. breviradiata	60
13	Punctatosporites minutus	57
14	Densosporites sphaerotriangularis	56
15	Apiculatisporis irregularis	55
16	Cifratriradiates saturni	54
11	Lophotriletes cf. microsaetosus	54
17	Fabasporites parvus	53
18	Lophotriletes commisuralis	52
19	Dictyotriletes bireticulatus	51
20	Calamospora para	50
20	Densosporites anulatus	50
20	Apiculatasporites spinulistratus	48
23	Verrucosisporites microtuberosus	48
24	Leiotriletes guennelii	47
25	Acanthotriletes echinatus	46
26	Densosporites cf. triangularis	45
27	Granulatisporites minutus	42
27	Endosporites zonalis	43
29	Apiculatisporis spinosaetosus	41
30	Lophotriletes granoornatus	40
31	Raistrickia cf. lowellensis	39
32	Lycospora rugosa	38
34	Densosporites gracilis	33
34	Apiculatisporis aculeatus	32
35	Leiotriletes cf. priddyi	30
36	Anapiculatisporites baccatus	30
36	Calamospora straminea	30
39	Microreticulatus harrisonii	29
40	Calamospora cf. pedata	28
41	Calamospora pallida	27
41	Punctatisporites punctatus	27
43	Acanthotriletes triquetrus	26
43	Camptotriletes bucculentus	26
43	Cingulizonates loricatus	26
43	Endosporites globiformis	26
47	Calamospora breviradiata	25
48	Calamospora nebulosa	24
48	Cristatisporites indignabundus	24
48	Pityosporites westphalensis	24
51	Granulatisporites adnatoides	22
51	Radiizonates tenuis	22
51	Vestispora pseudoreticulata	22
54	Cyclogranisporites cf. pressoides	21
55	Apiculatisporis abditus	21
56	Laevigatosporites vulgaris	20
56	Florinites cf.florini	20

TABLE 6.3 The 46 most prevalent species within siliciclastic subsections

Rank	Species	Number of siliciclastic subsections in which the species occurs
1	Lycospora pusilla	10
1	Lycospora pellucida	10
1	Calamospora parva	10
4	Leictrdetes cf. priddyi	9
4	Laevigatosporites cf. dunkardensis	9
4	Laevigatosporites minor	9
4	Fabasporites cf. exilis	9
8	Florinites cf. florini	8
8	Florinites mediapudens	8
8	Densosporites sphaerotriangularis	8
8	Densosporites anulatus	8
8	Densosporites triangularis	8
8	Dictyotriletes bireticulatus	8
8	Acanthotriletes echinatus	8
8	Verrucosisporites microtuberosus	8
8	Granulatisporites microgranifer	8
8	Punctatisporites punctatus	8
18	Apiculatisporites spinosaetosus	7
18	Densosporites gracilis	7
18	Lycospora orbicula	7
18	Cirratriradiates saturni	7
18	Cingulizonates loricatus	7
18	Radiizonates cf. striatus	7
24	Leiotriletes guennelii	6
24	Calamospora pallida	6
24	Cyclogranisporites cf. minutus	6
24	Lophotriletes commisuralis	6
24	Lophotriletes granoornatus	6
24	Lophotriletes cf. microsaetosus	6
24	Apiculatisporis irregularis	6
24	Raistrickia cf. lowellensis	6
24	Camptotriletes bucculentus	6
24	Reticulatisporites reticulatus	6
24	Savitrisporites nux	6
24	Crassispora kosankei	6
24	Lycospora rotunda	6
24	Punctatosporites minutus	6
24	Fabaporites parvus	6
39	Granulatisporites adnatoides	5
39	Granulatisporites minutus	5
39	Verrucosisporites sp. A.	5
39	Anapiculatisporites minor	5
39	Apiculatisporis aculeatus	5
39	Apiculatisporis cf. latigranifer	5
39	Apiculatasporis spinulistratus	5
39	Florinites pumicosus	5

TABLE 6.4 Coal Subsections: 51 species listed in descending order of frequency of occurrence within the abundance categories. (All species occurring at greater than the frequent category of abundance are listed)

Numerical Order	Species	Maximum Abundance	Very Abundant (9) 31.0	Abundant (11) 29.9	Very Common (16) 9.99	Common (15) 4.99	Frequent (22) 1.99
1	Lycospora pusilla	69.8	23	21	13	13	7
2	Fabasporites cf. exilis	44.6	8	22	10	12	11
3	Densosporites cf. anulatus	46.3	7	4	5	6	4
4	Densosporites sp. sphaerotriangularis	51.1	5	11	4	4	2
5	Densosporites gracilis	51.0	4	4	2	5	6
6	Lycospora rotunda	49.4	3	16	6	11	7
7	Laevigatosporites minor	36.8	1	24	28	22	3
8	Densosporites cf. triangularis	35.7	1	12	1	6	1
9	Apiculatisporis irregularis	44.5	1	1	2	6	12
10	Punctatosporites minutus	24.4		9	6	14	11
11	Lycospora orbicula	24.2		7	13	20	7
12	Crassispora kosankei	16.0		3	9	18	14
13	Cingulizonates loricatus	12.3		3	1	4	2
14	Retispora staplinii	18.9		2	3	0	0
15	Laevigatosporites cf. dunkardensis	11.3		1	3	19	18
16	Radiizonates tenuis	17.0		1	3	2	4
17	Cristatisporites connexus	14.8		1	2	3	0
18	Leiotriletes guennelii	18.7		1	1	11	13
19	Dictyotriletes bireticulatus	28.6		1	1	7	4
20	Granulatisporites adnatoides	10.7		1	1	2	4
21	Densosporites cf. granulosus	27.4		1	0	2	1
22	Lycospora pellucida	8.02			6	14	21
23	Calamaspora cf. breviradiata	7.49			5	13	18
24	Florinites mediapudens	7.92			4	20	15
25	Lophotriletes cf.microsaetosus	7.82			3	5	12
26	Acanthotriletes echinatus	7.33			3	4	8
27	Granulatisporites microgranifer	5.96			2	11	18
28	Calamospora parva	5.86			2	9	15
29	Fabasporites parvus	6.48			1	16	8
30	Anapiculatisporites minor	8.26			1	10	24
31	Densosporites cf. duriti	6.09			1	4	2
32	Cyclogranisporites cf. pressoides	8.47			1	3	5
33	Radiizonates cf. striatus	5.35			1	3	2
34	Lophotriletes commisuralis	6.28			1	2	10
35	Anapiculatisporites baccatus	6.96			1	2	7
36	Endosporites zonalis	4.23				10	13
37	Cristatisporites indignabundus	3.74				5	2
38	Acanthotriletes triquetrus	3.90				3	4
39	Leiotriletes cf. priddyi	3.33				3	2
40	Endosporites globiformis	2.61				3	4
41	Granulatisporites minutus	2.48				2	9
42	Cirratriradiates saturni	2.84				2	7
43	Pityosporites westphalensis	4.74				2	4
44	Verrucosisporites microtuberosus	4.96				2	3
45	Calamospora pallida	3.04				1	5
46	Apiculatisporis aculeatus	2.84				1	5
47	Apiculatisporis spinosaetosus	4.96				1	3
48	Lophotriletes granoornatus	2.01				1	3
49	Vestispora costata	3.91				1	0
50	Triquitrites protensus	2.12				1	0
51	Triquitrites tribullatus	2.39				1	0

Table 6.5 Siliciclastic subsections: 37 species listed in descending order of frequency of occurrence within the abundance categories (All species occurring at greater than the frequent category of abundance are listed)

	Maximum Abundance	Very Abundant	Abundant	Very Common	Common	Frequent
1. Lycospora pusilla	35.4	1	3	1	5	0
2. Laevigatosporites minor	14.7		3	2	2	2
3. Laevigatosporites cf. dunkardensis	15.1		2	3	2	1
4. Fabaporites cf. exilis	18.6		2	1	2	2
5. Lycospora pellucida	16.4		1	4	4	0
6. Densosporites cf. triangularis	11.4		1	2	2	1
7. Densosporites cf. anulatus	15.4		1	1	1	3
8. Leiotriletes cf. priddyi	14.1		1	1	0	3
9. Florinites cf. florini	12.7		1	1	0	2
10. Crassispora kosankei	14.9		1	0	1	3
11. Densosporites spaerotriangularis	7.39			2	4	1
12. Granulatisporites microgranifer	5.77			2	3	1
13. Radiizonates cf. striatus	7.39			2	2	1
14. Punctatisporites punctatus	4.35			1	3	0
15. Cingulizonates loricatus	5.20			1	2	0
16. Savitrisporites nux	6.15			1	0	0
17. Acanthotriletes echinatus	9.06			1	0	0
18. Calamospora parva	3.42				7	2
19. Lycospora rotunda	4.33				3	0
20. Densosporites gracilis	4.72				2	2
21. Florinites mediapudens	3.08				2	0
22. Endosporites zonalis	3.21				2	0
23. Granulatisporites granulatus	3.36				2	0
24. Verrucosisporites microtuberosus	2.17				1	4
25. Calamospora pallida	3.42				1	3
26. Lycospora orbicula	2.23				1	2
27. Punctatosporites minutus	3.11				1	1
27. Raistrickia cf. lowellensis	4.04			1	1	
27. Cyclogranisporites cf. minutus	2.15			1	1	
30. Apiculatisporis irregularis	4.84			1	1	
31. Endosporites globiformis	2.00			1	1	
32. Verrucosisporites sifati	2.48			1	1	
33. Camptotriletes bucculentus	2.17			1	0	
34. Punctatisporites obesus	2.46			1	0	
35. Raistrickia pilosa	2.17			1	0	
36. Calamspora microrugosa	2.17			1	0	
37. Wilsonites cf. delicatus	2.17			1	0	

subsections was carried out. Because of possible fundamental differences between coal and siliciclastic subsections the analysis for each was kept separate.

The most prevalent species in coal subsections are listed in Table 6.2 whilst those prevalent species in siliciclastic subsections are listed in Table 6.2. Several species occur near the top of both tables e.g. Lycospora pusilla and L. pellucida, and several species occurring high in one table appear lower down or not at all in the other table e.g. Florinites cf. florini, Leiotriletes cf. priddyi.

Abundance has been divided into eight categories (section 6.2) based on Smith and Butterworth (1967) and the distribution of the five most abundant categories is plotted for coal subsections (Table 6.4) and siliciclastic subsections (Table 6.5), together with the maximum abundance for each species. If the first 38 species in Tables 6.4 and 6.5 are compared it can be seen that both tables have Lycospora pusilla at their head as was the case for the prevalence tables. Similarly Fabasporites cf. exilis occurs the the top of both tables as it did with the prevalence tables. However, Table 6.3 shows several species of Densosporites near the top whereas Laevigatosporites minor and L. cf. dunkardensis take their place in Table 6.5 indicating a greater importance of Densosporites in the coal subsections. Both abundance tables have some species of Densosporites at higher positions than the prevalence tables suggesting maxima which are vertically more restricted. Several species occur in one table but not another.

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6.3.2 Division of the leaves of the Thick Coal using palynological data.

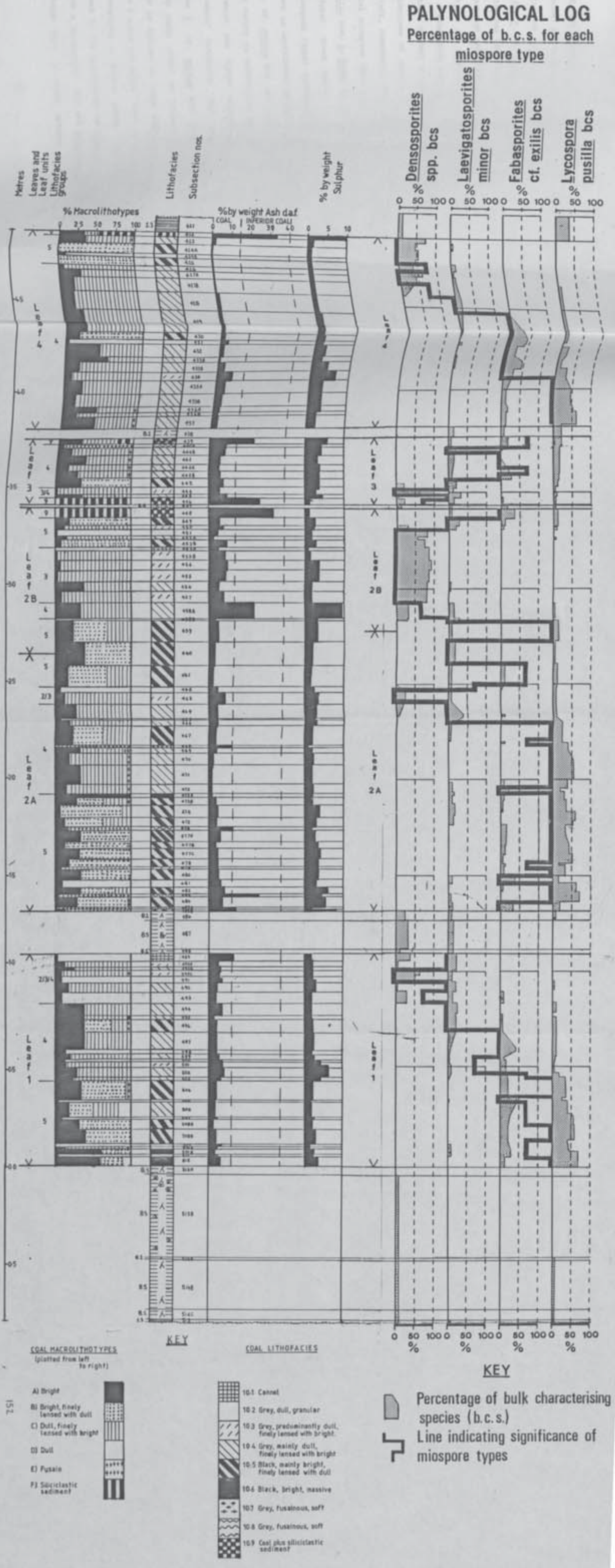
It is believed that if coal subsections can be defined using palynological data the Thick Coal can be divided into a number of beds so that a palaeoecological interpretation can be made. This type of analysis was attempted by Smith (1957) who studied five Westphalian B seams in the Yorkshire Coalfield in the centre of the Pennine Basin. He concluded that three phases could be recognised corresponding to high numbers of two species of the genus *Lycospora*, and one species from each of the genera *Laevigatosporites* and *Densosporites*, and that these phases occurred sequentially. Other authors have carried out similar analyses in France (Corsin *et al.* 1967), Canada (Hacquebard & Donaldson 1969) and Russia (Koval'chuk and Uziyuk 1973) but only recorded miospore genera. Use of miospore genera is likely to make the palaeoecological interpretation more difficult as it increases the possibility of grouping miospore species whose parent plants may have existed in different habitats. An advance was made by Smith (1962) working in the Yorkshire Coalfield, in the recognition of four phases, each characterised by an association of miospore species, although often one species was dominant. A similar analysis using miospore assemblages was carried out in the USA by Habib (1966).

The use of miospore associations is the best means of defining coal subsections by palynological methods, because it helps to ensure that the assemblage is autochthonous. However, it was decided to determine whether definition could be achieved using only a few miospore species. Twenty one species occur abundantly (*sensu* Smith & Butterworth 1967) ie. greater than 10% in the leaves of Thick Coal

(Table 6.4). Seven of these species are prevalent enough (Table 6.2) to define all the coal subsections viz. Densosporites cf. anulatus (Loose) Smith & Butterworth 1967; D. gracilis Smith & Butterworth 1967; D. sphaerotriangularis Kosanke 1950; D. cf. triangularis Kosanke 1950; Lycospora pusilla (Ibrahim) Schopf, Wilson & Bentall 1944; Laevigatosporites minor Loose 1934; and Fabasporites cf. exilis Clendening 1967. Because they make up the bulk of the miospore population they are called bulk characterising species (bcs). These seven species can be arranged to give four miospore types. Three types are formed from individual bcs viz. L. pusilla bcs, F. cf. exilis bcs and L. minor bcs. When the distribution of the four species of Densosporites were examined it was found that they often occurred together. For this reason they are grouped to give the fourth miospore type Densosporites spp. bcs.

Using the data from Appendix 'D' relative percentages of the four miospore types were plotted against subsections in which they occurred (Fig 6.10). Where subsections have not been counted, values have been interpolated from adjacent counted subsections. From Fig.6.10 it can be seen that each coal subsection and many siliciclastic subsections have at least one of the miospore types exceeding 10%. It was therefore necessary to devise a test of significance which can be applied to each subsection to determine which miospore type defines it. Because it is likely that different plants produced different numbers of miospores, and that their dispersal pattern and rate of destruction before and after incorporation within the coal was also different, it is probable that the significance of each miospore type is governed by a different relative percentage. This relative percentage is calculated by averaging those subsections containing in

Fig.6.10 Distribution of the percentage of bulk characterising species for each miospore type in the leaves of the Thick Coal at Longmeadow Wood borehole



excess of 10% (lower values are excluded because some may be allochthonous) for each miospore type, and using this value as a test of significance viz. 47% *Densosporites* spp. bcs; 18% for *L.minor* bcs; 22% for *F.* cf. *exilis* bcs, and 32% for *L. pusilla* bcs. In Fig. a thick line has been drawn beside each miospore type which is higher than the average calue and therefore considered significant.Where two miospore types are significant the line has been drawn between them, and where a subsection contains no significant miospore type the line has been drawn nearest or between the most significant miospore type.

Examinations of Leaves 1 and 4 (Fig.6.10) reveals a trend from right to left, commencing with subsections defined by *L. pusilla* bcs (the initial miospore type) and passing upward into those defined by *F.* cf. *exilis* bcs, *L. minor* bcs and *Densosporites* spp. bcs (the climax miospore type). These leaves display what can be described as a 'normal miospore (type) succession'; although firstly at the base of Leaf 1 there is oscillation between subsections defined by *L. pusilla* bcs and *F.* cf. *exilis* bcs, and secondly at the top of the same leaf there is a return to subsections defined by *L. minor* bcs. Leaves of coal in which the climax miospore type is present are termed 'long-residence' histosols. This normal succession compares well (apart from *F.* cf. *exilis* bcs) with the sequential relationship obtained by Smith (1957) of Lycospore to Transition to Densospore phases, and is similar to those observed by Corsin *et al.* (1967) in Westphalian C coals and Habib (1966) in Westphalian D age coals. Smith (1962) recognised a fourth phase, termed Incursion, which was characterised by the association of *Crassispora kosankei* (Potonie & Kremp) Smith & Butterworth 1967 and *Punctatosporites minutus* Ibrahim 1933. Although both of these species occur abundantly in many subsections within the leaves of the Thick Coal (Appendix 'D') no association between them has been observed by the author. It is possible that the 'indeterminate thin exines' in the Lycospore phase (Smith 1962) may correspond to the species F. cf. exilis, although this species may not have existed in such abundance in the seams investigated by Smith (1962), or filtration may have caused its removal from the samples.

In Leaf 2 there appear to be two 'miospore (type) cycles', the first existing between the base of the leaf and subsection 459, and the second from subsection 459 to the top of the leaf. A cycle is formed when the sequence in a normal miospore succession is mirrored in coal subsections lying directly above it, in the order a, b, c, d, c, b, a. The first cycle commences at the base of the leaf with subsections defined by alternations of F. cf. exilis bcs and L. pusilla bcs, followed in the normal miospore succession by subsections defined by L. minor bcs and Densosporites spp., bcs to subsection 463. In the subsections immediately above this there are oscillations between various miospore types culminating in L. pusilla bcs in subsection 459. From this subsection a second cycle is initiated passing up through L. minor bcs to subsections dominated by Densosporites spp. bcs towards the top of the leaf. Above this to the top of the leaf a return through L. minor bcs to F. cf. exilis bcs is visible. This cyclic sequence is similar (apart from the recognition of F. cf. exilis bcs) to that observed by Smith (1962) within two Westphalian B seams from the Yorkshire Coalfield ie. The Swallow Wood and Hazel seams.

The division of Leaf 2 into two parts in the middle of subsection 459 compares favourably with the division of this leaf made by sedimentological means (section 5.4.7.3). In the latter case the line of separation was placed in subsection 460 on the basis of the percentages of the coal macrolithotypes 'Bright' and 'Bright finely lensed with dull'.

Leaf 3 is unusual in that it commences with subsections defined by Densosporites spp. bcs and L. minor bcs but returns through an oscillating sequence to subsections defined by F. cf. exilis bcs and L. pusilla bcs at the top of the leaf.

The siliciclastic palaeosols between the leaves contain moderate percentages of the miospore types which occur in the coal subsections immediately below or above. Between Leaves 1 and 2 where the siliciclastic palaeosol is divided into 3 subsections a sequence is observable which reflects the bcs in both the under- and overlying leaves. Above Leaf 1 there is no relationship between the bcs in the underlying coal subsections and the overlying siliciclastic subsection. Subsections below Leaf 1 contain only low percentages of the bcs. It is unfortunate that the subsection immediately below the Thick Coal does not contain miospores.

6.4 PALAEOECOLOGICAL AND SEDIMENTOLOGICAL INTERPRETATION OF THE THICK COAL

Many of the palaeoecological interpretations of Westphalian coal seams were carried out during the 1960s (Butterworth 1964, 1966; Habib 1966; Habib & Groth 1967; Hacquebard & Donaldson 1969; Smith 1962, 1968). Since that time our understanding of the palaeoecology of modern histosols (Anderson & Muller 1975, Cohen & Spackman 1972, Haseldonckx 1977) and the environments in which they develop (Barber 1981; Cohen 1974, 1983; Coleman et al. 1970; McCabe 1984; and Moore & Bellamy 1974) has been considerably extended. With this documentation as a database it is now possible to attempt a more complete palaeoecological analysis of the miospore successions seen in the leaves of the Thick Coal, and to understand the determinants of the spatial and temporal distribution of those coal leaves.

6.4.1 Factors likely to affect miospore successions

The factors believed to influence the creation of miospore successions observed in the four leaves of the Thick Coal at Longmeadow Wood borehole can be divided into climatic and edaphic factors, which are discussed with reference to sedimentation in the Pennine Basin, and particularly the formation of the Thick Coal.

6.4.1.1 Climatic factors

Climatic control was proposed by Smith (1962) and endorsed by Chaloner & Muir (1968) to account for part of the sequence of palynological changes detected in Westphalian coal seams. Smith (1962) attributed the shift from his Transition to Densospore phase to an increase in both precipitation and atmospheric humidity. However, if histosol accumulation was more or less continuous at different localities throughout the Pennine Basin (Elliott 1985) and these exhibit similar miospore successions (Smith 1957, 1962; this work) it would be impossible for a change of climate to be the only factor controlling these successions within a leaf.

Climatic change is also believed to have occurred slowly during the Westphalian (Phillips and Peppers 1984), and not with the frequency necessary to allow the full development of sequences in a number of seams (Smith 1964) formed over relatively short intervals of geological time. Smith (1962) also suggested that the absence of Densospore phase in Westphalian Cage coals in Britain, in contrast to its occurrence in seams of Westphalian A and B age, might be due to inadequate precipitation during this Stage of the Westphalian. This interpretation was supported by Butterworth (1966) who studied the worldwide distribution of densospores. Unfortunately, the evidence presented by Phillips and Peppers (1984) for a drier climate over the North American - North European continental plate during the Westphalian B and C when compared with the Westphalian A and D does not fit the interpretations of Smith (1962) and Butterworth (1966).

Histosols can develop in a variety of climates providing accumulation of plant debris exceeds its degradation. Decay of plant debris proceeds more rapidly under aerobic conditions but these are prevented by waterlogging, so that one of the critical factors in preservation is that part of the hydrological cycle which existed within the histosol. This has been summarised in the form of an equation by Bellamy (1972):-

Inflow + Precipitation = Outflow + Evapo (transpiration) + Retention.

From this it may be seen that water may be supplied in two ways, either entirely by precipitation or by a combination of precipitation and groundwater. In this respect climate is partly responsible for the type of histosol which can develop, for only where precipitation is great enough to retain the water table near to the surface of a mire can an ombrophilous (Kulczynski 1949) bog evolve from a rheophilous (Kulczynski 1949) swamp. Both of these types of mire would have been able to develop in the Warwickshire Coalfield because, as shown previously, the climate envisaged for Westphalian B times was tropical - pure equatorial.

6.4.1.2 Edaphic factors

The interpretation of miospore successions within leaves of coal makes the fundamental assumption that the miospores forming them are autochthonous and represent a local population of parent plants. In both European (Tauber 1965) and tropical forests (Anderson & Muller 1975) it has been found that the majority of miospores have only travelled a few hundred metres from the plants which produced them. Changes in flora growing on Westphalian histosols are therefore likely to have taken place because the plants were limited by their ability to cope with changing edaphic conditions.

The distinction between the mode of formation of rheophilous high-ash histosols and ombrophilous low ash histosols has already been made in the lithofacies associations 'Very poorly drained siliciclastic dominated palaeosol/s' and 'Long-residence' histosols respectively. The Thick Coal is a group of 'Long-residence' histosols which are believed to have formed in ombrophilous bogs. Anderson (1983) published the results of a survey of tropical peats of Western Malasia which showed that edaphic factors subject to the greatest variation in ombrophilous bogs are water table position and the percentage of certain minerals. Variations in the water table during the dry season are minimal at the mire periphery (9-11cm) and at a maximum in the centre (up to 19cm), whilst during the wet season the water table may rise above the level of the mire surface at its periphery (Anderson 1964). Results from the central 19km of a 25km transect from the bog edge to centre, showed that phosphorous contents were reduced by over half (510 to 203 p.p.m.) whilst potassium contents were reduced by over one third (360 to 214 p.p.m). There was little variation in pH (3.3 to 3.6). It is believed that these edaphic variations are sufficient to produce the sequence of six plant communities recognised by Anderson & Muller (1975) in raised mires in NW Borneo, although the predominant control is probably that of water table variation. It should be noted that ash content along the 19km transect (Anderson 1983) varied from 3.6% by weight towards the edge to 1.2% at the centre.

Rheophilous swamps do not appear to create a sequence of numerous plant communities but instead produce an alternation of plant communities due to oscillations of wet and dry conditions. Cohen (1974) recognised two types of histosol in the Okefenokee Swamp on the basis of their macrofloral remains. Marsh plants produced histosols that were diagnostic of wet conditions, whilst trees and shrubs produced histosols diagnostic of drier conditions. A similar distribution of vegetation was observed by Spackman _et el_. (1969) in the freshwater environment of the Everglades in southern Florida, but in the coastal environment of the Everglades a separate type of vegetation recognised by Spackman _et al_. (1969) was shown to have formed under marine influence. Previously (Spackman _et al_. 1966) had shown the coastal vegetation to be transgressing onto the freshwater vegetation.

The transgression model above was used by Habib _et al_. (1966) and Habib & Groth (1967) to explain miospore successions in a Westphalian D age coal of Pennysylvania. They believed the change from a _Lycospore_ assemblage zone at the base of leaves through intermediate zones to a _Densosporites_ assemblage zone at the top could be explained by the increasing influence of salinity on the vegetation. This was because where this full succession occurred beds of brackish/marine origin rested directly on top of the coal, whereas at other localities without the _Densosporites_ assemblage zone the coal was overlain by beds of freshwater origin. The use of this model to explain similar miospore successions seen in the leaves of the Thick Coal can be rejected on the basis that these histosols were accumulating in a depositional setting distant from marine influence. An indicator of marine mudstones overlying coal is often a high level of sulphur within the coal (Williams & Keith 1963). Sulphur values for the leaves of the Thick Coal are low e.g. Figs. 5.45, 5.46 when compared with those values obtained from leaves lying below marine bands in the Warwickshire Coalfield (in excess of 9% by weight).

Smith (1962) initially believed climate to be partially responsible for the Densospore phase, but that changes in water level either as a result of isostacy, eustacy, or accumulation of peat were paramount in the formation of the other phases. Later Smith (in Smith & Butterworth 1967 p.86; and Smith 1968) postulated that a retreating waterfront would occur as peat built up from what can be interpreted as a reheophilous swamp covered by a roughly constant depth of water, to an ombrophilous bog with a water table below the peat surface. These changes in edaphic conditions were considered sufficient to account for the succession Lycospore to Transition to Densospore phases (Smith, in Smith and Butterworth 1967, and Smith 1968). An advancing waterfront caused by subsidence increasing above the rate of peat production would reverse the succession. Smith, in Smith and Butterworth (1967), and Smith (1968) believed the Incursion phase to be produced by faster flowing floodwaters carrying siliciclastic sediment in suspension across the surface of the peat.

The miospore successions illustrated by Smith (1962, 1964, in Smith and Butterworth 1967) took place in leaves of coal which are low in ash content (generally less than 10% by weight) and this is also true of the leaves of the Thick Coal (Figs.5.45, 5.46). It is believed that in active depositional settings, low-ash histosols are more likely to develop where the surface of the bog is raised above groundwater flood level, although it is possible that rheophilous swamps could also produce low-ash histosols. Staub & Cohen (1979) suggested that clay could be flocculated by acid swamp waters, dumping it at the edge of the swamp, although the ash contents of the histosols which they studied were still in excess of 12% (Renton et al. 1979). Alternatively if deposition of siliciclastic sediment was not taking place near the swamp a low-ash histosol could be produced. Also, at some stage the luxuriance of the vegetation may have aided the exclusion of siliciclastic particles from the histosol by decreasing the flow rate of water passing across its surface (Robertson 1952). The effect of diagenetic processes outlined by Cecil et al. (1979) and Renton and Cecil (1979) may also have contributed to the production of low-ash histosols.

However, if the rheophilous swamp was at first continually covered by water as proposed by Smith in Smith and Butterworth (1967), then in an active depositional setting within the Pennine Basin, it is believed that siliciclastic sediment would become incorporated in the mire to produce either a siliciclastic palaeosol or a high-ash histosol. The ash values for samples obtained by Spackman et al. (1969) in a rheophilous swamp range from 10-56%. It appears therefore that the palynological successions observed by Smith (1962, 1964, 1967) took place within ombrophilous bogs.

6.4.2 Interpretation of the Thick Coal at Longmeadow Wood borehole

The model proposed to account for miospore successions in the leaves of the Thick Coal at Longmeadow Wood borehole is illustrated by examining this sequence (including the siliciclastic sediments) from the base upwards. Prior to the formation of the Thick Coal at this locality, it is postulated that the rate of subsidence reduced from its higher rate, resulting in the near total filling of all waterlain areas by a variety of 'Channel fill' and 'Lacustrine' deposits. This led to the creation of an environment in which a rheophilous swamp developed. Sediment, input was low and discontinuous, and at times better drained resulting in the formation of the association 'Alternate poorly and imperfectly drained siliciclastic palaeosol/s'. In contrast with those miospores found within leaves of coal it is believed that many of the miospores within siliciclastic sediment were allochthonous. One of the main reasons for this is because the water moving across the sediment surface would have been quite capable of transporting miospores. A discussion of the distribution of miospores within siliciclastic sediments has been given by Marshall & Smith (1965). The low values of all miospore types in the subsections below the Thick Coal are attributed to the great distance between this and the nearest ombrophilous bog which was producing them.

When flooding from groundwaters carrying siliciclastic sediment ceased at this locality, the remaining area of shallow water was colonised by vegetation which produced L. pusilla bcs observed in subsections at the base of Leaf 1. This type of vegetation would be able to survive a partially exposed water table during the wet season (cf. Anderson 1964a) although during the dry seasons the water table probably lay just below the surface of the bog. Initially, some of those mechanisms outlined previously to prevent siliciclastic sedimentation reaching the bog surface may have operated. The vegetation which produced L. pusilla bcs may be regarded as equivalent to one of the principal species recognised in phasic community I of Anderson & Muller (1975). An increase in variation of the water table may have resulted in the growth of vegetation producing F. cf. exilis bcs and where several adjoining subsections are defined by F. cf. exilis bcs it is presumed that the continued accumulation of the histosol was responsible for the change in hydrological conditions, as in the middle of Leaf 1. However, because of the oscillations between subsections defined by L. pusilla bcs and F. cf. exilis bcs towards the base of Leaf 1, the change in these conditions may only have been small and in this case may be accounted for by a prolonged dry season.

As the surface of the bog became more raised it is postulated that the changes in hydrological conditions outlined by Anderson (1964a) took place, creating a habitat for the growth of vegetation producing L. minor bcs following that of F. cf. exilis in the upper half of Leaf 1. These two miospore types are the intermediate stages of the miospore succession observed in Leaf 1, and may be comparable to several of the phasic communities (II-V) recognised by Anderson & Muller (1975). It is believed that the creation of a flat-topped bog plain with the greatest variation in water table during the year enabled the climax vegetation to grow. This included those plants producing *Densosporites* spp. characterising the miospore type, defining subsections towards the top of Leaf 1. It is possible that this vegetation could correspond to phasic community VI (Anderson & Muller 1975) which is found extensively in the centre of inland bogs in Sarawak.

The miospore succession observed in Leaf 1 is very similar to that in Leaf 4, except that the underlying siliciclastic palaeosol contains moderate percentages of three miospore types probably derived from adjacent histosols. In both of these leaves the succession is the simplest type formed during the progressive creation of an ombrophilous bog. It is postulated that, when dealing with similar changes in vegetation, the most rapid creation of a fully raised bog (recognised in Westphalian coals of the Pennine Basin by the presence of *Densosporites* spp. bcs) will occur when the greatest differential exists between the lower rate of subsidence in the area of the bog and the higher rate outside it. Both Leaves 1 and 4 have similar thicknesses of coal defined by other miospore types (84 and 75cm respectively) before *Densosporites* spp. bcs is reached. In Leaf 2 there is an extended sequence of subsections defined by *L. pusilla* bcs and *F.* cf. *exilis* forming 116cm of coal before *Densosporites* spp. bcs is reached, implying a lower differential rate of subsidence for this leaf. However, those seams examined by Smith (1957, 1962) towards the centre of the Pennine Basin, have subsections containing abundant *Densosporites sphaerotriangularis* (one of the species characterising *Densosporites* spp. bcs) at a much earlier stage in their growth, between 46-68cm from their base. This may imply a greater differential rate of subsidence for the areas covered by these seams.

It is believed that reversal of the previously mentioned subsidence rates eventually resulted in the bog surface becoming lowered until groundwater carrying siliciclastic sediment floods across it. The most rapid increase in rate of subsidence observed in the leaves of the Thick Coal is evident in Leaf 4, where the bog was terminated whilst covered in the climax vegetation producing Densosporites spp. bcs. Overlying this leaf the siliciclastic subsection has been interpreted as 'Lacustrine suspension deposits' with the large percentage of L. pusilla bcs derived from a distant bog in the appropriate developmental state. In contrast to this the miospore succession from Densosporites spp. bcs to F. cf. exilis bcs at the top of Leaf 2 may be a response to a lower rate of subsidence. The surface of the bog could have become depressed causing water table variation to return to that suitable first for the vegetation which produced L. minor bcs and then F. cf. exilis bcs. A similar situation exists at the top of Leaf 3 where the uppermost coal subsection is defined jointly by F. cf. exilis bcs and L. pusilla bcs. At the top of Leaf 1 the rate of subsidence may have been slow at first (Densosporites spp. bcs to L. minor bcs) but then have increased more rapidly, although the overlying siliciclastic sediments contain moderate percentages of the miospore types found in the uppermost subsection of Leaf 2, testifying to the close proximity of vegetation producing these miospores.

The presence of two miospore cycles in Leaf 2 can be attributed to two episodes of reduced subsidence, separated by one of increased subsidence in this area. South of Longmeadow Wood borehole the increased rate of subsidence has resulted in a split in Leaf 2 comprising a siliciclastic palaeosol, which 3km away has increased in thickness to 0.3m (Fig.7.3).

The effect of drainage in determining the type of vegetation growing on the bog can be confirmed by an interpretation of the base of Leaf 3. At its base the unusual occurrence of a subsection defined jointly by Densosporites spp. bcs and L. minor bcs, and the presence of these miospore types in the overlying subsections, may be related to the underlying siliciclastic palaeosol. This fine grained sandstone is penetrated by in situ roots and spread over a wide area. Although it appears that a slow increase in the rate of subsidence was taking place during the accumulation of the preceeding leaf, it is postulated that this subsidence ceased prior to the deposition of the fine grained sandstone. At this time the bog surface could have been low enough to allow small channels, unconfined by steep levees, to move across it carrying a tractional bed load of fine grained sand. During high stage events sand could be transported from the channel in sheet floods forming a layer on the bog surface. When flow ceased and the surface became elevated, the sand would allow drainage into the underlying peat forming a surface suitable for the parent plants which produced both Densosporites spp. bcs and L. minor bcs.

6.5 CORRELATION OF THE LEAFES OF THE THICK COAL BY PALYNOLOGICAL MEANS

It is possible to use the information in Appendix D to determine if any miospore species (species) can be used as an aid to correlation of the leaves of the Thick Coal. Two methods of correlation were attempted in this study. Fistly by use of the presence or absence of species within leaves (Table 6.6), and secondly by use of increases and decreases in relative percentage between under and overlying leaves (Table 6.7).

6.5.1 Method of determining most useful species

If the relative percentages in Appendix 'D' for individual subsections within leaves are weighted according to the thickness of the subsection, added together and divided by the total thickness of subsections, an average relative percentage for each species within the leaf can be calculated. Where subsections within a leaf have not been counted values were interpolated from adjacent subsections. The greater the relative percentage at which a species occurs within leaves, the more likely it is to be significant if it is missing from any leaf. For this reason the 25 species listed in Table 6.6 are graded according to their average relative percentage within a leaf and those occurring below 0.05% are excluded. (Maxima within subsections are considerably greater than this). Only species with a minimum occurrence of 1% which increase by more than 3 times in adjacent leaves of the Thick Coal are included in Table 6.7. Those species which change the most between leaves are likely to be most useful.

6.5.2 Discussion of results

Welsh and Smith (1980) reported on the palynology of leaves of the Thick Coal at three locations to the east of Longmeadow Wood borehole.

Table 6.6 Miospore species present in at least one leaf but missing from one or more other leaves of the Thick Coal

	LEAF 1	LEAF 2	LEAF 3	LEAF 4
Species occurring at greater than 0.499				
Cyclogranisporites cf. pressoides	X	X	X	0
Anaplanisporites baccatus	X	X	0	X
Densosporites cf. duriti	X	0	X	X
D. cf. granulosus	X	X	X	0
Radiizonates cf. striatus	X	X	X	0
Retispora staplinii	X	0	0	0
Species occurring at greater than 0.099				
Leiotriletes cf. adnatus	0	X	X	X
Granulatisporites adnatoides	0	X	X	X
Apiculiretusispora sp.C	X	0	0	0
Verrucosisporites verrucosus	X	0	X	X
Dictyotriletes muricatus	0	0	X	X
Camptotriletes sp. A	X	X	0	X
Triquitrites protensus	X	X	X	0
Hymenospora paucirugosa	X	X	X	0
Vestispora tortuosa	X	X	X	0
Species occurring at greater than 0.049				
Leiotriletes levis	X	X	0	X
Leiotriletes sp. A	X	0	0	0
Punctatisporites obesus	X	X	X	0
Converrucosisporites armatus	X	X	X	0
Raistrickia fulva	X	0	0	0
R. pilosa	X	X	0	X
Triquitrites tribullatus	X	X	X	0
Tantillus triquetrus	X	X	0	X
Reticulatisporites polygonalis	X	0	X	X
Florinites millotti	X	X	0	0
F. pumicosus	X	X	0	0
F. similis	X	X	0	X

KEY:

X = present

0 = not present

Table 6.7 Miospore species with minimum occurrence of 1% which increase by more than three times in adjacent leaves of the Thick Coal

	LEAF 1	Amount of increase	LEAF 2	Amount of increase	LEAF 3	Amount of increase	LEAF 4
Leiotriletes guennelli	L		L	x 3	H		H
Calamospora cf. breviradiata	H		H	x 6	L	x 8	H
C. parva	L	x 3	H		H	x 5	L
Lophotriletes commisuralis	L		L		L	x 3	H
L. microsaetosus	L		L		L	x 3	H
Apiculatisporis irregularis	L		L	x 4	H	x 13	L
Acanthotriletes echinatus	L		L		L	x 3	H
Dictyotriletes bireticulatus	L		L		L	x 6	H
Crassispora kosankei	L		L	x 5	H	x 4	L
Densosporites cf. anulatus	L	x 15	H	x 4	L		L
D. gracilis	L	x 19	H	x 3	L		L
D. cf. triangularis	L		L		L	x 3	H
Lycospora orbicula	H		H	x 8	L	x 15	H
L. pellucida	H		H		H	x 4	L
L. rotunda	H		H		H	x 3	L
Cingulizonates loricatus	L	x 10	H		H	x 3	L
Radiizonates cf. striatus	L		L	x 18	H		O
R. tenuis	H	x 8	L		L	x 7	H
Endosporites zonalis	H		H	x 6	L	x 4	H
Laevigatosporites cf. dunkardensis	H		H		H	x 3	L

KEY:

L = low relative % abundance

H = high relative % abundance

O = not present

Firstly, they found that Savitrisporites concavus Marshal and Smith 1965 and S. nux (Butterworth and Williams) Sullivan 1964 were missing in Flints Green borehole from the equivalent of leaves 2, 3 and 4 at Longmeadow Wood borehole. Both of these species are present in all leaves at Longmeadow Wood borehole.

Secondly, they found at the same borehole that Densosporiites gracilis Smith and Butterworth 1967 was confined to the equivalent of the upper part of Leaf 2 and Leaves 3 and 4 at Longmeadow Wood borehole. Again this species is present in all leaves at Longmeadow Wood borehole although at a markedly greater relative percentage in Leaf 2 (Table 6.7).

In the same borehole they found that Crassispora kosankei (Potonie and Kremp) Smith and Butterworth 1967 occurred at a minimum in the equivalent of the lower part of Leaf 2 at Longmeadow Wood borehole. This is also the case for C. kosankei in Longmeadow Wood borehole although its relative percentage abundance is also low in Leaves 1 and 4.

High relative percentages of Dictyotriletes bireticulatus (Ibrahim) Smith and Butterworth 1967 were found by Welsh and Smith (1980) in the equivalents of Leaves 3 and 4 at Longmeadow Wood borehole. Although this species occurs in high relative percentages in Leaf 4 at Longmeadow Wood borehole it occurs in relatively low frequencies in the leaves below it.

None of the other species found in Tables 6.6, 6.7 were mentioned by Welsh and Smith (1980). Only by comparison of the leaves of the Thick coal at several localities can the usefulness of species listed in Tables 6.6, 6.7 be determined.

CHAPTER 7

DISCUSSIONS AND CONCLUSIONS

The study of the vertical distribution of lithofacies associations in borehole cores gives an indication of depositional environments which were laterally continguous. Similarly the vertical deposition of miospore types can be related to their lateral distribution. Using this data simplified depositional models were constructed to show these lateral relationships. The mechanisms controlling these spatial relationships can be inferred from a study of modern depositional environments, which are likely to be similar to those occurring in the Warwickshire Coalfield during the lower Silesian. Factors affecting the control of these lithofacies associations temporally are also discussed, with particular reference to the structural and palaeogeographical framework within which deposition took place.

7.1 DEPOSITIONAL MODELS

Correlation of coal seams within the Warwickshire Coalfield has shown that both 'Long-residence histosol/s' and seams within the lithofacies association 'Very poorly drained siliciclastic dominated palaeosols' were widespread over areas exceeding the boundaries of the Coalfield. Succeeding these are a variety of 'Lacustrine' lithofacies associations, the basal members of which are often equally as widespread as the preceding 'Palaeosol' associations. Therefore in this study the depositional models reflect the domination of either 'Palaeosol' or 'Lacustrine' lithofacies associations. This is in contrast to previous Westphalian A/B models proposed to account for deposition within the Pennine basin by authors who recognised few 'Palaeosol' associations, and inferred that 'Lacustrine' associations commonly occurred in close proximity to them (Scott 1976, 1978; Guion 1978; Fielding 1984a).

7.1.1 Lacustrine model

The layout of the lacustrine model follows the vertical relationships observed between lithofacies associations within the Warwickshire Coalfield, and also the spatial arrangement of channels and their products shown by other authors working on the Westphalian deposits of the Pennine basin (Scott 1976, 1978; Guion 1978; Fielding 1984a, 1986). Because the model has been drawn to show the greatest variety of lithofacies associations within the confines of the scale chosen, a major distributary has been included. As a result, the association 'Lacustrine suspension deposits' is not shown on the surface of the model but underlies it, representing the first stage of lake infill. The crevasse channels are shown relatively straight and at a high angle to the channel from which they are derived, and the minor distributary channels are shown as sinuous bodies following Fielding (1986). Because the surface of the model represents the final stages of lake fill, there are scattered areas where the association 'Impoverished siliciclastic palaeosol/s' has developed. At a great distance from the major distributary channel the association 'Very poorly drained siliciclastic palaeosol/s' is beginning to accumulate.

7.1.2 Palaeosol model

In this model the distribution of miospore types found in the lithofacies association 'Long-residence histosol/s' is shown, with the climax vegetation associated with Densosporites spp. bcs miospore type in the centre of a flat topped ombrophilous bog. Areas of vegetation associated with the other miospore types are shown adjacent to Densosporites spp. bcs, but from the underlying beds it can be seen that each of these types must at one time have covered the bog surface. Drainage channels are shown crossing the association

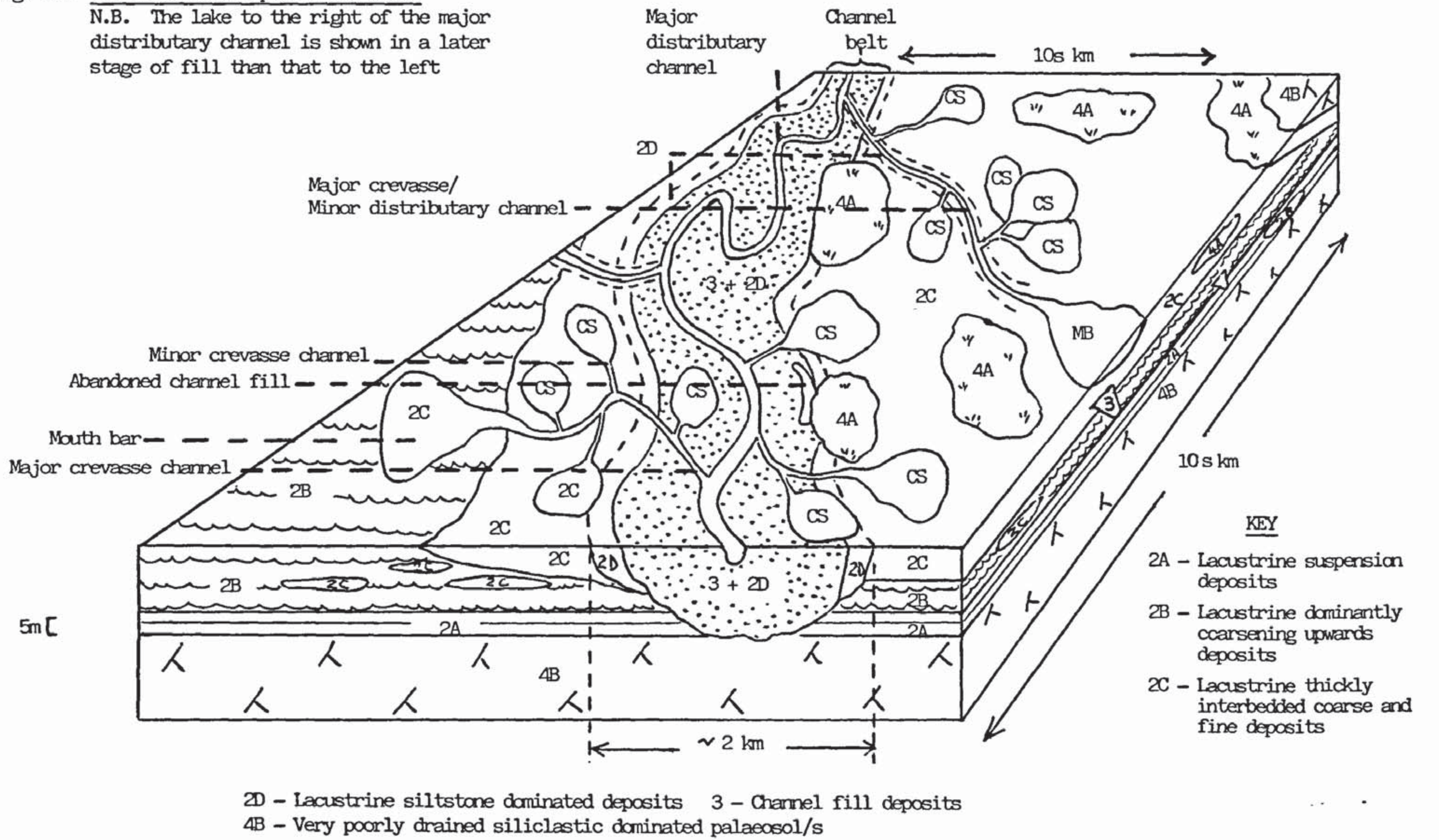
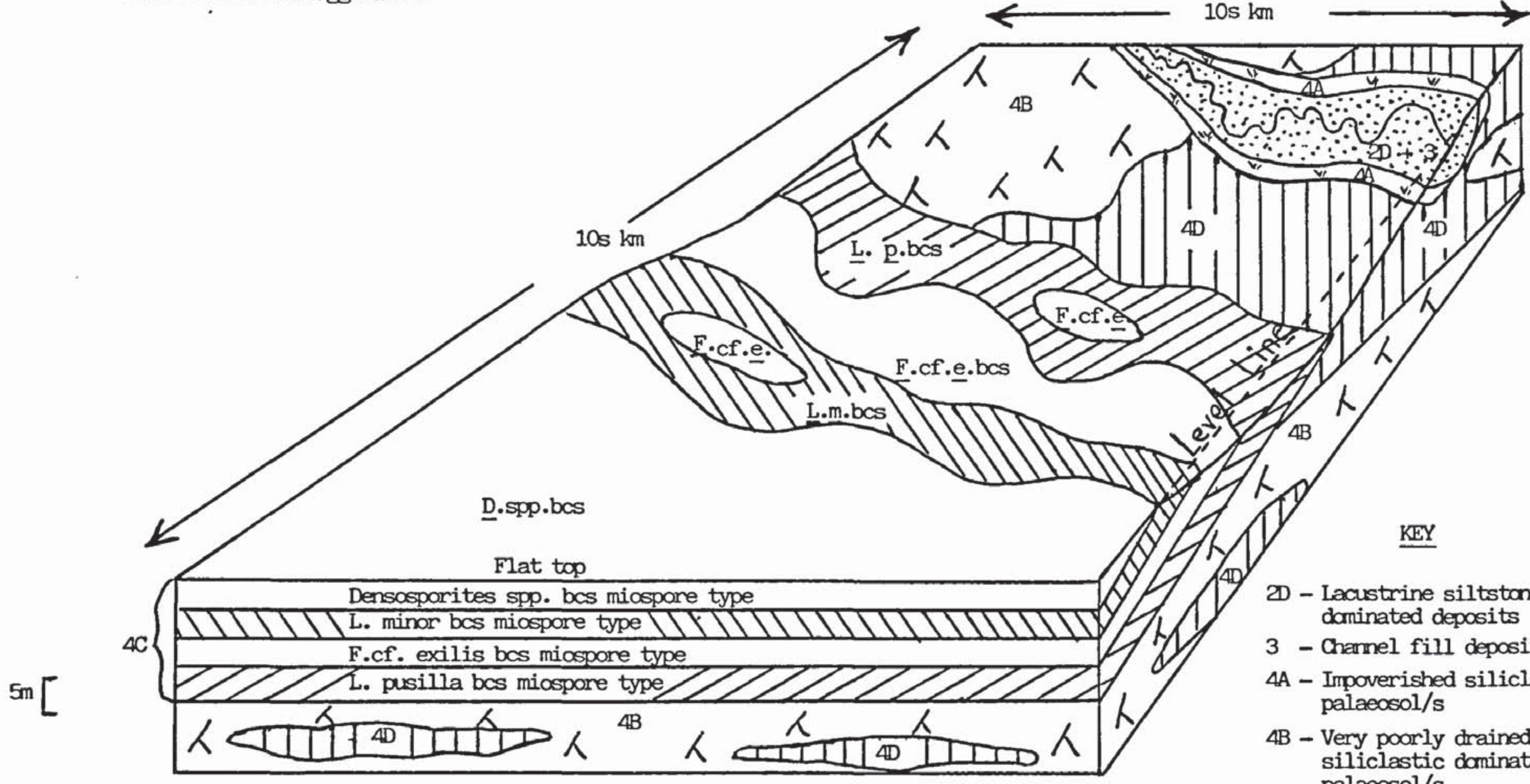


Fig. 7.1 The lacustrine depositional model
N.B. The lake to the right of the major distributary channel is shown in a later stage of fill than that to the left

Fig. 7.2 The palaeosol depositional model
N.B. Topography on the surface of the model has been exaggerated.



KEY

2D – Lacustrine siltstone dominated deposits
3 – Channel fill deposits
4A – Impoverished siliclastic palaeosol/s
4B – Very poorly drained siliclastic dominated palaeosol/s

4C – Long residence histosol/s   4D – Alternate poorly and imperfectly drained siliclastic palaeosol/s

'Long-residence histosol/s'. The boundary between the latter association and the two other 'Palaeosol' associations is fairly sharp and shows that either association can underlie 'Long-residence histosol/s'. The boundary between 'Very poorly drained siliciclastic dominated palaeosol/s' and 'Alternate poorly and imperfectly drained siliciclastic palaeosol/s' is gradational and lobate and in the beds underlying the surface of the model deposits of one association can be found within the other. A channel belt is shown crossing the latter two lithofacies associations.

7.2 MECHANISMS CONTROLLING DEPOSITION

It is believed that rate of subsidence was the most important factor governing whether sedimentation was characterised either by deposits similar to those in the 'Palaeosol' or 'Lacustrine' models. Only when both rate of subsidence and depth of water were low could extensive 'Palaeosol' associations form. The great thicknesses of coal within the lithofacies association 'Long-residence histosol/s' attests to long periods of time during which these conditions prevailed. Increase in the rate of subsidence above the rate of histosol accumulation is presumed to have caused the drowning of the mires in which 'Long-residence histosol/s were accumulating, changing telmatic/terrestial conditions to subaqueous conditions. It has been shown (section 6.4.2) that increase in the rate of subsidence was variable, and sometimes so rapid that vegetation could not adjust to it. Following and during high rates of subsidence lakes were formed which were terminated by their infilling with a variety of 'Lacustrine' associations and 'Channel fill deposits' as the rate of subsidence decreased.

7.2.1 Mechanisms controlling the lithofacies associations in the 'Lacustrine' model.

It is believed that the most important control on the distribution of lithofacies associations within the 'Lacustrine' model was the position of channels and their related products. Major changes in channel location were probably brought about following avulsion. This is often caused by crevasse channels taking more of the water away from the original channel (Speight 1965). The change from a crevasse to a distributary channel is only likely to happen if the area is well drained (Kruit 1955) so that the water can follow an advantageous gradient. Because of this, channels were probably attracted towards lakes undergoing more rapid subsidence than the surrounding area. Following the arrival of major and minor distributary channels, crevasse channels formed on a random basis as a result of water breaking through the levees during flood events.

Sediment from the channels was discharged into the lake by a variety of means. Although initially unconfined, following incision into the delta plain over a few years, levees formed from the lithofacies association 'Lacustrine siltstone dominated deposits' developed as a result of overbank flooding. At the mouth of the channels, depending on their type, crevasse splays or distributary mouth bars formed the lithofacies association 'Lacustrine thickly interbedded coarse and fine deposits'. Beyond the mouths of these channels the lithofacies association 'Lacustrine dominantly coarsening upwards deposits' was produced by a mixture of coarse grained bedload and finer grained sediment in suspension, as the splays and bars moved into the lake. Large areas of lakes which were at a great distance from channels carrying siliciclastic sediment received only fine grained mud in suspension together with floriclastic debris to form the lithofacies association 'Lacustrine suspension deposits'. (The presence of a major distributary channel on the surface of the model precludes the occurrence of 'Lacustrine suspension deposits' on the surface because of the scale involved). Lakes were slow to fill at first, but following the attraction of channels to them, they rapidly filled by the processes outlined above, because the rate of sedimentation exceeded the rate of subsidence. The decrease in depth of water allowed plants to periodically colonise the surface promoting the development of the lithofacies association 'Impoverished siliciclastic palaeosol'. This probably happened in small areas at first, but as the locus of deposition moved away, establishment of the lithofacies association 'Very poorly drained siliciclastic dominated palaeosol/s' occurred.

7.2.2 Mechanisms controlling the lithofacies associations in the 'Palaeosol' model.

It is believed that the most important control on distribution of 'Palaeosol' lithofacies associations was drainage, more specifically the position of the water table level relative to the depositional surface. Following from the previous model, when subsidence rates were low but slightly variable and water depths were fairly shallow, the lithofacies association 'Very poorly drained siliciclastic dominated palaeosol/s' formed. Within it short-residence histosols accumulated often with high ash contents relating to the proximity of siliciclastic deposition. During periods of slightly higher subsidence lacustrine sediments were deposited which were almost immediately subject to pedogenesis, following plant colonisation in the shallower waters created by the recent deposition of sediment.

Sustained low rates of subsidence in areas initially distant from siliciclastic deposition permitted the formation of the lithofacies association 'Long-residence histosol/s'. The miospore successions and cycles observed in the leaves of the Thick Coal took place as a result of seral growth, corresponding to the way in which phasic plant communities develop in Sarawak (Anderson & Muller 1975). This type of growth is termed hydroseral because it resulted mainly from variation in water table during the creation of an ombrophilous bog, similar to those discussed by Anderson (1964, 1983) in the Far East. The growth of ombrophilous bogs was permitted by the tropical-pure equatorial climate in the central and southern Pennine Basin during Westphalian B times. Changes in climate were believed by Smith (1962) and Butterworth (1966) to be responsible for the stratigraphic distribution of Densosporites. The miospore successions within leaves of coal reveal differing rates of subsidence. When accumulation of plant remains kept pace with subsidence the same edaphic conditions and therefore the same vegetation persisted, leading to increased thicknesses of coal of the same miospore type. A succession of miospore types was created due to change in edaphic conditions outlined above, when plant accumulation exceeded the rate of subsidence. The most rapid change in edaphic conditions, resulting in the fastest change from initial (L. pusilla bcs) to climax (Densosporites spp. bcs) miospore type was brought about by a large differential between the lower rate of subsidence in the area of the bog and the higher rate outside it. Later, when accumulations of plant remains became less than the rate of subsidence it was possible to complete a miospore cycle, with the climax miospore type reverting to the initial type due to a reversal of edaphic conditions. However, if the rate of subsidence in the area of the bog was too great plant growth was terminated by drowning before reversion to the initial miospore type could take place.

When better drained conditions prevailed and the rate of subsidence was low, histosols were either not produced or not preserved, resulting in the occurrence of the lithofacies association 'Alternate poorly and imperfectly drained siliciclastic palaeosol/s'. It is believed that the mean high water table often lay at some distance below the surface so that brown or red mottled palaeosol lithofacies formed. From the close vertical proximity of this association and the previous two, it appears that drainage conditions could change rapidly in this part of the Pennine basin. This situation may also occur laterally explaining the lobate boundary between this and the other two associations. The channel shown crossing the lithofaces associations 'Alternate poorly and imperfectly drained siliciclastic palaeosol/s' and 'Very poorly drained siliciclastic dominated palaeosol/s' provided the surrounding areas with sediment by the variety of processes listed in the previous section. However as water depths were shallow, or the water table lay below the surface, any deposits formed were rapidly penetrated by roots and converted into 'Palaeosol' lithofacies.

7.2.3 Mechanisms controlling deposition of the lithofacies association Marine deposits

Physical factors affecting deposition (subsidence, drainage, sedimentary processes) operating within the basin of deposition discussed above, are termed intrabasinal. Mechanisms controlled by processes occurring beyond the basin of deposition are termed extrabasinal, and it is believed that extrabasinal processes were responsible for the distribution if 'Marine deposits'. Eustatic control of sea level (section 5.4.1) has been suggested as the mechanism controlling distribution of the Namurian and Westphalian Marine bands in the Warwickshire Coalfield. Whether the changes in the volumes of ocean were caused by melting of ice or sea floor spreading is still a subject of discussion.

7.3 FACTORS CONTROLLING SUBSIDENCE

It is apparent from the previous discussion that subsidence played an important role in the control of depositional environments during the lower Silesian in the Warwickshire Coalfield. The mechanisms believed to control subsidence, and evidence of their direct effect on sedimentation are discussed below.

Two main processes responsible for subsidence were believed to have been in operation during the deposition of lower Silesian sediments in the Coalfield. Compactional subsidence occurred when sediment was loaded from above. The two extremes which occur in Coal Measure rocks are sandstones, where compaction is believed to be relatively low, and floriclastic palaeosols where sediment loading may reduce the thickness of a histosol by up to four times (Elliott 1985). Although compaction undoubtedly contributed to the overall subsidence it is believed that the effects of structurally generated subsidence were much greater.

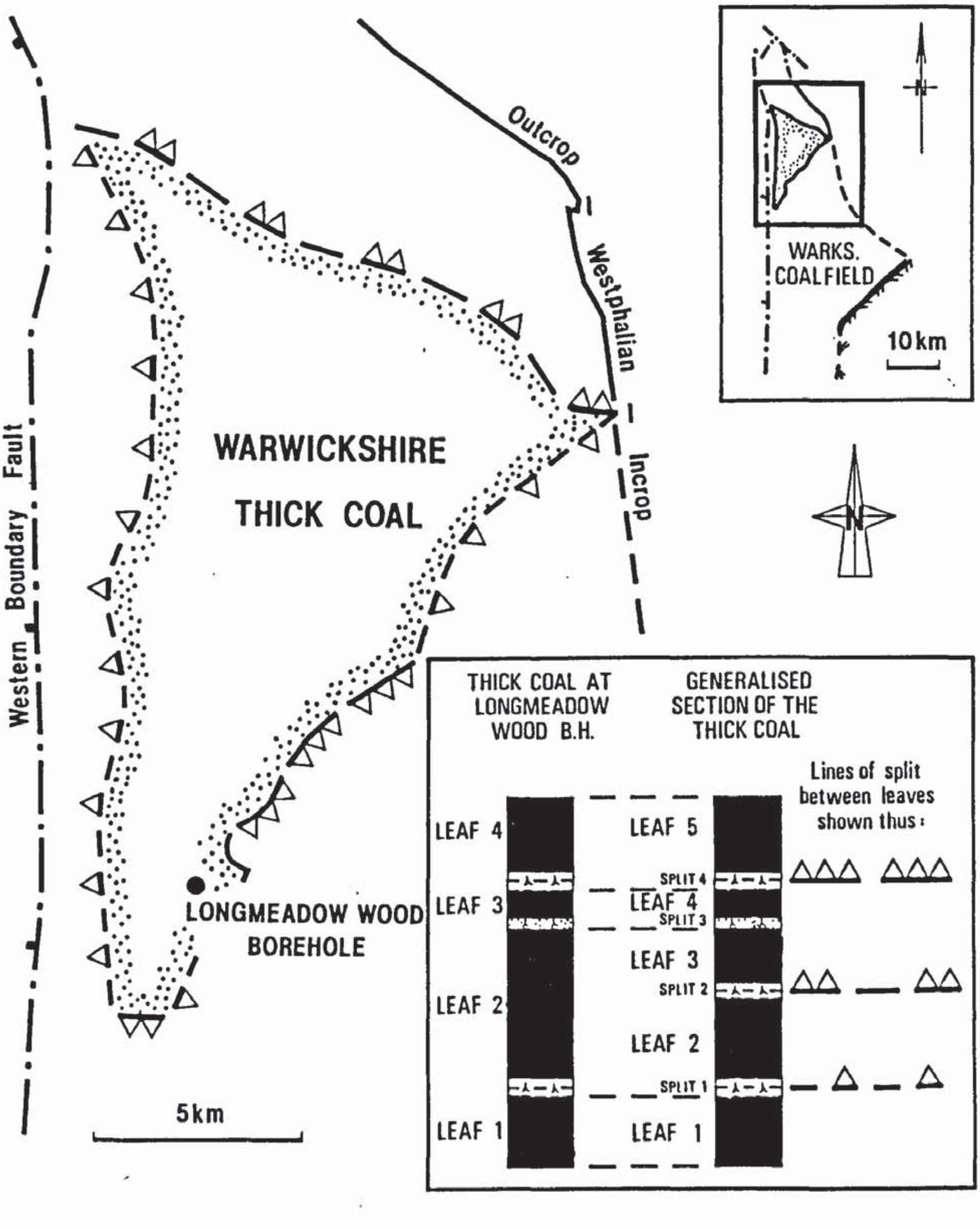
Structurally generated subsidence is believed to have been controlled by the prevailing tectonic regime (section 4.5). It is presumed that structural subsidence was accomplished by faulting at depth, as no evidence to suggest fault expression at the surface has been found in the Warwickshire Coalfield during the lower Silesian. To understand the basin evolution of the Warwickshire Coalfield would require a more sophisticated analysis of regional structural data, which is beyond the scope of this study. However, the effects of structural subsidence can be seen on both a local and regional scale.

On a local scale (10's km^2) Broadhurst and France (1986) have shown that intermittent fault movement affecting sedimentation was most easily detected in association with floriclastic palaeosols (coal seams) because of the length of time necessary for their formation.

This should be especially true of the 'Long-residence histosols' found in the Warwickshire Coalfield. Also the flat tops to the ombrophilous bogs in which some histosols accumulated should make them highly sensitive to changes in rates of subsidence. It is hypothesised that if faulting controlled the splitting of leaves of coal, the lines of split should be approximately linear, corresponding with the subsurface fault controlling them. Lines of split corresponding to an 0.3m interval between the leaves of the Thick Coal (Fig.7.3) form an approximately straight sided triangle limiting the area of the Thick Coal. (The lines continue some distance beyond their plotted positions). Trends of the split lines are very similar to the three structural trends mentioned in section 3.3 and demonstrate that all three must have been active during deposition of the leaves of the Thick Coal.

On a major scale it is believed that structural subsidence caused the changes in thickness seen on the isopachtye maps for the Namurian, Westphalian A and Westphalian B (Figs.4.9-11), and changes in the southern limit of deposition (or northern edge of the Wales-Brabant Island) for these times. It is postulated that structural subsidence began earlier in the north, accounting for the presence of Namurian sediments in that area, and gradually progressed southwards explaining the overlap of Namurian and Westphalian A sediments onto the basement. Structural subsidence is also believed to have been more rapid in the north with a resulting increase in seam intervals when compared with the centre and south of the Coalfield where a condensed sequence has formed (Figs.3.1-4). Although faulting has been shown to affect deposition in the Warwickshire Coalfield locally, the gradual change in thickness of the Westphalian A and B deposits may be the

Fig. 7.3 Positions of the 0.3m split lines between leaves of the Warwickshire Thick Coal Note: these split lines delimit the extent of the Thick Coal and extend beyond the positions shown.



result of the Coalfield behaving on a regional scale as a single structural block. It is possible that the large thickness of relatively undisturbed Cambrian strata (over 1km at outcrop) may have had a stabilising influence on the rate of subsidence. At the northern end of the Coalfield and beyond into the South Derbyshire Coalfield the rapid increase in thickness of lower Westphalian sediments may have been accomplished by a reactivation of the larger numbers of faults present in these areas.

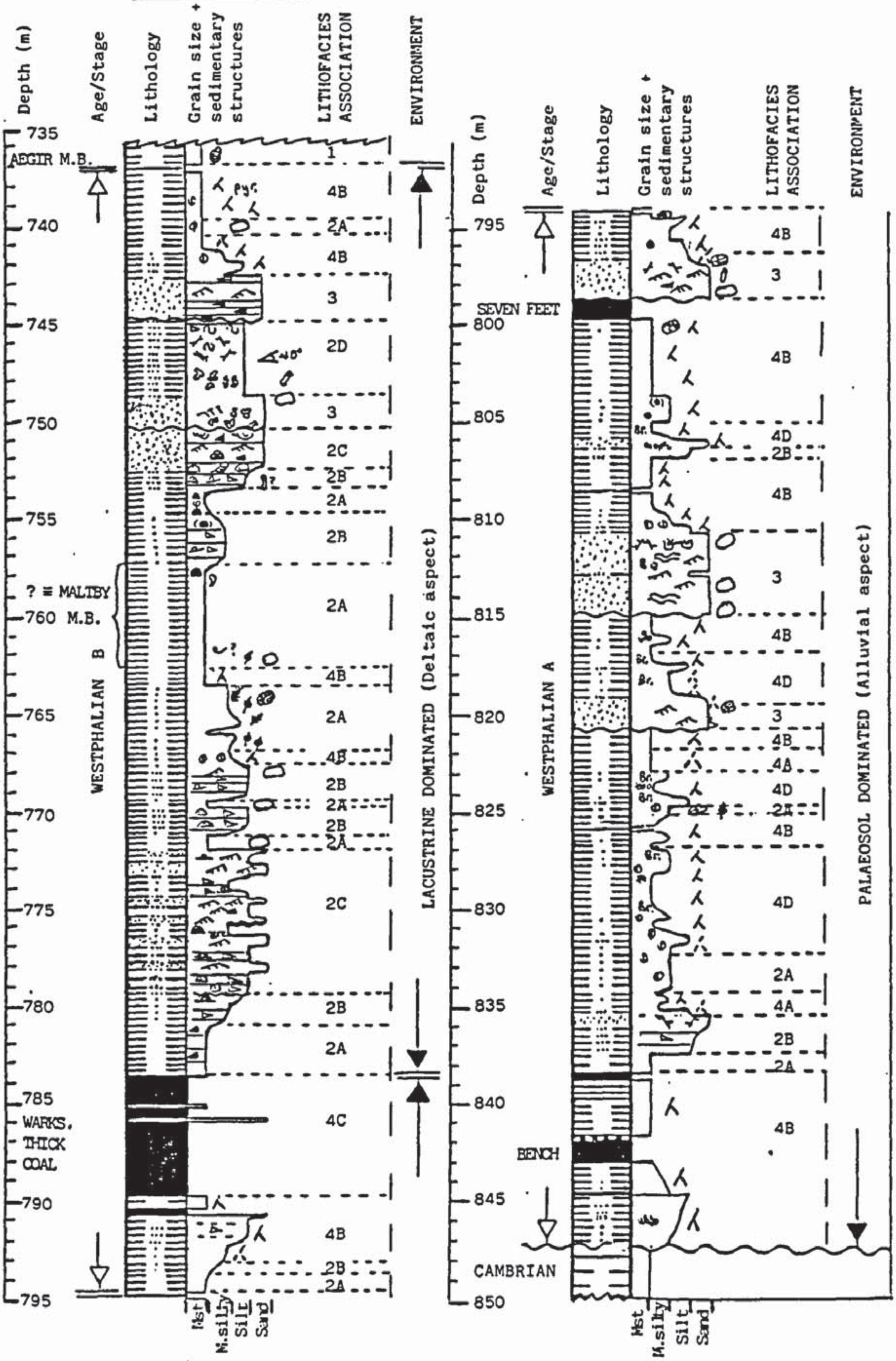
7.4 ENVIRONMENTAL SETTING

Previous authors (Elliott 1969, Scott 1978, Fielding 1984b) have interpreted lower Silesian sediments which accumulated in the Pennine basin as deltaic deposits and this interpretation is believed to be correct for those in the Warwickshire Coalfield. Comparison has been made with modern deltaic environment and terms such as alluvial, and upper and lower delta plain have been used to further characterise the environmental setting.

Fielding (1984b) believed one of the major controls on deposition in the Durham Coalfield was the gradual southward progradation of the Pennine delta system. He believed this resulted in a change from a lower delta plain setting characterised by common marine bands, shore line marine reworked sandstones and a paucity of coal seams in late Namurian and early Westphalian A times, to an upper delta plain with few marine bands and common, thicker, more widespread coal seams in late Westphalian A and Westphalian B times.

A similar situation exists in the north of the Warwickshire Coalfield. In Namurian and early Westphlian A times sedimentation was dominated by 'Lacustrine' and 'Marine' deposits, with occasional coarse sandstones and 'Palaeosol' deposits including the lithofacies association 'Alternate poorly to imperfectly drained siliciclastic palaeosol/s' (Fig.7.4). Above the first thick workable coal seam (Stanhope) marine bands are rare, and a combination of 'Lacustrine' and 'Palaeosol' deposits from the bulk of the sediments including thick widespread coal seams. If the change in frequency of marine inundation and increase in thickness and prevalence of coal seams took place at approximately the same time at either end of the Pennine basin, it may be better to interpret the change in terms of extrabasinal mechanisms rather than delta progradation.

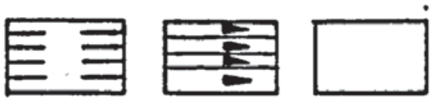
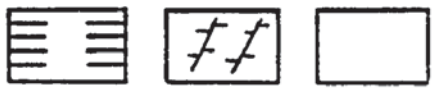
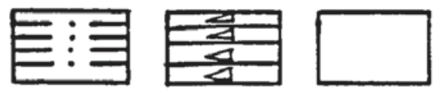
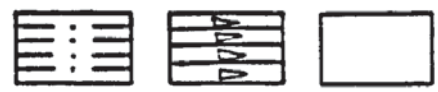
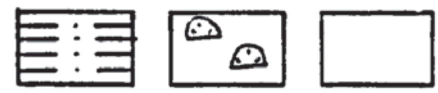
Fig.7.4 Distribution of 'Lithofacies associations' through the Westphalian A and B in Birch Tree Farm borehole showing change in environmental aspect in the lower Westphalian B.



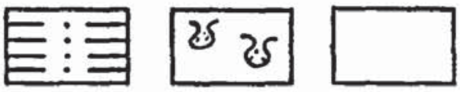
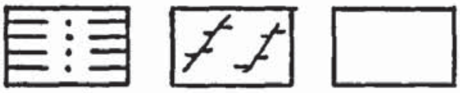
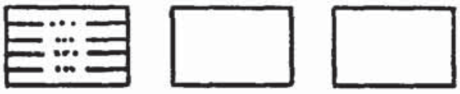
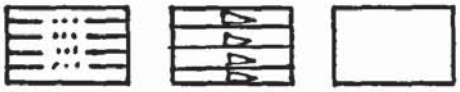
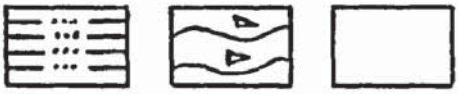
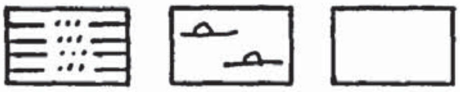
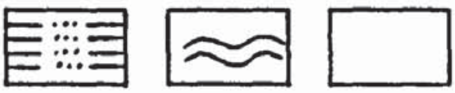
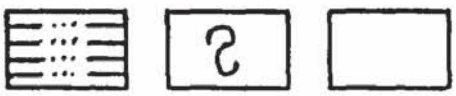
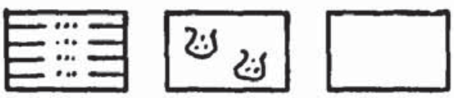
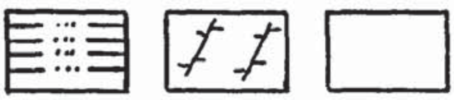
To the south of the Warwickwickshire Coalfield Westphalian A sediments are dominated by palaeosol deposits, often formed of the lithofacies association 'Alternate poorly to imperfectly drained siliciclastic palaeosol/s', and marine bands are poorly developed or absent. In these respects the Westphalian A sediments are alluvial in character. It may however, be better to regard these deposits as the product of a topographical control exerted by the proximity of the Wales-Brabant Island, from which freshwater flowed limiting marine transgressions, and near which locally better drained conditions persisted when compared with the north of the Coalfield.

APPENDIX 'B' Key to symbols used in graphic logs

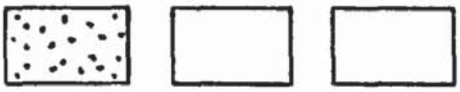
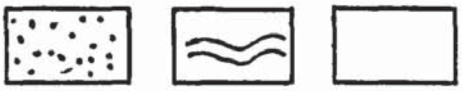
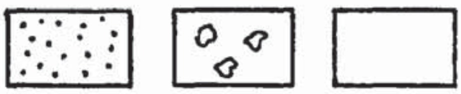
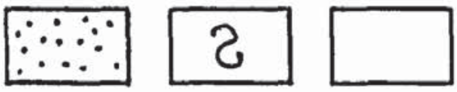
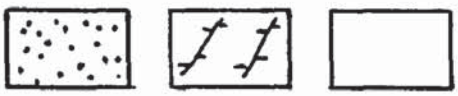
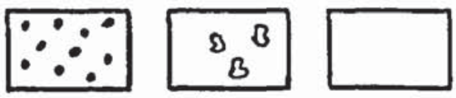
B1) LITHOFACIES SYMBOLS

Lithology / Inorganic Structures / Organic Structures		
	1.1	MUDSTONE, massive, medium to dark grey
	1.2	MUDSTONE, massive, with abundant plant fragments.
	1.3	MUDSTONE, massive, dark grey to black
	1.4	MUDSTONE, massive with marine/brackish fauna
	1.5	MUDSTONE, with coal lenses
	1.6	MUDSTONE, parallel stratified dark grey to black/medium grey
	1.7	MUDSTONE, medium grey with dark grey mudstone lenses
	1.8	MUDSTONE melange
	2.1	MUDSTONE SILTY, massive medium to dark grey
	2.2	MUDSTONE SILTY, massive with abundant plant fragments
	2.3	MUDSTONE SILTY, with coal lenses
	2.4	MUDSTONE SILTY, parallel stratified with mudstone
	2.5	MUDSTONE SILTY, medium grey with dark grey mudstone lenses
	2.6	MUDSTONE SILTY, parallel stratified with sandstone
	2.7	MUDSTONE SILTY, with undulating sandstone laminae
	2.8	MUDSTONE SILTY, with lenticular sandstone stratification
	2.9	MUDSTONE SILTY, wavy stratified with sandstone

APPENDIX B1) continued LITHOFACIES SYMBOLS

Lithology / Inorganic Structures / Organic Structures		
	2.10	MUDSTONE SILTY, slurried
	2.11	MUDSTONE SILTY, with load casts
	2.12	MUDSTONE SILTY, melange
	3.1	SILTSTONE, massive, pale to medium grey
	3.2	SILTSTONE, massive, with abundant plant fragments
	3.3	SILTSTONE, parallel stratified with sandstone
	3.4	SILTSTONE, with undulating sandstone laminae
	3.5	SILTSTONE, with sandstone mini lenses
	3.6	SILTSTONE, with lenticular sandstone stratification
	3.7	SILTSTONE, wavy stratified with sandstone
	3.8	SILTSTONE, ripple drifted with sandstone
	3.9	SILTSTONE/sandstone with small scale cross stratification
	3.10	SILTSTONE with convolute sandstone stratification
	3.11	SILTSTONE, slurried
	3.12	SILTSTONE with load structures
	3.13	SILTSTONE melange

APPENDIX B1) continued LITHOFACIES SYMBOLS

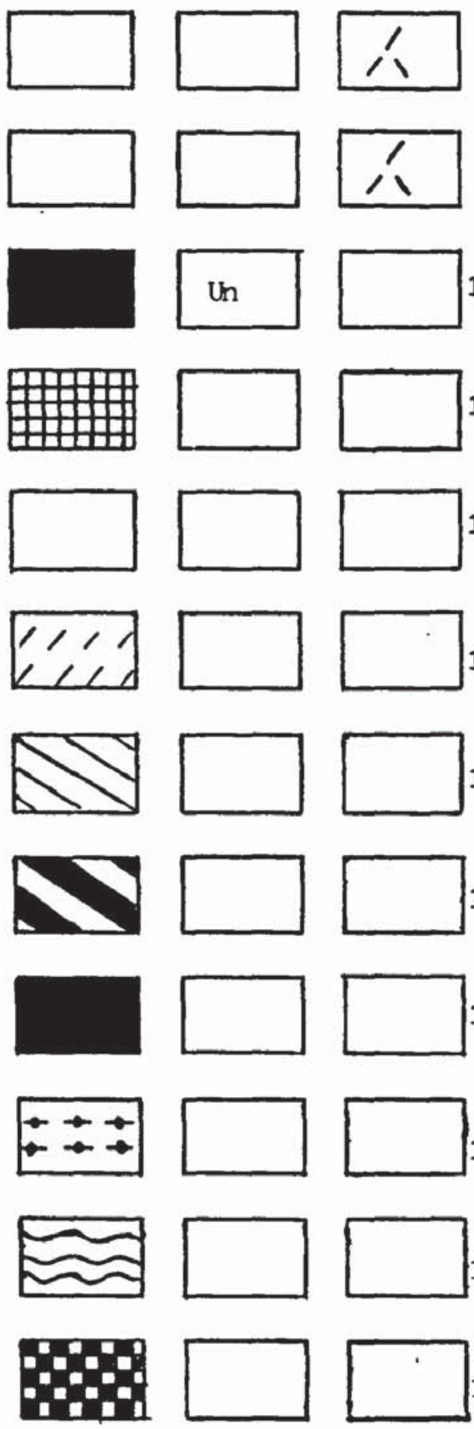
Lithology / Inorganic Structures / Organic Structures		
	4.1	SANDSTONE, FINE, massive, pale grey to off white
	4.2	SANDSTONE, FINE, wavy stratified
	4.3	SANDSTONE, FINE, flaser stratified
	4.4	SANDSTONE, FINE, ripple drifted with siltstone
	4.5	SANDSTONE, FINE, with small scale cross lamination
	4.6	SANDSTONE, FINE/Siltstone with small scale cross lamination
	4.7	SANDSTONE, FINE, parallel laminated
	4.8	SANDSTONE, FINE, with rare clasts
	4.9	SANDSTONE, FINE, with convolute siltstone stratification
	4.10	SANDSTONE, FINE, slurried
	4.11	SANDSTONE, FINE, with load structures
	4.12	SANDSTONE, FINE, melange
	5.1	SANDSTONE, MEDIUM TO COARSE GRAINED, massive
	5.2	SANDSTONE, MEDIUM TO COARSE GRAINED, with small scale cross stratification
	5.3	SANDSTONE, MEDIUM TO COARSE GRAINED, with large scale cross stratification
	5.4	SANDSTONE, MEDIUM TO COARSE GRAINED, with rare clasts

Appendix B1) continued LITHOFACIES SYMBOLS

Lithology	Inorganic Structures + Colour	Organic Structures		
	int.		6.1	CONGLOMERATE, intraformational
	ext.		6.2	CONGLOMERATE extra formational
	int.		7.1	BRECCIA, intraformational
	ext.		7.2	BRECCIA, extraformational
			7.3	BRECCIA. of plant stems
			8.1	SEATEARTH, mudstone grey
			8.2	SEATEARTH, mudstone silty, grey
			8.3	SEATEARTH, siltstone, grey
			8.4	SEATEARTH, sandstone, grey
	Br.		8.5	SEATEARTH, mudstone, brown
	Br.		8.6	SEATEARTH, mudstone silty, brown
	Br.		8.7	SEATEARTH, siltstone, brown
	Br.		8.8	SEATEARTH, sandstone, brown
			8.9	SEATEARTH, mudstone grey and/or brown, with red mottling
			8.10	SEATEARTH mudstone silty grey and/or brown, with red mottling
			8.11	SEAREARTH siltstone grey and/or brown, with red mottling

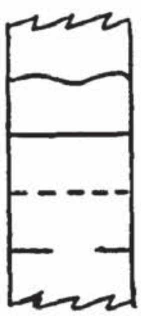
Appendix B1) continued LITHOFACIES SYMBOLS

Lithology | Qualifying Remarks | Organic Structures



9.1	SUBSEATEARTH, grey
9.2	SUBSEATEARTH, brown
10.0	COAL (lithofacies unspecified)
10.1	COAL, cannel
10.2	COAL, grey, dull, granular
10.3	COAL, grey, predominantly dull, finely lensed with bright
10.4	COAL, grey, mainly dull, finely lensed with bright
10.5	COAL, black, mainly bright, finely lensed with dull
10.6	COAL, black, bright, massive
10.7	COAL, grey, fusainous, soft
10.8	COAL, grey, fusainous, hard
10.9	COAL, plus siliclastic sediment.

B2) SYMBOLS NOT ATTACHED TO LITHOFACIES



Top of example

Erosive)
Abrupt)
Abrupt passage) Nature of contact
Passage)

Bottom of example

APPENDIX B2continued SYMBOLS NOT ATTACHED TO LITHOFACIES

Minerals

- Fe — Siderite laminae
- Siderite nodule
- Siderite lens
- Siderite bed
- Vertically elongate siderite root nodules
- Siderite patch
- Sphaerosiderite
- Pyrite

Organic structures

a) Fauna

- Non-marine bivalve
- Ostracods
- Fish
- Spirorbis
- Lingula
- Orbiculoidea
- Other brachiopods

b) Flora

- Plant fragments unspecified
- Leaves genus specified
- Leaves genus unspecified
- Plant frond
- Lycopod leafy shoot
- Cordaites
- Stem unspecified
- Medullosa
- Sigillaria

b) Flora (continued)

- Lepidodendron
- Calamites
- Stigmaria ficoides

c) Ichnofossils

- Burrows vertical
- Burrows horizontal
- Cochlichnus
- Planolites
- Pelecypodichnus
- Gyrochorte
- Guilielmites
- Small curved tracks and trails
- Faecal pellets

Sedimentary structures

- Train drift
- Parallel laminae with gentle erosion surfaces
- Faint parallel laminae
- Symmetrical ripples
- Clast

Colour

- Oc. — Ochreous
- Gr. — Green
- Pu. — Purple

- 10° — Dip of stratification

Quantities

- (( )) — Very rare
- ( ) — Rare

APPENDIX E

Plates illustrating all miospore species
encountered in this study

PLATE 1

Fig No.

1. *Leiotriletes* cf. *adnatus* (Kosanke) Potonie and Kremp 1955 in Nader 1983; ST9/2-1-19; 25.0/66.5; 8-10; Un-named seam at 512.52m, Solomon's Temple borehole, Warwickshire; Westphalian B.

2. *L.* cf. *adnatus*, ST8/2-1-10; 15.0/70.1; 8-24; Four Feet seam at 5.35.39m; Solomon's Temple borehole, Warwickshire; Westphalian B.

3. *Leiotriletes quennelii* Ravn 1979; Lmw 515/12-1-12; 3.0/61.3; 17-34.

4. *L. quennelii*; Lmw 452a-3-c; 2-3/69-1; 23-27.

5. *Leiotriletes levis* (Kosanke) Potonie and Kremp 1955; Lmw 515/5 1/2-1-10a; 25-5/68.0; 20-20.

6. *L. levis*; Lmw 512-3-B; 27.3/71.5; 23-28.

7. *Leiotriletes* cf. *priddyi* (Berry) Potonie and Kremp 1955 in Smith and Butterworth 1967, Lmw 515/5.5-1-14; 7.3/79.6; 20-28.

8. *L.* cf. *priddyi*; Lmw 515/5.5-1-24; *3-2/75.9; 20-40.

9. *L.* cf. *priddyi*; Lmw 515/12-1-3; 12.2/65.9; 17-35.

10. *Leiotriletes sphaerotriangulus* (Loose) Potonie and Kremp 1954; Lmw 515/12-1-12, *3.2/80.8; 17-2.

11. *L. sphaerotriangulus*; Lmw 515/5.5-1-30; 3.3/75.3; 21-17.

12. *L. sphaerotriangulus*; Lmw 502-1-7; 14.1/73.7; 23-29.

13. *L. sphaerotriangulus*; Lmw 514/14-3-2; 29.1/69.5; 35-38.

14. *Leiotriletes* sp. A; Lmw 486-3-B; 5.4/81.2; 23-30.

15. *L.* sp. A; Lmw 498-3-D; 15.3/81.4; 23-31.

16. *Punctatisporites* cf. *edgarensis* Peppers 1970 in Ravn 1979; Lmw 515/12-2-10; *4.1/75.3; 19-37.

17. *P.* cf. *edgarensis*; Lmw 515/12-2-10; *4.1/75.3; 19-38; distal surface

18. *P.* cf. *edgarensis*; ST4/2-2-14; *26.1/73.0; 4-36; Un-named seam at 569.12m, Solomon's Temple borehole, Warwickshire; Westphalian A.

19. *P.* cf. *edgarensis*; Lmw 515.12-1-33; *3.8/68.0; 18.9.

PLATE 1

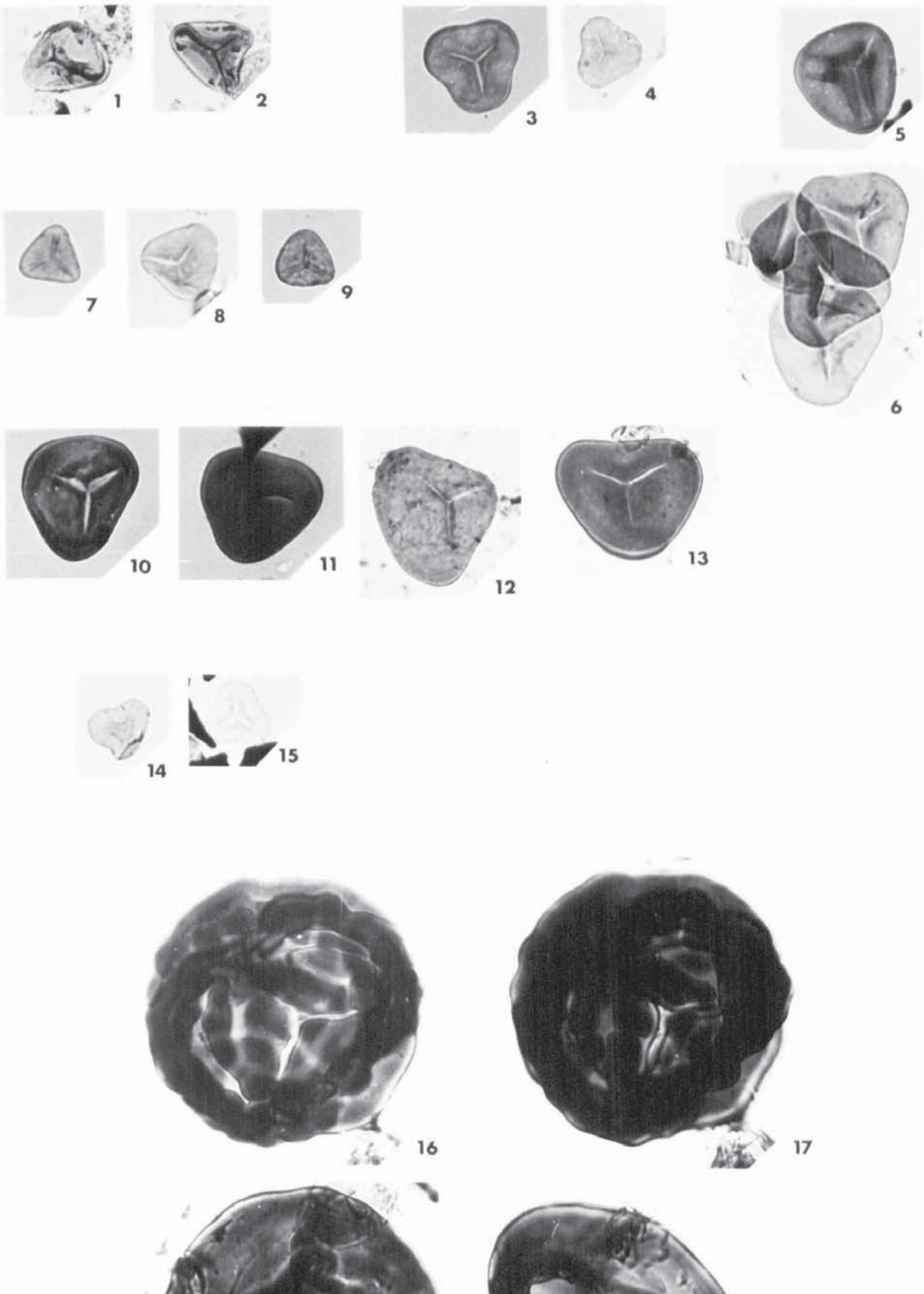


PLATE 2

Fig No.

1. *Punctactisporites obesus* (Loose) Potonie and Kremp; 1955 Lmw 438/14-3-C; 24.3/69.5; 23.32.
2. *P. obesus*; ST/9/2-1-5; 20.1/63.5; 8.7; Un-named seam at 512,52m, Solomon's Temple borehole, Warwickshire; Westphalian B.
3. *P. obesus*; ST10-1-10; 29.4/71.0; 7-9; Un-named seam at 505.43m Solomon's Temple borehole, Warwickshire; Westphalian B.
4. *Punctactisporites punctatus* Ibrahim 1932; Lmw 515/5.5-1-56; 19.6/85.0; 21.2.
5. *P. punctatus*; Lmw 515/12-1-17; *4.6/79.9; 17-7.
6. *P. punctatus*; Lmw 515/5.5-3-4; 18.9/82.8; 23.21.
7. *Punctatisporites* sp. A; Lmw 474-2-R1; 18.5/71.8; 23-36.
8. *P.* sp. A; Lmw 438/14-1-R1; 6.4/79.8; 23-35.
9. *P.* sp. A; Lmw 515/12-3-B1; 13.0/73.6; 35-1.
10. *Calamospora breviradiata* Kosanke 1950; Lmw 496-1-6c; 1.0/66.5; 23-37.
11. *C. breviradiata*; Lmw 4336-1-R2; 19.0/57.8; 24-44.
12. *C.* cf. *breviradiata* Kosanke 1950 in Smith and Butterworth 1967; Lmw 504-2-2; 3.9/61.4; 24-2.
13. *C.* cf. *breviradiata*; Lmw 475-1-6b; 10.3/68.7; 24-11.
14. *C.* cf. *breviradiata*; Lmw 478-3-B; 8.8/68.5; 24-4.

PLATE 2

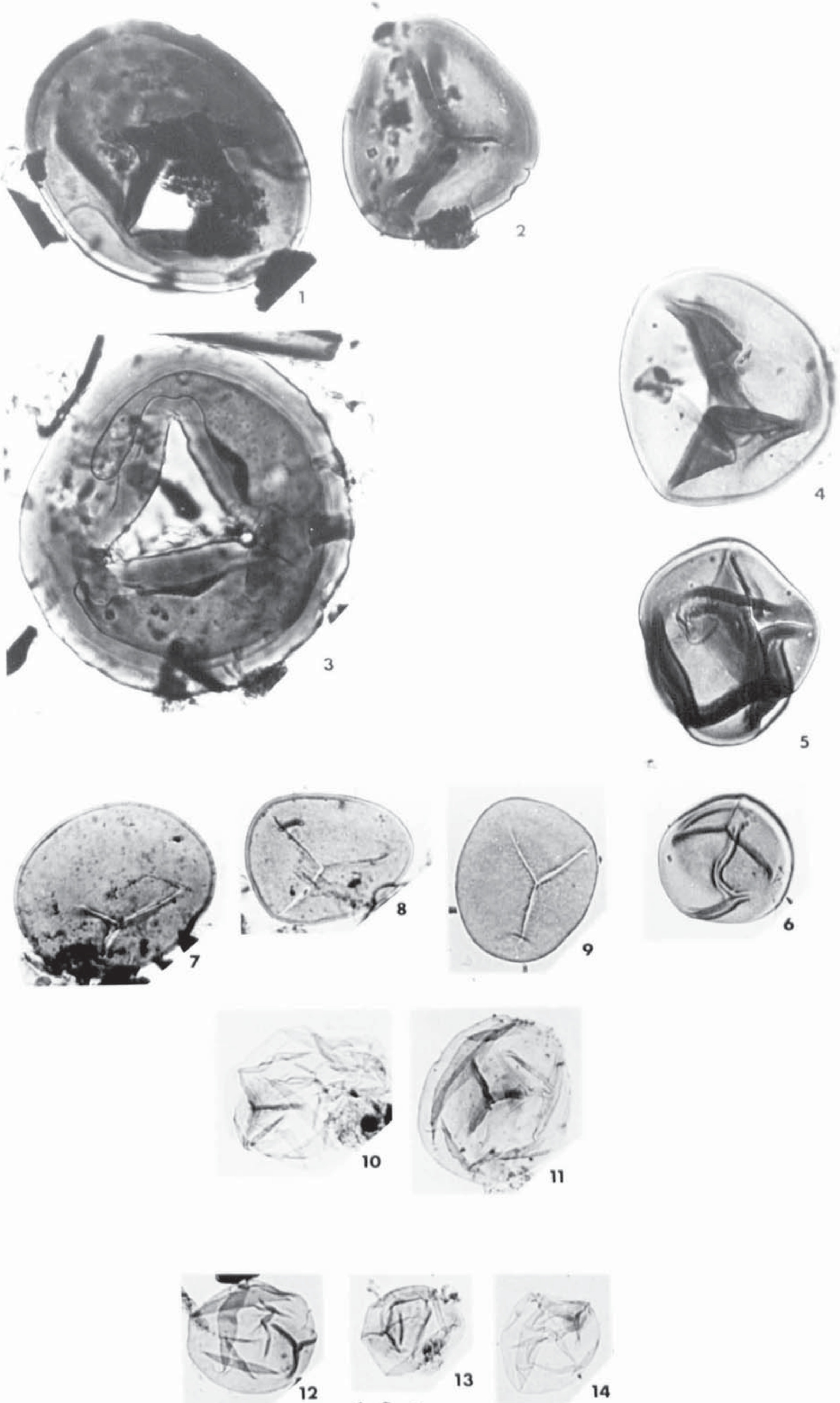


PLATE 3

Fig No.

1. Calamospora cf. laevigata (Ibrahim) Schopf, Wilson and Bentall 1944 in Smith and Butterworth 1967; Lmw 515/12-2-22; 12.7/72.9; 19-11; mag. X200.
2. c. cf. laevigata; Lmw 474-2-B1; 20.4/66.1; 31-28.
3. C. cf. laevigata; Lmw 477a-3-A; 23.2/73.2; 24-6; detail of Caleurae.
4. Calamospora microrrugosa (Ibrahim) Schopf, Wilson and Bentall 1944; Lmw 515/12-1-2; 8.5/66.7; 17-38.
5. C. microrugosa; Lmw 515/12-1-43; 24.1/86.8; 18-20.
6. C. microrugosa; Lmw 474-3-A; 7.2/68.3; 24-8.
7. Calamospora nebulosa Ravn 1979; Lmw 515/12-2-5; 7.8/64.3; 18-25.
8. C. nebulosa; Lmw 515/5 1/2-1-1; 8 7.2/86.3; 19-18.
9. C. nebulosa; Lmw 426.2-1-7; 10.3/68.7; 24-11.
10. C. nebulosa; Lmw 496-1-11; 25.0/70.9; 31-30.
11. Calamospora pallida (Loose) Schopf, Wilson and Bentall 1944; Lmw 515/5 1/2-1-53; *7.2; 64.7; 21-43.
12. C. pallida; Lmw 498-1-R7;l 81.5; 31-31.
13. C. pallida; Lmw 515/12-1-41; 65.4; 18-18.
14. Calamospora parva Guennel 1958; Lmw 428-2-R2; 21.6/52.5; 24-16.
15. C. parva; Lmw 440a-1-17; 4.7/69.6; 24-14.
16. C. parva; Lmw 458b-3-F; 2.4/72.9; 24-15.
17. C. parva; Lmw 458b-1-R3, 5.9/61.9; 13-19.

PLATE 3

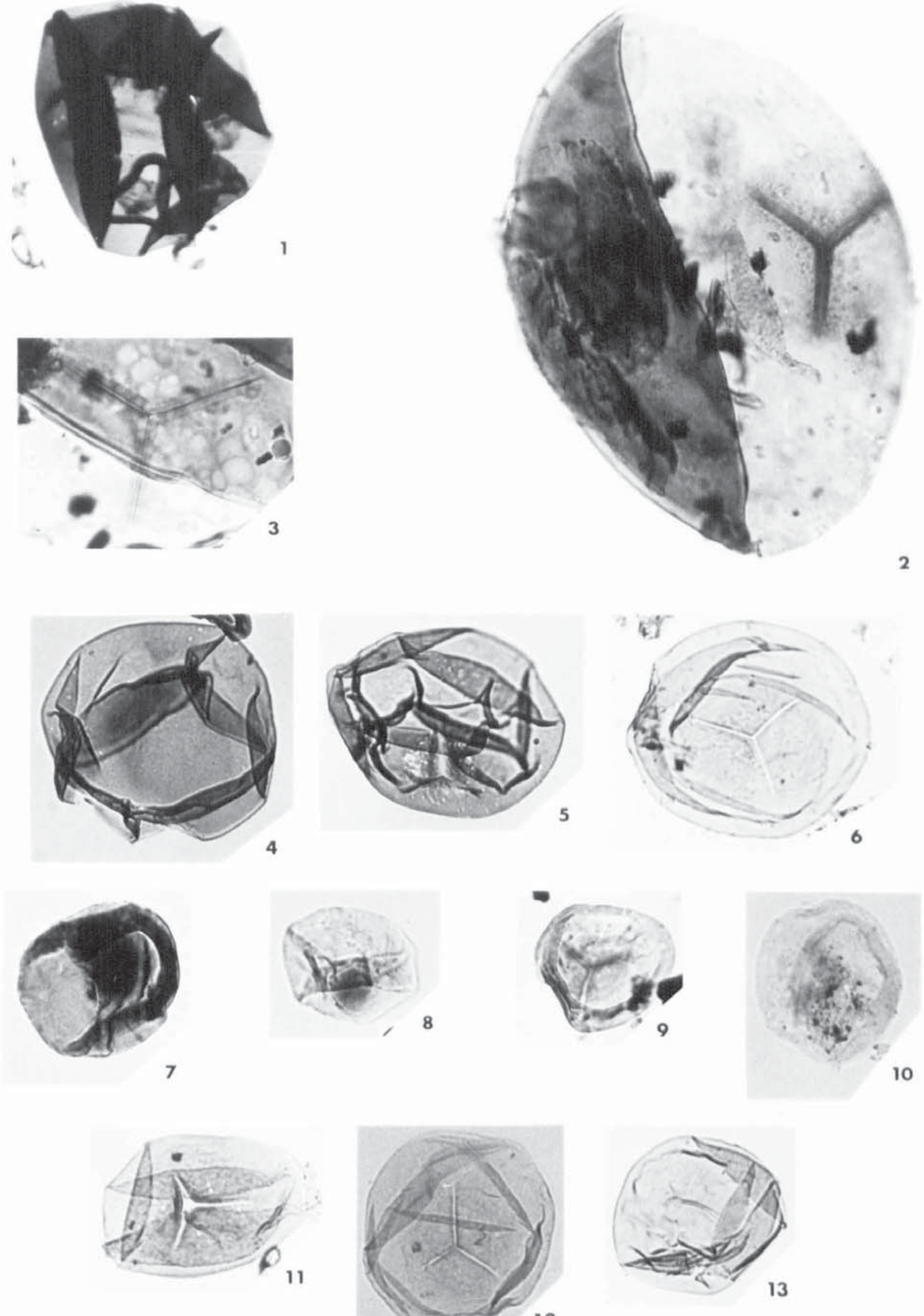


PLATE 4

Fig No.

1. Calamospora pedata Kosanke 1950; Lmw 478-2-B1; 4.5/82.2; 31-32.
2. C. pedata; Lmw 458b-1-P1; *1.3/73.5; 13-2.
3. C. pedata; Lmw 515/5.5-1-43; 29.3/80.5; 21-32.
4. Calamospora cf. pedata Kosanke 1950 in Ravn 1979; Lmw 485a-1-7; 5.9/63.5; 24-18.
5. C. cf. pedata; Lmw 515/5.5-3-2; 26.4/62.9; 22-39.
6. C. cf. pedata; Lmw 459-3-B; 20.0/61.4; 24-17.
7. C. cf. pedata; Lmw 515/5.5-3-11; 4.3/62.0; 22-44.
8. Calamospora straminea Wilson and Kosanke 1944; Lmw 459-1-3b; *3.1/69.0; 24-3.
9. C. straminea; Lmw 515/5.5-1-18; 20.5/70.9; 20-34.
10. Adelisporites multiplicatus Ravn 1979; Lmw 458b-3-k; *4.5/61.4; 24-20.
11. Granulatisporites adnatoides (Potonie and Kremp) Smith and Butterworth 1967; Lmw 423-2-17; 29.3/56.3; 24-22.
12. G. adnatoides; Lmw 424a-3-E; 21.3/56.5; 24-25.
13. G. adnatoides; Lmw 424a-3-F; 25.3/76.5; 24-23.
14. G. adnatoides; Lmw 424a-3-Gl 17.4/75.2; 24-24.
15. Granulatisporites granulatus Ibrahim 1933; Lmw 515/5.5-3-30b; 24.8/72.9; 23-12.
16. G. granulatus; Lmw 515/12-1-7b; 8.1/82.1; 17-41.
17. G. granulatus; Lmw 515/12-1-27b; 26.3/78.1; 18-41.
18. Granulatus micrograñifer Ibrahim 1933; Lmw 515/12-1-14; 18.9/69.9; 17-14.
19. G. microgranifer; Lmw 489-1-1; 20.0/58.4; 24-2B.
20. G. microgranifer; Lmw 4246-1-6; 30.5/63.7; 24-26.
21. G. microgranifer; Lmw 430-1-4, 18.7/63.2; 24-27.
22. Granulatisporites minutus Potonie and Kremp 1955; Lmw 448-1-B1; 28.1/64.5; 14-10.
23. G. minutus; Lmw 484-1-2; 7.3/68.3; 24-29.
24. Cyclogranisporites aureus (Loose) Potonie and Kremp 1955; Lmw 515/5.5-1-20; 17.9/72.6; 20-36.
25. C. aureus; Lmw 515/12-1-31a; 19.6/79.0; 18.3.
26. C. aureus; Lmw 515/12-1-11; *0.8/81.5; 17-1.
27. C. aureus; Lmw 515/5.5-3-30a; 24.3/73.8; 23-11.
28. Cyclogranisporites minutus Bharadwaj 1957; Lmw 515/5.5-1-33a; *7.9/71.7; 21-20.
29. C. minutus; Lmw 475-1-7a; 19.2/73.4; 24-30.
30. C. minutus; Lmw 477c-1-6; 16.6/63.0; 24-31.
31. Cyclogranisporites cf. minutus Bharadwaj 1957 in Smith and Butterworth 1967; Lmw 515/5.5-1-26; 16.2/74.4; 20-42.
32. C. cf. minutus; Lmw 467-1-4; 20.0/60.0; 13-33.

PLATE 4

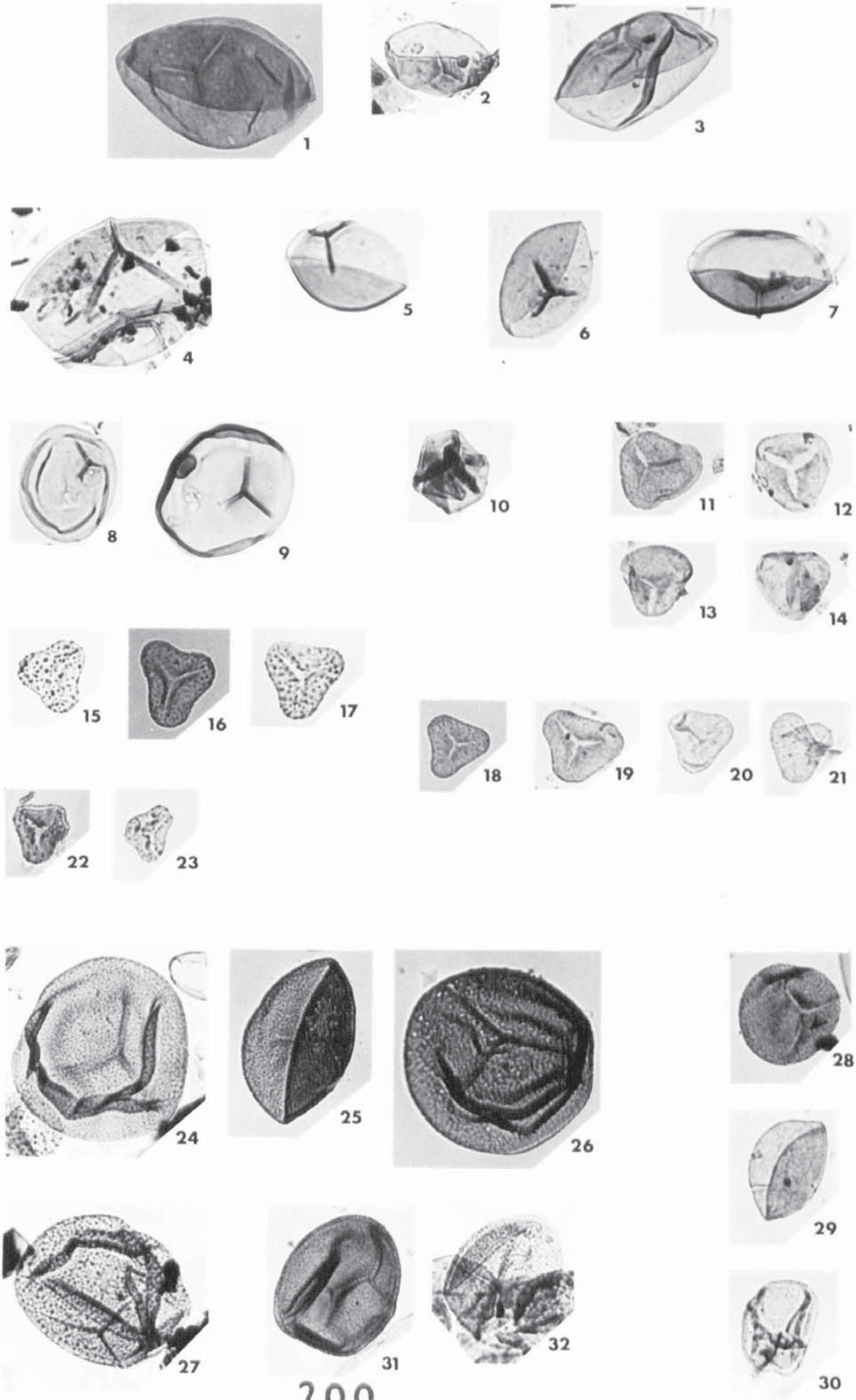

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PLATE 5

Fig No.

1. Cyclogranisporites cf. pressoides Potonie and Kremp 1955; Lmw 515/12-1-18; 24.6/71.4; 17-8.
2. C. cf. pressoides; Lmw 515/12-1-18; 24.6/71.4; 35-33; mag. X1000.
3. C. cf. pressoides; Lmw 443-1-B1; 3.7/63.8; 24-33.
4. C. cf. pressoides; Lmw 443-1-B1; 3.7/63.8; 24-36; mag. X1000.
5. C. cf. pressoides; Lmw 515/5.5-1-35; 15.5/77.9; 21-24.
6. C. cf. pressoides; Lmw 515/5.5-1-35; 15.5/77.9; 21.25; mag. X1000.
7. Cyclogranisporites sp. A; Lmw 474-3-Bi; 11.9/73.7; 25-9.
8. C. sp. A; Lmw 474-3-Bii; 12.0/73.7; 25-10.
9. C. sp. A; Lmw 474-3-Bii; 12.0/73.7; 25-8; distal surface.
10. Apiculiretusispora sp. A; Lmw 505-1-3; 16.5/58.5; 25-15.
11. A. sp. A; Lmw 505-1-3; 16.5/58.5; 25-16; distal surface.
12. A. sp. A; Lmw 478-3-E; 5.5/62.8; 25-13.
13. Apiculiretusispora sp. B; Lmw 446-1-1; 29.8/60.5; 25-25.
14. A. sp. B; Lmw 453b-1-1; 2.7/62.1; 25-26.
15. A. sp. B; Lmw 423-1-5; 25.6/64.8; 25-18.
16. A. sp. B; Lmw 423-1-5; 25.6/64.8; 25-18; mag. X1000.
17. Apiculiretusispora sp. C; Lmw 495-1-10; 71.2/66.9; 35-41; mag. X1000.
18. A. sp. C; Lmw 495-1-10; 71.2/66.9; 35-41 mag. X1000.
19. A. sp. C; Lmw 495-1-2; 25.0/59.5; 35-39; mag. X1000.
20. A. sp. C; Lmw 495-1-2; 25.0/59.5; 25-24.
21. A. sp. C; Lmw 496-3-A; 30.3/63.8; 25-28; distal surface.
22. Conerrucosisporites armatus (Dybova and Jachowicz) Smith and Butterworth 1967; Lmw 474-3-E; 29.5/74.1; 25-31.
23. C. armatus; Lmw 515/12-1-1; *1.7/84.9; 17-33.
24. C. armatus; Lmw 516/14-5-11; 20.5/72.6; 22-29.
25. Verrucosisporites donarii Potonie and Kremp 1955; Lmw 465-3-B5; 16.2/57.3; 25-34; distal surface.
26. V. donarii; Lmw 516/14-2-16; 16.8/80.8; 22-33; distal surface.
27. V. donarii; Lmw 515/12-2-16; 20.5/68.6; 19-4.
28. V. donarii; Lmw 515/12-2-16; 20.5/68.6; 19-5; distal surface.
29. V. donarii; Lmw 438/14-3-K; 11.7/67.4; 31-35.
30. Verrucosisporites microtuberosus (Loose) Smith and Butterworth 1967; *4.9/68.3; 25-36.
31. V. microtuberosus; Lmw 515/12-2-28; 15-2/82.7; 19-17.
32. V. microtuberosus; Lmw 516/14-2-10; 15-2/74.6; 31-39.
33. V. microtuberosus; ST4/2-3-7; 5.5/73.1; 6-9; Un-named Seam at 569.12m, Solomon's Temple borehole, Warwickshire; Westphalian A.

PLATE 5

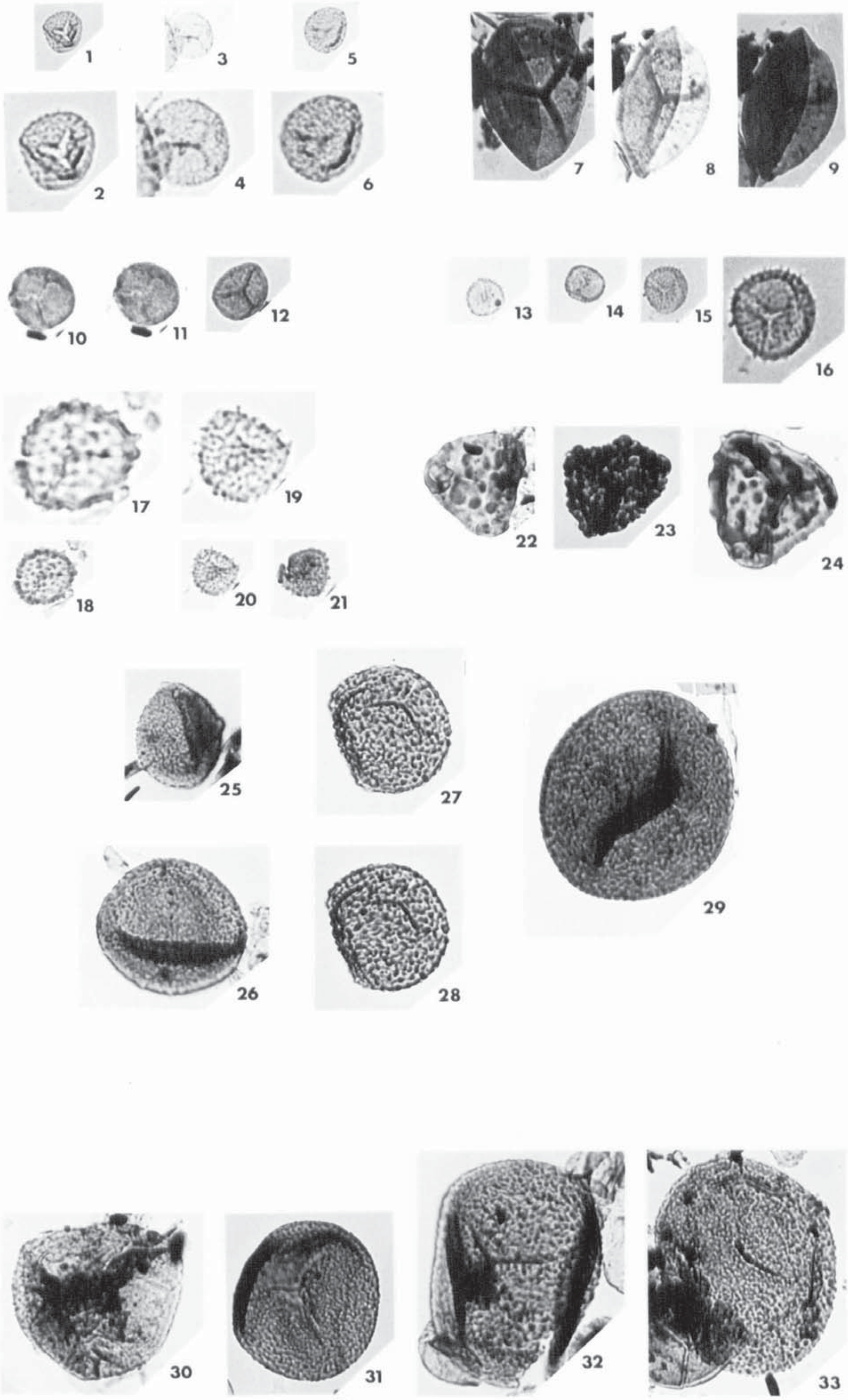
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PLATE 6

Fig No.

1. Verrucosisporites sifati (Ibrahim) Smith and Butterworth 1967; Lmw 515/5.5-1-48; 2.9/68.0; 21-37.

2. V. sifati; Lmw 515/12-1-6; 12.9/67.1; 17-39.

3. V. sifati; Lmw 515/5.5-1-25; 15.9/73.9; 20-41.

4. V. sifati; Lmw 515/5.5-1-31; *5.4/74.3; 21-18.

5. V. sifati; Lmw 477a-3-G; 30.3/65.8; 25-39.

6. Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933; Lmw 446-3-R1; 30.7/61.0; 25-41.

7. V. verrucosus; Lmw 516/14-2-8; 6.5/75.3; 22-27.

8. V. verrucosus; Lmw 515/5.5-1-54; *1.9/64.4; 21-44.

9. Verrucosisporites sp. A; Lmw 452b-1-3; *4.5/78.9; 31-38.

10. V. sp. A; Lmw 515/5.5-3-16; 12-3/72.0; 22-4.

11. V. sp. A; Lmw 515/12-1-4; 26.9/65.4; 17-36; distal surface.

12. V. sp. A; Lmw 452b-1-3; *4.5/78.9; 31-36; distal surface.

13. Lophotriletes commisuralis (Kosanke) Potonie and Kremp 1955; Lmw 515/12-1-36; 12.7/81.8; 18-13.

14. L. commisuralis; Lmw 433b-1-R6; 3-9/63.8; 26-21a.

15. L. commisuralis; Lmw 515/5.5-1-21; 7.8/72.8; 20-37.

16. Lophotriletes cf. granoornatus Artuz 1957 in Peppers 1970; Lmw 449-3-A; *4.6/74.3; 31-40.

17. L. cf. granoornatus Lmw 432-1-9; 22.3/59.2; 26-22.

18. L. cf. granoornatus Lmw 515/5.5-3-7; 15.4/78.9; 23-8.

19. L. cf. granoornatus Lmw 515/12-1-30; 4.4/78.9; 18-2.

20. Lophotriletes cf. microsaetosus (Loose) Potonie and Kremp 1955 in Smith and Butterworth 1967; Lmw 515/5.5-1-51; *10.5/66.7; 21-40.

21. L. cf. microsaetosus; Lmw 431-3-5c; 29.2/71.4; 26-24.

22. L. cf. microsaetosus; Lmw 498-1-R6, 18.9/76.9; 26-26; gulaferous compression.

23. L. cf. microsaetosus; Lmw 428-2-R1; 7.7/59.2; 26-23.

24. Waltzispora prisca (Kosanke) Sullivan 1964; Lmw 515/12-2-21; 23.9/71.8; 19-9.

25. W. prisca; Lmw 423-2-14; 21.4/79/1; 31-41.

26. W. prisca; Lmw 514a./14-3-B1; 4.1/62.3; 26-28.

27. Waltzispora sp. A; Lmw 42-1-18; *3.5/67.5; 26-29.

PLATE 6

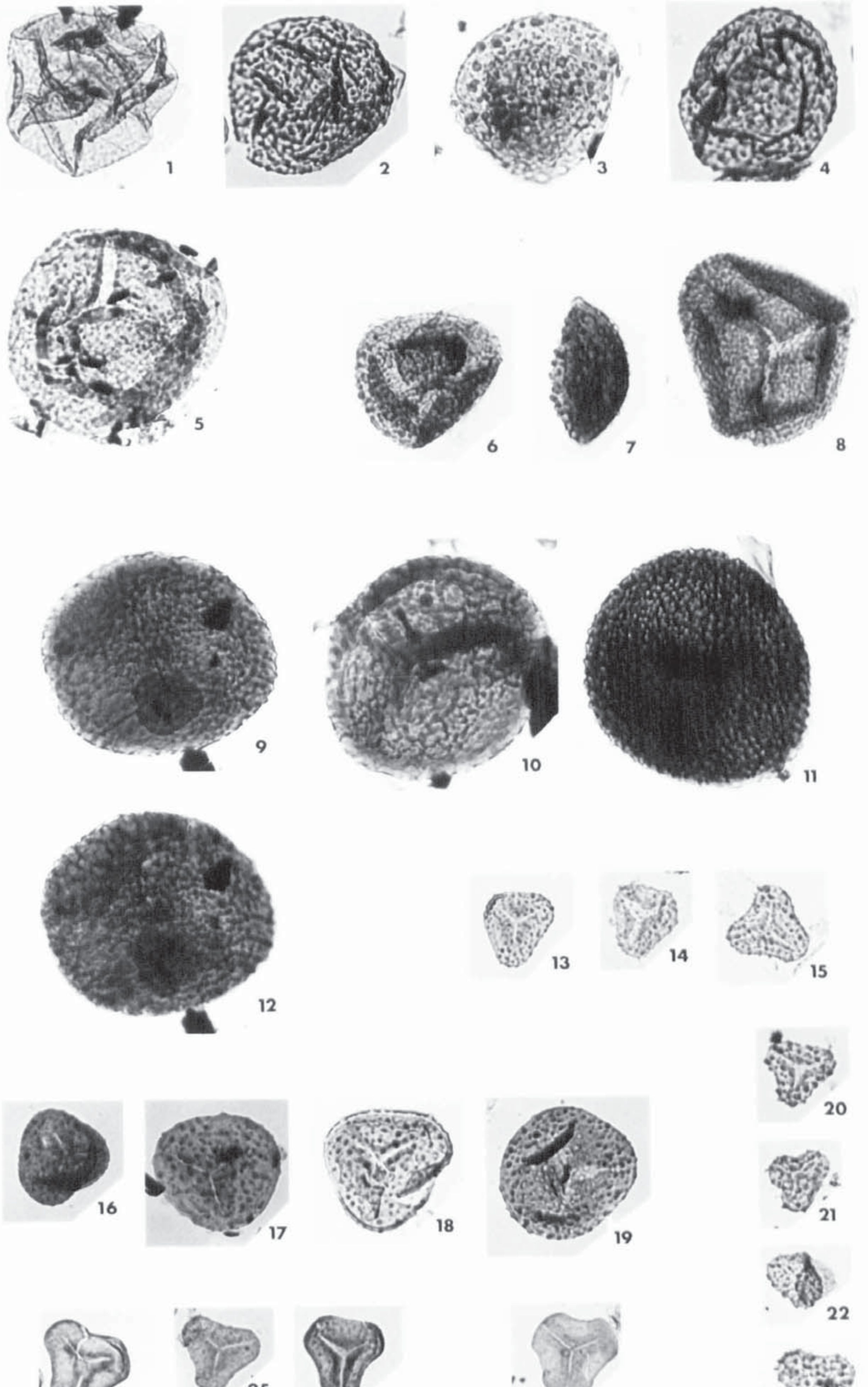

PLATE 7

Fig No.

1. Anapiculatisporites minor (Butterworth and Williams) Smith and Butterworth 1967; Lmw 428-2-R6; 30.6/68.6; 26-30.
2. A. minor; Lmw 436b-1-6c; 5.5/73.6; 26-32.
3. Anapiculatisporites sp. A; Lmw 427a-1-2b; 27.1/62.9; 26-33.
4. A. sp. A; Lmw 504-2-8; 26.8/77.3; 31-43; equatorial view.
5. A. sp. A; Lmw 515/12-2-18; *4.2/80.0; 19-6; distal surface.
6. Anapiculatisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967; Lmw 511-1-1; 14.1/66.8; 31-2; tetrad.
7. A. baccatus; Lmw 461-3-G; 6.1/62.0; 26-37.
8. A. baccatus; Lmw 473b-2-2e; 21.3/80.1; 31-1; equatorial view.
9. A. baccatus; Lmw 461-1-2; 19.4/63.8; 26-35; equatorial view.
10. A. baccatus; Lmw 480-1-4; 9.5/58.6; 26-39; distal surface.
11. Anapiculatisporites sp. A; Lmw 458b-1-R2; 16.1/60.5; 13-17; equatorial view.
12. A. sp. A; Lmw 4586-1-G6; 17.0/59.1; 13-17; equatorial view.
13. Pustulatisporites pustulatus Potonie and Kremp 1954; Lmw 438/14-3-6; 16.3/59.6; 26-40.
14. P. pustulatus; Lmw 438/14-3-G; 21.0/73.2; 26-41.
15. P. pustulatus; Lmw 438/14-3-G; 21.0/73.2; 26-42, distal surface.
16. Apiculatisporis abditus (Loose) Potonie and Kremp 1955; Lmw 472-1-6a; 9.6/73.8; 26-44.
17. A. abditus; Lmw 472-1-6a; 9.6/73.8; 26-43; distal surface.
18. A. abditus; Lmw 492-3-GBii; 29.8/79.1; 31-17; equatorial view.
19. Apiculatisporis aculeatus (Ibrahim) Smith and Butterworth 1967; Lmw 515/52-1-34; 1.9/77.8; 21-23; distal surface.
20. A. aculeatus; Lmw 515/5.5-1-556; 7.3/84.9; 21-1.
21. A. aculeatus; Lmw 454-1-8; 3.5/61.6; 26-3.
22. Apiculatisporis irregularis (Alpern) Smith and Butterworth 1967; Lmw 485a-3-H; 11.0/63.8; 26-5.
23. A. irregularis; Lmw 461-1-4b; 4.0/63.9; 26-6; tetrad.
24. A. irregularis; Lmw 490b-2-R5; 18.6/73.3; 26-8.
25. A. irregularis; Lmw 443-1-B2; *4.8/70.1; 26-7.
26. Apiculatisporis cf. latigranifer (Loose) Potonie and Kremp 1955 in Smith and Butterworth 1967; Lmw 440b-1-4; 12.2/68.9; 26-10.
27. A. cf. latigranifer; Lmw 448-1-16; 25.8/71.1; 26-9.
28. Apiculatisporis spinosaetosus (Loose) Smith and Butterworth 1967; Lmw 490c-1-8; 3.4/80.0; 27-20.
29. A. spinosaetosus; Lmw 461-3-Dl 6.1/69.8; 26-12.
30. A. spinosaetosus; ST4/2-3-15; 23.0/81.5; 6-16; Un-named seam at 569.12m, Solomon's Temple borehole Warwickshire; Westphalian A.

PLATE 7

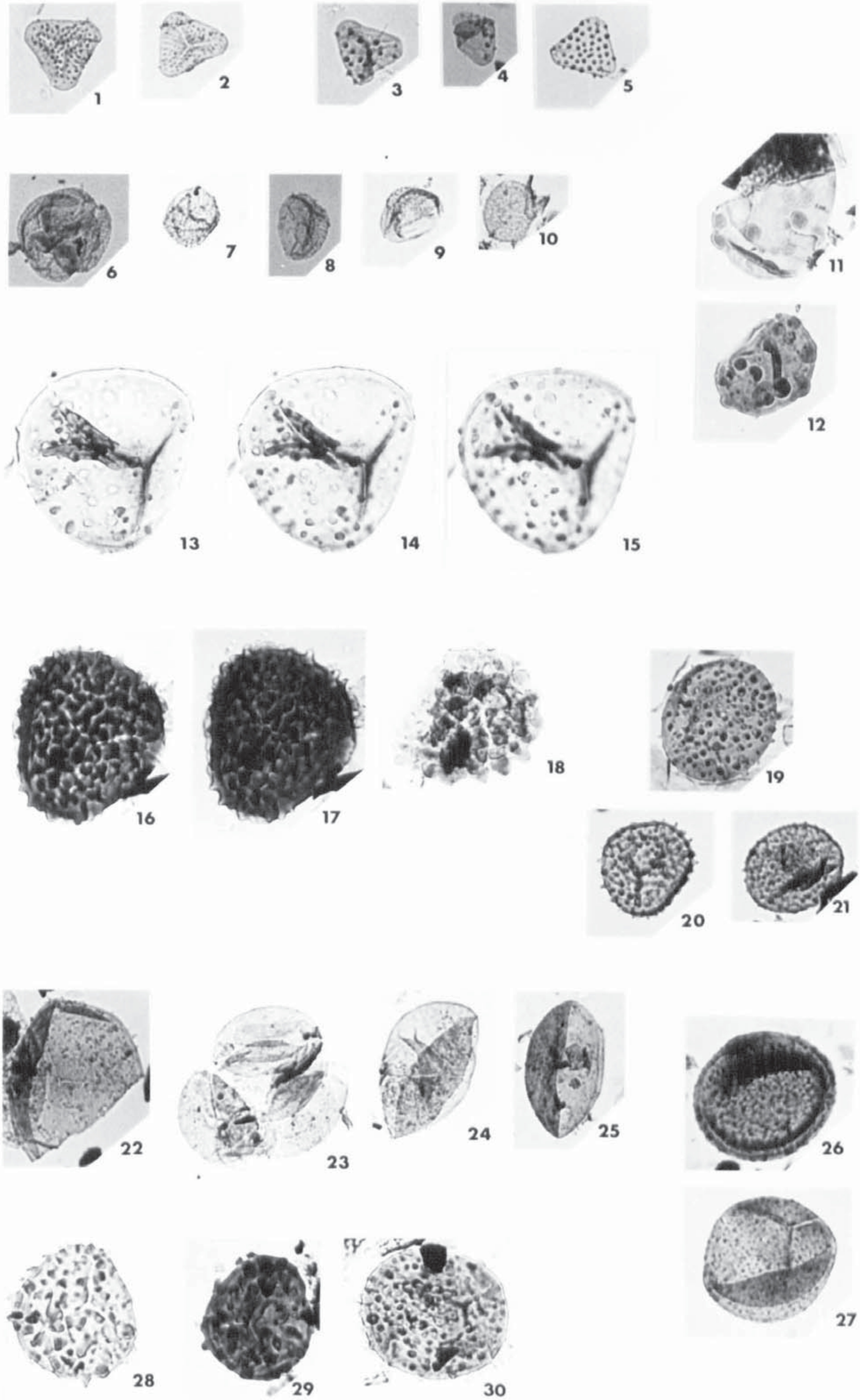
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PLATE 8

Fig No.

1. Planisporites granifer (Ibrahim) Knox 1950; Lmw 449-1-8a; 20.0/40.1; 11-7.
2. P. granifer; Lmw 515/5.5-1-12c; 5.6/69.9; 20.24.
3. P. granifer; Lmw 515/12-3-84; 33.0/80.8;35-4.
4. P. granifer; Lmw 443-2-BK; 17.3/71.0; 27-21.
5. Apiculatasporities spinulistratus (Loose) Ibrahim 1933; Lmw 467-3-4; 8.8/71.9; 27-24.
6. A. spinulistratus; Lmw 437-3-Fii; 29.1/81.3; 27-22.
7. A. spinulistratus; ST4/2-2-2; 19.5/62.0; 5-20; Un-named seam at 569.12m, Solomon's Temple borehole, Warwickshire; Westphalian A.
8. Acanthotriletes echinatus (Knox) Potonie and Kremp 1955; Lmw 424b-1-1; 30.6/76.3; 27-25.
9. A. echinatus; Lmw 515/12-1-31b; 19.6/79.9; 18-4.
10. A. echinatus; Lmw 515/5.5-1-5; *2.3/81.8; 19-24.
11. A. echinatus; Lmw 515/5.5-1-59; 27.3/85.5; 22-17.
12. Acanthotriletes triquetrus Smith and Butterworth 1967; Lmw 435-3-C; 11.2/81.8; 27-27.
13. A. triquetrus; Lmw 515/12-2-1; *8.4/83.5; 18-21.
14. A. triquetrus; Lmw 515/12-2-14b; 10.1/69.2; 19-44.
15. A. triquetrus; Lmw 515/1-2-; 14.4/76.9; 27-26.
16. Ibrahimispores sp. A; Lmw 469-1-2; 27.8/72.7; 27-29.
17. I. sp. A; Lmw 449-2-1; 10.8/69.1; 27-31.
18. I. sp. A; Lmw 449-2-1; 10.8/69.1; 14-8; distal surface.
19. Raistrickia firma (Loose) Smith 1971; Lmw 515/12-2-24; 22.0/76.6; 35-44.
20. R. firma; Lmw 515/12-1-20; 16.0/75.3; 17-10.
21. R. firma; Lmw 494-3-A; 307/74.1; 27-32.
22. R. firma; Lmw 515.12-2-9; *8.1/83.8; 19-36; distal surface.
23. Raistrickia fulva Artuz 1957; Lmw 515/12-2-19; *6.5/79.9; 19-7.
24. R. fulva; Lmw 515/5.5-3-38a; 29.1/83.9; 23-19.
25. R. fulva; Lmw 515/5.5-1-3b; 8.7/66.1; 19-22.
26. R. fulva; Lmw 515/12-1-7a; *8.1/82.2; 17-40.
27. Raistrickia cf. lowellensis Peppers 1970; Lmw 424b-1-10; 26.2/85.0; 27-33.
28. R. cf. lowellensis; Lmw 508b-3-A; 22.2/68.7; 27-40.
29. R. cf. lowellensis; Lmw 485a-3-B; 26.2/76.5; 27-38.
30. R. cf. lowellensis; Lmw 449-3-L; 16.8/76.6; 27-35.

PLATE 8

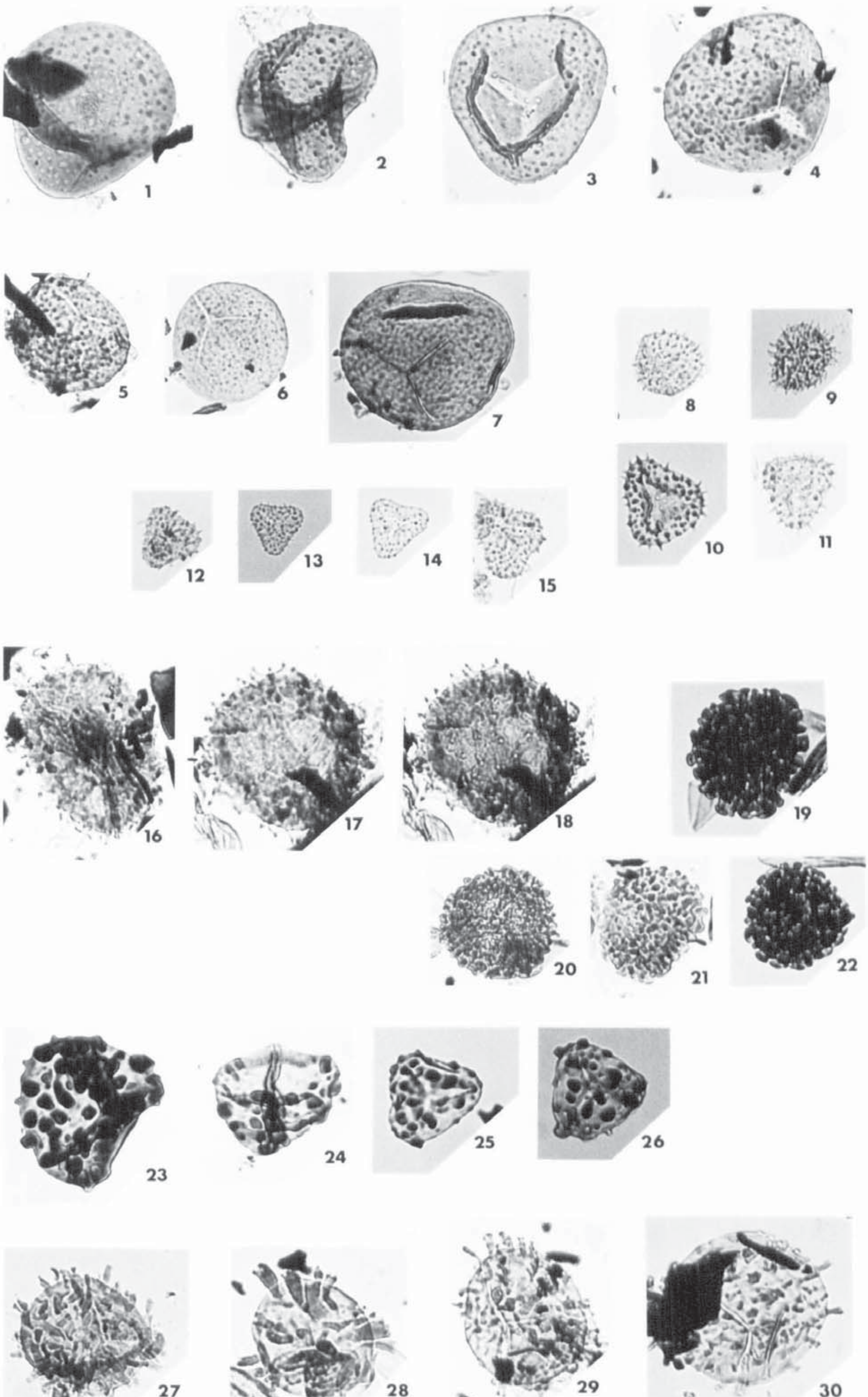
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PLATE 9

Fig No.

1. Raistrickia pilosa Kosanke 1950; Lmw 513b-12-1-4; 23.5/70.1; 27-43.
2. R. pilosa; Lmw 514a/14-1-J; 20.4/81.2; 27-44.
3. R. pilosa; Lmw 473b-3-0; 22.8/80.2; 27-42.
4. Raistrickia saetosa (Loose) Schopf, Wilson and Bentall 1944; Lmw 473a-3-B; 4.6/75.3; 27-37.
5. R. saetosa; Lmw 495-1-8a; 25.9/77.0; 27-3.
6. R. saetosa; Lmw 496-1-9b; 13.5/69.2; 31-6; distal surface.
7. R. saetosa; Lmw 515/5.5-1-5b; 29.1/85.1; 22-15; distal surface.
8. Raistrickia solaria Wilson and Hoffmeister 1956; Lmw 449-3-F; *5.1/70.8; 27-5.
9. R. solaria; Lmw 471-3-D; 14.3/77.0; 27-7.
10. Spackmanites ellipticus Habib 1966; Lmw 480-1-G3; 21.4/74.8; 31-7.
11. S. ellipticus; Lmw 495-1-6; 1.8/67.8; 27-13; distal surface.
12. S. ellipticus; Lmw 473a-3-C; 13.5/78.2; 27-10.
13. S. ellipticus; Lmw 473a-3-C; 13.5/78.2; 27-11; distal surface.
14. Convolutispora sp. A; 485b-1-9; 24.1/74.7; 28-22.
15. C. sp. A; Lmw 426-1-Ci; 24.5/66.5/28-20.
16. Convolutispora sp. B; Lmw 453a-1-R3; 25.1/71.0; 28-23.
17. C. sp. B; Lmw 515/5.5-1-8; 17.9/68.5; 20-18.
18. Convolutispora sp. C; Lmw 504-2-9; 18.5/69.0; 31-9.
19. C. sp. C; Lmw 485a-3-J; 5.0/73.4; 28-26.
20. C. sp. C; Lmw 492-3-ci; 3.0/71.6; 28-24; distal surface.
21. C. sp. C; Lmw 515/5.5-1-12a; 8.7/76.3; 20-25.
22. C. sp. C; Lmw 515/5.5-1-12a; 8.7/76.3; 20-24; distal surface.
23. C. sp. C; Lmw 484-3-C; 12.1/76.6; 28-37; distal surface.
24. Convolutispora sp. D; Lmw 426/2-1-10; 24.7/81.2; 28-27.
25. C. sp. D; Lmw 492-1-9; *46.1/82.8; 28-29.
26. C. sp. D; Lmw 504-2-1; *39.0/79.5; 31-8.
27. Microroeticulatisporites harrisonii Peppers 1970; Lmw 442b-3-C; 16.2/81.2; 28-31.
28. M. harrisonii; Lmw 515/5.5-1-38; 5.0/78.9; 21-28.
29. M. harrisonii; Lmw 473a-3-A; *46.7/75.6; 28-32.
30. Microreticulatisporites nobilis (Wicher) Knox 1950; Lmw 491-3-C; 6.4/80.5; 28-33.
31. M. nobilis; Lmw 490c-3-H; 20.1/80.9; 28-35.

PLATE 9

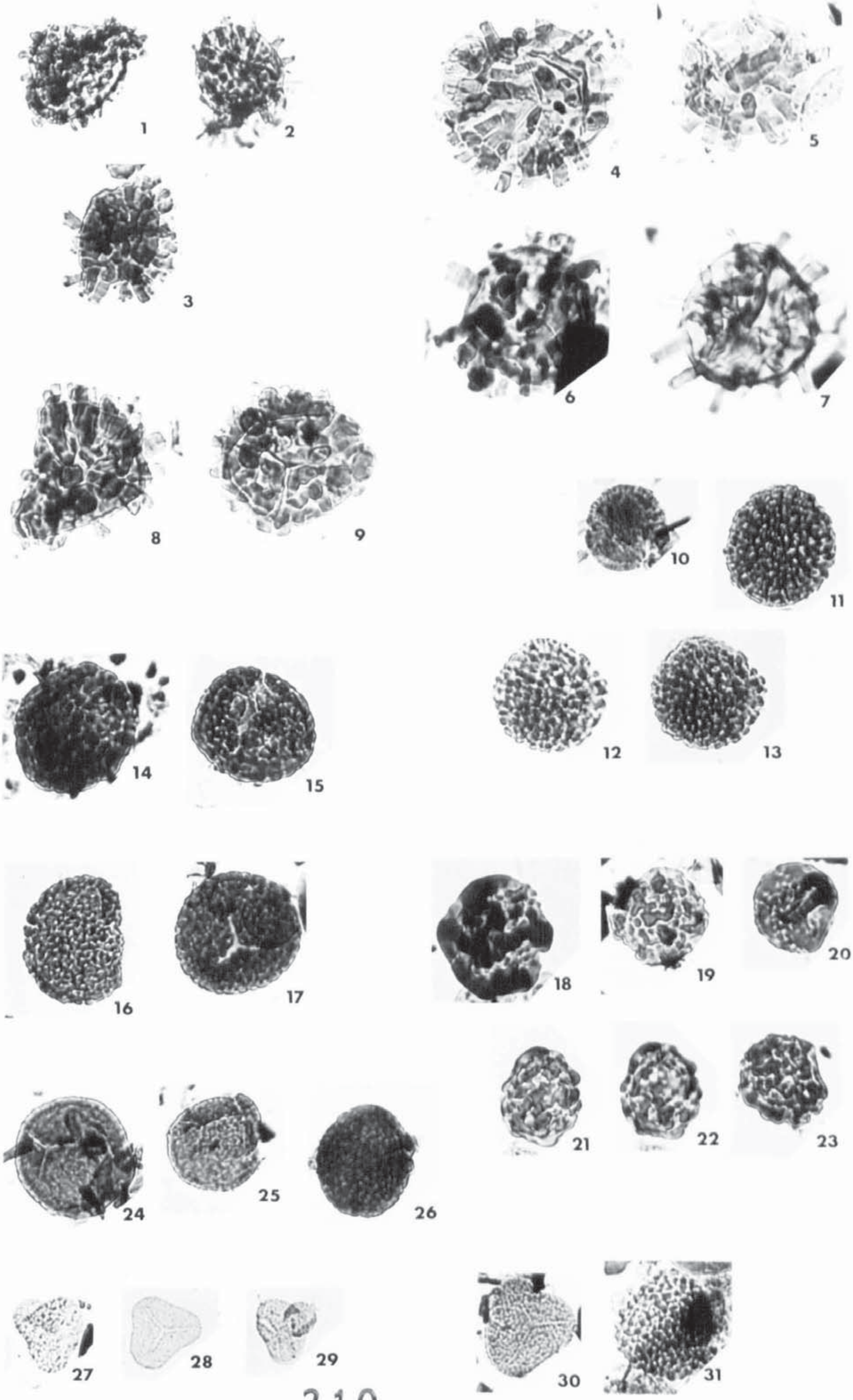
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PLATE 10

Fig No.

1. Secarisporites remotus Neves 1961; Lmw 448-1-19; 4.0 x 72.1; 12-9.
2. S. remotus; Lmw 474-3-F;26,.4/84.0; 28-36.
3. S. remotus; Lmw 488-3-B; 12.3/73.6; 28-1.
4. Dictyotriletes bireticulatus (Ibrahim) Smith and Butterworth 1967; Lmw 449-3-Eii; 5.1/66.5; 12-5.
5. D. bireticulatus; Lmw 428-2-B; 12.5/72.1; 28-39.
6. D. bireticulatus; Lmw 449-1-8b; 4.7/72.0; 28-40; equatorial view.
7. Dictyotrietes castaneaeformis (Horst) Sullivan 1964; Lmw 515/5.5-1-13; *2.9/79.8; 20-27.
8. D. castaneaeformis; Lmw 515/5.5-3-38b; 29.8/79.3; 35-31.
9. D. castaneaeformis; Lmw 515/5.5-3-38b; 29.8/79.3; 35-32; Mag. X1000.
10. D. castaneaeformis; Lmw 455-3-C; 23.8/74.5; 28-41.
11. D. castaneaeformis; Lmw 458b-1-G4; 1.9/66.7; 28-43.
12. Dictyotriletes falsus Potonie and Kremp 1955; Lmw 515/12-2-26; 18.7/79.4; 19-14.
13. D. falsus; Lmw 485a-1-6; 9.9/70.9; 28-44.
14. D. falsus; Lmw 515/12-2-2; *5.0/85.5; 18-22.
15. Dictyotriletes muricatus (Kosanke) Smith and Butterworth 1967; Lmw 515/12-1-16; *6.5/78.6; 17-6.
16. D. muricatus; MHG-1-2; *4.1/82.9; 31-11; Leaf 2, Thick Coal; Moat House Farm borehole, Warwickshire; Westphalian B.
17. D. muricatus; Lmw 492-1-16; 20.5/71.5; 28-2.
18. Dictyotriletes reticulocingulum; (Loose) Smith and Butterworth 1967; Lmw 515/5.5-3-24; 10.7/73.7; 23-5.
19. D. reticulocingulum; Lmw 515/5.5-3-24; 10.7/73.7; 23-5; distal surface.
20. D. reticulocingulum; Lmw 515/12-1-2b; 21.4/77.5; 18-38.
21. D. reticulocingulum; Lmw 515/5.5; *8.9/83.0; 19-23.
22. D. reticulocingulum; Lmw 443-2-BL; 30.8/72.9; 28-4.
23. Camptotriletes bucculentus (Loose) Potonie and Kremp 1955; Lmw 449-1-1; 5.3/66.4; 28-6.
24. C. bucculentus Lmw 515/5.5-1-23; *12.2/75.4; 20-39.
25. C. bucculentus Lmw 508b-3-F; 8.0/76.9; 28-10.
26. C. bucculentus Lmw 508b-3-F; 8.0/76.9; 28-9; distal surface.
27. C. bucculentus; Lmw 484-3-B; 14.0/71.8; 28-8.
28. Camptotriletes corrugatus; (Ibrahim) Potonie and Kremp 1954; Lmw 515/12-2-20; 27.2/71.4; 19-8.
29. C. corrugatus; Lmw 515/5.5-3-49; *41.0/84.5; 31-12.

PLATE 10

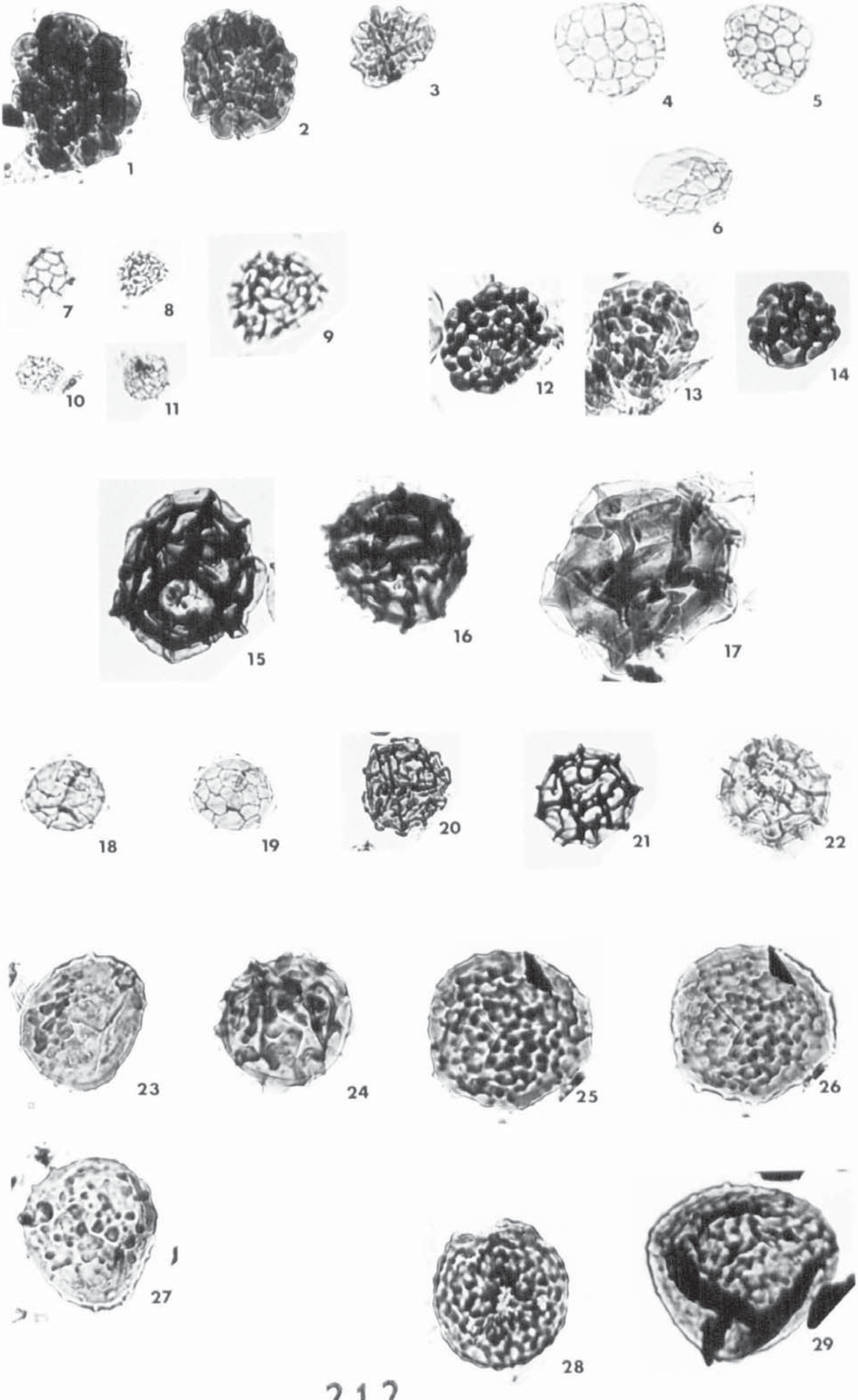

PLATE 11

Fig No.

1. Camptotriletes sp. A; Lmw 434-1-4; 10.5/82.8; 28-13.
2. C. sp. A; Lmw 481-1-5; 20.5/70.7; 29-19.
3. C. sp. A; Lmw 473a-1-1; 5.9/72.5; 29-17.
4. C. sp. A; Lmw 490a-3-3b; 26.7/78.4; 29-20.
5. Ahrensisporites guerickei (Horst) Potonie and Kremp 1954; Lmw 515/12-1-23 *9.5/72.3;17-14.
6. A. guerickei; Lmw 515/12-2-6; 13.2/64.3; 18-26.
7. A. guerickei; Lmw 515/5.5-1-37; 10.0/78.7; 21-27.
8. A. guerickei; Lmw 515/5.5-1-32; *12.4/71.9; 21-19; equatorial view.
9. Triquitrites protensus Kosanke 1950; Lmw 490c-3-B; *30.9/81.6; 29-22.
10. T. protensus; Lmw 515/5.5-3-1; *6.2; 22-38.
11. T. protensus; Lmw 515/12-1-37; 2.8/82.0; 18-14.
12. T. protensus; Lmw 515/12-1-35; *6.4/68.9; 18-12.
13. Triquitrites tribullatus (Ibrahim) Schopf, Wilson and Bentall 1944; Lmw 446-1-9b; 26.6/72.9; 29-24.
14. T. tribullatus; Lmw 453b-3-f; 30.5/67.7; 29-25.
15. Tantillus triquetrus Felix and Burbridge 1967; Lmw 489-1-3a; 8.6/66.6; 29-29.
16. T. triquetrus; Lmw 515/5.5-1-50; 17.1/82.3; 21-39.
17. T. triquetrus; Lmw 430b-3-B; *5.1/70.8; 29-26.
18. T. triquetrus; Lmw 443-2-BM; 10.4/74.0; 29-27.
19. Reinschospora speciosa (Loose) Schopf, Wilson and Bentall 1944; Lmw 460/2-3D; 24.4/73.9; 29-31.
20. R. speciosa; Lmw 492-1-G12; 9.4/71.9; 29-33.
21. Reinschospora triangularis Kosanke 1950; ST8/2-1-3; 0.1/61.1; 8-19.
22. Knoxisporites triradiatus Hoffmeister, Staplin and Malloy 1955;1 Lmw 461-1-6; 20.6/81.6; 29-34.
23. K. triradiatus; Lmw 476-3-Fi; 1.2/71.9; 29-35.
24. Reticulatisporites polygonalis (Ibrahim) Smith and Butterworth 1967; Lmw 516/14-2-12; 24.6/75.0; 22-30.
25. R. polygonalis; Lmw 516/14-2-12; 24.6/75.0; 22-31; distal surface.
26. R. polygonalis; Lmw 516/14-2-4; *7.3/78.5; 22-24.
27. Reticulatisporites reticulatus Ibrahim 1933; Lmw 502-3-B; 42.7/73.4; 29-40; distal surface.
28. R. reticulatus; Lmw 428-2-R3; 23.5/67.1; 29-39; distal surface.
29. R. reticulatus; Lmw 515/12-3-B2; 30.0/71.9; 35-2.

PLATE 11

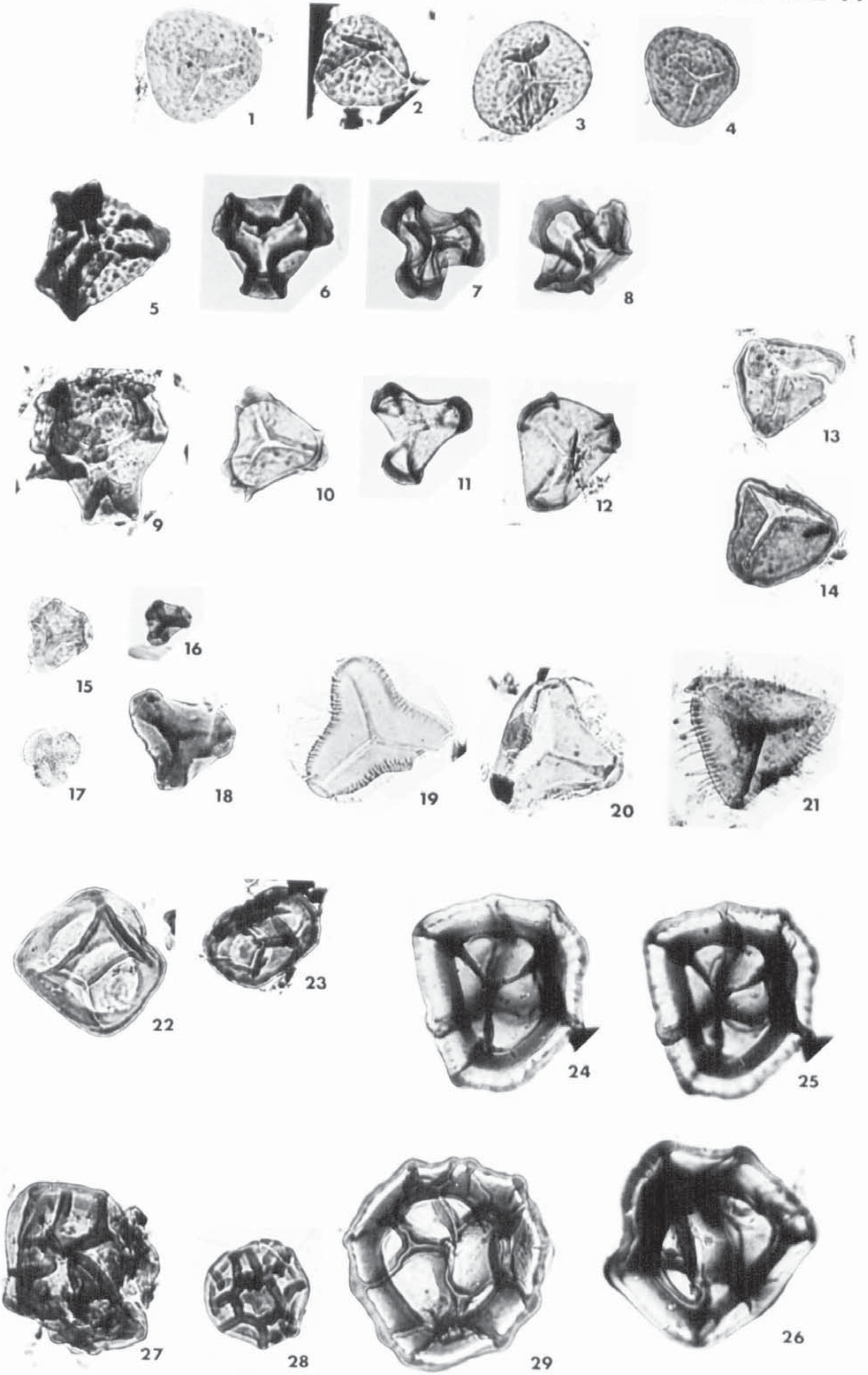

PLATE 12

Fig No.

1. Savitrisporites concavus Marshall and Smith 1965; Lmw 514a/14-1-E; *7.1/76.2; 29-43.
2. S. concavus; Lmw 450-3-C; 7.5/81.7; 29-1.
3. S. concavus; Lmw 451-1-B2; 29.1/75.0; 14-27.
4. S. concavus; Lmw 513b/14-3-G; 30.9/73.3; 29-44.
5. Savitrisporites nux (Butterworth and Williams) Sullivan 1964; ST4/2-1-4b; 7.1/71.0; 3-27; Un-named seam at 569.12m Solomon's Temple borehole, Warwickshire; Westphalian A.
6. S. nux; Lmw 514a/14-3-7; 4.9/81.3; 29-2.
7. S. nux; ST4/2-1-5; 18.5/71.1; 3-35; Un-named seam at 569.12m, Solomon's Temple borehole, Warwickshire; Westphalian A.
8. Savitrisporites sp. A; Lmw 490c-1-9; 18.1/81.1; 29-5.
9. S. sp. A; Lmw 445-3-C; 15.4/72.7; 29-3.
10. Grumosisporites varioreticulatus (Neves) Smith and Butterworth 1967; Lmw 475-1-9; 23.0/66.9; 29-6.
11. G. varioreticulatus; Lmw 475-3-A; 12.6/71.0; 29-8.
12. Diaphanospora parvigracila (Peppers) Ravn 1979; Lmw 515/5.5-3-7b; *2.3/83.0; 22-40.
13. D. parvigracila; Lmw 449-1-7; 12.0/72.8; 30-20.
14. D. parvigracila; Lmw 449-1-7; 12.0/72.8; 30-19; distal surface.
15. D. parvigracila; Lmw 494-1-2; 8.3/66.7; 30-18.
16. Diaphanospora sp. A; Lmw 485b-3-B; 11.5/76.8; 30-21.
17. D. sp. A; Lmw 515.5 1/2-3-17b; 6.0/70.5; 22-6.
18. D. sp. A; Lmw 515.5-3-17b; 6.0/70.5; 22-7; distal surface.
19. D. sp. A; Lmw 515.5--1-52; 28.2/82.8; 21-41.
20. D. sp. A; Lmw 515.5-1-52; 28.2/82.8; 21-42; distal surface.
21. Hymenospora multirugosa Peppers 1970; Lmw 428-3-B; 26.1/77.0; 30-24.
22. H. multirugosa; Lmw 515/12-1-21; *6.2/73.7; 17-11.
23. H. multirugosa; Lmw 515/12-1-24; 8.4/77.5; 18-26; distal surface.
24. H. multirugosa; Lmw 515/12-1-32b; *0.3/68.9; 18-7.
25. H. multirugosa; Lmw 515/12-1-32b; *0.3/68.9; 18-7; distal surface.
26. Hymenospora cf. paucirugosa Peppers 1970; Lmw 515/12-3-B5; 24.5/68.2; 35-5.
27. H. paucirugosa; Lmw 452b-1-B1; 20.1/40.0; 14-32.
28. H. paucirugosa; Lmw 508b-1-D; 22.7/74.3; 30-25.
29. Crassispora kosankei (Potonie and Kremp) Smith and Butterworth 1967; Lmw 443-2-G1; 12.2/81.6; 30-27.
30. C. kosankei; Lmw 459-3-A; 25.7/74.7; 30-29; equatorial view.
31. C. kosankei; Lmw 425/2-1-14; 14.0/68.2; 30-28; tetrad.

PLATE 12

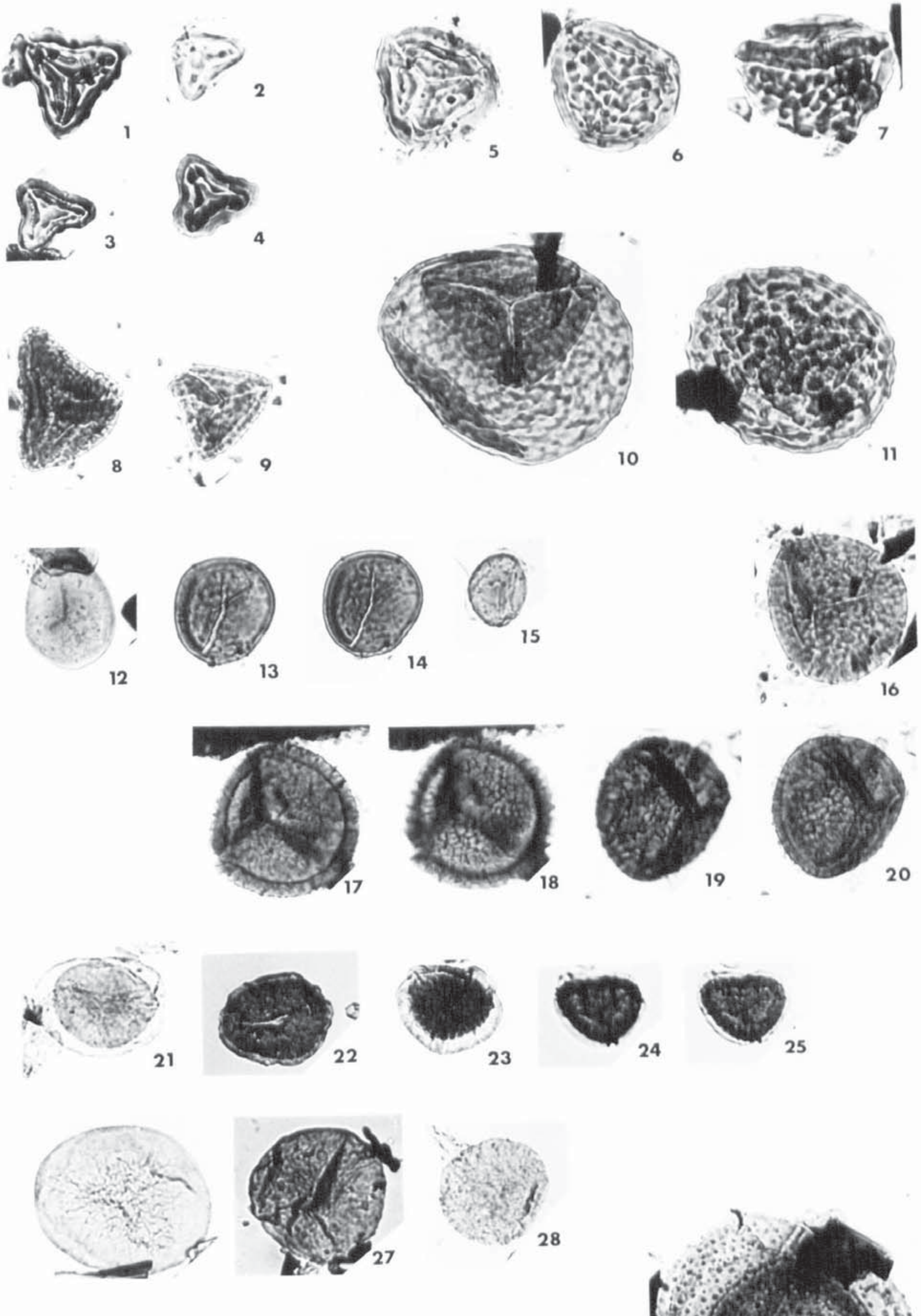

PLATE 13

Fig No.

1. Simozonotriletes intortus (Waltz) Potonie and Kremp 1954; Lmw 489-3-D; *39.0/67.6; 30-32.
2. S. intortus; Lmw 491-3-B; 25.5/85.3; 30-30.
3. S. intortus; Lmw 494-3-E; 22.1/85.4; 30-31.
4. Densosporites cf. anulatus (Loose) Smith and Butterworth 1967; Lmw 490c-3-G; *2.9/82.1; 30-41; equatorial view.
5. D. cf. anulatus; Lmw 490c-3-A; *2.9/69.3; 30-40; tetrad.
6. D. cf. anulatus; Lmw 457a-3-Ga; 18.5/66.4; 30-1.
7. D. cf. anulatus; Lmw 427a-3GA; 4.6/75.2; 30-42.
8. D. cf. anulatus; Lmw 453b-1-G; 10.9/78.3; 30-39.
9. D. cf. anulatus; Lmw 451-2-1; 32.1/70.5; 14-26.
10. D. cf. anulatus; Lmw 490c-1-G1; 29.8/65.3; 30-2.
11. D. cf. anulatus; Lmw 450-1-G1; 0.1/73.9; 30-38.
12. D. cf. anulatus; MHH-1-G1; 8.8/81.4; 30-37; Leaf 3, Thick Coal, Moat House Farm borehole, Warwickshire; Westphalian B.
13. D. cf. anulatus; MHH-1-G1; 8.8/81.4; 30-36; distal surface; Leaf 3; Thick Coal, Moat House Farm borehole, Warwickshire; Westphalian B.
14. D. cf. anulatus; Lmw 493-1-G5; 26.9/82.3; 30-33.
15. Densosporites cf. duriti; Potonie and Kremp 1956; Lmw 492-1-G9; 12.1/83.0; 30-11; equatorial view.
16. D. cf. duriti; Lmw 515/5.5-1-17; 14.2/70.8; 20-32.
17. D. cf. duriti; MHC-1-G1; 3.2/71.7; 30-3-; Leaf 1; Thick Coal; Moat House Farm borehole; Warwickshire; Westphalian B.
18. D. cf. duriti; Lmw 445-3-G3b; *6.1/83.5; 30-7.
19. D. cf. duriti; Lmw 492-1-G3; 5.4/81.0; 30-5.
20. D. cf. duriti; Lmw 492-1-G11; 16.9/72.9; 30-8.
21. D. cf. duriti; Lmw 492-1-G11; 16.9/72.9; 30-9; distal surface.
22. D. cf. duriti; Lmw 492-3-GB; 29.8/79.1; 31-16; tetrad proximal focus.
23. D. cf. duriti; Lmw 492-3-GB; 29.8/79.1; 31-17; tetrad distal focus.
24. Densosporites gracilis Smith and Butterworth 1967; Lmw 445-1-7; 18.5/59.5; 14-13.
25. D. gracilis; Lmw 445-1-7; 14.7/66.5; 31-18; distal surface.
26. D. gracilis; Lmw 453a-1-B1; 14.9/68.1; 32-4; distal surface.
27. D. gracilis; Lmw 489-1-G5; 3.6/70.0: 32-1.
28. D. gracilis; Lmw 492-3-GC; 26.2/63.9; 32-6; tetrad.
29. D. gracilis; Lmw 455-1-2; 20.1/40.0; 12-31; equatorial view.
30. D. gracilis; Lmw 493-1-G7; *41.1/66.9; 32-5; equatorial view.

PLATE 13

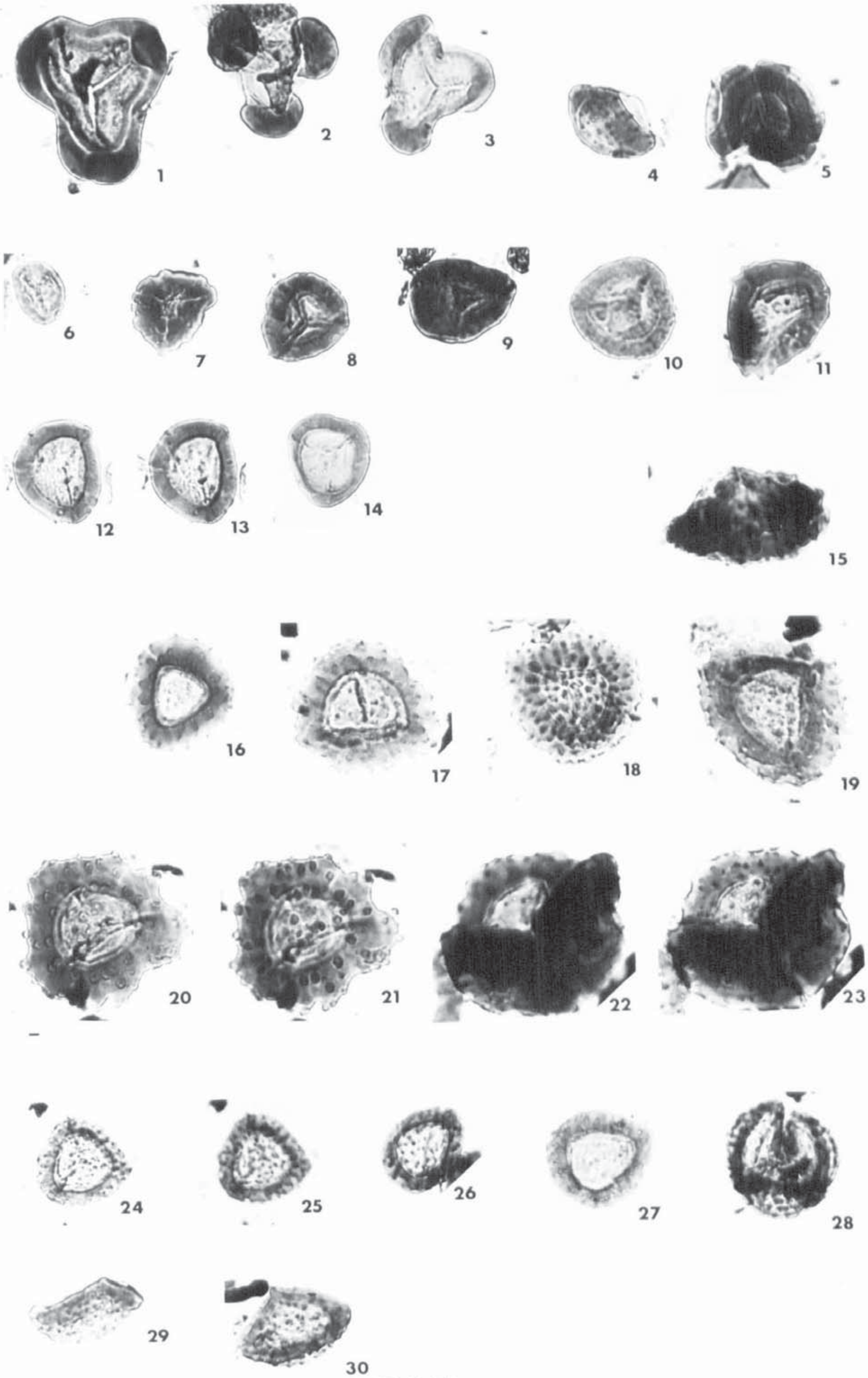
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PLATE 14

Fig No.

1. Densosporites cf. granulosus Kosanke 1950; Lmw 491-3-G3; 9.4/82.9; 32-7.
2. D. cf. granulosus; MHD-3-GC; 19.8/77.5; 32-9; Leaf 1; Thick Coal; Moat House Farm borehole; Warwickshire; Westphalian B.
3. D. cf. granulosus; MHD-3-GC;19.8/77.5; 32-8; distal surface; Leaf 1; Thick Coal; Moat House Farm borehole; Warwickshire; Westpahlian B.
4. D. cf. granulosus; Lmw 467-3-I; 19.0/79.1; 32-11.
5. D. cf. granulosus; Lmw 467-3-I; 19.0/79.1; 32--12; distal surface.
6. D. cf. granulosus; Lmw 492-1-G12; 10.1/72.0; 32-13; circle of vacuoles present.
7. D. cf. granulosus; Lmw 474-1-G1; 7.5/68.3; 31-10; medial focus.
8. D. cf. granulosus; Lmw 491-1-G13; 19.0/79.4; 32-18; equatorial view.
9. D. cf. granulosus; Lmw 491-1-GS; 6.0/69.8; 32-16; equatorial view.
10. D. cf. granulosus; Lmw 491-1-GS; 6.0/69.8; 32-16; equatorial view; mag. X1000.
11. Densosporities sphaerotriangularis Kosanke 1950; Lmw 452a-3-GB; 12.2/74.5; 32-19; distal surface.
12. D. sphaerotriangularis; Lmw 451-1-1f; 20.0/40.1; 12-16.
13. D. sphaerotriangularis; Lmw 490c-3-G6;l 3.9/75.6; 32-23.
14. D. sphaerotriangularis; Lmw 490c-3-G; 9.2/70.9; 32-22; distal surface.
15. D. sphaerotriangularis; Lmw 451-1-3a; 20.1/40.0; 12-20.
16. D. sphaerotriangularis; Lmw 451-1-1d; 10.0/40.1; 12-15; distal surface.
17. D. sphaerotriangularis; Lmw 490c-3-G1; 25.1/65.8; 32-20; distal surface.
18. D. sphaerotriangularis; Lmw 489-3-G; 26.5/76.8; 32-24; tetrad.
19. D. sphaerotriangularis; Lmw 452b-2-GA; *42.0/82.2; 32-27; equatorial view.
20. D. sphaerotriangularis; Lmw 491-3-G3b; 9.3/82.8; 32-25; equatorial view.
21. Densosporites triangularis Kosanke 1950; Lmw 452a-3-B; 1.2/71.8; 32-31.
22. D. triangularis; Lmw 451-1-G2a; 11.3/69.7; 12-18; circles of vacuoles present.
23. D. triangularis; Lmw 515/5.5-1-61a; 1.1/64.8; 22-20; distal surface.
24. D. triangularis; Lmw 490c-1-G3; 26.9/80.1; 32-28.
25. D. triangularis; Lmw 490c-1-G3; 26.9/80.1; 32-29; distal surface.
26. D. triangularis; Lmw 489-1-2; 14.5/66.7; 32-33; equatorial view.
27. D. triangularis; Lmw 515/12-1-44; 4.6/69.2; 35-34; vacuoles in central area.
28. Lycospora orbicula (Potonie and Kremp) Smith and Butterworth 1967; Lmw 480-3-I; 19.5/74.3; 32-35.
29. L. orbicula Lmw 480-3-F; 14.5/79.1; 32-34.
30. L. orbicula Lmw 480-3-J; 0.1/73.3; 32-36; equatorial view.

PLATE 14

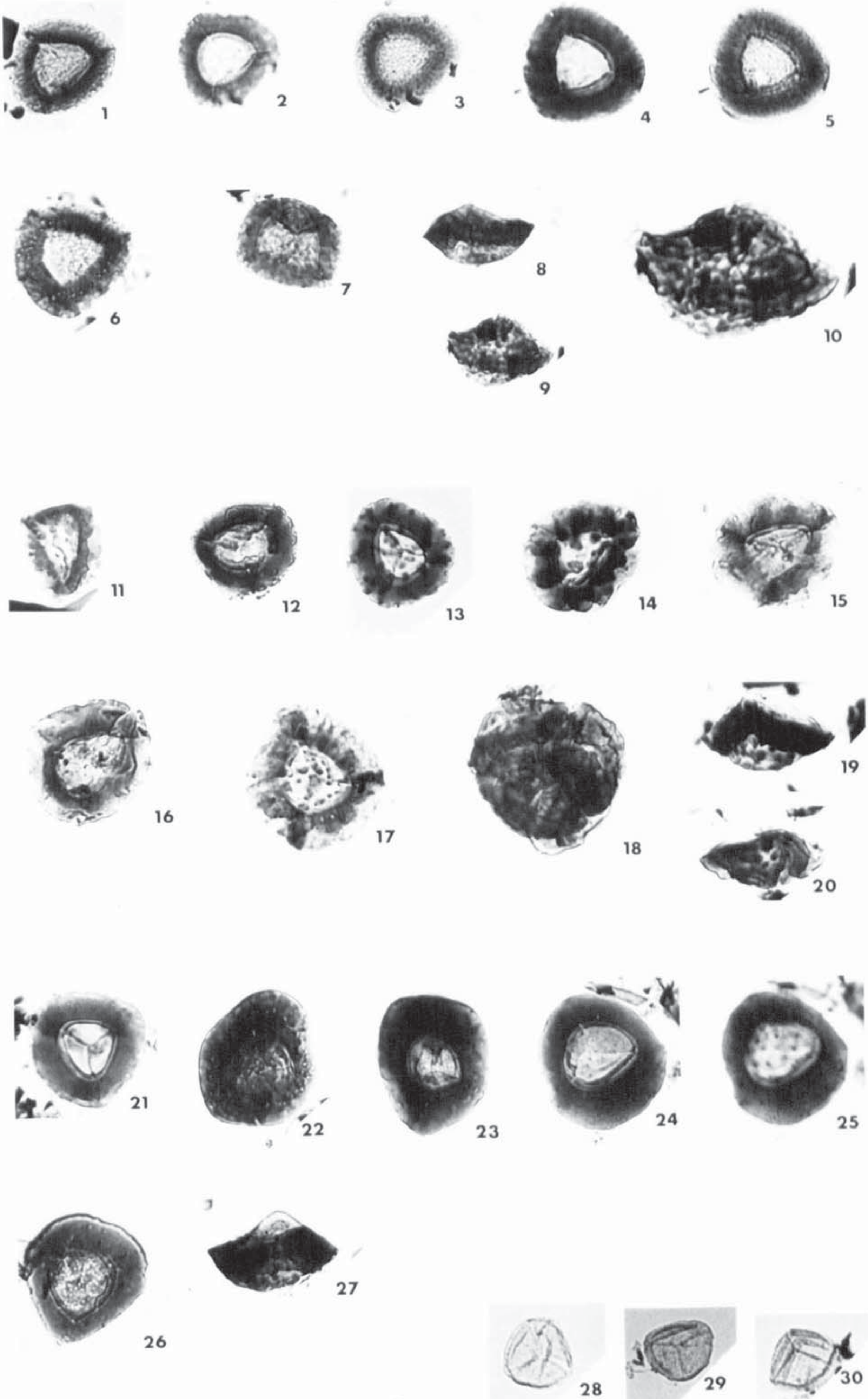

PLATE 15

Fig No.

1. Lycospora pellucida (Wicher) Schopf, Wilson and Bentnall 1944; Lmw 449-3-Ei; 5.1/67.2; 12-5.
2. L. pellucida; Lmw 480-3-GS; 19.9/67.8; 32-39.
3. L. pellucida; Lmw 515/5.5-3-26; 12.3/79.5; 23-7.
4. L. pellucida; Lmw 461-1-16; 14.3/66.9; 33-26; equatorial view.
5. Lycospora pusilla (Ibrahim) somers 1972; Lmw 480-3-GC; 33-27.
6. L. pusilla; Lmw 473b-2-GBii; 12.2/72.4; 33-29.
7. L. pusilla; Lmw 473b-2-GC; 21.0/70.8; 33-31.
8. L. pusilla; Lmw 473b-2-GB; 12.0/73.2; 33-32; tetrad.
9. L. pusilla; MHA-3-A; 11.3/66.6; 33-33; Leaf 1, Thick Coal; Moat House Farm borehole; Warwickshire; Westphalian B; equatorial view.
10. L. pusilla; Lmw 480-3-GG; 30.1/78.5; 35-8; equatorial view.
11. Lycospora rotunda (Bharadwaj) Somers 1972; Lmw 515/5.5-1-11; 16.1/69.4; 20-23.
12. L. rotunda; Lmw 480-3-GH; 25.4/82.2; 33-38.
13. L. rotunda; Lmw 515/5.5-1-33b; *7.5/71.9; 21-21.
14. L. rotunda; Lmw 477c-1-1; 21.3/66.6; 33-39; equatorial view.
15. L. rotunda; Lmw 459-1-G2; 17.3/73.3; 33-37; equatorial view.
16. L. rotunda; Lmw 440b-1-8a; 22.3/72.9; 33-40; equatorial view.
17. Lycospora rugosa Schemel 1951 (in Smith and Butterworth 1967); Lmw 515/12-2-2; 1.4/64.6; 18-23.
18. L. rugosa; Lmw 480-3-GA; *39.5/82.3; 33-41.
19. L. rugosa; Lmw 515/5.5-1-6b; 28.9/66.7; 19-26.
20. L. rugosa; Lmw 443-1-B8; *4.9/71.0; 33-42.
21. Cristatisporites connexus Potonie and Kremp 1955; Lmw 495-3-6; 5.7/64.6; 33-44; distal surface.
22. C. connexus; Lmw 515/12-2-15; 12.7/68.1; 19-2.
23. C. connexus; Lmw 515/12-2-15; 12.7/68.1; 19-3; distal surface.
24. C. connexus; Lmw 492-3-GD; *43.9/83.6; 33-4; equatorial view.
25. C. connexus; Lmw 492-3-GH; 9.5/71.8; 35-43; tetrad.
26. Cristatisporites indignabundus; (Loose) Staplin and Jansonius 1964; Lmw 515/5.5-1-19; *7.0/79.1; 20-35.
27. C. indignabundus; Lmw 465-3-B1; 2.9/88.6; 33-7.
28. C. indignabundus; Lmw 475-3-D; 21.2/71.7; 33-9.
29. Cirratriradiates saturni (Ibrahim) Schopf, Wilson and Bentall 1944; Lmw 480-3-F; 22.8/78.6; 33-14; equatorial view.
30. C. saturni; Lmw 460-1-9; 19.5/73.5; 33-15.
31. C. saturni; Lmw 477c-3-B; *41.3/78.3; 33-12.
32. C. saturni; Lmw 515/5.5-3-34; *3.5/73.2; 23-16.
33. Cingulizonates loricatus (Loose) Butterworth and Smith (in Butterworth et al. 1964); Lmw 515/12-1-39; 16.5/82.9; 18-16.
34. C. loricatus; Lmw 473b-3-A; 11.8/64.5; 33-16.
35. C. loricatus; Lmw 473b-3-A; 1.8/64.5; 33-16; high focus.
36. C. loricatus; Lmw 473b-2-F; 15.0/84.2; 33-19; tetrad.
37. C. loricatus; Lmw 473b-2-F; 15.0/84.2; 33-18; tetrad, high focus.

PLATE 15

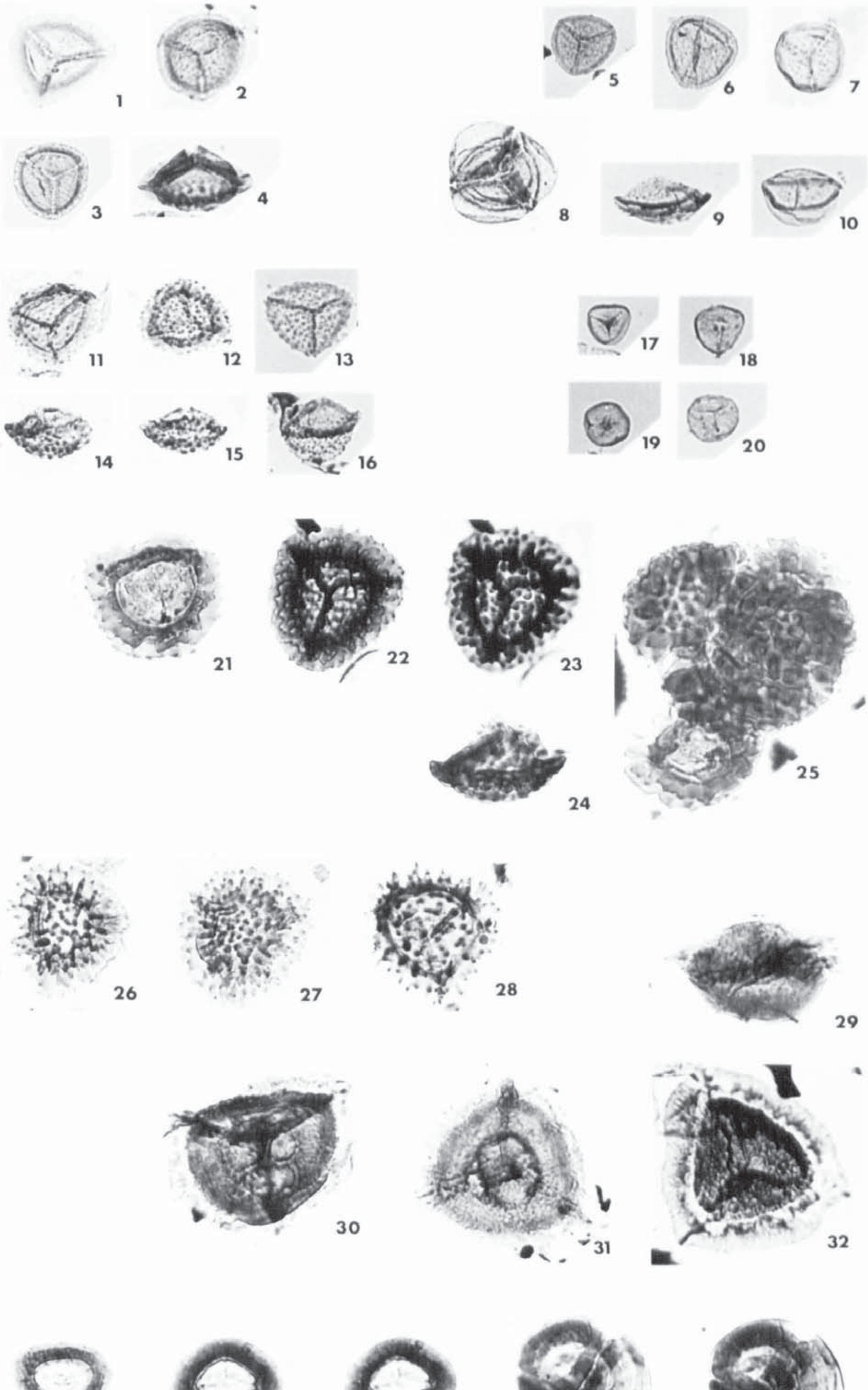
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PLATE 16

Fig No.

1. Radiizonates cf. striatus (Knox) Staplin and Jansonius 1964 in Smith and Butterworth 1967; Lmw 440b-1-G4; 26.4/80.1; 34-4.

2. R. cf. striatus; Lmw 440b-1-G2; *5.9/82.3; 34-1.

3. R. cf. striatus; Lmw 440b-1-1; 23.3/66.5; 34-3.

4. Radiizonates tenuis (Loose9 Butterworth and Smith (in Butterworth et al. 1964); Lmw 494-3-9; 6.3/78.0; 34-10.

5. R. tenuis; Lmw 492-1-14a; 2.8/77.0; 34-7.

6. R. tenuis; Lmw 492-1-8; *43.5/83.3; 34-6.

7. R. tenuis; Lmw 494-3-8; 6.2/74.8; 34-9.

8. R. tenuis; Lmw 494-3-6; 13.1/71.9; 34-8.

9. Spencerisporites radiatus (Ibrahim) Felix and Parks 1959; Lmw 460/2-3-E; 4.1/66.0; 34-13.

10. S. radiatus; Lmw 460/2-2-C; 7.8/82.5; 34-12; detail of central body.

11. Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944; Lmw 460/2-1-7; 4.3/73.9; 34-16.

12. E. globiformis; Lmw 460/2-3-F; 1.6/83.3; 34-15.

13. E. globiformis; Lmw 449-2-5; 17.8/84.2; 34-14.

14. Endosporites zonalis (Loose) Knox 1950; Lmw 515/5.5-1-Ja; 8.5/65.9; 19-21.

15. E. zonalis; Lmw 473b-2D; 18.7/81.0; 34-20.

16. E. zonalis; Lmw 480-1-G1; 25.3/65.1; 34-18.

17. E. zonalis; Lmw 460-2-1-6; 7.3/70.6; 34-19.

PLATE 16

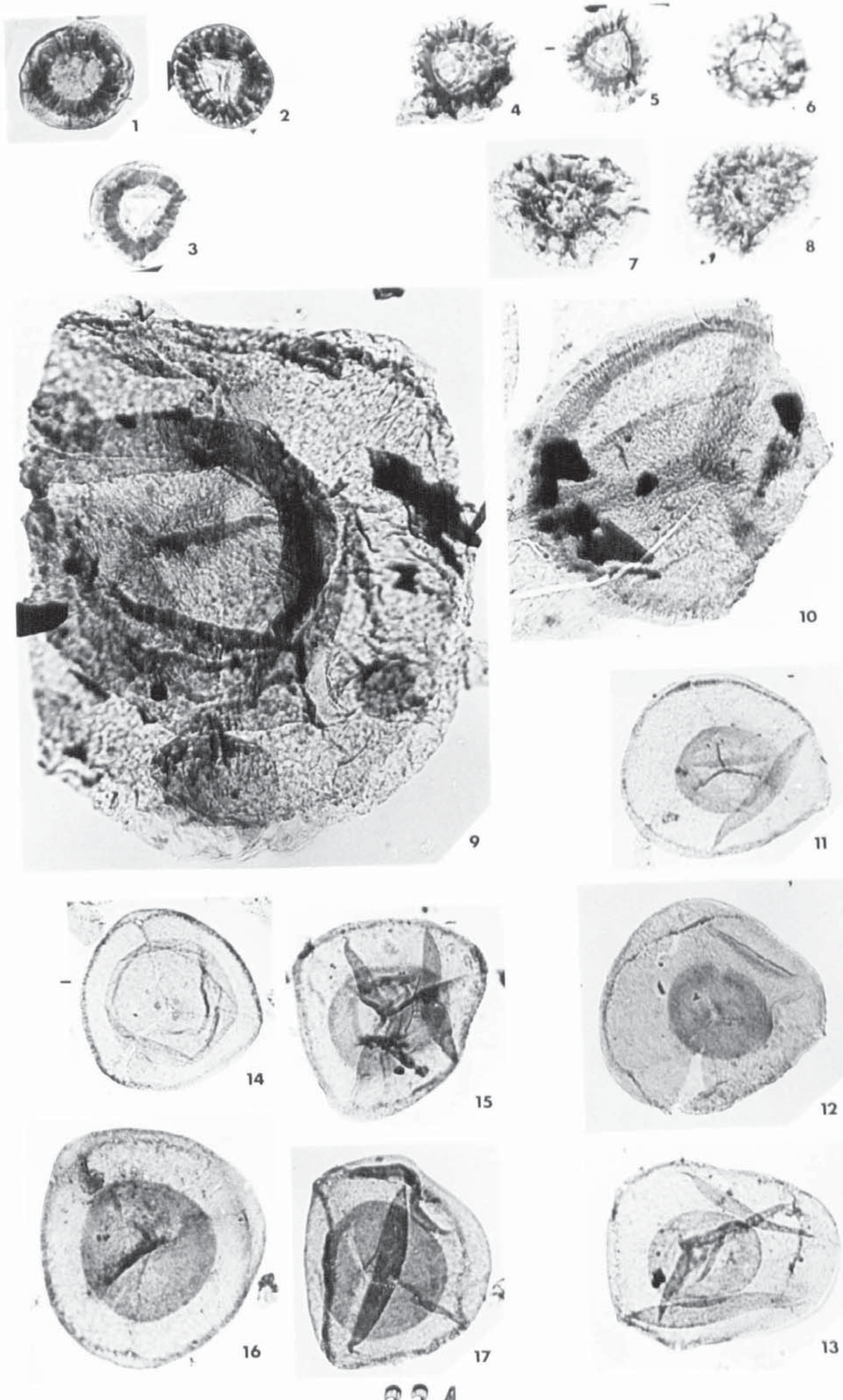


PLATE 17

Fig No.

1. Retispora staplinii (Gupta and Boozer) Ravn and Fitzgerald 1982; Lmw 490c-2-G6; 20.1/40.0; 34-26.
2. R. staplinii; Lmw 490a-2-G5; 23.4/79.3;34-24.
3. R. staplinii; Lmw 490b-1-8B; 21.7/72.9; 34-21.
4. R. staplinii; Lmw 490a-1-1; 13.9/66.8; 34-23.
5. R. staplinii; Lmw 488-14-3; 14.9/78.8; 34-22.
6. Alatisporites pustulatus Ibrahim 1932; Lmw 494-1-3; *38.5/84.1; 34-27.
7. A. pustulatus; Lmw 494-3-D; 11.0/82.4; 34-28.
8. Laevigatosporites cf. dunkardensis Clendening 1970; Lmw 515/5.5-3-10; 5.0/64.5; 22-43.
9. L. cf. dunkardensis; Lmw 515/12-1-38; 10.9/82.8; 18-15.
10. L. cf. dunkardensis; Lmw 515/5.5-1-2; 21.9/64.7; 19-19.
11. L. cf. dunkardensis; Lmw 515/12-1-34a; 24.0/81.0; 18-10.
12. Laevigaosporities minor Loose 1934; Lmw 461-2-3; 17.8/75.3; 34-29.
13. L. minor; Lmw 515/12-1-9; *3.3/81.7; 17-43.
14. L. minor; Lmw 515/12-1-40; 20.1/83.6; 18-17.
15. L. minor; Lmw 515/12-1-42; 18.4/85.4; 18-19.
16. L. minor; Lmw 515/5.5-1-9; 28.4/68.8; 20-19.
17. Laevigatosporites vulgaris Ibrahim 1933; Lmw 515/12-1-64; 21.5/85.4; 35-35.
18. L. vulgaris; Lmw 495-2-G1; 8.4/82.7; 35-37.
19. L. vulgaris; Lmw 494-1-G1; 11.4/81.9; 35-36.
20. Punctatosporites minutus Ibrahim 1933; Lmw 449-1-4; 14.1/68.6; 34-31.
21. P. minutus; Lmw 477c-3-A; 20.1/81.1; 34-32.
22. P. minutus; Lmw 515/5.5-1-46; 10.4/80.8; 21-35.
23. P. minutus; Lmw 442b-1-6; 24.1/76.7; 34-30.
24. P. minutus; Lmw 438-14-3-B; 20.4/68.5; 23-33; 'trilete' suture.
25. P. minutus; Lmw 515/12-1-29; 1.3/78.0; 18-1; 'trilete' suture.
26. Vestispora costata (Balme) Spode in Smith and Butterworth 1967; Lmw 437-2-G2; 22.4/85.0; 34-35.
27. V. costata; Lmw 480-2-G1; 19.8/65.0; 34-34.
28. V. costata; Lmw 461-1-17; 29.3/80.2; 34-37; tetrad.

PLATE 17

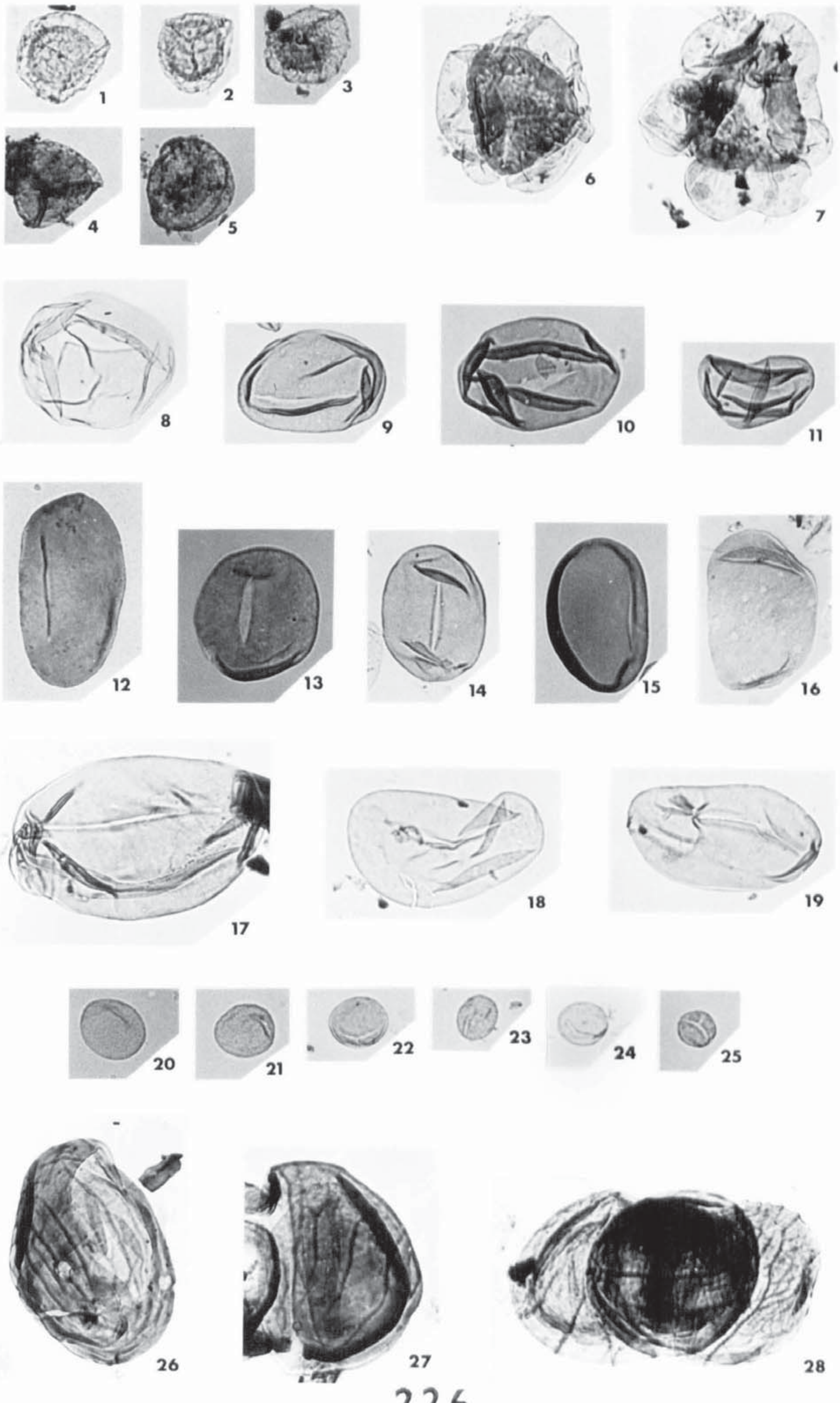


PLATE 18

Fig No.

1. Vestispora laevigata Wilson and Ventkachala 1963; Lmw 512/2-2-G1; 14.1/79.4; 35-12.
2. V. laevigata; Lmw 480-1-6; 16.3/71.8; 35-9.
3. Vestispora pseudoreticulata Spode in Smith and Butterworth 1967; Lmw 467-3-E; 18.4/72.5; 35-13.
4. V. pseudoreticulata; ST8/2-2-17; 1.1/74.0; 10-34, Un-named seam at 535.39m, Solomon's Temple borehole, Warwickshire; Westphalian B.
5. V. pseudoreticulata; Lmw 449-2-4; 11.5/83.2; 35-14; operculum.
6. Vestispora tortuosa (Balme) Spode in Smith and Butterworth 1967; Lmw 437-2-G1; 27.5/69.2; 35-17; detail of ornament.
7. V. tortuosa; Lmw 436b-3-C; 38.1/68.3; 35-16.
8. V. tortuosa; Lmw 515/12-1-4; 28.9/80.3; 35-15; tetrad.
9. Fabasporites cf. exilis Clendening 1970; Lmw 433b-1-G1; 1.5/71.9; 35-19.
10. F. cf. exilis; Lmw 433b-1-G3; 5.8/79.1; 35-21.
11. F. cf. exilis; Lmw 504-2-G3; 33.0/79.0; 35-22.
12. F. cf. exilis; Lmw 511/2-3-c; 0.1/76.9; 35-23.
13. Fabasporites parvus Clendening 1970; Lmw 504-2-G7; 16.5/75.2; 36-4.
14. F. parvus; Lmw 504-2-G4; 33.0/81.3; 36-3.
15. F. parvus; Lmw 504-2-G2; 33.0/72.5; 36-2.
16. F. parvus; Lmw 511-2-3-D; 14.1/75.5; 36-9.
17. Florinites cf. florini Imgrund 1960 in Smith and Butterworth 1967; Lmw 461-2-2; 2.5/68.5; 36-11.
18. F. cf. florini; Lmw 475-2-5; 4.1/72.8; 36-12.
19. F. cf. florini; Lmw 513b/12-2-3.1; 20.6/78.8; 36-13.
20. F. cf. florini; Lmw 515/12-1-8; 12.9/67.1; 17-42.
21. Florinites mediapudens (Loose) Potonie and Kremp 1956; Lmw 513b/12-1-11; 9.1/73.6; 36-19.
22. F. mediapudens; Lmw 475-3-K; 16.8/66.7; 36-24.
23. F. mediapudens; Lmw 495-3-B; 29.5/80.3; 36-15.
24. F. mediapudens; Lmw 475-3-G; 6.1/84.2; 36-17.

PLATE 18

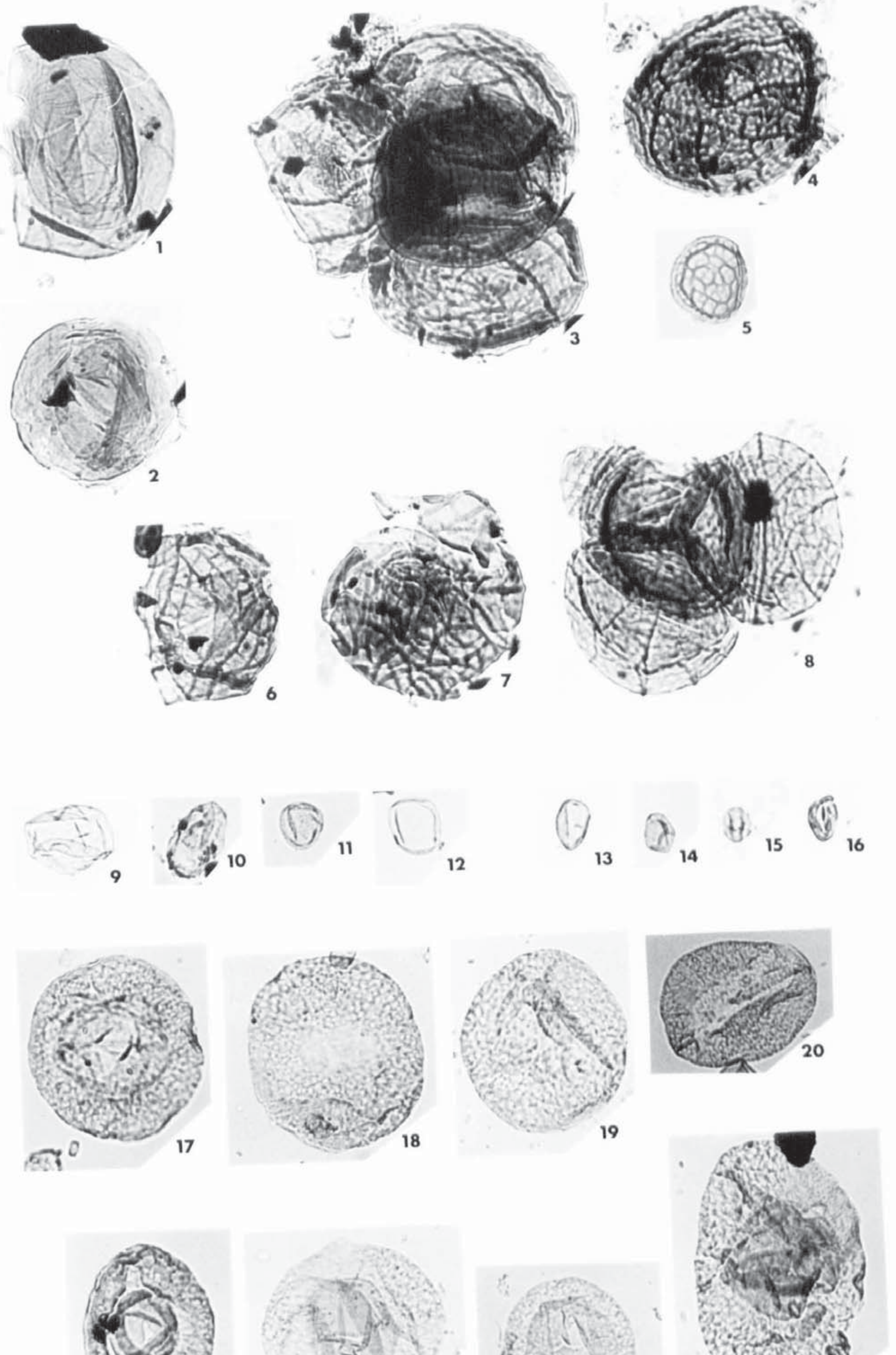


PLATE 19

Fig No.

1. *Florinites millotti* Butterworth and Williams 1954; Lmw 496-1-9a; 17.5/69.1; 36-26.

2. *F. millotti*; Lmw 496-1-14; *8.2/86.5; 36-28.

3. *Florinites pumicosus* (Ibrahim) Schopf Wilson and Bentall 1944; Lmw 513b/12-1-10; 14.0/71.7; 36-29.

4. *F. pumicosus*; Lmw 438/14-3-P; 13.0/84.8; 36-30.

5. *Florinites similis* Kosanke 1950; Lmw 461-1-19; 5.0/75.1; 36-31.

6. *F. similis*; Lmw 461-3-H; 1.8/73.7; 36-33; trilete suture.

7. *Florinites triletus* Kosanke 1950; Lmw 504-1-1; 19.0/66.6; 37-26.

8. *F. triletus*; Lmw 425/2-2-1; 17.5/77.8; 37-24.

9. *F. triletus*; Lmw 496-3-F; 26.1/73.8; 37-25.

10. *Florinites visendus* (Ibrahim) Schopf, Wilson and Bentall 1944; Lmw 461-2-3; 12.0/79.5; 37-28.

11. *F. visendus*; Lmw 461-3-I; 17.9/79.9; 37-29; trilete suture.

12. *F. visendus*; Lmw 461-1-5; 27.6/71.6; 37-27.

PLATE 19

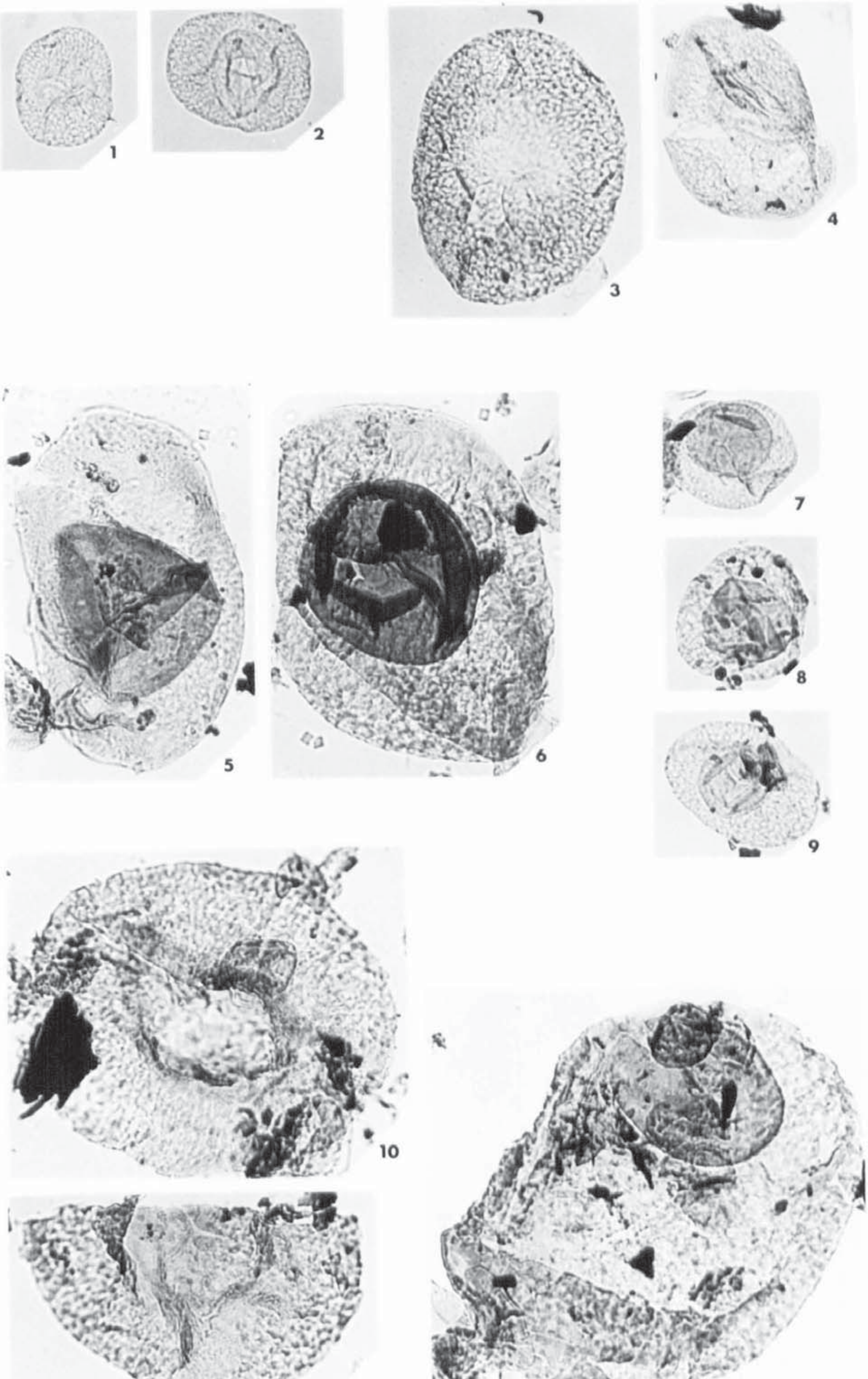


PLATE 20

Fig No.

1. Wilsonites cf. delicatus Kosanke 1950 in Smith and Butterworth 1967; Lmw 496-2-3; 27.1/83.9; 37-32.

2. W. cf. delicatus; Lmw 434-1-6; 3.0/76.4; 37-30.

3. W. cf. delicatus; Lmw 504-2-7; 29.3/74.3; 37-33.

4. Potonieisporites cf. elegans (Wilson and Kosanke) Habib 1966; Lmw 449-2-6; 20.1/79.9; 37-35.

5. P. cf. elegans; Lmw 463-1-G4; 25.9/71.3; 37-36.

6. Costascyclus crenatus (Felix and Burbridge) Urban 1971; Lmw 475-3-I; 26.6/85.0; 37-41.

7. C. crenatus; Lmw 475-3-I; 26.6/85.0; 37-40; high focus.

8. C. crenatus; Lmw 459-1-8; 8.5/78.3; 37-39.

PLATE 20

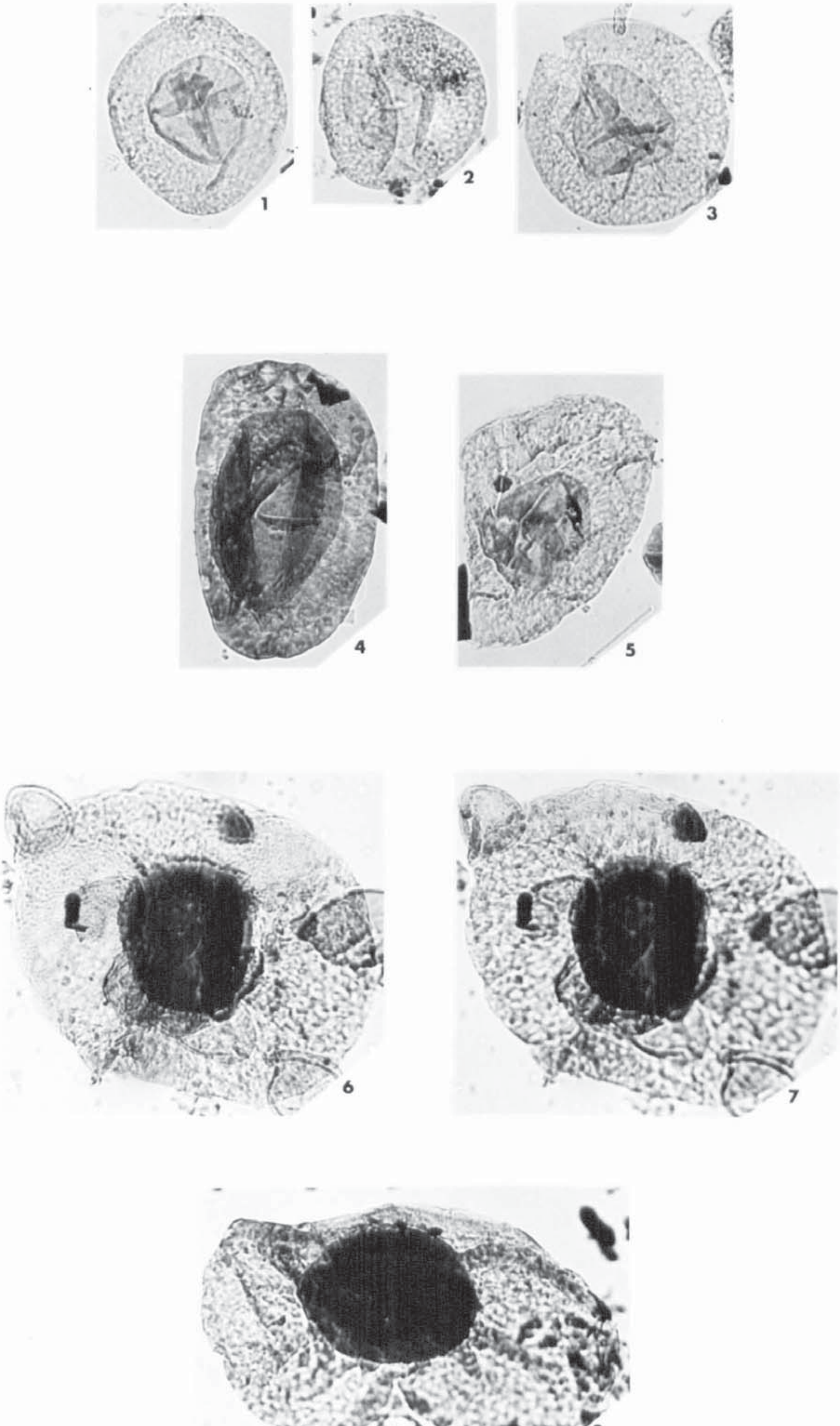


PLATE 21

Fig No.

1. *Pityosporites* cf. *kittaningensis* Habib 1966; Lmw 476-1-3; 15.6/71.5; 37-44.

2. *P.* cf. *kittaningensis*; Lmw 434-1-7; 1.4/81.0; 37-43.

3. *Pityosporites westphalensis* Williams 1955; Lmw 490a-2-G10; 0.1/77.9; 37-2.

4. *P. westphalensis*; Lmw 485a-2-G1; 12.8/64.5; 37-4.

5. *P. westphalensis*; Lmw 485a-2-G1; *39.9/64.6; 37-6.

6. *Schopfipollenites ellipsoides* var. corporeus Neves 1961; Lmw 508-3-G; 28.2/70.1; 37-7.

7. *S. ellipsoides* var. corporeus; Lmw 512/2-1-3; 12.5/72.9; 37-10.

8. Spore type A; Lmw 515/5.5-3-48; *6.9/69.5; 23-26.

9. Spore type A; Lmw 515/5.5-1-36; *6.9/71.7; 21-26.

10. Spore type A; Lmw 515/12-2-8; 25.0/62.5; 19-33.

11. Spore type A; Lmw 515/12-2-12; 5.8/63.1; 19-41.

12. Spore type A; Lmw 515/5.5-3-23; 1.4/75.0; 22-8.

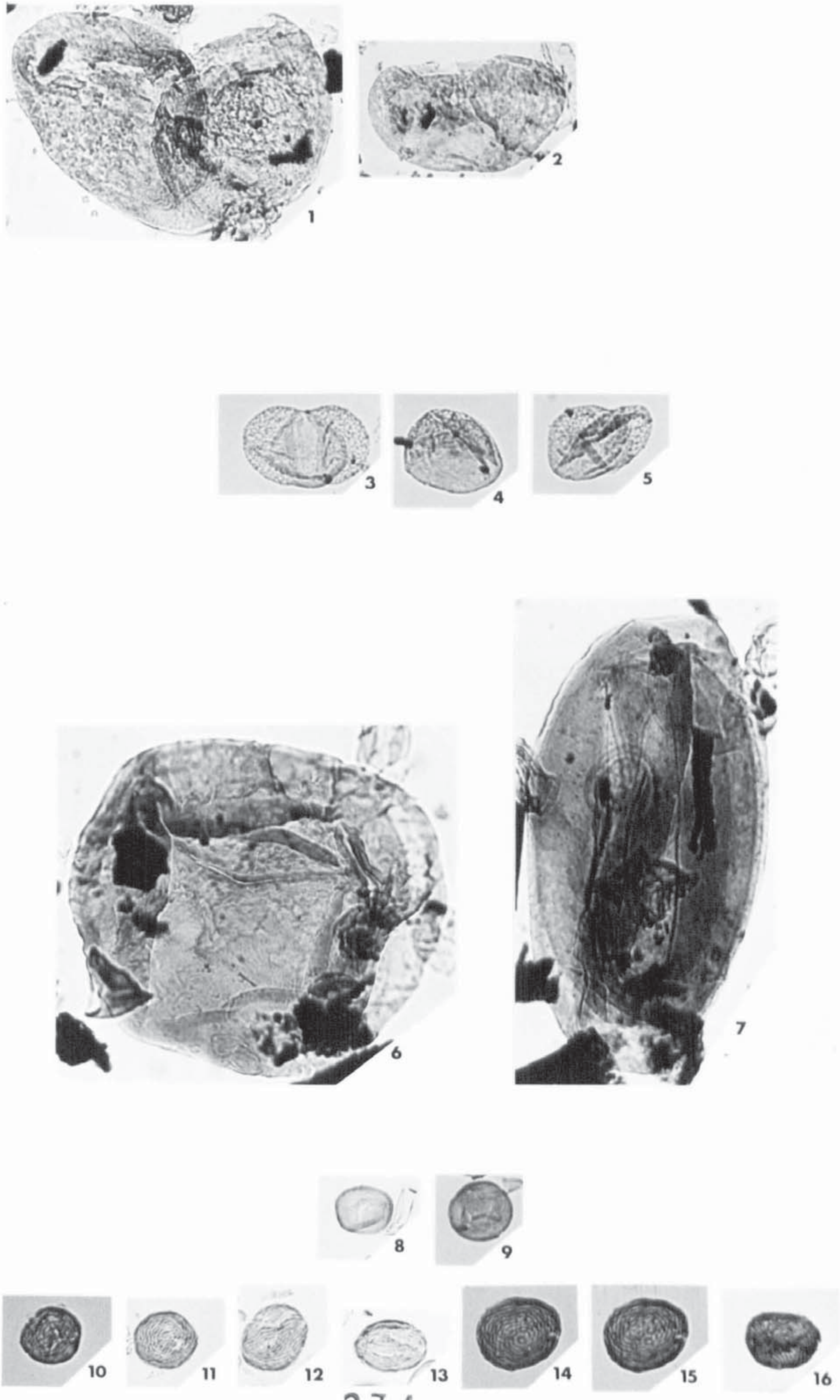
13. Spore type A; Lmw 515/5.5-3-31; 27.0/74.5; 23-13.

14. Spore type A; Lmw 515/5.5-1-6a; 28.9/66.7; 19-25.

15. Spore type A; Lmw 515/5.5-1-6a; 28.9/66.7; 19-27; high focus.

16. Spore type A; Lmw 516/14-2-5; *3.5/77.8; 22-25.

PLATE 21



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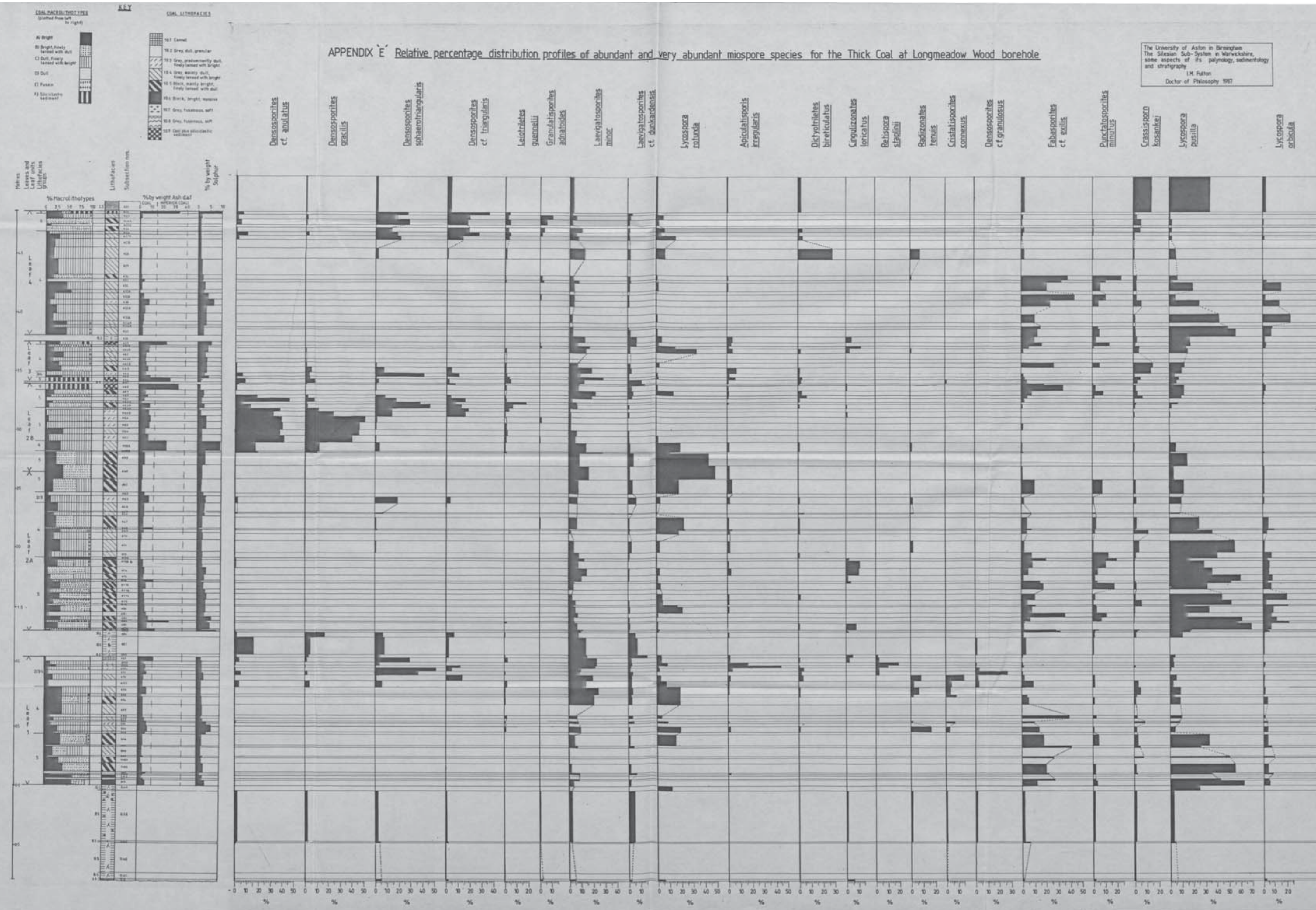
APPENDIX 'E' Relative percentage distribution profiles of abundant and very abundant miospore species for the Thick Coal at Longmeadow Wood borehole

The University of Aston in Birmingham
The Silesian Sub-System in Warwickshire, some aspects of its palynology, sedimentology and stratigraphy
I.M. Fulton
Doctor of Philosophy 1987



The University of Aston in Birmingham

The Silesian Sub-System in Warwickshire, some aspects of its palynology, sedimentology and stratigraphy.

I.M. Fulton

Doctor of Philosophy 1987

APPENDIX "C"

Miospore count table for the Thick Coal at Longmeadow Wood borehole.

The University of Aston in Birmingham

The Silesian Sub-System in Warwickshire, some aspects of its palynology, sedimentology and stratigraphy.

I.M. Fulton

Doctor of Philosophy 1987

APPENDIX "D"

Miospore species relative percentage distribution table for the Thick Coal at Longmeadow Wood borehole.

The University of Aston in Birmingham

THE SILESIAN SUB SYSTEM IN WARWICKSHIRE
SOME ASPECTS OF ITS
PALYNOLOGY, SEDIMENTOLOGY AND STRATIGRAPHY

I.M. FULTON
Doctor of Philosophy
1987

APPENDIX A Data on which Markov Chain analysis was carried out - Print of borehole table together with the state matrix table, bed thickness summary table, transition array table, independent trials array table and difference array table for Birch Tree Farm, Bockendon, Outwoods, Solomons Temple and Stareton boreholes.

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
PRINT OF BOREHOLE VOL2.SMDHOLES .BIRCHT

PROGRAM SMD50003.02/0002.41

NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP NO. DEPTH CMS TYP

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SMDHOLES .BIRCHT

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SMDHOLES .BIRCHT

23 24 25 26 27 28 29 30 31 32 33

[illegible]

PROGRAM SMD50003.02/0002.41

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
SEQ THICKNESS SUMMARY

SEQ	THICKNESS	COUNT	AVERAGE	MAXIMUM	MINIMUM
1 SILT MUD	127	10	13	46	2
2 PLANTY MUD	265	10	29	119	5
3 CARB MUD	409	13	39	150	1
4 MARINE MUD	227	1	227	227	227
5 CHALK [illegible]	102	16	13	30	1
6 CLR LR MUD	496	5	126	179	47
7 LR MUD	95	3	32	65	9
8 SILT MASS	456	11	41	110	5
9 SILT PLANTY	622	6	104	234	16
10 SILT MD LR	17	1	11	11	11
11 SILT R LR	988	14	71	221	8
12 SILT LENT	72	2	36	53	19
13 SILT WAVY	237	5	47	142	15
14 SILT/SAND	135	7	19	32	9
15 SAND MASS C	30	3	7	16	3
16 SAND MASS F	131	3	44	63	25
17 SAND RIPP C	409	11	37	153	5
18 SAND RIPP F	290	9	32	75	8
19 SAND/SILT C	108	5	20	65	1
20 SAND/SILT F					
21 SAND PLASTY	61	7	17	54	4
22 SAND WAVY	122	3	41	63	9
23 SAND TAB X	9	2	4	5	3
24 BRECCIA					
25 CONGLOM	370	7	53	76	9
26 SEAT MUD	1002	22	50	215	2
27 SEAT SILT	1055	17	62	315	7
28 SEAT SAND	11	1	11	11	11
29 SEAT MUD R	551	17	30	147	4
30 SEAT SILT R	337	11	49	151	12
31 SEAT SAND R	138	2	69	67	51
32 COAL	1419	22	65	405	1
33 CANNEL					
TOTAL	10904	249	44		

PROGRAM SAD[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY [illegible]

[illegible]	[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY [illegible]

[illegible]	[illegible]

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY [illegible]

[illegible]	[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DEPENDENT TRIALS ARRAY HOLE/DRUMHOLES .BIRCH

[illegible]

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY HOLE/DRUMHOLES .BIRCH

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY HOLE/DRUMHOLES .BIRCH

[illegible]

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
POINT OF DRUMHOLE HOLE/DRUMHOLES .ROCKER
PROGRAM [illegible]

NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP NO. DEG CRS TYP

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
SEQ THICKNESS SUMMARY

SEQ	THICKNESS	COUNT	AVERAGE	MAXIMUM	MINIMUM
1 GREY MUD	554	7	79	265	1
2 PLANTY MUD	168	3	56	119	29
3 CANN MUD	179	7	26	67	5
4 MARINE MUD	134	1	134	134	134
5 COALY MUD	37	3	12	16	7
6 CLR LM MUD	117	2	58	117	4
7 LM MUD					
8 SILT MASS	616	8	77	225	5
9 SILT PLANTY	508	3	169	475	19
10 SILT MU LM					
11 SILT D LM	1207	10	121	502	19
12 SILT LENS					
13 SILT WAVY	123	3	41	68	16
14 SILT/SAND	71	1	71	71	71
15 SAND MASS L	86	3	29	43	18
16 SAND MASS P	81	2	41	47	34
17 SAND RIPP L	151	1	151	151	151
18 SAND RIPP P					
19 SAND/SILT L	332	5	66	168	31
20 SAND/SILT P					
21 SAND FLASER	76	1	76	76	76
22 SAND WAVY	224	4	56	152	19
23 SAND [illegible]					
24 BRECCIA					
25 CONGLOM	26	1	26	26	26
26 SEAT MUD	229	6	38	119	16
27 SEAT SILT	1378	[illegible]	100	528	17
28 SEAT SAND	58	1	58	58	58
29 SEAT MUD S	1000	12	84	269	9
30 SEAT SILT S	769	9	84	501	21
31 SEAT SAND S	78	1	78	78	78
32 COAL	617	13	47	193	6
33 CANNEL					
TOTAL	[illegible]	119	62		

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1												.142				
2													.333		.396	
3									.143						.167	
4																
5									.067						.333	
6													.500			
7																
8		.125							.125							
9										.333	.336					
10																
11		.250			.500											
12																
13					.336											
14																
15								.336								
16																
17										1.000						
18																
19													.200			
20																
21																
22		.250		.250									.300			
23																
24																
25		1.000														
26													.167		.195	
27												.300	.200		.100	
28										1.000						
29										.231			.077		.615	
30										.333		.555		.111		
31																
32									.154	.077		.385				
33																

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY VOL2.SMODULES .DOCKER

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
PRINT OF BOREHOLE VOL2.SMODULES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SMODULES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SMODULES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
SEQ THICKNESS SUMMARY

SEQ	THICKNESS	COUNT	AVERAGE	MAXIMUM	MINIMUM
1 SPLT MUD	209	6	22	35	4
2 PLANTY MUD	429	7	61	129	20
3 CARB MUD	917	15	60	695	1
4 MARINE MUD	64	1	64	64	64
5 COALY MUD	177	11	16	49	3
6 CLR LM MUD	119	2	59	100	19
7 LM MUD					
8 SILT MASS	264	6	44	111	20
9 SILT PLANTY	146	4	36	107	6
10 SILT MD LM	49	1	49	49	49
11 SILT S LM	998	11	62	245	9
12 SILT LLNT	35	2	28	33	22
13 SILT WAVY	35	4	9	14	6
14 SILT/SAND	76	2	38	39	38
15 SAND MASS C	479	6	80	109	5
16 SAND MASS F	47	1	47	47	47
17 SAND RIPP C	759	12	63	239	6
18 SAND RIPP F	199	5	40	51	23
19 SAND/SILT C	109	5	21	34	19
20 SAND/SILT F					
21 SAND FLASER	163	2	81	143	19
22 SAND WAVY	609	13	47	161	7
23 SAND TAB X	6	1	6	6	6
24 BRECCIA					
25 CONGLOM	335	6	56	132	13
26 SEAT MUD	675	15	48	160	13
27 SEAT SILT	730	9	81	271	23
28 SEAT SAND	373	3	124	232	38
29 SEAT MUD S	803	14	57	219	14
30 SEAT SILT S	254	6	42	61	18
31 SEAT SAND S	82	2	41	63	20
32 COAL	1508	19	33	271	3
33 CANNEL					
TOTAL	9566	184	51		

PROGRAM SNG06093.03/0001.01

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY SOL2.SMCMOLIS .OUTWDD

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		.111						.111		.111	.333						.111
2					.429				.286								
3	.083				.063	.063		.063									
4	1.000																
5		.273															
6	.083										.500						
7																	
8	.167		.167			.167					.167						
9		.250									.250						.250
10	1.270																
11								.182					.091	.091	.091		
12																	
13											.250						.750
14																	
15																	.167
16																	
17	.083										.083		.167		.083		
18								.200							.200		
19								.200			.200			.200		.200	
20																	
21												.500					
22									.083		.167	.083	.083		.083		.250
23																	
24																	
25																	.167
26		.100	.200		.150												
27		.111							.111								.111
28			.333														.333
29	.077		.154		.231										.077		
30			.167														
31																	
32	.105		.474	.053	.158										.053		
33																	

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY SOL2.SMCMOLIS .OUTWDD

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1												.111			.333	
2									.143						.143	
3									.190			.100		.063	.269	
4																
5										.071		.152			.056	
6																
7																
8		.182														
9										.278						
10																
11	.091	.182			.272											
12				.100	.500											
13																
14	.500				.500											
15					.333			.167		.167					.100	
16					1.000											
17					.083			.250	.083	.083				.091		
18					.200						.200		.200			
19								.250								
20																
21										.500						
22	.083			.083		.095										
23	1.000															
24																
25	.167	.167			.333						.166					
26								.150		.150		.200			.100	
27									.222		.111		.222		.111	
28										.154						
29									.077	.077					.307	
30									.167	.154		.444				
31													1.000			
32									.053			.158				
33																

PROGRAM SNG06093.03/0001.01

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY SOL2.SMCMOLIS .OUTWDD

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY VOL2.SMOKELES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY VOL2.SMOKELES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY VOL2.SMOKELES .OUTWOO

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
PRINT OF SONDHOLE VOL2.SMOKELES .COLTER

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SHOWOLES .SOLTEN

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SHOWOLES .SOLTEN

[illegible]

PROGRAM SH3U4X0I.ASFOOROL01

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
SEQ THICKNESS SUMMARY

SEQ	THICKNESS	COUNT	AVERAGE	MAXIMUM	MINIMUM
1 GREY MUD	197	15	13	51	3
2 PLANTY MUD	76	2	38	71	5
3 CARB MUD	328	9	36	217	7
4 MARINE MUD					
5 COALY MUD	117	19	11	17	3
6 CLY LM MUD	405	6	68	217	9
7 LM MUD	46	1	46	46	46
8 SILT MASS	639	13	49	219	6
9 SILT PLANTY	115	5	23	61	9
10 SILT MU LM	168	7	24	59	5
11 SILT R LM	559	23	35	100	1
12 SILT LCHT	18	1	18	18	18
13 SILT WAVY	47	1	47	47	47
14 SILT/SAND	347	13	29	93	3
15 SAND MASS C	704	8	88	448	2
16 SAND MASS F	41	5	8	19	6
17 SAND RIPP C	304	18	17	68	3
18 SAND RIPP F	38	2	15	33	4
19 SAND/SILT C					
20 SAND/SILT F					
21 SAND FLASER					
22 SAND WAVY	76	4	19	33	6
23 SAND FAX R	15	3	5	6	3
24 BRECCIA	13	1	13	13	13
25 CONGLOM	234	7	33	126	3
26 SEAT MUD	547	17	32	125	9
27 SEAT SILT	524	14	37	130	10
28 SEAT SAND					
29 SEAT MUD X	969	23	42	157	5
30 SEAT SILT X	607	4	152	284	37
31 SEAT SAND X	59	1	59	59	59
32 COAL	997	33	31	167	1
33 CANNEL					
TOTAL	7902	234	34		

PROGRAM SH3U4X0I.ASFOOROL01

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY VOL2.SHOWOLES .SOLTEN

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY VOL2.SRDHOLES .SOLTON

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	-.009				-.016	-.014	-.005	.101	.155	-.084		.550	.049	-.005	-.096	
2	-.055				-.017	-.012	-.004	-.030	-.073	-.080		-.099	-.017	-.004	-.092	
3	-.079				-.016	-.013	-.004	-.031	.092	-.083		.089	-.018	-.004	.358	
4																
5	-.089				-.018	-.013	-.006	-.031	.156	-.083		.257	-.018	-.004	.194	
6	-.059				-.118	-.013	-.004	-.231	-.075	-.081		-.131	-.018	-.006	-.092	
7	-.058				-.017	-.013	-.004	-.030	-.073	-.080		-.099	-.017	-.004	-.091	
8	-.069				-.015	-.016	-.005	.045	-.077	.013		-.104	-.019	-.005	-.092	
9	-.069				-.017	-.013	-.006	-.031	-.076	-.151		-.102	-.017	-.006	-.093	
10	-.059				-.518	.418	-.004	.111	-.075	-.002		-.101	-.018	-.004	-.095	
11	-.088				.028	-.018	-.005	.015	-.001	-.077		-.109	-.019	.062	-.096	
12	-.087				-.017	-.013	-.004	-.030	-.072	-.068		-.095	-.017	-.004	-.091	
13	-.088				-.017	-.013	-.004	-.030	-.072	-.088		-.099	-.017	-.004	-.091	
14	-.089				-.019	-.014	-.005	-.032	-.077	.014		-.104	.058	-.005	-.092	
15	-.079				.232	-.013	-.004	-.031	-.075	-.082		-.102	-.318	-.004	-.093	
16	-.089				-.017	-.013	-.004	-.031	-.076	-.081		-.100	-.017	-.004	-.093	
17	.102				.036	-.016	-.005	-.032	-.075	-.005		-.105	-.019	-.005	-.097	
18					-.117	-.013	-.004	-.030	-.071	.440		-.099	-.017	-.004	-.092	
19																
20																
21																
22	-.089					-.013	-.004	-.030	-.076	.189		-.150	-.017	-.004	-.093	
23	-.089				-.017		-.004	-.030	-.076	-.051		-.150	-.017	-.004	-.091	
24	-.079				-.017	-.013		-.030	.027	-.000		-.099	-.017	-.004	-.091	
25	-.089				-.016	-.013	-.006		-.075	.001		.062	.126	-.004	-.095	
26	-.059				-.010	-.016	-.005	.227		.111		-.180	-.016	-.005	.257	
27	-.089				-.018	-.014	-.006	-.032	.137			.910	-.018	-.005	-.093	
28																
29	-.079				-.019	-.016	-.070	.012	-.036	.141			-.015	-.055	.312	
30	-.059				-.017	-.013	-.004	-.030	.026	-.001		.150		-.004	-.093	
31	-.059				-.017	-.012	-.004	-.030	-.073	-.080		-.099	.003		-.091	
32	-.289				-.017	-.014	-.005	-.033	.063	-.000		.092	-.019	-.006		
33																

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
POINT OF BOREHOLE VOL2.SRDHOLES .START

PROGRAM [illegible]

NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP	NO.	DEG	CMS	TYP
[illegible]																															

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SRDHOLES .START

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
[illegible]																						

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
TRANSITION ARRAY VOL2.SRDHOLES .START

	23	24	25	26	27	28	29	30	31	32	33	
[illegible]												

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
SEQ THICKNESS SUMMARY

SEQ	THICKNESS	COUNT	AVERAGE	MAXIMUM	MINIMUM
1 GREY MUD	405	12	34	155	1
2 PLANTS MUD	133	3	44	90	7
3 CARB MUD	550	22	25	117	2
4 MARINE MUD	76	1	76	76	76
5 CHALKY MUD	201	13	15	20	4
6 CLR LM MUD	16	1	16	16	16
7 LM MUD					
8 SILT MASS	613	16	38	237	1
9 SILT PLANTS	437	6	72	104	17
10 SILT NO LM					
11 SILT 6 LM	1554	29	53	195	6
12 SILT LCNT					
13 SILT WAVY	154	3	50	77	23
14 SILT/SAND	22	1	22	22	22
15 SAND MASS C	763	16	48	229	4
16 SAND MASS P	53	3	18	37	5
17 SAND RIPP C	966	16	60	365	3
18 SAND RIPP P	77	4	19	35	17
19 SAND/SILT C					
20 SAND/SILT P					
21 SAND FLASER	35	1	35	35	35
22 SAND WAVY	9	1	9	9	9
23 SAND FAN B					
24 BRECCIA					
25 CONGLOM	113	3	37	69	11
26 SEAT MUD	752	19	40	167	9
27 SEAT SILT	1067	14	76	245	3
28 SEAT SAND	7	1	7	7	7
29 SEAT MUD C	1746	40	42	106	4
30 SEAT SILT C	1262	15	83	196	5
31 SEAT SAND C	114	2	57	79	35
32 COAL	974	27	36	157	4
33 CANNEL					
TOTAL	12965	248	46		

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY [illegible]

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
ACTUAL PROBABILITY ARRAY [illegible]

[illegible]

PROGRAM [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY [illegible]

[illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
INDEPENDENT TRIALS ARRAY   VOL2,UNSHALES   .START

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
2	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
3	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
4	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
5	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
6	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
7																
8	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
9	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
10																
11	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
12																
13	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
14	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
15	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
16	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
17	.016			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
18	.012			.004	.004			.012	.077	.057	.004	.121	.061	.008	.109	
19																
20																
21	.016				.004			.012	.077	.057	.004	.121	.061	.008	.109	
22	.016			.004				.012	.077	.057	.004	.121	.061	.008	.109	
23																
24																
25	.016			.004	.004			.004	.077	.057	.004	.121	.061	.008	.105	
26	.016			.004	.004			.012	.073	.057	.004	.121	.061	.008	.109	
27	.016			.004	.004			.012	.077	.053	.004	.121	.061	.008	.109	
28	[illegible]			.004	.004			.012	.077	.057		.121	.061	.008	.109	
29	.016			.004	.004			.012	.077	.057	.004	.117	.061	.008	.109	
30	.016			.004	.004			.012	.077	.057	.008	.121	.057	.008	.109	
31	.016			.004	.004			.012	.077	.057	.008	.121	.061	.004	.109	
32	.016			.004	.004			.012	.077	.057	.004	.121	.061	.006	.105	
33																

MASUPAR [illegible]

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY   VOL2,UNSHALES   .START

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	-.061	-.112	.161	.179	-.052	-.004		.259	-.028		.000		-.012	-.004	-.005	-.012	-.057
2	-.342	-.090	-.109	-.204	.290	-.004		-.345	-.028		-.091		-.012	-.004	-.005	-.012	-.057
3	.121	.022	-.093	-.109	.051	.041		-.065	-.028		.836		-.012	-.004	-.005	-.012	-.057
4	-.063	-.112	-.004		-.053	-.004		-.065	-.376		-.061		-.012	-.004	-.065	-.012	-.057
5	.039	-.012	-.012	-.204	-.340	-.004		-.065	-.028		-.091		-.012	-.004	.012	-.012	-.057
6	-.044	-.012	-.030	-.096	-.012			-.065	-.028		-.091		-.012	-.004	.035	-.012	-.057
7																	
8	-.049	-.112	-.025	-.096	-.053	-.374		-.061	.079		-.010		-.010	-.004	.121	.051	.191
9	-.341	.136	-.009	-.309	.114	-.004		-.206	-.135		-.091		-.012	-.004	-.005	-.012	-.057
10																	
11	-.049	-.112	-.154	-.209	-.053	-.004		-.165	.076		-.077		-.012	-.004	.105	.036	.191
12																	
13	-.042	-.012	-.009	-.096	-.052	-.004		-.065	-.028		-.091		-.059	-.004	.002	-.012	.176
14	-.042	-.112	-.309	-.096	-.053	-.004		-.065	-.078		-.341		-.012		-.005	-.012	-.053
15	-.049	-.112	-.009	-.296	-.053	-.004		.121	-.024		.294		.051	-.004	.002	-.012	.100
16	-.349	-.012	-.009	-.096	-.053	-.004		-.065	-.026		.252		-.012	-.004	-.005	-.008	-.057
17	-.049	-.012	-.009	-.096	-.053	-.004		.435	-.026		.205		.059	.067	-.005	-.012	-.053
18	-.049	-.012	-.009	-.004	-.053	-.004		-.065	-.026		.169		-.012	-.004	.185	.296	-.057
19																	
20																	
21	-.049	-.012	-.009	-.096	-.053	-.104		-.365	-.026		.019		-.012	-.004	-.061	-.012	-.057
22	-.042	-.012	-.009	-.004	-.053	-.104		-.065	-.026		-.091		-.012	-.004	-.065	-.012	-.057
23																	
24																	
25	-.049	-.012	-.009	-.004	-.153	-.054		-.065	.301		-.301		-.012	-.004	.268	-.012	-.057
26	-.049	-.012	.122	-.004		-.059		-.065	-.026		-.091		-.012	-.004	-.065	-.012	-.057
27	-.049	-.112	-.009	-.204	-.053	-.004		.079	-.026		-.071		.059	-.074	-.065	-.012	.006
28	-.049	-.112	.711	-.006	-.053	-.004		-.065	-.026		-.091		-.012	-.004	-.065	-.012	-.057
29	-.349	.321	.035	-.209	.090	-.004		-.365	.084		-.219		-.012	-.004	-.065	-.012	-.057
30	.018	-.012	-.009	-.004	.214	-.004		-.065	-.026		-.091		-.012	-.004	-.065	-.012	.019
31	-.049	-.012	-.009	-.004	-.053	-.004		-.065	-.074		-.091		-.012	-.004	-.065	-.012	-.057
32	.171	-.012	.123	-.004	.011	-.004		-.065	.013		-.044		-.012	-.004	-.065	-.012	-.057
33																	

NATIONAL COAL BOARD - SOUTH MIDLANDS AREA
DIFFERENCE ARRAY   VOL2,UNSHALES   .START

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	-.016			-.004	-.004			-.012	-.077	-.057	-.004	-.130	-.061	-.008	-.029	
2	-.010			-.004	-.004			-.012	.592	-.057	-.004	-.121	-.061	-.008	-.109	
3	-.016			-.008	-.004			-.012	-.032	-.057	-.004	-.036	-.004	-.008	.302	
4	-.016			-.004	-.004			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
5	-.016			-.004	-.004			.004	.077	-.057	-.004	.110	.016	-.008	.121	
6	-.016			-.004	-.004			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
7																
8	.142			-.004	-.004			-.012	-.077	.058	-.004	-.121	.061	-.008	-.109	
9	-.015			-.004	-.004			-.012	.090	.110	-.004	.196	.186	-.008	-.109	
10																
11	.234			-.004	-.004			.030	-.077	-.057	-.004	-.121	.019	.092	-.109	
12																
13	-.016			-.004	-.004			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
14	-.016			.096	-.004			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
15	-.016			-.004	-.004			.054	-.077	.008	-.004	-.001	-.061	-.008	-.109	
16	.317			-.004	-.004			-.012	-.077	-.057	-.004	-.121	.273	-.008	-.109	
17	-.016			-.004	-.004			-.012	-.077	-.057	-.004	-.121	.011	-.008	-.105	
18	-.012			-.004	.146			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
19																
20																
21	-.016				-.004			-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
22	.994			-.004				-.012	-.077	-.057	-.004	-.121	-.061	-.008	-.109	
23																
24																
25	-.016			-.004	-.004			-.008	-.077	.277	-.004	-.121	-.061	-.008	-.109	
26	-.016			-.004	-.004			-.012	-.073	.040	-.004	.037	.044	-.008	.259	
27	-.016			-.004	-.004			-.012	.352	-.053	-.004	.022	-.061	-.008	-.035	
28	-.016			-.004	-.004			-.012	-.077	-.057		-.121	-.051	-.008	-.109	
29	-.016			-.004	-.004			-.012	.056	.043	.029	-.117	.072	-.008	.059	
30	-.016			-.004	-.004			-.012	-.077	.019	-.004	.146	-.057	-.008	-.044	
31	-.016			-.004	-.004			-.012	-.077	-.057	-.008	.179	.439	-.008	-.128	
32	-.016			-.004	-.004			-.012	.236	.017	-.008	.162	-.061	-.008	-.105	
33																

MASUPAR [illegible]
33

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01 02 03 04 05 06 07 08 09
[illegible] 10 11 12 13 14 00 00
15 16 17 18 19 20 21 22 23
24 00 00 00 00 00 00 00 00
25 00 00 00 00 00 00 00 00
26 27 28 29 30 31 00 00 00
32 33 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00
01 02 BRICK MUD          PLANTY MUD
03 04 SAND MUD           MARINE MUD
05 06 COALY MUD          CLR LM MUD
07 08 LM MUD             SILT MASS
09 10 SILT PLANTY        SILT MD LM
11 12 SILT S LM          SILT CEMT
13 14 SILT WAVY          SILT/SAND
15 16 SAND MASS C        SAND MASS F
17 18 SAND RIPP C        SAND RIPP F
19 20 SAND/SILT C        SAND/SILT F
21 22 SAND FLASER        SAND WAVY
23 24 SAND TAR R         BRECCIA
25 26 CONGLOM            SEAT MUD
27 28 SEAT SILT          SEAT SAND
29 30 SEAT MUD S         SEAT SILT S
31 32 SEAT SAND S        COAL
33 34 CANNEL
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