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SPECIAL PAPERS IN PALAEONTOLOGY NO. 1

MIOSPORES IN THE COAL SEAMS OF THE CARBONIFEROUS OF GREAT BRITAIN

BY

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AND

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With 27 collotype plates, 72 text-figures and 5 tables

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PREFACE

THIS volume is the first of a series of longer papers to be published by the Palaeontological Association in conjunction with its established journal *Palaeontology*. The publication of this work has been made possible by a considerable financial grant from the National Coal Board towards the cost.

T. S. WESTOLL
President

N. F. HUGHES
Secretary, Publications Sub-committee

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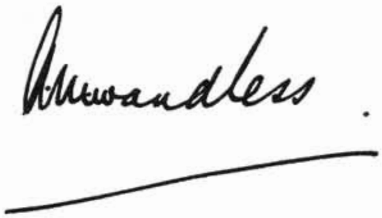
ABSTRACT. The use of dispersed miospores isolated from coals for the subdivision of the Carboniferous of Great Britain and in the solution of problems of seam correlation is described. Eleven spore Assemblages are recognized ranging from the Viséan to the Westphalian D, or possibly Lower Stephanian, based on sequences of seams from all the major British coalfields. The Assemblage boundaries are based, as far as possible, on the first appearances of new species. The diagnostic species of each Assemblage are listed and the frequencies of the common spores are shown for each coalfield. The geological factors which determine the nature of spore profiles within seams are considered as a necessary background to the use of spores in seam correlation. The use of statistical methods including discriminatory analysis is discussed and sections are included describing spore morphology and methods of maceration. Systematic descriptions of 204 species of 63 genera are given, the palaeobotanical relationships of these genera and the frequencies and ranges of each species being included. The majority of the species are referable to previously described types, but one new genus, *Grumosisporites*, and six new species are proposed—*Cyclogranisporites multigranus*, *Acanthotriletes triquetrus*, *Convolutispora jugosa*, *Rotaspora crenulata*, *Densosporites gracilis*, and *Punctatosporites oculus*. A revised scheme of supra-generic classification based on Dettmann (1963) is proposed.

FOREWORD

THE Identification of coal seams during coalfield explorations has for economic reasons long engaged the attention of mining engineers and Coal Measures geologists. Generally solutions have been sought in stratigraphical and palaeontological studies of the strata associated with the seams and comparatively little attention has been paid to the valuable evidence provided by the seams themselves—notably in the fossil spore assemblages in the coal. A careful study of these minute fossils may not only lead to the identification of seams in unproved regions but may also assist in the solution of some of the many problems associated with seam correlation in proved areas.

Pioneer work on megaspores in British coals was begun by the late Dr. L. Slater and his staff at the Sheffield Coal Survey Laboratory and on miospores by Dr. A. Raistrick at Armstrong (later King's) College, Newcastle upon Tyne. Investigations into the use of spores for seam correlation purposes have been mainly carried out by the Coal Survey laboratories, initially under D.S.I.R. and subsequently within the National Coal Board. At the Stoke on Trent (later Chester) Coal Survey Laboratory, Dr. J. O'N. Millott studied the seams of North Staffordshire, and at the Sheffield Coal Survey Laboratory Mr. J. J. Walker examined many of those of Yorkshire. At a somewhat later date Dr. E. M. Knox worked on Scottish coals at Edinburgh University and Mr. T. S. Tomlinson on those of Cumberland at the Newcastle Coal Survey Laboratory. These investigations extended from the mid 1920s to the 1940s. In the late 1940s a considerable impetus was given to the work following the inception of an extensive exploratory borehole programme by the National Coal Board. To cope with the greatly increased numbers of samples resulting from this programme and from the many new underground drivages at collieries, Dr. M. A. Butterworth was appointed as a full-time palynologist working at the Chester Coal Survey Laboratory and, successively, Mr. B. E. Balme, Dr. R. W. Williams, and Dr. A. H. V. Smith at the Sheffield Coal Survey Laboratory. As a result of this work a large amount of information has been accumulated on the miospore floras of the principal (and also many of the minor) seams in all of the coalfields of Great Britain. It is the purpose of this monograph to place these results on record so that the information may be available, not only to all workers in this specialized field, but also to non-specialists in the mining industry who may be interested in the applications of palynology to problems of seam correlation and identification. The monograph has been compiled by Dr. Smith and Dr. Butterworth, the two workers who have been most continuously engaged on the palynology of British coal seams in the last decade. They have been ably assisted by Dr. J. O'N. Millott who has acted as general editor in this work and who has had a long and active association with the subject since its pioneer days.

The preparation of this monograph has entailed a critical study of the very large amount of literature on fossil spores that has appeared during this period. Spore systematics has been one of the major problems and it has been one of the principal tasks of the authors to examine the various species critically and to adopt those names considered applicable to the specimens encountered by them. In a rapidly expanding science such as palynology, in which work has been carried out more or less simultaneously in many different countries, synonymy is only to be expected, but it is hoped that the section of the monograph dealing with this aspect of the subject will go some way to resolve the chaos of recent years. This is the principal aim of the Commission Internationale de Microflore du Paléozoïque (C.I.M.P.) and both authors have participated actively in the work of this body since its inception in 1958.



Signed A. M. Wandless
Director of Scientific Control
National Coal Board
London
February 1966

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Dr. A. Raistrick kindly provided information on the early history of spore investigations with which he was connected. The provision of photographs of certain spore types named by Ibrahim and Loose (by Dr. W. Krutsch), Playford (by Mr. N. F. Hughes), and Butterworth and Williams (by Dr. W. G. Chaloner) has greatly assisted the authors in their work. Slides in the collection of the Department of Geology, Sheffield University, were examined through the courtesy of Professor L. R. Moore. The authors also record their gratitude to the late Dr. E. M. Knox, Dr. R. M. Kosanke, Dr. R. Neves, and Mr. F. Spode for providing spores for examination and for helpful discussions. Particularly thanks are due to Dr. H. J. Sullivan for constructive criticism of those parts of the systematics which were completed before his departure from Sheffield University and to two former colleagues who worked at the Sheffield Coal Survey Laboratory—Dr. R. W. Williams and Dr. A. E. Marshall, without whose efforts the work would have been considerably protracted. The help of Mr. G. E. Staples, who was largely responsible for the statistical aspect of the present work, is also gratefully acknowledged.

One of us (M. A. B.) gratefully acknowledges the receipt of a grant from the National Coal Board which enabled her work to be completed in the Department of Geology, University of Sheffield; thanks are also due to Professor L. R. Moore for facilities provided in his Department.

INTRODUCTION

In Great Britain the study of spores in coal was undertaken primarily for the purposes of exploring their use in the correlation of coal seams and for this reason has been carried out mainly within the mining industry. These studies, begun in the early 1930s, are still in progress. The earlier investigations were based mainly on megaspores but subsequently attention was transferred almost entirely to the more abundant, and in some respects more easily studied, miospores. These are defined by Guennel (1952) as fossil spores and spore-like bodies, smaller than 200 μ and including homospores, true microspores, small megaspores, pollen grains, and pre-pollen. The investigations have shown that miospore studies may have considerable value not only in the solution of local seam correlation problems but also in the broader context of stratigraphy and ecological palaeontology. In the past little or no attention has been directed to the use of spores in rocks other than coal in the elucidation of correlation problems, but recently this aspect of palynological work has been receiving considerable attention.

The present work seeks to provide a comprehensive account of the miospore floras of British coal seams and to record the ranges and the frequencies of occurrence of the more common species. The information falls broadly into two parts—stratigraphic and taxonomic. The former includes an account of eleven stratigraphically distinctive miospore Assemblages and their occurrence in the different coalfields. This is followed by a consideration of the factors affecting the distribution of spores in coal seams with particular reference to their use in seam correlation. The taxonomic section is preceded by an account of the sampling, maceration, and counting procedures used by the authors during their investigations. In presenting these data the authors acknowledge their indebtedness to their predecessors and also to their colleagues outside the coal industry.

Coal seams have been investigated from each of the principal coalfields of Great Britain. The seam sequences examined were based mainly on boreholes (surface and underground) put down in recent years in connexion with the National Coal Board's explorations in various coalfields, underground drivages at collieries, and provings (boreholes and trial pits) at opencast sites. Where, owing to the absence of suitable explorations, it was not possible to obtain long sequences of seams these have been established from samples of individual seams and small groups of seams, taken, wherever possible, at neighbouring collieries and/or at the outcrops. The seam samples taken primarily for analytical purposes by the Coal Survey section of the Scientific Department of the National Coal Board have proved invaluable in this connexion.

The extent to which the miospore data can be regarded as covering the coalfields adequately varies considerably from field to field. In some areas, particularly those in the Central Province, where large numbers of explorations, both surface and underground, have been made within recent years, and where the rank of the coal is normally sufficiently low to permit the isolation of the spores, the information covers most districts of the individual coalfields. In other areas, however, such as in certain coalfields of the Southern Province and in Scotland, the information is less satisfactory. In part this is due to the limited time that has been available for the investigations but it may

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also be due to the paucity of exposures, or to the difficulties inherent in obtaining suitable miospore separations from seams of high rank. In South Wales and Kent, for example, the seam sequences have necessarily had to be restricted to those districts of the coalfields where the rank of the seams is not so high as to prohibit satisfactory isolation of the spores.

HISTORY OF APPLIED COAL SPORE STUDIES IN GREAT BRITAIN

Prior to 1950

Although both megaspores and miospores had been figured and described by Hutton, Lomax, and others from their appearance in thin coal sections, their first use for seam identification and correlation purposes is generally attributed to Thiessen (1923, 1924). He considered that seams contained characteristic spore types by which they could be identified. In Britain, Slater, Evans, and Eddy, using Thiessen's method, investigated the megaspores present in various coals, particularly in the Yorkshire Coalfield, and attempted to apply the results for the purposes of seam correlation. The findings are given in various Fuel Research Survey papers (1930, 1932) and in Slater (1932). In the course of the work it soon became apparent that the distribution of spores in a seam was more likely to be a suitable feature for correlation purposes than the presence or absence of a single characteristic spore as suggested by Thiessen.

Although an attempt to classify the various types of miospore present in coal, based on their appearance in thin section, was made by Evans (1926) in the course of studies on the Parkgate Seam of Yorkshire, Raistrick may properly be regarded as the first investigator in this country to study them systematically and to use them for the purposes of seam correlation. His interest in spores was aroused when working with Kendall at King's College, Newcastle upon Tyne, in the period 1924–8. Raistrick was also interested in the related field of peat pollen analysis using the methods of Erdtman and in 1930, in association with K. B. Blackman, he examined the possibility of widespread correlation of peat deposits. The first attempts to isolate miospores from coal involved the use of pyridine—the method employed by Stopes and Wheeler at an earlier date. This proved unsuccessful and in all subsequent work Schulze solution was employed. The results of the investigations were published in two papers dealing with certain coals in the Coal Measures of Northumberland (Raistrick and Simpson 1933; Raistrick 1934) and in a third paper concerned with the Busty and related seams in Durham and the Trencherbone Seam of Lancashire (Raistrick 1939). In these papers, in addition to descriptions of various spore types, the use of miospores in the correlation of seams was discussed. A paper published in 1937 gave an account of the miospores present in some seams in the Lower Carboniferous of Northumberland and recorded the presence of several spore types not previously observed in the Upper Carboniferous of this region. In describing the use of miospores for seam correlation purposes, Raistrick grouped the spores into two categories—'general' and 'accessory', and recorded the frequencies of the various types within each category. The results were expressed in the form of block diagrams. Based on the frequencies of the 'general' spores (as reflected in the block diagrams) it was considered that seams which were equivalent gave diagrams having a similar pattern which differed from those of neighbouring seams. Where different seams gave diagrams having similar patterns, distinctions could generally be made on the basis of the 'accessory' spore diagrams. He also found that certain spores, particularly in the 'accessory' class, had restricted vertical ranges—a feature which was also of significance in relation to seam correlation. Subsequent work by other investigators has shown, however, that these methods have only a rather limited use. Thus the 'general' diagrams given by successive seams tend to approximate in pattern to two types only, depending on the dominant spore types, while the differences in the 'accessory' spore diagrams are often only slight. Correlations based on whole seam samples using these methods are only possible where seam structure remains approximately constant—where splitting and rapid variations in thickness occur, difficulties are experienced. Nevertheless the restricted vertical ranges of certain spore types have proved a feature of great value in elucidating various problems of seam identification and correlation.

Miospore investigations by other workers in these and other coalfields quickly followed Raistrick's pioneer work. The main interest lay in the search for new types and in establishing their vertical ranges. Thus, T. S. Tomlinson of the Newcastle Coal Survey Laboratory, who had also investigated the seams of the Northumberland and Durham Coalfields, made a preliminary (unpublished) investigation of the seams of the Productive Coal Measures of the Cumberland Coalfield, while Millott examined the seams of the North Staffordshire Coalfields and Paget those of Warwickshire and later South Derbyshire. Most of the spore types described by Raistrick were identified by these authors and many new forms identified. The results of the investigations were published by Paget in 1936 and 1937 and by Millott in 1939 and 1946. In an attempt to utilize cingulate spores (Raistrick's Group A) for correlation purposes, Paget subdivided the group into a large number of types, some of which are now accepted as species. Many of the ecological generalizations made by him are, however, a less satisfactory feature of his work. The systematic examination of miospores in the Yorkshire and Nottinghamshire Coalfield was undertaken by Walker during the years 1936–42. In this period twenty-five seam sequences were examined and much valuable data accumulated, particularly from north Nottinghamshire, where extensive drilling was carried out in the oil exploration programme during the early years of World War II. These investigations, largely unpublished, confirmed the restricted stratigraphic range within the Coal Measures of Raistrick's type C_1 (*Endosporites globiformis*) (Walker 1938) and indicated the stratigraphic significance of another previously recognized type, A_7 (*Radiizonates aligerens*). Later Crookall and Morris (1952) questioned the stratigraphic value of type C_1, but a critical examination of the time range of this type and of a morphologically closely similar type, C_4, in the seams of the Yorkshire Coalfield (Smith and Williams 1957) amply confirmed the findings of Walker and his contemporaries. During this work he experimented with, and eventually adopted, the Zetzsche and Kälin method of maceration (without pretreatment with bromine) since it had none of the disadvantages associated with the use of alkali.

In Scotland the pioneer studies were made by Knox. The first coals examined were from the Productive Coal Measures of Fife (1942) but subsequently the investigations were extended to seams in the corresponding part of the succession in the Central Coalfield (1945) and later to the coals of the Limestone Coal Group (1948). In the first two papers Knox observed the occurrence of certain accessory spores in strata of comparable age in Scotland and England which thus had value as zone fossils. In her 1948 paper she noted that only a relatively small number of spore types were common to the coals of the Productive Coal Measures and the Limestone Coal Group.

Post 1950

A significant advance in applied spore studies in Great Britain was the publication in 1952 of a paper by Balme and Butterworth, which established the basis of a zonal scheme for the Productive Measures of the Central Group of British Coalfields. These authors recognized that significant changes in the compositions of the miospore floras of coal seams took place at certain levels in the succession. In practice the Assemblage boundaries were delimited by the presence, or absence, of certain species. Butterworth and Millott (1955) subsequently added three further Assemblages after working on those coalfields of the Central Group not included in the earlier investigations (further details are given in a later section). Descriptions of certain of the stratigraphically significant species, regarded as of most value by these authors, are given by Balme (1952) and Butterworth and Williams (1954).

Butterworth and Millott's findings related solely to the coalfields of the Central Province but later Williams (thesis 1956) showed that the Assemblages described by these investigators could also be recognized in the coalfields of the Southern Province. He further demonstrated that by using all of the constituent species of the miospore floras, rather than a few stratigraphically significant types, it was possible to subdivide the Assemblages of the previous authors. Included in Williams's work were the results of an examination of the miospore floras from a borehole in the concealed Coal Measures of Oxfordshire. These suggested that the uppermost part of the succession present was equivalent to part of the Radstock Group of the Bristol and Somerset Coalfields. Williams's investigations thus supplied data on the miospore floras in the highest part of the British Carboniferous. Information on the seams at lower horizons than the Coal Measures was comparatively scanty, but this was largely rectified by the investigations of Butterworth and Williams (1958) on the miospore floras of the seams of the Limestone Coal Group and Upper Limestone Coal Group of Scotland. The completion of this work enabled a zonal scheme, based on miospores, covering the full sequence of Carboniferous strata in Great Britain to be attempted and this scheme was put forward by Butterworth and Millott in 1960.

In the ensuing period the investigations have been greatly extended so as to include seams from all the principal coalfields of Great Britain. This has entailed the examination of several long sequences not previously available from certain coalfields and the systematic investigation, for the first time, of sequences from the Cumberland and Bristol and Somerset Coalfields. The information thus accumulated has been continually applied by the Coal Survey palynologists to the solution of correlation problems involving both long and short seam sequences. The correlations suggested on the basis of spore evidence have often provided support for conclusions derived from other evidence, and where this has been lacking, they have generally proved to be correct by subsequent exploration. Little of this work has been published, however, except by Butterworth and Millott (1957) and Smith (1962*b*).

Palaeoecological and statistical investigations having a direct bearing on these applied studies were also undertaken during this period. All the early workers had recognized that the environment at the time of peat deposition influenced the quantitative aspects of their results, the effect being most apparent in the reciprocal relationship of certain species of *Densosporites* and *Lycospora* and the association of these species respectively with certain petrographic types of dull and bright coal. These relationships obviously diminish the value of Raistrick's 'general' spore histogram for the purposes of long-distance seam correlation. Because little was known of the ecology of naturally occurring spore associations in Carboniferous coals and because of the need for such information in the interpretation of spore data, a combined petrographic and palynological investigation of some Yorkshire seams was begun in 1955. The results of these preliminary investigations were published by Smith (1957, 1962*a*, and 1964) and Marshall and Smith (1965) and are discussed more fully in the section of this work dealing with seam correlation.

An important contribution to the statistical aspects of spore studies was made by R. C. Tomlinson in a paper published in 1957. In this he discussed the accuracy of spore counts made by three independent operators and provided a basis upon which 'absence' could be determined with reasonable certainty.

In recent years, as in the past, important contributions to our knowledge of the Carboniferous miospore floras have also been made by workers outside the coal industry. Thus Neves (1958) demonstrated qualitative and quantitative differences between the miospore floras in the coal, the fresh water, and the marine shales associated with the *Gastrioceras subcrenatum* Marine Horizon of North Staffordshire, and in a more extensive investigation of the miospore floras in clastic sediments and coals of Namurian age in the Southern Pennine region of the Central Province (1961), he examined the extent to which genera and species are restricted to sediments of a particular type. Although the number of coals examined was few, they provide a valuable addition to the somewhat limited data available for the coals of this age in the Northumberland Coalfield. Love (1960) described the miospores in a variety of rock types (including coal) in the Lower Oil-shale Group of Scotland and showed that the differences between the miospore floras in rocks of marine and non-marine origin were not pronounced. Sullivan (1962) provided the first published account of the miospores in coals and shales based on a Coal Measures sequence at Caerphilly, South Wales and showed that species whose stratigraphic ranges had previously been established from coals had the same ranges when these were established from the sediments. In a later work (1964) this investigator also described the miospores from a shale and a coal, of Viséan and probable Westphalian A age respectively, in the Forest of Dean. Love and Neves (1964) described the miospores from a thin coal, some coal lenticles, and a seat-earth from the most north-westerly of the known Carboniferous outcrops in Scotland at Inninmore.

Spore Nomenclature

Nomenclature is an essential adjunct to applied spore studies and the contribution of British workers deserves mention in this context. Raistrick using a system of letters and numbers distinguished seven spore groups (A to G), each group containing one or more types. In his later work nearly forty types were recognized, which number was increased by subsequent workers. This arbitrary classification proved adequate in the earlier investigations but the limitations imposed soon became apparent; these limitations are discussed by Moore (1946) and Knox (1950). The binomial system of nomenclature, already in use in Germany and America, was first adopted in Great Britain by Knox in

1950 thus bringing the fossil spore classification in use in this country into line with the recognized practice of botanical taxonomy. Knox also subdivided and emended certain of the genera recognized by Schopf, Wilson, and Bentall (1944) and at the same time provided a key to the genera and species of Palaeozoic miospores. The Palaeozoic spore genera introduced by her and later workers are based on morphological criteria since the botanical affinities of dispersed spores are largely unknown. The binomial system has now been adopted by all British workers although confusion at first arose in equating some of Raistrick's types with spores named by the early workers in Germany, notably Ibrahim, Loose, and Wicher. These errors persisted until the type material of these authors was figured in the comprehensive publications of Potonié and Kremp (1954, 1955, and 1956).

OUTLINE OF STRATIGRAPHY

With the exception of a few small areas such as near Brora in Scotland, coal deposition in Great Britain was confined to the Carboniferous. This occurred at various times from the Lower Carboniferous to the top of the Upper Coal Measures (Viséan to late Westphalian or possibly early Stephanian), but over most of the country was at a maximum in the Middle Coal Measures (Westphalian B). In Scotland and northern England, in addition to coals in the Coal Measures (Westphalian) there are workable seams in strata of both Carboniferous Limestone (Viséan) and Millstone Grit (Namurian) ages, which, further south, are replaced by massive marine sediments. In central England, although minor coals occur in the upper part of the Millstone Grit Series, the important seams are confined to the Lower and Middle Coal Measures and the lower part of the Upper Coal Measures (Westphalian A, B, and C). In this region, as in Scotland and the north of England, higher horizons in the Coal Measures are represented by strata, often reddened, which are barren and in which only minor coals are present. In South Wales and other coalfields in the south of England, coal deposition was also mainly confined to the Coal Measures although here principally to higher horizons (Middle and Upper Coal Measures—Westphalian B, C, and D). Whether certain coal-bearing strata in this region and a few other areas in Great Britain are of Lower Stephanian age, is controversial.

The classification of the British Carboniferous has been carried out on a basis of corals, brachiopods, and goniatites in the Lower Carboniferous (Tournaisian and Viséan), and of non-marine lamellibranchs, goniatites, and plants in the Upper Carboniferous (Millstone Grit Series and Coal Measures). Goniatites are of major importance in the Millstone Grit Series and non-marine lamellibranchs and, to a lesser extent, plants in the Coal Measures. The principal subdivisions of the British Carboniferous are shown in text-fig. 1.

In most of the British coalfields marine bands occur at certain horizons in the Coal Measures and, where present, are made the basis of their subdivision into Lower, Middle, and Upper groups. The marine band occurring within the Modiolaris Zone defines the upper limit of the Lower group and that at the top of the Similis–Pulchra Zone, the upper limit of the Middle group. The *Gastrioceras subcrenatum* Marine Band, where present, is used to define the base of the Coal Measures. The names which these bands have received in the various coalfields are shown in text-fig. 2.

Floral Zones (DIX)	Coral-Brachiopod Zones	Goniatite Stages	Non-Marine Lamellibranch Zones	Heerlen Convention	Northern Province		Central Province	Southern Province
					Scotland	Northern England		
I			Prolifera	Stephanian ?	Upper (Barren) Coal Measures	Upper Coal Measures	Upper Coal Measures	Pennant or Upper Coal Measures
H			Tenuis	Westphalian D				
G			Phillipsii	Westphalian C				
F			Similis-Pulchra	Westphalian B	Middle Coal Measures	Middle Coal Measures	Middle Coal Measures	Middle Coal Measures
E		A						
D			Modiolaris					
C			Communis	Westphalian A	Lower Coal Measures	Lower Coal Measures	Lower Coal Measures	Lower Coal Measures
		G	Lenisulcata					
B		R		Namurian A, B & C	Passage Group	"Millstone Grit"	Millstone Grit Series	Millstone Grit Series
A		H						
		E_2			Upper Limestone Group	Upper Limestone Group		
		E_1			Limestone Coal Group			
	D_2	P_2		Viséan	Lower Limestone Group	Middle Limestone Group	Carboniferous Limestone	Carboniferous Limestone
	D_1	P_1			Lower and Upper Oil-shale Groups	Lower Limestone Group		
	S_2	B				Scremerston Coal Group		
	S_1					Fell Sandstone Group		
	C_2				Cementstone Group	Cementstone Group		
	C_1			Tournaisian				
	Z							
	K							

TEXT-FIG. 1. Subdivisions of the British Carboniferous System

Sub-Division of Coal Measures	Great Britain: Northern Province			Great Britain: Central Province								Great Britain: Southern Province			Germany, Ruhr Basin
	Scotland	Cumberland	Northumberland & Durham	Yorkshire & Nottinghamshire	Lancashire	N. Staffordshire	North Wales	Leicestershire & South Derbyshire	Warwickshire	S. Staffordshire & Cannock Chase	Shropshire	South Wales	Bristol & Somerset	Kent	
Upper				TOP	PRESTWICH	BAY						UPPER CWM GORSE	WINTERBOURNE		
	SKIPSEY'S	BOLTON	RYHOPE	MANSFIELD	DUKINFIELD	GIN MINE	WARRAS	OVERSEAL	NUNEATON	CHARLES	CHANCE PENNYSTONE	CEFN COED	CROFTS END	TILMANSTONE	ÄGIR
Middle		? TEN QUARTER	HIGH MAIN	TWO FOOT	ASHCLOUGH	MOSS CANNEL	POWELL			SUB BROOCH	? BLACKSTONE				
	QUEENSLIE	SOLWAY	HARVEY	CLAY CROSS	SUTTON MANOR	7 FT. BANBURY	LLAY	BAGWORTH (MOLYNEUX)	SEVEN FEET	STINKING	PENNYSTONE	AMMAN	HARRY STOKE	RIPPLE	KATHARINA
Lower															
		G. S.*		POT CLAY	SIX INCH	G. S.	AQUEDUCT	G. S.	? G. S.	G. S.		G. S.	G. S.		SARNSBANK
Millstone Grit															

* GASTRIOCERAS SUBCRENATUM BAND

TEXT-FIG. 2. Equivalence of certain Upper Carboniferous marine bands

Based on geological and geographical considerations the British coalfields are usually grouped into three provinces, viz. Northern, Central, and Southern. The Northern Province includes the coalfields of Scotland, Northumberland, Durham, and Cumberland. The Central Province embraces those of Yorkshire, Nottinghamshire, and North Derbyshire, Lancashire, North Staffordshire, North Wales, Leicestershire and South Derbyshire, Warwickshire, South Staffordshire, and Shropshire. This region, which originally formed a single area of deposition, was probably continuous with that of the Northern Province. The Southern Province includes the coalfields of South Wales, Bristol and Somerset, the Forest of Dean, and Kent. During Coal Measures times coal deposition in this province, which formed part of the Sub-Variscan Foredeep, although probably continuous with that in the Central Province over a restricted area in the west, was separated from it over the greater part of its extent by the Midland land barrier. The locations of the British coalfields are shown in text-fig. 3.

Details of the stratigraphy of the various coalfields, the Coal Measures succession, and the palaeontology are given in the publications of the Geological Survey and also in Trueman's *The Coalfields of Great Britain* (1954). Certain geological papers having a bearing on the present investigations, and which have appeared subsequent to 1953, are referred to in the text.

DELINEATION OF MIOSPORE ASSEMBLAGE BOUNDARIES

In 1952 Balme and Butterworth described three miospore Assemblages from the coalfields of Central England. Their limits were defined as the horizons at which certain stratigraphically younger species became constant members of the Assemblages and at which certain stratigraphically older species disappeared. The two horizons thus taken coincided with the marine bands occurring at the base of the Middle Coal Measures and in the upper part of the Middle Coal Measures (top of the Westphalian B) respectively; each horizon was underlain by a small group of seams having a miospore flora of a transitional nature. This procedure in delineating Assemblage boundaries was subsequently criticized as being contrary to accepted palaeontological practice. Although it is not a precise method of subdivision of thestrata involved, experience indicated that it was useful.

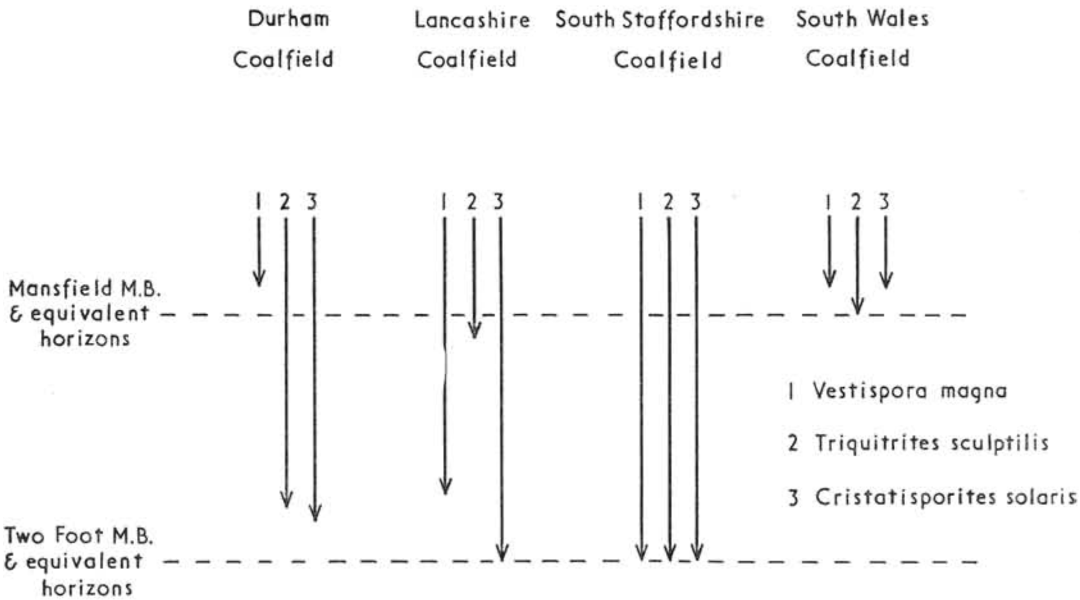
In a later paper (Butterworth and Millott 1955) three further Assemblages were described and their limits drawn at the horizons of the first appearances of the younger species. The base of the lowest of the original three Assemblages was drawn at a horizon towards the middle of the Lower Coal Measures (just above the top of the Lenisulcata Zone), and a further Assemblage described from below it; the two additional Assemblages had their bases a short distance below the lower boundary of the Upper Coal Measures and at a horizon near the middle of the Upper Coal Measures respectively. The six Assemblages were referred to by figures prefixed by the letter S—S0 to Upper S4 in ascending order. The limitations of this nomenclature became apparent when Butterworth and Millott (1960) extended the scheme to include coals below the base of the Coal Measures, that is coals from horizons lower than those previously assigned to the S0 Assemblage. In order to surmount this difficulty spore names were substituted for the letter and figures previously used. The transition Assemblages were not recognized

TEXT-FIG. 3. The coalfields of Great Britain separately. In these investigations the Assemblages were referred to as Zones but in the present work the term Assemblage is again used for reasons given subsequently.

Several factors later made it necessary for the scheme to be revised. Additional coals have been examined from most horizons in the Carboniferous, particularly from the higher parts of the Namurian, so that it has been possible to check and adjust, where necessary, the limits of certain species. As a result the *Cincturasporites carnosus* Zone has been replaced by the *Crassispora kosankei* Assemblage, which occupies a thicker group of strata and has more positive significance than the original *Cincturasporites carnosus* Zone, the top of which was never defined. The spore previously recognized as *Schulzospora ovata* is now known to be another species and the *S. ovata* Zone has been replaced by the *Densosporites anulatus* Assemblage to which a lower limit can be drawn. The *Rotaspora knoxi* and *Cirratriradites aligerens* Zones have each been subdivided and the base of the *Novisporites magnus* Zone has been lowered from the level of the Mansfield Marine Band (top of the Westphalian B) to the horizon of the Two-Foot Marine Band, which is somewhat lower in the sequence. Four of the species used to identify the zones, *Cincturasporites carnosus*, *Cirratriradites aligerens*, *Novisporites magnus*, and *Verrucososporites obscurus*, have been assigned to other genera; this is a drawback to the use of species names for Assemblages and Zones which is generally recognized, but the authors do not think that it is serious enough for discontinuing the use of the system. *Aligerens*, *magna*, and *obscura* are retained as Assemblage names under their new generic designations.

During the course of their revision of the zonal scheme put forward by Butterworth and Millott (1960) the present authors have attempted to place the dividing lines between the Assemblages at the levels of the first appearances of the stratigraphically younger species; the base of the *Vestispora magna* Assemblage is thus lowered to the horizon of the Two-Foot Marine Band in order to include within it coals which were originally assigned to the S2–S3 Transition Assemblage. It is found, however, that the diagnostic species tend to be very rare in their earliest occurrences and, as might be expected in terrestrial fossils, their lateral distributions are uneven. Text-fig. 4 shows diagrammatically the variations in the distributions of the species *Vestispora magna*, *Cristatisporites solaris*, and *Triquitrites sculptilis* in the seams of the Middle Coal Measures above the Two-Foot Marine Band and equivalent horizons in selected coalfields. These variations may, in part, be due to the uneven distribution of the coals examined, and it is possible that a more intensive examination of seams in this part of the succession will show less variation between the coalfields. Complications also arise from the existence of transitional forms between certain species, as, for example, between *Vestispora magna* and the longer-ranging species of the genus *Vestispora*, and between *Cristatisporites solaris* and the stratigraphically older *C. indignabundus*. In the Upper Limestone Groups of Scotland and Northumberland there is a similar transition between *Crassispora kosankei* and the older species *C. maculosa*; the base of the *C. kosankei* Assemblage is placed at a horizon a little below that of the Orchard Limestone in West Fife, where *C. kosankei* first appears, although in association with *C. maculosa*.

The use of the disappearance of *Dictyotriletes bireticulatus* to mark the top of an Assemblage (Balme and Butterworth 1952, S2 Assemblage) is obviously impracticable when the horizons of its disappearance in various coalfields differ so markedly (text-fig. 56). There are instances, however, where the disappearance of a spore has great practical value, as, for example, that of *Schulzospora* at the Mid-Modiolaris Marine Band and of *Radiizonates aligerens* a little lower in the sequence. Such horizons could not be used as true zonal limits and would have to delimit some form of subzone. The introduction

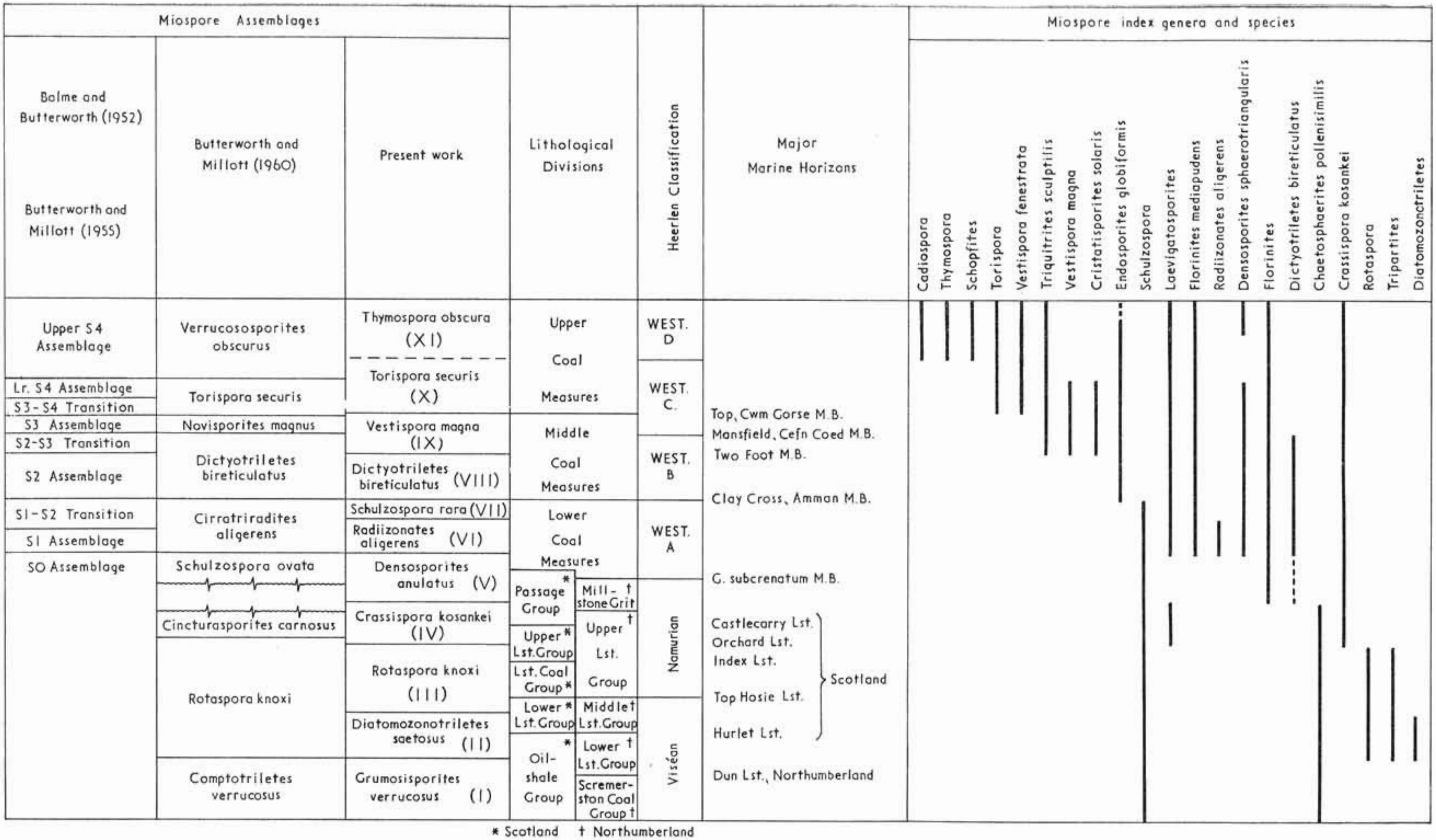


TEXT-FIG. 4. Approximate horizons at which the index species of Assemblage IX appear in different coalfields

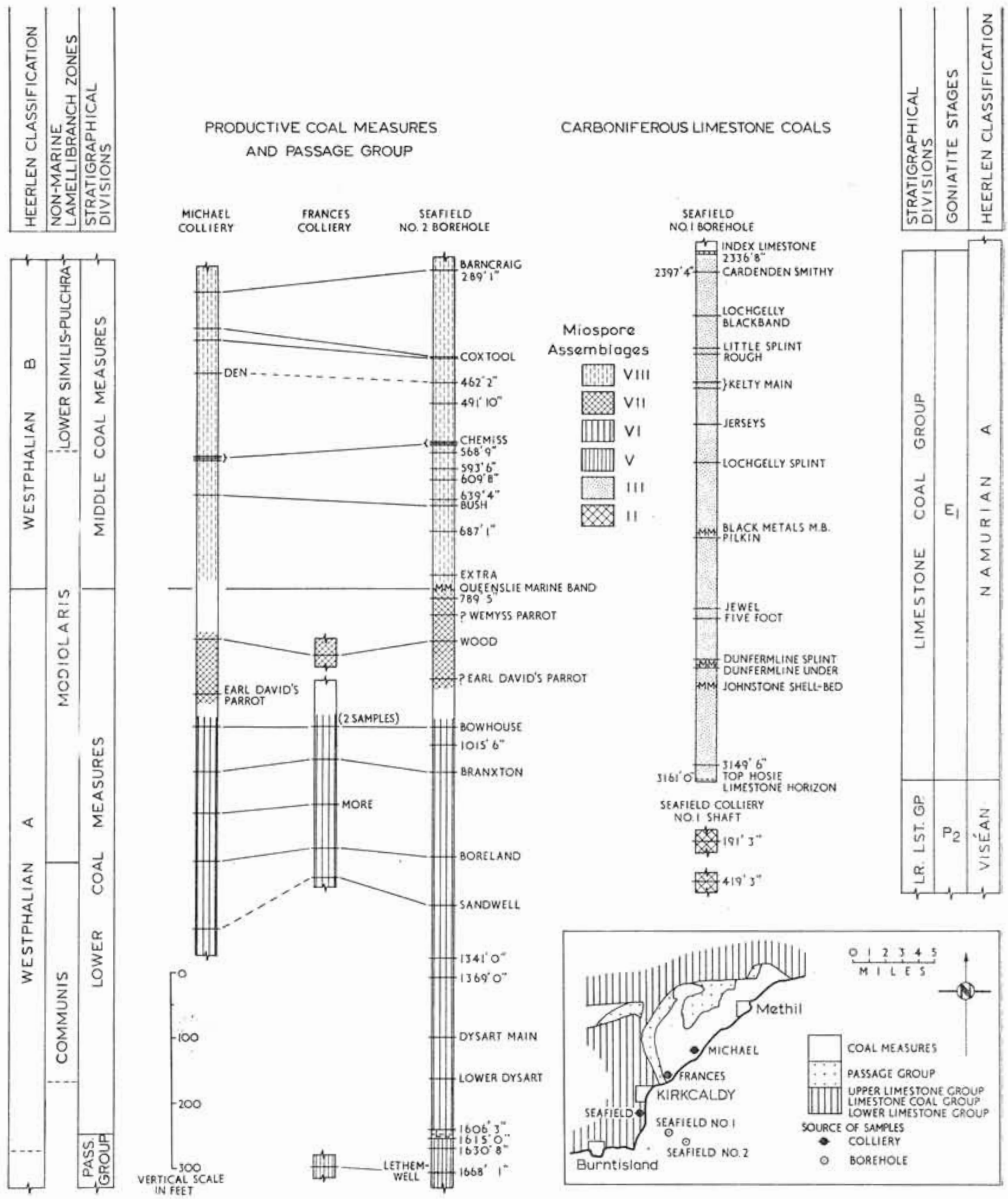
of subzones, however, would tend to raise unnecessary complications in the system of nomenclature or numbering used. For these reasons the authors decided that to retain a rigid system of zones throughout the coalfields would inevitably lead to some distortion of the facts, and a return has therefore been made to the use of the more flexible term Assemblage. For ease of reference in this work the Assemblages, which are subsequently described in detail, have been numbered from I to XI in ascending order. Their present limits, together with those previously applicable, are shown in text-fig. 5 alongside the ranges of some of the more stratigraphically significant genera and species.

THE MIOSPORE ASSEMBLAGES IN BRITISH COALFIELDS

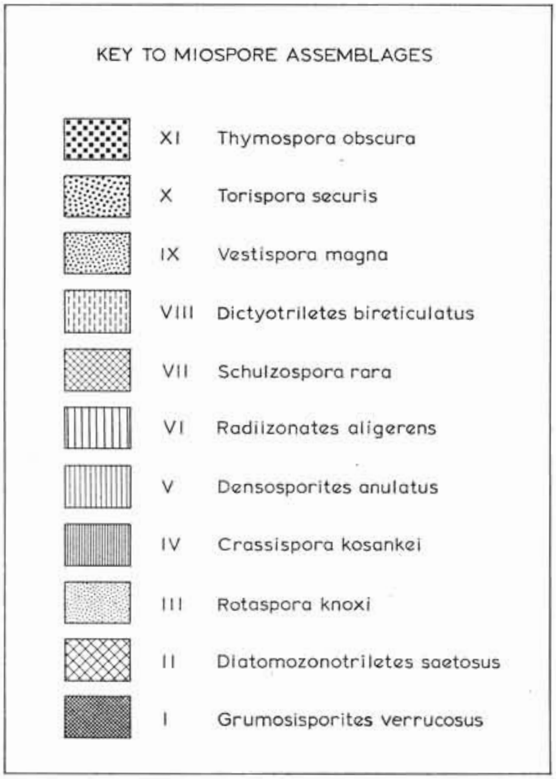
In this section an account is given for each coalfield of the main features of the miospore Assemblages and of the coals in which they occur. Each account is preceded by a brief statement of the sequences examined in relation to the geological horizons of the coal-bearing strata present. Two figures accompany the text for most of the coalfields. The first shows the sequences of seams examined and the locations of the sequences. The ranges of the miospore Assemblages are indicated on the sections by different types of hatching, the data in these sections being summarized in a composite section which shows the horizons of all the seams in the various sequences examined in their approximate stratigraphic positions. As any particular coalfield may have several different



TEXT-FIG. 5. Boundaries of the miospore Assemblages and the ranges of index genera and species

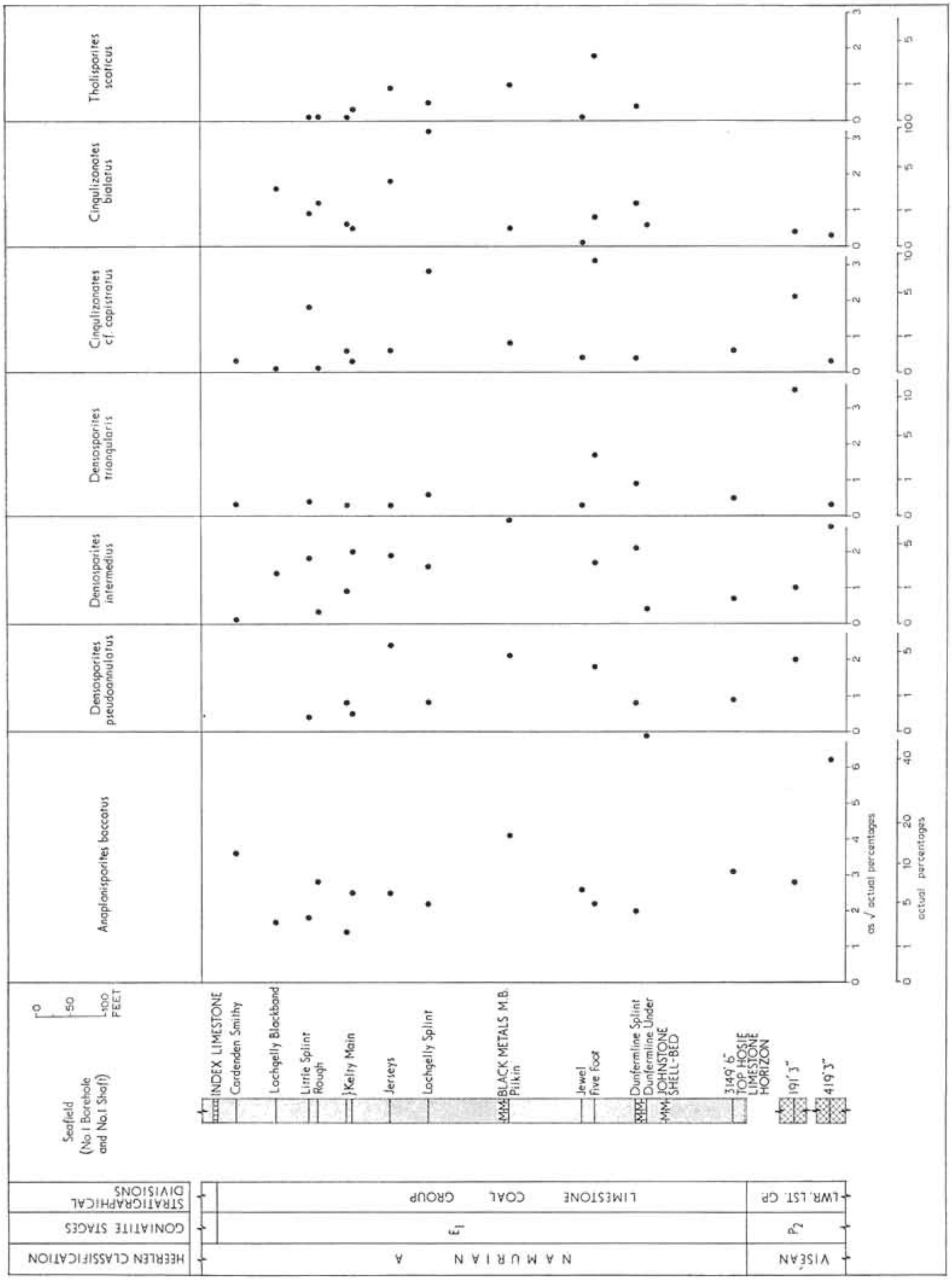


TEXT-FIG. 6. Location of samples and sequences of seams examined from the East Fife Coalfield

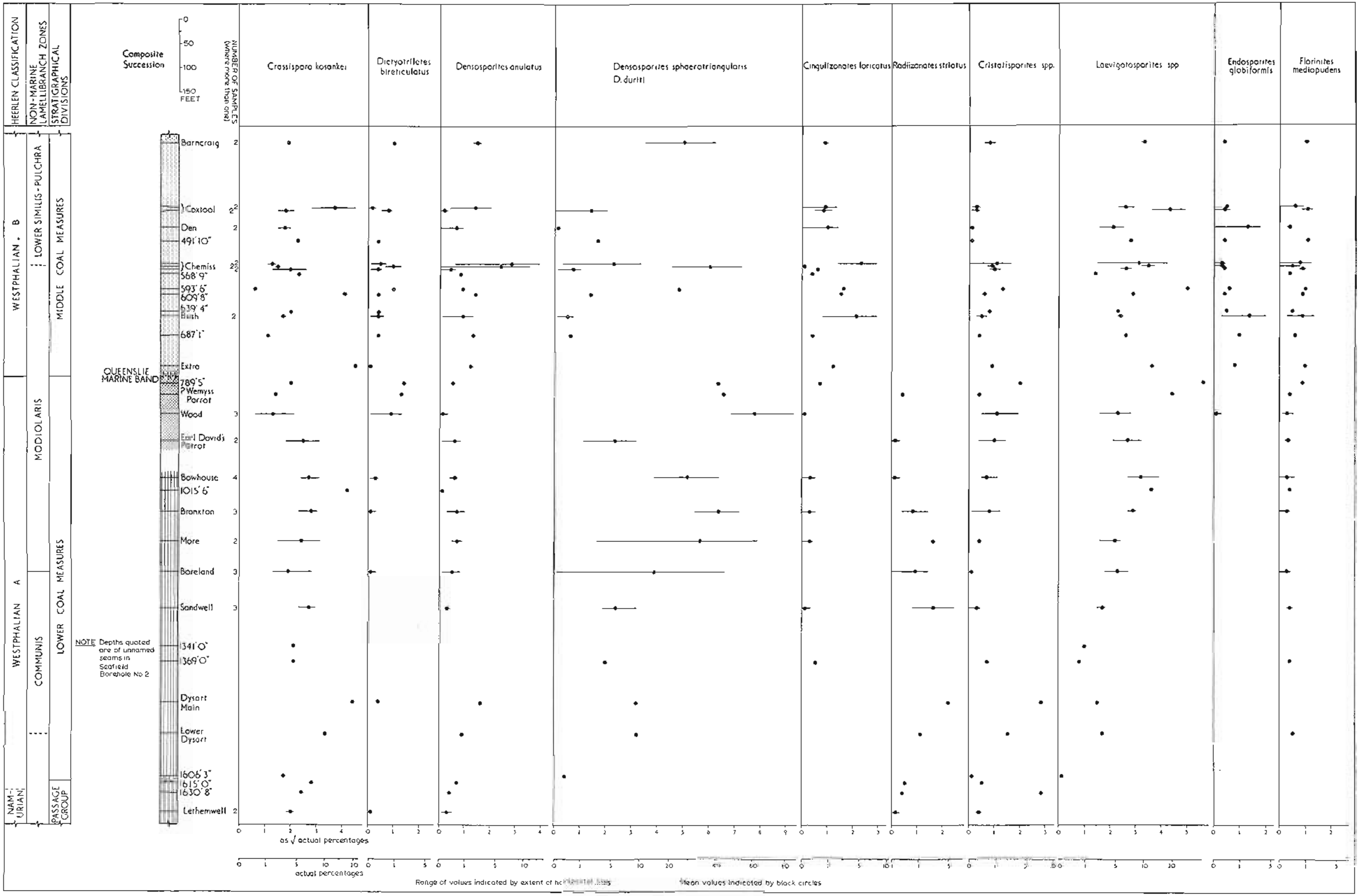


sequences this composite section does not correspond to a generalized section of strata. The lower limit of each Assemblage (in the composite section) is shown at the horizon of the oldest coal in which the characteristic species of the Assemblage have been seen; those portions of the individual sequences within the same coalfield in which the relevant species have not been found at equivalent, or younger, horizons, are left unhatched. The Assemblage boundaries, as shown in the composite sections, may, therefore, vary from one coalfield to another. The second figure shows the vertical variations in the abundance of the more common spores, with the exception of *Lycospora spp.*, which are abundant in very nearly all of the coals examined. Other species seldom have frequencies exceeding 1% in whole seam samples. The sequences of seams shown in these figures are reproduced from the composite sections in the first figure. In order to compress the data into a reasonable space, the square roots of the percentage frequencies are plotted; the circles represent the mean frequencies at each horizon and the horizontal bars the spread of the individual frequencies.

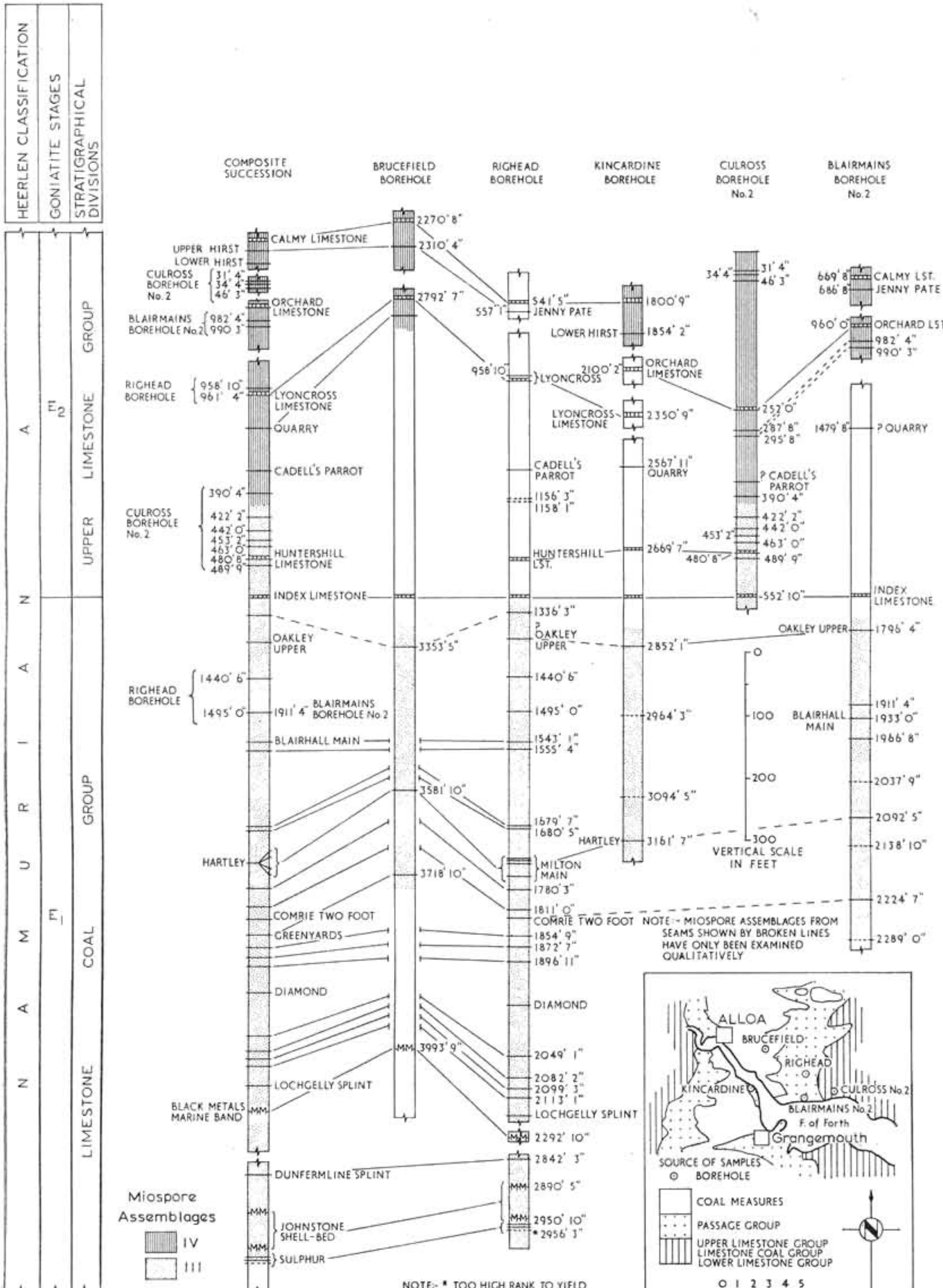
The number of occasions (expressed as percentages) on which selected spores occurred in the samples examined from a given Assemblage are shown in four tables, one for each Province. In these tables the generalized Assemblage boundaries shown in text-fig. 5 are used. This method of showing the stratigraphic ranges of spores and their value as index fossils was suggested by Harris (1952) and subsequently used by Couper (1958).



TEXT-FIG. 7. Frequencies of selected miospore species in certain seams of the Lower Limestone and Limestone Coal Groups of the East Fife Coalfield



TEXT-FIG. 8. Frequencies of selected miospore species in certain seams of the Passage Group and Coal Measures of the East Fife Coalfield.



TEXT-FIG. 9. Locations of samples and sequences of seams examined from the West Fife Coalfield

A value of 100 for a given species in a particular Assemblage means that it has been found in every sample which has been examined from within the range of that Assemblage.

The Scottish Coalfields

The major Scottish coalfields include those of East Fife, West Fife (including Alloa, Clackmannan, and Stirling), Lothians, Central, and Ayrshire. There are also several smaller fields, including Canonbie (in which mining has ceased).

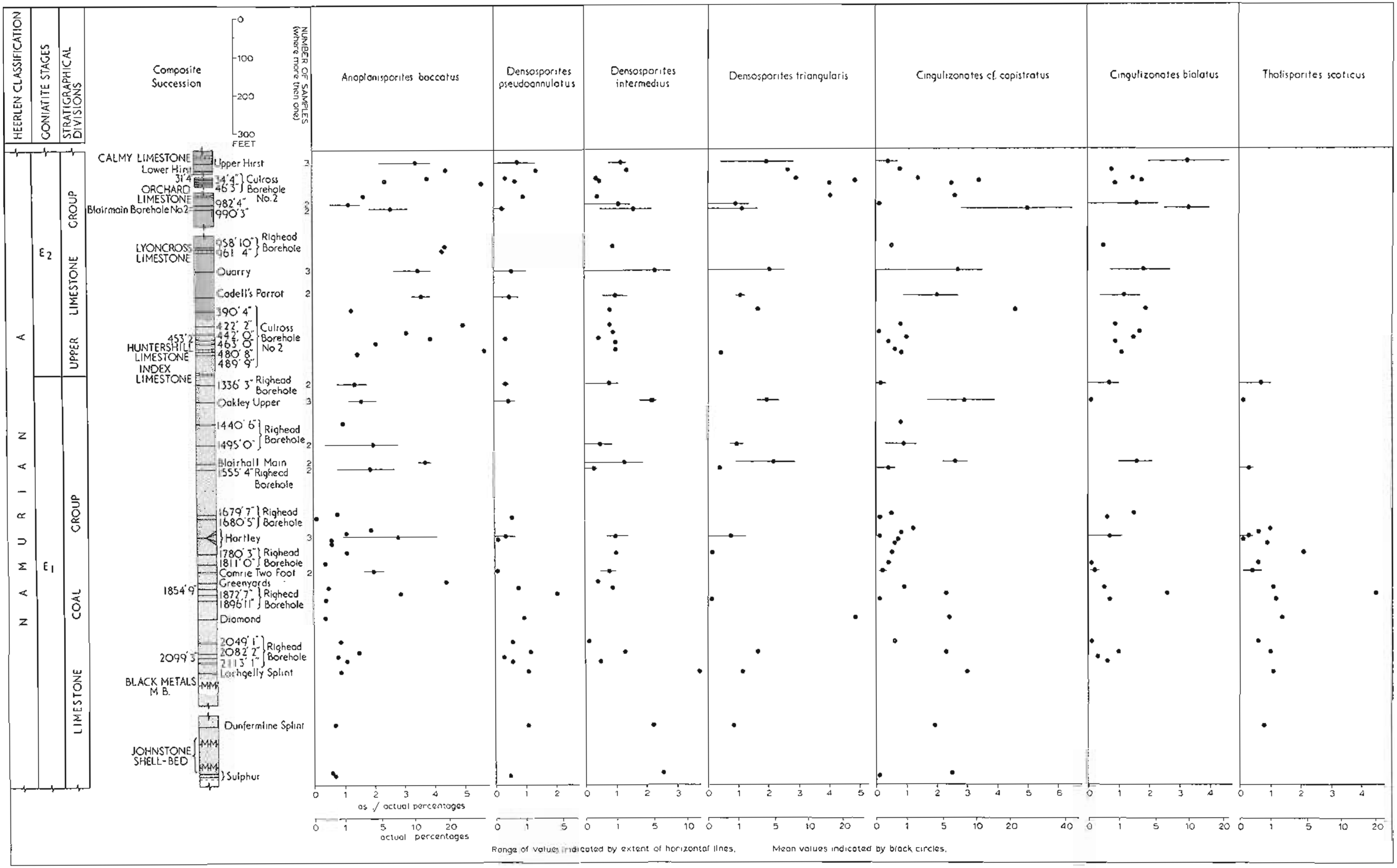
Coal seams are present in both the Lower and Upper Carboniferous; they occur throughout the succession from the Oil Shale Group of the Calciferous Sandstone Series (Viséan) to the Barren Red Measures lying in the upper part of the Coal Measures. The economically important seams are mainly confined to the Limestone Coal Group (Namurian A), and the Productive or Lower and Middle Coal Measures (Westphalian A and B).

Previous investigations on the miospores of Scottish coals were carried out by Knox (1942), who examined a number of sequences from East Fife and recorded the vertical ranges of several spore types. Analogous ranges were later found in sequences in the Central Coalfield and the relationship between miospore distribution and the non-marine lamellibranch and floral zones was noted (Knox 1946). In 1948 this investigator published a preliminary account of the miospores present in seams of the Limestone Coal Group, mainly in Fife, and drew attention to the large numbers of species present in the Namurian A seams and to the absence of *Laevigatosporites* from the older coals. She also showed that the reciprocal relationship between *Densosporites* and *Lycospora*, previously noted by other workers as occurring in Coal Measures seams, also occurred in the Limestone Coal Group. Many of the spores figured in Knox's earlier papers, and designated by a numerical method of nomenclature, were subsequently redescribed and assigned to genera and species using the binominal system (Knox 1950). More recently, Butterworth and Williams (1958) have described further miospore species present in the Limestone Coal Group and the Upper Limestone Group (Namurian A) of the West Fife, Lothians, and Central Coalfields, and Love (1960) has described assemblages present in the Oil Shale Group of the Lothians.

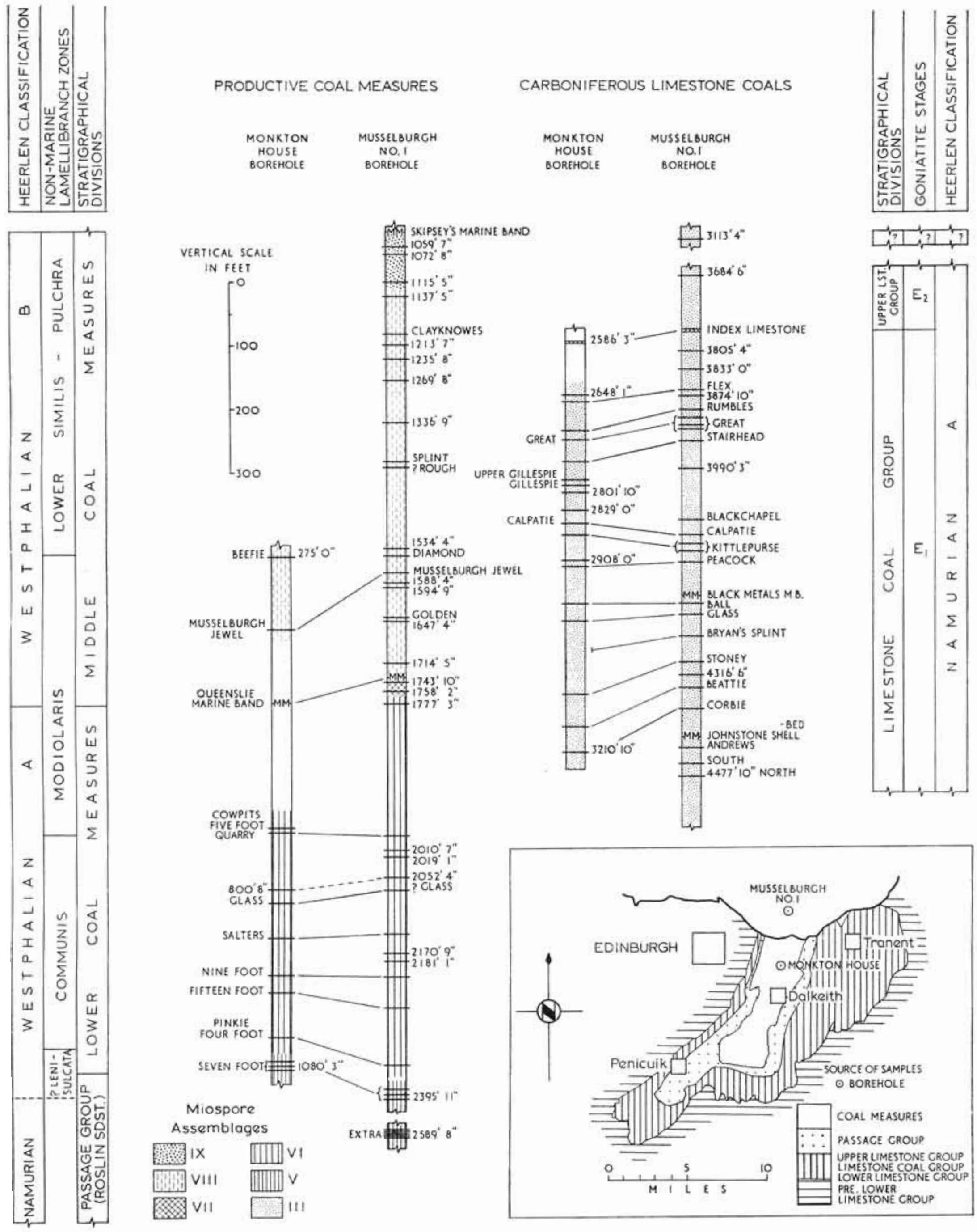
Relatively few sequences have been investigated from Scotland in the course of the present investigations. The lowest seam examined occurred in the Oil Shale Group of the Central Coalfield and the highest in the Barren Red Measures (Westphalian C) of Canonbie. Seams of Namurian age were investigated from the East Fife, West Fife, Lothians, and Central fields and of Westphalian age from all the coalfields except West Fife.

In East Fife (text-fig. 6) samples of two seams in the Lower Limestone Group were examined from the Seafield Colliery No. 1 Shaft and of seams in the Limestone Coal Group, the Passage Group, and the Productive Coal Measures from the Seafield Nos. 1 and 2 boreholes, described by Ewing and Francis (1960). The sequence of seams in the Productive Coal Measures was augmented by samples from Michael and Frances Collieries. The highest seam examined, the Barncraig, lies some distance below the top of the Middle Coal Measures.

In West Fife (text-fig. 9) seams in the Limestone Coal Group and the Upper Limestone Group were investigated from the Brucefield, Righead, Kincardine, and Blairmains



TEXT-FIG. 10. Frequencies of selected miospore species in certain seams from the West Fife Coalfield.



TEXT-FIG. 11. Locations of samples and sequences of seams examined from the Lothians Coalfield

No. 2 boreholes. A more extensive sequence of Upper Limestone Group coals was supplied by the Culross No. 2 borehole. Certain of the seams—the Five Feet at 2,667 ft. 0 in. and the overlying coal at 2,612 ft. 0 in. in the Righead borehole, and the coals below the seam at 2,289 ft. 0 in. in the Blairmains borehole—were of too high rank for satisfactory maceration (the seams concerned are not shown in text-fig. 9).

Seams in the Limestone Coal Group, Upper Limestone Group, Passage Group, and Productive Coal Measures of the Lothians field (text-fig. 11) were examined from the Monkton House and Musselburgh No. 1 boreholes. The highest seam occurred just below the horizon of Skipsey's Marine Band at the top of the Middle Coal Measures.

In the Central Coalfield seams were examined from the Oil Shale Group, Limestone Coal Group, Upper Limestone Group, and Productive Coal Measures (text-fig. 14). A sample of the Houston Coal occurring in the Oil Shale Group was obtained from the Coalheughhead Mine. Seams in the Limestone Coal Group were examined from the Cawder Cuilt, Queenslie Bridge, and Darnley No. 3 boreholes and those in the Upper Limestone Group from Cawder Cuilt and Darnley Nos. 3 and 4 boreholes. The Limestone Coal Group sequences are among those considered by Forsyth and Read (1962) in their correlations of boreholes in the Glasgow–Stirling region. Samples of seams in the Productive Coal Measures were obtained from the Queenslie Bridge and Foulsykes No. 18 boreholes supplemented by some from Bothwell Castle and Cadzow Collieries. The highest seam examined, the Upper, occurs near the top of the Middle Coal Measures.

Only one sequence was examined from Ayrshire—that in the Slatehole Farm borehole (text-figs. 17 and 18). This sequence extends from the Twenty Fathom Seam in the Lower Coal Measures to the Ell Seam in the higher part of the Middle Coal Measures.

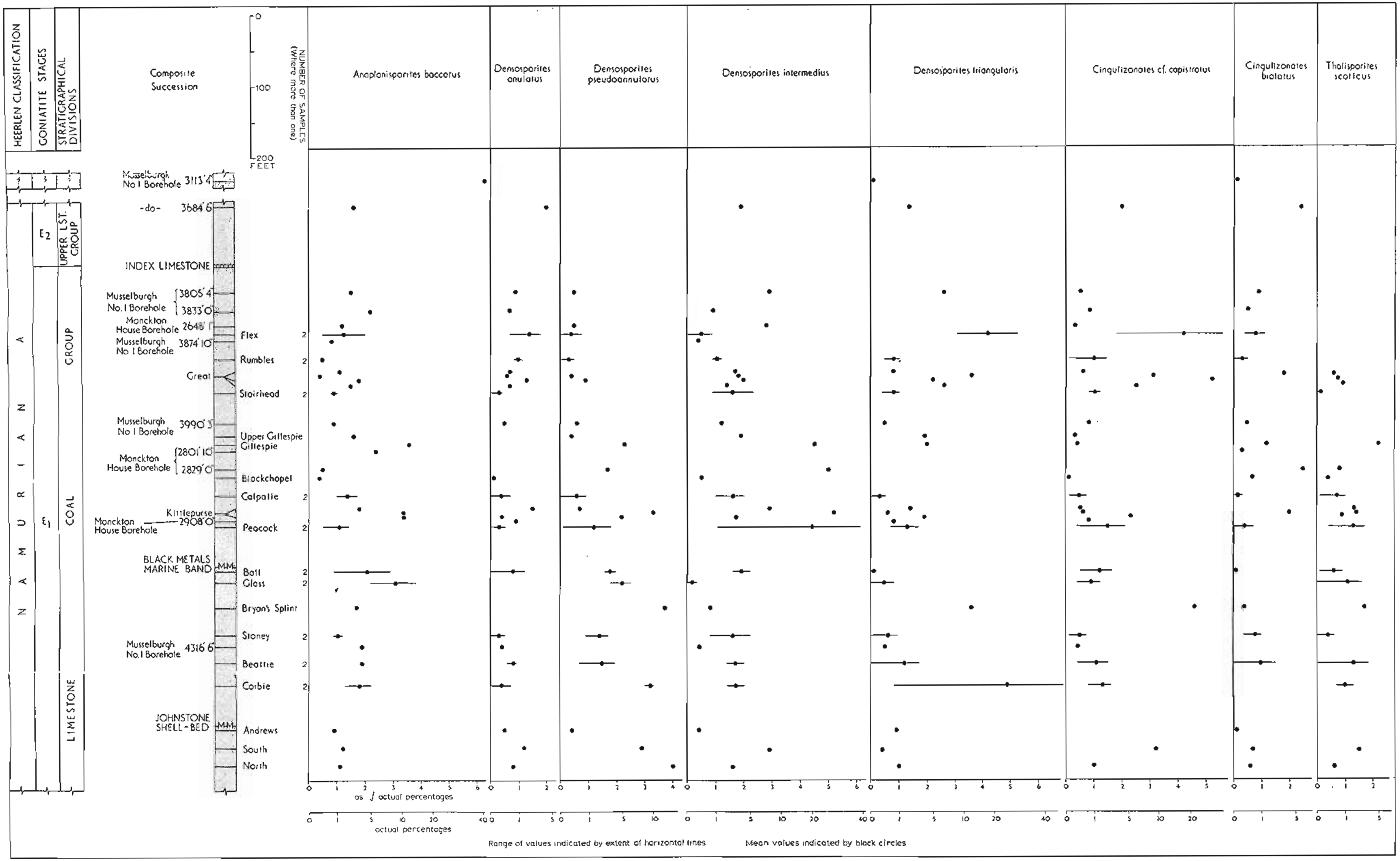
In the Canonbie Coalfield (text-fig. 19) seams in the upper part of the Lower Coal Measures, the Middle Coal Measures, and the lower part of the Upper Coal Measures were examined from the Rowanburnfoot borehole. In addition, several of the coals in the Middle Coal Measures and lower part of the Upper Coal Measures were investigated from the Knottyholm Farm borehole.

The frequencies of occurrence of the more significant genera and species in the various coalfields are shown in text-figs. 7, 8, 10, 12, 13, 15, 16, 18, and 20.

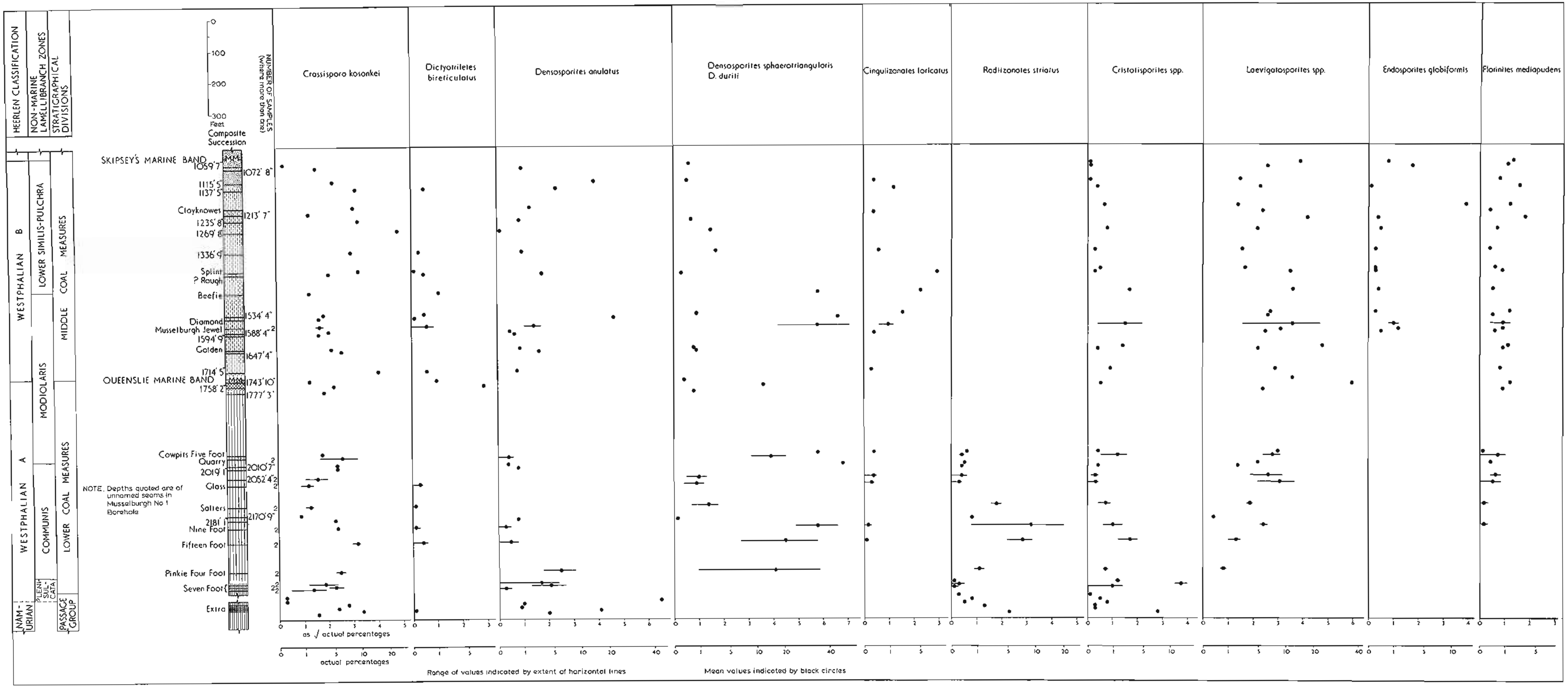
The most recent general geological account of the Scottish coalfields is that given by Macgregor in Trueman (1954).

Diatomozonotriletes saetosus Assemblage II (Houston Coal, Central Coalfield and seams at 419 ft. 3 in. and 191 ft. 3 in., Seafield Colliery No. 1 Shaft, East Fife).

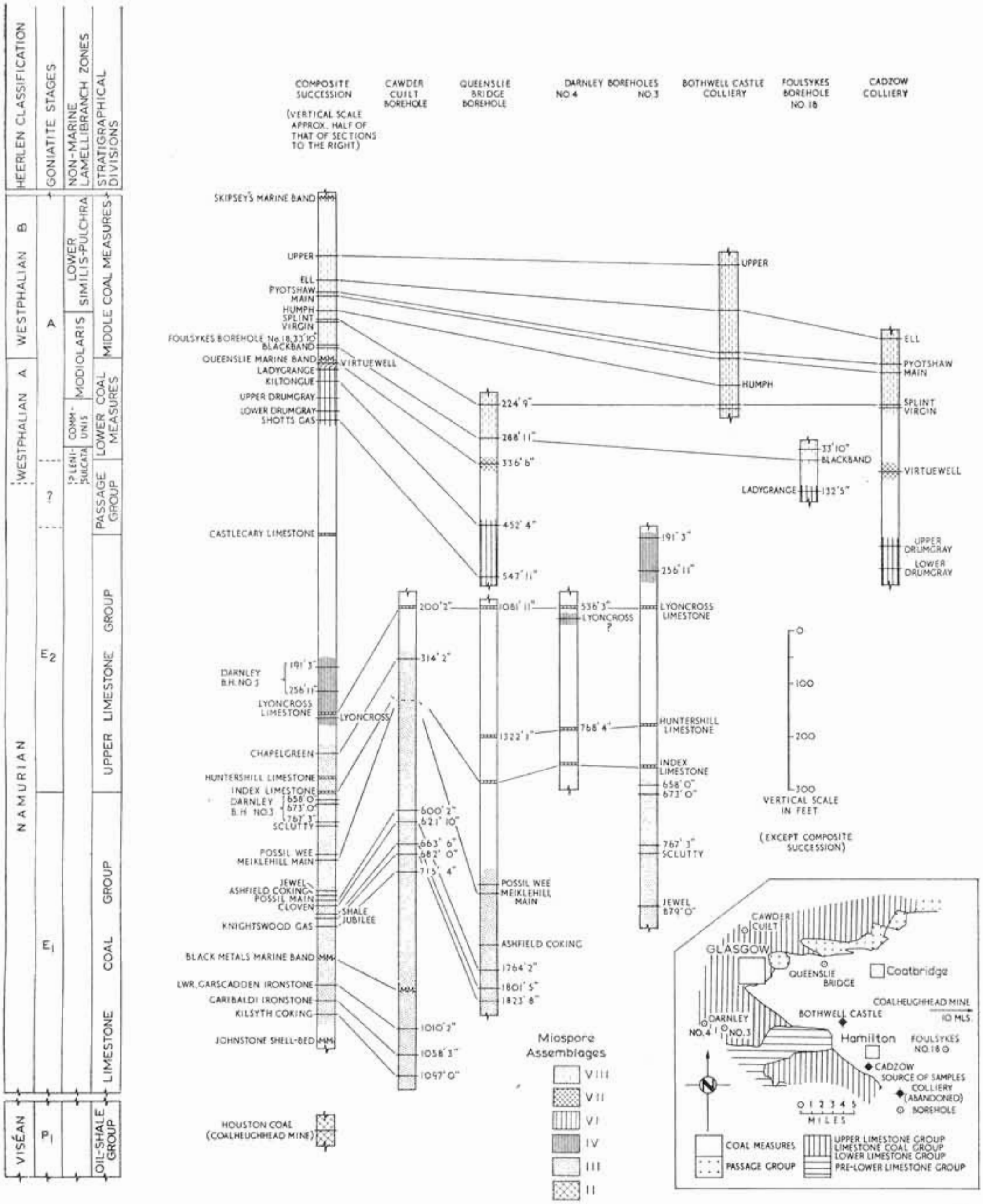
The Houston Coal (not shown in text-fig. 16), occurring towards the top of the Oil Shale Group in the Central Coalfield, has a typical Viséan miospore flora containing *Diatomozonotriletes saetosus* and *Procoronaspora dumosa*. *Tripartites vetustus* is occasionally present, but no species of *Rotaspora* have been seen. The seams present in the Lower Limestone Group of East Fife contain *Diatomozonotriletes cervicornutus* and *Procoronaspora fasiculata*, in addition to species of *Rotaspora* and *Tripartites*. The more common species are similar to those in the succeeding Assemblage with the exception of *Tholisporites scoticus*, which is rare, being present only in the Houston Coal.



TEXT-FIG. 12. Frequencies of selected miospore species in certain seams of the Limestone Coal Group and Upper Limestone Group of the Lothians Coalfield.



TEXT-FIG. 13. Frequencies of selected miospore species in certain seams in the Passage Group and Coal Measures of the Lothians Coalfield.



TEXT-FIG. 14. Locations of samples and sequences of seams examined from the Central Coalfield of Scotland

Rotaspora knoxi Assemblage III (seams of the Limestone Coal Group, East Fife, West Fife, Lothians, and Central Coalfields, to seam at 422 ft. 2 in., Culross No. 2 borehole, West Fife, and to seam at 3,113 ft. 4 in., Musselburgh No. 1 borehole, Lothians, also to Chapelgreen Seam at 314 ft. 2 in., Cawder Cuilt borehole, Central Coalfield).

As will be seen from Table 1 this Assemblage is very varied. It is distinguished from the *D. saetosus* Assemblage by the absence of species of *Diatomozonotriletes* and *Rotaspora crenulata* and by the presence of *Convolutispora cerebra*, *Savitrisporites nux*, *Bellispores nitidus*, and *Vestispora lucida*. The common Namurian A species are fewer in number than those of the Coal Measures, and their vertical distributions do not exhibit marked patterns of variation. The frequencies of the seven most abundant types, excepting *Lycospora spp*., are shown in text-figs. 8, 10, 13, and 16. *Anaplanisporites baccatus* is most frequent in coals of the Upper Limestone Group (West Fife, text-fig. 10), where it may constitute 25% of the total assemblage; in coals of the Limestone Coal Group it exceeds 10% only occasionally. *Tholisporites scoticus* has been recorded from only one horizon in the Upper Limestone Group (Central Coalfield, text-fig. 16), and is otherwise restricted to the Limestone Coal Group and lower horizons. It reaches a maximum frequency (rarely more than 5%) in the seams above the Black Metals Marine Band, and becomes infrequent as the Index Limestone is approached.

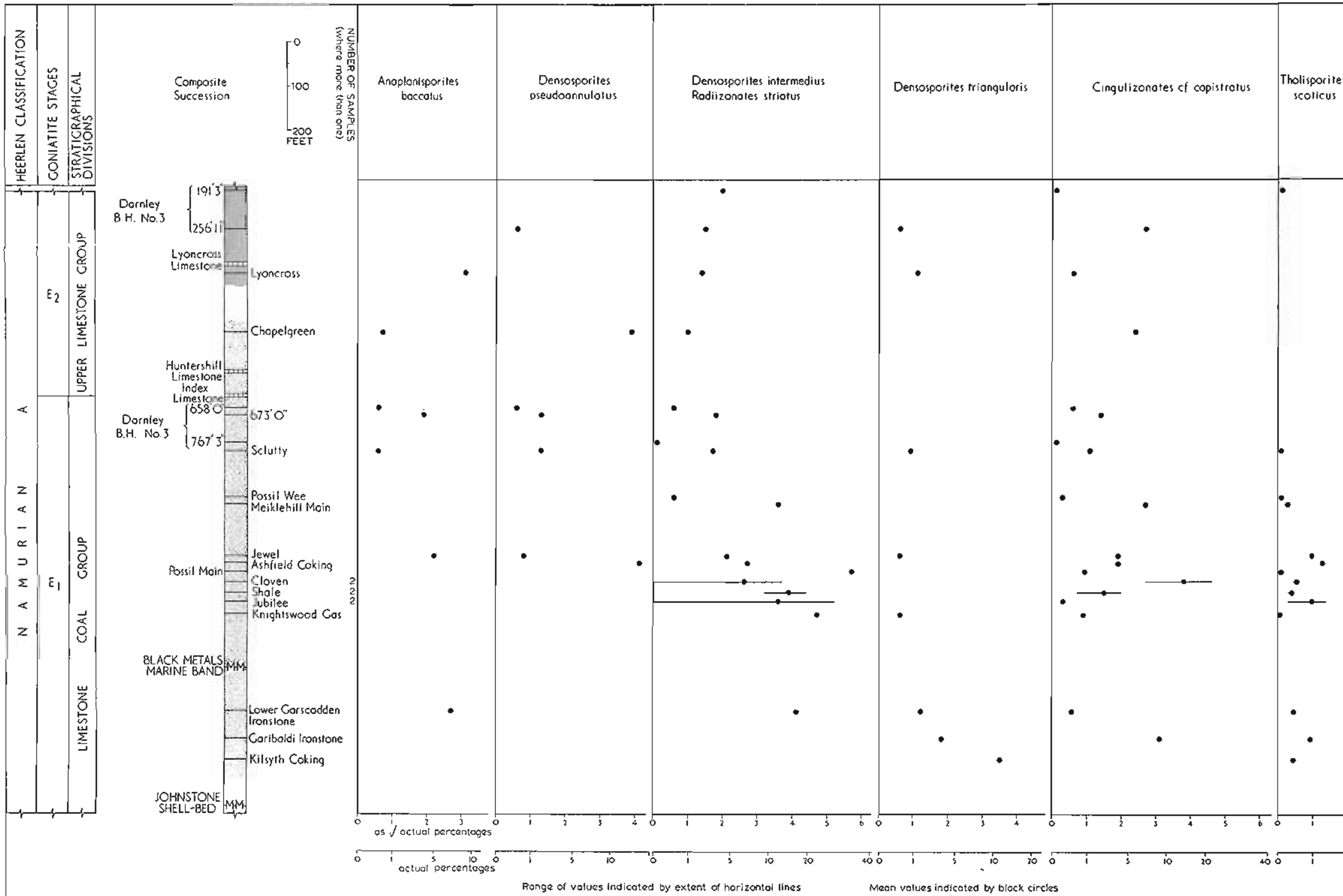
The remainder of the common spores belong to the densospore group; their frequency distributions show a common pattern, that is at horizons where one species is common several, or all, of the remainder are also common. *Tholisporites scoticus*, and to a less marked extent *Anaplanisporites baccatus*, appear to be distributed similarly. The pattern is one of fairly frequent alternations of densospore-rich and densospore-poor seams, the former containing up to 45% of densospores in the Lothians Coalfield, where they tend to be most abundant, and up to about 40% elsewhere. *Cingulizonates* cf. *capistratus* is rather more frequent in the coals of the Upper Limestone Group and in the Lothians sequence *Densosporites pseudoannulatus* tends to decrease in numbers from the bottom to the top of the Assemblage.

Crassispora kosankei Assemblage IV (seam at 390 ft. 4 in., Culross No. 2 borehole, and overlying seams of the Upper Limestone Group, West Fife; Lyoncross Seam, Darnley No. 4 borehole, and overlying seams of the Upper Limestone Group, Central Coalfield).

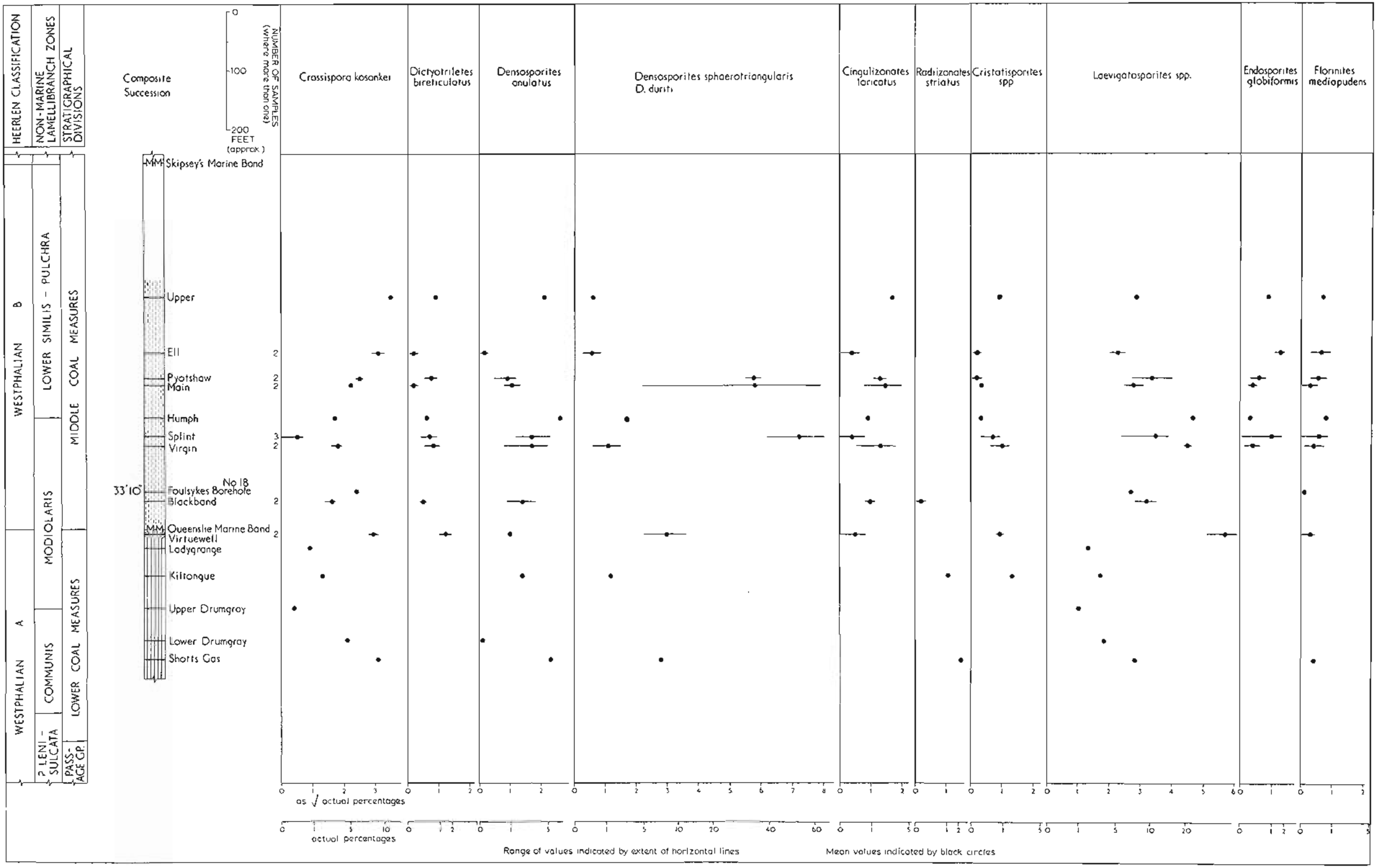
C. kosankei was first noted in the seam at 390 ft. 4 in. in the Culross No. 2 borehole; in this and the succeeding seams it is not always easy to distinguish it from *C. maculosa*, which occurs in most of the coals examined. The Jenny Pate and Lower Hirst Seams and other seams above the horizon of the Orchard Limestone are distinguished from those lower in the sequence by the absence of species of the genera *Rotaspora* and *Tripartites*. Characteristic, but not common, species include *Convolutispora cerebra*, *Savitrisporites nux*, *Reticulatisporites carnosus*, *Stenozonotriletes bracteolus*, and *Bellispores nitidus*. The frequencies of the more common spores are roughly similar to those in the Assemblage below.

Densosporites anulatus Assemblage V (Lethemwell Seam and overlying seams in the Passage Group, East Fife, and Extra and Seven Foot Seams, Lothians).

These seams have miospore floras which are essentially Westphalian in character, few of the typical Namurian A species being represented. *Florinites* is present in the

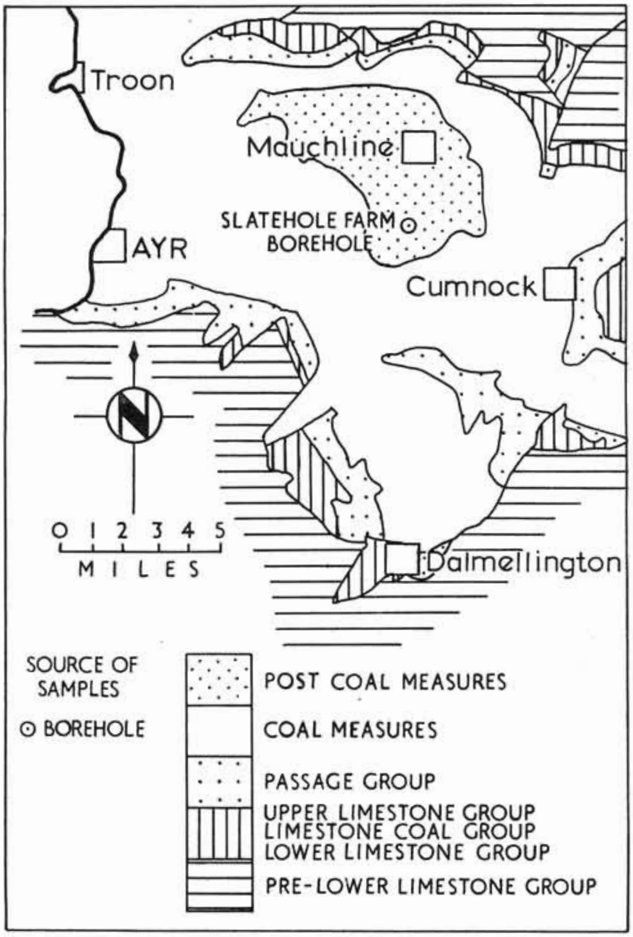


TEXT-FIG. 15. Frequencies of selected miospore species in certain seams in the Limestone Coal Group and the Upper Limestone Group of the Central Coalfield of Scotland.



TEXT-FIG. 16. Frequencies of selected miospore species in certain seams in the Coal Measures of the Central Coalfield of Scotland.

form of *F. similis* and characteristic, but very infrequent species include *Punctatisporites sinuatus, Mooreisporites fustis, Savitrisporites sp.*, and *Reinschospora speciosa. Dictyotriletes bireticulatus* is very occasionally present.



TEXT-FIG. 17. Location of the Slatehole Farm borehole, Ayrshire Coalfield

Densosporites anulatus and *Radiizonates striatus* are not so frequent as at similar horizons in other Provinces. The Seven Foot and Extra Seams (Lothians Coalfield) contain a complex of *Cristatisporites spp.*, sometimes in abundance, which has not yet been resolved into separate species.

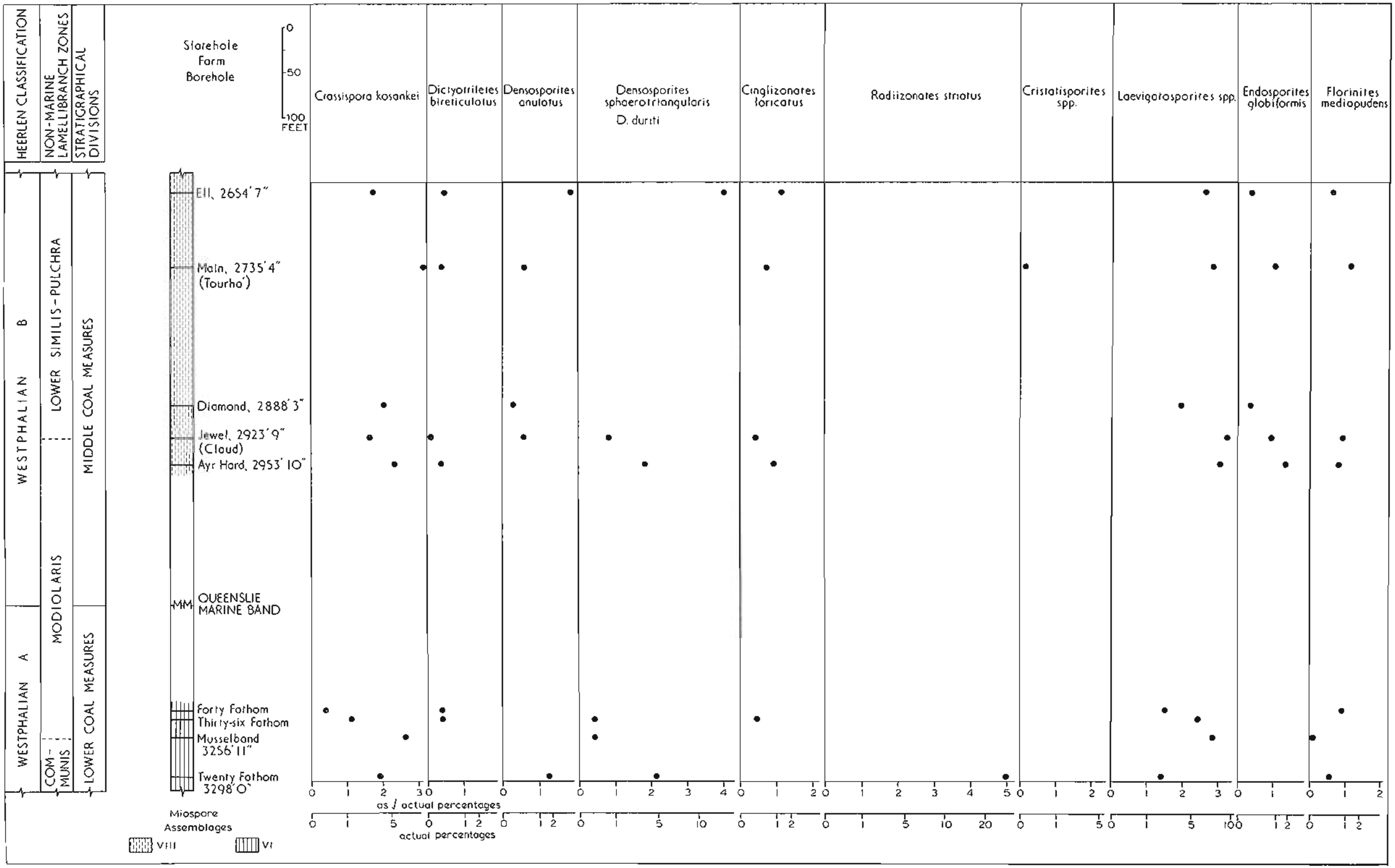
Radiizonates aligerens Assemblage VI (seam at 1,606 ft. 3 in., Seafield No. 2 borehole to Bowhouse Seam, East Fife; Pinkie Four Foot Seam to seam at 1,777 ft. 3 in., Musselburgh No. 1 borehole, Lothians; Shotts Gas Seam to Ladygrange Seam, Central; Twenty Fathom Seam to Forty Fathom Seam, Ayrshire).

In East Fife *Laevigatosporites* first appears in the seam at 1,606 ft. 3 in. in the Seafield No. 2 borehole, where it is rare, and *Florinites mediapudens* in the Lower Dysart, the seam above. In the Lothians Coalfield *Laevigatosporites* appears first in the Pinkie Four Foot Seam and *F. mediapudens* in the Nine Foot Seam. *Laevigatosporites* is very common and *F. mediapudens* is present in the Shotts Gas Seam (the lowest coal examined from the Productive Coal Measures of the Central Coalfield) and both are present in the Twenty Fathom Seam, the lowest coal examined from the Slatehole Farm borehole, Ayrshire. *R. striatus* is very common in the Fifteen Foot Seam and locally abundant in the Nine Foot Seam of the Lothians field; it is abundant in the Twenty Fathom Seam of Ayrshire. Elsewhere it is never abundant, but is most frequent in the Dysart Main, Sandwell, and More Seams of East Fife and in the Shotts Gas Seam of the Central Coalfield. In East Fife, *R. aligerens* first appears in the Dysart Main Seam and is locally common in the More and Bowhouse Seams. In the Lothians Coalfield it appears first in the Nine Foot Seam and may be common in the Glass and Quarry Seams. The Shotts Gas and Musselband Seams mark the horizons of its first appearance in the Central and Ayrshire Coalfields respectively, where it is never common. *Densosporites sphaerotriangularis* is abundant at several horizons in both the East Fife and Lothians Coalfields; elsewhere it is not prominent, but is very common in the Shotts Gas Seam in the Central Coalfield and common in the Twenty Fathom Seam of Ayrshire. *Cristatisporites connexus* is common, or very common, at a few horizons in the East Fife, Lothians, and Central Coalfields but has not been seen in this Assemblage in Ayrshire.

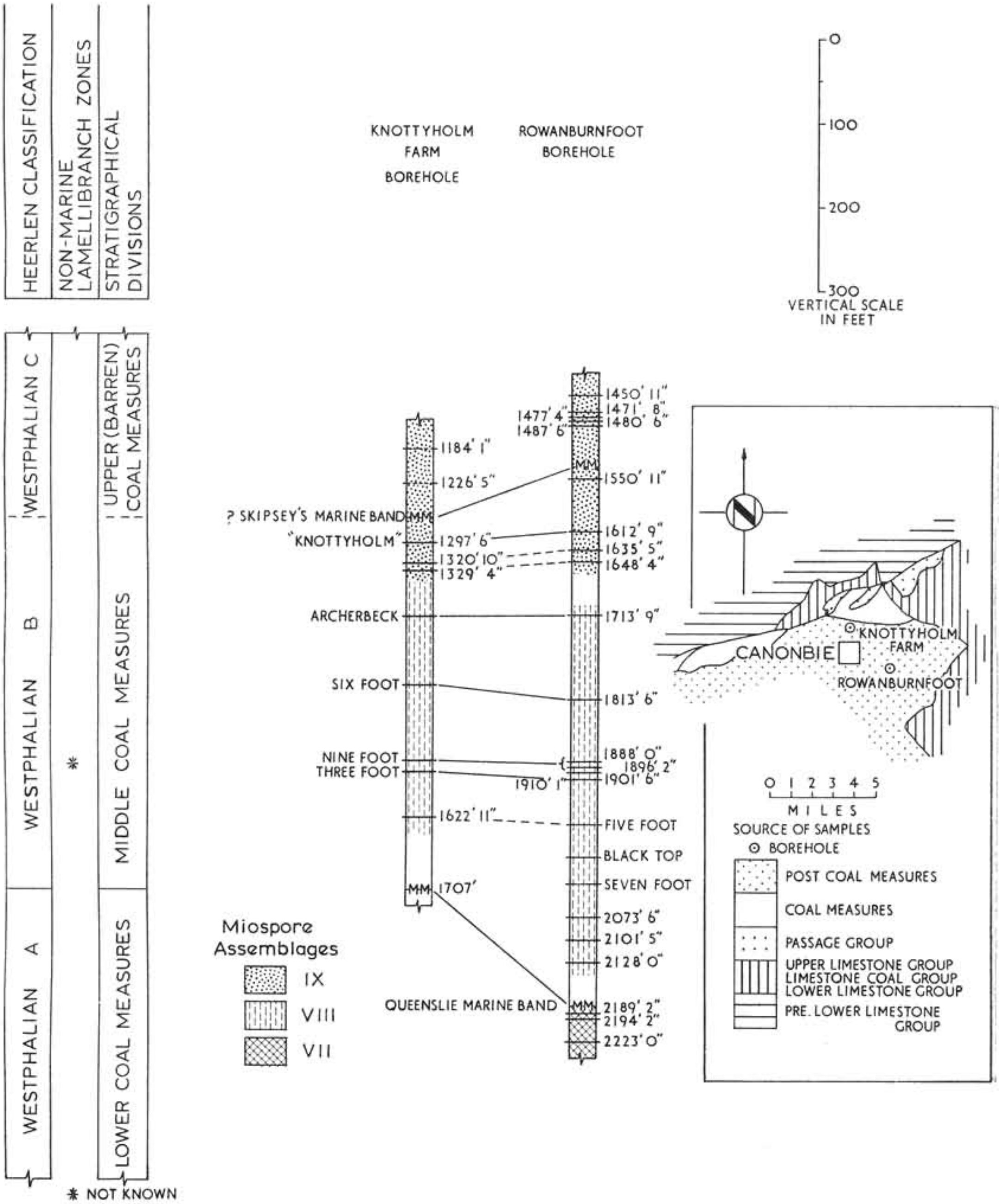
Schulzospora rara Assemblage VII (Earl David's Parrot Seam to seam at 789 ft. 5 in., Seafield No. 2 borehole, East Fife; seam at 1,758 ft. 2 in. and seam at 1,743 ft. 10 in., Musselburgh No. 1 borehole, Lothians; Virtuewell Seam, Central; seam at 2,223 ft. 0 in. to seam at 2,189 ft. 2 in., Rowanburnfoot borehole, Canonbie).

The number of seams containing this Assemblage varies from one in the Central Coalfield to four in East Fife; the Earl David's Parrot Seam in the latter field, however, does not show other miospore characteristics of the Assemblage and it may be that further investigation would reveal the presence of *Radiizonates aligerens*; this would mean the inclusion of the seam in the Assemblage below. No coals were present in the 100 ft. of measures between the Forty Fathom Seam and the Queenslie Marine Band in the Slatehole Farm sequence in Ayrshire.

In most of the seams examined *Dictyotriletes bireticulatus* and *Cristatisporites connexus* are present, and sometimes common, *Vestispora spp.* are present, and *Densosporites sphaerotriangularis* is common or abundant. Exceptions include the three seams in the Canonbie Coalfield, in which both *D. sphaerotriangularis* and *C. connexus* are absent, or extremely rare, and Earl David's Parrot Seam in East Fife in which *Dictyotriletes bireticulatus* has not been seen. More than 20% of *Laevigatosporites* has been recorded in the seam immediately below the Queenslie Marine Band in the East Fife, Central, and Canonbie Coalfields; in the Lothians Coalfield this high frequency occurs in the second seam below the marine band. *Schulzospora rara* has not been seen above the Queenslie Marine Band. *Endosporites globiformis* occurs in the Wood Seam, East Fife; elsewhere in Scotland it is generally restricted to seams above the marine band.



TEXT-FIG. 18. Frequencies of selected miospore species in certain seams in the Slatehole Farm Borehole, Ayrshire Coalfield.



TEXT-FIG. 19. Locations of samples and sequences of seams examined from the Canonbie Coalfield

Dictyotriletes bireticulatus Assemblage VIII (Extra Seam to Barncraig Seam, East Fife; seam at 1,714 ft. 5 in. to seam at 1,137 ft. 5 in., Musselburgh No. 1 borehole, Lothians; Blackband Seam to Upper Seam, Central; Ayr Hard Seam to Ell Seam, Ayrshire; seam at 2,128 ft. 0 in., Rowanburnfoot borehole to Archerbeck Seam, Canonbie).

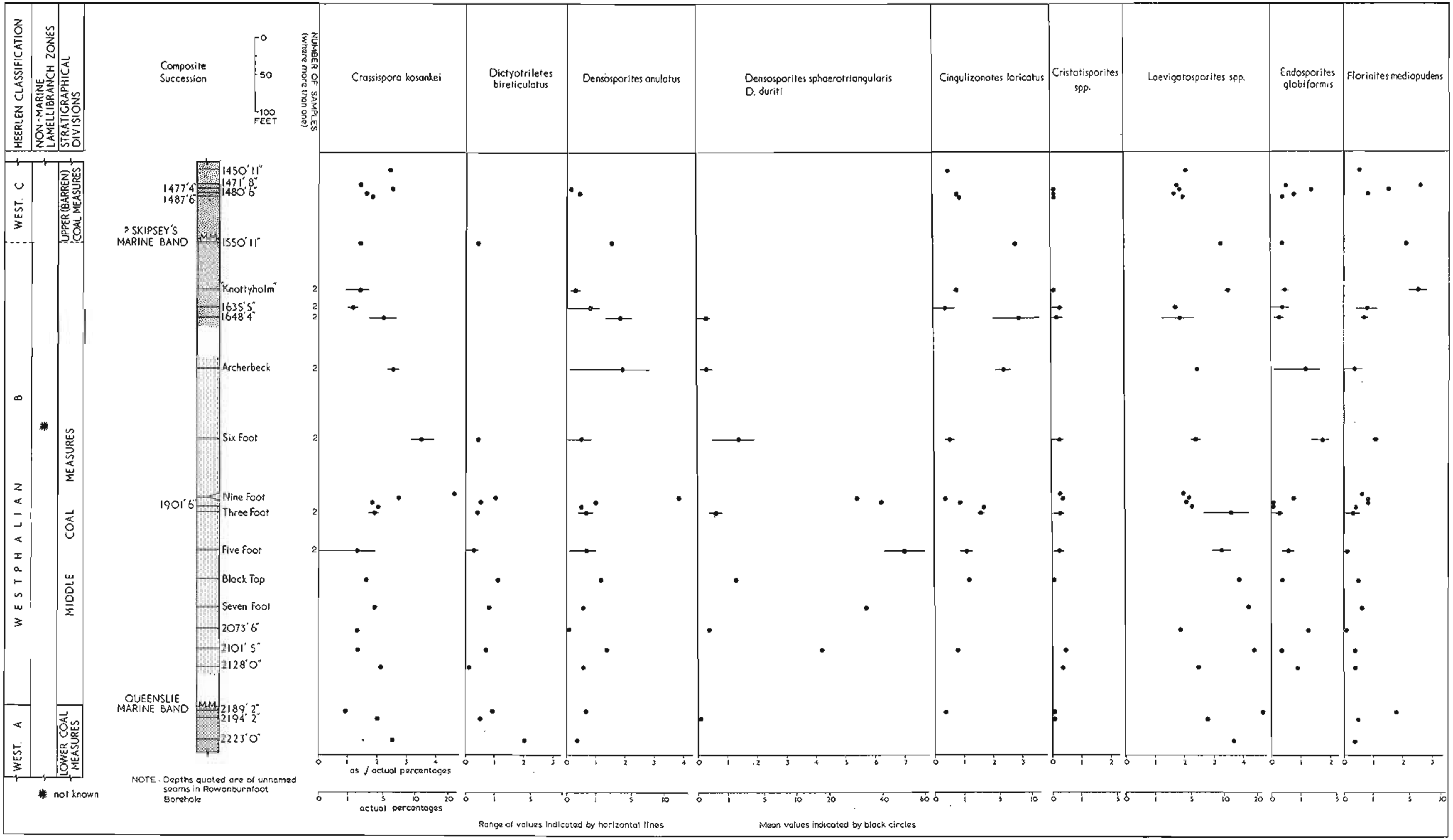
In Ayrshire and Canonbie *Endosporites globiformis* first appears in the seam above the Queenslie Marine Band but in the Lothians and Central Coalfields at a somewhat higher horizon. *Laevigatosporites spp.* are more common than at lower horizons but never reach the high percentages present in the seam below the marine band. *Florinites mediapudens* is present throughout the Assemblage, but is rarely common.

In certain of the coalfields *Densosporites anulatus* and *D. sphaerotriangularis* tend to be abundant in one or two seams towards the middle of the sequence and occasionally near the top (the Barncraig Seam of East Fife and the Ell Seam of Ayrshire). Species of *Cristatisporites* are never very common in the East Fife and Central Coalfields and are rare in Ayrshire and Canonbie, especially the former. They are, however, common in the Musselburgh Jewel and Beefie Seams and very common in the seam above the Diamond in the Lothians Coalfield. *Cingulizonates loricatus* is fairly numerous, particularly in the Bush and Chemiss Seams of East Fife, the Beefie and ? Rough Seams of the Lothians Coalfield, and in the Archerbeck Seam of Canonbie, but is infrequent in Ayrshire. The distribution of *Crassispora kosankei* follows the same general pattern as noted in the Middle Coal Measures of other provinces. Seams containing minimum numbers of this spore include the coal at 593 ft. 6 in., Seafield No. 2 borehole (East Fife), the Beefie (Lothians), the Splint (Central), the Jewel (Ayrshire), and the Five Foot (Canonbie). Seams near the top containing maximum numbers include the Coxtool (East Fife), the seams at 1,137 ft. 5 in. and 1,269 ft. 8 in., Musselburgh No. 1 borehole, the Splint (Lothians), the Ell and Upper (Central), the Main (Ayrshire), and the upper leaf of the Nine Foot and the Six Foot (Canonbie).

Vestispora magna Assemblage IX (seam at 1,115 ft. 5 in. to seam at 1,059 ft. 7 in., Musselburgh No. 1 borehole, Lothians and seam at 1,648 ft. 4 in. to seam at 1,450 ft. 11 in., Rowanburnfoot borehole, Canonbie).

The equivalent of the Two Foot Marine Band of Yorkshire and Nottinghamshire has not been recorded in any of the Scottish coalfields, but species characteristic of the *V. magna* Assemblage have been found in seams below Skipsey's Marine Band at the top of the Productive Coal Measures (top of Westphalian B) in the Lothians and Canonbie Coalfields and in the five seams examined from above this horizon in the latter field.

V. magna and *Triquitrites sculptilis* have not been recorded in the Lothians Coalfield but *Cristatisporites solaris* occurs in each of the three seams examined; *Dictyotriletes bireticulatus* has not been seen in these coals. In Canonbie occasional specimens of *V. magna*, *T. sculptilis*, and *C. solaris* occur in the seams below Skipsey's Marine Band, but these species are more common in the seams above this horizon. *D. bireticulatus* has not been recorded in any of the seams above the marine band and is only rarely present in the lower seams. In the Lothians Coalfield the Assemblage is also characterized by increases in the percentages of *Endosporites globiformis* and *Florinites mediapudens*, and in Canonbie, in its lower part, by fairly high numbers of *Cingulizonates loricatus*. In the higher seams of the Canonbie Coalfield no specimens were seen of *Torispora securis*



TEXT-FIG. 20. Frequencies of selected miospore species in certain seams of the Canonbie Coalfield.

or *V. fenestrata*, which would indicate a horizon at about that of the Top Marine Band of Yorkshire and Nottinghamshire.

TABLE 1. Assemblage frequencies for the coalfields of Scotland and Northumberland (pre-Coal Measures and the lower part of the Lower Coal Measures)

Assemblages	IV		III				II		IV	III	II	I
Coalfields	West Fife	Central	East Fife	West Fife	Lothians	Central	East Fife	Central	Northumberland			
Number of samples	26	4	14	45	44	19	2	1	9	18	3	7
	Percentage occurrence in total number of samples from each Assemblage											
Miospore species												
**Laevigatosporites spp.*	4								78			
**Crassispora kosankei*	35	50							44			
**Punctatisporites sinuatus*			7	2	2	21			11			
Convolutispora cerebra	38	25	29	9	5	26						
C. jugosa	19		14	51	25	32			33	39		
Stenozonotriletes bracteolus	65	25		18	16	42						
Reticulatisporites carnosus	31			13	9	21			33	6		
**Savitrisporites nux*	35	50	21	9	9	21			44	6		
**Bellispores nitidus*	35	25	7	9	11	16			22	6		
Vestispora lucida	19	25	21	27	32	53						
Leiotriletes tumidus	58	25	71	38	73	58	50	100	56	67	67	
Grumosisporites inaequalis	77	25	57	69	18	37		100		39		
Acanthotriletes falcatus	19		50	24	36	53	50		11	28	67	
Convolutispora ampla	31		21	27	32	42		100	22	11		
C. varicosa	12	25	29		30	68				22	33	
Microreticulatisporites punctatus	73	75	57	56	68	74		100		44		
**Ahrensisporites guerickei*	15					5	50		11		33	
Tripartites spp.	38	75	79	91	80	84	100	100		83	100	
Procoronaspora ambigua	8		36	13	34	37		100		22	33	
**Knoxisporites spp.*	15	75	21	29	20	37	50	100	33	39		
Rotaspora fracta and *R. knoxi*	42	50	93	80	77	74	100			94	100	
Crassispora maculosa	27	25	79	67	57	74	100			44	67	
Cingulizonates cf. *capistratus*	88	100	93	76	93	100	100	100		78		
**Spencerisporites radiatus*	35	75	43	20	39	68	50	100	22	56	67	
Diatomozonotriletes cervicornutus							50				100	
D. saetosus											100	
D. ubertus											67	
Procoronaspora dumosa								100			67	
P. fasciculata							50				33	
Rotaspora crenulata											33	
Remysporites magnificus	46	100	64	33	30	74	50	100	22	28	33	
Chaetosphaerites pollenisimilis	69	50	64	67	73	53	100	100	44	72	67	57
Grumosisporites rufus	38	25	79	31	45	11		100	44	39		14
**Anapiculatisporites spp.*	69	50	93	87	82	89	100	100	67	67	100	43
**Anaplanisporites baccatus*	100	50	100	100	98	26	100	100	78	89	100	86
Acanthotriletes castanea	4		14	7	11	26	50			11		29
Grumosisporites verrucosus	58	25	86	64	70	58		100	33	50		86
Densosporites pseudoannulatus	42	50	71	40	66	26	50	100	22	78	33	14
D. triangularis	58	50	71	51	75	32	100	100	56	78	67	29
**D. intermedius*	81 }		93	51	93 }		100	100	100	83	67	71
	}	100			}	79						
Cingulizonates bialatus	81 }		93	53	55 }		100	100	78	28	100	14
Tholisporites scoticus		25	79	44	55	84		100		78	33	14
**Schulzospora spp.*	88	100	100	93	93	100	100	100	89	83	100	100

* Genera and species also recorded in younger Assemblages.

TABLE 2. Assemblage frequencies for the coalfields of Scotland—Coal Measures

Assemblages	IX		VIII					VII				VI				V	
Coalfields	Lothians	Canonbie	East Fife	Lothians	Central	Ayrshire	Canonbie	East Fife	Lothians	Central	Canonbie	East Fife	Lothians	Central	Ayrshire	East Fife	Lothians
Numbers of samples	3	14	23	18	16	5	17	7	2	2	3	21	20	5	4	5	12
	Percentage occurrence in total number of samples from each Assemblage																
Miospore species																	
Microreticulatisporites sulcatus		14															
Triquitrites sculptilis		50															
Cristatisporites solaris	100	36															
Vestispora magna		57															
Endosporites globiformis	67	79	69	72	75	100	82	14									
Radiizonates faunus																	
R. tenuis		7	30	50	50	20	24	43									
Vestispora pseudoreticulata *V. costata* and *V. tortuosa*	100	100	74	78	87	100	82	71	100	100	67	14	10	40	50		
Dictyotriletes reticulocingulum		7		17	19			14				10	10				8
Radiizonates aligerens												48	55	40	75		
Florinites mediapudens	100	93	96	100	75	80	82	100	50	50	100	67	85	20	75		
Pityosporites westphalensis		43	52	44	50	60	29	29	100	50	33	38	35		25		
Dictyotriletes bireticulatus		7	87	50	81	80	65	71	100	100	100	33	20		50	20	8
Densosporites duriti and *D. sphaerotriangularis*	67	7	56	61	81	60	94	100	100	100	67	90	90	40	75		
**Laevigatosporites spp.*	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100	20	
Acanthotriletes echinatus		7	35	22	44	20	35	14	50	50		14				20	
Reinschospora speciosa			13	6	12		6	57	50	50	33	19	25				16
**Anapiculatisporites minor*	67	36	65	78	69	60	76	85	100	100	100	67	45	20	75	20	50
**Crassispora kosankei*	100	100	100	100	94	100	100	100	100	100	100	100	100	100	100	100	100
Simozonotriletes intortus			4		25		6	14		50		5	15				8
Cristatisporites connexus and *C. indignabundus*	33	7	87	67	75	20	59	85	50	100	67	85	75	20		100	92
Reticulatisporites reticulatus	33	14	39	11	12	20	12	29	50	50	33	33	10			40	42
R. polygonalis	67		48	56	56	40	35	43	100	100	67	48	50		25	20	75
Cingulizonates loricatus	33	64	78	56	75	80	82	29		50	67	24	30		25		
Alatisporites pustulatus		14	22	22	25		18	57	50	50		33	20				8
**Camptotriletes spp.*			13	11	25	20	12	14		50		29	55			40	92
**Ahrensisporites spp.*			43	17	31	80	29	14				10	5			20	25
**Savitrisporites nux*			9	6	6	20	6					48	40			60	50
**Densosporites anulatus*	67	64	74	72	87	100	100	57		100	67	81	40	80	25	80	75
Radiizonates striatus								29			33	67	75	60	25	60	75
**Spencerisporites radiatus*		7	35	28	44		18	57	100	50	67	19	30	40	50	20	58
**Schopfipollenites spp.*		14	30	11	12	40	29					5				20	8
Schulzospora rara								43		100	67	67	70	40	75	60	84

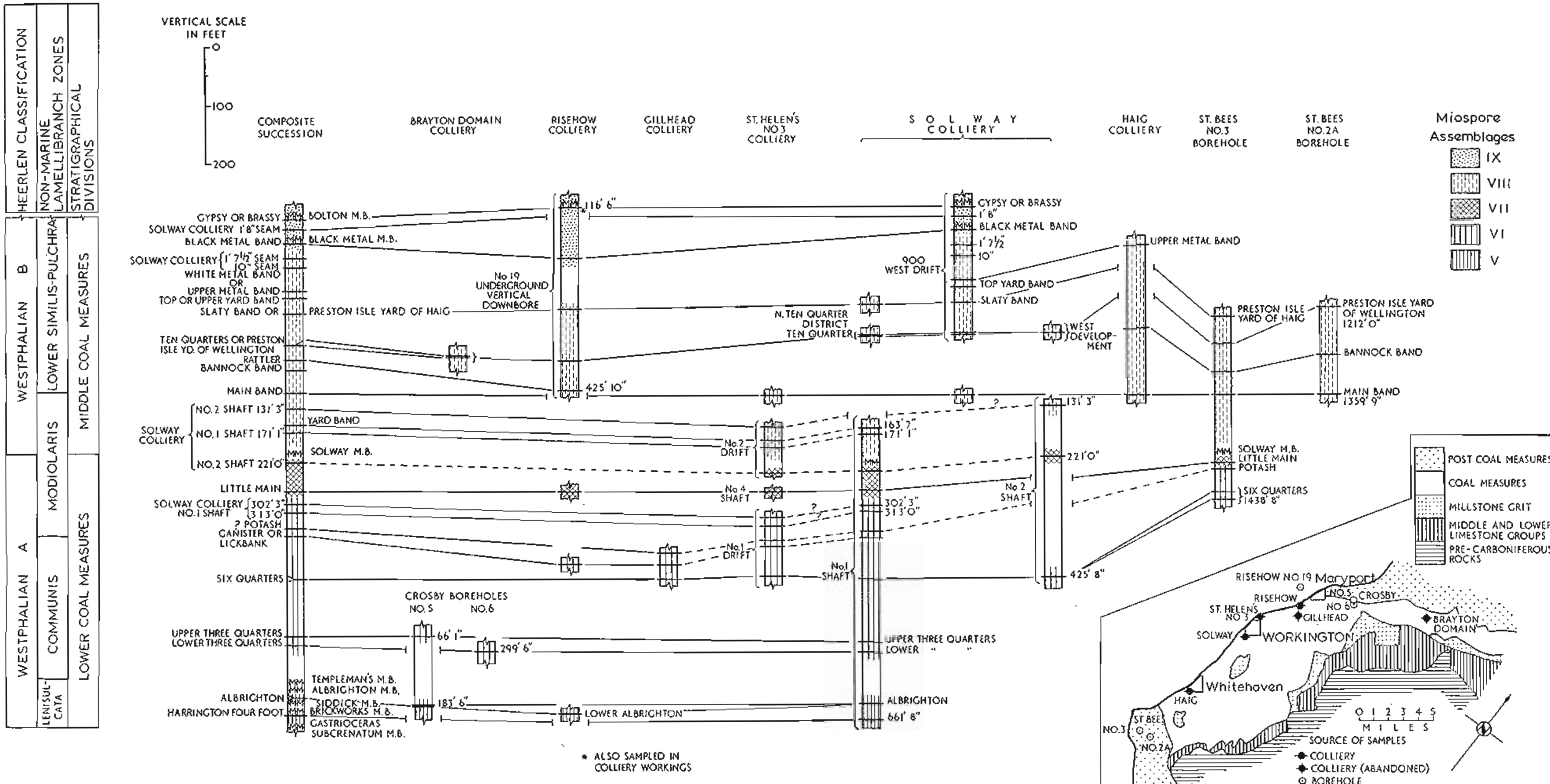
* Genera and species recorded from older Assemblages at least in certain coalfields.

The Cumberland Coalfield

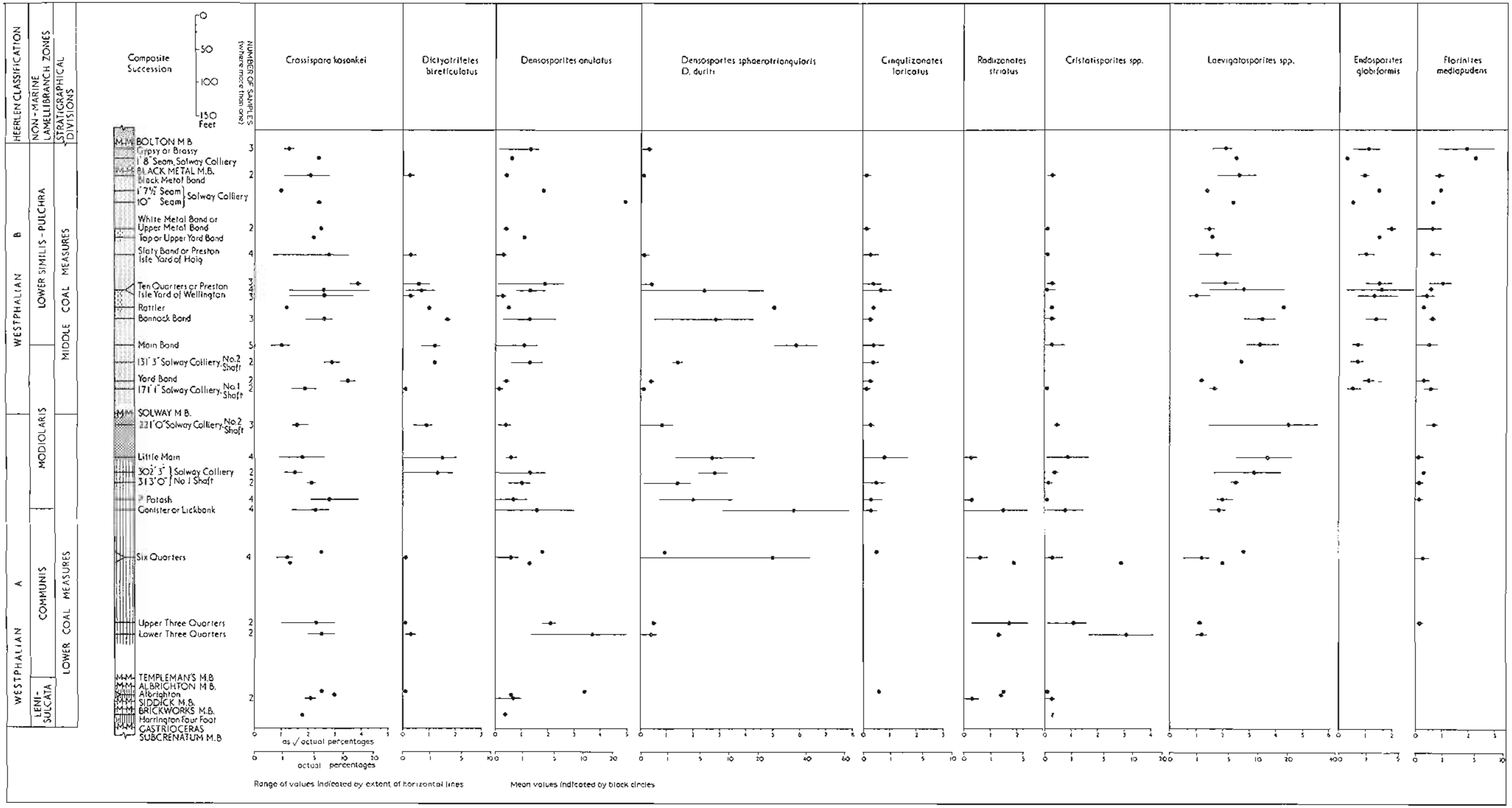
Coal seams are present in the Lower and Upper Carboniferous. They occur throughout the succession from the Fell Sandstone in the Viséan to the lower part of the Upper (Barren) Coal Measures (Westphalian C). Although economically important coals are confined to the Productive (Lower and Middle) Coal Measures the seams in the Viséan and Namurian have been worked to a limited extent in the past. The seams in the Whitehaven Sandstone Group, which overlies the Productive Coal Measures, are thin and relatively unimportant commercially.

No account of miospore distribution in the coalfield has been published but a preliminary examination of the seams of the Productive Coal Measures in the Solway No. 1 Shaft was made by Mr. T. E. Tomlinson (1940) of the National Coal Board, Coal Survey Laboratory, Newcastle upon Tyne. He noted the restricted vertical ranges of *Radiizonates aligerens*, *Endosporites globiformis*, and certain other species.

In the present investigations only one seam was examined from below the Productive Coal Measures; the results on this coal (the Oakshaw Ford Seam) are included with



TEXT-FIG. 21. Locations of samples and sequences of seams examined in the Cumberland Coalfield.



TEXT-FIG. 22. Frequencies of selected miospore species in certain seams of the Cumberland Coalfield.

those of similar age in the section on the Northumberland and Durham Coalfields. In the Productive Coal Measures seam samples from the Six Quarters horizon up to the Upper Metal Band horizon were obtained from the St. Bees boreholes and Haig Colliery in the southern part of the coalfield. Representatives of all coal horizons up to the Gypsy Seam were taken at Solway and St. Helen's Collieries in the Workington area and most of these seams were also examined from the Crosby boreholes and Risehow and Gillhead Collieries in the Maryport area. The rank of the seams was generally such that satisfactory spore separations were possible, but the Harrington Four Foot Seam in the St. Bees No. 2A borehole gave unsatisfactory results.

The locations of the sampling points and details of the sections examined are given in text-fig. 21. Text-fig. 22 shows the frequencies of occurrence of selected species of nine genera of miospores in the Productive Coal Measures of the coalfield.

The most recent geological account of the coalfield is that by Taylor and Calver (1961). Various sequences are described, among them those in the Crosby, Risehow, and St. Bees boreholes and at St. Helen's, Gillhead, Solway, and Haig Collieries.

Densosporites anulatus Assemblage V (Harrington Four Foot Seam and Albrighton Seam).

The miospore floras in both of these seams are typical of the Assemblage, although *D. anulatus* is abundant only in the top leaf of the Albrighton; this coal also contains occasional specimens of *Dictyotriletes bireticulatus*. *Mooreisporites fustis* is present in both seams and *Radiizonates striatus* is generally common in the Albrighton.

Radiizonates aligerens Assemblage VI (Lower Three Quarters Seam to seam at 302 ft. 3 in., Solway Colliery No. 1 Shaft).

Laevigatosporites spp. first appear in the Lower Three Quarters Seam and become common at about the level of the Six Quarters. *Florinites mediapudens* is rare throughout, but is generally present above the Lower Three Quarters. *Radiizonates striatus* is common, or very common, only in the Upper Three Quarters Seam in the Crosby borehole, the Lower Six Quarters Seam in the St. Bees No. 3 borehole, and the Ganister or Lickbank Seam of Gillhead and St. Helen's Collieries and is never abundant. *Radiizonates aligerens* is constantly present in the Six Quarters and higher seams, but common only in the Ganister or Lickbank Seam of Risehow Colliery. *Cristatisporites* is very common in some of the lower seams. *Densosporites sphaerotriangularis* is sometimes abundant.

Schulzospora rara Assemblage VII (Little Main Seam and seam at 221 ft. 0 in., Solway Colliery No. 2 Shaft).

Dictyotriletes bireticulatus is generally common in both seams and *S. rara* is invariably present. *Laevigatosporites spp.* show a characteristic increase in abundance, but the large numbers of *Cristatisporites spp.* and *Densosporites sphaerotriangularis* generally found at these horizons are absent. *Vestispora tortuosa* and *Pityosporites westphalensis* are commonly present.

Dictyotriletes bireticulatus Assemblage VIII (seam at 171 ft. 1 in., Solway Colliery, No. 1 Shaft to 1 ft. 7½ in. Seam in 900 West Drift, Solway Colliery).

Endosporites globiformis first appears in the seam above the Solway Marine Band which marks the base of the Assemblage. *Radiizonates* cf. *striatus* and *Cristatisporites connexus* are both unusually rare in the seams above this horizon. *Densosporites sphaerotriangularis* is abundant in the Main Band and Bannock Band Seams. *Crassispora kosankei* is present in minimum numbers in the Main Band and then increases to reach maximum abundance in the upper leaf of the Ten Quarters Seam. It is thought that this may be a comparable horizon to that of the Winter Seam in Yorkshire and the Stone Delph Seam in Lancashire, etc. Taylor and Calver (1961, fig. 5) query the presence of the equivalent of the Two-Foot Marine Band of Yorkshire above the Ten Quarters Seam. At the Risehow Colliery borehole, however, the seams named the Rattler and Ten Quarters by the Geological Survey (Calver, personal communication) contain abundant *D. sphaerotriangularis* and small numbers of *C. kosankei*; on this basis the seams would be placed slightly lower in the sequence.

Vestispora magna Assemblage IX (Black Metal Band Seam to Gypsy Seam).

The species characteristic of the *V. magna* Assemblage have not been found below the Black Metal Band; *V. magna* and *Cristatisporites solaris* both occur in this seam, and in the Gypsy Seam *Triquitrites sculptilis* is also present. *Dictyotriletes bireticulatus* occurs in the Black Metal Band and has not been found in the higher seams. *Florinites mediapudens* is prominent in the Gypsy and the underlying seam. No Upper Coal Measures coals (that is from above the horizon of the Bolton Marine Band) have been examined.

The Northumberland and Durham Coalfields

The coal-bearing measures of Northumberland are continuous with those of Durham and for the purposes of this work the miospore successions in the two coalfields are considered together.

Coal seams are present in both the Lower and Upper Carboniferous but are most conspicuous in the Lower and lower part of the Middle Coal Measures of both fields. In the Northumberland Coalfield the lithological divisions which, in the Central and Southern Provinces, distinguish the Viséan, Namurian, and Westphalian are much less well marked. Coals occur, and have been worked, in the Scremerston Coal Group and the Lower and Middle Limestone Groups (Viséan) and in the Upper Limestone Group and 'Millstone Grit' (Namurian). The coals in the 'Millstone Grit', which probably only represents the upper part of this division in the Central Province, are few and insignificant. It should be noted that the Upper Limestone Group is equivalent to the lower part of the Passage Group and the combined Upper Limestone and Limestone Coal Groups of Scotland, the Middle Limestone Group of Northumberland to the Lower Limestone Group of Scotland, and the Lower Limestone Group and Scremerston Coal Group of Northumberland to part of the Oil Shale Group of Scotland.

Raistrick and Simpson (1933) described the spore contents of the Plessey, Beaumont, and Tilley Seams from the Coal Measures of the Northumberland Coalfield. In a subsequent paper, Raistrick (1934) extended this survey to include all the seams from the Bottom Busty up to the High Main and demonstrated that the spore assemblages of individual seams were distinguishable from each other, and remained constant, when traced over wide areas. He later (1938) also examined some of the better-known coals of the Lower Carboniferous and noted the differences between the spore assemblages of these seams and those present in the Upper Carboniferous. He further recorded a 'break' between the horizons of the Cooper Eye and Shilbottle Seams in the Scremerston Coal and Middle Limestone Groups respectively. In his only paper on the Durham Coalfield, Raistrick (1939) dealt with the variations in the frequencies of the more common spore types in the Bottom and Top Busty Seams and in seams up to, and including, the Harvey.

In the present investigations miospore examinations were made on coal samples from horizons within the Scremerston Coal Group (Viséan) to within the Middle Coal Measures (lower part of the Westphalian C). The treatment of the Viséan coals is preliminary and is included primarily in order that the approximate positions at which the Namurian A genera and species first make their appearances could be determined.

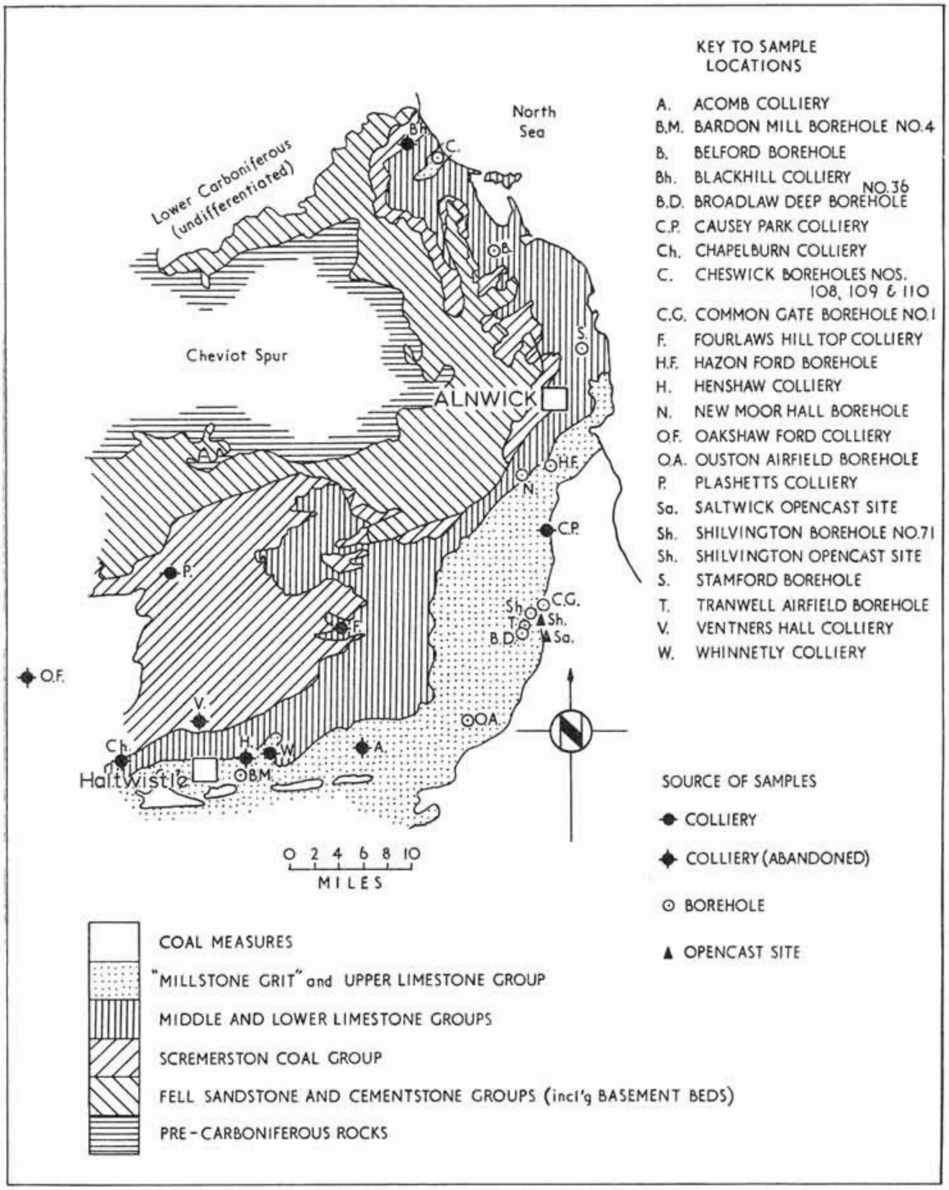
The lowest seam examined, that sampled at Oakshaw Ford near Bewcastle, although originating from Cumberland, has been considered with the lowest coals in the Northumberland sequence because of its comparable age. The remainder of the Viséan samples were from well-scattered localities and occur at wide intervals in this part of the succession; only two seams, the Thirlwall in the Scremerston Coal Group and the Shilbottle in the Middle Limestone Group, were sampled at more than one locality.

Namurian A assemblages were studied in the Little Limestone, Oakwood, and other seams in the Upper Limestone Group. They were obtained chiefly from the Cheswick boreholes in the northern part of the Northumberland field and the Ouston Airfield borehole in the south. A sequence of coals in the 'Millstone Grit' was examined from Tranwell Airfield and Broadlaw Deep No. 36 boreholes on the north-western edge of the exposed Coal Measures.

The lowest seams in the Coal Measures of Northumberland were obtained from the Common Gate and Shilvington boreholes. At higher horizons the most complete sequences were obtained in the south-eastern part of the coalfield, where coals in the Lower and Middle Coal Measures were available in the West Moor borehole and in the Weetslade Colliery Nos. 2 and 3 Shafts (the three seams below the High Main were sampled in both shafts). The seam samples in the Lower Coal Measures and lower part of the Middle Coal Measures were obtained from Rising Sun Colliery. These sequences were augmented by samples of the lower seams taken at the Havannah Drift Mine and Callerton and Woolsington boreholes in the south-west. The seams below the Bentinck were obtained from the Gordon Road, Link House, and Newsham Park Farm boreholes in the central part of the coalfield. In the Ashington district samples of the Moorland and lower seams were obtained mainly from boreholes, as were those of the Main and lower seams in the extreme northern part of the coalfield.

Most of the seams gave good spore separations, but those occurring below the Beaumont in the Hadston Carrs borehole were of too high rank for satisfactory maceration.

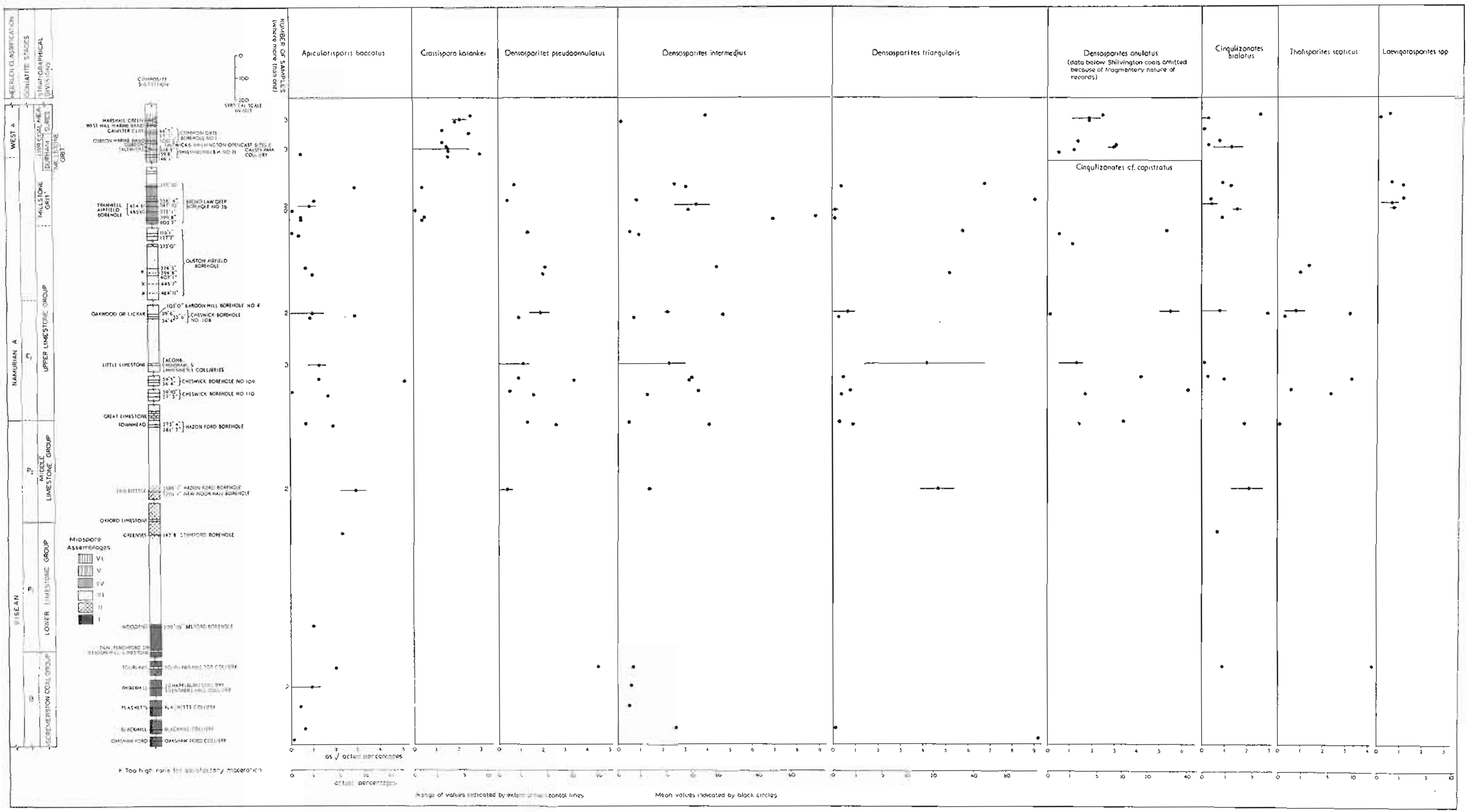
In Durham most of the sequences examined were from the concealed coalfield, or adjacent part of the exposed coalfield; there are few data for the seams in the western part of the region. The seams investigated are those of most importance in the Lower and Middle Coal Measures. The samples were mostly from boreholes which only covered



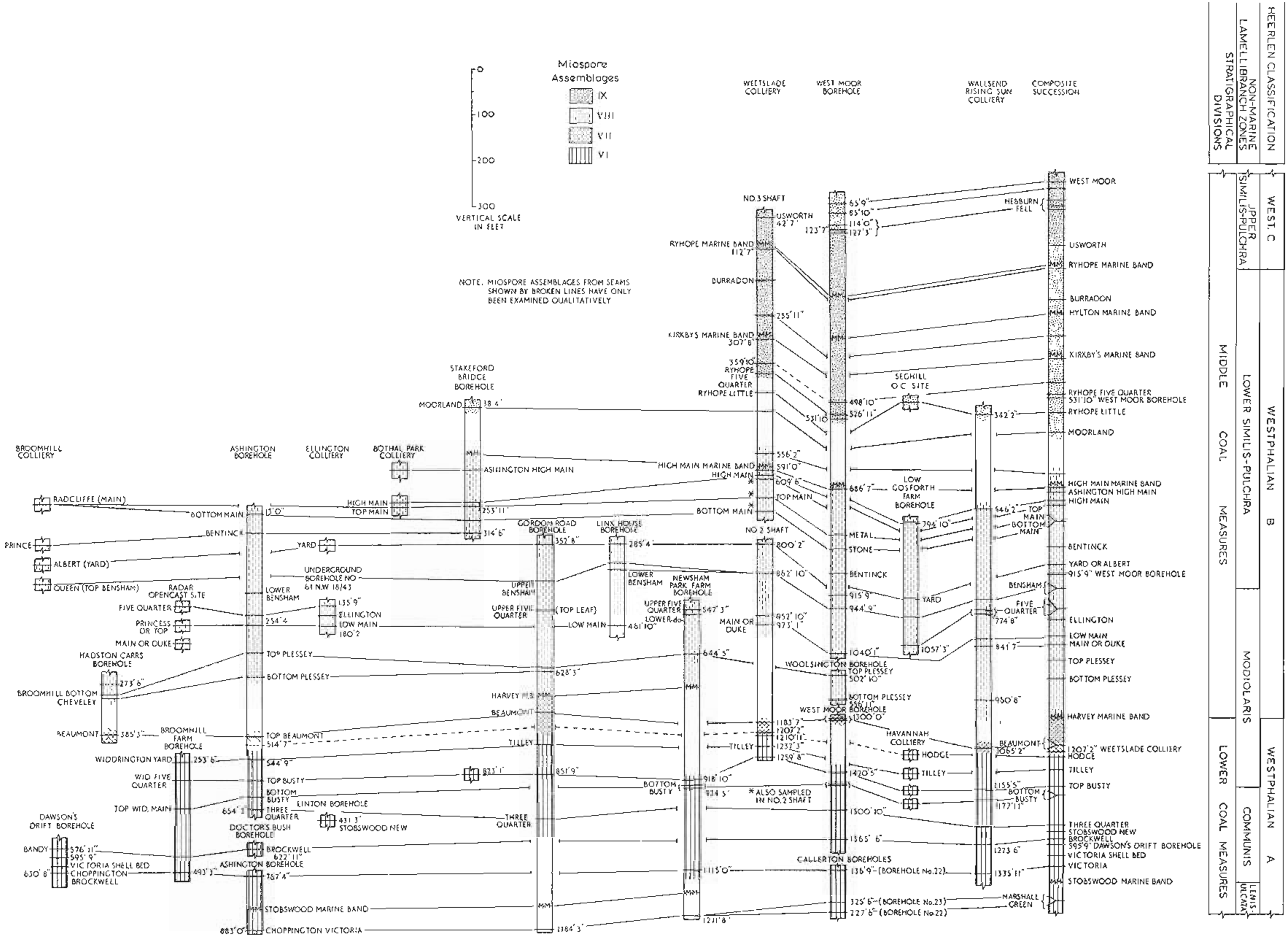
TEXT-FIG. 23. Locations of samples from the pre-Coal Measures and lower part of the Lower Coal Measures of the Northumberland Coalfield

restricted portions of the sequence, but two long sequences were supplied by the No. 1 and No. 2 Off-shore boreholes. Seams above the level of the Ryhope Marine Band were mainly covered by a sequence from the No. 4 Off-shore borehole.

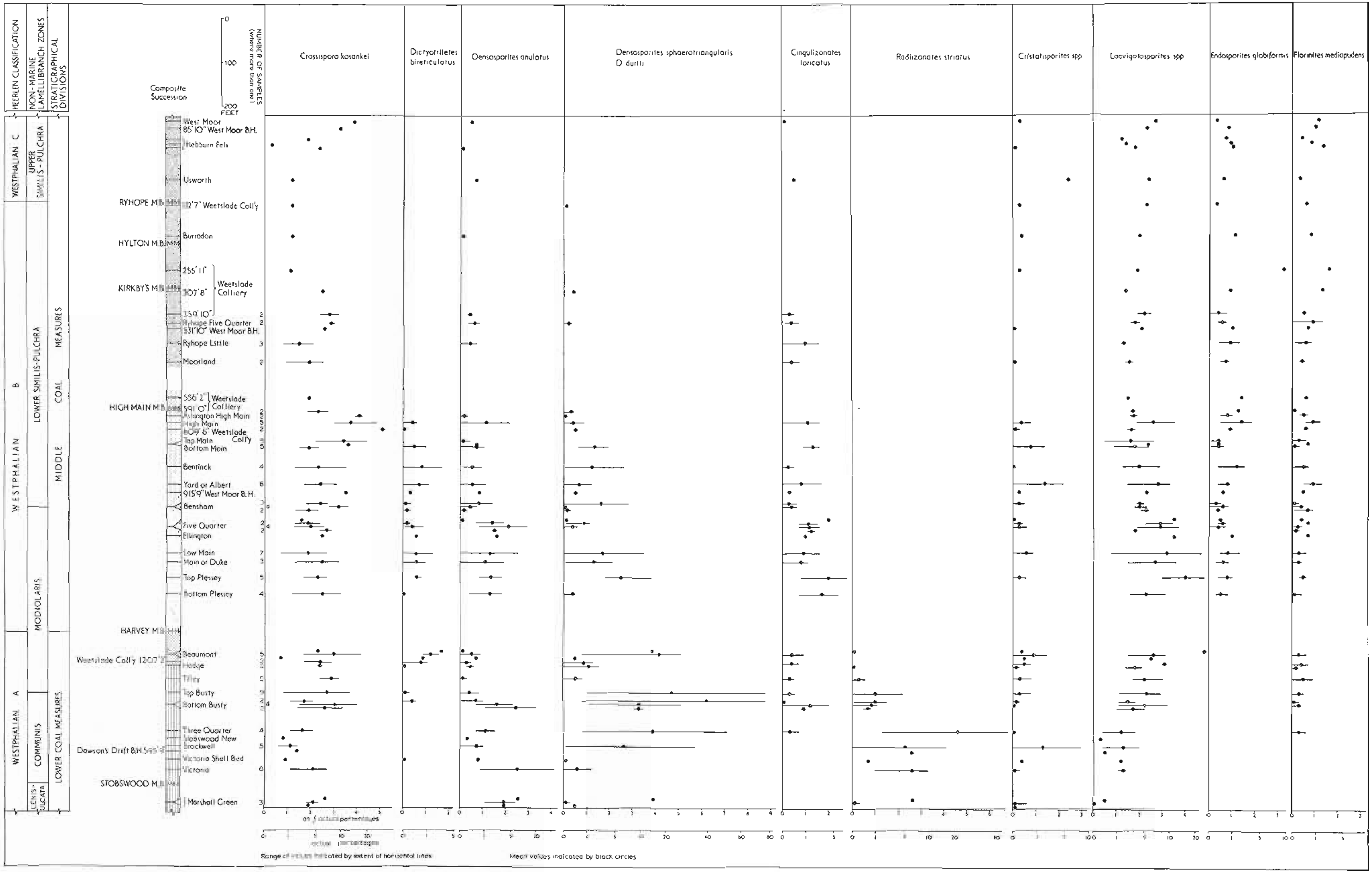
A map showing the locations of the sampling points and details of the sequences examined of the coals in the Scremerston Coal Group to the lower part of the Lower Coal Measures in the Northumberland Coalfield is given in text-fig. 23 and for the



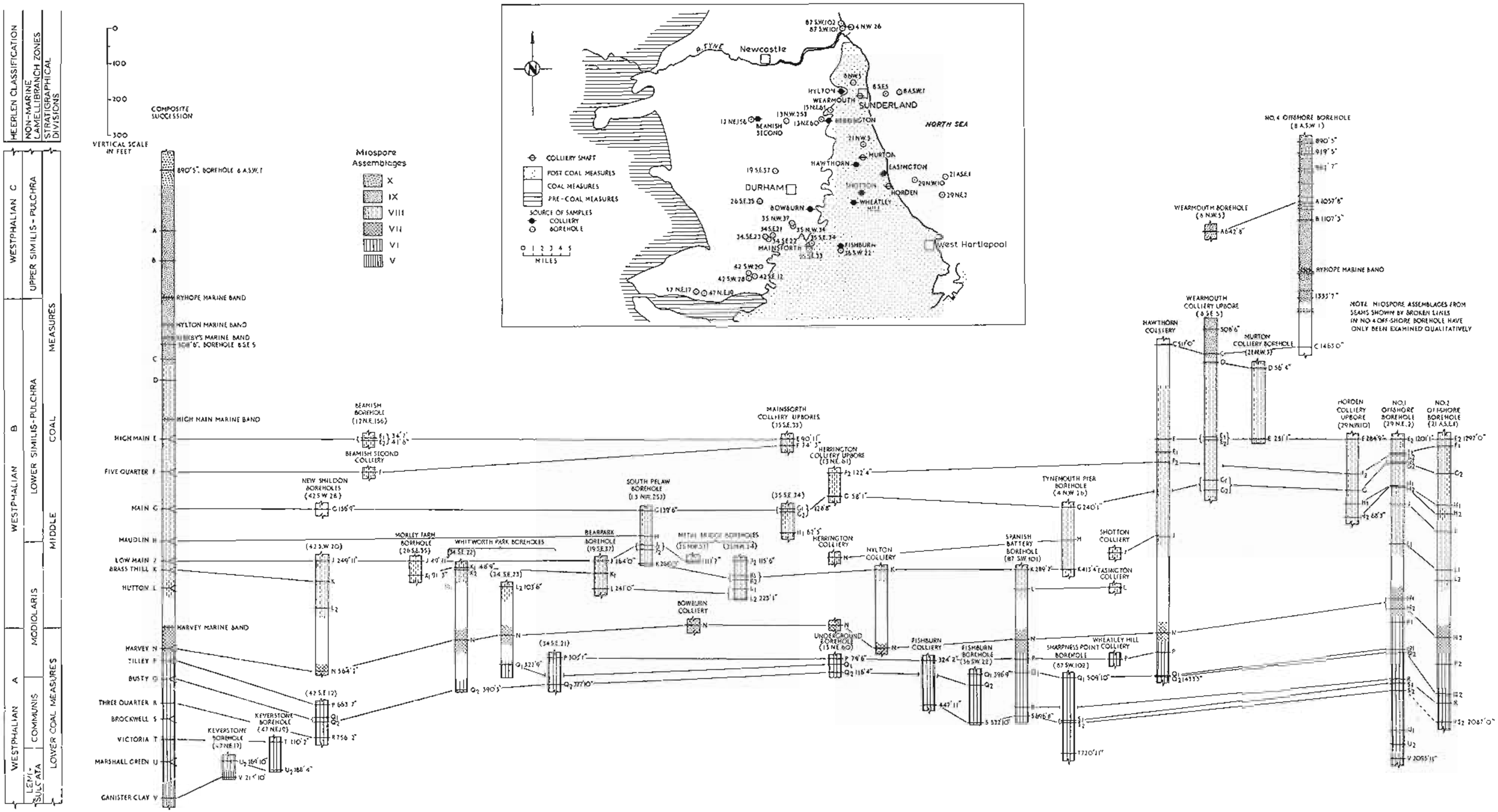
TEXT-FIG. 24. Frequencies of selected miospore species in the seams of the pre-Coal Measures and the lower part of the Lower Coal Measures of the Northumberland Coalfield.



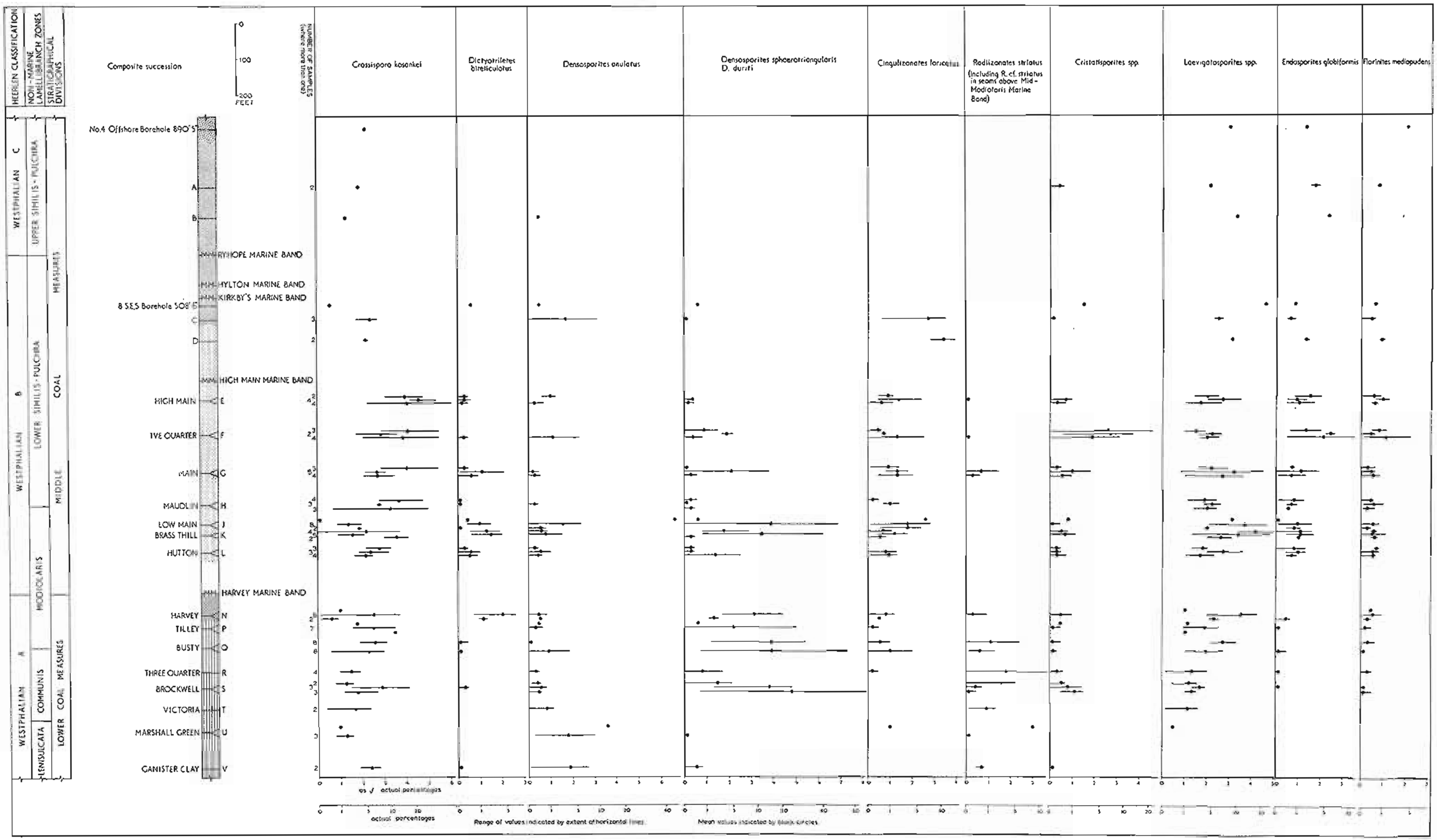
TEXT-FIG. 25. Locations of samples and sequences of seams examined in the Coal Measures of the Northumberland Coalfield.



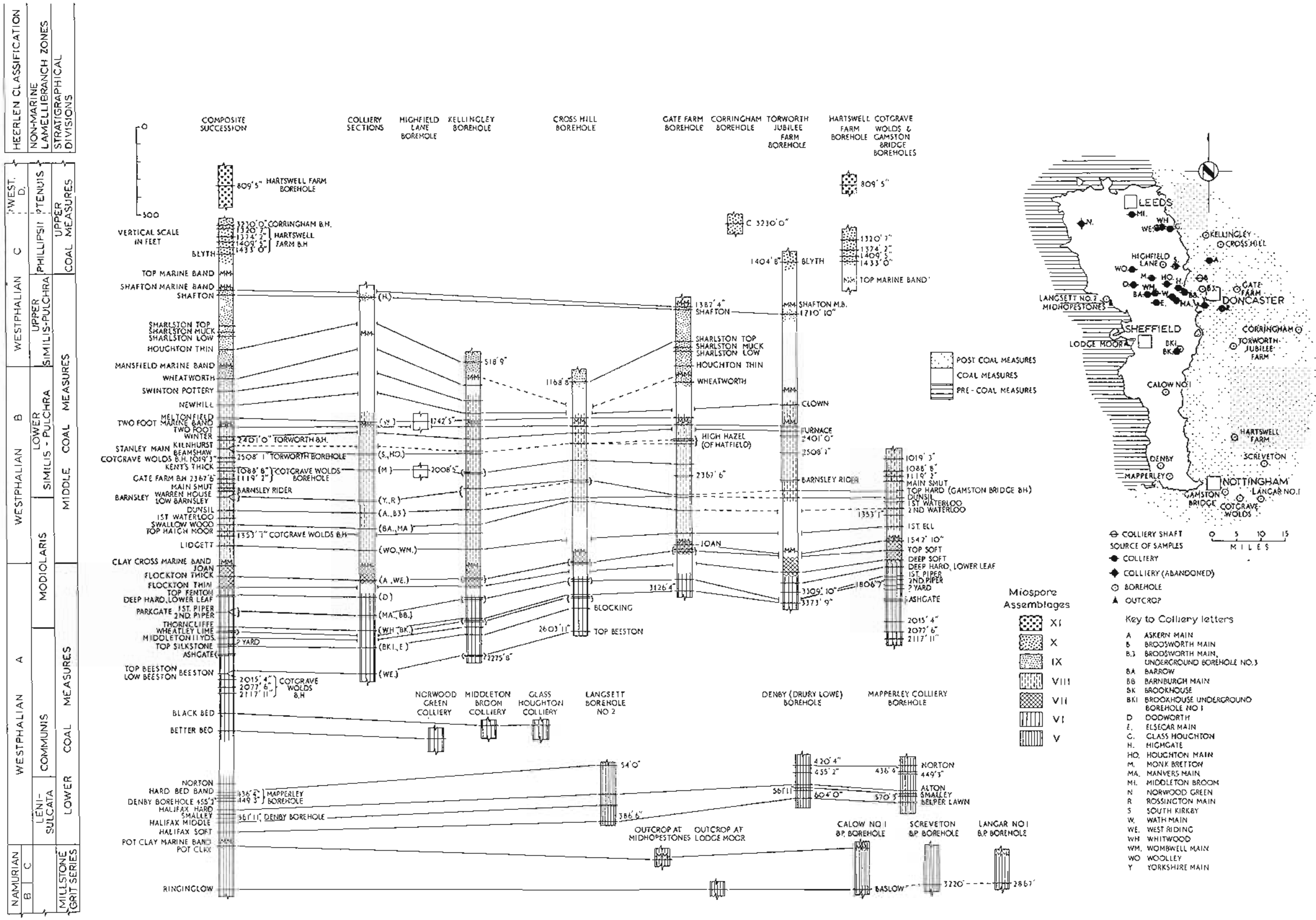
TEXT-FIG. 26. Frequencies of selected miospore species in the seams of the Coal Measures of the Northumberland Coalfield.



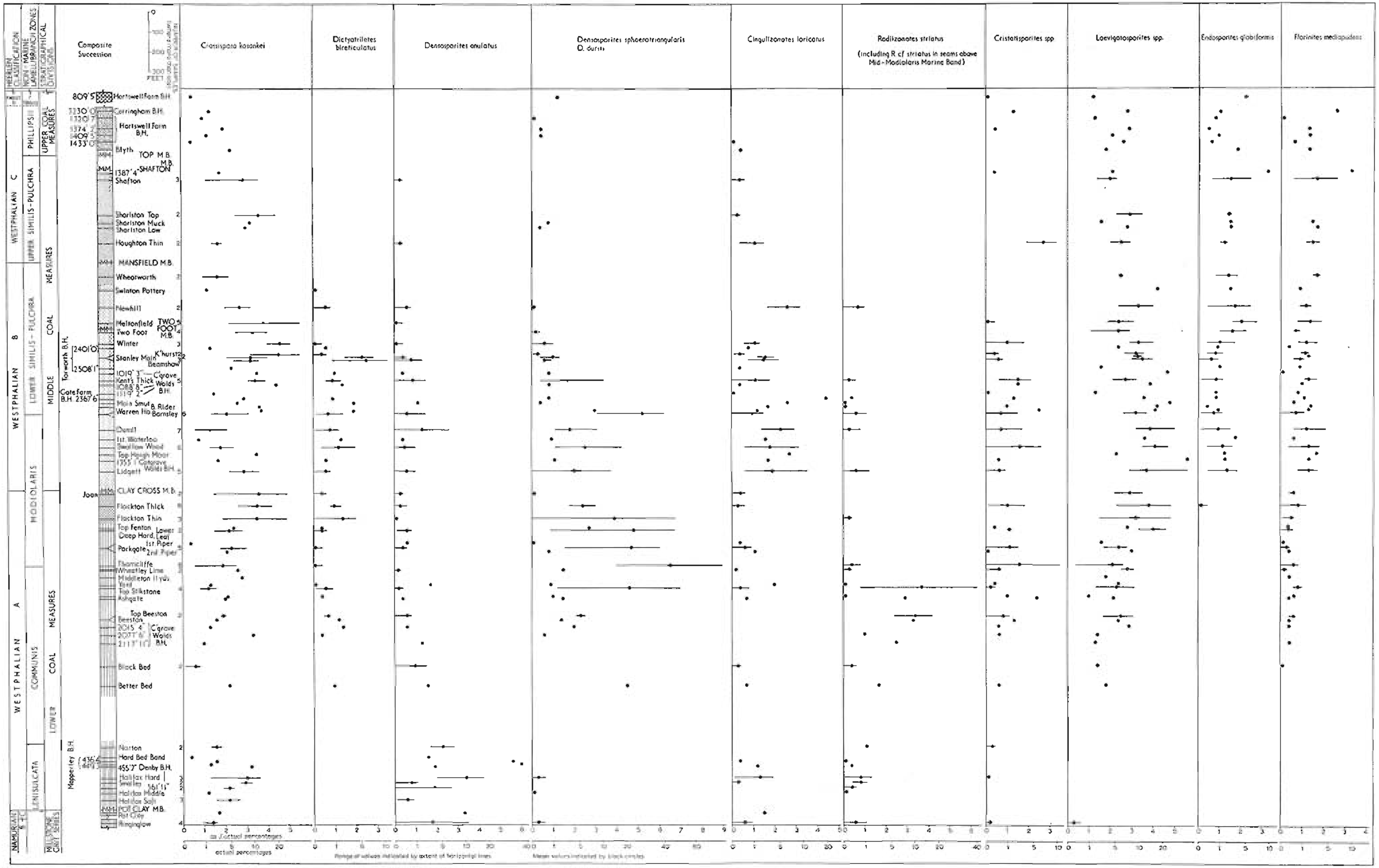
TEXT-FIG. 27. Locations of samples and sequences of seams examined from the Durham Coalfield.



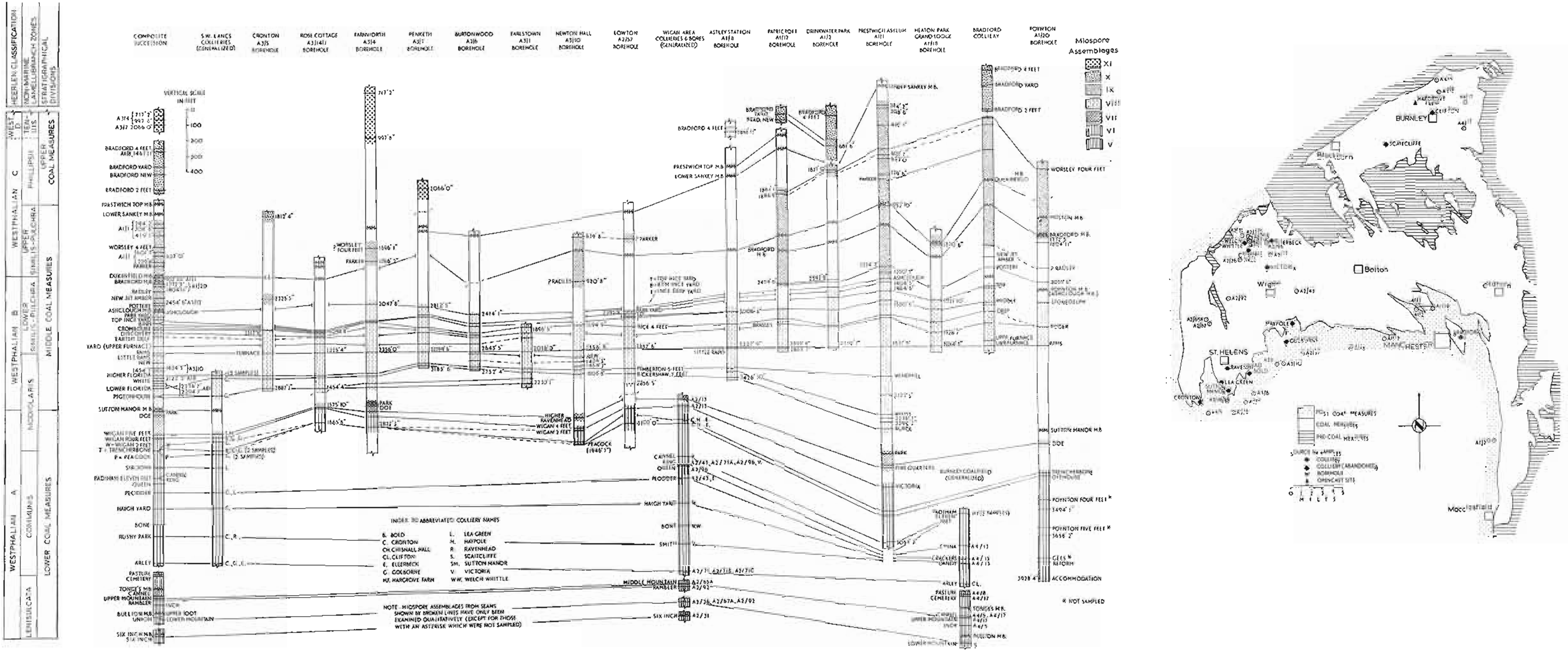
TEXT-FIG. 28. Frequencies of selected miospore species in certain seams of the Durham Coalfield.



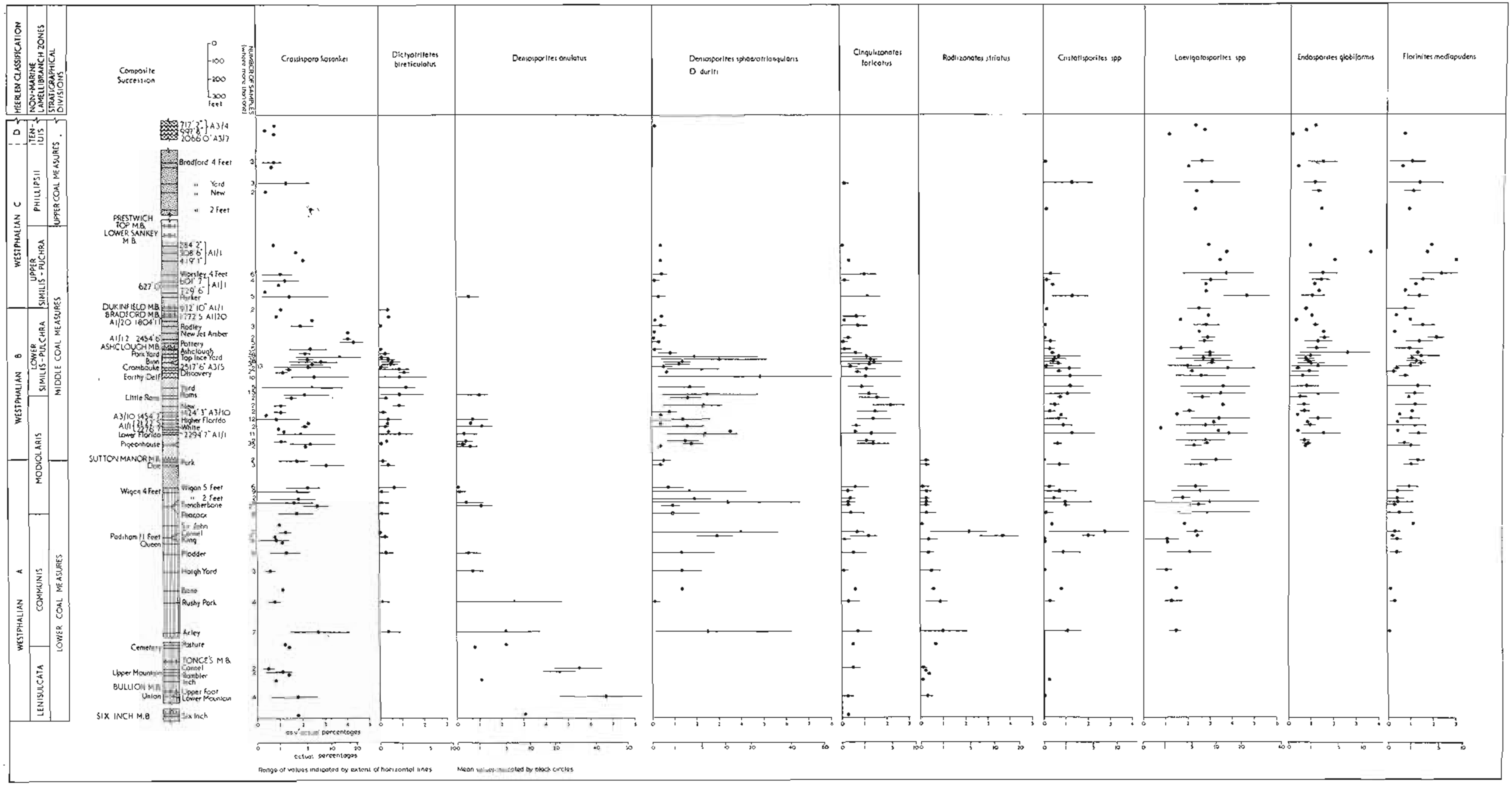
TEXT-FIG. 29. Locations of samples and sequences of seams examined from the Yorkshire and Nottinghamshire Coalfields.



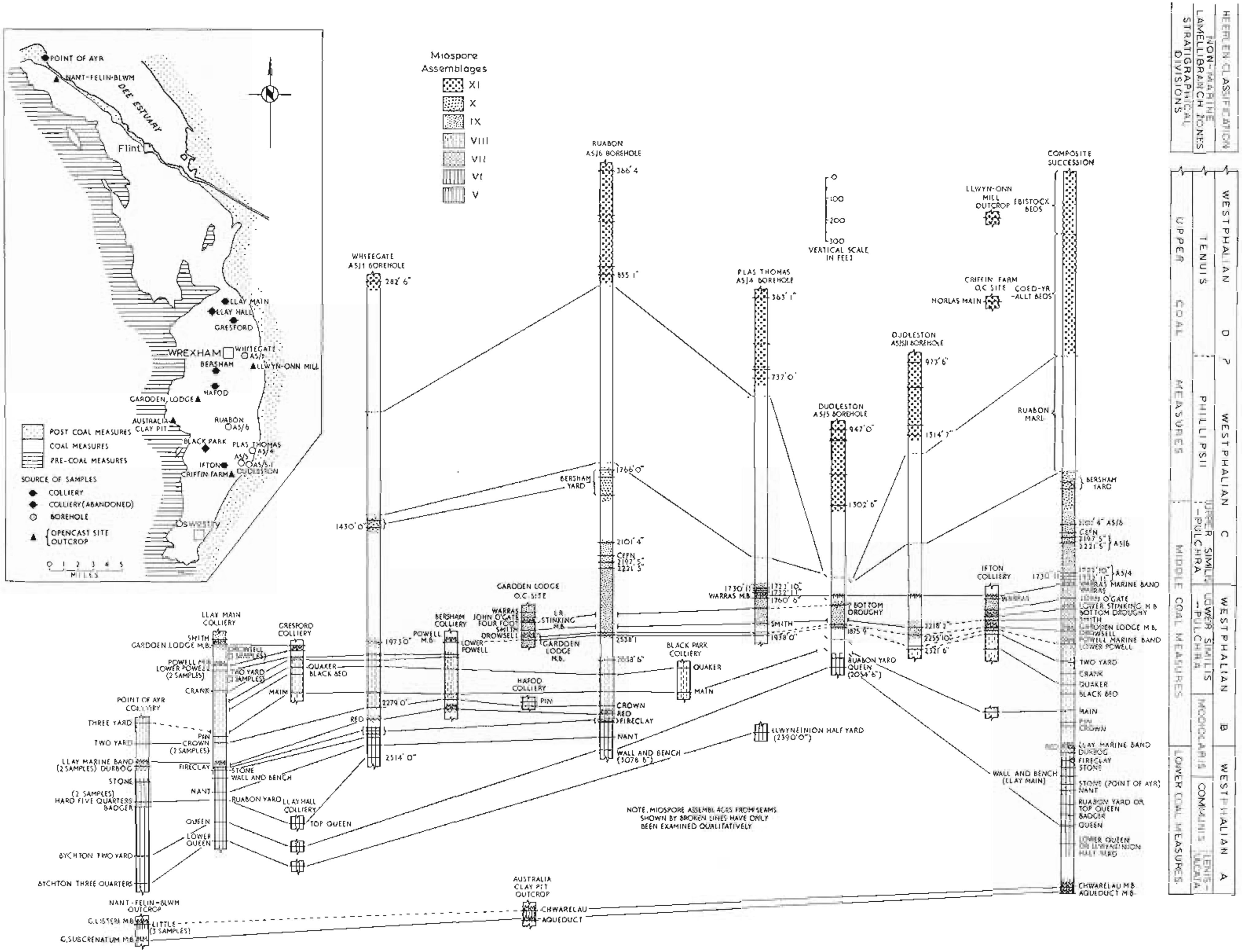
TEXT-FIG. 30. Frequencies of selected miospore species in certain seams of the Yorkshire and Nottinghamshire Coalfields.



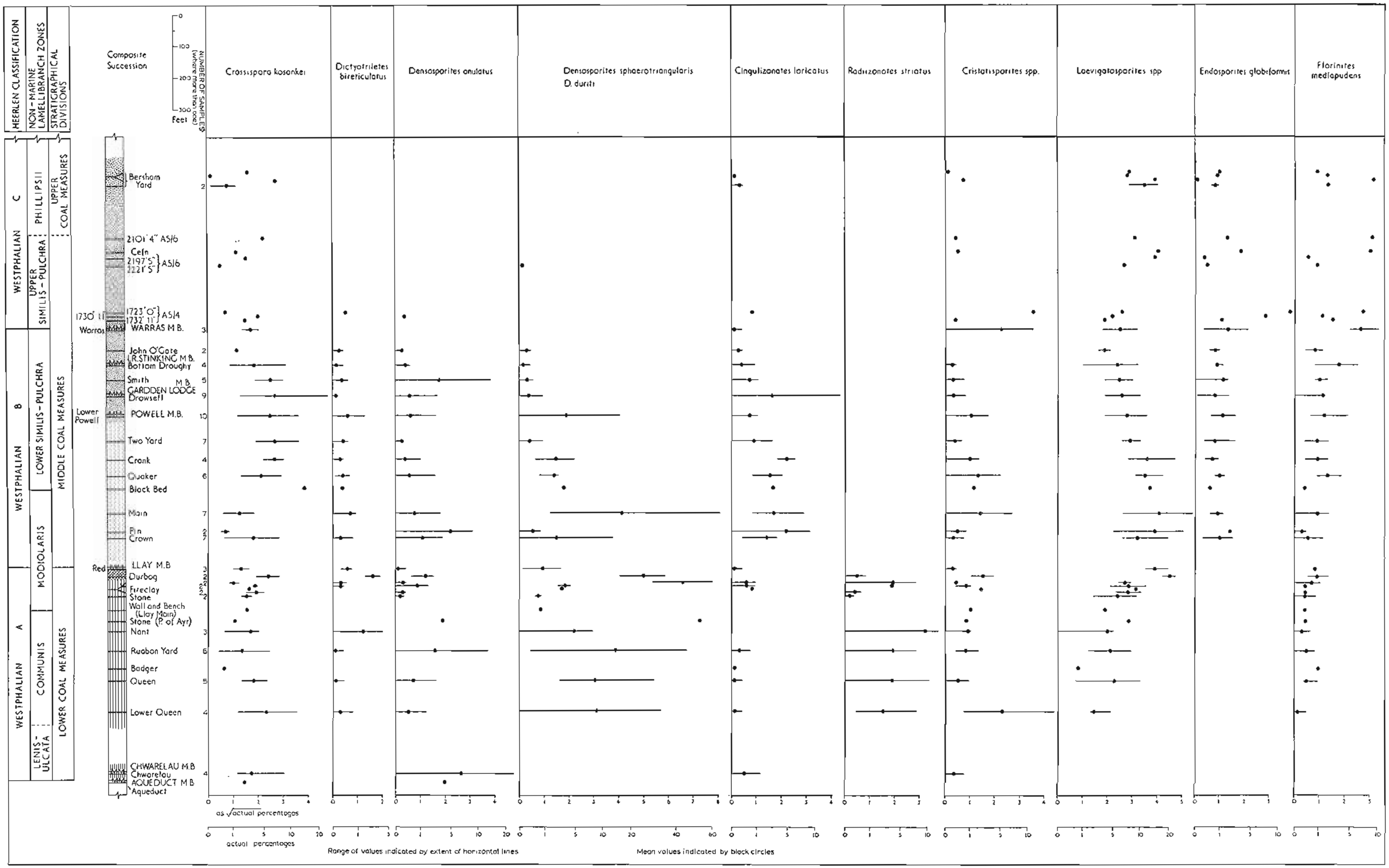
TEXT-FIG. 31. Locations of samples and sequences of seams examined from the Lancashire Coalfield.



TEXT-FIG. 32. Frequencies of selected miospore species in certain seams in the Lancashire Coalfield.



TEXT-FIG. 33. Locations of samples and sequences of seams examined from the North Wales Coalfields.



TEXT-FIG. 34. Frequencies of selected miospore species in certain seams of the North Wales Coalfields.

Coal Measures coals in text-fig. 25. Text-fig. 27 gives similar details for the Durham Coalfield. The frequencies of occurrence of selected species of six genera of miospores in the Scremerston Coal Group to the lower part of the Lower Coal Measures of Northumberland are shown in text-fig. 24. Text-figs. 26 and 28 give similar information for selected species of nine genera of miospores in the Coal Measures of the Northumberland and Durham Coalfields respectively. In the No. 4 Off-shore borehole in Durham the frequencies were determined for only four seams; the miospore floras of the remaining seams (shown by broken lines in text-fig. 27) were only examined qualitatively.

Grumosisporites verrucosus Assemblage I (Oakshaw Ford Seam to Woodend Seam).

This Assemblage is present in all of the seams examined from the Scremerston Coal Group and from the Woodend Seam in the lower part of the Lower Limestone Group. The number of species recorded is small and would probably be increased by closer study. All of the coals contain *Anaplanisporites baccatus* and *Schulzospora spp.*; *Densosporites intermedius*, *Grumosisporites verrucosus*, and *Chaetosphaerites pollenisimilis* are present in almost all of them. The Oakshaw Ford Seam is distinguished by the presence of over 80% of *Densosporites regalis* and by the occurrence of *Anapiculatisporites concinnus*, *Verrucosisporites baccatus*, and *Convolutispora* cf. *usitata*, each of which has been recorded from the Viséan of either Spitsbergen (Playford 1962, 1963) or Canada (Staplin 1960). The Fourlaws Seam contains 20% of *Densosporites pseudoannulatus* and 18% of *Tholisporites scoticus*—the only record of the latter genus in the Assemblage.

Diatomozonotriletes saetosus Assemblage II (Greenses Seam and Shilbottle Seam).

The genera *Rotaspora*, *Tripartites*, *Diatomozonotriletes*, and *Remysporites* occur for the first time in the Greenses Seam near the top of the Lower Limestone Group. The Shilbottle Seam in the Middle Limestone Group has an extremely varied miospore flora which, in addition to the above genera, contains *Spencerisporites*, *Perotriletes*, and the species *Leiotriletes tumidus*, *Crassispora maculosa*, and *Grumosisporites inaequalis*. Species which have been found only within this Assemblage include *Procoronaspora serrata*, *P. fasiculata*, *D. cervicornutus*, *D. saetosus*, *D. ubertus*, and *Rotaspora crenulata*. *Densosporites triangularis* is abundant in the Shilbottle Seam.

Rotaspora knoxi Assemblage III (seam at 281 ft. 7 in., Hazon Ford borehole to seam at 116 ft. 1 in., Ouston Airfield borehole).

Cingulizonates cf. *capistratus* first appears in the seam at 281 ft. 7 in., Hazon Ford borehole and becomes common, and even abundant, in some of the higher seams. *Densosporites intermedius*, *D. pseudoannulatus*, *D. triangularis*, and *Cingulizonates bialatus* are prominent at various horizons and *Tholisporites scoticus* is present, and occasionally very common, up to the horizon of the seam at 374 ft. 5 in. in the Ouston Airfield borehole. Characteristic species are *Chaetosphaerites pollenisimilis*, *Leiotriletes tumidus*, *Anaplanisporites baccatus* (locally abundant), *Anapiculatisporites spp.*, *Grumosisporites inaequalis*, *G. rufus*, *Convolutispora jugosa*, *C. varicosa*, *Tripartites nonguerickei*, *T. trilinguis*, *T. vetustus*, *Rotaspora fracta*, *R. knoxi*, and *Crassispora maculosa*. *Savitrisporites*, *Diatomozonotriletes*, and *Remysporites* are rare and *Vestispora lucida* has not been found.

Crassispora kosankei Assemblage IV (seams from Broad Law Deep borehole No. 36 and Tranwell Airfield borehole).

Crassispora and *Laevigatosporites* appear for the first time in the seams in these two boreholes but neither genus is common. The following Namurian A species are present occasionally, but do not persist higher in the sequence—*Chaetosphaerites pollenisimilis*, *Leiotriletes tumidus*, *Grumosisporites rufus*, *G. verrucosus*, *Acanthotriletes falcatus*, *Convolutispora ampla*, *C. jugosa*, *C. tesellata*, *Bellispores nitidus*, and *Remysporites magnificus*. *Densosporites intermedius* and *D. triangularis* are abundant in certain seams, and *Cingulizonates bialatus* is occasionally common; *Anaplanisporites baccatus* and *Schulzospora spp.* are generally present.

Densosporites anulatus Assemblage V (seam at 146 ft. 1 in., Shilvington borehole No. 71 to Ganister Clay Seam in Northumberland; Ganister Clay Seam in Durham).

Crassispora kosankei is common at most horizons and *Laevigatosporites* and the Namurian A spores listed above are absent. Occasional specimens occur of *Acanthotriletes echinatus*, *Mooreisporites fustis*, *Dictyotriletes bireticulatus*, *Reinschospora sp.*, *Schopfipollenites ellipsoides*, and *Florinites similis*. *Densosporites anulatus* is the most prominent densospore and *Cingulizonates bialatus* is occasionally common.

Radiizonates aligerens Assemblage VI (Marshall Green Seam to Hodge Seam, Northumberland; Marshall Green Seam to Tilley Seam, Durham).

The base of the Assemblage has been taken below the horizon of the Marshall Green Seam because of the occasional occurrence in it of *Laevigatosporites spp.*, *Densosporites sphaerotriangularis*, and *Radiizonates aligerens*. These spores are not so common in this seam as at the horizon of their first appearance in the coalfields of the Central Province. *Laevigatosporites spp.* first become common in the Victoria or Choppington Brockwell Seam and show a further increase in frequency at the Busty Seam horizon. *D. anulatus* is locally very common in both beds of the Marshall Green and in the Bottom Busty, where *Cingulizonates loricatus* may also be common; *D. anulatus* is frequent, to abundant, in the Victoria Seam of Northumberland. *Radiizonates striatus* is common, or locally abundant, in the Victoria, Brockwell, Three Quarter, and Top Busty Seams. *D. sphaerotriangularis* first becomes a prominent member of the miospore floras in the Brockwell and has been recorded from succeeding seams. This species, however, varies considerably in abundance, probably in response to changes in the structure of individual seams. Spores of the *D. duriti* and *Cristatisporites connexus* complex are frequent in both beds of the Brockwell and in smaller numbers in the Top and Bottom Busty Seams in Durham but are numerous only in the Bandy (Brockwell) Seam of Dawson's Drift in Northumberland. *Radiizonates aligerens* is most prominent in the Brockwell, Busty, and Tilley Seams and has not been found above the Hodge Seam.

Schulzospora rara Assemblage VII (seam at 1,207 ft. 2 in., Weetslade Colliery and Beaumont Seam in Northumberland; Harvey Seam in Durham).

Dictyotriletes bireticulatus is common and *Densosporites sphaerotriangularis* is abundant in the Beaumont and occasionally very common in the Harvey Seam but *Cristatisporites connexus*, which is usually prominent in this part of the sequence, is common only in the Top Beaumont at Ashington. *Vestispora tortuosa* occurs in all samples of the Beaumont Seam and is more frequent in the Harvey Seam than at lower horizons.

Dictyotriletes bireticulatus Assemblage VIII (Bottom Plessey Seam to seam at 556 ft. 2 in., Weetslade Colliery, Northumberland; Hutton Seam to Seam D, Durham).

The appearance of *Endosporites globiformis* as a persistent member of the miospore flora of the Bottom Plessey Seam of Northumberland and the Hutton Seam of Durham marks the base of the Assemblage. *Crassispora kosankei* is generally common to abundant throughout the Assemblage, except in the Low Main Seam and in the Brass Thill Seam of Durham, maximum numbers occurring in the High Main and in the coals below, and above, this horizon in Northumberland. *Densosporites sphaerotriangularis* is common to abundant in the Brass Thill, where fully developed, and in the Low Main and Five Quarter Seams of Durham; in Northumberland it may be abundant in the Top Plessey and Low Main Seams, but is less frequent than is usual at these horizons. *Cristatisporites indignabundus* is generally distributed in small numbers throughout the Assemblage. *Cingulizonates loricatus* occurs throughout and is sometimes common, or very common. *Radiizonates tenuis* is a characteristic member of the miospore floras of this Assemblage in most coalfields, but in Northumberland and Durham it has only been recorded from a few seams and is generally scarce. As in most other coalfields the miospore floras of seams in this Assemblage are particularly rich in species. *Dictyotriletes bireticulatus* has not been recorded from above the High Main Seam in Northumberland although it has been recorded from the succeeding Assemblage in Durham.

Vestispora magna Assemblage IX (Moorland Seam to West Moor Seam, Northumberland; Seam C to seam at 962 ft. 7 in., No. 4 Off-shore borehole, Durham).

The diagnostic species of this Assemblage appear at different levels and its base cannot, on present evidence, be placed lower than the Moorland Seam in Northumberland (containing *Cristatisporites solaris*) and Seam C in Durham (Wearmouth Upbore 8 SE. 5) in which *C. solaris* and *Vestispora magna* are present. In the Durham No. 4 Off-shore borehole *V. magna* and *Triquitrites sculptilis* first occur in a thin coal at 1,333 ft. 7 in. and Seam B at 1,107 ft. 3½ in. respectively. The occurrence of *Densosporites anulatus* in large numbers in Seam C from this borehole was unexpected. In Northumberland *V. magna* has not been found below the Ryhope Little Seam and *T. sculptilis* has not been recorded from below the Ryhope Marine Band in the upper part of the Middle Coal Measures (top of the Westphalian B). *C. solaris* is rare except in the Usworth Seam of Northumberland. *V. tortuosa* is frequent to very common throughout the Assemblage (including the thin coals not specifically considered in the present work). *Cingulizonates loricatus* may be common in the Ryhope Little Seam in Northumberland, and Seam C of Durham, but otherwise this species is unusually rare. *Dictyotriletes bireticulatus* is only recorded in this Assemblage in Durham in the seam at 508 ft. 6 in. in the Wearmouth Upbore 8 SE. 5.

Torispora securis Assemblage X (seams at 919 ft. 5 in. and 890 ft. 5 in., No. 4 Off-shore borehole, Durham).

Vestispora fenestrata is present in the coal at 919 ft. 5 in. in the No. 4 Off-shore borehole. The assemblages in this seam and that lying above (the highest encountered in this borehole) belong to Assemblage X. No other species diagnostic of this Assemblage have been seen.

TABLE 3. Assemblage frequencies for the coalfields of the Northern Province—Coal Measures

Assemblages	IX			VIII			VII			VI			V		
Coalfields	Cumberland	Northumberland	Durham	Cumberland	Northumberland	Durham	Cumberland	Northumberland	Durham	Cumberland	Northumberland	Durham	Cumberland	Northumberland	Durham
Number of samples	6	21	24	34	69	73	7	8	11	22	47	43	5	11	2
	Percentage occurrence in total number of samples from each Assemblage														
Miospore species															
Vestispora fenestrata			4												
Microreticulatisporites sulcatus															
Triquitrites sculptilis	17	14	42												
Cristatisporites solaris	17	38	17												
Vestispora magna	33	62	46												
Endosporites globiformis	100	95	100	94	91	96			9			7			
Radiizonates faunus															
R. tenuis	17		4	18	25	23	14	87			2	2			
Vestispora pseudoreticulata *V. costata* and *V. tortuosa*	100	100	75 92	82	90	70	57	87	73	14	11	12			
Dictyotriletes reticulocingulum		5	8	6	10	10		50	9		2	5			
Radiizonates aligerens										73	53	67			
Florinites mediapudens	100	100	92	74	84	81	71	75	91	36	47	35			
Pityosporites westphalensis	50	29	17	29	25	26	57	12	9	27	4	12			
Dictyotriletes bireticulatus	17		8	62	49	59	86	75	91	23	9	12	20	18	50
Densosporites duriti and *D. sphaerotriangularis*	33	14		62	65	59	86	87	91	86	75	63			50
**Laevigatosporites spp.*	100	100	100	100	100	100	100	100	100	100	92	93			
Acanthotriletes echinatus				6	10	12	14	12			4	9		9	
Reinschospora speciosa				21	3	3	29	25	9	9	4	9		9	
**Anapiculatisporites minor*	17	38	33	29	49	52	71	37	64	54	36	53	80	46	50
**Crassispora kosankei*	100	100	92	100	100	99	100	100	100	100	100	100	100	91	50
Simozonotriletes intortus				12	16	5	14	12		5	2	2			
Cristatisporites connexus and *C. indignabundus*	33			38	46	36	100	75	55	68	36	33	40	18	50
Reticulatisporites reticulatus	17	5	38	24	19	22	14	25	45	14	17	21	20		50
R. polygonalis	33	24	4	12	26	12	43	50	36	41	26	16	40	37	50
Cingulizonates loricatus	17	43	29	44	69	77	29	25	73	18	21	35	20		
Alatisporites pustulatus	17	10	12	27	9	22	43	12	18	5	13	7		9	
**Camptotriletes spp.*				15	7	11	29	25	27	50	15	14	80	27	50
**Ahrensisporites spp.*				21	29	15			9	5	2	2		9	
**Savitrisporites nux*		5		6	16	18	14		9	14	13	21	60	18	50
**Densosporites anulatus*	100	57	29	82	72	40	100	62	55	82	77	58	80	73	100
D. striatus and *D.* cf. *striatus*						7	14	12	9	64	68	53	60	64	100
**Spen:erisporites radiatus*			8	21	25	8	71	25	64	50	21	26	20	18	50
**Schopfipollenites spp.*	17		33	24	39	29		12	9	23	9	16	80	9	50
**Schulzospora rara*							86	62	55	73	66	60	60	37	50

* Genera and species recorded from older Assemblages, at least in certain coalfields.

The Yorkshire, Nottinghamshire, and North Derbyshire Coalfields

Although stratigraphically a continuous region, from the mining viewpoint the Yorkshire Coalfield in the north is generally separated from the Nottinghamshire and North Derbyshire field in the south; the boundary between them is drawn arbitrarily. In the present investigations miospore distribution has been considered in the region as a whole.

The lowest coals in the sequence occur in the higher part of the Millstone Grit Series (Namurian) but they are of no commercial importance. The most valuable seams are confined to the Lower and Middle Coal Measures. In the south of the region reddened beds of Etruria Marl facies are present a short distance above the base of the Upper Coal Measures. These beds occur at progressively higher horizons in moving northwards. Whether strata of Westphalian D age are represented in the Upper Coal Measures in the coalfield is conjectural but miospore evidence suggests that this is possible.

A preliminary account of the miospore assemblages in certain seams in the Coal Measures of the region, based on sequences in boreholes and samples taken at collieries, was given by Balme and Butterworth (1952). The relationships between the different spore associations and the coal types in which they occur have been examined by Smith (1957, 1962*a*) from certain seams in this coalfield.

The present investigations were carried out on seams at all horizons from the upper part of the Millstone Grit Series to the Upper Coal Measures. The samples were obtained from boreholes put down at various points in the region, supplemented (in Yorkshire) by some from individual collieries and taken at the outcrop. The choice of boreholes was dictated mainly by considerations of future developments within the region. Because of the easterly thinning of the seams the spore assemblages in individual coals may not be typical of those in the same seams in the exposed part of the coalfields.

The locations of the sampling points and details of the sections examined are given in text-fig. 29. Text-fig. 30 shows the frequencies of occurrence of selected species of nine genera of miospores present in the Coal Measures of the region.

A recent paper having a bearing on the investigations is that of Wilcockson and Goossens (1957) which describes examples of seam correlations established during the past decade.

Densosporites anulatus Assemblage V (Ringinglow Seam to Norton Seam).

The oldest coals examined in this region are the Ringinglow and a seam at about this horizon in the three British Petroleum Co. Ltd. boreholes in Nottinghamshire. These coals occur in the Millstone Grit Series. The Assemblage contains *Crassispora kosankei* and *Florinites spp.* and is characterized by *Densosporites anulatus* (sometimes in large numbers), *Apiculatisporis variocorneus*, *Raistrickia fulva*, and *Triquitrites spp.*

Radiizonates aligerens Assemblage VI (Better Bed Seam to Top Fenton Seam).

The occurrence in some numbers of *Laevigatosporites spp.* and *Densosporites sphaerotriangularis* in the Better Bed Seam marks the first appearance of this Assemblage in the succession. *D. sphaerotriangularis* is usually the dominant species in beds of dense, dull coal and is therefore abundant in seams such as the Top Silkstone (or Blocking), Thorncliffe, and Parkgate in which this coal type is usually a characteristic feature. Exceptions are the Blocking and Parkgate Seams of the Cross Hill and Kellingley boreholes, which, at both localities, consist predominantly of bright coal. *Radiizonates aligerens*, a species confined to this Assemblage, was not recorded below the Black Bed Seam. Other species which first appear in the Assemblage are *Dictyotriletes bireticulatus* and *Florinites mediapudens*. *R. striatus*, which occurs in small numbers in Assemblage V, is common in the Beeston and Top Silkstone (or Blocking) Seams of Yorkshire and in two seams in the Cotgrave Wolds borehole of Nottinghamshire, namely the seam at 2,117 ft. 11 in. and the lower leaf of the Ashgate Seam (no Yorkshire equivalent). It is rare in the Yard Seam of Nottinghamshire, which has no precise Yorkshire equivalent, but probably corresponds to the combined upper part of the Top Silkstone and Silkstone Rider Seams of Yorkshire. *R. striatus* becomes scarce in coals above the level of the Top Silkstone. *Cristatisporites spp.* have been recorded (generally in small numbers) from most seams in this Assemblage. *C. connexus* and *Densosporites duriti* are characteristic of the Thorncliffe, in which they are sometimes common. *Vestispora spp.* first occur in the Thorncliffe.

The two samples of the Deep Hard Seam from the Nottinghamshire boreholes were from the lower leaf, which is probably the correlative of the Low Fenton Seam of Yorkshire. *R. aligerens* has been recorded from one of these samples and from the Top Fenton of Yorkshire but not from seams higher in the sequence. The Top Fenton, therefore, marks the upper limit of Assemblage VI.

Schulzospora rara Assemblage VII (Flockton Thin Seam to Joan Seam).

This Assemblage includes only three seams, the Flockton Thin, the Flockton Thick, and the Joan. The Deep Soft Seam of the Jubilee Farm and Cotgrave Wolds boreholes is probably the correlative of the Eckington Deep Soft of the Sheffield area and the Flockton Thin Seam of West Yorkshire. *S. rara* makes its final appearance in the Coal Measures in these coals. *Dictyotriletes bireticulatus* and *Vestispora tortuosa* are persistent and more common members of this Assemblage than they are of that below.

Dictyotriletes bireticulatus Assemblage VIII (Lidgett Seam to Swinton Pottery Seam).

The seams above the Clay Cross Marine Band in this Assemblage, in general, possess miospore floras which are richer in species than those in any other part of the Productive Measures. *Densosporites sphaerotriangularis*, *Crassispora kosankei*, *Cingulizonates loricatus*, and *Densosporites anulatus* occur throughout in varying frequencies. Fluctuations in the numbers of these species do not follow a common pattern, and are therefore a useful stratigraphic feature. *Crassispora kosankei* is very common (exceeding 5%) in the Lidgett and Top Haigh Moor, but less so in the other seams up to the Dunsil where minimum values occur. Above this level *C. kosankei* increases in frequency, maximum numbers being recorded in the Kilnhurst and Winter Seams. On the other hand, *Cingulizonates loricatus* and*Densosporites anulatus* together are generally common in seams up to, and including, the Dunsil but they decrease in abundance at higher horizons. Excepting in the Cross Hill borehole, *D. sphaerotriangularis* is generally abundant in the Barnsley, its frequency being related to the presence of massive beds of dense, dull coal. In this borehole the Warren House (68 in.) and the Low Barnsley (26 in.) Seams are close together and have accordingly been treated as a composite coal. Because of the preponderance of bright coal in the Warren House portion, the spore content of the seam as a whole differs from that in the typical Barnsley Seam and compares closely with that of the Warren House Seam in the Kellingley borehole. Above the Barnsley, *D. sphaerotriangularis* is not generally very numerous. Exceptions are the Kent's Thick Seam in the Cross Hill borehole and the High Hazel Seam of the Hatfield and Thorne districts of the Yorkshire Coalfield (data for the Hatfield and Thorne districts are not included in text-fig. 30). The High Hazel here is not the precise equivalent of the seam of the same name in the Sheffield region. Its structure and relationship to the coals of the Stanley Main group of West Yorkshire have been considered by Wilcockson and Goossens (1957). The two beds of the Stanley Main Seam in the Kellingley borehole, although separated by a considerable thickness of measures, have been treated as a composite sample. The seam at 2,508 ft. 1 in. in the Jubilee Farm borehole is also a member of this group, but its precise correlation is uncertain. Spore frequencies in this seam have therefore been considered separately. It is also interesting to note that maximum numbers of *Radiizonates tenuis* occur at about the same horizon in different parts of the region. Thus in Yorkshire the spore is present in the Kent's Thick Seam (1–3%) and in Nottinghamshire in the seam at 1,088 ft. 8 in., Cotgrave Wolds borehole, where the numbers reach 8%. *Cristatisporites indignabundus* is also a common constituent in these and certain other coals within the Assemblage. Two species of *Vestispora* occur in this Assemblage, *V. pseudoreticulata* and *V. tortuosa*. *V. tortuosa* is found usually without *V. pseudoreticulata* in seams up to, and including, the Dunsil. It may be frequent in these seams. In the Barnsley and seams up to, and including, those of the Stanley Main group this species is rare and it is usual to find *V. pseudoreticulata* in small numbers. In the Winter and younger seams both species occur together, although *V. pseudoreticulata* is more numerous in the Meltonfield and Newhill Seams. Except for the Meltonfield there are very few data for seams between the Two Foot and the Mansfield Marine Bands.

Vestispora magna Assemblage IX (Wheatworth Seam to seam at 1,387 ft. 4 in., Gate Farm borehole).

The base of the Assemblage is not clearly defined in Yorkshire; diagnostic spores have not been found lower than the Wheatworth Seam, in which *V. magna* is present. In Nottinghamshire Balme recorded *Triquitrites sculptilis* in the Two Foot Seam in the Manton Colliery borehole and *Cristatisporites solaris* in the same seam, and the seams immediately above, at other Nottinghamshire localities (Balme and Butterworth 1952). In Yorkshire *C. solaris* is present in some numbers in the Houghton Thin Seam, just above the Mansfield Marine Band, but below this horizon the species has not been identified with certainty. Above the Mansfield Marine Band *V. magna* and *T. sculptilis* are persistent members of the miospore floras. *V. pseudoreticulata* and *V. tortuosa* also both occur in the Assemblage. The highest seams in which *Dictyotriletes bireticulatus* is present are the Swinton Pottery of Yorkshire and the Clown of Nottinghamshire. With a few exceptions the seams within the Assemblage are characterized by relatively large numbers of *Endosporites globiformis* and *Florinites mediapudens*. The increase in the frequency of occurrence of *E. globiformis* begins in the Two Foot Seam of the preceding Assemblage.

Torispora securis Assemblage X (Blyth Seam and seams at 1,433 ft. 0 in. to 1,320 ft. 7 in., Hartswell Farm borehole, and seam at about 3,230 ft., Corringham borehole).

Miospore floras typical of the Assemblage occur in the seam at about 3,230 ft. in the Corringham borehole, in the Blyth Seam from the Torworth Jubilee Farm borehole, and in seams between 1,433 ft. 0 in. and 1,320 ft. 7 in. in the Hartswell Farm borehole. *Vestispora magna* was, however, only recorded in the Blyth Seam, the seam at 1,433 ft. 0 in. in the Hartswell Farm borehole, and the seam at about 3,230 ft. in the Corringham borehole. *Torispora* has only been seen in the seam in the Corringham borehole, where it is associated with *V. laevigata* and *Cristatisporites solaris*.

Thymospora obscura Assemblage XI (seam at 809 ft. 5 in., Hartswell Farm borehole).

The spore assemblage in this seam contains small numbers of *Thymospora obscura* and *Triquitrites spinosus*. A single specimen of *Cadiospora magna* has also been recorded. These species are characteristic of Westphalian D miospore floras. Other species present are *Raistrickia aculeata*, *Vestispora laevigata*, and small numbers of *Densosporites sphaerotriangularis* and *Triquitrites bransonii*.

The Lancashire Coalfield

The coalfield includes the small Burnley field in the north and the main South Lancashire field in the south.

In the main field coals occur in the higher part of the Millstone Grit Series and throughout most of the Coal Measures but only those in the Lower, Middle, and lower part of the Upper Coal Measures are worked in deep mines today. The seams higher in the Upper Coal Measures are thin and of no economic value. In the Burnley field seams are restricted to the higher part of the Millstone Grit Series and the Lower Coal Measures, only those in the latter being of importance.

A preliminary account of the miospore floras of several seams in the Lower and Middle Coal Measures of the region, based on samples taken at certain collieries, was given by Balme and Butterworth (1952). Butterworth (1956) extended these investigations by an examination of samples from a series of deep boreholes located along the southern boundary of the field; some of these samples were from coals in the Upper Coal Measures. Butterworth and Millott (1957) examined in detail the miospore floras of certain seams in the Middle Coal Measures of the eastern part of the coalfield.

In the present investigations much of the earlier work has been revised and additional material examined from boreholes, collieries, and opencast sites. In the Burnley field and the northern part of the South Lancashire field the samples were from all of these sources, but elsewhere in the main field mainly from boreholes located between Cronton Colliery in the west, the Prestwich district in the east, and the extension of the coalfield into Cheshire in the south-east. These sequences were supplemented by seam samples taken at certain collieries in the south-west and at Bradford Colliery in the east. In the Burnley field several of the lowest seams were of too high rank for satisfactory maceration, but their equivalents in the northern part of the main coalfield gave better separations.

The locations of the sampling points and details of the sections examined are given in text-fig. 31. Text-fig. 32 shows the frequencies of occurrence of nine genera of miospores in the Coal Measures of the coalfield. Recent papers having a bearing on the investigations are those of Earp and Magraw (1955) and Magraw (1957), which concern the geology of the lower part of the Lower Coal Measures of the coalfield. Earp, Poole, and Whiteman (1961) have described the succession in the Burnley Coalfield, Trotter (1952–3) the earlier boreholes in the south-western part of the main coalfield, and Poole and Whiteman (1954–5) the sequences in boreholes in the Prestwich district of that field. The drivages at Bradford Colliery in the South Lancashire field have been described by Magraw and Calver (1959–60), and Magraw (1961) has described borehole sequences in the southern part of the central district of this coalfield. All of the papers contain references to the many marine bands identified in Lancashire during the last decade or so.

Densosporites anulatus Assemblage V (Six Inch Seam to Pasture Seam).

This Assemblage is present in the lowest seams of the Coal Measures sequence, that is from the Six Inch Seam at the base of the Lower Coal Measures to the Pasture Seam at the top of the Lenisulcata Zone. *D. anulatus* is abundant in the Lower Mountain, Upper Mountain, and Cannel Seams.

Radiizonates aligerens Assemblage VI (Arley Seam to Wigan Four Feet Seam).

Dictyotriletes bireticulatus, *Densosporites sphaerotriangularis*, *R. aligerens*, *Laevigatosporites spp.*, and *Florinites mediapudens* first appear in the Arley Seam near to the base of the Communis Zone in the Lower Coal Measures. *R. striatus* is not so common as in other coalfields but it has been found in large numbers in the Padiham Eleven Feet Seam of Burnley, in the Reform Seam of the Poynton A1/20 borehole in North Cheshire, and in the cannel roof of the Rushy Park Seam in the west of the main coalfield. *R. aligerens* is common in the Peacock, Trencherbone, Wigan Two Feet, and Wigan Four Feet Seams; in the Trencherbone it is sometimes associated with large numbers of *D. sphaerotriangularis*.

Schulzospora rara Assemblage VII (Wigan Five Feet Seam to Park Seam).

In Lancashire up to three seams may contain this Assemblage—the Wigan Five Feet, Doe, and Park occurring immediately below the Sutton Manor Marine Band. *Densosporites sphaerotriangularis*, *Dictyotriletes bireticulatus*, and *Cristatisporites spp.* are not so common as at similar horizons elsewhere. *Vestispora tortuosa* is invariably present.

Dictyotriletes bireticulatus Assemblage VIII (Pigeonhouse Seam to Ashclough Seam).

Endosporites globiformis first appears in the Pigeonhouse Seam, which is restricted to the western part of the coalfield. The Lower and Higher Florida Seams (Bickershaw Seven Feet and Pemberton Five Feet respectively) remain fairly constant in the sections examined, but are separated by thinner coals in the Manchester area where the sequence increases in thickness. *Radiizonates* cf. *striatus* is generally frequent in both Florida Seams and in the Pigeonhouse Seam. The Lower Florida is characterized by a *Densosporites sphaerotriangularis–Cristatisporites connexus* complex, the former being very common. The Higher Florida and overlying New Seam contain consistently low numbers of *Crassispora kosankei*; this spore increases in frequency in the Rams Seam and may be very common in the seams above this horizon, particularly in the eastern part of the coalfield.

The seams above the Floridas have presented the main correlation problems in the coalfield. The correlative of the Rams, or Furnace Seam, at Bradford Colliery is assumed to be the Lower Furnace (Magraw and Calver 1960) and revised correlations are adopted of the seams between the Crombouke and Ashclough horizons in the Manchester and St. Helens districts (Butterworth and Millott 1957; Magraw and Calver 1960; Magraw 1961). Most of the seams in this part of the sequence have fairly distinctive miospore floras. In that of the Rams Seam all of the significant genera are well represented and the number of species present is high. The seams between the Rams and Crombouke horizons vary considerably. In the western part of the coalfield the Yard Seam has a microflora similar to that of the Rams whereas the succeeding Earthy Delf has a microflora dominated by *Lycospora spp*. The Upper Furnace Seam at Bradford Colliery in the eastern part of the field (in the present work assumed to be the correlative of the Yard Seam in the west) is distinguished by significant numbers of *Radiizonates tenuis*. The overlying Brassey Seam, occupying a similar position to the Earthy Delf and assumed to be its correlative, contains a band of durain rich in *Densosporites sphaerotriangularis*; the resulting microflora is therefore more varied than that of the Earthy Delf.

The variation in miospore floras in the above seams is more complicated when account is taken of sections not considered in the present investigations; the Ince Seven Feet Seam, for instance, occupies a position in the central part of the main coalfield analogous to that of the Earthy Delf in the south-west and the Brassey in the east, but has a microflora more similar to those of the underlying Yard and Rams Seams.

The Crombouke Seam microflora remains constant over the whole field and is characterized by low numbers of *Laevigatosporites spp*. and by the virtual absence of *Dictyotriletes bireticulatus*. This seam was not encountered in the Poynton A1/20 borehole in North Cheshire, where it is considered by the present authors to have coalesced with the underlying Roger Seam, the local correlative of the Brassey (there is a diminution in the numbers of *Densosporites sphaerotriangularis* in the Roger Seam in the A1/20 borehole compared with those in the Roger at Bradford Colliery and the Brassey of the adjacent Prestwich boreholes; this is due to the presence of a thickness of predominantly bright coal towards the top of the Roger in the A1/20 borehole which probably represents the Crombouke).

The Binn Seam has a less constant microflora, but it is generally distinguished by relatively high numbers of *Cingulizonates loricatus*. In the central part of the coalfield this seam is represented by two leaves, the Bottom Ince Yard and the Ince Deep Yard, but in the south-western part of the field it coalesces with the underlying Crombouke, the combined seam being known as the Felcroft and Pasture. The Stonedelph (Top Ince Yard) and Ashclough Seams are mainly confined to the eastern part of the field, where the former is rich in *Crassispora kosankei* and the latter has a miospore flora with low numbers of *Laevigatosporites spp*., similar to that of the Crombouke.

Vestispora magna Assemblage IX (Pottery Seam to seam at 284 ft. 2 in., Prestwich Asylum A1/1 borehole).

Representatives of these seams are restricted mainly to the eastern part of the coalfield; their relationship to the occasional seams present in the western part is unknown. *Cristatisporites solaris* first occurs in the Pottery Seam but is not invariably present. *Triquitrites sculptilis* occurs in the Radley Seam at Bradford Colliery and in the seam below the Bradford Marine Band in the Poynton A1/20 borehole. *V. magna* first occurs in the seam below the Dukinfield Marine Band. Although these spores are usually present in coals above the Dukinfield Marine Band they are never numerically common. The Pottery and New Jet Amber Seams are exceptionally rich in *Crassispora kosankei*. The only economically important seams present in the uppermost part of the Middle Coal Measures (lower part of the Westphalian C) are the Parker and Worsley Four Feet. *Florinites mediapudens* is occasionally very common in the latter seam. No coals have been examined from between the seam at 284 ft. 2 in. in the Prestwich Asylum A1/1 borehole, which lies some distance below the top of the Upper Similis–Pulchra Zone, and the seams of the Bradford Group in the higher part of the Phillipsii Zone.

Torispora securis Assemblage X (the Bradford Group of seams).

This group of seams includes the New, Yard, Four Feet, etc., which are present at Bradford Colliery and in three of the adjacent boreholes, but which are not represented in the western part of the field except for an unnamed seam at 1,812 ft. 4 in. in the Cronton A3/5 borehole. *Torispora securis* and *Vestispora fenestrata* are present in all of these coals except those in the Astley Station A1/8 borehole. The coals at Bradford Colliery differ from those in the boreholes and in the Blackband Group of North Staffordshire (correlated with the Bradford Group by Kidston 1905) in containing significant numbers of *Cristatisporites solaris*. In other coalfields densospores are rare in the lower part of the Upper Coal Measures (Westphalian C) above the horizon at which *T. securis* first appears.

Thymospora obscura Assemblage XI (seams of the Tenuis Zone).

Only three seams in Lancashire have been examined having this Assemblage—that at 717 ft. 2 in. in the Farnworth A3/4 borehole (in the Upper Group of Trotter 1952–3, p. 263), and those at 997 ft. 8 in. in the A3/4 borehole and at 2,066 ft. 0 in. in the Penketh A3/7 borehole (in the Lower Group of Trotter, loc. cit., p. 266). Several of the characteristic species of the Assemblage occur in each of the three seams examined, but never in large numbers. *Crassispora kosankei*, *Endosporites globiformis*, and *Florinites mediapudens* are also relatively rare.

The North Wales Coalfields

The coalfields include the separate mining regions of Flintshire in the north and Denbighshire in the south. In the former field only one colliery is now in existence.

Coals occur in the higher part of the Millstone Grit Series and throughout most of the Coal Measures but the most valuable coals are confined to the upper part of the Lower Coal Measures and to the Middle Coal Measures. The seams in the Millstone Grit Series are thin and of no economic importance, as are those in the Upper Coal Measures, which are represented in the Ruabon Marl, Coed-yr-Allt, and Erbistock Beds.

Earlier accounts of spore distribution in the coalfields of North Wales by Butterworth and Millott (1955) and Butterworth (1956) were based on samples from Llay Main, Gresford, and Point of Ayr Collieries, the Whitegate A5/1 borehole, Gardden Lodge, and the north-west Flintshire opencast sites and various outcrops.

In the present investigations the earlier results have been revised and further material examined from the Dudleston A5/5 and Ruabon A5/6 boreholes, parts of the Plas Thomas A5/4 and Dudleston A5/5/1 boreholes, and from additional collieries. In Flintshire the parts of the sequence covered therefore range from the base of the Lower Coal Measures to the lower part of the Middle Coal Measures, the seams examined being restricted to those occurring at Point of Ayr Colliery and an outcrop sample in the extreme north-western part of the field. In Denbighshire the range is from the base of the Lower Coal Measures to the Erbistock Beds in the Upper Coal Measures, where the samples were from localities well spaced throughout the coalfield.

The locations of the sampling points and details of the sequences examined are shown in text-fig. 33. Text-fig. 34 shows the frequencies of occurrence of selected species of nine genera of miospores in the Coal Measures of both coalfields. In the composite succession shown in the figures, the Point of Ayr Colliery sequence in Flintshire has been combined with the Denbighshire sequence and the constituent seams shown separately where the correlation is uncertain.

In a recent paper on the North Wales Coalfields Magraw and Calver (1960) described sections from Gardden Lodge Opencast Site and from Hafod, Bersham, Llay Main, and Gresford Collieries, and recorded several new marine horizons. Much of their material has been used in compiling the sections in text-fig. 33.

Densosporites anulatus Assemblage V (Aqueduct and Chwarelau Seams).

The lowest coals examined were the Aqueduct from below the *Gastrioceras subcrenatum* Marine Band in Denbighshire, the Chwarelau from slightly higher in the sequence, and the probable correlative of the latter, the Little Coal of Picton, samples of which were examined from the outcrop at Nant-Felin-Blwm in north-west Flintshire, and from above which Shanklin (1956) has recorded the *G. listeri* Marine Band. Each of these coals contains miospores typical of the Assemblage. *D. anulatus* is abundant in the Chwarelau Seam.

Radiizonates aligerens Assemblage VI (Lower Queen Seam to Fireclay Seam).

R. aligerens, *Laevigatosporites spp.*, and *Florinites mediapudens* first appear in the Lower Queen Seam of Denbighshire and in the Bychton Three Quarters Seam of Flintshire which also contains *Dictyotriletes bireticulatus*. *R. striatus* is common in the Queen, Ruabon Yard, and Nant Seams and their equivalents. *Densosporites sphaerotriangularis* is locally abundant in the Queen and Fireclay Seams of Denbighshire and in the Bychton Three Quarters, Hard Five Quarters, and Stone Seams at Point of Ayr Colliery. *R. aligerens* persists up to the Stone and Fireclay Seams respectively.

Schulzospora rara Assemblage VII (Red Seam and Durbog Seam).

This Assemblage is confined to the Red of Denbighshire (the seam immediately below the Llay Marine Band) and the Durbog of Point of Ayr Colliery. *Densosporites sphaerotriangularis* is abundant in the Durbog and *Cristatisporites connexus* is common; *Dictyotriletes bireticulatus* and *Vestispora tortuosa* are present in both seams.

Dictyotriletes bireticulatus Assemblage VIII (Crown Seam to Two Yard Seam).

Endosporites globiformis first appears in the Crown Seam of Denbighshire and in the Two Yard Seam at Point of Ayr Colliery. *Densosporites sphaerotriangularis* is particularly abundant in the Two Yard and Three Yard Seams at Point of Ayr and, to a lesser extent, in the Main Seam of Denbighshire; it remains locally common up to the horizon of the Powell Seam, above which it is rare. This distribution of *D. sphaerotriangularis* is unusual for a coalfield in the Central Province, where it generally decreases in abundance above the base of the Lower Similis–Pulchra Zone, that is two or three seams lower in the sequence than in North Wales. *Crassispora kosankei* increases in frequency at the horizon of the Black Bed Seam and continues to be abundant almost to the top of the Lower Similis–Pulchra Zone; it shows no marked peak below the Powell Marine Band, which is thought to be the equivalent of the Two Foot Marine Band of Yorkshire and Nottinghamshire (Magraw and Calver 1960, p. 346). *Cristatisporites spp.* are generally present, and occasionally common, in the Main Seam. *Radiizonates* cf. *striatus* is common in the Crown, Pin, and Main Seams of the Denbighshire Coalfield and in the Two Yard of Point of Ayr Colliery. *Cingulizonates loricatus* is present in most of the seams and is common in the Crank. *R. tenuis* is abundant in the Crank at Gresford Colliery and present in the Main, Quaker, Crank, and Two Yard (Denbighshire) elsewhere.

Vestispora magna Assemblage IX (Powell Seam to seam at 2,101 ft. 4 in., Ruabon A5/6 borehole).

Cristatisporites solaris and *Triquitrites sculptilis* first appear in the Powell at Ifton Colliery and in the Ruabon A5/6 borehole. *V. magna* first appears in the Drowsell Seam. The Powell may occur in three leaves—Upper, Middle, and Lower; the Upper Powell is equivalent to the Drowsell, which is overlain by the Gardden Lodge Marine Band; the Lower Powell, generally known as the Powell, is overlain by the Powell Marine Band (Magraw and Calver 1960). In some of the samples which were obtained before the marine bands were recognized it is not known with certainty whether the Middle or Lower Powell was represented. At Llay Main, Gresford, and Bersham Collieries, where the Powell Marine Band has been identified above the seam, the spores characteristic of the *V. magna* Assemblage are not found in the Powell.

The seams between the Powell Marine Band and the top of the Lower Similis–Pulchra Zone are all rich in *Crassispora kosankei* and contain relatively low numbers of the *V. magna* Assemblage spores, except the Smith Seam, which can be distinguished by its content of *V. magna* (sometimes greater than 5%).

The Warras Seam and the thin coals above it in the Plas Thomas A5/4 borehole are rich in *Cristatisporites solaris*, *Florinites mediapudens*, and *Endosporites globiformis*. The highest recorded occurrence of *Dictyotriletes bireticulatus* in the coalfield is in one of the thin coals above the Warras Marine Band. The equivalent of the Bay Marine Band of North Staffordshire has not been found in the North Wales Coalfields. The Cefn Group of seams (Ruabon A5/6 borehole) contains all the typical *V. magna* Assemblage species and large numbers of *Florinites spp.*; they have, therefore, a similar miospore flora to the Winghay Seam of North Staffordshire, except that *Torispora securis* has not been seen in them.

Torispora securis Assemblage X (Bersham Yard Seam).

The Bersham Yard Group of seams, from high horizons in the Whitegate A5/1 and Ruabon A5/6 boreholes, contains a typical *T. securis* Assemblage, indicating horizons above that of the Top Marine Band of Yorkshire. No coals from the overlying Ruabon Marl have been examined.

Thymospora obscura Assemblage XI (Seams of the Coed-yr-Allt and Erbistock Beds).

The succeeding Coed-yr-Allt Beds contain many thin coals all of which have miospore floras containing several of the spores characterizing the *T. obscura* Assemblage. Only very occasional specimens of *Densosporites* are found in these seams, or in that from the Erbistock Beds sampled at Llwyn-onn Mill. Less than 1% of *Crassispora kosankei* has been recorded from most of the coals and *Florinites mediapudens* is generally absent. *Endosporites globiformis* is common throughout.

The North Staffordshire Coalfields

The principal coalfields included in this region are the main Potteries field in the west and the Cheadle field in the east. The present investigations have been confined to the Potteries Coalfield.

Coal seams occur in the Millstone Grit Series and throughout the Coal Measures, but the most valuable coals are confined to the Lower and Middle Coal Measures and the lower part of the Upper Coal Measures. The seams in the Millstone Grit Series, and in the upper part of the Upper Coal Measures (Etruria Marl, Newcastle, and Keele Groups), are mostly thin and of no economic importance.

Millott (1939, 1946) examined the miospore floras of seam sequences from the Millstone Grit Series to the lower part of the Middle Coal Measures in both the Potteries and Cheadle fields and paid particular attention to the Holly Lane, Bowling Alley, and Hardmine Seams. Balme and Butterworth (1952) re-examined certain of these seams to confirm the presence of *Radiizonates aligerens* and *Schulzospora rara* at comparable horizons to those in other coalfields of the Central Province. Butterworth and Millott (1955) and Butterworth (1956) examined a succession of coals from horizons ranging from the Millstone Grit Series to the Upper Coal Measures; colliery and outcrop samples were supplemented by seams from the Blacklake and Pie Rough boreholes. Neves (1958, 1961) described a sequence of miospore assemblages in Namurian sediments, including coals, from the southern Pennines, and showed that these measures could be zoned by their miospore contents. He also compared the spore floras in the coal seams with those in the associated marine and non-marine sediments.

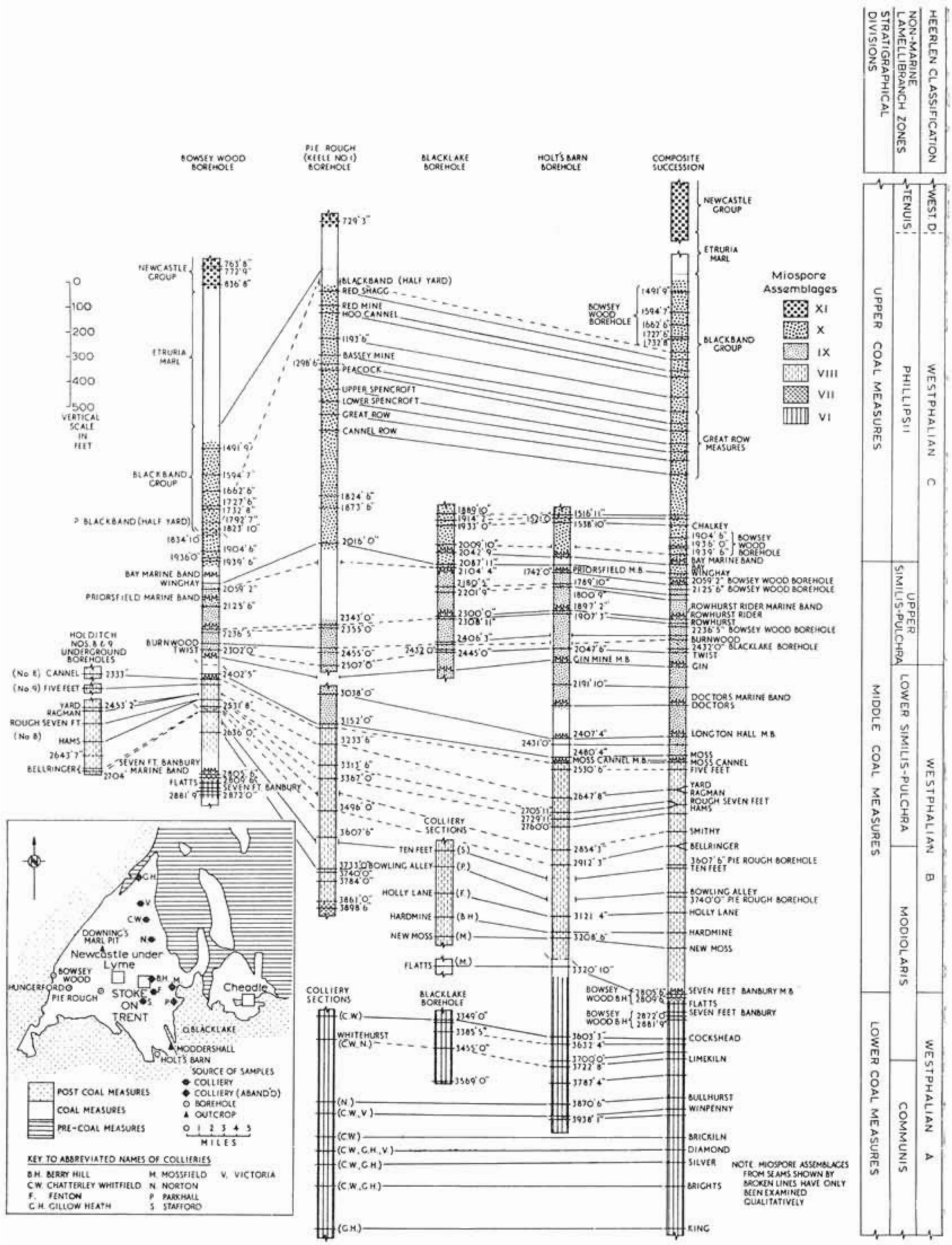
In the present investigations attention was confined mainly to the Bowsey Wood, Pie Rough, Blacklake, and Holt's Barn boreholes. Additional samples from above the Ten Feet Seam horizon were obtained from Holditch Colliery underground boreholes, and of seams from the King to the Ten Feet from collieries indicated in the sections (text-fig. 35). Samples of two seams in the Etruria Marl Group were taken, one from the Hungerford borehole and the other from Downing's Marl Pit. A sample of a seam in the Keele Group was taken at the outcrop at Moddershall. These seams are not shown in text-fig. 35. The Pie Rough borehole was of the oil-well (mud flush) type, the coal samples being in the form of fine cuttings. The rank of the samples was such that satisfactory maceration was generally possible except in the case of the Seven Feet Banbury and deeper seams in the Pie Rough borehole.

The locations of the sampling points and details of the sections examined are shown in text-fig. 35. Text-fig. 36 shows the frequencies of occurrence of selected species of nine miospore genera in the Coal Measures of this coalfield.

Radiizonates aligerens Assemblage VI (King Seam to Flatts Seam).

A complete sequence of these coals was not present in any of the boreholes examined but samples of all seams from the King to the Cockshead were obtained from collieries in the northern part of the field.

Laevigatosporites spp., *Densosporites sphaerotriangularis*, and *Endosporites zonalis* are present in the King Seam, which is therefore included in the *R. aligerens* Assemblage.



TEXT-FIG. 35. Locations of samples and sequences of seams examined from the North Staffordshire Coalfields

R. striatus is locally common in the Diamond Seam and may be abundant in the Winpenny (the seam at 3,569 ft. in the Blacklake borehole contains virtually no specimens of *R. striatus*; because of this, and as its original correlation with the Winpenny Seam is tentative, it has not been included in the calculations of the Winpenny Seam frequencies). *R. aligerens* first occurs in the Silver Seam and *Florinites mediapudens* in the overlying Diamond Seam. *D. sphaerotriangularis* and *Laevigatosporites spp.* increase in frequency at the horizon of the seam below the Limekiln, where also *F. mediapudens* becomes a constant member of the miospore flora. The Seven Feet Banbury, one of the seams which has not been adequately sampled, contained no specimens of *D. sphaerotriangularis*, which, as Raistrick's type A1, Millott (1939) recorded as being abundant at this horizon at Mossfield Colliery in the south-eastern part of the coalfield, but rare at Rookery Colliery in the west.

Schulzospora rara Assemblage VII (seams at 2,809 ft. 6 in. and 2,805 ft. 6 in., Bowsey Wood borehole).

Radiizonates aligerens has not been seen above the Seven Feet Banbury Seam except in the Flatts Seam at 2,831 ft. 0 in., Bowsey Wood borehole; it does not occur in the samples of the Flatts from Mossfield Colliery or Holt's Barn borehole. *S. rara* has not been found above the Seven Feet Banbury Marine Band. *Densosporites sphaerotriangularis* is locally common but never abundant and *Cristatisporites spp.* and *Dictyotriletes bireticulatus* are less frequent than at similar horizons elsewhere. *Vestispora spp.* are invariably present.

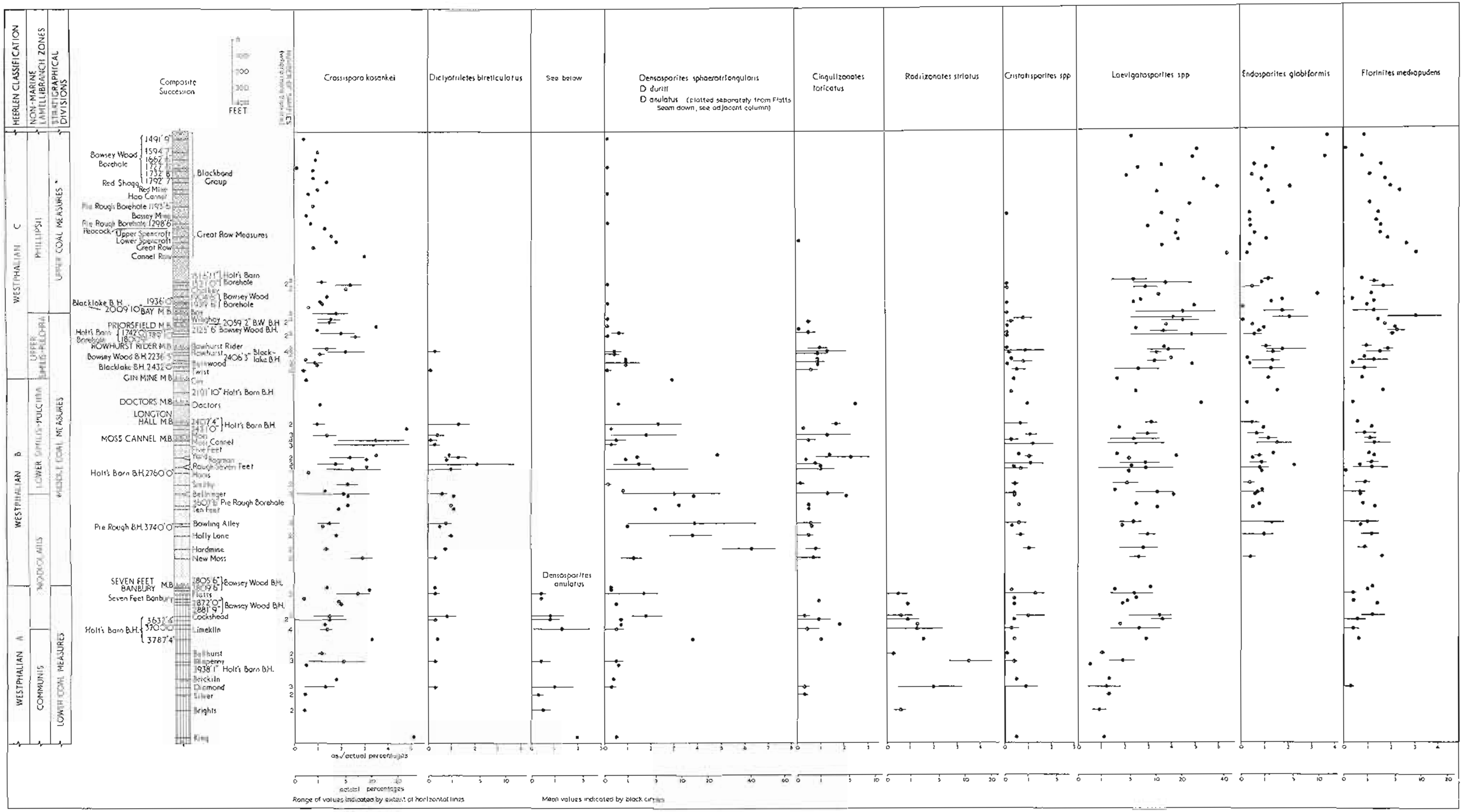
Dictyotriletes bireticulatus Assemblage VIII (New Moss Seam to Moss Cannel Seam).

Endosporites globiformis is present in most seams above the Seven Feet Banbury Marine Band. *Densosporites sphaerotriangularis* is common, or abundant, up to the Bellringer horizon, above which it is less frequent, except in the seam at 2,760 ft. 0 in., Holt's Barn borehole and in the Yard Seam where it may be abundant. *Cingulizonates loricatus* and *Cristatisporites spp.* are relatively rare in the lower seams, but the former may be common in the Bellringer, Hams, and combined Yard and Ragman Seams and the latter is also occasionally common in the Five Feet Seam. A value of less than 1% has been recorded for *Crassispora kosankei* in the unnamed seam below the Hams but it increases in frequency above this horizon and reaches a maximum in the Five Feet and Moss Cannel Seams. *Dictyotriletes bireticulatus* is moderately common in some of the higher seams.

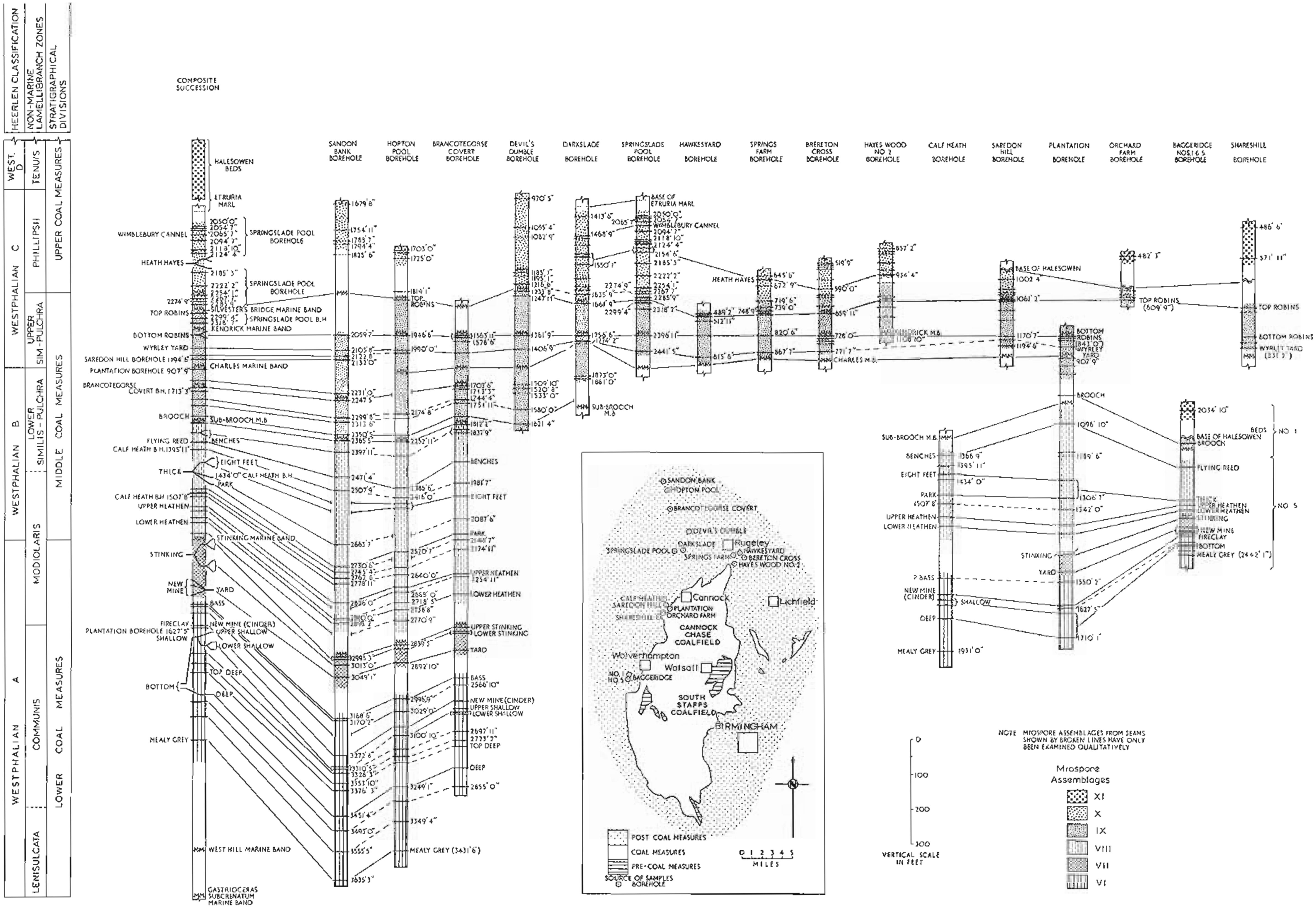
Vestispora magna Assemblage IX (Moss Seam to seam at 2,059 ft. 2 in., Bowsey Wood borehole).

Relatively few seams have been examined from the lower part of the Assemblage, partly because of the faulting out of this part of the sequence in the Bowsey Wood borehole and partly because no seams from below the Gin Mine Marine Band in the Blacklake borehole were included in the investigations.

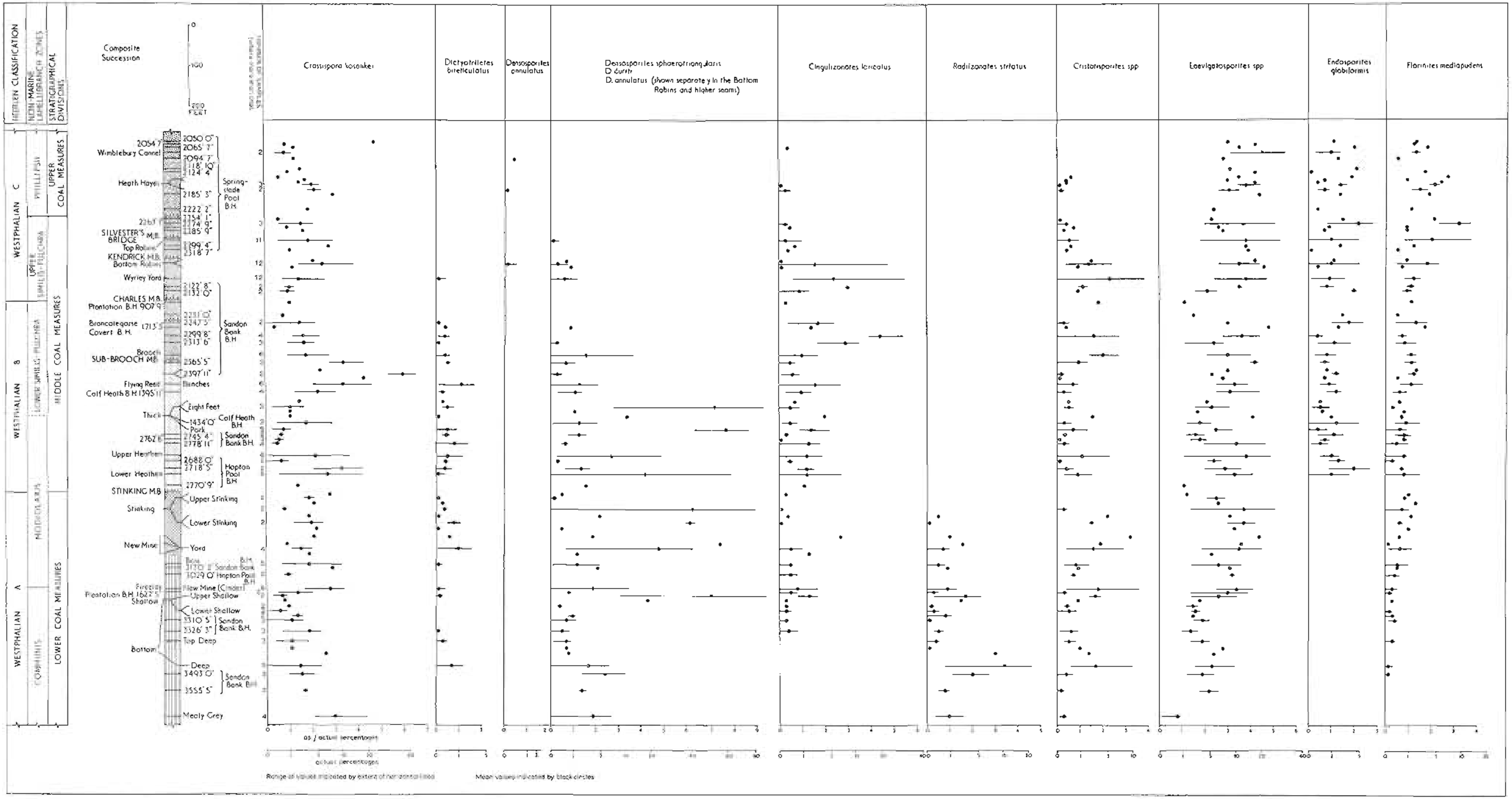
The spores characterizing the Assemblage have not been found below the Longton Hall Marine Band in the Holt's Barn borehole although *V. magna* occurs in the Moss Seam, and *Cristatisporites solaris* in the seam below, that is the Birchenwood Seam in the Pie Rough borehole. Above the Gin Mine Marine Band *Triquitrites sculptilis*, *V. magna*,



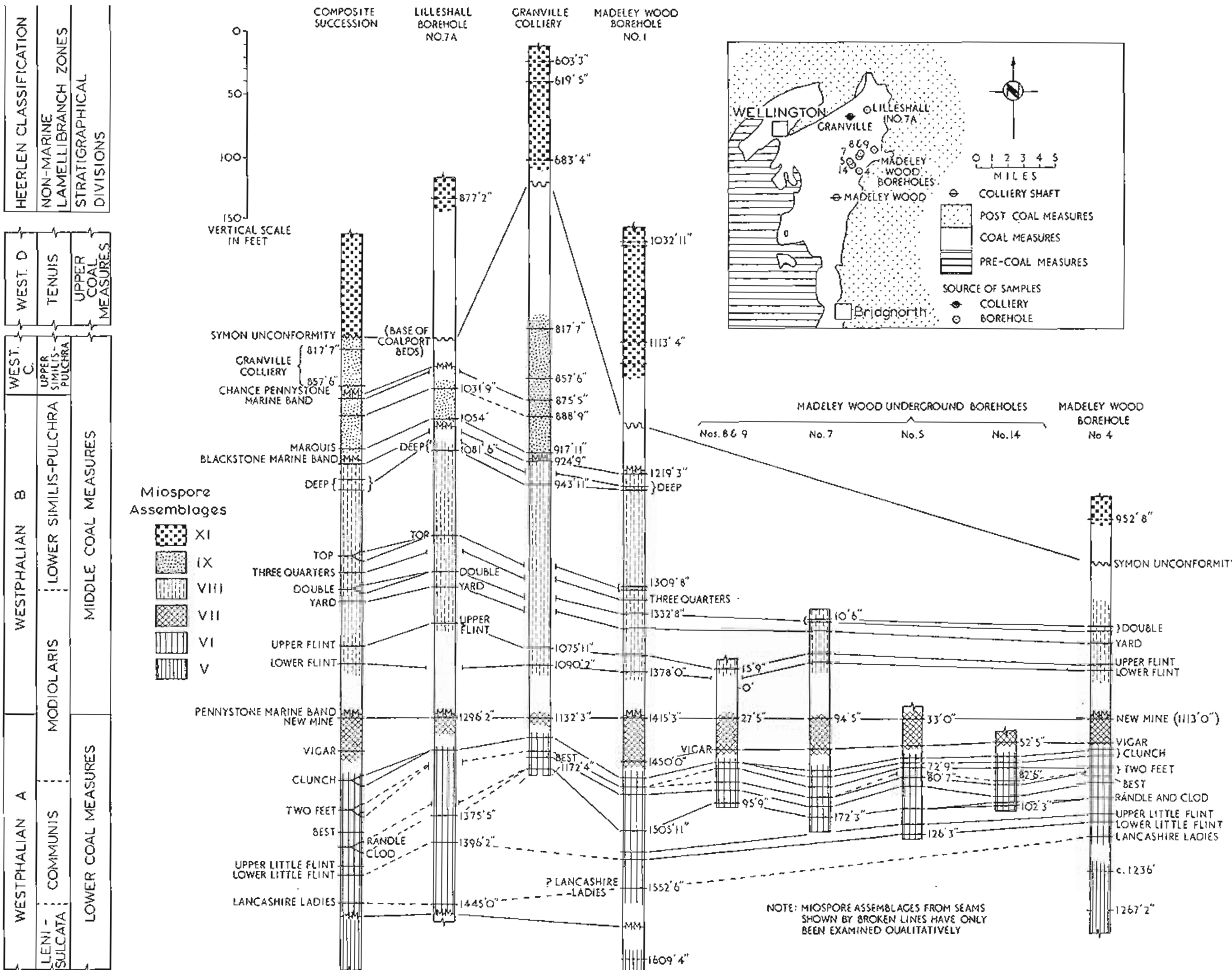
TEXT-FIG. 36. Frequencies of selected miospore species in certain seams of the North Staffordshire Coalfields.



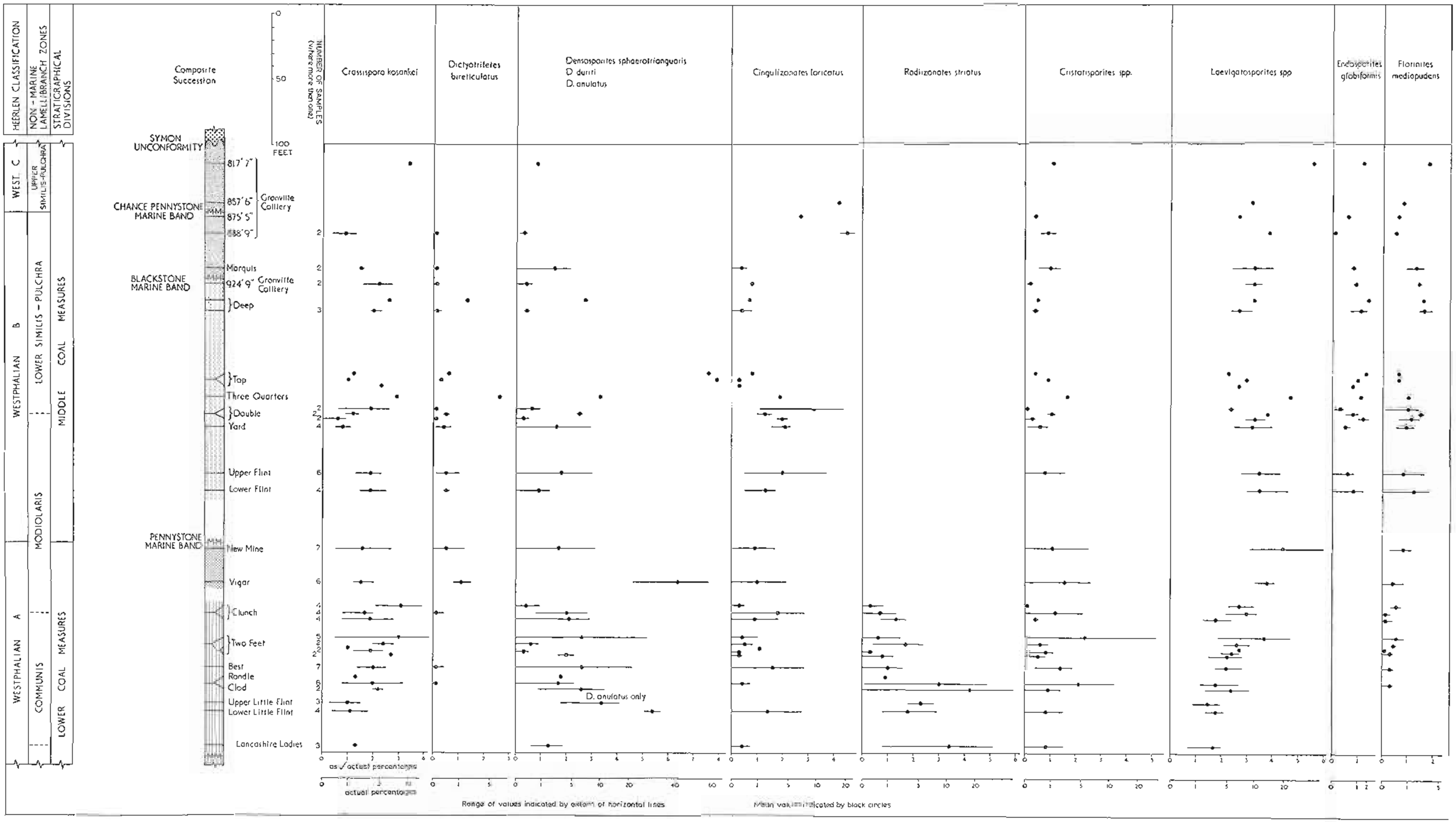
TEXT-FIG. 37. Locations of samples and sequences of seams examined from the South Staffordshire Coalfields.



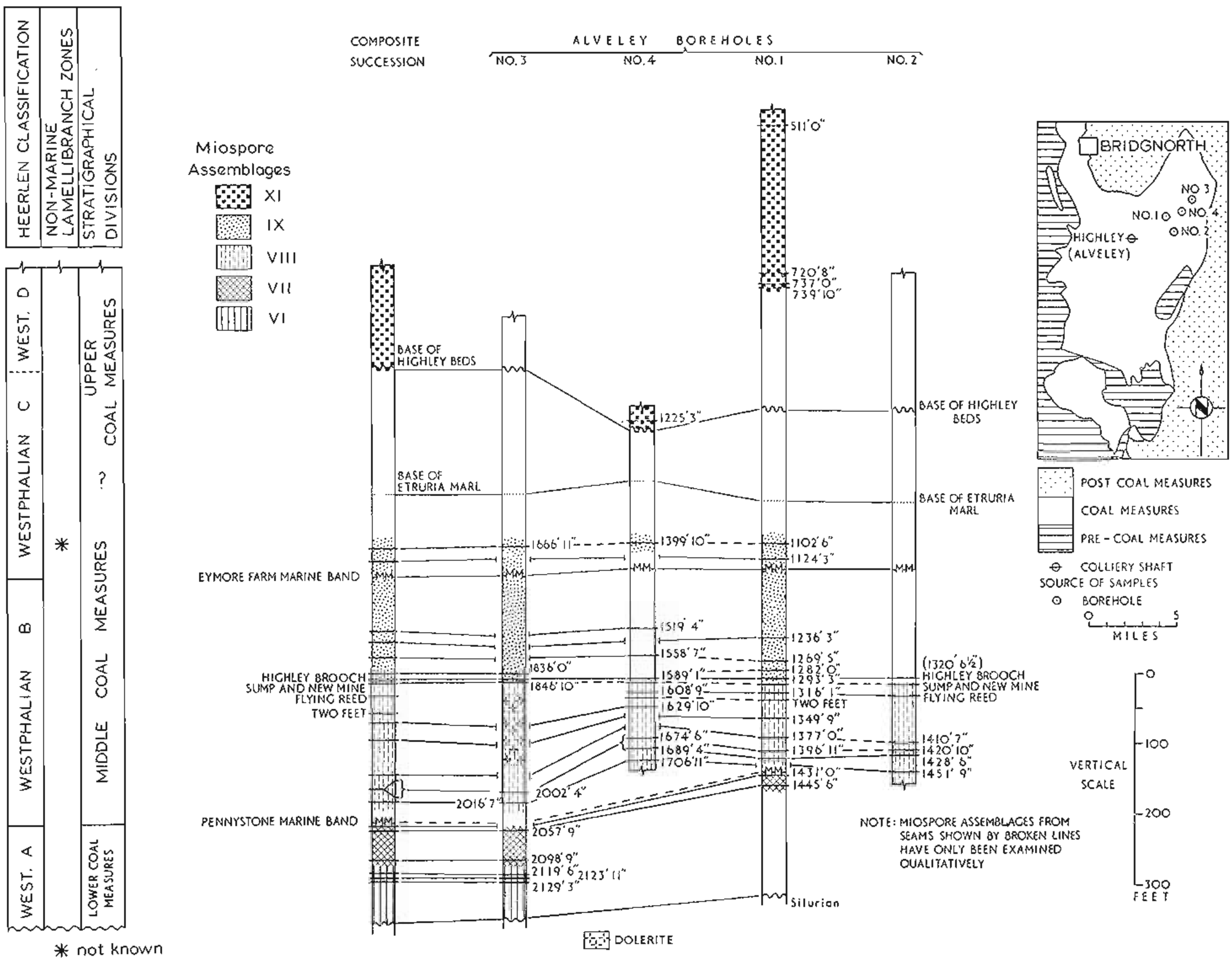
TEXT-FIG. 38. Frequencies of selected miospore species in certain seams of the South Staffordshire Coalfields.



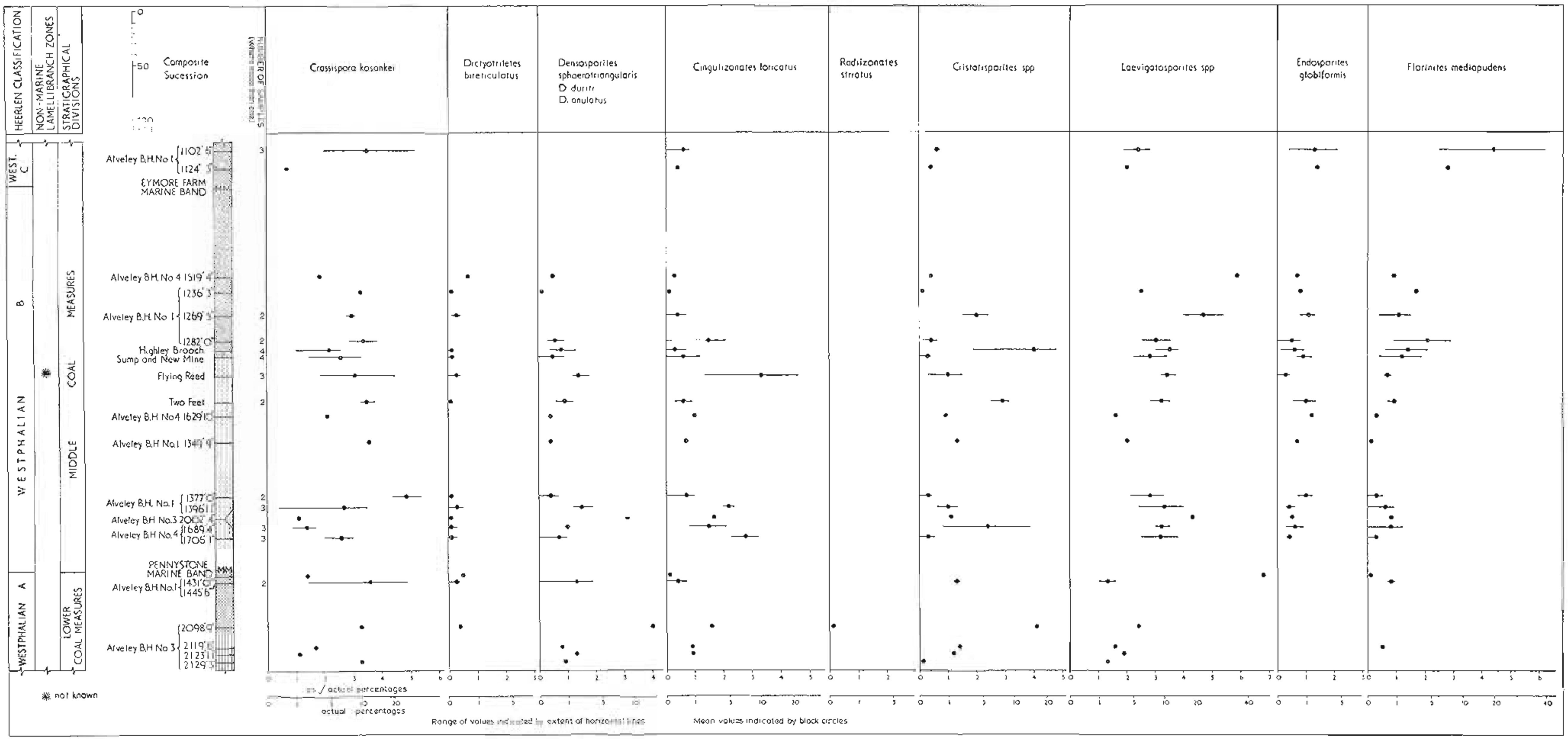
TEXT-FIG. 39. Locations of samples and sequences of seams examined from the Coalbrookdale Coalfield.



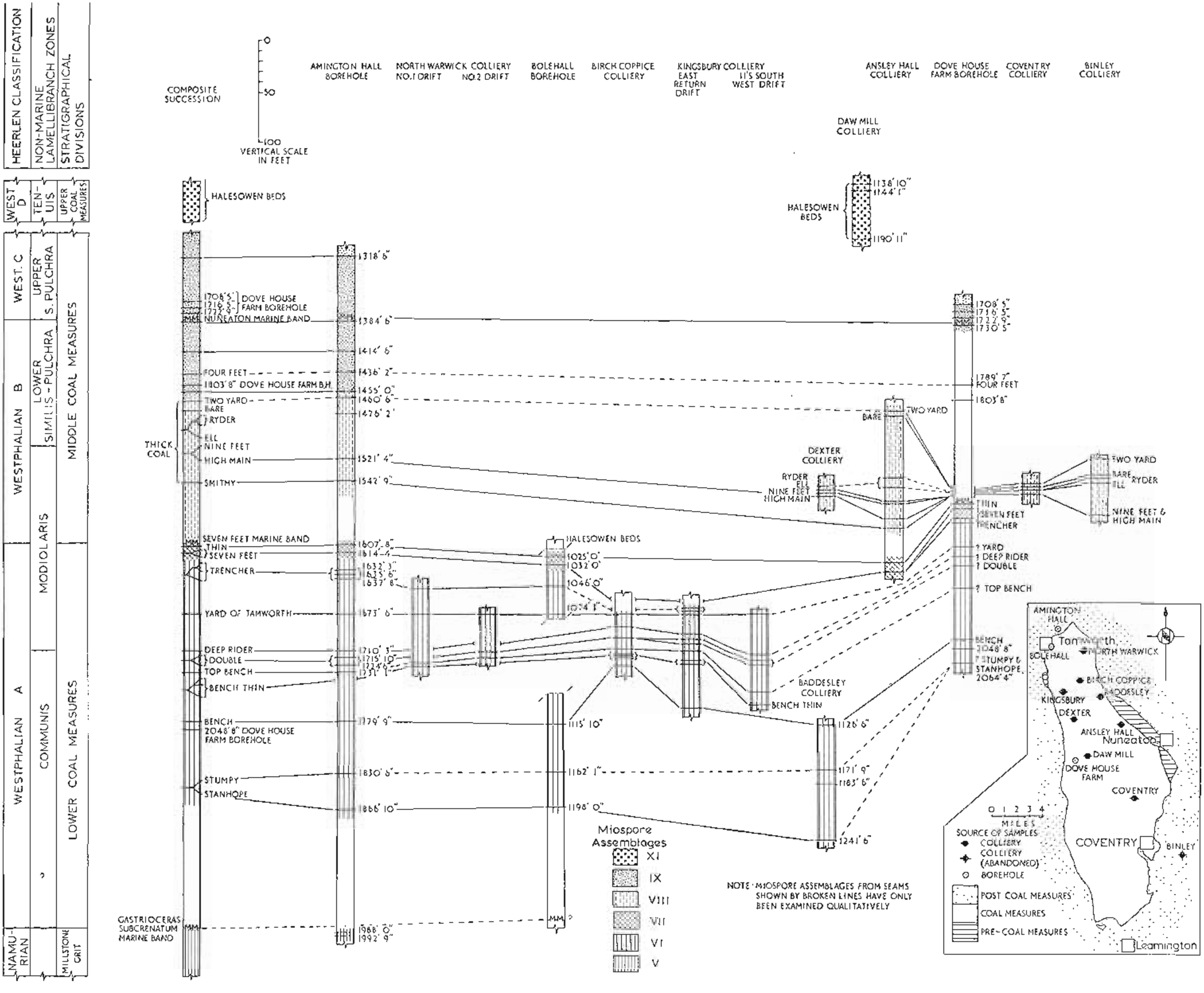
TEXT-FIG. 40. Frequencies of selected miospore species in certain seams of the Coalbrookdale Coalfield.



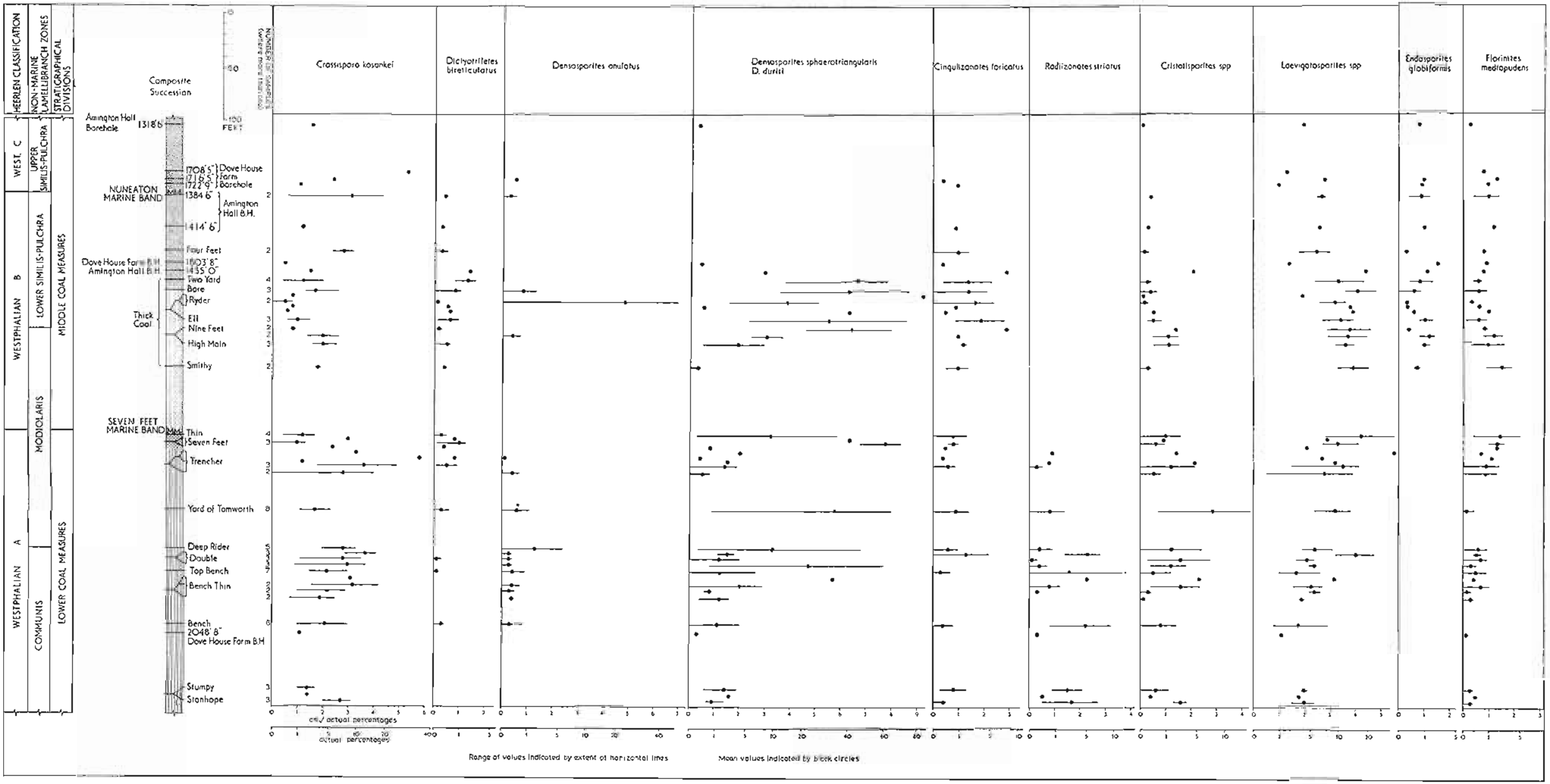
TEXT-FIG. 41. Locations of samples and sequences of seams examined from the Forest of Wyre Coalfield.



TEXT-FIG. 42. Frequencies of selected miospore species in certain seams of the Forest of Wyre Coalfield.



TEXT-FIG. 43. Locations of samples and sequences of seams examined from the Warwickshire Coalfield.



TEXT-FIG. 44. Frequencies of selected miospore species in certain seams of the Warwickshire Coalfield.

and *C. solaris* are all present in most of the seams examined but none of them is ever common. *Dictyotriletes bireticulatus* is sometimes common up to the horizon of the Longton Hall Marine Band and has not been found above the Rowhurst Seam. *Microreticulatisporites sulcatus* is occasionally present above the horizon of the Gin Mine Marine Band. *Florinites mediapudens* increases in frequency towards the top of the Assemblage.

Torispora securis Assemblage X (Winghay Seam to seam at 1,491 ft. 9 in., Bowsey Wood borehole).

The lower part of the Upper Coal Measures (Westphalian C) is thicker in North Staffordshire than elsewhere in the coalfields of central England and coal seams are present throughout. The samples of the group of seams associated with the Bay Marine Band towards the base were obtained from all four of the boreholes examined; those in the overlying Great Row Measures and those in the lower part of the Blackband Group were obtained from the Pie Rough borehole; the seams in the upper part of the Blackband Group were from the Bowsey Wood borehole.

All of these coals contain a *Torispora securis* Assemblage with significant numbers of *Triquitrites sculptilis*, *Endosporites globiformis*, and *Florinites mediapudens*; the last-named spore may be abundant towards the base, particularly in the Winghay Seam. In common with *Crassispora kosankei* it tends to decrease in numbers towards the top. *E. globiformis* is occasionally abundant in the upper part of the Blackband Group. *Densosporites spp.* and *Cingulizonates loricatus* are very rare throughout and *Cristatisporites spp.* become very rare above the Winghay; there is no development of *Cristatisporites solaris* in the Blackband Group to correspond with that occurring in the Bradford Group of Lancashire. *Vestispora fenestrata* and *T. securis* occur in the Winghay but are not invariably present; they are both rare throughout the sequences examined. *V. magna* does not occur above the Chalkey and associated seams.

Thymospora obscura Assemblage XI (seams of the Etruria Marl to Keele Group).

For the purposes of the present investigations three seams were examined from the Etruria Marl, that at 729 ft. 3 in. in the Pie Rough borehole, that at 998 ft. 0 in. in the Hungerford borehole, and an outcrop sample from Downing's Marl Pit, Chesterton. In the Newcastle Group seams were examined from the Bowsey Wood borehole and in the Keele Group one seam from the outcrop at Moddershall. The stratigraphical position of the Etruria Marl is uncertain because of the paucity within it of organic remains.

All of the species characterizing the *Thymospora obscura* Assemblage are present in one or more of the coals examined from the Etruria Marl. The seams in the Pie Rough and Hungerford boreholes contain an abundance of *Endosporites globiformis*. The three coals in the Newcastle Group in the Bowsey Wood borehole contain very few of these species and there is little to distinguish them from the coals of the Blackband Group below. In this respect, therefore, they differ from the coals in the equivalent Halesowen and Coalport Beds of South Staffordshire and Shropshire, in which the characteristic species of the assemblage are fairly common. The seam from the Keele Group contains a typical assemblage with *Cadiospora magna*, *Schopfites dimorphus*, *Thymospora spp.*, and *Mooreisporites inusitatus*. In all of the coals examined from this part of the sequence in North Staffordshire *Crassispora kosankei* is very rare and *Florinites mediapudens* is virtually absent.

The South Staffordshire Coalfields

The Coal Measures are continuous over the whole region but are regarded as occurring in two separate coalfields—the Cannock Chase field in the north and the South Staffordshire field in the south.

Workable coals occur in the higher part of the Lower Coal Measures, the Middle Coal Measures, and the lower part of the Upper Coal Measures. The thin coals present in the Halesowen Group which, with the overlying Keele and Enville Groups, occur higher in the Upper Coal Measures are of no economic importance.

Balme and Butterworth (1952) examined the miospore floras of seams lying between the Shallow and Bottom Robins horizons in the Cannock Chase Coalfield and showed that the vertical ranges of the spores corresponded with those found in the fuller sequences examined in other coalfields of the Central Province. Butterworth and Millott (1955) and Butterworth (1956) extended these investigations by the examination of seam samples from boreholes situated in the northern and north-eastern extensions of the Cannock Chase Coalfield. The coals examined were from all horizons between the upper part of the Lower and the Upper Coal Measures.

In the present investigations the earlier results were revised and six further boreholes examined in the northern extension of the Cannock Chase Coalfield and two boreholes in the main part of the field. In the South Staffordshire Coalfield the investigations were confined to a single sequence from the Baggeridge Nos. 1 and 5 boreholes.

The locations of the sampling localities and details of the sequences examined are given in text-fig. 37. Text-fig. 38 shows the frequencies of occurrence of selected species of nine genera of miospores present in the coalfields.

An account of the north-eastern part of the coalfield was given by Stevenson and Mitchell (1955), who included a description of the Hawkesyard borehole. In their account of the Lea Hall Colliery area, Hoare and Mitchell (1955) described the Hawkesyard, Springs Farm, Brereton Cross, and Hayes Wood No. 2 boreholes sequences.

Radiizonates aligerens Assemblage VI (Mealy Grey Seam to Bass Seam).

The lowest coal examined, the Mealy Grey Seam, contains *Densosporites sphaerotriangularis*, *Radiizonates aligerens*, and *Laevigatosporites spp.*, indicating an horizon within Assemblage VI. *D. anulatus* was not recorded separately from *D. sphaerotriangularis* in some of the sequences examined and the two species are included in a single column for the seams below the horizon of the Bottom Robins in the spore frequency chart (text-fig. 38). In the boreholes for which separate records are available *D. anulatus* is the more abundant of the two species in the Deep and lower seams. *R. striatus* is common, or abundant, in the Deep, except in the Calf Heath borehole, where *Cristatisporites connexus* is abundant and *R. striatus* is rare. *R. aligerens* becomes common in the succeeding Shallow and New Mine (Cinder) Seams and *D. sphaerotriangularis* may be locally abundant; *Laevigatosporites spp.* show an increase in frequency in these seams.

Schulzospora rara Assemblage VII (Yard Seam and Stinking Seams).

Radiizonates aligerens is not present in the seams above the Bass, whereas *S. rara* is almost invariably present in the succeeding Yard, or New Mine, and Stinking Seams.

Densosporites sphaerotriangularis is generally common, or abundant, in the Yard and locally abundant in the Stinking Seams. *Dictyotriletes bireticulatus*, *Vestispora spp.*, and *Florinites mediapudens* are generally present and *Cristatisporites connexus* is occasionally common at these horizons.

Dictyotriletes bireticulatus Assemblage VIII (seam at 2,770 ft. 9 in., Hopton Pool borehole to seam at 2,365 ft. 5 in., Sandon Bank borehole).

Although varying considerably in frequency, *Densosporites sphaerotriangularis* is locally abundant at some of the lower horizons, particularly in the Park and Eight Feet Seams, which combine in the southern part of the field to form the Thick Seam of Staffordshire (e.g. in the Baggeridge No. 5 borehole). *Endosporites globiformis* first appears in the seam immediately above the Stinking Marine Band. *Cristatisporites spp.*, *Radiizonates* cf. *striatus*, and *Dictyotriletes bireticulatus* are also present in the lower seams, but never very common. *Crassispora kosankei* is common, or abundant, in the Heathen Seams, but considerably less common in the succeeding Park and Eight Feet Seams; it increases in frequency in the seam below the Benches, reaches a maximum in the unnamed seams above the Benches, and decreases fairly sharply above the Sub-Brooch Marine Band. *Cingulizonates loricatus* is less prominent than at similar horizons in other fields, but may be common in the Benches Seam.

Vestispora magna Assemblage IX (Brooch Seam to seam at 2,274 ft. 9 in., Springslade Pool borehole).

The characteristic species are rare in the seams between the Sub-Brooch Marine Band, at the base of the Assemblage, and the Charles Marine Band. *Triquitrites sculptilis*, *Cristatisporites solaris*, and *V. magna* are occasionally present in the Brooch but in the Hopton Pool and Plantation boreholes none of the characteristic species has been found in this seam. It is often possible, however, to identify the Brooch by the frequency of *C. indignabundus*, which ranges up to 7%. In the Devil's Dumble borehole this seam also contains an abundance of *Densosporites sphaerotriangularis*. Above the Charles Marine Band the characteristic species are almost invariably present; *C. solaris* and *T. sculptilis* may be common in the Wyrley Yard and Top Robins Seams respectively. The Wyrley Yard also contains high numbers of *Cingulizonates loricatus* and *Radiizonates faunus* and is the highest horizon in this coalfield at which *Dictyotriletes bireticulatus* has been recorded.

Torispora securis Assemblage X (seam at 2,267 ft. 7 in. to seam at 2,050 ft. 0 in., Springslade Pool borehole).

The seams above the Silvester's Bridge Marine Band are very variable in thickness and extent and are consequently difficult to correlate. The highest recorded marine band in the coalfield, that occurring above the seam at 1,185 ft. 1 in. in the Devil's Dumble borehole, has not been found elsewhere.

In the compilation of the composite succession, the fullest sequence available above the Top Robins Seam, i.e. that from Springslade Pool borehole, has been used as a basis. In the calculation of the spore frequencies the data from the seams in this borehole have been supplemented by some from the Heath Hayes, Wimblebury Cannel, and an unnamed seam at 1,216 ft. 6 in. (Devil's Dumble borehole) and 1,635 ft. 9 in. (Darkslade borehole); these are the only seams which have been correlated with those of the Springslade Pool borehole.

T. securis and *Vestispora fenestrata* both first occur in the seam immediately above the Silvester's Bridge Marine Band, but either, or both, of these species may be absent from the lowest two or three seams. *Endosporites globiformis*, *Florinites mediapudens*, and *Microreticulatisporites sulcatus* all tend to be more common at these than at lower horizons, *F. mediapudens* being most frequent in the third seam above the Silvester's Bridge Marine Band; it is thought that this seam, from its position and spore content, may be correlative with the North Staffordshire Winghay Seam. Species of *Densosporites*, *Cingulizonates*, and *Cristatisporites* are all rare and *Laevigatosporites spp.* and *Triquitrites spp.* are relatively more common than at lower horizons.

Thymospora obscura Assemblage XI (seams of the Halesowen Beds).

Coals from the Halesowen Beds were obtained from the Orchard Farm, Baggeridge No. 1, and Shareshill boreholes. Each of the coals examined contained several of the species characteristic of the *T. obscura* Assemblage, *Cadiospora magna*, *T. pseudothiessenii*, and *Punctatosporites oculus* being the most commonly occurring. *Vestispora magna* and *Torispora spp.* have not been found in any of the coals; *Crassispora kosankei* and *Florinites mediapudens* are rare and sometimes absent.

The Shropshire Coalfields

The coalfields included in this small group are those of Shrewsbury, Coalbrookdale, and the Forest of Wyre. The investigations have been confined to Coalbrookdale and the Forest of Wyre as mining has ceased in the Shrewsbury field.

In Coalbrookdale workable coals occur in both the Lower and Middle Coal Measures but in the Forest of Wyre mainly in the Middle Coal Measures. In the former field an unconformity ('Symon Fault') brings reddened strata consisting of Coalport Beds at the base, succeeded by Keele and then Enville Beds, directly on to the upper part of the Middle Coal Measures. The Upper Coal Measures in the Forest of Wyre consist of reddened strata of Etruria Marl facies succeeded by the Highley Beds and then the Keele and the Enville Beds. The Highley Beds are the lateral equivalent of the Coalport Beds and both contain seams which have been worked to a limited extent.

Previous investigations of the miospore floras of the seams of the coalfields were made by Butterworth (1956), who examined sequences from two boreholes (Lilleshall and Madeley Wood) in Coalbrookdale and one from Highley (Alveley) Colliery, the only colliery now working in the Forest of Wyre. She showed that all of the Coal Measures miospore Assemblages were represented, except that occurring in the Phillipsii Zone (this Zone has been removed by the Symon unconformity).

In the present work miospore examinations were made on seams from all available horizons in the Coal Measures. In Coalbrookdale the samples were from the Granville Colliery Shaft, the Lilleshall No. 7A borehole, and from seven boreholes associated with Madeley Wood Colliery. The four sequences examined from the Forest of Wyre field were from the Alveley boreholes. Some of the seams in the lower part of the Middle Coal Measures in the Alveley No. 3 borehole are replaced by dolerite.

The locations of the sampling localities and details of the sequences examined are given in text-figs. 39 and 41. Text-figs. 40 and 42 show the frequencies of occurrence of selected species of nine genera of miospores present in the coalfields.

Densosporites anulatus Assemblage V (seams below the Lancashire Ladies Seam, Coalbrookdale).

A seam at 1,609 ft. 4 in. in the Madeley Wood No. 1 borehole and seams at about 1,236 ft. and 1,267 ft. 2 in. in the Madeley Wood No. 4 borehole (not shown in text-fig. 40) contain miospore floras typical of this Assemblage. *D. anulatus* and *Radiizonates striatus* both attain high frequencies in these coals. *Laevigatosporites spp*. and *Florinites mediapudens* are absent from all three seams and *Crassispora kosankei* is rare. Unusual occurrences are the presence of *Dictyotriletes bireticulatus* in the seam in the No. 1 borehole and of *Pityosporites westphalensis* in the higher of the two seams in the No. 4 borehole.

Radiizonates aligerens Assemblage VI (Lancashire Ladies Seam to Clunch Seam, Coalbrookdale; seam at 2,129 ft. 3 in. to seam at 2,119 ft. 6 in., Alveley No. 3 borehole, Forest of Wyre).

In Coalbrookdale, *Laevigatosporites spp*. appear first in the Lancashire Ladies Seam and *R. aligerens* and *Florinites mediapudens* in the Upper Little Flint and the combined Randle and Clod Seams respectively; both species are relatively infrequent throughout the Assemblage, although the former may be occasionally common in the Two Feet Seam. *Densosporites anulatus* may be abundant in the Little Flint Seam and common in the Two Feet Seam. *R. striatus* is generally abundant in the Randle and Clod and Lancashire Ladies Seams and sometimes common in the Little Flint. *Cristatisporites connexus* is locally abundant in the Upper Two Feet, Best, and Randle and Clod Seams. It is also common in the Clunch Seam. There is an increase in the frequency of *Laevigatosporites spp*. in the upper part of the Two Feet.

In the Forest of Wyre Coalfield *R. aligerens* has not been recorded in any of the seams occurring below the Pennystone Marine Band, none of which measures more than a few inches in thickness. *Laevigatosporites spp*. occur in all of the seams and *Savitrisporites spp*., including *S. nux*, are abundant in several of them. *Schulzospora rara* has not been seen.

Schulzospora rara Assemblage VII (Vigar and New Mine Seams, Coalbrookdale; seam at 2,098 ft. 9 in., Alveley No. 3 borehole and seams at 1,445 ft. 6 in. and 1,431 ft. 0 in., Alveley No. 1 borehole, Forest of Wyre).

In Coalbrookdale *Radiizonates aligerens* is not found above the Clunch Seam. *Densosporites sphaerotriangularis* is abundant in the Vigar Seam, and *Cristatisporites connexus* is occasionally common, and *Dictyotriletes bireticulatus* frequent, in this seam and in the overlying New Mine. *Vestispora tortuosa*, *Alatisporites pustulatus*, and *Pityosporites westphalensis* occur in most of the seams examined. *S. rara* is not found above the horizon of the New Mine.

The presence of *D. bireticulatus* and the abundance of *C. connexus* in the seam at 2,098 ft. 9 in. in the Alveley No. 3 borehole, Forest of Wyre, suggest that this and the two higher seams should be included with those having this Assemblage.

Dictyotriletes bireticulatus Assemblage VIII (Lower Flint Seam to seam at 924 ft. 9 in., Granville Colliery, Coalbrookdale; seam at 1,706 ft. 1 in., Alveley No. 4 borehole to Sump and New Mine Seams, Forest of Wyre).

Endosporites globiformis first appears in the Lower Flint Seam of Coalbrookdale and in the unnamed group of seams lying above the Pennystone Marine Band in the Forest of Wyre; *Densosporites sphaerotriangularis*, *Cingulizonates loricatus*, *Radiizonates* cf. *striatus*, and *Cristatisporites connexus* are locally common in the latter group of seams and the first two species are generally common in the Upper Flint, Yard, and Double Seams of Coalbrookdale. *D. sphaerotriangularis* is abundant in the Top Seam of Coalbrookdale. Among the higher seams, the Two Feet of Forest of Wyre is characterized by high numbers of *C. connexus* and the overlying Flying Reed by abundant *Cingulizonates loricatus*. *Crassispora kosankei* is occasionally abundant in the Two Feet and higher seams. These characteristic high frequencies (except for that for *C. kosankei*) are not found in the equivalent seams in Coalbrookdale.

Vestispora magna Assemblage IX (Marquis Seam to seam at 817 ft. 7 in., Granville Colliery Shaft, Coalbrookdale; Highley Brooch Seam to seam at 1,102 ft. 6 in., Alveley No. 1 borehole, Forest of Wyre).

In Coalbrookdale *Cristatisporites solaris* and *V. magna* first appear in the Marquis Seam and *Triquitrites sculptilis* in the seam at 875 ft. 5 in. in the Granville Colliery Shaft. In the Forest of Wyre *C. solaris* first appears in the Highley Brooch Seam and *V. magna* and *T. sculptilis* in the seam above. None of these species is found in the samples of the Highley Brooch from Alveley Nos. 2 and 3 boreholes, although they do contain the abundance of *C. indignabundus* typical of this horizon. *T. sculptilis* and *V. magna* are common in seams from above the Eymore Farm Marine Band; these seams are also occasionally characterized by an abundance of *Florinites mediapudens*. *Cingulizonates loricatus* is abundant in the two seams below, and the one seam above, the Chance Pennystone Marine Band of Coalbrookdale. *Dictyotriletes bireticulatus* is not found above this, or the equivalent Eymore Farm Marine Band, in the Forest of Wyre.

Thymospora obscura Assemblage XI (seams from the Coalport Beds, Coalbrookdale and the Highley Beds, Forest of Wyre).

Schopfites dimorphus, *Triquitrites spinosus*, *Cadiospora magna*, *Thymospora spp.*, and *Punctatosporites oculus* have all been recorded from most of the samples examined; *Thymospora spp.* occasionally occur in abundance. *C. magna* and *Mooreisporites inusitatus* are less consistently present. *Endosporites globiformis* is occasionally numerous in the Highley Beds. *Crassispora kosankei* and *Florinites mediapudens* are rare, or absent, in both fields.

The Warwickshire Coalfield

Coal seams occur in the higher part of the Millstone Grit Series and throughout the Coal Measures, but only those in the Lower and Middle Coal Measures are of economic importance. The Upper Coal Measures are represented in the Etruria Marl, Halesowen, Keele, and Enville Beds; the Halesowen Beds contain occasional thin coals. In the absence of the characteristic marine band, the base of the Upper Coal Measures is generally taken at the base of the Etruria Marl.

Paget (1936, 1937) examined samples of all the coals worked in the field and compared their miospore assemblages at various localities. Butterworth (1956) examined seams from the Amington Hall and Bolehall boreholes and from Baddesley, Coventry, and Dexter Collieries, the sequence investigated extending from the top of the Millstone Grit Series to the upper part of the Middle Coal Measures. Comparable miospore floras were found to those present in the South Staffordshire and certain other coalfields in the Central Province.

In the present investigations coals were examined from the top of the Millstone Grit Series to the Halesowen Beds. Most of the samples were from the northern part of the field and were mainly obtained from the Amington Hall, Bolehall, and Dove House Farm boreholes, augmented by some from drifts and shafts at nine collieries.

The locations of the sampling points and details of the sections examined are given in text-fig. 43. Text-fig. 44 shows the frequencies of occurrence of selected species of nine genera of miospores present in the Coal Measures of the coalfield.

Densosporites anulatus Assemblage V (seams below *Gastrioceras subcrenatum* Marine Band).

The lowest seams examined occurred just below the presumed horizon of the *G. subcrenatum* Marine Band in the Amington Hall borehole. They contained numerous *D. anulatus* and significant numbers of *Radiizonates striatus* and *Cristatisporites spp.*; *Savitrisporites* and *Ahrensisporites* were present, but rare.

Radiizonates aligerens Assemblage VI (Stanhope Seam to Trencher Seams).

Densosporites sphaerotriangularis, *R. aligerens*, *Laevigatosporites spp.*, and *Florinites antiquus* first appear in the Stanhope, the lowest seam examined above the horizon of the *Gastrioceras subcrenatum* Marine Band. *R. striatus* is occasionally common in the Stanhope and Double Seams and is generally common, and sometimes abundant, in the Bench group of seams. *R. aligerens* is most prominent in the Double and Deep Rider Seams. Parts of the Bench Thin, the lower bed of the Double, the Deep Rider, and the Yard of Tamworth contain an abundance of *D. sphaerotriangularis*, and *Cristatisporites connexus* may be common. These species are also common in the succeeding Trencher Seams.

Schulzospora rara Assemblage VII (Seven Feet Seam and Thin Seam).

Radiizonates aligerens does not occur above the Trencher group of seams but *S. rara* persists up to the horizon of the Seven Feet Marine Band. *Densosporites sphaerotriangularis* is abundant in the upper bed of the Seven Feet Seam and locally abundant in the overlying Thin Seam; *Cristatisporites connexus* and *Dictyotriletes bireticulatus* are occasionally common in both of these seams, but are not so prominent as at equivalent horizons elsewhere. *Vestispora tortuosa* and *Florinites mediapudens* are more commonly present than in lower seams.

Dictyotriletes bireticulatus Assemblage VIII (Smithy Seam to Two Yard Seam).

Endosporites globiformis first appears in the Smithy Seam. *Cingulizonates loricatus* and *Cristatisporites spp.* are locally common in most of the seams and *Densosporites sphaerotriangularis* is generally abundant in the Nine Feet and succeeding seams.

The miospore floras in this part of the sequence are complicated by the existence in the southern part of the field of the Thick Coal, which is a combination of the Smithy, High Main, Nine Feet, Ell, Ryder, Bare, and Two Yard Seams; it also includes the Thin Rider Seam from slightly higher in the succession (Mitchell and Stubblefield 1942), but this seam has not been identified in any of the sequences examined. The constituent seams of the Thick Coal mostly contain abundant *D. sphaerotriangularis*, which often represents over 50% of the total miospore frequency; *Crassispora kosankei* is consequently unusually infrequent in the seams above the Nine Feet. *Cingulizonates loricatus* is generally common (and locally very common) throughout. *Dictyotriletes bireticulatus* is sometimes common in the Two Yard, the highest constituent seam of the Thick Coal.

Vestispora magna Assemblage IX (seam at 1,455 ft. 0 in. to seam at 1,318 ft. 6 in., Amington Hall borehole).

Cristatisporites solaris has been found in the seam at 1,455 ft. 0 in. in the Amington Hall borehole and *V. magna* is present in the overlying Four Feet; these spores have not been found in the corresponding seams in the Dove House Farm borehole. The equivalent of the Two Foot Marine Band of Yorkshire, near to which the lower limit of the Assemblage generally occurs, has not yet been found in Warwickshire. *Triquitrites sculptilis*, *C. solaris*, and *V. magna* are rare throughout the Assemblage, although the last-named species is present in all of the seams examined from above the Nuneaton Marine Band.

Thymospora obscura Assemblage XI (seams of the Halesowen Beds).

Strata bearing seams generally characterized by the *Torispora securis* Assemblage are represented in Warwickshire by barren rocks of the Etruria Marl facies. The three coals examined from the Halesowen Beds at Daw Mill Colliery contain typical *Thymospora obscura* Assemblages although *Cadiospora magna* and *T. pseudothiessenii* have not been recorded. *Endosporites globiformis* and *Vestispora fenestrata* are present in large numbers in the two higher seams; *Florinites mediapudens* is rare throughout.

The Leicestershire and South Derbyshire Coalfield

This small mining region includes the Leicestershire Coalfield in the east, and the South Derbyshire field in the west.

In Leicestershire, coal seams are confined to the Lower Coal Measures and the lower part of the Middle Coal Measures, the remainder of the Coal Measures having being denuded prior to the deposition of the New Red Sandstone. In South Derbyshire, while the important seams are confined to the same parts of the Coal Measures as in Leicestershire, thin seams are also present in the upper parts of the Middle Coal Measures. Higher horizons in the Coal Measures are represented by reddened beds of Etruria Marl facies, and possibly also by strata equivalent to the Halesowen and Keele Beds elsewhere.

A preliminary account of the miospore floras in the seams of the South Derbyshire field, based on the Acresford borehole, was given by Balme and Butterworth (1952). The seams examined occurred in the Lower and Middle Coal Measures.

The present investigations were made on two sequences, one from South Derbyshire and one from Leicestershire. In the former, the samples were from the Caldwell Ashley House borehole, and in the latter from short sequences in the Coalfield Farm, Lindridge Hall Farm, and Snibston Barn boreholes, supplemented by some taken in the workings at Whitwick and Bagworth Collieries. The seams in both coalfields are confined to the Lower Coal Measures and lower part of the Middle Coal Measures.

The locations of the sampling points and details of the sections examined are given in text-fig. 45. Text-fig. 46 shows the frequencies of occurrence of selected species of nine genera of miospores in the coalfield.

Radiizonates aligerens Assemblage VI (Kilburn Seam to Slate Seam, South Derbyshire; Kilburn Seam to Upper Lount Seam, Leicestershire).

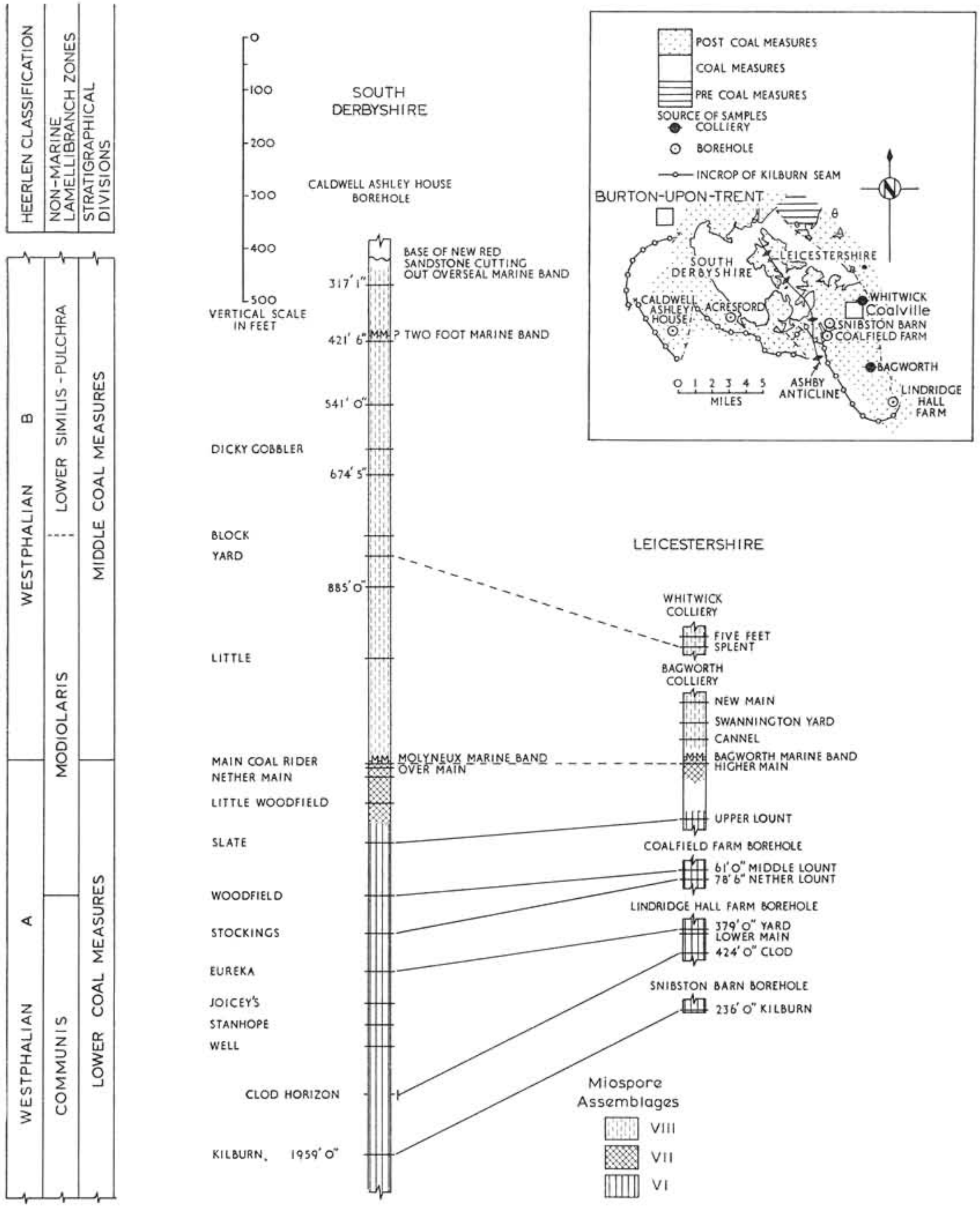
The presence of *Laevigatosporites spp.*, *Densosporites sphaerotriangularis*, and *Florinites mediapudens* in the Kilburn Seam indicates that the lowest seam examined from this coalfield belongs to this Assemblage. The numbers of *D. anulatus* and *R. striatus* in this coal and in the Clod suggest a position towards the base. *R. striatus* is common in seams up to, and including, the Lower Main of Leicestershire; its occurrence is therefore comparable with that in other coalfields. *D. sphaerotriangularis* occurs throughout the Assemblage and is abundant in the Stanhope and Stockings Seams of South Derbyshire and in the Nether, Middle, and Upper Lount Seams of Leicestershire. *Cristatisporites indignabundus* is frequent in the Leicestershire Kilburn Seam but infrequent elsewhere in this Assemblage. *R. aligerens* has not been recorded with certainty from seams below the Eureka of South Derbyshire, or its correlative in Leicestershire, the Yard. It is present in all of the succeeding seams up to, and including, the Slate (Upper Lount of Leicestershire). These seams therefore mark the upper limit of the Assemblage.

Schulzospora rara Assemblage VII (Little Woodfield Seam to Main Coal Rider Seam, South Derbyshire; Higher Main Seam of Leicestershire).

Four seams in the Caldwell Ashley House borehole and the Higher Main of Leicestershire have been assigned to this Assemblage on the basis of the presence of *S. rara* and the absence of *Radiizonates aligerens*. The presence of *Dictyotriletes bireticulatus* is typical of the Assemblage and, except in the Little Woodfield and the Main Coal Rider Seams, this spore is frequent, or common.

Densosporites sphaerotriangularis Assemblage VIII (Little Seam to seam at 317 ft. 1 in., Caldwell Ashley House borehole, South Derbyshire; Cannel Seam to Five Feet Seam, Leicestershire).

Crassispora kosankei shows the usual gradual decline in numbers in seams above the Mid-Modiolaris Marine Band; it has not been recorded from the seam at 885 ft. 0 in. in the Caldwell Ashley House borehole. The increase in frequency is apparent in the Yard Seam of South Derbyshire (Splent of Leicestershire) and continues until maximum values are reached in the seam at 541 ft. 0 in. in the Caldwell Ashley House borehole. In Leicestershire there are no seams at a comparable horizon. In Leicestershire, as in the Yorkshire–Nottinghamshire and Lancashire Coalfields, the seam at the base of the Similis–Pulchra Zone, the Splent, is characterized by an abundance of *D. sphaerotriangularis*, although this spore is infrequent in the Yard Seam, which is considered to be its correlative in



TEXT-FIG. 45. Locations of samples and sequences of seams examined from the Leicestershire and South Derbyshire Coalfield

South Derbyshire. Below this horizon the species is also abundant in the Little Seam of South Derbyshire and the New Main Seam of Leicestershire, but it is absent, or only present in very small numbers, in the other seams in this part of the succession. Above the Splent the species is very common, or abundant, in the Five Feet of Leicestershire and the Block, Dicky Gobbler, and the seam at 317 ft. 1 in. in the Caldwell Ashley House borehole. The latter seam occurs above the Lingula Band, which may be the equivalent of the Two Foot Marine Band of the Yorkshire–Nottinghamshire Coalfield. *Cingulizonates loricatus* is generally frequent to common throughout the Assemblage. *Radiizonates* cf. *striatus* is frequent in the New Main and Five Feet Seams of Leicestershire and the Yard and Dicky Gobbler Seams of South Derbyshire; this species is more abundant than in seams at this horizon in the Yorkshire–Nottinghamshire Coalfield. On the other hand, *Cristatisporites indignabundus*, which is sometimes common in seams of this Assemblage in the Yorkshire–Nottinghamshire region, is infrequent in the Leicestershire and South Derbyshire Coalfield. The abundance of *Densosporites gracilis* in the Dicky Gobbler Seam is noteworthy.

Vestispora magna Assemblage IX.

There is no evidence that this Assemblage is represented in the Caldwell Ashley House borehole although it does occur in South Derbyshire according to Balme and Butterworth (1952), who found *Triquitrites sculptilis* to be a prominent member of the miospore flora in the one seam examined from above the Overseal Marine Band in the Acresford borehole.

The South Wales Coalfield

Coal seams occur in the upper part of the Millstone Grit Series and throughout the Coal Measures, those in the former formation having, however, little economic value. Whilst the most important coals occur in the Lower and Middle Coal Measures, valuable seams are also present in the Upper Coal Measures, in the Lower Pennant Series (upper part of the Westphalian C) and to a lesser extent in the Upper Pennant Series (Westphalian D). The higher part of the Upper Pennant Series, on macrofloral evidence, may be of Lower Stephanian Age.

The only published accounts of miospore distribution in the coalfield are a brief summary of a thesis by R. W. Williams included in a paper by Butterworth and Millott (1960, p. 159) and that of Sullivan (1962). Williams examined a sequence of seams in the Lower and Middle Coal Measures and lower part of the Lower Pennant Series encountered in the Nantgarw Colliery cross measures drivages. He also investigated samples of seams from various collieries and outcrops in the south-eastern part of the coalfield including some from seams higher in the succession than are represented at Nantgarw. These higher seams, which occur in the upper part of the Lower Pennant Series and in the Upper Pennant Series, were sampled at Graig Fawr, Hafodyrynys, and Tirpentwys Collieries and at the Tirpentwys opencast site. Sullivan examined the distribution of miospores through coals and shales collected at 45 horizons within the Coal Measures sequence exposed in the Wernddu Clay pit, situated near Caerphilly. He showed that the changes in the compositions of the miospore floras of the Coal Measures shales are related to those known to occur in the coals.

Because the rank of the coals in the western part of the South Wales Coalfield is high the present investigations were confined to the south and east of the coalfield, where the rank is at a minimum and satisfactory spore separations can be obtained. It is unfortunate that in these areas the sequence is reduced in thickness owing to the considerable unconformity occurring below the Mynyddislwyn Seam (Woodland, Evans, and Stephens 1957). In the course of the work most of the spore separations prepared by Williams have been re-examined, and in addition the miospore floras in the Garw Seam, and in seams up to the horizon of the Cwmgorse Marine Band in the Margam Nos. 3 and 4 boreholes, have been investigated to supplement the data available from the condensed sequence at Nantgarw Colliery. Difficulties occurred with the seams below the Amman Marine Band in the Margam boreholes, which gave poor separations when the normal methods of maceration were used. By substituting other methods and by carefully controlling the maceration process satisfactory separations were, however, obtained with these coals in the case of the No. 4 borehole.

The locations of the various sampling points and details of the sections examined are shown in text-fig. 47. Text-fig. 48 shows the frequencies of occurrence of selected species of nine genera of miospores in the Coal Measures of the coalfield.

Radiizonates aligerens Assemblage VI (Garw Seam to Lower Seven Feet Seam).

Laevigatosporites spp. and *Densosporites sphaerotriangularis* occur in the Garw Seam, the oldest coal examined in the coalfield, and indicate an horizon at, or above, the base of Assemblage VI. The upper limit of the Assemblage is taken at the level of the Lower Seven Feet Seam. *R. aligerens* is present in this seam at Margam No. 4 borehole. The seam was not available for examination at Llanharan Colliery, but the species occurs in the Top Cribbwr Seam below. It is also present in the No. 28 Seam at Nantgarw Colliery and in the Top Coal of the Old Coal Seam at Hafodyrynys Colliery. There are few records of *Schulzospora* from this Assemblage. *D. sphaerotriangularis* is abundant in most of the seams and is often the dominant spore of the miospore floras. *Laevigatosporites*, which occurs in small numbers in the Garw Seam, becomes more common towards the top of the Assemblage. *R. striatus* is present in all the seams except the Lower Seven Feet and is very common, to abundant, in the Gellideg Seam. This species is a constant component of the miospore floras of seams at, or just below, this horizon in other coalfields. At a slightly higher level in the sequence, that is in the top leaf of the Five Quarters Seam of Margam No. 4 borehole, spores of the *Cristatisporites connexus*, *Densosporites duriti* complex become common.

Schulzospora rara Assemblage VII (Upper Seven Feet Seam to Amman Rider Seam).

In other Provinces the seams of this Assemblage normally contain *S. rara*. In South Wales, however, the species has not been recorded in it and, as already noted, is scarce in the preceding Assemblage. The increase in the incidence of *Dictyotriletes bireticulatus* in the seams below the Mid-Modiolaris Marine Band, which is a widespread feature in other coalfields, is also evident in South Wales. In contrast to several other coalfields, however, *Densosporites sphaerotriangularis* is abundant and *Radiizonates striatus* is frequent in certain seams (the Meadow, Yard, and No. 27 of Nantgarw). The No. 27 Seam at Nantgarw is formed by the coalescence of several seams which occur in this Assemblage in the south and east of the coalfield. The only occurrence of

Vestispora tortuosa was in the Meadow Seam of Hafodyrynys Colliery; it has not been recorded from seams lower in the sequence.

Dictyotriletes bireticulatus Assemblage VIII (Bute Seam to seam at 1,051 ft. 6 in., Margam No. 4 borehole).

Endosporites globiformis is present as a frequent and constant member of the miospore floras in seams above the Mid-Modiolaris Marine Band in most coalfields and is used to define the base of the Assemblage. In South Wales it is present in the Bute Seam in the Margam No. 4 borehole. *Crassispora kosankei* declines steadily in numbers in the seams above this horizon to a minimum value in the leaves of the Red (Caerau) Seam in the Margam boreholes. The Red Seam does not occur at Nantgarw and Hafodyrynys Collieries, due to the thinning of the measures. At higher horizons in the Assemblage the species progressively increases in abundance, maximum numbers occurring in the Upper Four Feet Seam, above which the species declines in abundance. In seams up to and including the Red the numbers of *Densosporites sphaerotriangularis* are high and usually dominate the miospore floras in the individual seams with the result that they are relatively impoverished in species. Above this level the species is only abundant in the Six Feet and Two Feet Nine Seams and is never very common in the remaining seams, in which *Lycospora spp.* are the dominant spores. *Radiizonates* cf. *striatus* is generally common, or very common, in the lower part of the Assemblage; it is abundant in the upper bed of the Red Seam and frequent in the Six Feet Seam and in its constituent leaves, but has only been recorded at higher horizons from the Two Feet Nine Seam and the seam at 1,051 ft. 6 in. in the Margam No. 4 borehole. *Cristatisporites spp.* are rather variable in occurrence. *Cingulizonates loricatus* and *Densosporites anulatus* are both generally distributed and are sometimes common; the latter species is generally somewhat more abundant in the seams in the upper part of the Assemblage. *Radiizonates tenuis* occurs in small numbers in certain seams.

The spore evidence accords with the correlation shown for Nos. 18, 19, and 20 Seams at Nantgarw Colliery (text-fig. 47) and also with the absence of the Two Feet Nine Seam at this Colliery. An alternative correlation, not based on the spore evidence, is that Nos. 18 to 20 Seams at Nantgarw correlate with the Two Feet Nine, Upper Four Feet, and Lower Four Feet Seams respectively.

Vestispora magna Assemblage IX (Gorllwyn Seam to seam at 401 ft. 5 in., Margam No. 4 borehole).

The base of the Assemblage is difficult to define. Sullivan (1962, p. 360) records *Cristatisporites solaris* from the Grey Vein Seam below the Cefn Coed Marine Band but neither *Triquitrites sculptilis* nor *V. magna* have been recorded from below the marine band in the present investigations. Species diagnostic of the Assemblage occur in the seams of the Gorllwyn–Pentre Group lying above this marine band. *V. magna* is present in Seam No. 15 at Nantgarw. This spore, together with other diagnostic species such as *C. solaris* and *T. sculptilis*, is present in the Lower Pentre (the seam above the Gorllwyn) in both boreholes at Margam. These species are also present in the correlatives of the Pentre Group of seams, that is the Thick Seam of Llanharan Colliery and Nos. 12, 13, and 14 Seams at Nantgarw Colliery.

In general the miospore floras of the Assemblage are dominated by *Lycospora spp.*;

Laevigatosporites is common to abundant. *Crassispora kosankei*, which is not numerous in the Gorllwyn Seam, becomes so in the seams of the Pentre Group. *Densosporites sphaerotriangularis* is rare in the Assemblage but *Radiizonates faunus* is common in the Gorllwyn and Pentre Seams at Margam and abundant in the Thick Seam at Llanharan Colliery and Nos. 15 and 13 Seams at Nantgarw Colliery. *Endosporites globiformis* is more common in this, than in the preceding Assemblage.

In the Southern Province *Dictyotriletes bireticulatus* extends its range above the marine band at the boundary of the Similis–Pulchra and Phillipsii Zones. Thus in South Wales it has been recorded from No. 15 Seam at Nantgarw Colliery, the Thick Seam at Llanharan Colliery, and the Pentre Rider and Lower Pentre Seams in the Margam Nos. 3 and 4 boreholes respectively.

Torispora securis Assemblage X (seam at 366 ft. 10 in., Margam No. 4 borehole to Tillery Seam).

The Assemblage extends from seams occurring a short distance below the Lower Cwmgorse Marine Band to the Tillery Seam lying just below the Phillipsii/Tenuis or Westphalian C/D boundaries. The first record of a miospore diagnostic of the Assemblage is that of *Vestispora fenestrata*, which occurs below the marine band in the seam at 366 ft. 10 in. in the Margam No. 4 borehole. At Nantgarw Colliery no species diagnostic of the Assemblage were recorded in the present investigations from below No. 8 Seam, the first coal above the Upper Cwmgorse Marine Band, although Williams records *V. fenestrata* from Nos. 10 and 11 Seams. *Torispora* is abundant in No. 8 Seam; at higher horizons it is frequent, or common. Sullivan (1962, p. 361) records *Torispora* (under 0·01%) in the Bodwr Fawr Seam, immediately below the Upper Cwmgorse Marine Band. In the seams up to, and including, the Big Rock the more abundant genera present in the miospore floras are *Lycospora*, *Laevigatosporites*, and *Crassispora*. Above this horizon *Crassispora* seldom exceeds a frequency of 1% in any seam and *Laevigatosporites* is only common. *Lycospora spp.* are dominant. The miospore floras are characterized by varying numbers of small, monolete species of *Laevigatosporites* and *Latosporites*. *Cingulizonates loricatus* and *Densosporites anulatus* do not appear above the Abergorki Group of seams at the base of the Assemblage. *Florinites* cf. *florini* is common in the seam at 294 ft. 2 in. in the Margam No. 4 borehole and is frequent in the Rock Seam of Nine Mile Point Colliery, but is scarce, or absent, from other seams.

Miospores diagnostic of Assemblage X such as *Triquitrites sculptilis* and *Vestispora magna* occur in all seams in the Assemblage excepting the Tillery, but *Cristatisporites solaris* does not appear at higher horizons than No. 5 Seam at Nantgarw. *T. bransonii* is infrequent and has only been recorded from a few seams. The Tillery Seam at the top of the Assemblage contains several species which are absent from the miospore floras of seams lower in the South Wales sequence; they include *Microreticulatisporites sulcatus* and the small, thick-walled *Punctatosporites oculus*, together with *V. laevigata*.

Thymospora obscura Assemblage XI (Tillery Rider Seam to an undetermined horizon above the Mynyddislwyn Seam).

T. obscura, a diagnostic species of the Assemblage, is present in the Tillery Rider and Mynyddislwyn Seams. Further west in the coalfield a greater number of seams occur between the horizons represented by these two coals, but the rank of the coal prohibits investigation of the spores.

The miospore floras of the two seams are rich in species. *Lycospora* is the dominant spore with *Laevigatosporites* more abundant than in the seams in the previous Assemblage. *Florinites spp.* are abundant in the Tillery Rider Seam from the outcrop near the Hafodyrynys Colliery; about half the specimens are *F.* cf. *florini.* At Tirpentwys *Calamospora* species are very common and include numbers of *Calamospora* cf. *breviradiata.* Small, laevigate, monolete species are also common, to abundant, and *Triquitrites spp.* are prominent in the miospore floras. Among the less common spores, *Mooreisporites* and *Alatisporites trialatus* occur for the first time in the Tillery Rider Seam, but most of the species present are those which have already appeared in the preceding Assemblage. The occurrence of *Thymospora pseudothiessenii* in the Mynyddislwyn Seam is significant in view of its presence in the seams of the Radstock Group of the Somerset Coalfield. On the other hand, *Endosporites globiformis* and *Vestispora laevigata*, which are not recorded from this group in Somerset, are present. Certain species diagnostic of the Assemblage, and which occur in the Somerset and Forest of Dean Coalfields, have, however, not been recorded in South Wales up to the present.

The Bristol and Somerset Coalfields

The coalfields include a main field in the east and one or two subsidiary fields in the west.

Workable coals occur in the Lower, Middle, and Upper divisions of the Coal Measures. In the Lower and Middle Coal Measures (Westphalian A and B), seams are present in the Vobster Group and the lower part of the New Rock Group, and in the Upper Coal Measures (Westphalian C and D, and possibly the Lower Stephanian), they occur in the upper part of the New Rock Group, the Pennant Group, the Farrington Group, and the lower part of the Radstock Group. The Barren Red Group in the Upper Coal Measures (Westphalian D) is devoid of seams, and those in the Pennant Group, lower in the Upper Coal Measures (Westphalian C), are relatively thin and unimportant commercially.

Previous work on the miospore floras of the Bristol and Somerset seams was carried out by Williams (1956) who investigated the miospores in six seams, three of which occur in the Farrington Group and three in the Radstock Group. This work is unpublished but a brief summary of the findings is given in Butterworth and Millott (1960, p. 159).

In the present investigation the miospore floras of seams occurring in all the subdivisions of the Coal Measures have been examined. The seam samples from the Vobster and New Rock Groups were mainly obtained from the Harry Stoke 'B' borehole, but as the Harry Stoke Marine Band was not identified in this borehole, but was present in the neighbouring 'A' borehole, some additional samples (including one of the seam immediately below the marine band) were obtained from the 'A' borehole. The seams in the lower part of the sequence are not well developed in the area in which these boreholes were sited and for this reason samples of the presumed Ashton Top, Ashton Great, and Ashton Little Seams were examined from the Geological Survey borehole at Ashton Park. The spores from certain of the seams in the Harry Stoke boreholes were corroded and associated with varying amounts of obscuring opaque detritus. Satisfactory separations from the relatively high-rank coals in the Ashton Park borehole were only obtained by using hydrogen peroxide as the macerating agent. The seams investigated in the higher part of the Upper Coal Measures (Farrington and Radstock Groups) were those which had previously been examined by Williams.

The locations of the sampling points and details of the sections examined are given in text-fig. 49. Text-fig. 50 shows the frequencies of occurrence of selected species of nine genera of miospores present in the coalfields.

Densosporites anulatus Assemblage V (Ashton Little Seam, Ashton Park borehole).

The lowest seam in the Ashton Park borehole, in which *Laevigatosporites* has not been seen, is placed in this Assemblage. *D. anulatus* is infrequent, although it is often numerous in seams with this Assemblage in other coalfields. A small form of *Florinites* about the size of *F. mediapudens* is present and several specimens of *D. sphaerotriangularis* have also been seen. These species are not usually found in this Assemblage.

Radiizonates aligerens Assemblage VI (seam at 2,111 ft. 8 in., Harry Stoke 'B' borehole to seam at 866 ft. 10 in., Harry Stoke 'A' borehole).

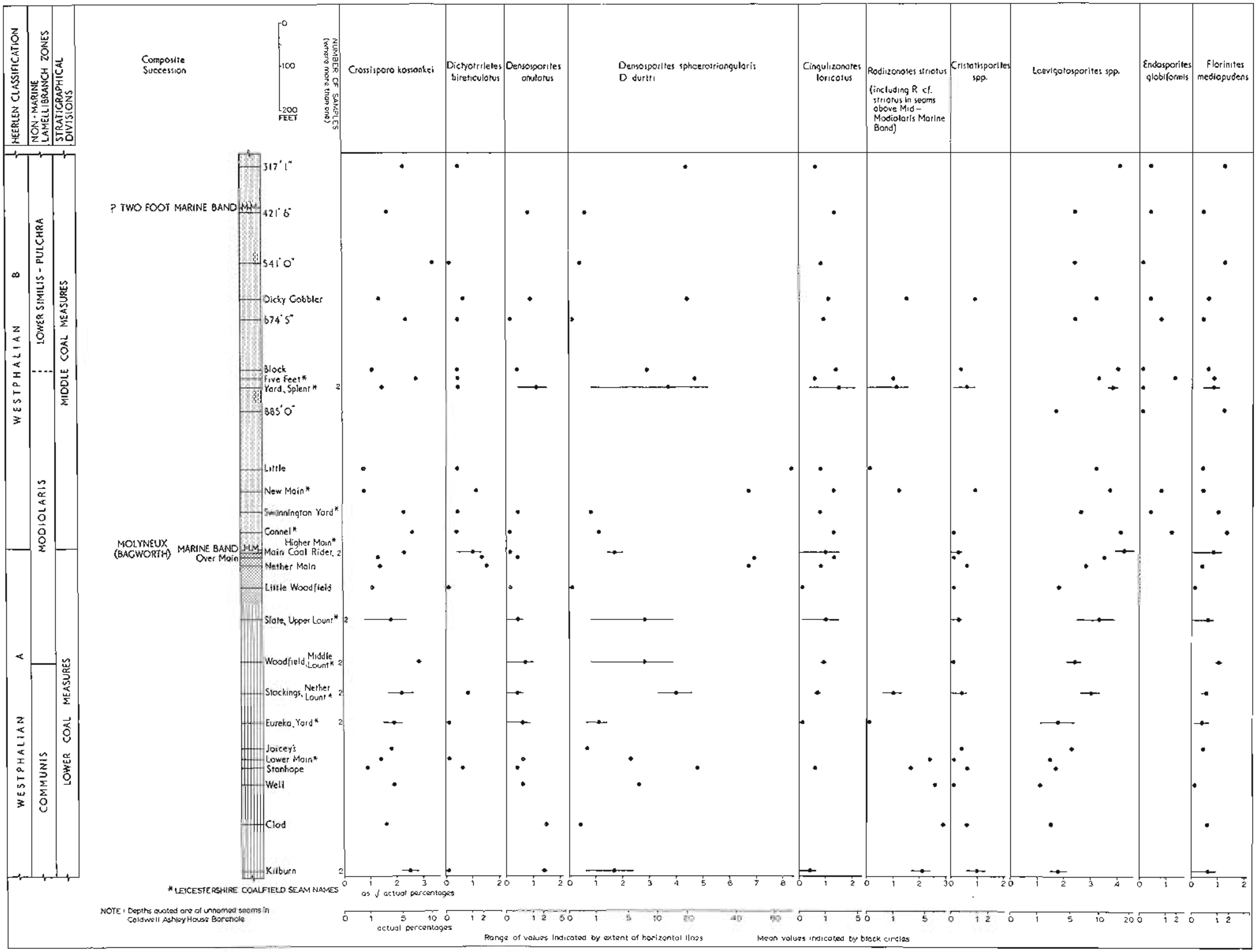
The occurrence of *Laevigatosporites* in the seam at 2,111 ft. 8 in. in the Harry Stoke 'B' borehole indicates an horizon within Assemblage VI. In the absence of *R. aligerens* the upper limit of the Assemblage is uncertain, but it has been placed above the horizon of the seam at 866 ft. 10 in. in the 'A' borehole on the basis of the general character of the miospore floras from the seams lying within these limits. The miospores are typical of those from seams assigned to this Assemblage in other fields. Thus, *R. striatus* is numerically common, to very common, in all seams except in the Ashton Top Seam and that at 866 ft. 10 in. ('A' borehole), from which it has not been recorded. *Cristatisporites connexus* is very common in the seam at 866 ft. 10 in. (Harry Stoke 'A' borehole). Unusual features are the abundance of *D. anulatus* in the seam at 1,000 ft. 2 in. (Harry Stoke 'A' borehole) and the apparent absence of *R. aligerens* in all the seams of the Assemblage. The apparent absence of this species in this coalfield cannot, however, be considered established on the basis of the present investigations. The occurrence of *Vestispora pseudoreticulata* in the seam at 1,000 ft. 2 in. (Harry Stoke 'A' borehole) is exceptional as it has not been recorded in seams of comparable age elsewhere.

Schulzospora rara Assemblage VII (seams at 819 ft. 0 in. and 764 ft. 1 in., Harry Stoke 'A' borehole).

The Assemblage contains two seams, the miospore floras of which are rich in species and typical of those in seams elsewhere in this Assemblage. *Schulzospora* occurs in the seam at 764 ft. 1 in. and *Dictyotriletes bireticulatus* and *Vestispora tortuosa* are frequent in both seams.

Dictyotriletes bireticulatus Assemblage VIII (seam at 1,697 ft. 3 in. to seam at 1,163 ft. 4 in., Harry Stoke 'B' borehole).

The lowest seam in which *Endosporites globiformis* has been seen is that at 1,697 ft. 3 in. in the Harry Stoke 'B' borehole above the Harry Stoke Marine Band. In the seams above the marine band *Crassispora kosankei* gradually declines in abundance up to the seam at 1,487 ft. 4 in. The species becomes common, to abundant, in succeeding seams



TEXT-FIG. 46. Frequencies of selected miospore species in certain seams of the Leicestershire and South Derbyshire Coalfield.

TABLE 4. Assemblage frequencies for the coalfields of the Central Province

Percentage occurrence in total number of samples of each Assemblage

Assemblage XI

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire	Shropshire	Warwickshire
Number of samples	1	3	22	4	5	14	3
Miospore species							
Cadiospora magna	100	67	32	50	80	50	33
Schopfites dimorphus		33	32	25	20	43	33
Triquitrites spinosus	100	100	55	50	40	29	
Mooreisporites inusitatus		33	18	50	60	21	33
Alatisporites hoffmeisterii							
A. trialatus							
Punctatosporites oculus		67	45	50	80	57	33
Thymospora obscura	100	67	45	50	40	7	33
T. pseudothiessenii		33	55	75	60	50	
Vestispora laevigata	100	100	73	100	80	71	33
Triquitrites bransonii	100	67	86	50	60	71	67
Torispora securis		67	23	25		21	
Vestispora fenestrata	100	67	82	100	80	57	100
Microreticulatisporites sulcatus		67	14	50	40	14	
Triquitrites sculptilis	100		23	100	80	36	67
Cristatisporites solaris							
Vestispora magna							
Endosporites globiformis	100	100	93	100	80	100	67
Radiizonates faunus							
R. tenuis							
Vestispora pseudoreticulata							
V. costata and *V. tortuosa*							
Dictyotriletes reticulocingulum							
Radiizonates aligerens							
Florinites mediapudens		33	32	50	40	14	67
Pityosporites westphalensis	100	33	50	25	40	29	33
Dictyotriletes bireticulatus							
Densosporites duriti and *D. sphaerotriangularis*	100	33	23		60	21	33
**Laevigatosporites* spp.	100	100	100	100	100	100	100
Acanthotriletes echinatus							
Reinschospora speciosa							
**Anapiculatisporites minor*				25		7	
**Crassispora kosankei*	100	100	82	100	60	50	100
Simozonotriletes intortus	100						
Cristatisporites connexus and *C. indignabundus*	100						100
Reticulatisporites reticulatus							
R. polygonalis	100						
Cingulizonates loricatus							
Alatisporites pustulatus							
**Camptotriletes* spp.							
**Ahrensisporites* spp.							
**Savitrisporites nux*							
**Densosporites annulatus*							
D. striatus and *D.* cf. *striatus*							
**Spencerisporites radiatus*							
**Schopfipollenites* spp.							
Schulzospora rara							

Assemblage X

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire
Number of samples	6	11	5	32	51
Vestispora laevigata	17				
Triquitrites bransonii	33				
Torispora securis	17	55	80	69	4
Vestispora fenestrata	83	73	60	66	65
Microreticulatisporites sulcatus		9		23	31
Triquitrites sculptilis	100	100	100	100	98
Cristatisporites solaris	67	36	40	23	37
Vestispora magna	50	18	40	13	39
Endosporites globiformis	100	100	100	100	94
Radiizonates faunus					10
R. tenuis	17				
Vestispora pseudoreticulata	67}				
V. costata and *V. tortuosa*	50}	100	100	72	92
Dictyotriletes reticulocingulum	17	9			4
Florinites mediapudens	100	100	100	97	98
Pityosporites westphalensis		45		13	18
Densosporites duriti and *D. sphaerotriangularis*	50	18	14	26	12
**Laevigatosporites* spp.	100	100	100	100	100
Acanthotriletes echinatus			20		4
Reinschospora speciosa				3	2
**Anapiculatisporites minor*	33	27		16	22
**Crassispora kosankei*	100	91	100	100	96
Cristatisporites connexus and *C. indignabundus*		18			
Reticulatisporites reticulatus	17	9			
R. polygonalis				3	
Cingulizonates loricatus	33	18	40		16
Alatisporites pustulatus		9		13	8
**Camptotriletes* spp.	17				

Assemblage IX

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire	Shropshire	Warwickshire	Leics. and South Derby
Number of samples	20	37	31	41	105	21	11	1
Microreticulatisporites sulcatus		8	3	22	11	14	18	
Triquitrites sculptilis	40	62	45	73	76	33	27	
Cristatisporites solaris	10	54	52	64	63	62	37	
Vestispora magna	35	51	74	66	64	48	55	
Endosporites globiformis	100	100	97	98	90	86	91	100
Radiizonates faunus / *R. tenuis*	5	3	26	22	34	48	18	100
Vestispora pseudoreticulata	75}							100
V. costata and *V. tortuosa*	85}	95	100	95	98	95	100	100
Dictyotriletes reticulocingulum			10	12	10	33	9	
Florinites mediapudens	100	98	100	100	99	100	100	100
Pityosporites westphalensis	20	24	29	22	24	29		100
Dictyotriletes bireticulatus	10	16	32	15	18	43	45	100
Densosporites duriti and *D. sphaerotriangularis*	10	49	29	61	25	57	27	100
**Laevigatosporites* spp.	100	100	100	100	100	100	100	100
Acanthotriletes echinatus	5	3	3	7	2			
Reinschospora speciosa		3	3	5	2	14	9	
**Anapiculatisporites minor*	30	38	48	37	32	43		100
**Crassispora kosankei*	100	100	100	98	97	91	100	100
Simozonotriletes intortus				2				
Cristatisporites connexus and *C. indignabundus*	20	24	19	22	22	76	45	
Reticulatisporites reticulatus	20	19	23	12	23	38		100
R. polygonalis		3	32	10	10	19		
Cingulizonates loricatus	35	62	45	54	57	67	55	100
Alatisporites pustulatus	10	11	19	22	18	33	18	
**Ahrensisporites* spp.			3			19		
**Savitrisporites nux*				5	2	10	18	
**Densosporites annulatus*	20							
D. striatus and *D.* cf. *striatus*	5							
**Spencerisporites radiatus*	5		3		1			
**Schopfipollenites* spp.	10				1			

Assemblage VIII

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire	Shropshire	Warwickshire	Leics. and South Derby
Number of samples	54	123	46	41	59	53	25	13
Endosporites globiformis	89	97	100	93	93	94	96	92
R. tenuis	33	33	37	44	41	42	20	31
Vestispora pseudoreticulata	56}							23
V. costata and *V. tortuosa*	48}	80	70	76	80	81	60	31
Dictyotriletes reticulocingulum	24	12	9	10	15	19	16	23
Florinites mediapudens	98	95	93	88	85	85	84	100
Pityosporites westphalensis	35	40	46	61	39	26	36	8
Dictyotriletes bireticulatus	78	66	74	66	70	74	80	85
Densosporites duriti and *D. sphaerotriangularis*	76	92	76	81	80	77	96	92
**Laevigatosporites* spp.	100	100	100	100	100	100	100	100
Acanthotriletes echinatus	31	9	7	17	19	15	16	69
Reinschospora speciosa	17	4	4	7	7	19	12	15
**Anapiculatisporites minor*	78	38	46	56	49	32	40	46
**Crassispora kosankei*	100	99	100	100	98	98	96	92
Simozonotriletes intortus	7	2	4	2	7		12	15
Cristatisporites connexus and *C. indignabundus*	54	68	72	66	68	77	72	38
Reticulatisporites reticulatus	26	13	39	10	17	40	8	38
R. polygonalis	20	8	11	12	29	25	12	15
Cingulizonates loricatus	83	79	91	71	75	92	88	92
Alatisporites pustulatus	19	13	24	7	14	32	24	31
**Camptotriletes* spp.	11	6	9	7	20	8	4	
**Ahrensisporites* spp.	6	13	22	10	24	28	8	23
**Savitrisporites nux*	4	2		15	12	13		
**Densosporites annulatus*	33							62
D. striatus and *D.* cf. *striatus*	20							38
**Spencerisporites radiatus*	17	1		2	2	9		31
**Schopfipollenites* spp.	22	2	2		3		4	15

Assemblage VII

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire	Shropshire	Warwickshire	Leics. and South Derby
Number of samples	12	11	5	3	17	9	17	5
Endosporites globiformis				67				
R. tenuis				33	6	11	6	
Vestispora pseudoreticulata	8}							
V. costata and *V. tortuosa*	100}	100	100	67	82	67	53	60
Dictyotriletes reticulocingulum	17				12	11		20
Florinites mediapudens	83	100	100	100	82	89	77	60
Pityosporites westphalensis	8	55	60	67	47	33	59	40
Dictyotriletes bireticulatus	83	82	100	33	76	89	83	100
Densosporites duriti and *D. sphaerotriangularis*	83	64	80	100	88	100	71	100
**Laevigatosporites* spp.	100	100	100	100	100	100	100	100
Acanthotriletes echinatus			20		6	22	6	
Reinschospora speciosa			20		24	11	12	20
**Anapiculatisporites minor*	58	9	60	100	53	33	41	40
**Crassispora kosankei*	100	100	100	100	100	89	100	100
Simozonotriletes intortus			20		6	11		
Cristatisporites connexus and *C. indignabundus*	67	73	80	33	59	56	35	80
Reticulatisporites reticulatus	33	27	40	67	23		35	
R. polygonalis	25	27		33	35	22	47	20
Cingulizonates loricatus	42	36	40	33	35	67	53	100
Alatisporites pustulatus	42	9	60		29	67	41	
**Camptotriletes* spp.			20		47		35	
**Ahrensisporites* spp.			60			11	24	
**Savitrisporites nux*			20		12	11	18	
**Densosporites annulatus*	25							60
D. striatus and *D.* cf. *striatus*		36	20		47	11	24	
**Spencerisporites radiatus*	33		60		41	11	47	40
**Schopfipollenites* spp.	8				12			
Schulzospora rara	92	91	100	67	82	67	88	80

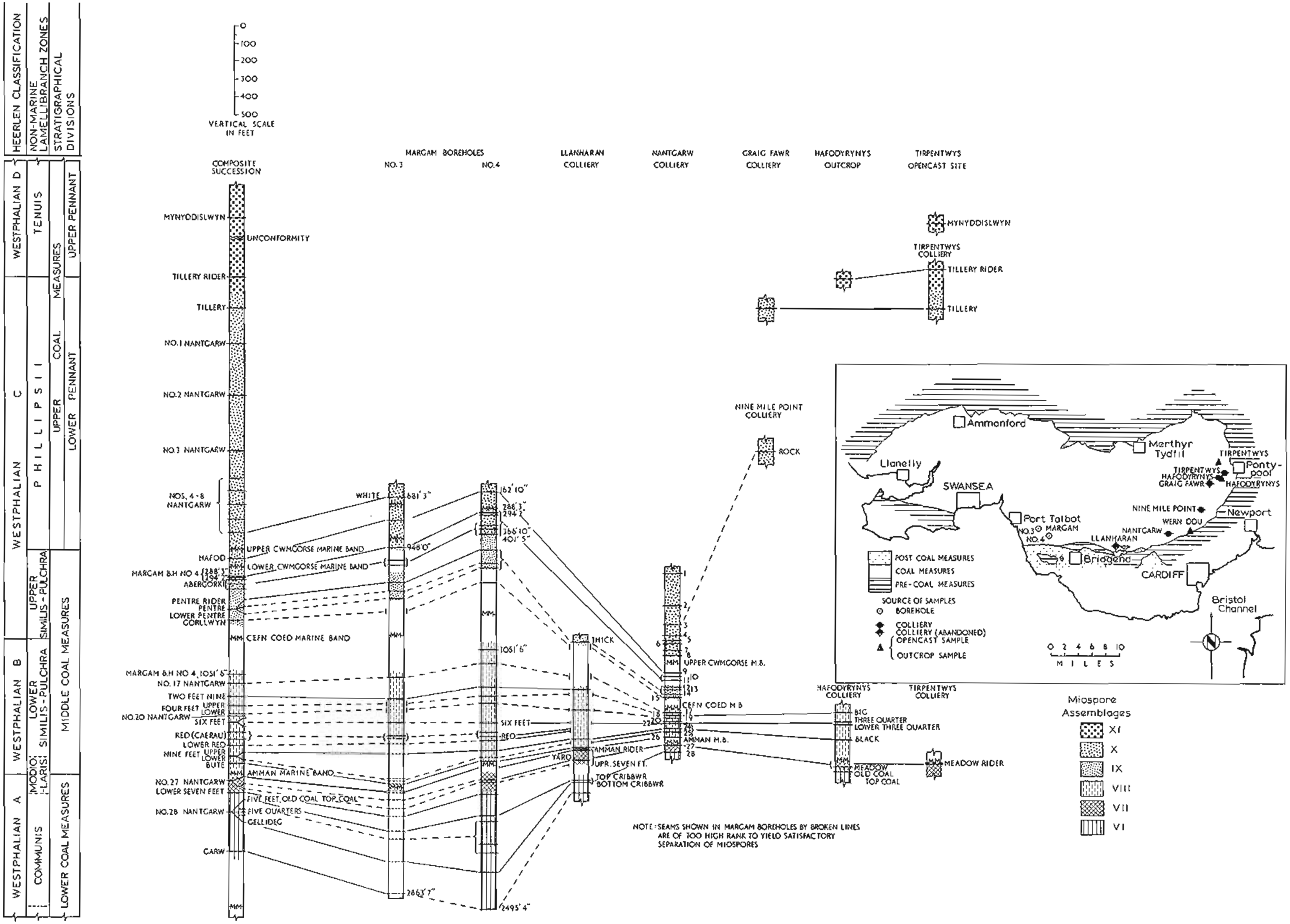
Assemblage VI

Coalfields	Yorks. and Notts.	Lancashire	North Wales	North Staffordshire	South Staffordshire	Shropshire	Warwickshire	Leics. and South Derby
Number of samples	41	64	30	33	51	53	59	15
R. tenuis		2					2	
V. costata and *V. tortuosa*	17}	19	20	21	12	11	10	7
Dictyotriletes reticulocingulum	12	2	3	6	6	11	5	20
Radiizonates aligerens	80	73	70	60	60	45	52	53
Florinites mediapudens	71	64	63	42	42	38	59	73
Pityosporites westphalensis	7	31	10	36	20	21	22	7
Dictyotriletes bireticulatus	46	22	30	24	30	11	22	40
Densosporites duriti and *D. sphaerotriangularis*	80	69	86	57	72	58	90	100
**Laevigatosporites* spp.	100	100	100	100	100	100	100	100
Acanthotriletes echinatus	15	8	3	21	4	4	10	13
Reinschospora speciosa	27	3	3		6	9	7	7
**Anapiculatisporites minor*	63	37	33	48	48	45	46	60
**Crassispora kosankei*	100	98	100	96	96	100	98	100
Simozonotriletes intortus	12	3		6	8	9	8	13
Cristatisporites connexus and *C. indignabundus*	63	78	80	60	82	70	70	67
Reticulatisporites reticulatus	10	11	15	9	12	21		13
R. polygonalis	12	13	26	9	22	47	25	27
Cingulizonates loricatus	34	50	30	30	40	45	39	60
Alatisporites pustulatus	27	6		6	10	6	24	
**Camptotriletes* spp.	5	23	20	45	56	24	36	7
**Ahrensisporites* spp.	7	20	6	15	10	11	20	27
**Savitrisporites nux*	15	13	3	18	12	13	44	27
**Densosporites annulatus*	41							67
D. striatus and *D.* cf. *striatus*	44	61	66	57	76	68	66	60
**Spencerisporites radiatus*	41	6	6	6	8	28	17	27
**Schopfipollenites* spp.	2	2			2		2	7
Schulzospora rara	46	77	53	72	66	64	59	73

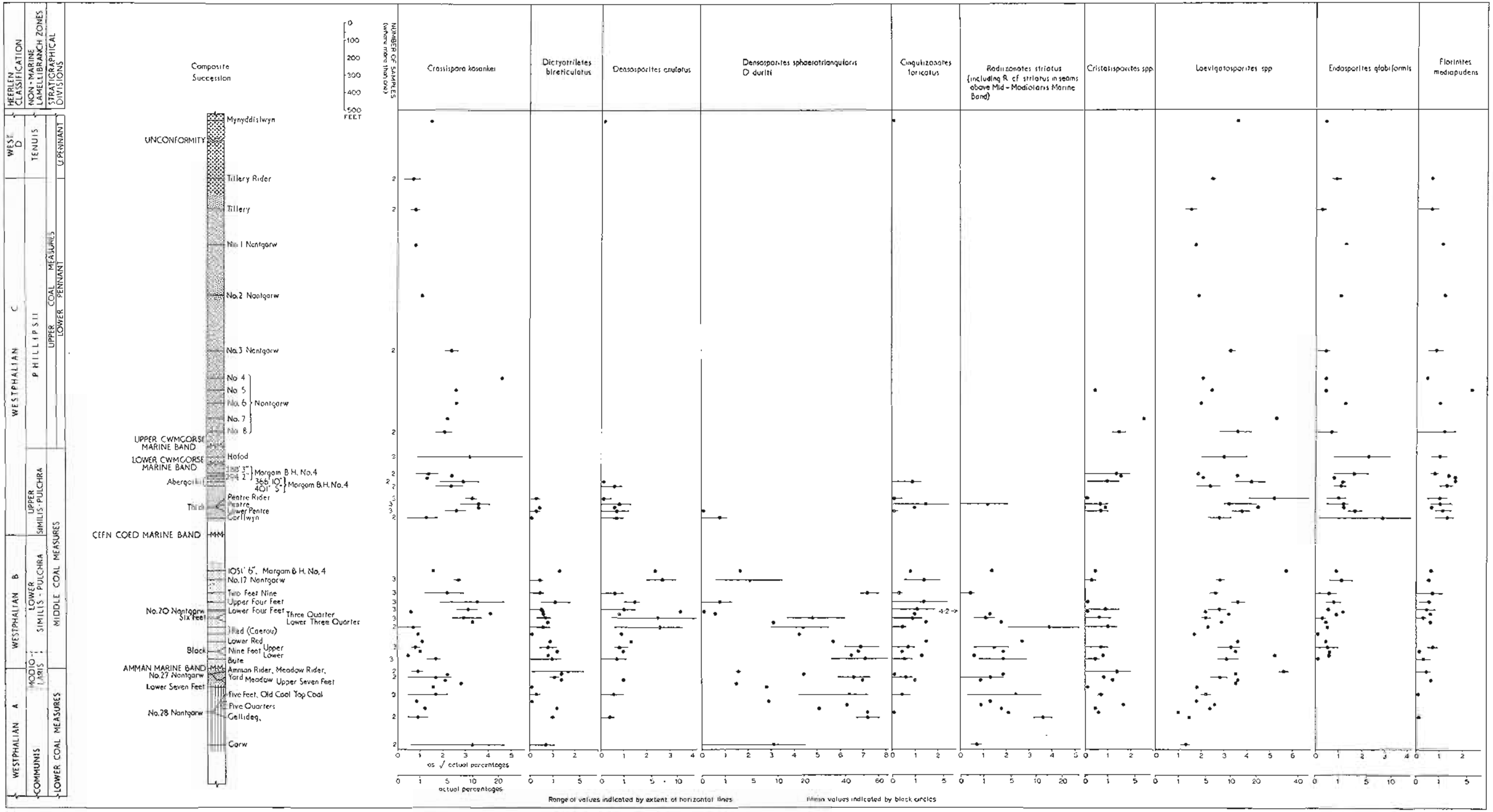
Assemblage V

Coalfields	Yorks. and Notts.	Lancashire	North Wales	Shropshire	Warwickshire
Number of samples	22	13	5	3	2
Densosporites duriti and *D. sphaerotriangularis*	9				
**Laevigatosporites* spp.	9				
Acanthotriletes echinatus	5				
Reinschospora speciosa	23				
**Anapiculatisporites minor*	41	8	20	100	
**Crassispora kosankei*	100	100	100	100	50
Simozonotriletes intortus				33	
Cristatisporites connexus and *C. indignabundus*	23	15	20	33	100
Reticulatisporites reticulatus			20	33	
R. polygonalis	27	8			50
Cingulizonates loricatus	41	31	40		
Alatisporites pustulatus	5	8			
**Camptotriletes* spp.	27	15	60		
**Ahrensisporites* spp.	32	23	60	67	50
**Savitrisporites nux*	23	8	20		100
**Densosporites annulatus*	91	100	80	100	100
D. striatus and *D.* cf. *striatus*	77	61	40	100	100
**Spencerisporites radiatus*	14				
**Schopfipollenites* spp.	9		20		
Schulzospora rara	64	100	60	100	

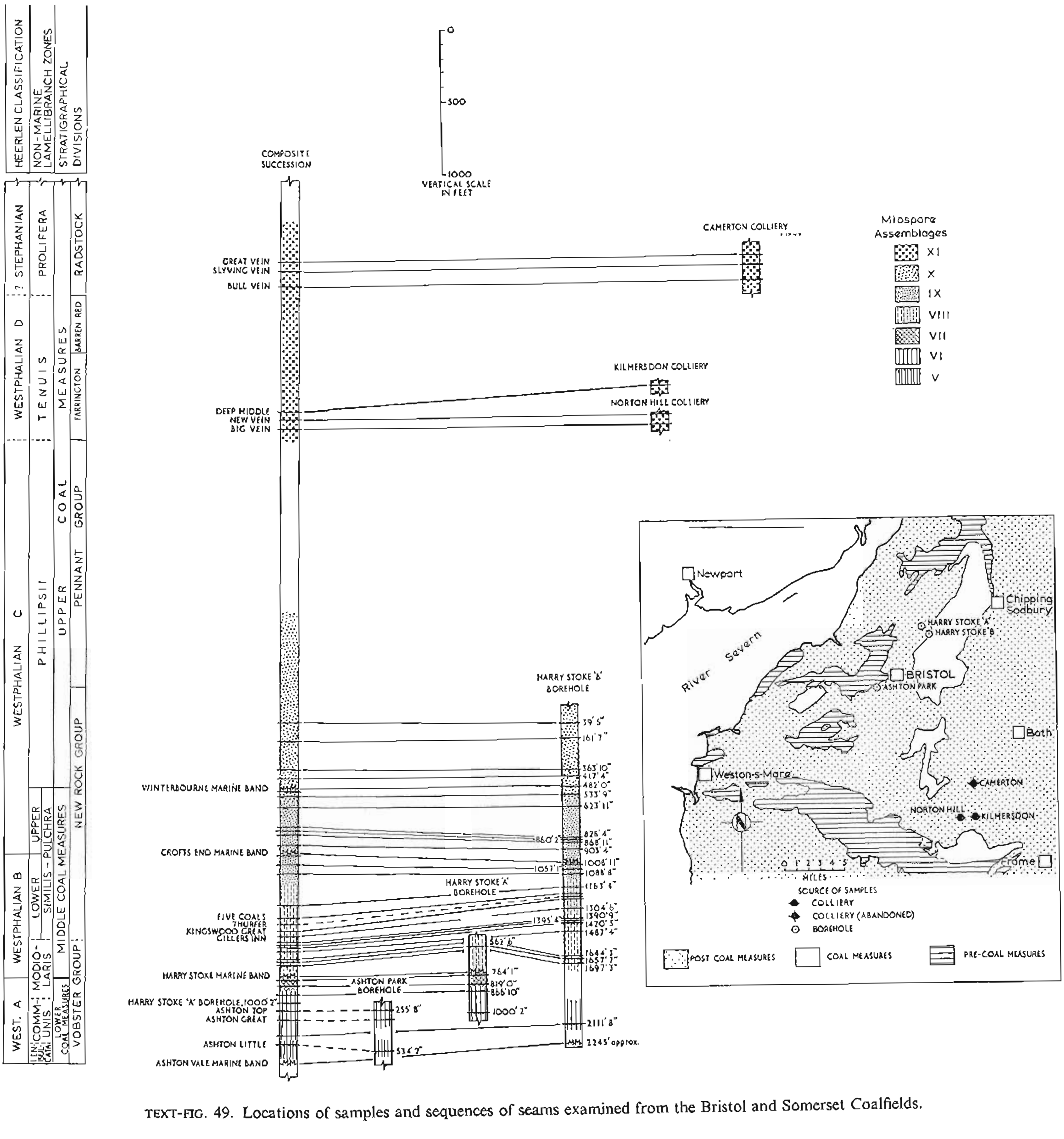
* Genera and species recorded from older Assemblages at least in certain coalfields.



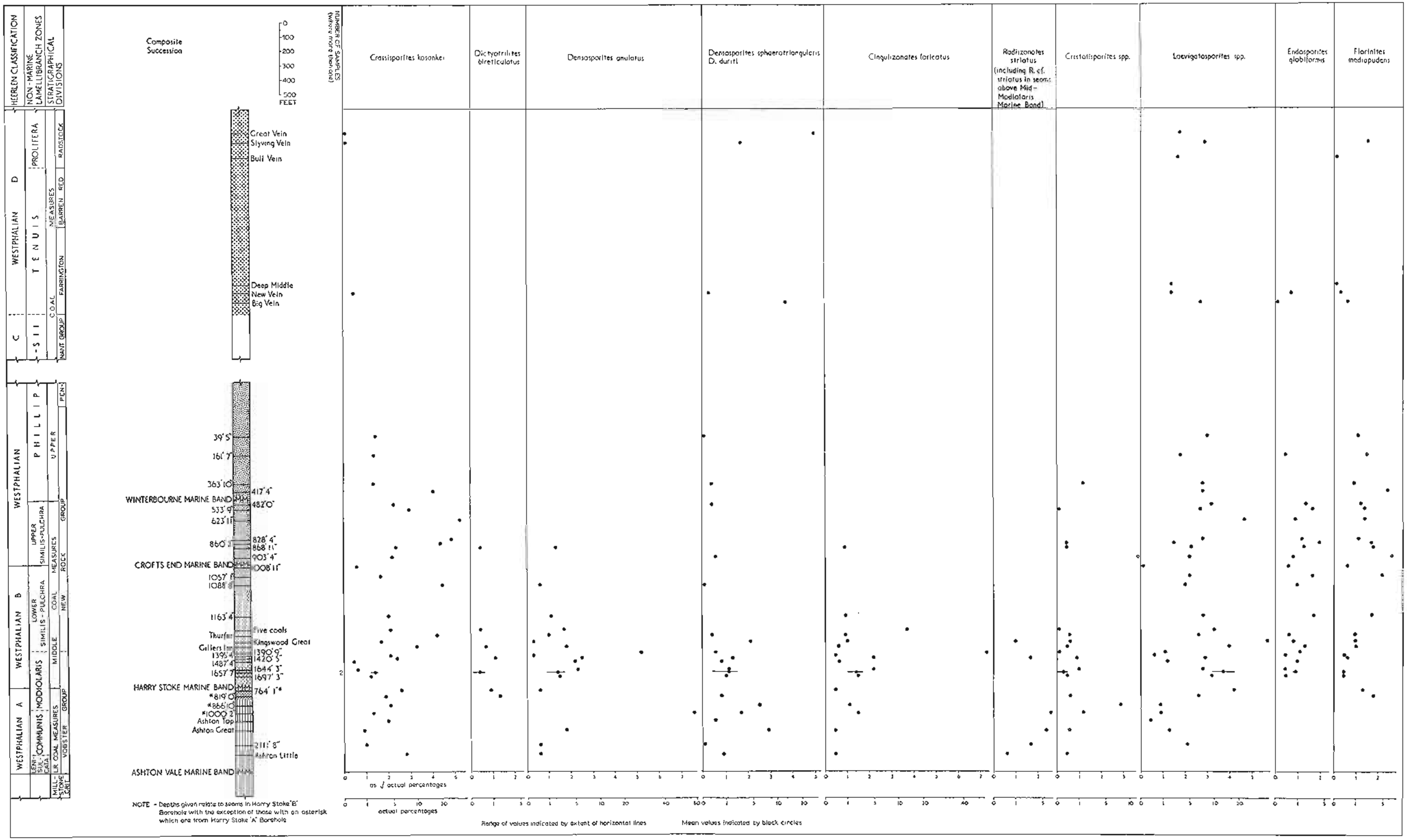
TEXT-FIG. 47. Locations of samples and sequences of seams examined from the South Wales Coalfield.



TEXT-FIG. 48. Frequencies of selected miospore species in certain seams of the South Wales Coalfield.



TEXT-FIG. 49. Locations of samples and sequences of seams examined from the Bristol and Somerset Coalfields.



TEXT-FIG. 50. Frequencies of selected miospore species in certain seams of the Bristol and Somerset Coalfields.

in the sequence, except that at 1,390 ft. 9 in., maximum numbers being recorded from the ? Thurfer Seam. *C. kosankei* was not recorded from the 3 in. coal at 1,390 ft. 9 in. The separation from this seam contained large amounts of opaque debris, and unusually high numbers of *Cingulizonates loricatus* and *Densosporites anulatus*. *D. sphaerotriangularis* occurs in many seams in the Assemblage but is never abundant. The highest numbers recorded are 4% in the Kingswood Great Seam. In other coalfields this species is often a prominent member of the miospore floras at this horizon. Above this seam *C. loricatus* and *D. anulatus* are present throughout the Assemblage and *C. loricatus* is abundant in the Five Coals Seam. *Cristatisporites indignabundus* occurs as an infrequent species of the miospore floras in most of the seams and *Radiizonates tenuis*, which is characteristic of this Assemblage in other coalfields, is also occasionally present. Transitional forms between *Vestispora tortuosa* and *V. magna* are present in the seam at 1,163 ft. 4 in., in which a particularly varied miospore flora occurs. *Florinites mediapudens* is also more common in this seam than in those below, heralding the increased frequency of this species in Assemblage IX.

Vestispora magna Assemblage IX (seam at 1,088 ft. 8 in. to seam at 623 ft. 11 in., Harry Stoke 'B' borehole).

The base of the Assemblage lies some 80 ft. below the Crofts End Marine Band at, or just below, a seam containing *Triquitrites sculptilis*. *Cristatisporites solaris* and *V. magna* occur together in the first seam above the marine band. *C. solaris* is abundant in this seam but is absent, or infrequent, in the remaining seams within the Assemblage. *V. magna* is infrequent to common in the upper part of the Assemblage, but becomes less numerous in seams immediately above, and below, the marine band. *Radiizonates faunus* occurs as an infrequent member of the miospore floras, an unusual feature of which is the occurrence, often as a common or very common constituent, of *Florinites* cf. *florini*. As in South Wales, *Dictyotriletes bireticulatus* is present somewhat higher in the sequence than in other Provinces. It occurs in the seam at 868 ft. 11 in., which lies approximately 140 ft. above the Crofts End Marine Band. A transitional form between *V. fenestrata* and *V. tortuosa* was noted for the first time in this seam. Another interesting record is the occurrence of *Dictyotriletes mediareticulatus* as a very common constituent of the miospore flora in the seam at 903 ft. 4 in.

Torispora securis Assemblage X (seam at 533 ft. 9 in. to seam at 39 ft. 5 in., Harry Stoke 'B' borehole).

The Assemblage extends below the Winterbourne Marine Band to just below the seam at 533 ft. 9 in., in which *Vestispora fenestrata* is present. A new feature appears in the miospore floras with the occurrence in the seam immediately below the marine band of monolete forms belonging to *Latosporites* and *Punctatosporites*. These forms become an important constituent of the miospore floras in seams above the highest marine band in the Coal Measures in all coalfields where seams of this age are present. *Torispora* is first seen in the seam at 363 ft. 10 in., and is abundant. Except for the four spores mentioned the compositions of the miospore floras of Assemblages IX and X are similar.

Thymospora obscura Assemblage XI (Big Vein Seam to Great Vein Seam).

The seams in the Farrington and Radstock Groups fall within this Assemblage. The miospore floras are rich in species and include such diagnostic forms as *T. obscura* and *Punctatosporites oculus*. Species of *Latosporites* are also a common constituent, although not confined to this Assemblage. Other interesting features of the miospore floras are the scarcity of *Crassispora kosankei* (less than 1%), the relative paucity of *Laevigatosporites*, and the reappearance of a species of *Densosporites* similar to *D. sphaerotriangularis*. This species is abundant in the Big Vein Seam of the Farrington Group and the Great Vein Seam of the Radstock Group. Other species characteristic of the miospore floras in the seams of both Groups are *Alatisporites trialatus*, *Microreticulatisporites sulcatus*, and *Triquitrites bransonii*. Certain species such as *Endosporites globiformis* and *Vestispora laevigata*, up to the present, have only been recorded from the seams of the Farrington Group. *Thymospora pseudothiessenii* has only been seen in the seams of the Radstock Group.

The Forest of Dean Coalfield

The Coal Measures succession is very restricted in this coalfield and, except very locally, only the Upper division (Westphalian C and D) is represented. The sequence is divided into the Trenchard Group at the base succeeded by the Pennant and Supra-Pennant Groups. Coal seams occur, and have been worked, in all three Groups, those in the Supra-Pennant Group being, however, thin.

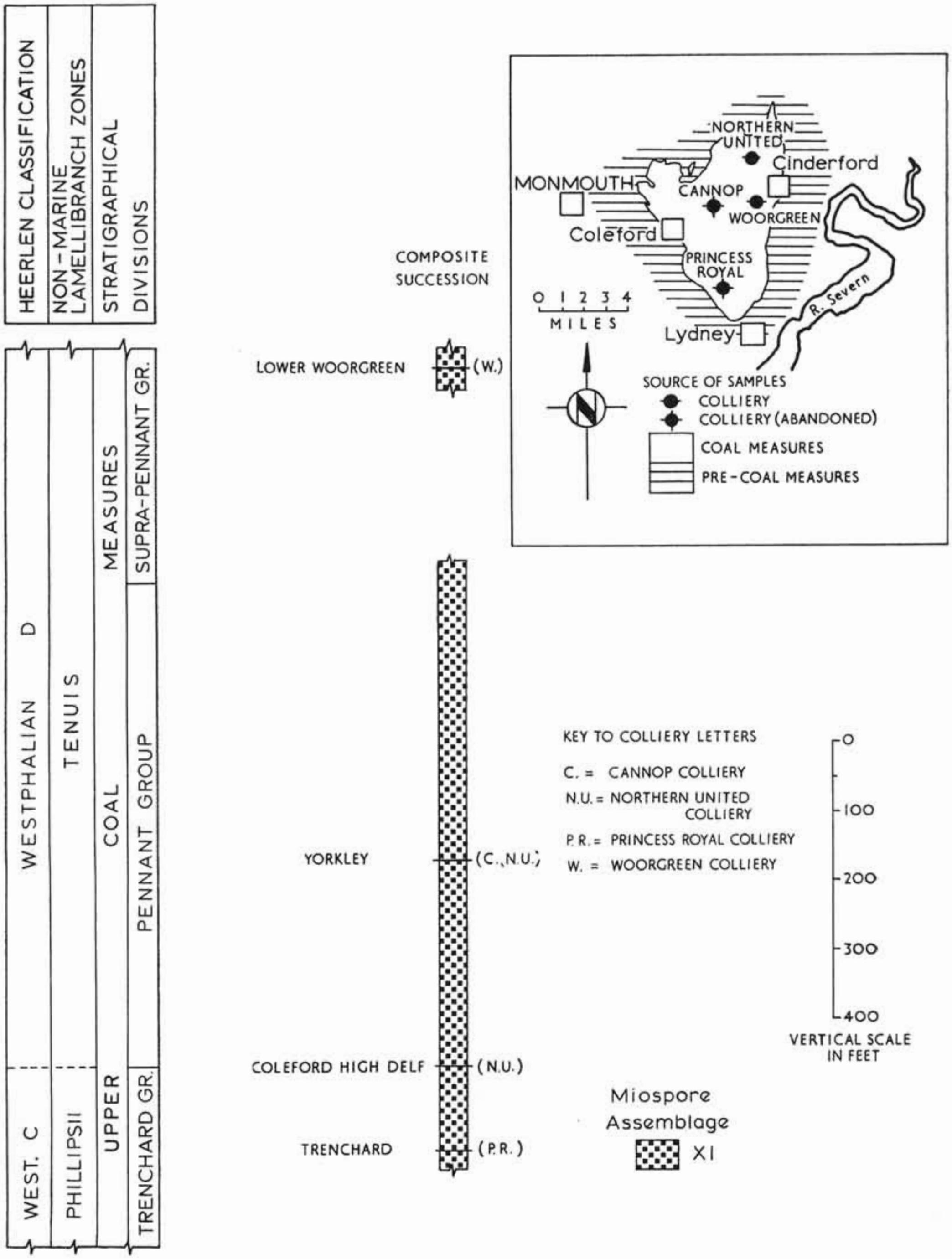
Williams examined the miospore flora of the Trenchard, Coleford High Delf, and Yorkley Seams; the results are briefly summarized in Butterworth and Millott (1960, p. 159). Sullivan (1964) described the miospores from the Edgehills Seam, which is probably of Lower Coal Measures (Westphalian A) age.

Comparatively few investigations were made on the seams of this coalfield but the miospore floras in at least one seam in each of the three main divisions of the succession were examined. The miospore separations prepared by Williams formed the basis of this work. The sample of the Lower Woorgreen Seam present in the upper part of the Supra-Pennant Group was not representative of the full seam thickness, but the data obtained from it are included in the following account because of the interesting stratigraphical position of the seam.

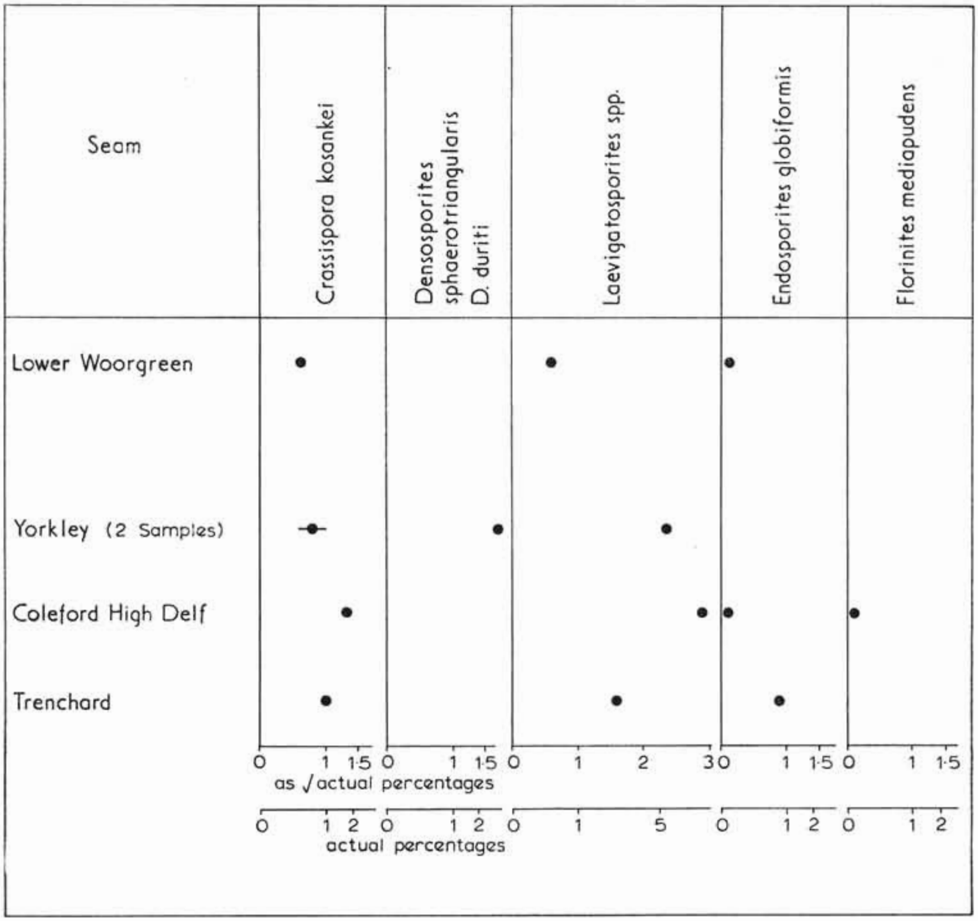
The locations of the sampling points and details of the sections examined are given in text-fig. 51. Text-fig. 52 shows the frequencies of occurrence of selected species of five genera of miospores present in the coalfield.

Thymospora obscura Assemblage XI (Trenchard Seam to Lower Woorgreen Seam).

The miospore floras in these seams are rich in species and contain many spores diagnostic of the Assemblage. *Thymospora obscura* occurs in all of them. Among other species which have been recorded from one or more seams are *Alatisporites trialatus* (Yorkley and Coleford High Delf Seams), *Cadiospora magna* (Trenchard Seam), *Microreticulatisporites sulcatus* (all seams except the Woorgreen), *Mooreisporites* cf. *inusitatus* (Yorkley Seam), *Punctatosporites rotundus* (Coleford High Delf Seam), *P. oculus* (Yorkley Seam), *Raistrickia aculeata* (Yorkley and Woorgreen Seams), *Schopfites dimorphus* (Woorgreen Seam) and *Triquitrites spinosus* and *Vestispora laevigata* (all seams except



TEXT-FIG. 51. Locations of samples and the sequence of seams examined from the Forest of Dean Coalfield the Trenchard). In view of the restriction of *V. laevigata* and *Endosporites globiformis* to seams of the Farrington Group in the Upper Coal Measures in the Bristol and Somerset Coalfield it is worth recording that both species also occur in the Woorgreen Seam. It is perhaps significant that *Thymospora pseudothiessenii*, which is restricted to the



TEXT-FIG. 52. Frequencies of selected miospore species in certain seams in the Forest of Dean Coalfield

Radstock Group in the Upper Coal Measures in Bristol and Somerset, has not been recorded from any of the coals examined in the Forest of Dean. The miospore floras in these Forest of Dean seams also contain many species characteristic of Assemblage X, as, for instance, *V. fenestrata*, *Latosporites spp.*, *Punctatosporites granifer*, *Torispora sp.*, and *Triquitrites bransonii*. Of the species which show considerable variation in abundance at different levels in the Upper Carboniferous, *Crassispora kosankei* is scarce, the larger forms of *Laevigatosporites* never abundant, and *Densosporites sphaerotriangularis* occurs in only one seam, the Yorkley, where it is common.

The Kent Coalfield

Coal seams occur throughout most of the Coal Measures; all the subdivisions of the Westphalian are represented. The sequence is usually divided into a Lower (or Shale) Division and an Upper (or Sandstone) Division, the former representing the Lower Coal Measures and the lower part of the Middle Coal Measures, and the latter the upper part of the Middle Coal Measures and the Upper Coal Measures. The most important seams occur in the Lower Division.

The only previous work on the miospore floras of the coalfield is that of Williams (1956), who examined the spores from coals at seven horizons at Chislet Colliery, only one of which, Chislet No. 5, is worked at this colliery. The remaining six seams were from four boreholes driven from the No. 5 Seam. These boreholes cover the part of the sequence from just below the Ripple Marine Band to the Tilmanstone Marine Band. No seams in the Upper Division were available for examination owing to the proximity of the Mesozoic/Coal Measures unconformity to the Tilmanstone Marine Band. Williams's results have not been published but a brief reference to them is given in Butterworth and Millott (1960, p. 159).

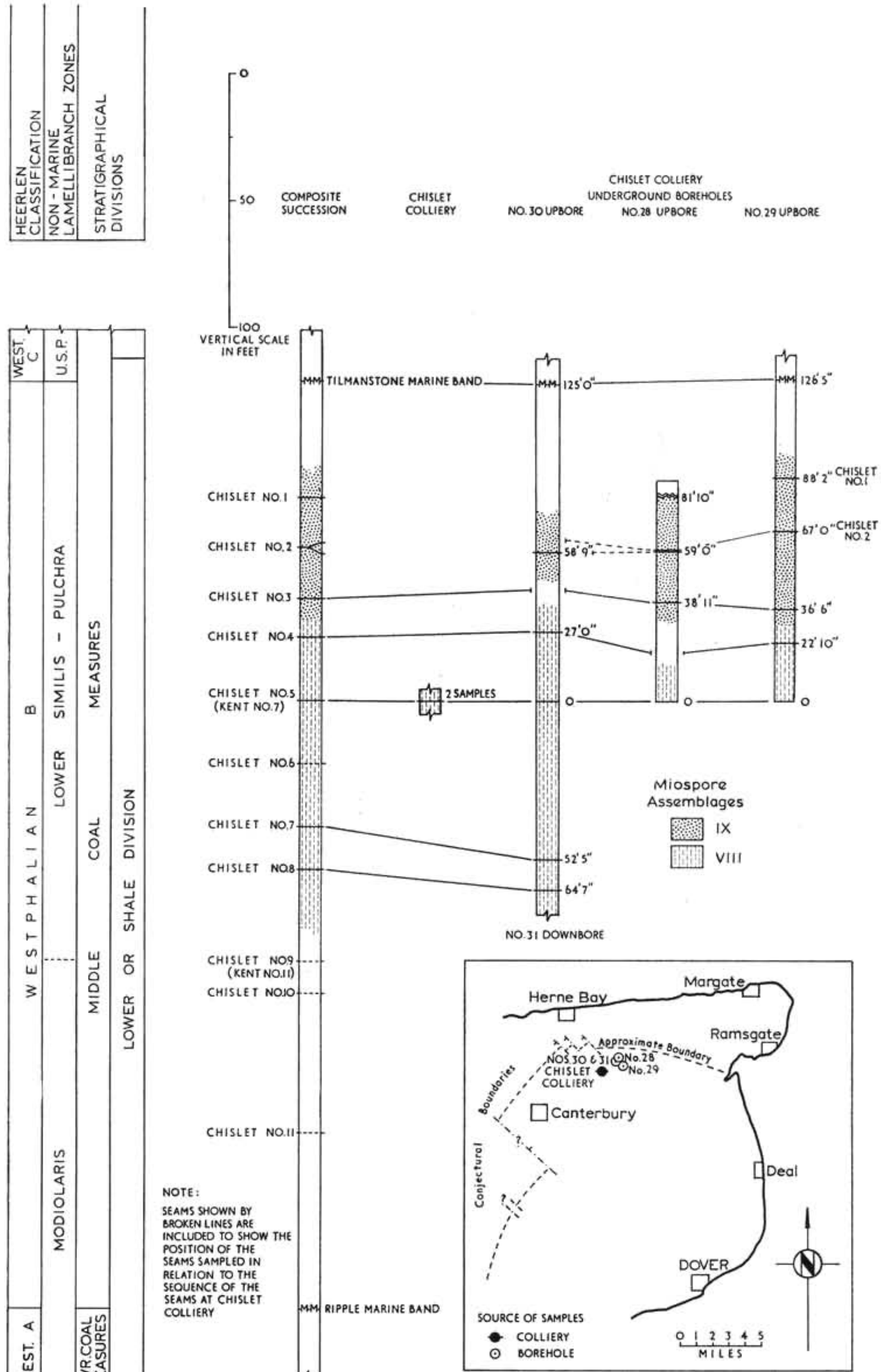
The present investigations were based on the samples used by Williams. Most of them presented difficulties in maceration owing to the high rank of the coals and except for a short sequence in the upper seams it was not possible to isolate the miospores satisfactorily. Hydrogen peroxide generally gave better separations than other macerating reagents. The seam numbers referred to below relate to the numbers used at Chislet Colliery. The locations of the sampling points and details of the sections examined are given in text-fig. 53. Text-fig. 54 shows the frequencies of occurrence of selected species of nine genera of miospores present in the coalfield.

Dictyotriletes bireticulatus Assemblage VIII (No. 8 Seam to No. 4 Seam, Chislet Colliery).

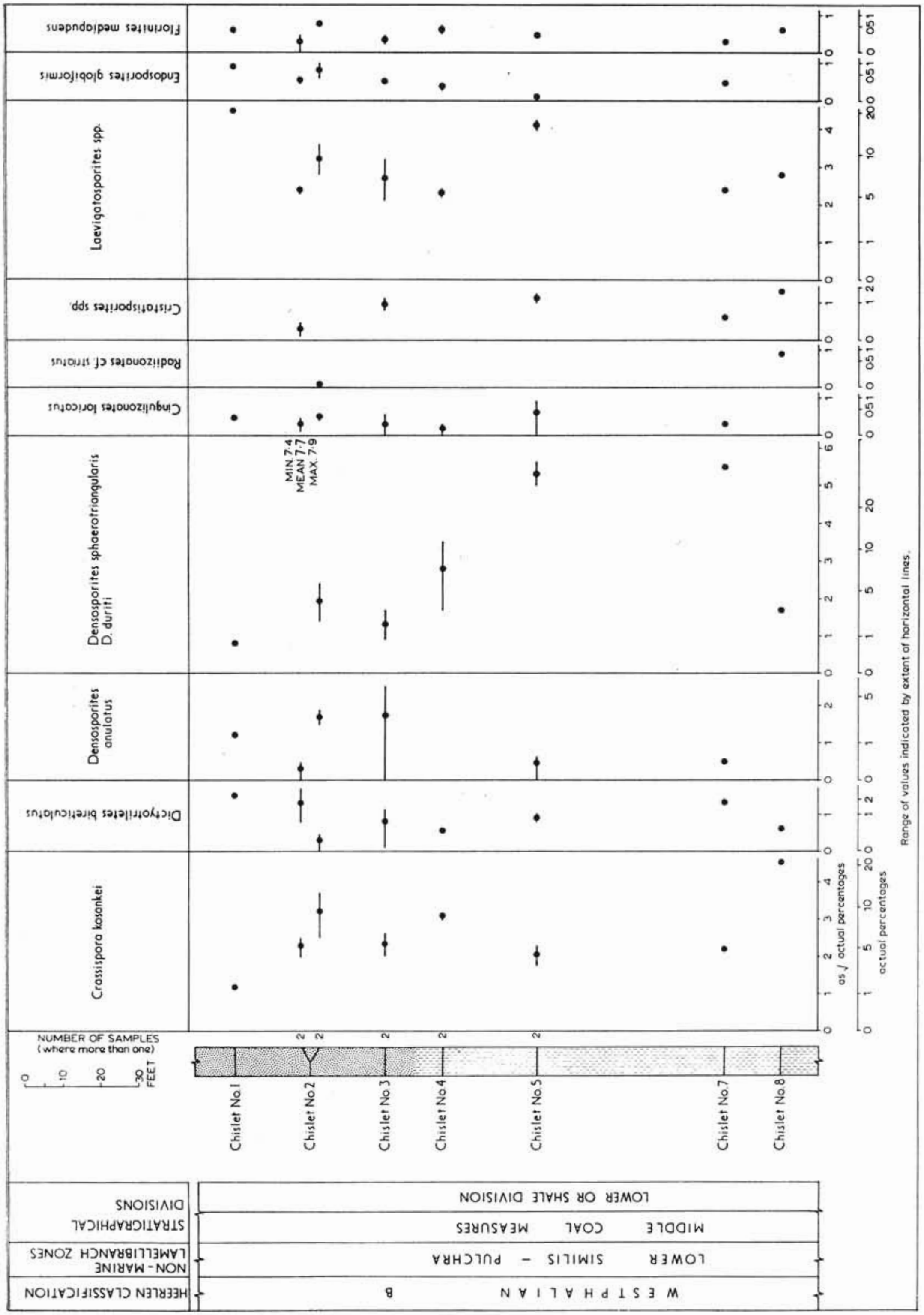
The numbers of *Crassispora kosankei* are relatively high in these seams, suggesting a position in the upper part of the Assemblage. Comparison with other coalfields is difficult owing to the restricted part of the sequence for which data are available. *Densosporites sphaerotriangularis* is abundant in No. 7 and No. 5 Seams in contrast to the generally low numbers of this species in this part of the succession in other British coalfields. *D. faunus*, which is generally more common in the coalfields of the Southern Province than elsewhere, is common in No. 8 Seam and frequent in No. 7 and No. 4 Seams; *Radiizonates tenuis* is only frequent in No. 4 Seam.

Vestispora magna Assemblage IX (No. 3 Seam to No. 1 Seam, Chislet Colliery).

The base of this Assemblage has been placed at the No. 3 Seam, where *Triquitrites sculptilis* occurs. Specimens of what is probably *Cristatisporites solaris* are also present in this seam, and in the No. 2 Seam, where *Florinites millotti* also occurs. *Dictyotriletes bireticulatus* is present in all three seams in the Assemblage and is frequent in the No. 1 Seam (No. 29 borehole), lying just 40 ft. below the Tilmanstone Marine Band. In contrast to its occurrence in the seams of this Assemblage in more northerly coalfields *Densosporites sphaerotriangularis* is abundant in the upper leaf of the No. 2 Seam in boreholes No. 28 and No. 29. (The lower leaf of this seam from borehole No. 29 was not available for



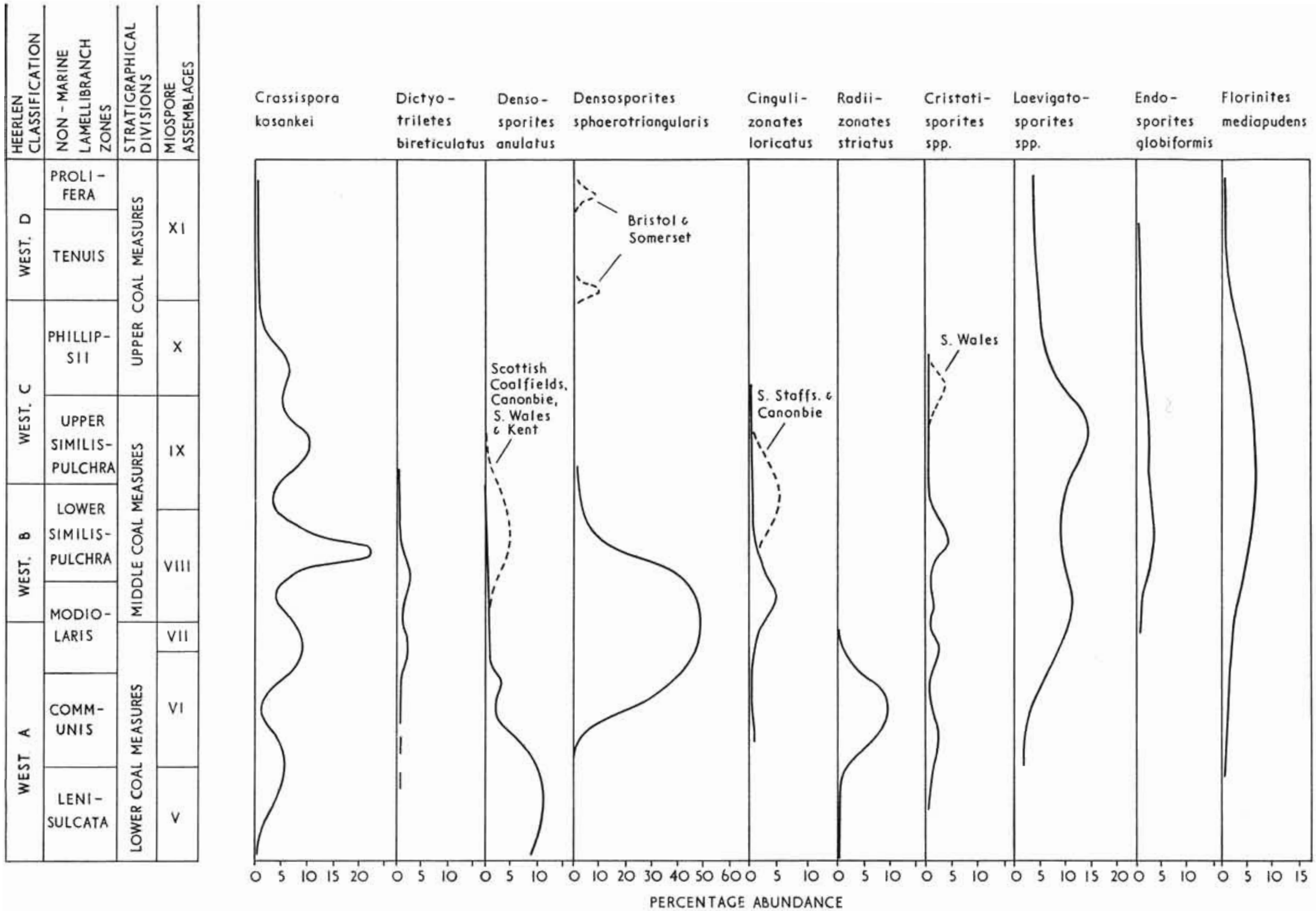
TEXT-FIG. 53. Locations of samples and sequences of seams examined from the Kent Coalfield



TEXT-FIG. 54. Frequencies of selected miospore species in certain seams in the Kent Coalfield examination.) The coal bed at 58 ft. 9 in. in borehole No. 30, on spore evidence, is considered to be the equivalent of the lower bed of this seam. *Radiizonates faunus* and *R. tenuis* are present in all three seams but never exceed 2% of the total miospore flora. *Endosporites globiformis* and *Florinites mediapudens* are less frequent in the seams below the Tilmanstone Marine Band than in those at a comparable horizon in other coalfields.

TABLE 5. Assemblage frequencies for coalfields of the Southern Province

Assemblages	XI			X		IX			VIII			VII		VI		V
Coalfields	South Wales	Bristol and Somerset	Forest of Dean	South Wales	Bristol and Somerset	South Wales	Bristol and Somerset	Kent	South Wales	Bristol and Somerset	Kent	South Wales	Bristol and Somerset	South Wales	Bristol and Somerset	Bristol and Somerset
Number of samples	3	6	5	12	4	29	10	7	27	13	6	7	2	12	5	1
	Percentage occurrence in total number of samples from each Assemblage															
Miospore species																
Cadiospora magna			20													
Schopfites dimorphus			20													
Triquitrites spinosus	33		80													
Mooreisporites inusitatus	67		20													
Alatisporites hoffmeisterii		33														
A. trialatus	67	83	60													
Punctatosporites oculus	67	100	40	8												
Thymospora obscura	100	83	100													
T. pseudothiessenii	33	67														
Vestispora laevigata	67	33	80	8												
Triquitrites bransonii	100	100	100	33	25											
Torispora securis	100	83	60	67	75											
Vestispora fenestrata	100	33	60	58	100	10	10									
Microreticulatisporites sulcatus	33	83	60	25		7										
Triquitrites sculptilis	33		40	83	100	69	90	71								
Cristatisporites solaris				33	25	41	30	29								
Vestispora magna				50	100	76	50									
Endosporites globiformis	100	33	60	67	50	93	100	100	85	77	67					
Radiizonates faunus				8		14		57	26		67					
R. tenuis				17	25	34		57	52	31	50					
Vestispora pseudoreticulata				17	25	55	60	14	19	8	17				20	
V. costata and *V. tortuosa*			20	42	75	62	40	57	11	8		14	100			
Dictyotriletes reticulocingulum				8		38		43	37	23	33	14		17		
Radiizonates aligerens														75		
Florinites mediapudens	67	83	20	75	100	100	90	86	59	69	100	29	100	17		
Pityosporites westphalensis				8		24	20	29	7	31		29	50	8		
Dictyotriletes bireticulatus						28	10	86	85	38	100	86	100	67		
Densosporites duriti and *D. sphaerotriangularis*		67	40	8	50	34	20	100	93	54	100	100	50	92	100	100
Laevigatosporites spp.	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
Acanthotriletes echinatus				8	25	24			22	8	17	14		25		
Reinschospora speciosa						14	10		7		17			17		
Anapiculatisporites minor			20	33	25	38	20	71	56	38	83	71		58	60	
Crassispora kosankei	100	50	100	100	100	100	100	100	96	92	100	100	100	83	100	100
Simozonotriletes intortus								14		8			50	8		
Cristatisporites connexus and *C. indignabundus*						21	10	57	74	69	67	57	50	50	60	100
Reticulatisporites reticulatus			20	17		66	60	86	37	46	83	43	50		40	
R. polygonalis						21	20	14	26	15		14		25	20	
Cingulizonates loricatus	33					38	10	86	59	100	50	43	50	17	20	100
Alatisporites pustulatus						21	20	71	22		17	43		8		
Camptotriletes spp.							20	14		8				8		
Ahrensisporites spp.									7	8						
Savitrisporites nux														17	20	
Densosporites anulatus	33					41	20	71	78	100	33	14	50	8	60	100
Radiizonates striatus						7		14	67	15	50	43		92	60	100
Spencerisporites radiatus	33					17	10	14	37	23	17	57		50		
Schopfipollenites spp.	33					7		14	4	15				8		
Schulzospora rara													50	17	20	100



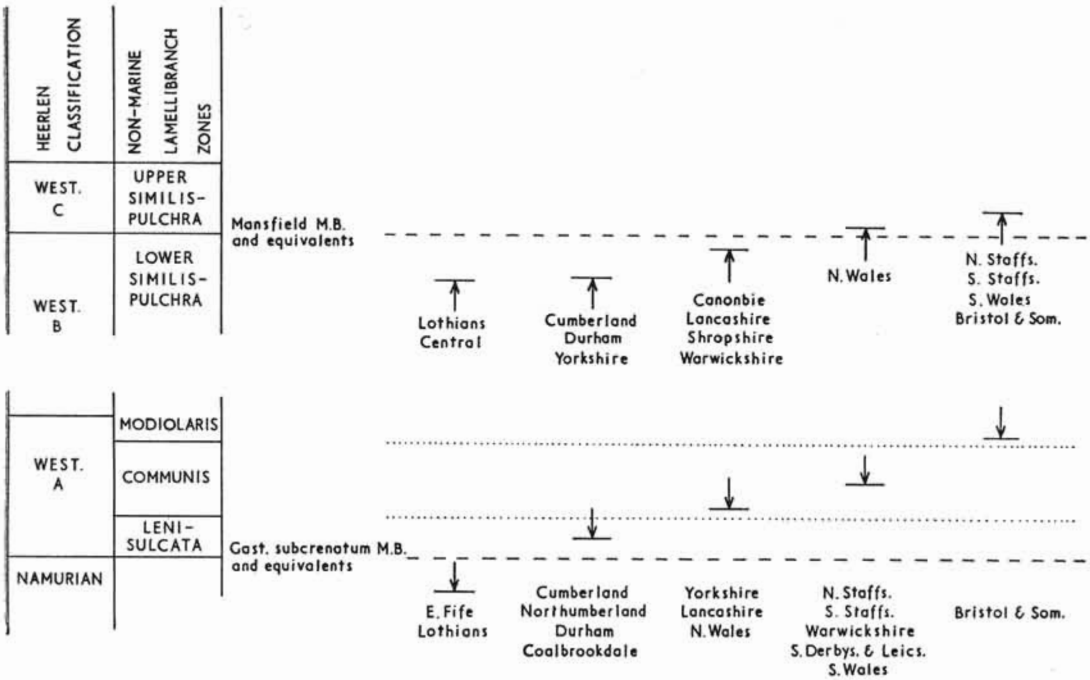
TEXT-FIG. 55. Generalized abundance curves of the more common Coal Measures miospores

DISTRIBUTION OF SELECTED SPORES IN THE COAL MEASURES

Certain of the more commonly occurring spores show marked changes of abundance at different levels within their ranges. These troughs and peaks of abundance, when stratigraphically restricted and widespread, provide a valuable aid to seam correlation and identification. An analysis has, therefore, been made of the abundance of those species, mainly confined to the Coal Measures, whose frequencies have been plotted for each coalfield. There is insufficient data for a similar analysis of spores from older coals. The results of this analysis are presented in text-fig. 55 as a suite of generalized abundance curves. The curves were prepared in two stages. An approximate mean curve was first derived by eye for the selected species in each coalfield and these curves were then superimposed, after reduction to a common scale. This part of the analysis was initially made on a Province basis and the curves for all the coalfields in one Province compared with those for other Provinces. Finally a mean curve for each species was derived from the superimposed curves. The dotted curves in text-fig. 55 show where the data from one, or a small number of coalfields, are at variance with the remainder of the data.

The shape of the curve for *Crassispora kosankei* is rather complex. The species first appears in the Upper Limestone Group of Scotland and the 'Millstone Grit' of Northumberland, but does not become abundant until about the middle of the Lower Coal Measures, where it may reach a frequency of 20% in Lancashire and in several of the Scottish Coalfields (in South Wales there is a marked peak at the horizon of the Garw Seam, slightly higher in the succession). The next peak appears towards the top of the Lower Coal Measures and is well demonstrated in East Fife, Durham, Lancashire, Warwickshire, and South Wales. A similar peak appears in the lower part of the Middle Coal Measures (East Fife, Durham, South Staffordshire, Leicestershire and South Derbyshire, and Bristol and Somerset). After a series of low values at about the top of the Modiolaris Zone maximum values occur in the Lower Similis–Pulchra Zone, this maximum (sometimes 40%) being present in one or two of the coals below the Two Foot Marine Band and its equivalents. This peak occurs in all coalfields. The low value occurring just below, or above, the marine band at the top of the Lower Similis–Pulchra Zone is succeeded by a less prominent peak in the highest part of the Middle Coal Measures (Yorkshire, North Staffordshire, South Staffordshire, and South Wales). In coalfields where coal deposition continued in younger strata a peak of from 5 to 10% occurs in the lower part of the Upper Coal Measures (North Wales, North and South Staffordshire, and South Wales). Thereafter *Crassispora* becomes increasingly rare.

Dictyotriletes bireticulatus is the least abundant of the spores described in this section but it has two significant peaks of frequency. It first appears in the coals of the Passage Group of Scotland; in other coalfields it appears later in the succession. In those coalfields in which sequences of seams have been examined from the base of the Coal Measures, it may be significant that its first appearance becomes progressively later in moving from north to south. It is rarely common until frequencies of between 4 and 9% are reached in the small group of seams below the Mid-Modiolaris Zone Marine Band (especially in the Lothians and South Wales Coalfields). A rather more prominent peak occurs in the highest part of the Modiolaris Zone, as in Durham, Yorkshire, Lancashire, North Staffordshire, Coalbrookdale, and South Wales. In Scotland (except Canonbie) *D. bireticulatus* disappears some distance below Skipsey's Marine Band. Further south, for instance in the Lancashire and Shropshire Coalfields, it is present in the seam below the equivalent marine band. In North Wales it occurs in a seam above the Warras Marine Band, in North Staffordshire in a seam some distance above the Gin Marine Band, and in South Wales in four seams above the Cefn Coed Marine Band. This is the only clear example of progressive diachronism in the disappearance of a spore noted during the present work. The first and last appearances of the species in the different coalfields are summarized in text-fig. 56.



TEXT-FIG. 56. Regional variation in the stratigraphic range of *Dictyotriletes bireticulatus*

The frequencies of the five densospores considered in text-fig. 55 are more variable than those of other groups but certain generalizations can be made. In the early part of the present work *Densosporites anulatus* was unfortunately not always recorded separately from *D. sphaerotriangularis*, which is a shorter-ranging species. *D. anulatus*, which persists from the Lower Carboniferous, occurs in small numbers throughout the Lower, Middle, and lower part of the Upper Coal Measures. It is most prominent in coals occurring in the Lenisulcata Zone, where it may constitute over 40% of the spore assemblages (Lothian, Yorkshire, and Lancashire Coalfields) and at various horizons in the overlying Communis Zone (especially in Cumberland, Lancashire, North Wales, Coalbrookdale, and Bristol and Somerset). It is also abundant at isolated horizons in the lower part of the Middle Coal Measures.

D. sphaerotriangularis first appears in the Coal Measures at about the base of the Communis Zone and becomes very rare near the top of the Middle Coal Measures; within this relatively narrow range it may be exceedingly abundant from the upper part of the Communis Zone to the lower part of the Lower Similis–Pulchra Zone. The single peak shown in text-fig. 55 is compounded of several separate peaks which vary somewhat in horizon from coalfield to coalfield. High percentages are first recorded in the Communis Zone in the Lothians but the first general peak occurs at about the boundary of the Communis and Modiolaris Zones, where frequencies of up to 80% are not uncommon. In East Fife and in the coalfields of the Central Province a similar peak occurs in the coals below the Mid-Modiolaris Zone Marine Band, especially in South Staffordshire and Warwickshire. In the Middle Coal Measures large numbers of *D. sphaerotriangularis* have been recorded in all fields in the upper part of the Modiolaris Zone and occasionally (Central Coalfield of Scotland, Cumberland, North Staffordshire, Leicestershire and South Derbyshire, South Wales, and Kent) in the Lower Similis–Pulchra Zone, above which there is a marked hiatus. Spores similar to *D. sphaerotriangularis*, apart from their slightly smaller size, occur in coals of the Tenuis and Prolifera Zones of Bristol and Somerset, and, to a lesser extent, elsewhere. An analysis of the distribution of *D. sphaerotriangularis* in the Middle Coal Measures of certain fields in the Central Province was made by Butterworth (1964).

Cingulizonates loricatus is one of the less abundant species, seldom reaching frequencies exceeding 10%. The species is present at the base of the Coal Measures in the Yorkshire and Lancashire Coalfields but elsewhere it does not appear until later. It only becomes a significant member of the miospore floras in the upper part of the Modiolaris Zone and the lower part of the Lower Similis–Pulchra Zone. The species then becomes rare except in the Canonbie, Durham, and North and South Staffordshire Coalfields, where relatively high percentages are again recorded for seams near, or at, the top of the Lower Similis–Pulchra Zone. In South Staffordshire the species remains common in several seams above the marine band at this horizon. It is interesting to note that the species only exceptionally occurs with a frequency greater than 1%, and is often absent from seams immediately below the Clay Cross, Two Foot, and Mansfield Marine Bands, or their equivalents in the different coalfields. The exceptions mainly relate to a group of coalfields with condensed sequences lying to the south of the Central Province, i.e. Coalbrookdale, Warwickshire, and Leicestershire and South Derbyshire. In these fields values up to 6% have been recorded from seams below these marine bands. Elsewhere, the only exception is a value of 7% in one sample from below Skipsey's Marine Band in the Canonbie Coalfield. The scale of the generalized curve is too small to show troughs corresponding to these minimum values.

Radiizonates striatus is a useful marker species restricted to the upper part of the Namurian and the Lower Coal Measures; it is usually very abundant in one or more seams within the Communis Zone, where it occurs along with *Densosporites anulatus*. It is relatively rare in certain fields (East Fife and the Scottish Central Coalfield and Cumberland). In the Lancashire Coalfield it is only abundant in the Wigan and Burnley areas in the north. Above the horizon of the Mid-Modiolaris Zone Marine Band *R.* cf. *striatus* may be common. As this species was not separated from *Cingulizonates loricatus* by one author (M. A. B.), the peak of abundance for *C. loricatus* shown just above the Mid-Modiolaris Zone Marine Band in some fields, e.g. Coalbrookdale, may, therefore, include *R.* cf. *striatus*.

Cristatisporites spp. are uncommon in the seams examined from the coalfields of Central Scotland, Ayrshire, Canonbie, North Staffordshire, Leicestershire and South Derbyshire, and Kent. Peaks of abundance occur in several of the remaining coalfields at different horizons throughout the Lower, Middle, and lower part of the Upper Coal Measures, but frequencies in excess of 10% are exceptional. The most significant peaks of abundance in particular coalfields occur at the following horizons: at the base of the Communis Zone in the Lothians Coalfield and at the top of the Zone in the Coalbrookdale Coalfield; in the lower part of the Modiolaris Zone in the Warwickshire Coalfield and in the upper part of the Zone in the Lothians Coalfield; at about the middle of the Lower Similis–Pulchra Zone in the Forest of Wyre Coalfield; at the boundary of the Upper Similis–Pulchra and Phillipsii Zones in the South Wales Coalfield.

The generalized curve for the species of *Laevigatosporites* has a simple form. In the Coal Measures the species first appear at the base of the Communis Zone and rapidly become dominant members of the miospore floras; they reach maximum values of about 20% (sometimes as high as 40%) in seams at the base of the Middle Coal Measures. In the coalfields of Scotland and the north of England, after this peak, they gradually decrease in numbers, averaging between 5 and 10% in the highest seams examined (e.g. East Fife and Cumberland). In the coalfields to the south, where coals occur higher in the succession, these relatively low frequencies may be succeeded at the top of the Middle Coal Measures by frequencies which are sometimes greater than those present lower in the sequence; such distributions are seen particularly clearly in the North Staffordshire and South Wales Coalfields. In the higher part of the Upper Coal Measures the frequencies remain at between 5 and 10%.

Endosporites globiformis generally first appears in the miospore floras in seams at the base of the Middle Coal Measures, thereafter increasing to about 4% in the Lower Similis–Pulchra Zone (occasionally 10% as in the Lothians and Kent fields). Similar frequencies are maintained in the Upper Similis–Pulchra Zone (Lancashire and South Wales), and in the Phillipsii Zone (North Staffordshire). At higher horizons it becomes very rare (Forest of Dean and Bristol and Somerset). It is relatively rare in Scotland and in the more southern part of the Central Province.

Florinites mediapudens seldom exceeds 1% in the coalfields of Scotland and the north of England, although values of 4% occur below the Mid-Modiolaris Zone Marine Band in Cumberland and 5% below Skipsey's Marine Band in the upper part of the Middle Coal Measures of Canonbie and Cumberland. In most of the coalfields of the Central and Southern Provinces it generally increases to about 4% towards the top of the Middle Coal Measures, thereafter decreasing in frequency. The species is rare in the coals examined from the Forest of Dean Coalfield.

These curves provide evidence of stratigraphic changes and regional differences in the sequences of the more common Coal Measures spores. The onset of marine conditions seems to be associated with a reduction in the numbers of at least one species (*Cingulizonates loricatus*). It is important, therefore, to examine the character of the generalized curves in greater detail not only for their stratigraphic value, but for the evidence which they provide of plant distribution and of environmental differences during Coal Measures times.

From the stratigraphic viewpoint it is necessary to consider whether the troughs and peaks shown by the curves accurately represent the situation in the separate coalfields or whether the curves conceal much individual variation. For instance, the curves for *Endosporites globiformis* and *Florinites mediapudens* appear simple in form but in reality they conceal numerous fluctuations in frequency occurring at different levels in the various coalfields. It is possible to recognize two types of curves: (1) those which show considerable inter- and intra-seam variation and in which there is no coincidence between the peaks of abundance in the different coalfields, and (2) those in which there is less deviation between adjacent seams and in which peaks occur at comparable horizons in the different fields. Obviously curves of the second type provide the most reliable basis for the solution of stratigraphic problems. A curve of the first type is given by *Densosporites sphaerotriangularis*, a species which appears to be associated with specialized conditions in the peat swamp (see section on seam correlation). *Crassispora kosankei* and to a lesser extent *Laevigatosporites spp.* have curves of the second type. The parent plants of these species were probably responding to some factor outside the swamp environment, since it is inconceivable that the edaphic conditions in the swamp would have been similar in all the British coalfields at any one period of time. Climate seems the obvious determining factor. It is unlikely that the peaks and troughs are the artificial result of the changing frequencies of the other abundant species, although the overwhelming dominance of one or more species will influence to some extent the frequencies of other species in the Assemblage.

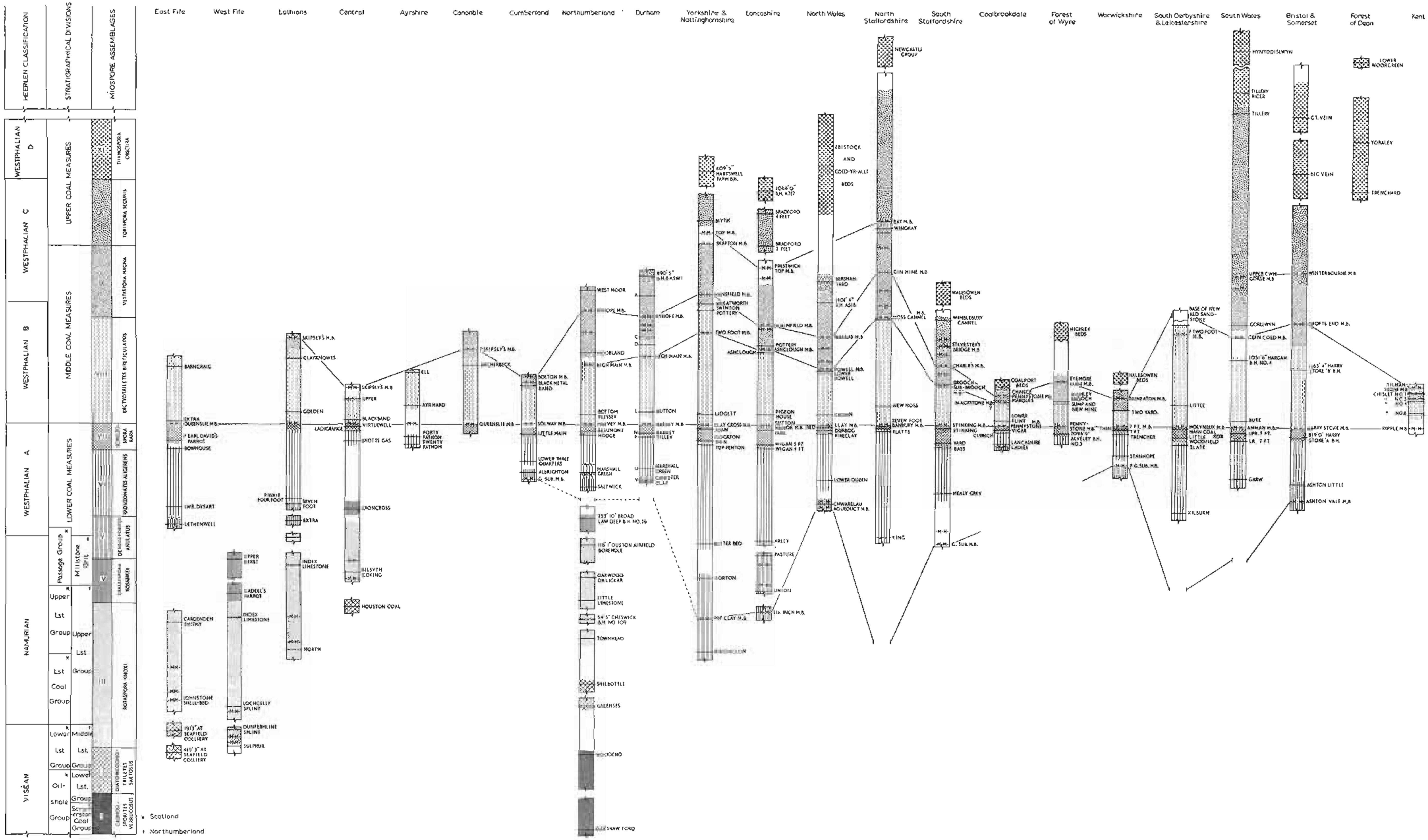
Climate may also account for the geographical variation in the distribution of the saccate *Florinites mediapudens* and the pseudosaccate *Endosporites globiformis*. A latitudinal effect suggests itself providing an adequate temperature gradient between the equator and the poles can be assumed during the appropriate part of Carboniferous time. Possibly topography may have locally influenced the climate. There is, however, another possibility. There is evidence that *Florinites spp.* may have come from plants growing marginal to (Neves 1958), or even outside (Chaloner 1958*c*), the areas of peat deposition. If the species is an allochthonous element in the miospore floras of coal seams as suggested by Smith (1962*a*) then it would suggest that the coalfields of Scotland and the north of England were more remote from the source of the parent plants than other coalfields. The influence of wind direction and of water currents may also determine the proportions of allochthonous species in an assemblage. There is no evidence, however, that *Endosporites spp.* were allochthonous. The elucidation of such questions is necessary if spore evidence is to be used reliably in the solution of stratigraphic problems concerning coal-bearing strata.

SUMMARY OF THE CHARACTERISTICS OF THE MIOSPORE ASSEMBLAGES

This section provides a summary of the data presented in greater detail in the preceding accounts of individual coalfields. The stratigraphic limits of each Assemblage shown in text-fig. 57 for the different coalfields are defined and followed by a statement of the diagnostic species and any features of miospore distribution which are significant in characterizing the Assemblage. Significant differences in the ranges or abundance of species in the different coalfields are also considered.

Grumosisporites verrucosus Assemblage I

More work requires to be done on this Assemblage, which was originally put forward by Butterworth and Millott (1960) to include coals examined from the Scremerston Coal and Lower Limestone Groups of Northumberland (Viséan). The most commonly



TEXT-FIG. 57. Comparison of miospore Assemblage boundaries in the different coalfields based on the composite sections.

occurring spores are species of *Lycospora*, *Calamospora*, and *Granulatisporites*, together with *Anaplanisporites baccatus*. The densospore group is represented by *Densosporites anulatus*, *D. intermedius*, *D. pseudoannulatus*, *D. triangularis*, and *Cingulizonates bialatus*. *Tholisporites scoticus* is abundant at one horizon. Less common in their occurrence are *Grumosisporites verrucosus* and *Schulzospora campyloptera*. *Chaetosphaerites pollenisimilis*, *Cyclogranisporites lasius*, *Verrucosisporites baccatus*, species of *Anapiculatisporites* and *Procoronaspora*, *Acanthotriletes castanea*, and unassigned species of *Leiotriletes*, *Punctatisporites*, *Waltzispora*, and *Convolutispora* have been found at one or more horizons.

Diatomozonotriletes saetosus Assemblage II

This Assemblage originally formed the lower part of the *Rotaspora knoxi* Zone (Butterworth and Millott 1960). It is found in the Greenses Seam of the Lower Limestone Group and the Shilbottle Seam of the Middle Limestone Group of Northumberland; also in the Houston Seam of the Upper Oil Shale Group and in various unnamed seams in the Lower Limestone Group of Scotland. The Assemblage is rich and contains, in addition to the spores present lower in the sequence, species of *Tripartites*, *Rotaspora*, and *Diatomozonotriletes*; the latter genus is apparently restricted to this Assemblage. *Cingulizonates* cf. *capistratus* may be present occasionally.

Some differences have been observed in the miospore floras in the seams of this Assemblage. The Houston Seam, which is at a lower horizon than other coals examined, has an assemblage distinguished by the absence of species of *Rotaspora* and by the presence of relatively high percentages of *Procoronaspora dumosa*. Species of *Diatomozonotriletes*, principally *D. saetosus* and *D. cervicornutus*, are more prominent in the Greenses and Shilbottle Seams, and *D. ubertus* is restricted to these coals. *Rotaspora crenulata* has only been recorded from the Greenses Seam. The greater variety of species present in the Shilbottle Seam is probably due to the fact that it is a relatively thick coal containing several miospore associations including that characterized by densospores. *Cingulizonates* cf. *capistratus*, which does not occur in the Houston, Greenses, and Shilbottle Seams, reaches 5% in the higher of the two coals examined from the Lower Limestone Group of Scotland.

Rotaspora knoxi Assemblage III

Typical Assemblage III miospore floras are present in coals of the Limestone Coal Group and part of the Upper Limestone Group of Scotland and the Upper Limestone Group of Northumberland (Namurian A). Incoming spores include species of *Grumosisporites*, *Microreticulatisporites*, and *Convolutispora*. *Cingulizonates* cf. *capistratus* is more common than at lower horizons and occasionally may be abundant. The horizons at which most of these miospores first occur have not yet been determined precisely. Relatively few of the species present are numerically important. Of the seven species shown in the frequency diagrams for seams in the Namurian A, six belong to the densospore group (*Densosporites*, *Cingulizonates*, and *Tholisporites*). In the seams of the Upper Limestone Group of Northumberland (and the Townhead and associated seams towards the top of the Middle Limestone Group), the assemblages are essentially similar to those found in Scotland. Of the species used to distinguish between Assemblages II and III, *Convolutispora cerebra* and *Vestispora lucida* were not found in the Northumberland coals and *Savitrisporites nux* and *Bellispores nitidus* were less common than in the Scottish coals. This may be due, in part, to the fact that the Northumberland coals do not extend quite so high in the sequence as those from Scotland, where it was noted that several of these species are more commonly present in the higher coals. Bearing this fact in mind, the distributions of *Anaplanisporites baccatus* and *Tholisporites* are similar in the two regions, the latter reaching maximum frequencies about half-way up the E_1 Goniatite Stage. In Northumberland, as in Scotland, *Densosporites pseudoannulatus* tends to decrease in numbers towards the top of the Assemblage. The alternation of densospore-rich and densospore-poor seams present in the Scottish sequences is not so marked in Northumberland, possibly because the coals are mostly thinner. The majority of the Northumberland seams contain less than 30% of densospores compared with 40–45% in Scotland.

Crassispora kosankei Assemblage IV

The base of this Assemblage is defined by the horizon at which the common Coal Measures species *C. kosankei* first appears. The horizon is not easily defined for reasons given earlier, but it lies a short distance below the Orchard Limestone in West Fife. The genera *Rotaspora* and *Tripartites* disappear at about the horizon of the Orchard Limestone in Scotland; they are not present in the coals of the Broad Law Deep and Tranwell Airfield boreholes in Northumberland, which also contain this Assemblage.

Crassispora kosankei is rare and is sometimes accompanied by infrequent specimens of two other spores which become abundant in the Coal Measures—*Lycospora granulata* and *Laevigatosporites spp*. The following lower Namurian A species are present in both Scotland and Northumberland—*Chaetosphaerites pollenisimilis*, *Leiotriletes tumidus*, *Grumosisporites rufus*, *G. verrucosus*, *Acanthotriletes falcatus*, *Convolutispora ampla*, *Reticulatisporites carnosus*, *Savitrisporites nux*, *Bellispores nitidus*, *Densosporites intermedius* (more frequently in Northumberland), *D. pseudoannulatus*, and *Remysporites magnificus*. *Convolutispora cerebra*, small species of *Microreticulatisporites*, *Crassispora maculosa*, *Stenozonotriletes bracteolus*, *Cingulizonates* cf. *capistratus*, and *Vestispora lucida* are all present in the coals of the Upper Limestone Group of Scotland but have not been recorded from the seams in the Broad Law Deep and the Tranwell Airfield boreholes of Northumberland. Of the more common species *Anaplanisporites baccatus* and *Lycospora noctuina* are sometimes abundant, the former reaching higher percentages in West Fife (generally less than 10% in Northumberland).

Densosporites anulatus Assemblage V

This Assemblage, in which *Crassispora* is more frequent and in which *Florinites* (another Coal Measures genus) is present, occurs in the seams of the R Goniatite Stage of the Yorkshire and Nottinghamshire Coalfields, the Passage Group of Scotland, and in the lower part of the Lower Coal Measures. A few of the species present in Assemblage IV persist into the younger Assemblage; they include *Punctatisporites sinuatus*, *Anaplanisporites baccatus*, *Ahrensisporites guerickei*, *Savitrisporites nux*, *Bellispores nitidus*, *Crassispora kosankei*, *Densosporites intermedius*, *Spencerisporites radiatus*, and *Laevigatosporites spp*. Characteristic species include *Densosporites anulatus*, *Radiizonates striatus*, and *Cristatisporites spp.*; *Apiculatisporis variocorneus*, *Reinschospora speciosa*, and *Schulzospora rara* are occasionally present. The Namurian (Millstone Grit) Coals in the Nottinghamshire and Yorkshire Coalfields and those in the Passage Group of Scotland contain more varied Assemblages than are present in the coals occurring in the Lenisulcata Zone. Species which have not so far been recorded from the latter include *Mooreisporites fustis*, *Dictyotriletes bireticulatus* (except in the coalfields of the Northern Province and in Coalbrookdale), *Densosporites sphaerotriangularis*, and *Laevigatosporites spp.* (except in Northumberland).

Radiizonates aligerens Assemblage VI

In most coalfields this Assemblage first appears near the base of the Communis Zone and is well defined by the incoming of *Florinites mediapudens*, *Endosporites zonalis*, *Radiizonates aligerens*, *Pityosporites westphalensis*, *Densosporites sphaerotriangularis*, and by the reappearance of *Laevigatosporites spp.* In the Northumberland and Durham Coalfields occasional specimens of *Laevigatosporites spp.* occur, however, in the Marshall Green Seam, which lies in the Lenisulcata Zone. The seams in the lower part of the Assemblage contain large numbers of *D. anulatus* and *R. striatus*; the percentages of the latter species generally reach a maximum in coals towards the base of the Modiolaris Zone. *R. aligerens*, which does not occur in the lowest seams of the Assemblage, becomes more common above this horizon, except in the Southern Province where it is relatively rare. In the Southern Province *Schulzospora rara* is also less commonly present, in this and the succeeding Assemblage, than it is elsewhere. Locally, significant numbers of *D. sphaerotriangularis* and *Cristatisporites connexus* may occur in seams in the upper part of this Assemblage.

Schulzospora rara Assemblage VII

The Assemblage is restricted to one, two, or, very occasionally, three coals below the Mid-Modiolaris Zone Marine Band. The distinction between Assemblages VI and VII is slight, being based on the absence from Assemblage VII of *Radiizonates aligerens*, but there are other features by which this Assemblage may be recognized. The numbers of *Dictyotriletes bireticulatus*, for instance, are significantly higher than in the preceding Assemblage and, locally, very large numbers of *Densosporites sphaerotriangularis* and *Cristatisporites connexus* may occur. *Vestispora tortuosa*, only occasionally found in the *R. aligerens* Assemblage, is generally present.

Dictyotriletes bireticulatus Assemblage VIII

The lower limit of the Assemblage occurs at the Mid-Modiolaris Zone Marine Band; it differs from the preceding Assemblage in containing *Radiizonates tenuis* (not always distinguished from *R. faunus*) and *Endosporites globiformis* (Smith and Williams 1957), and in the absence of *Schulzospora rara*. *E. globiformis* is restricted to this Assemblage and higher horizons everywhere, except in the Lothians, Durham, and North Staffordshire Coalfields, where occasional specimens have been found in seams below the Mid-Modiolaris Zone Marine Band. Typical species in the lower seams include *Densosporites sphaerotriangularis*, *Cristatisporites connexus*, *Cingulizonates loricatus*, *Radiizonates* cf. *striatus*, and *Vestispora tortuosa*. *Crassispora kosankei* is fairly common in the lower seams, but becomes very infrequent in a seam either just below, or just above, the base of the Lower Similis–Pulchra Zone; above this horizon it increases in frequency, reaching maximum numbers in a seam just below the Two Foot Marine Band of Yorkshire. The higher seams are also characterized by significant numbers of *Cingulizonates loricatus*, *Cristatisporites connexus*, *C. indignabundus*, and *V. pseudoreticulata*. Where *V. pseudoreticulata* has been recorded separately from *V. costata* and *V. tortuosa* it has been found that it is almost invariably confined to Assemblage VIII and higher horizons, whereas the other species have longer ranges. *Densosporites sphaerotriangularis*, *D. gracilis*, and *Radiizonates faunus* may be locally abundant, the latter species particularly in the coalfields of the Southern Province.

Vestispora magna Assemblage IX

The characteristic species, *Triquitrites sculptilis*, *Cristatisporites solaris*, and *V. magna*, first appear in the coal above the Two Foot Marine Band and its equivalents but they are rare, and sometimes absent, in the seams between this horizon and the Mansfield Marine Band, although invariably present (and often common) in the coals above the latter horizon. *Dictyotriletes bireticulatus* is rare in the Assemblage and does not persist above it. In seams in the higher part of the Middle Coal Measures, *C. solaris* is often accompanied by large numbers of *Radiizonates faunus* and *Cingulizonates loricatus*. *Endosporites globiformis* and *Florinites mediapudens* are more common than at lower horizons.

Torispora securis Assemblage X

The Assemblage remains as defined by Butterworth and Millott (1960). The base is defined by the appearance of *Torispora securis* and *Vestispora* (*Foveolatisporites*) *fenestrata* in seams containing a group of small, monolete spores including *Punctatosporites granifer*; only where these small monolete spores occur in appreciable numbers are forms assignable to *T. securis* generally found. *Acanthotriletes triquetrus* and *Cirratriradites megaspinosus* are characteristic of the Assemblage but are never common. *Florinites mediapudens* may be abundant towards the base. *Densosporites* and associated genera are infrequent, but *Cristatisporites solaris* may be locally common near the top of the Westphalian C. At about the same horizon *Vestispora laevigata* and *Triquitrites bransonii* have been recorded from Yorkshire, North Staffordshire (*V. laevigata* only), South Wales, and Bristol and Somerset (*T. bransonii* only). It seems probable that further search would reveal these spores at similar horizons elsewhere.

Thymospora obscura Assemblage XI

This Assemblage occurs in thin seams in the Etruria Marl, Newcastle, and Keele Beds of North Staffordshire, the Coed-yr-Allt and Erbistock Beds of North Wales, the Coalport Beds of Shropshire, the Halesowen Beds of South Staffordshire and Warwickshire, and at equivalent horizons elsewhere. It contains large numbers of small, monolete spores including the verrucose forms *T. obscura* and *T. pseudothiessenii*. The typical species *Mooreisporites inusitatus*, *Schopfites dimorphus*, and *Cadiospora magna* are infrequent. Species of *Triquitrites*, including *T. spinosus* and *T. bransonii*, are fairly common. The characteristic species of Assemblage XI vary slightly in occurrence between the Central and Southern Province: *Alatisporites hoffmeisterii* and *A. trialatus* are confined to the Southern Province and the genera *Cadiospora* and *Schopfites* only occur in the coalfields of the Central Province and in the Forest of Dean. *Crassispora kosankei*, *Densosporites sphaerotriangularis*, and *Florinites mediapudens* are relatively rare in the Central Province but may be common at certain horizons in the Southern Province. The lowest horizons at which the characteristic spores *Cadiospora*, *Schopfites*, and *Thymospora* occur are thin coals in the Etruria Marl of North Staffordshire, generally regarded as being of Westphalian C age. Elsewhere the coals with Assemblage XI are of uppermost Westphalian C age (Forest of Dean), or of undisputed Westphalian D age. Further work on a sequence which can be controlled by other means is necessary before the base of the Assemblage can be determined with certainty.

General comment

It is evident that the vertical changes taking place in the miospore floras of the coal seams of the Carboniferous are broadly similar in the different coalfields. Such regional differences as have been observed in contemporary miospore floras relate more to variations in abundance than to differences in composition. Few species are confined to, or absent from, any one coalfield. The miospore Assemblage boundaries are based on relatively minor changes in the spore floras; the magnitude of these changes is exaggerated in the assemblage frequency tables since the species selected are only a portion of the total miospore flora and the appearance of a new species in the table does not necessarily mean that its range begins at the base of a particular Assemblage. The tables show that in general more than half of the species recorded in a given Assemblage also occur in the preceding and succeeding Assemblages.

There is little similarity between the miospore Assemblage boundaries described and those defined by various authors on the distribution of plant macrofossils. Notable changes in the miospore flora do not take place at the base of the Westphalian nor at the limits of its subdivisions, with the possible exception of the Westphalian C–D boundary. Assemblages IX, X, and XI have similar limits to Dix's Floral Zones F, G, and H, but in the lower part of the succession there is no comparison between the limits of the Floral Zones and those of the miospore Assemblages. The base of Kidston's Yorkian (Westphalian) Stage, on the other hand, more or less coincides with the base of Assemblage VI. This horizon, which lies in the middle of the Lower Coal Measures (Westphalian A), and of Dix's Floral Zone C, occurs where the miospore flora of the Lower and Middle Coal Measures first becomes established. There is no doubt, however, that the ease of definition of such limits is dependent to a very large extent on the conditions obtaining locally at the time of deposition. This is particularly so when work is restricted, as in the present case, to the distribution of miospores within a particular facies. The ease with which the base of Assemblage VI is distinguished in the Yorkshire and Lancashire Coalfields is not paralleled in the Scottish Coalfields, for instance, where the seams in this part of the succession are more closely spaced.

APPLICATION OF MIOSPORES TO STRATIGRAPHY AND THE CORRELATION OF COAL SEAMS

Fossil spores are a valuable source of palaeontological evidence for the solution of problems concerning the stratigraphy and correlation of coal seams. They not only provide information in support of conclusions obtained by other methods but are often the only available source of evidence. This occurs, for instance, when the macrofossils are largely destroyed by the drilling techniques employed. Thus material derived from drillings of the oil-well (mud flush) type, and often from many narrow-diameter borings of other types, is of a fragmentary nature. Sometimes, also, the coal geologist is confronted with a problem which cannot be solved using macrofossils, as, for instance, when attempting to relate the constituent parts of a split seam to the parent seam.

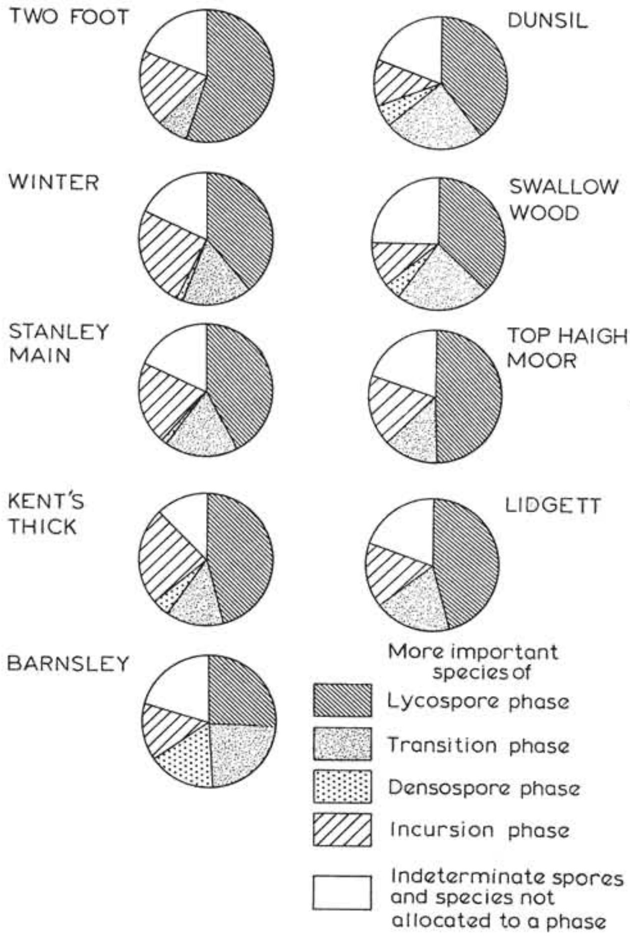
The correlation of coal seams by means of their contained spores is usually based on the subjective comparison of the miospore floras derived either from whole seam samples or from a series of subsections representing the full seam thicknesses. Positive correlation is assumed if the species comprising the floras under comparison are the same and their frequencies are roughly similar. While accurate correlations are often achieved by this means over fairly large areas, serious errors can arise due to changes in seam structure within short distances. Also, similar floras may occur within separate seams of approximately the same stratigraphic age.

Within recent years attempts have been made to increase the accuracy of interpretations based on palynological data from coal seams in two directions. Firstly, by furthering knowledge of the environmental conditions relating to the deposition and development of coal seams (Thomson 1951, von Karmasin 1952) and particularly the ecology of the coal swamps miospore flora (Smith 1962*a*, Marshall and Smith 1965), and secondly, by removing some of the subjectivity by the use of statistical methods (Tomlinson 1957, Gray and Guennel 1961, de Jekhowsky 1963). In the following section consideration is given to each of these aspects.

Effect of environment on the miospore floras

The miospore floras of Carboniferous coal seams are rich in species, most of which are considered to be derived from vegetation growing within the basin of peat deposition. Present-day observations show the marked filtering effect of forest vegetation, so that pollen grains transported from distant sources (generally the smaller grains under 30 μ in size) do not make a great contribution to the pollen spectrum at ground level. References to some of this evidence are given by Dimbleby (1961). It is probably safe to conclude that similar effects operated with spores in Carboniferous times. Another possible source of confusion in palaeoecological studies based on palynological evidence is the effect of differential preservation of the spore exines. It is known that environment affects the rate of decomposition of pollen grains and that even under identical conditions there is considerable variability in their fossilization (Sangster and Dale 1961). It is not known how far the Carboniferous spore floras are representative of the spore rain of the time, so that conclusions based on visibly decomposed floras should obviously be treated with caution.

Despite the large number of spore types described in the literature only a small number, some twenty to fifty species, occur with any regularity in seams formed during a restricted period of geological time and only a few of these species are abundant. In the Upper Carboniferous the abundant genera include *Lycospora*, *Laevigatosporites*, *Densosporites*, and *Crassispora*. The species of these genera vary in abundance at different horizons within coal seams and it is therefore possible to subdivide the miospore floras into a small number of distinctive spore associations, each usually dominated by one or other of these genera (Smith 1957). These spore associations are assumed to correspond to the different types of vegetation growing in a particular environment within the area of peat deposition.



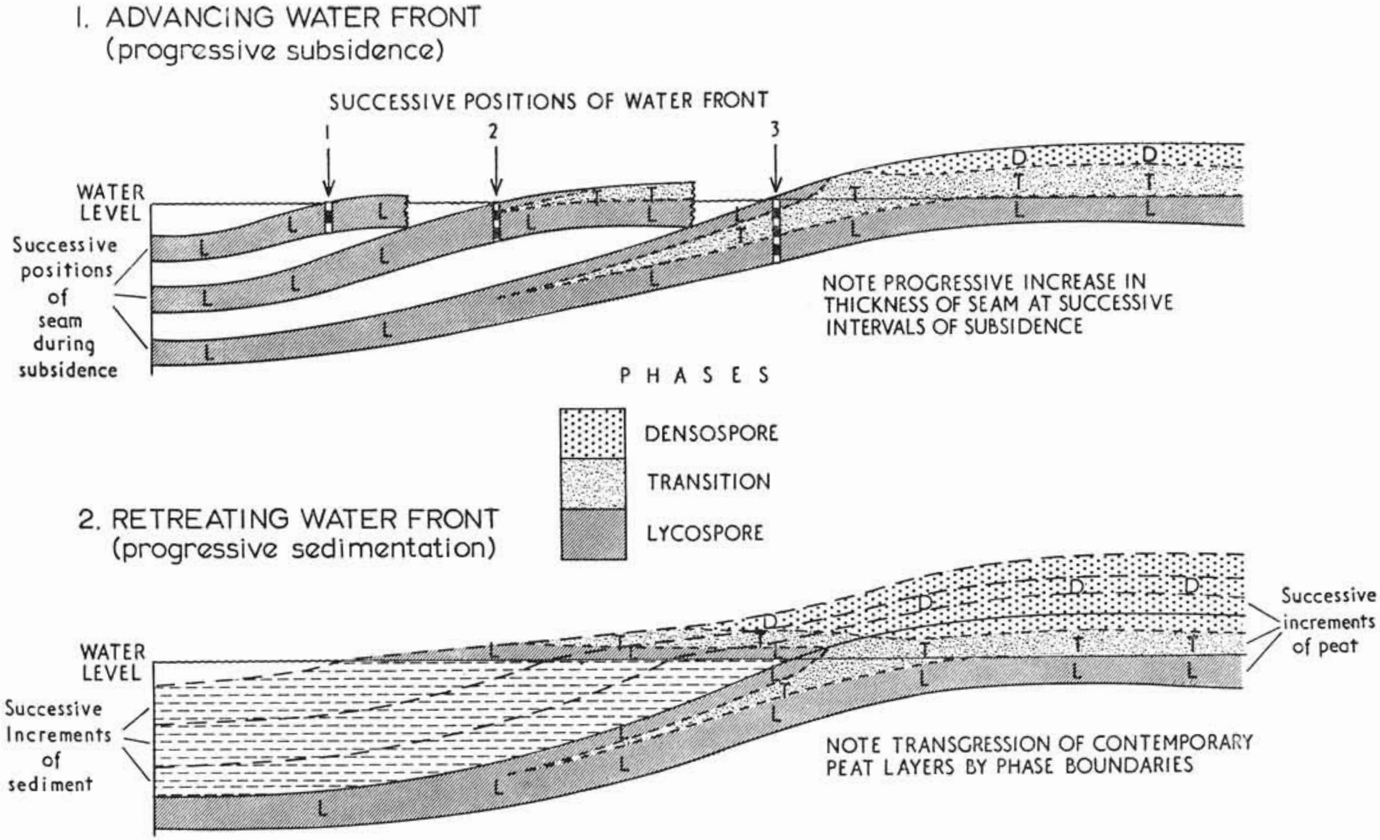
TEXT-FIG. 58. Proportions of the different miospore phases in seams between the Clay Cross and Two Foot Marine Bands of the Yorkshire Coalfield (summary of data from the Kellingley, Cross Hill, and Gate Farm boreholes)

In Britain, in thick seams of Upper Carboniferous age, the vertical successions of the spore associations within the seams follow the same basic pattern and are related broadly to the petrographic coal types (Smith 1962*a*, 1964). The miospore floras in the thicker seams in a restricted part of the geological sequence, therefore, consist of the same species in roughly the same proportions. However, the influence on the vegetation of geological and climatological factors, particularly those which influence the water-levels within the swamp, tend to give the vertical successions of spore associations within seams a distinctive and characteristic pattern by which they can be recognized over wide areas.

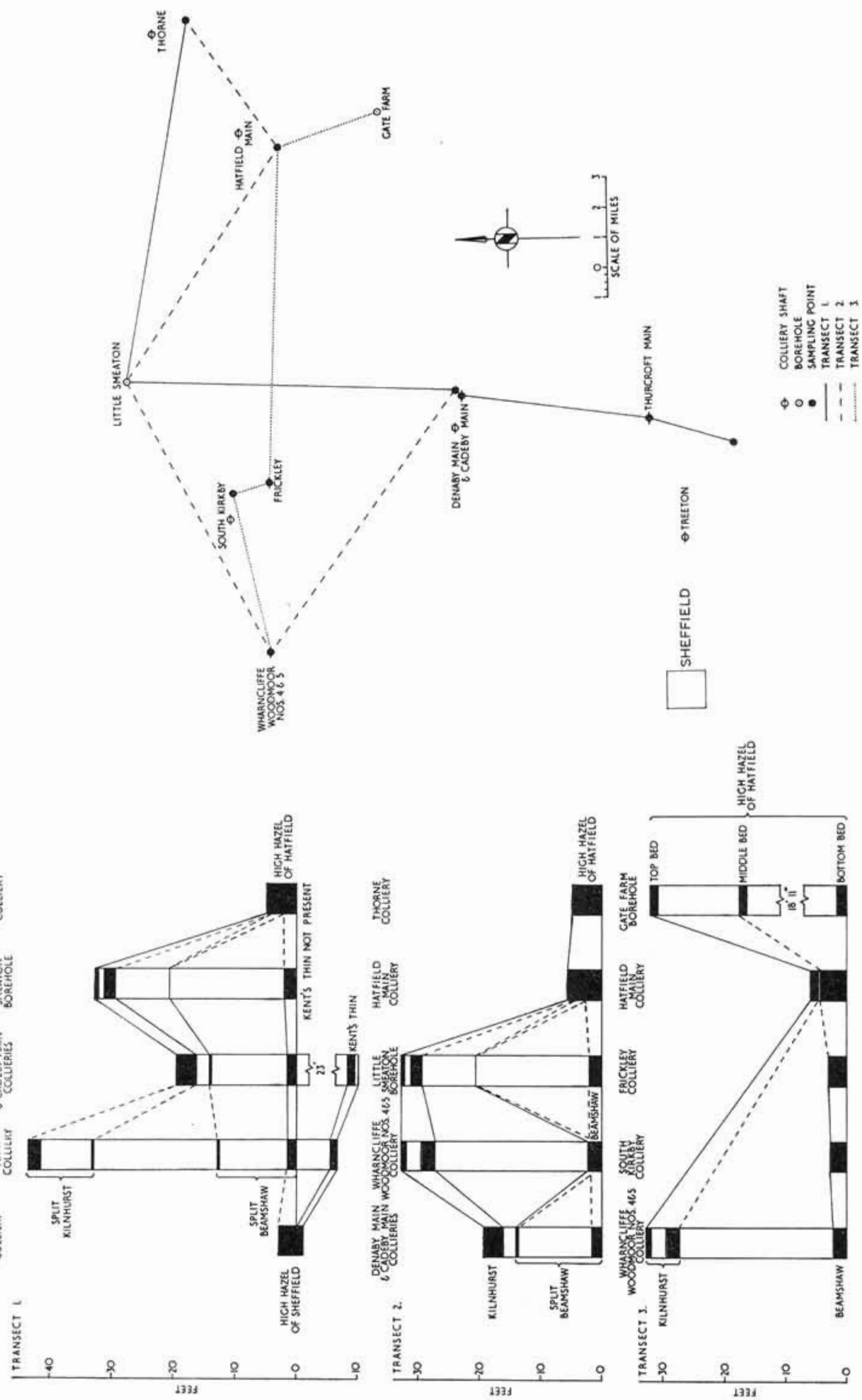
It is convenient to refer to the successive portions of seams characterized by the different spore associations as phases. The species which characterize the four phases so far recognized are listed by Smith (1962*a*). It is important to note that not all the species of *Lycospora* and *Densosporites* belong to the phases bearing the names of these genera. Text-fig. 58 shows the proportions of these four spore associations in the more important seams of the Yorkshire Coalfield lying between the Clay Cross and the Two Foot Marine Bands.

The generalized sequence begins at the floor of the seam with the Lycospore phase, usually associated with bright, vitrainous coal, and culminates in the middle or upper portions with the Densospore phase. The later is usually associated with dense, hard, durainous coal. Between these two phases the Transition phase occurs, which is frequently characterized by *Laevigatosporites spp.* and associated with coals of petrographic types the same as, or intermediate between, those of the phases above and below. Where peat formation continued after the Densospore phase the sequence is reversed so that in some seams bright coal of the Lycospore phase is found adjacent to the seam roof. The fourth (Incursion) phase, which has been so named because it may, in part, result from fresh-water incursion over the peat surface, may occur at any level in the seam. The spore association of this phase, which may be accompanied by allochthonous petrographic constituents, characterizes inferior or durainous coals. These coals (tenuidurites) are petrographically distinct from those associated with the Densospore phase (crassi-durites). The spore species present usually include those of the Lycospore or Transition phase. The sequence of phases is often more complex than that described; thus portions of the spore sequence may be repeated at successive levels within the seam, and in some seams (particularly where thin), the full sequence may not occur. The thickness of coal associated with the different phases may vary considerably, hence it is important that seams are sampled at close intervals and with due consideration of all obvious petrographic changes in the profile. Only in this way can a true record of the vertical succession of miospore assemblages within a seam be obtained for the satisfactory elucidation of correlation problems.

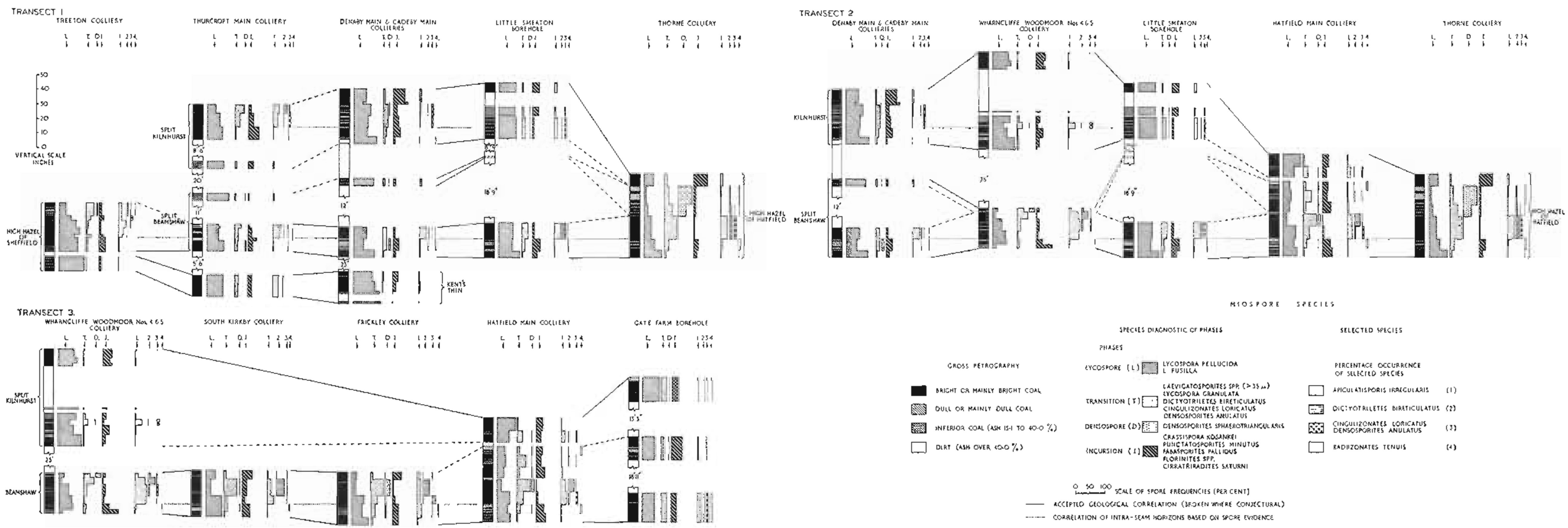
The conditions which determine the sequence of phases within a seam are complex and as yet not fully understood. Regional studies of individual seams or seam sequences where the geology and palaeogeography have been established have, however, proved helpful. Thick beds of durain of the Densospore phase extending over many square miles are the exception rather than the rule in British coal seams, although the phase may be present in many seams in thin layers of limited lateral extent. The conditions favouring the growth of the vegetation giving rise to the Densospore phase would appear to have been rather specialized. A prerequisite for the formation of this phase seems to have been the prior accumulation of some thickness of peat in a relatively stable environment. In such an environment the depth of water covering the peat during successive stages in its formation would diminish as the thickness of the peat accumulated, always assuming that the climate was sufficiently humid to allow the peat to form as a separate hydrological unit above the general ground water level. If, however, subsidence maintained a roughly constant depth of water over the peat subsequent to the initial stages of peat formation, it is likely that only the Lycospore or Incursion phases would occur. This interpretation is supported by the investigations of Butterworth (1964) in certain coalfields of the Central Province, who showed that densospores are more abundant in



TEXT-FIG. 59. Development of miospore phases in relation to the formation of a split seam (reproduced by permission of Oliver and Boyd, Edinburgh)

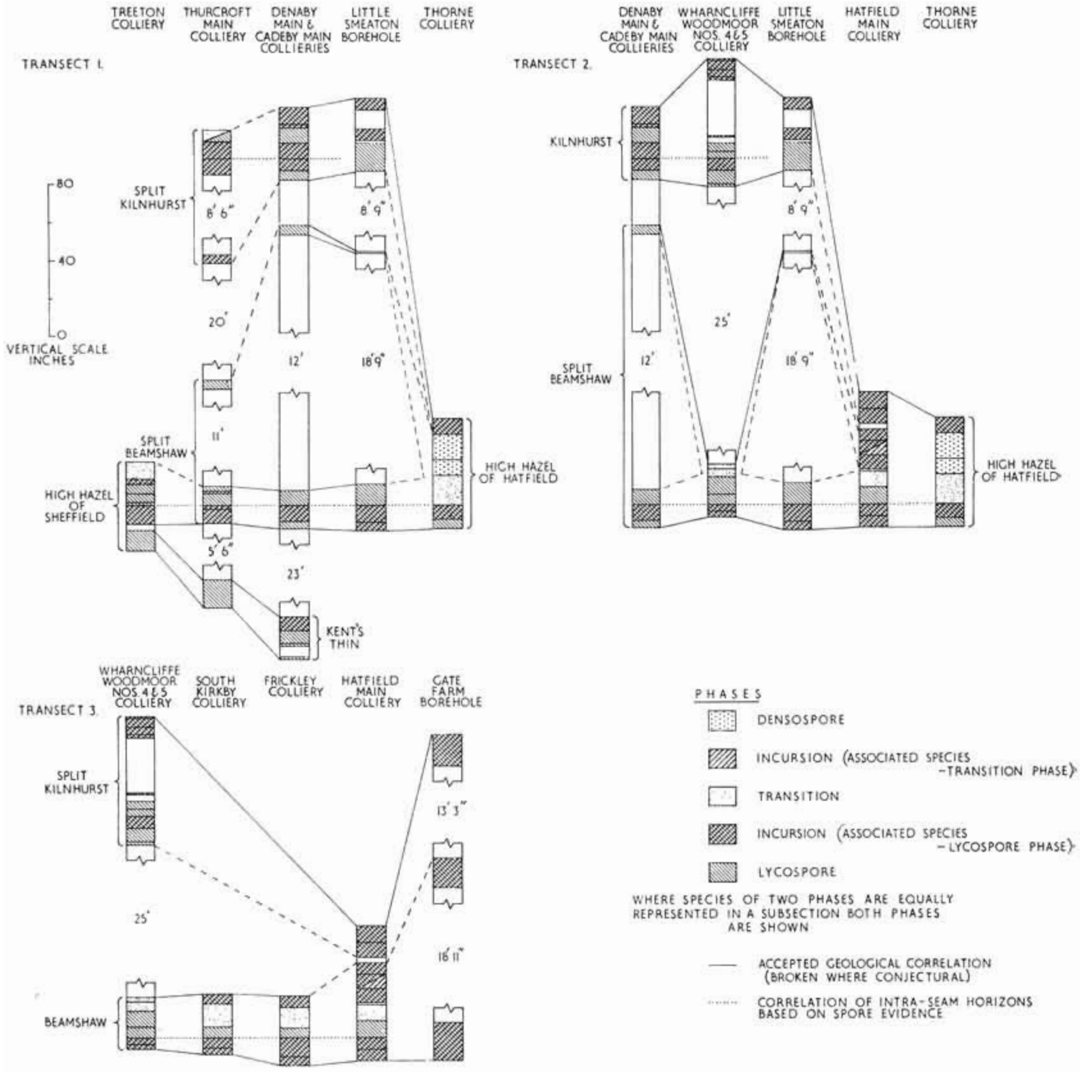


TEXT-FIG. 60. Location and correlation of samples of the High Hazel Seam and its constituent beds examined for miospores



TEXT-FIG. 61. Profiles of selected miospores and of miospore associations characterizing the different phases in the High Hazel Seam and its constituent beds.

the thicker seams in the condensed part of the sequence, and that in those parts of the coalfields where the sequence is expanded, and the seams on the whole thinner and more numerous, the numbers of these spores are diminished.



TEXT-FIG. 62. Miospore phases in the High Hazel Seam and its constituent beds

Subsidence and seam-splitting may therefore greatly influence the compositions of the miospore floras in coal seams. It is of particular importance in seam correlation work to consider the relationship between the sequences of miospore associations in the leaves of a split seam and the sequence in the seam formed by their union. The generalized development of the sequence of miospore associations in a case involving a single split is shown in text-fig. 59. It is important to notice that the sequence of phases in the combined seam is not the sum of the sequences found in each of the beds into which it splits.

An actual example, chosen to show how the vertical distributions of spores and phases within a seam are related to changes in its thickness and structure, is given in text-figs. 60–62. In this example the seams concerned are the High Hazel of Hatfield and the beds into which it splits in the west and south-west known as the Kilnhurst and the Beamshaw. Both the Kilnhurst and the Beamshaw are subject to further splitting in certain directions and in the Sheffield area the latter seam unites with an underlying coal, the Kent's Thin, to form the seam there also known as the High Hazel.

The locations of the samples taken for miospore examination and a series of transects across the coalfield to show the relationship of the various coals, based on the work of Wilcockson and Goossens (1957), are given in text-fig. 60. Text-fig. 61 shows the gross petrography and the vertical distributions of the miospore associations constituting the different phases, together with the distributions of certain spores which are restricted to particular parts of the seams. The subdivisions of the seams used in the investigation were those prepared for seam analysis in the course of normal Coal Survey work but for these special miospore investigations were unfortunately rather thick. They show sufficient detail, however, to be instructive in the present context. The continuous and broken lines in text-fig. 61 show the accepted correlations of the coals; they do not necessarily join parts of seams with comparable miospore assemblages—these are indicated by dotted lines.

It is apparent that the pattern of spore distribution in the profile of the High Hazel Seam at Thorne Colliery possesses features which are not shown in the profiles of the beds into which this seam splits. Also that the profiles of the Beamshaw, Kilnhurst, and Kent's Thin Seams differ from one another although the characteristics of each seam persist laterally, and are in part recognizable in portions of the combined seam at Hatfield Main Colliery.

In the High Hazel of Hatfield Seam at Thorne Colliery all four phases are represented, the sequence beginning and terminating with the Lycospore phase (associated with species of the Incursion phase at the top of the seam). A prominent feature is the presence of a considerable thickness of coal in the upper part of the seam representing the Densospore phase. Spore species of the Transition phase occur on either side of this phase but due to the thicknesses of the subsections used in the examinations they only dominate the miospore floras in the part below.

The assemblages in the Beamshaw Seam show significant changes at different levels in the seam. At Frickley and South Kirkby Collieries, for instance, *Lycospora spp.* dominate the assemblages up to about the middle of the seam but decrease markedly in numbers above this level, becoming slightly more abundant towards the top. Where the numbers of *Lycospora spp.* decline, *Laevigatosporites spp.* and *Dictyotriletes bireticulatus*, species typical of the Transition phase, become more abundant and associated with them are numbers of *Densosporites sphaerotriangularis*. Species characteristic of the Incursion phase are present in significant numbers in the lowest and highest parts of the seam. A distinctive feature of the spore profile of this seam is the relatively sudden appearance at all localities of large numbers of *Apiculatisporis irregularis* at the level indicated by the dotted line. Another species with a distinctive vertical distribution within the seam, and which is present at the same level in most profiles, is *Radiizonates tenuis*. The sequence of miospore assemblages is not everywhere as fully developed as at South Kirkby and Frickley Collieries. To the south at Thurcroft Main and Denaby Main Collieries and in the north at Little Smeaton borehole, for instance, the top portion of the Beamshaw Seam is separated from the main bed by some thickness of sediment. The Transition phase is obviously here cut out by the subsidence which temporarily interrupted peat deposition.

The spore profile of the Kilnhurst Seam at Cadeby Main Colliery mainly comprises spores of the Lycospore and Incursion phases. Small numbers of spores of the Transition phase occur in the lower and middle parts of the seam below the horizon at which a prominent dirt parting is present at Wharncliffe Woodmoor Colliery and in the Little Smeaton borehole. Except at Thurcroft Main Colliery the top part of the seam is everywhere characterized by large numbers of species of the Incursion phase.

The Kent's Thin Seam, which lies below the Beamshaw, is characterized by having a spore flora poor in species. These species mainly belong to the Lycospore phase with relatively small numbers of species of the Transition and Incursion phases. At Denaby Main Colliery, where it was possible to examine the seam by subsections, a general diminution in the numbers of *Lycospora spp.* occurs from the floor to the roof of the seam with a corresponding increase in the numbers of the remaining spore types.

In order to show more concisely the quantitative data given in text-fig. 61, in text-fig. 62 profiles have been constructed showing the sequence of phases in the individual seam sections. The correlation lines are as previously given. It will be seen that there is quite good agreement between the two sets of data.

The significant feature which emerges from this investigation is the effect of subsidence on the development of floras adjacent to, and removed from, a zone of instability. The spore profile of the seam at Thorne Colliery differs significantly from that at Hatfield Main Colliery and from those of the separate beds elsewhere, in possessing an horizon in the upper part of the seam containing abundant spores of *Densosporites sphaerotriangularis*. The spore profile of the lower part of the seam at this colliery, as might be expected, closely resembles that of the Beamshaw Seam elsewhere. It seems clear that the subsidence which took place to the south and to the west of Hatfield Main Colliery, and which led to the considerable thickness of dirt separating the Beamshaw Seam from the Kilnhurst Seam, modified the peat-forming environment at Hatfield Main in such a way that it was unfavourable for the prolonged growth of the vegetation of the Densospore phase. No modifying influence was operative at Thorne Colliery, however, and the spore profile reflects the normal sequence of vegetation types which is found repeatedly in most thick coals of Carboniferous age.

Much of the work on seam correlation in the British coalfields concerns structural changes of this type, although sometimes these changes are more complex. The careful study of spore profiles along the lines described generally gives information of value. One advantage in using spore associations for correlation purposes is that while individual species may be variable in their occurrences and frequencies, the associations of which they are members often persist more or less unchanged over wide areas. The dangers of basing conclusions on a small number of samples must be emphasized, however. Thus in text-fig. 61 it will be seen that the spore profile of the Beamshaw Seam at Frickley Colliery resembles that of the High Hazel Seam at Thorne Colliery and the comparison of these two profiles in isolation could easily lead to the erroneous conclusion that the coals are equivalent. Similarly, the close similarity in the spore profile of the top bed of the Kilnhurst Seam at Thurcroft Main Colliery to that of the main bed of the Beamshaw Seam in the Little Smeaton borehole could also lead to an incorrect correlation.

Techniques of correlation by spores

The general approach to correlation problems is discussed first and is followed by a consideration of the aspect of accuracy and the use of statistical procedures. These procedures are being more intensively investigated at the present time.

(*a*) *Extended sequences*

When the problem concerns the correlation of seams encountered in deep boreholes or cross measure drivages without the help of a nearby established sequence for comparison, the first essential is to establish as precisely as possible the position of the Assemblage boundaries relating to the part of the geological succession under investigation. For this purpose three lines of evidence are used: firstly that based on the established ranges of certain species (unfortunately the most useful spore types are often among the less common), secondly the qualitative composition of the miospore flora, and thirdly the abundance of certain species which vary in their frequencies at different parts of their stratigraphic ranges. These data can usually be obtained from the examination of composite samples representing the full thickness of each seam. If the sequence of seams is in, or near, a part of a coalfield where the general succession of seams is well established it may be possible to suggest the identity of the major seams within each Assemblage by interpolation. De Jekhowsky (1963) has given a method of correlating horizons in two boreholes using the relative frequencies of all the pollen grains (grouped into broad categories) in the horizons, based on the concept of 'minimal distance'. The method, however, is not applicable to the identification of individual seams in a closely spaced sequence in which there are no progressive changes in the frequencies between adjacent seams.

The search for the stratigraphically significant spore species may be facilitated by the examination of the particular petrographic coal types with which they are known to be normally associated (Smith 1962*a*). Further, it may be possible to decide from the petrography of the seam whether the 'absence' of a particular species is due to ecological rather than evolutionary causes. Adequate statistical safeguards must, however, be employed in recording 'absence'. R. C. Tomlinson (1957) has provided a basis on which this can be determined with a considerable degree of reliability. In using the frequencies (or ratios of frequencies) of species it is necessary to consider trends over a number of seams, since these are a more reliable guide to stratigraphic position than spore numbers in individual seams, which may be occasioned by local environmental factors temporarily favouring the parent plants. Greater precision is sometimes possible for determining the stratigraphic positions of seams within an Assemblage. On present evidence, certain species appear to be restricted in their occurrence in a coalfield to particular seams within a given Assemblage. Thus, by using such species collectively, it is possible to suggest certain seams and eliminate others as possible correlatives when dealing with seams in extended sequences. Several such species are known and their numbers may increase with a more intimate knowledge of the miospore compositions of seams within the different coalfields. Eventually their occurrence may prove to be of more than local significance.

Another possible means of relating seams to their approximate positions within an

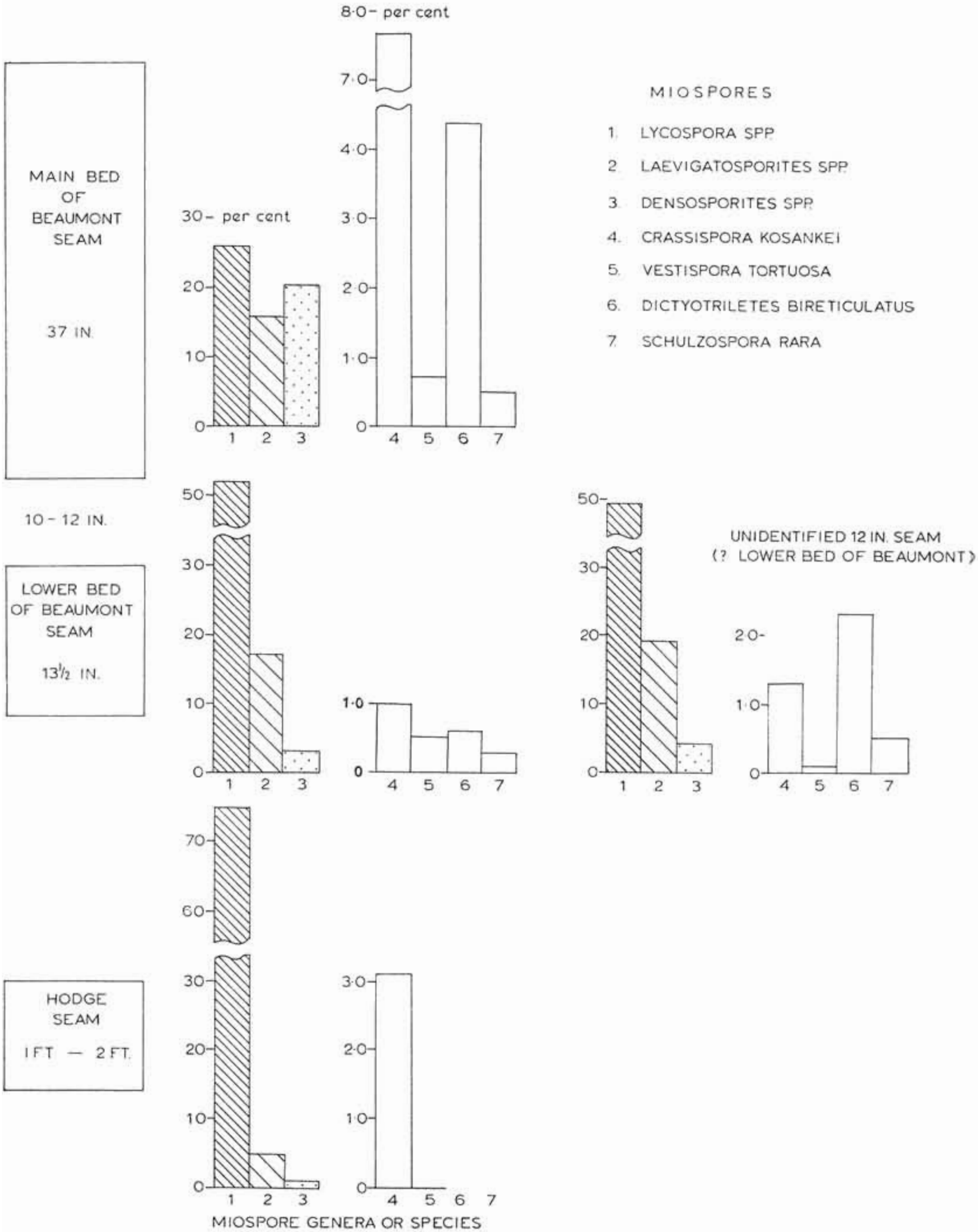
Assemblage stems from trends in size which some spores exhibit over their stratigraphic ranges. The size variation of *Crassispora kosankei* is at present being studied in this connexion and other species are also under investigation. Only the more abundant species in the Assemblage are potentially useful in this respect.

(*b*) *Individual seams*

In favourable instances it may be possible to distinguish between adjacent seams in a sequence by comparing the miospore floras of composite samples. The comparison should take account of the total number of genera and species present, the relative abundance of the commoner and rarer species, the number of different naturally occurring spore associations (phases) represented in the miospore floras, and the relative abundance of the species comprising each association.

An example of the solution of a correlation problem using composite samples is shown in text-fig. 63. This problem concerned the loss of the Beaumont Seam over a fairly wide front at the Montagu Colliery, Northumberland. It was uncertain whether the failure of the seam was to be attributed to a fault or to a wash-out. In a short heading, driven from the Beaumont Seam workings through the discontinuity, a 12-in. coal was found and the question arose whether this 12-in. coal was the lower bed of the Beaumont Seam (the main bed above the dirt band having been washed out), or the up-faulted Hodge Seam. The histograms in text-fig. 63 show the percentage frequencies of certain selected miospores in the coal samples examined. A comparison of the data leaves little doubt that the unidentified coal was the correlative of the lower bed of the Beaumont Seam, a conclusion which was subsequently verified. Further examples of the use of spore frequencies, based on composite seam samples, are given by Butterworth and Millott (1957, pl. 3) in their correlation of certain seams in the Lancashire Coalfield.

The overall characteristics of the miospore floras in adjacent coals in a sequence are often so similar that it is impossible to discriminate with certainty between individual seams. In these instances, and where distances separating the sampling localities are fairly large and structural changes may have taken place in one or more of the seams, it is necessary to examine the spores from subsections of the seam. The boundaries between these subsections should, if possible, correspond to obvious changes in petrographic composition. The comparisons in these instances are based on features of the spore profiles. In the past it has been the practice to consider only the profiles of a limited number of species—usually those which show marked changes in frequency within the seam, or which are restricted to a portion of the seam profile. Examples of this method of correlation are to be found in Butterworth and Millott (1957, pls. 4, 5) and Smith (1962*b*). As mentioned previously, a more consistent picture of vertical changes taking place within a seam is obtained by plotting the proportions of species belonging to the different naturally occurring plant associations (phases). This type of analysis also permits a more reliable assessment of the significance of the less common species. The variable occurrence of such species in a series of profiles does not necessarily imply lack of correlation if the phase to which they belong is present in all profiles, although considered in isolation the evidence of such species might suggest a contrary conclusion. The suite of histograms for the Beamshaw Seam (text-fig. 62) is an example of the potential value of using the sequence of phases for correlation purposes. A further advantage of using natural associations of spores is that it provides a rapid means of



TEXT-FIG. 63. Miospore frequencies in coal seams at Montagu Colliery assessing the gross changes in the vertical distributions of miospores within a seam. With thick seams the time required for preparing and counting spore separations in order to establish profiles of individual species is considerable; further, in many operations involving the construction of drivages and the drilling of boreholes, a rapid answer to a problem may result in a considerable financial saving. The phase of a sample can sometimes be established by inspection; if this is not possible, in most cases it can be ascertained from a count not exceeding 100 spores, since in most coals a small number of species is clearly dominant. Thin seams, however, may prove difficult to identify, even on a profile basis, since they probably originated under more or less constant environmental conditions and changes in the distributions and frequencies of the contained spores are likely to be minimal.

The comparison of one set of data with another is largely subjective and the conclusions depend to some extent on the experience of the individual. Statistical methods designed to test for significant differences between miospore floras have been used with some success (see below), but because of the number of variables involved in dealing with them, such methods have so far only been applied to data based on whole seam samples. In assessing the significance of spore data it is necessary to take account of the differences arising from counting and preparation errors and also the lateral variations in spore numbers arising from natural causes. All species, for instance, may not fluctuate in their numbers to the same degree. For these reasons, in correlation problems, it is always advisable to sample the named seams at several localities in order to establish the degree of variability in their spore floras.

(*c*) *Statistical considerations*

There are three main questions to which statistical methods can provide answers: (1) How well does the distribution of spores, as given by a spore count, represent the distribution in the seam sample? (preparation and counting errors). (2) Is the spore distribution at one point similar to that at points several miles away in the same seam (within seam variability)? (3) How reliably can a seam be identified using the distribution of species?

(1) *Preparation and counting errors.* Tomlinson (1957) has discussed the first two questions and given estimates of the size of the errors. Using preparations and counts by the authors and R. W. Williams, he showed that for common spores counting errors were of the same order as those predicted by assuming a binomial distribution for the spores, i.e. if n spores of this (common) type were observed in a total count of N spores, the predicted standard deviation of the counting error would be

$$\sqrt{\left(\frac{n(N-n)}{N}\right)}.$$

Tomlinson also showed that the preparation errors were of the same order as, or larger than, the counting errors. He demonstrated that to increase the accuracy of a count, it was better to count N spores on two independent preparations from the same pillar sample than to count $2N$ spores on a single slide.

In collecting data for the present work, 500 spores were counted on each slide. Table

6, which has been calculated from Table 4 of Tomlinson (1957), shows how the maximum error of the reported figure can vary with the number of spores counted.

TABLE 6. Maximum error of reported figure

Total number of spores counted	*Lycospora* (*Spore* D1) (*Average* 28·5%)	*Crassispora* (*Spore* B4) (*Average* 4%)
500	±7·2%	±2·9%
1000	±6·2%	±2·7%
2000	±5·6%	±2·5%

Increasing the number of spores counted by a factor of 4 would have decreased the maximum error by only about 20%. In the absence of preparation errors, the maximum error would have decreased by 50%. Discussions of the increased accuracy obtainable by increasing the number of spores counted often ignore the effect of preparation errors, and can give a false picture of the effects on the errors of the reported figure. Tomlinson concluded that 'the errors arising from the preparation and counting of the samples are not too great and that the examination of a few thousand spores on one or two slides provides a satisfactory estimate of the average conditions in the seam section'. The above table suggests that this conclusion is also valid when 500 spores are counted. The possibility of errors due to bias between two counters, or between counts by the same individual at different times, needs to be mentioned. Such biases can usually be eliminated by check counting.

On the question of rare spores Tomlinson gives a table showing the limits of the number of spores of a rare type in a seam for various numbers of the spore observed in the count. If no spores of a particular type are recorded in a count of 500 spores, the percentage of this spore in the population could still be as high as 0·92. For a count of 2,000 spores this upper limit on the percentage in the population is reduced to 0·23. Clearly, a rare spore has a greater chance of being recorded 'absent' in a count of 500 than in a count of 2,000. In practice, however, the whole area of the slide is scanned for the presence of spore types not found in the counted area, so that a spore type recorded as 'absent' could only be present in the seam in very small numbers, if at all.

(2) *Variability within a seam*. Tomlinson analysed the results from a number of seams at different localities separated by several miles. On this limited information, he concluded that a pillar section does give a reasonable picture of the spore population in a seam over a limited area and it appears likely that a discriminatory analysis between coal seams is possible on the basis of their spore content.

(3) *Seam identification using statistical methods*. (i) χ^2 test. Gray and Guennel (1961) suggest that the χ^2 test may be used to identify a seam using the relative abundance of miospore types. The observed frequencies of the spore types in the unidentified seam are compared with those in samples from known seams, and the value of χ^2 is calculated for each comparison. If the value of χ^2 for the comparison with Seam A is not significant, but the values for other seams are significant, then the unknown sample is considered to be from Seam A. For this method to be of use, comparisons between samples which are known to come from a limited area of the same seam must not

give significant values of χ^2 or there will be no standard against which the sample from the unknown seam may be compared. Thus in the following example, which concerns three seams in the Yorkshire Coalfield, when all possible pairs of samples from the same seam were compared all but one gave a significant χ^2 value and the test was therefore inapplicable.

Seam	*Number of samples*	*Number of pairs*	*Number of pairs with χ^2 significant*
Barnsley	6	15	14
Dunsil	6	15	15
Swallow Wood	5	10	10

(ii) Discriminant analysis. This type of analysis removes some of the subjectivity associated with the visual comparison of spore frequencies. If it is known that the unknown sample is from one of two possible seams, the relative frequencies of spore types in several samples from each seam are used to calculate L, the linear discriminant function, having the form:

$$L = ap_1+bp_2+...+cp_n,$$

where p_1 are proportions of spore type 1,
p_2 the proportions of spore type 2, etc.;
a, b, c, etc., are constants;

such that the values of L for the samples from Seam I differ as much as possible from the values for Seam II. If the average value of L for Seam I is L_1 and the average for Seam II is L_2 and if $L_1 > L_2$, then, for the unidentified sample, the value of L can be calculated and the sample could be

either assigned to Seam I if $L \geqslant \dfrac{L_1+L_2}{2}$

or assigned to Seam II if $L < \dfrac{L_1+L_2}{2}$.

The number of spore types used in L will be small, generally less than 5, as the amount of calculation required to obtain L increases rapidly with the number used. There are simple mathematical procedures for selecting the spore types to be used from all the spore types identified in the seams.

The method may also be extended to assign an unidentified sample to one of three or more seams, but it is rather elaborate for more than three seams. The method for two seams is given in statistical textbooks and the extensions of the method in Rao (1952).

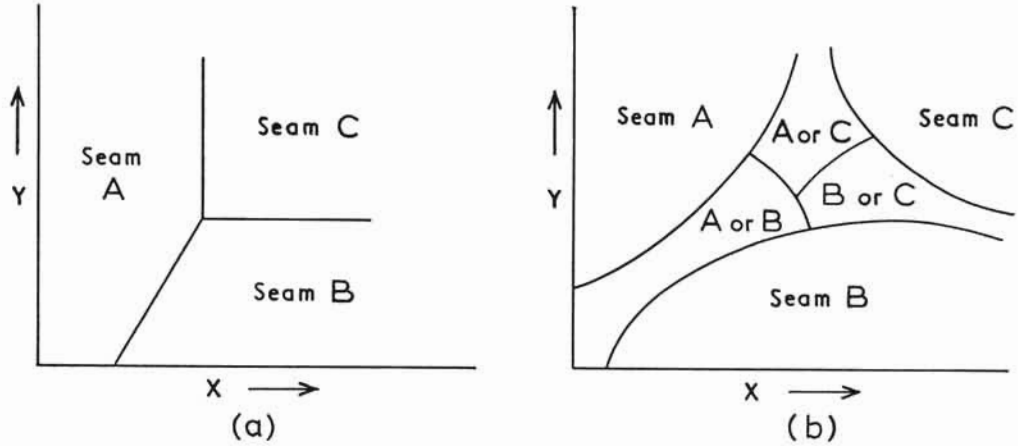
The method of discriminating between three seams (A, B, C) is a simple extension of the two-seam method. Two discriminant functions have to be found:

X for discriminating A from C;

Y for discriminating B from C.

$X+Y$ gives a third condition for discriminating A from B.

To use these functions, X is plotted against Y. The three discriminants divide the area of the graph into three portions, corresponding to the three seams, and the unidentified sample is assigned to the seam in whose region the value of (X, Y) falls (text-fig. 64*a*).

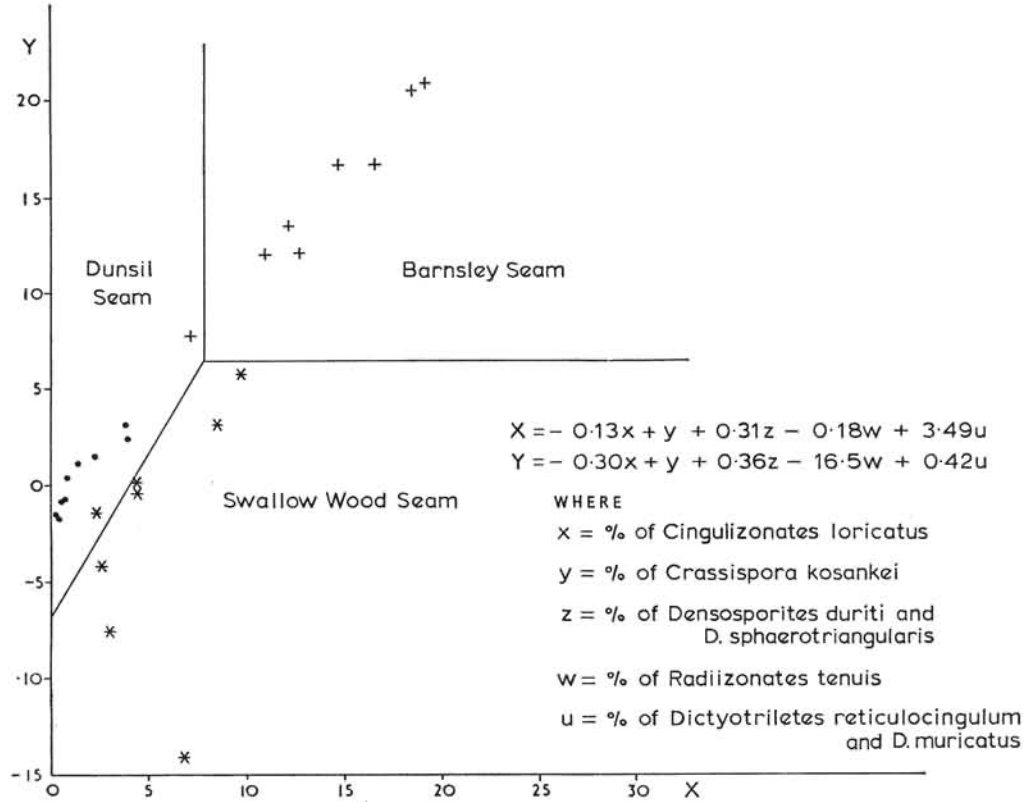


TEXT-FIG. 64. Discriminant functions to separate three seams when (*a*) discrimination between seams is good and (*b*) discrimination is poor

If the seams have rather similar spore distributions, it may not be possible to find discriminants which give a good separation. In this case the situation shown in text-fig. 64*b* would arise where there are six regions, and some samples can only be assigned to one of two seams. This might still be of use, as the more typical samples would still be assigned correctly, and it may be possible to assign the other samples using other properties of the coal. Indeed, it would be possible to use certain properties of the coal in the discriminant function. One could, for example, use: $L = a \times$ per cent. spore $A + b \times$ per cent. chlorine $+ c \times$ strength of coal. The amount of calculation involved in the case of three seams is generally more than twice that involved in the case of two seams, as it will often happen, for instance, that three spores are sufficient to discriminate between seams A and B but may not discriminate well enough between A and C, and perhaps two extra spores will be required to improve the contrast. This occurs in the case of the three seams (Swallow Wood, Dunsil, and Barnsley) for which the discriminating graph using the data mentioned in (i) above is shown in text-fig. 65. It is apparent that quite good separation is achieved, particularly for the majority of the samples of the Barnsley Seam. The incorrect identification of one sample of this seam is due to the reduction, in this sample, of the amount of massive dull coal and the associated spores which normally characterize the seam.

SAMPLING AND SAMPLE PREPARATION

The samples of coal upon which this work is based were obtained either directly from exposures of the seams or from borehole cores. The majority of the samples taken from exposures of seams in colliery workings were 'pillar' sections, i.e. blocks of coal, roughly 1 sq. ft. in cross-section, which, fitted together, corresponded to the full height of the seam. Other underground sections were obtained as either 'horizon' or 'channel' samples. In the former, the seam was examined *in situ* and substantial amounts of coal were obtained representative of successive layers of the seam from roof to floor. The thicknesses of the various layers (or 'horizons') were dependent upon variations in



TEXT-FIG. 65. Use of discriminant functions to identify three successive seams of the Yorkshire Coalfield

quality or petrography noted during the *in situ* examination. The 'channel' samples were chippings representative of the full height of the seam from roof to floor. Where the conditions allowed, the amount of material collected was similar to that of a 'pillar' section, a strip about 1 sq. ft. in cross-section being removed from the coal face. The 'channel' samples and, to some extent, the 'horizon' samples were inferior to the 'pillar' sections in that where seams showed complex structures only the 'pillar' sections allowed careful examination and detailed subdivision under laboratory conditions.

The samples of seams which could not be obtained underground were taken from shallow pits (trial holes) dug into the ground near the outcrop in connexion with opencast workings, or from the actual outcrops of the seams in river banks, etc. These samples were of the 'horizon' or 'channel' type.

Many of the seams examined were obtained as 2–5-in. diameter borehole cores drilled from the surface or underground. In some boreholes recovery was incomplete and the core was fragmented. These borehole samples, in general, were less satisfactory than those obtained from exposures of the seams as the quantity of material available was less. Also, there was often some doubt as to how far the cores were representative of the seams in the locality of the borehole. In underground workings care was always taken to sample the seam where it was normal in thickness and structure. In the case of boreholes it was obviously impossible to take such precautions.

The laboratory examination and sample preparation followed a uniform pattern. All seams were examined in as much detail as the sample allowed and were normally divided into a series of subsections on a basis of petrography and quality as judged by an experienced operator. Sample crushing and reduction were carried out according to the procedure of British Standard Specification 1017 on each subsection, or on the whole seam where no subdivision had taken place. Approximately 1 lb. of coal ground to pass a 14 B.S. mesh sieve was obtained from each sample. 20 g. of this material was taken by increments, crushed by hand in an agate mortar to pass a 36 B.S. mesh sieve, and, after thorough mixing, about 1 g. removed for maceration.

MACERATION AND MOUNTING TECHNIQUES

The literature contains details of a number of maceration techniques applicable to coal but there is little information concerning the method most suited to the particular type of coal being examined. Reference is rarely made to the limitations of the different methods and comparative counts are seldom given to substantiate the use of a particular procedure. The choice of method in part depends on the chemical and the petrographic composition of the coal. The time required to isolate the spores in a condition suitable for quantitative evaluation varies with the type and condition of the coal, the strength and nature of the reagents used, and the temperature at which the reaction is carried out. Wherever possible, reference is made to these factors in the text.

Most of the coals examined were unweathered. Their carbon contents varied from 78 to 90% and their volatile matter contents from 45 to 25% (both on the dry, mineral-matter-free basis). It has not proved possible to isolate spores from coals of higher rank than corresponds to 90% carbon.

Most of the assemblages examined were obtained using fuming nitric acid (SG $> 1{\cdot}5$). Some of the coals were macerated with the reagent used by Schulze in 1855. These methods, particularly the Schulze procedure, are widely used by palynologists today, but they are unsatisfactory for certain types of coal and, for these, other methods have been employed.

Method using Schulze reagent and alkali

Schulze reagent is a mixture of potassium chlorate and concentrated nitric acid and can be employed in two ways. The so-called wet method uses 1 part of a saturated potassium chlorate solution and 2 parts of concentrated nitric acid. In the dry method, used by Raistrick (1934) and the authors, concentrated nitric acid is added to a mixture of equal parts of potassium chlorate and coal. After attack, the residue is treated with dilute alkali to dissolve the decomposition products. The dry method is favoured (except for weathered coals) since it is quicker and the spores are less liable to damage by long contact with the oxidizing medium. A residue of partly oxidized coal particles should be avoided if a representative assemblage is to be obtained, because the spores are not randomly distributed in coal and certain petrographic types may be differentially attacked.

In practice, the coal is crushed just to pass a 36 B.S. sieve (aperture 0·42 mm.); further crushing tends to increase appreciably the proportion of broken exines. 10 ml. of concentrated nitric acid are then added to a mixture of 1 g. of the coal and 1 g. potassium chlorate in a 100-ml. beaker. For optimum reaction the amount of nitric acid should be just enough to dissolve the potassium chlorate (larger amounts slow down the reaction). If the proportion of potassium chlorate to coal is increased the reaction is quicker, but there is a possibility of damaging the exines. With most coals the reaction is allowed to continue at room temperature for about 16 hours (overnight). A small test quantity of residue is then treated with 5% potassium hydroxide. If the reaction has proceeded far enough, the coal particles should just break down leaving only isolated spores, pieces of cuticle, clumps of semitranslucent material, and fusinized cell fragments. When this stage is reached, the sample is decanted, washed free of acid using a centrifuge, and 20–30 ml. of 5% potassium hydroxide added. Most of the decomposition products are dissolved after a few minutes. The residue is then decanted into a sintered glass funnel (Pyrex, porosity grade 3) and the spores, etc., washed, first with alkali until the filtrate appears clear, and then with distilled water. Filtration can be assisted by blowing air periodically through the funnel from below to keep the pores free from small spores and fine sediment (Neves and Dale, 1963). An electrically driven blower pump is suitable for this purpose. If, after 16 hours, the reaction has not reached the optimum stage a further solution of chlorate and nitric acid (1 g. to 20 ml.) is added after centrifuging and decantation. The mixture is tested at fairly frequent intervals until the residue is judged to be suitable for bulk alkali treatment. Best results are obtained if the oxidation is not allowed to proceed far beyond the point at which the particles just break up in alkali.

Method using fuming nitric acid

Fuming nitric acid is a powerful oxidizing agent and has the added advantage of dissolving the decomposition products of the ulmins. According to Zetzsche and Kälin (1932*a*), halogenation of the coal with bromine increases the resistance of the spore exines to oxidation, but for most coals such pretreatment appears unnecessary. 20–30 ml. of fuming nitric acid are added to 0·5–1 g. of coal (36 B.S. mesh) in a 100 ml. beaker. For most low- and medium-rank bituminous coals the reaction is allowed to proceed for at least 16 hours, but shorter periods may give satisfactory separations even from coals of higher rank. After the appropriate time, the products are filtered using a sintered glass funnel. The residue is washed first with fuming nitric acid until the filtrate is colourless, then with concentrated nitric acid followed by dilute nitric acid, and finally distilled water. With most coals a satisfactory maceration within 24 hours can only be obtained if the specific gravity of the acid is not less than 1·5. As the acid decomposes in contact with air it is advisable to keep it in small bottles so that the fresh reagent can always be used. Fuming nitric acid has several advantages over potassium chlorate and concentrated nitric acid as a macerating agent. The method is simple and does not require the use of alkali with its possible damaging effects on the spore exines; the period of oxidation also appears to be less critical so that consistently reproducible assemblages can be obtained. With many coals, 48 hours in fuming nitric acid does not appear to damage the exines, which are stained yellow with nitro compounds in contrast to the often pale, or even colourless, exines resulting from the use of Schulze reagent.

It is not possible to generalize about oxidation times using fuming nitric acid or Schulze reagent. Maceration of a number of hand-selected, bright coals by these methods failed to show any general relationship between coal rank and maceration time. Each coal must, therefore, be treated individually. The reaction can be accelerated by using a water bath, when most coals can be treated within 8 hours. For low- and medium-rank bituminous coals the oxidation time is less critical than for coals of higher rank. This is because, with increasing rank, the chemical properties of the petrographic constituents become more alike so that separation based on differential attack becomes increasingly difficult.

Method using hydrogen peroxide

A dilute solution of this reagent is sometimes used for macerating lignites. With certain coals, such as those from below marine bands and those of relatively high rank (carbon, 88–90%), a more concentrated solution gives better results than either of the methods previously described. The coals from immediately below marine bands are often characterized by high organic and pyritic sulphur contents and it is not certain why such coals frequently fail to yield satisfactory assemblages by the conventional maceration methods. Zetzsche and Kälin (1932*b*), however, suggest that the stability of fossil sporopollenins is in part determined by their sulphur content, a high sulphur content leading to rapid destruction of exines by acid.

The method consists in gently boiling about 1 g. of coal (36 B.S. mesh) with about 50 ml. of 100 volume hydrogen peroxide for 4–6 hours, or longer, until the bulk of the coal is oxidized and only spores and 'carbonized' fragments remain. Further hydrogen peroxide is added as the liquid evaporates. Heating should be carried out carefully with coals containing appreciable amounts of pyrites as the reaction may be rather violent. The products are examined at frequent intervals when the colour of the solution begins to clear. The maceration time varies from coal to coal, and even for the subsections of one seam, probably due to petrographic differences. The liquid remaining after the reaction is often milky, but this may be cleared by the addition of a few drops of concentrated hydrochloric acid. Finally, after centrifuging, the residue is washed several times with distilled water.

Other methods

Other methods of macerating coals have been investigated with varying degrees of success. They are referred to briefly here because they may be applicable to certain types of coal. Raistrick (1934, p. 143) stated that high-rank coals respond better to treatment with Schulze reagent if the coals are first soaked in cold pyridine for 24 hours. Better results are obtained, however, by first refluxing the coal with boiling pyridine for about 16 hours. 1 g. of this pretreated coal is then mixed with an equal weight of potassium chlorate, about 25 ml. of fuming nitric acid added, and the maceration allowed to continue for 16 hours at room temperature. The method gives better results with some relatively high-rank coals than potassium chlorate and concentrated nitric acid, but is not as satisfactory as hydrogen peroxide.

Other reagents which have been reported as suitable for macerating coal include sodium hypochlorite (Hoffmeister 1960), *aqua regia*, concentrated nitric acid saturated with potassium dichromate (Funkhouser and Evitt 1959), and a mixture of solid periodic acid and 50% perchloric acid (Spielholtz, Thomas, and Diehl 1962). None of these reagents gave better results with coals than were obtained by the methods described above.

Removal of carbonates and silicates

Mineral sediment is sometimes present in samples in sufficient quantity to make the identification and counting of isolated spores difficult. If carbonates are present they should be removed with hydrochloric acid before treating the sample with hydrofluoric acid to remove silicates. This avoids the formation of calcium fluoride, which is not readily soluble. The authors prefer to remove silicates after maceration by treating the residues with 20–30 ml. of 40% hydrofluoric acid in a 100-ml. polythene beaker for 24 hours, or longer, at room temperature. The solution is then decanted off and the residue thoroughly washed with distilled water.

Use of ultrasonic vibrations

The spore residues from all macerations can be improved, sometimes markedly, by treatment with ultrasonic vibrations to disrupt aggregates and remove particles of adhering matter from the exines. The treatment is particularly effective with residues from certain types of durain. The best separations from such coals are obtained by slight under-maceration with Schulze reagent before alkali and ultrasonic treatment. The equipment used is a 80/40 W Transistorized 'Soniclean' with tank type transducer (Type 1141A), manufactured by Dawe Instruments Ltd. The time of treatment is not critical, but generally 10–30 secs. is adequate. The equipment is not sufficiently powerful to cause damage to the spore exines during this period.

Storage and mounting of spore residues

The maceration residues of all the treated coals are retained in small specimen tubes with tight-fitting polythene stoppers. A few drops of mould inhibitor are added. To prepare a temporary slide for examination under the microscope, the tube containing the residue is thoroughly shaken and several drops of sample are withdrawn with a narrow-diameter pipette and transferred to a slide. A single drop of warm glycerine jelly is added and the slide warmed on a hotplate. An even distribution of spores over the surface of the slide is obtained by stirring the jelly with the point of a dissecting needle. Excess moisture is evaporated off on the hotplate. If the spores are not evenly distributed, which sometimes occurs when ultrasonics are not used, a few drops of water are added to the slide and the surface film is restirred with a needle. If the spores are obscured by excessive amounts of opaque débris, an improved separation can be obtained by applying the swirl technique to the original suspension. The method is described by Funkhouser and Evitt (1959) and requires only a 3-in. diameter clock glass.

Permanent slides may be prepared using hard mounting media as recommended by Funkhouser and Evitt (1959), Jeffords and Jones (1959), and Wilson (1959). The authors use a 2% aqueous solution of hydroxethyl cellulose (cellosize). A drop of the spore residue is placed on a cover glass and nearly allowed to dry. Several drops of the cellosize solution are then mixed with the spores until they are evenly dispersed over the cover glass and the film is set aside to dry at, or just above, room temperature. When dry the cover glass is sealed to the slide by a small quantity of Euparal (R.I. 1·485) or Canada Balsam dissolved in xylol.

Effect of maceration techniques on spore exines

Work carried out by the authors has shown that the exines of different spore types may be differentially attacked during the maceration process. The oxidizing reagents and the type of alkali used influence the quantitative character of an assemblage. The data in Table 7 show the proportions of five spore types produced from two unweathered coals of medium and high rank (carbon 84 and 88·7% respectively) by different methods of maceration.

TABLE 7. Percentage frequencies of selected spore types isolated from a medium- and a high-rank coal by different maceration methods

	Medium rank		*High rank*			
	A	B	C	D	E	B
Spore types	*Percentage occurrence per 500 spores counted*					
Lycospora spp.	43	44	45	44	48	18
Laevigatosporites spp.	10	7	6	6	6	12
Crassispora sp.	6	30	14	12	7	5
Densosporites spp.	<1	<1	14	15	20	34*
Small forms (20–25 μ)	12	4	not recorded			

* exines pitted

Method A. Schulze reagent: equal parts of potassium chlorate and coal, 24 hours, followed by 5% potassium carbonate solution.
,, B. Fuming nitric acid: 16 hours at room temperature.
,, C. Hydrogen peroxide (100 volume): boiled 3–4 hours.
,, D. Pretreated with boiling pyridine 16 hours, followed by fuming nitric acid and potassium chlorate (equal parts chlorate and coal): 16 hours at room temperature.
,, E. Schulze reagent: 6 parts of potassium chlorate to 1 part coal, 2–3 hours at room temperature, followed by 5% ammonium hydroxide.

There are significant differences in the results, certain methods being better for particular genera. It appears, however, that a given method does not necessarily have the same influence on spores in coals of different rank. Over-maceration leads to the over-representation of the more resistant spores. The high percentage of *Densosporites* in the assemblage from the high-rank coal macerated with fuming nitric acid may have arisen from this cause, since the exines of these spores were slightly pitted.

Table 8 shows the numerical differences observed when the residues from the Schulze reaction are treated with different alkalis of the same strength (5% solution). The same medium-rank coal was used as before.

TABLE 8. Effect of different alkalis on the percentage frequencies of selected spore types isolated from medium-rank coal by the Schulze method

Spore types	*Potassium hydroxide*	*Ammonium hydroxide*	*Potassium carbonate*
Lycospora spp.	26	43	43
Laevigatosporites spp.	22	9	10
Crassispora sp.	0	2	6
Small forms (20–25 μ)	13	14	12

Potassium hydroxide gives the most satisfactory separation visually but it appears to be damaging to certain types of exine, particularly if the coals have been slightly over-macerated. Ammonium hydroxide and potassium carbonate are less liable to cause damage and the exines are more highly coloured than when potassium hydroxide is used. These reagents are also more easily washed from the residue. A 5% solution of potassium hydroxide does not appear to give noticeably better results than a 10% solution.

Tschudy (1958) reported that weathered coals macerated with Schulze reagent yielded significantly richer assemblages if the humates were rendered soluble in an 80% solution of acetone and water instead of in 10% sodium hydroxide. The use of the alkali resulted in a great many of the spores being destroyed, or swollen beyond recognition. The choice of alkali affects the size of certain genera but not others. Butterworth and Williams (1954) record varying differences in the mean size of different species obtained by using on the one hand fuming nitric acid, and on the other Schulze reagent followed by potassium hydroxide solution. Some spores, particularly the larger and thicker-walled types, swell considerably if oxidation by Schulze reagent is followed by treatment with potassium hydroxide, particularly if the coal is slightly over-macerated. Measurements of *Crassispora kosankei* macerated in this manner showed a 30% increase in size over the mean size of specimens treated with potassium carbonate solution. The mean size of the latter was identical with that obtained with fuming nitric acid alone. It is also worth recording that specimens of *C. kosankei* mounted in glycerine jelly increase in size with time. In view of these facts, comparative work should always be based on material prepared in the same way.

Counting techniques

There is little agreement among palynologists concerning the number of spores, or pollen grains, that should be counted to ensure that the recorded assemblage is reasonably representative of the spores in a specified coal sample. Various workers have advocated counts ranging from 150 to 1,000 individuals (Morgan 1955, p. 23). Barkley states in his statistical theory of pollen analysis (1934, p. 288) that there is no advantage in counting more than 200 pollen grains per slide. Dimbleby (1957, p. 14) demonstrates graphically that the rate of increase of species recorded declines rapidly after about 250 specimens have been counted; all species which have a final percentage of one or more are represented within the first 250 grains. Cross (1950, p. 23) suggests that the diversity of the flora and the relative abundance of individuals should be taken into account in determining the size of the count. The purpose for which the count is required should also be considered. In stratigraphic work, where many of the index species are among the less common forms in the assemblage, it is necessary to undertake counts which ensure adequate representation of such forms. A statistical basis for defining absence with a reasonable degree of certainty is proposed by Tomlinson (1957, p. 24), but it involves the counting of a larger number of specimens. On the other hand, correlation work which aims at comparing the broad features of spore distribution within seams requires less exacting counting.

Most of the quantitative work carried out by the authors involved counts of 500 specimens encountered during a series of traverses (×250) of one slide. Partly broken spore exines were included if identification was possible, but small fragments of exine were ignored. Forms which could not be identified at generic level, or which, for instance, were unrecognizable due to gross folding, were recorded as a separate category in the counts. The remainder of the slide was examined for genera and species not recorded during the count.

NOMENCLATURE AND CLASSIFICATION

It is normal practice to treat Palaeozoic spores as form taxa subject to the rules of priority and typification laid down in the International Code of Botanical Nomenclature (1961). Spores are thus accorded the status of botanical species assignable to genera on the basis of morphographical features, but independent of any natural or phylogenetic relationships. This is undoubtedly the most satisfactory basis upon which to designate them while their botanical relationships are still being explored. This procedure is acceptable to stratigraphic palaeontologists and has been followed in the present work. Recently Corsin, Carette, Danzé, and Laveine (1962) have emended many of the established generic names to conform to a logical system of nomenclature in which the names of spore and pollen genera are terminated by *sporites* and *pollenites* respectively. These authors have also consistently terminated the root of spore names by the vowels *a*, *o*, and *i* to indicate respectively the alete, monolete, and trilete condition. The alterations required by these emendments are considerable and in the opinion of the authors not justified in view of the long-established usage of the existing nomenclature.

It is not unexpected in a young and rapidly evolving science that some species and even genera will exist in the literature under more than one name. The task of resolving these problems of synonymy is considerable. The confusion may sometimes have arisen through simultaneous publication but all too often in the past it has originated from poor descriptions, generally as a result of the examination of too few specimens, which do not show the full range of variation. Thus comparisons have often been made without regard to the possible effects of maceration technique on the size of spore exines. The present authors, whilst recognizing that variations in spore size may occur at different localities within strata of similar age, as well as in strata of different ages, regard small size differences as insufficient reasons for establishing new species. The danger of using only the holotype to typify a species in comparative investigations is stressed by Schopf (1960).

There is at the present time no universally accepted scheme for the classification of dispersed spore taxa into suprageneric categories. The naming of these categories is not subject to international control and different authors (listed in Dettmann 1963, p. 12) have used various criteria for their erection. The system of classification used in this work is based on that proposed by Potonié and Kremp (1954), and subsequently expanded by these authors (1955, 1956), Potonié (1956, 1958, 1960), and Corsin, Carette, Danzé, and Laveine (1962). This system, which is the most comprehensive and widely used outside Russia, has been revised in part by Dettmann (1963). The revision is confined to the classification of Sporites H. Potonié. It has removed certain inconsistencies inherent in the original system, which made it possible to allocate spores of identical morphology to more than one suprageneric category. This has been achieved by adopting a monothetic system of mutually exclusive taxonomic units, which at any particular rank are based on one diagnostic character only. The scheme, which has been applied to Mesozoic spore floras by Dettmann, provides a sound basis for the morphographical classification of spores. Richardson (1965, p. 585) has, however, criticized the classification and terminology of categories based on exine stratification. Discussion of this subject is difficult owing to uncertainty about the origin and equivalence of exine layers, not only in spores and pollen grains, but also in different spore types. Initially Dettmann subdivided trilete and monolete spores on a basis of their exine stratification into acavate and cavate types. These categories of trilete spores were named at the suprasubturma level Acavatitriletes and Perinotrilites respectively. Richardson (1965) has commented on the possible confusion arising out of using cavate in a different sense from its original meaning and on the use of Perinotrilites. In using the Dettmann system the authors have followed her use of cavate for spores (*sensu stricto*) and hope that it will become generally acceptable in the sense defined by her, since the terms saccate and vesiculate are available and are generally used to describe the presence of more or less equatorially situated air sacs in pollen grains. The authors agree with Richardson that the root 'Perino' in combination with triletes, monoletes, or hilates is unsatisfactory as a comprehensive term for cavate spores and that it should be retained for spores in which there is a perispore or perispore-like membrane. In the present work two suprasubturmae of trilete aperinate cavate spores are recognized, Laminatitriletes s.subturma nov. for spores such as *Densosporites* in which the exine layers are separated but remain in close contact and Pseudosaccitriletes (proposed as a subturma by Richardson 1965) for spores such as *Endosporites* with a well-developed cavity between the two layers of the exine. Until it is necessary to recognize more than one category of cavate monolete or cavate hilate spores it is proposed that the terms Cavatomonoletes s.subturma nov. and Cavatihilates s.subturma nov. be used.

Following the Dettmann scheme the authors have subdivided these suprasubturmae wherever applicable into zonate and azonate groups on the presence or absence of equatorial structures. Thus cavate spores in which the exoexine and intexine are not well separated are classified under Azonolaminatitriletes subturma nov. and Zonolaminatitriletes subturma nov. A new infraturma, Tuberculornati, is proposed for azonate cavate spores in which there is neither a thickening nor an extension of the exoexine at the equator. This infraturma at present includes the single genus *Grumosisporites* gen. nov. Zonate cavate spores are assigned to one of three infraturmae, namely Crassiti (Bharadwaj and Venkatachala) emend., Cingulicavati infraturma nov. or Patinati (Butterworth and Williams) emend. Cingulicavati includes cingulate or zonate spores formerly included under the infraturmae Cingulati *sensu* Potonié and Klaus and Zonati *sensu* Potonié and Kremp.

Richardson (1965) has proposed using the existing infraturmae Intrornati and

Diagnostic feature	Category													Rank
	SPORITES													Anteturma
Aperture	TRILETES						MONOLETES			HILATES			ALETES	Turma
Stratification	ACAVATITRILETES		LAMINATITRILETES		PSEUDO-SACCITRILETES	PERINOTRILITES	ACAVATO-MONOLETES		CAVATO-MONOLETES	ACAVATI-HILATES	CAVATI-HILATES			Suprasubturma
Equatorial features	AZONOTRILETES	ZONOTRILETES	AZONOLAMINATITRILETES	ZONOLAMINATITRILETES			AZONOMONOLETES	ZONOMONOLETES			AZONOCAVATIHILATES	ZONOCAVATIHILATES		Subturma
Sculpture / equatorial thickening and/or extension	LAEVIGATI APICULATI MURORNATI	AURICULATI TRICRASSATI CINGULATI	TUBERCULORNATI	CRASSITI CINGULICAVATI PATINATI	MONOPSEUDOSACCITI POLYPSEUDOSACCITI		LAEVIGATOMONOLETI SCULPTATOMONOLETI				EPITYGMATI OPERCULATI			Infraturma

TEXT-FIG. 66. Revised scheme for the classification of Sporites based on Dettmann (1963)

Extrornati as subdivisions of Pseudosaccitriletes. It is not always easy, however, to decide whether an exoexine possesses sculpture, infrastructure, or both, and in any case the classification of taxa on these criteria has less value in view of the separation of pseudosaccate spores from saccate pollen grains with their marked infrastructure. Two new infraturmae are proposed, Monopseudosacciti infraturma nov. and Polypseudosacciti infraturma nov., based on the number of pseudosacci. Included in these infraturmae are spores formerly assigned to Monosaccites and Polysaccites by Potonié (1958).

The classification of hilate spores was carried out in collaboration with F. Spode, who has proposed (in press) the infraturma Epitygmati for hilate azonate cavate spores in which the polar aperture is proximal. Similar spores in which the aperture is distal are referred to Operculati Venkatachala and Goczan 1964, but such spores have not been recorded from British coal seams. In accepting this grouping of the hilate spores the authors are aware of the difficulty of classifying the genus *Vestispora*, which is hilate, but also possesses a proximal trilete aperture to the intexine.

The turma Aletes is included within the anteturma Sporites after Corsin, Carette, Danzé, and Laveine (1962), who, as originally intended by Ibrahim, restricted the turma to spores (*sensu stricto*) without a dehiscence mark.

The revised and expanded Dettmann classification of Sporites is shown in text-fig. 66. The scheme is not comprehensive, and, apart from certain suprageneric taxa added for completeness, it shows only those taxa necessary to accommodate the genera of Carboniferous spores referred to in the systematic section of this work.

SPORE MORPHOLOGY AND GLOSSARY OF DESCRIPTIVE TERMINOLOGY

This account of the basic features of spore morphology and the glossary of descriptive terms are not intended to be complete; they cover only such features as are necessary for the adequate description of the dispersed spores (including the seminules of certain pteridosperms and gymnosperms which are believed to function as pollen grains) referred to in the present work. Most of the terms used are widely accepted and their definitions are generally agreed, although not necessarily those of the original authors. For an explanation of terms used in the descriptions of other authors quoted in this work, reference should be made to the original papers. In the compilation of this section extensive use has been made of the work of Erdtman (1952), Harris (1955), Potonié and Kremp (1955), and Couper and Grebe (1961, unpublished glossary prepared for the C.I.M.P.). The author's name is given only when an established term is used in a new sense, or when the term is of recent origin.

Spore morphology

1. *Symmetry and orientation*. Spores originate by a twofold division of the contents of a spore mother cell. During maturation the products of these divisions remain together as a tetrad within the sporangium. The arrangement of the spores in the tetrad determines their symmetry. Thus spores with a tetrahedral form possess three contact areas, a free rounded outer surface, and have a *radial* symmetry. Spores with *bilateral* symmetry are elongate and possess only two contact areas.

The polarity of a spore is determined by its position in the tetrad in reference to an axis which passes through the centre of the spore and is directed towards the centre of the tetrad. Each spore thus has an inner, or *proximal* and an outer, or *distal* pole, situated at the centre of the proximal and distal faces respectively. The boundary between the two polar hemispheres is the *equator* (text-fig. 67).

2. *Shape*. The shape of trilete spores is seldom spherical owing to close contact in the tetrad. They are generally tetrahedral in shape, the base being rounded. Monolete spores are elongate with one long and two short axes. The shape or *contour* of a spore, where possible, is described first as seen in *proximal* view and secondly as seen in equatorial view. The *amb* or equatorial contour can be of three basic shapes—circular, triangular, or oval. Triangular spores have convex, straight, or concave sides and the angles may be narrowly rounded, broadly rounded, or truncated. In equatorial view the shape of the proximal and distal surfaces may be flat, convex, pointed, or concave. In monolete spores the shape of the proximal surface varies according to whether it is seen in longitudinal or transverse view (text-fig. 67*f*, *g*).

3. *Haptotypic characters*. These are characters imparted to spores 'due to contact and other relations with their neighbours during growth' (Wodehouse 1935, p. 158). They include features of the proximal hemisphere, particularly the *tetrad mark* and the adjoining *contact areas* (text-fig. 68). The character of the tetrad mark, whether linear or triradiate, its length, and the extent to which the adjacent spore wall may be modified, are important diagnostic characters of the spore, as is the possible reduction of any surface ornament on the proximal face. In most trilete and monolete spores the tetrad mark corresponds in position to the dehiscence fissure (or proximal aperture) and in the present work the two features are collectively referred to as the *laesura*(*e*). In trilete spores the length of the laesura is expressed as a proportion of the spore radius; in monolete spores, of the longest diameter. In a few instances, fossil spores lack a tetrad scar and are considered to be *alete*.

4. *Spore wall*. In living spores the walls consist of two or more layers, an inner *intine*, an *exine*, and, in some instances, an outer *perispore*. The intine is cellulosic and is not preserved in fossil material, in contrast to the durable exine. A perispore has seldom been recorded in Palaeozoic spores. The exines of certain fossil spores are stratified and in certain genera, e.g. *Densosporites*, two membranes, which are more or less in contact, can be detected (Bharadwaj 1958; Smith 1960). These layers have been variously named, but are often referred to as the *intexine* and *exoexine*. In other genera, e.g. *Endosporites*, the separation of the two membranes in the mature spore has progressed much further, the exoexine appearing as a comprehensive air sac well separated from the intexine at the equator as well as distally. The two membranes, however, remain in contact proximally. In other genera the contact between the exine layers is distal. Trilete spores in which the exine layers are more or less separated have been termed *cavate* by Harris (1955), Dettmann (1961, 1963), and Balme (1963). Forms in which the separation of the wall layers results in baculoid elements adhering to the inner surface of the exoexine and in the formation of more or less equatorially situated air sacs or *sacci* are termed *saccate*. (The term cavate was originally used in this sense for pollen grains by Faegri and Iversen 1950, p. 160, and subsequently applied to spores by Harris 1955, p. 25, who

pointed out that it may then refer to the separation of the perispore.) Saccate spores are also distinguished by the presence of a distal furrow and the absence of a proximal aperture (but not necessarily a tetrad mark), e.g. *Florinites*. Monosaccate, bisaccate, and polysaccate forms are recognized. (Monosaccate trilete spores *sensu* Potonié and Kremp are now referred to as pseudosaccate and are included within the cavate group.)

Structural ornament arising internally out of the separation of the exine layers is referred to as *infrasculpture*. Other structural differentiation of the exine may take the form of thickenings or extensions of the exine.

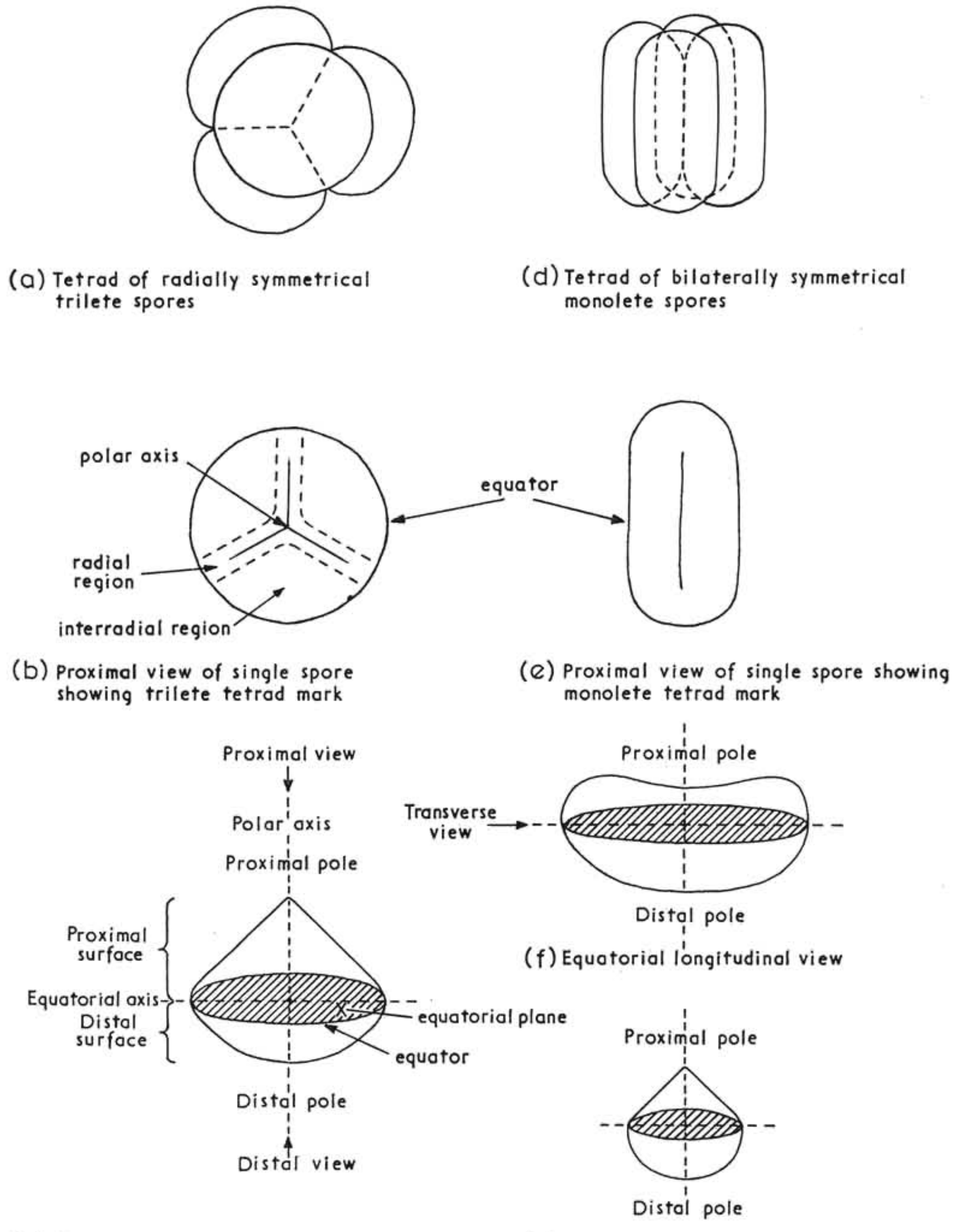
Colour is not considered to be of diagnostic value; it is, in part, a reflection of wall thickness, but is also influenced by the rank of the coal and the chemical treatment used to isolate the spores from their matrix.

The outer surface of the exine may be smooth (*laevigate*), or possess *sculpture*; the sculpturing may take the form of indentations or projections. When it is uncertain which form of ornament prevails the distinction can be made by observing the pattern of the light and dark areas on the surface at successive levels of focus from high to low. This method is sometimes referred to as LO-analysis (Erdtman 1956, p. 135). Where the ornament is of a fine grade and closely spaced it is not always easy to decide its nature. It is, however, important to distinguish between sculptural elements which project from the surface and internally directed infrasculpture previously mentioned. The outer surface of saccate spores with infrasculpture is often smooth.

In describing sculpture the shapes of the sculptural elements in plan view and in profile are important as well as their size (height and diameter), the distance apart of the elements, and their distribution (that is, whether confined to, or better developed in, certain areas). It is the dominant type of sculptural element which is of diagnostic value when more than one element is present. As the character of the sculpture modifies the margin of the compressed spore to a varying degree, the appearance of the margin is significant.

5. *Size*. Spores range in size from about $10\,\mu$ to more than $2{,}000\,\mu$; by convention the distinction between miospores and megaspores is usually taken at $200\,\mu$. Size can be a useful criterion for distinguishing forms with similar structure and ornament, although the use of a single criterion, whether it be size or character of ornament, to discriminate between species often leads to uncertainty in comparative studies where there is overlap in the range of variation. Even when the ranges of species do not overlap at a particular time horizon they may do so at some other time in the course of evolution of the species. These difficulties beset the concept of species in all branches of palaeontology and are discussed by Sylvester-Bradley (1956).

It is usual to express measurements of size as a mean (or sometimes the mode) with extreme limits. Such measurements are of little value for comparative purposes when only based on a few specimens. Providing the distribution curve is more or less Gaussian some authors calculate the mean and the standard deviation of their sample. This provides a useful basis for comparison since 95% of the sample then lies within $\pm 2\times$ standard deviation of the mean. In order to establish the order of variation of size, both geographically and stratigraphically, of spores considered to be of the same species, the authors have recorded, whenever possible, size ranges for different localities and horizons. A further source of variation in the published data on spore sizes is the method



TEXT-FIG. 67. Diagrammatic illustrations of terms used to describe the symmetry and orientation of spores of isolating the spores from their parent rocks. It is known, for instance, that the use of certain alkalis following Schulze reagent may result in swelling of the exines (see section on preparation).

Glossary of descriptive terms

This glossary comprises only terms used by the authors and which are confined to descriptive palynology, or which may have acquired a specialized meaning in this science.

1. *Terms used to describe orientation and shape*

Amb: shape of equatorial outline of spore seen in proximal view.

Distal pole: the point opposite the proximal pole (text-fig. 67*c, f, g*).

Distal surface: the part of the spore that was directed outwards in the tetrad and is therefore opposite the tetrad mark.

Equator: the region where the proximal and distal surfaces meet (text-fig. 67*b, e*).

Equatorial axis: any axis in the equatorial plane which intersects the polar axis (text-fig. 67*c, f*).

Interradial region: that portion of the exine lying between adjacent laesurae in trilete spores, and the corresponding portion of the distal surface (text-fig. 67*b*).

Monolete: possessing an unbranched tetrad mark (text-fig. 67*e*).

Polar axis: the axis joining the proximal and distal poles (text-fig. 67*c*).

Proximal pole: the geometrical centre of the spore tetrad and, in the case of a trilete spore, the point of origin of the trilete mark (text-fig. 67*c*). In the case of monolete spores, it is the mid-point of the monolete mark (text-fig. 67*f*).

Proximal surface: the part of the spore that was directed inwards in the tetrad and which usually bears a tetrad mark.

Radial region: that portion of the proximal surface in the immediate vicinity of the tetrad mark and the corresponding portion of the distal surface (text-fig. 67*b*).

Trilete: possessing a triradiate tetrad mark (text-fig. 67*b*).

2. *Terms used to describe the germinal aperture and associated features*

Apical papilla: dark spot, or prominence, on intexine close to the proximal pole in the interradial region (text-fig. 68*b*). A single papilla may occur in each interradial segment of trilete cavate spores; often obscured by ornament of exoexine.

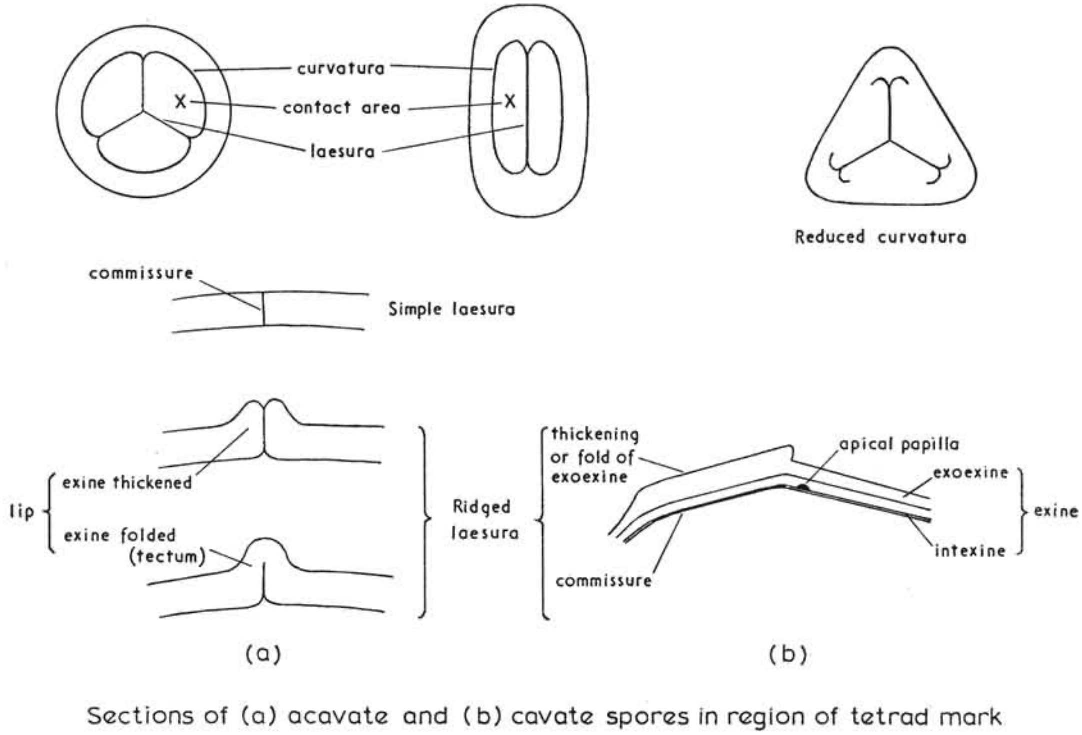
Commissure: the proximal line of dehiscence, which in trilete and monolete spores corresponds in position to the tetrad mark (text-fig. 68). In certain trilete cavate spores, the commissures and the tetrad mark are separately recognizable on the inner and outer layers of the exine.

Contact area: that portion of the proximal face in contact with a similar face of another spore in the tetrad (text-fig. 68). Trilete spores possess three contact areas of equal extent; monolete spores two such areas. In trilete spores the contact area is determined by the length of the laesurae and equals the proximal surface only where these extend to the equator.

Curvatura: the more or less curved line marking the distal limit of the contact area (this line does not occur in all spores). Sometimes referred to as an arcuate ridge (text-fig. 68).

Hilum: a germinal aperture formed by the natural breakdown of the exine in an area showing structural and/or sculptural modification about the proximal or distal pole. The term was originally applied to pollen grains (Erdtman 1952, p. 12) but has subsequently been used to describe a similar condition in spores (Dettmann 1963, p. 18). Spores possessing this feature are described as hilate. The only genus of hilate spores recorded in this work is *Vestispora*. In this genus a sculpturally defined portion (operculum) of the outer exine layer occurs proximally and may become detached from the remainder of the spore.

Laesura: the commissure and that part of the exine in association with it, which may be modified (thickened or folded). The laesura is referred to as simple (exine without modification), or ridged (exine modified). The commissure of a ridged laesura may be enclosed within a fold of the exine (tectum *sensu* Potonié and Kremp 1955, p. 11), without any inherent thickening, or the exine adjacent to the commissure may be thickened (text-fig. 68*a*). Microtome sections of exines showing these two forms of ridged laesura are given in Hughes, Dettmann, and Playford 1962 (pl. 37, figs. 5, 8, 11), and Dettmann and Playford 1963 (pl. 96, figs. 6, 7). No distinction is here made between these two conditions, which can only be reliably determined in sections of the spores.



TEXT-FIG. 68. Diagrammatic illustrations of terms used to describe features associated with the tetrad mark and laesura of spores

Lip: this term is applied in a broad sense to the modified (thickened or folded) portion of the exine adjacent to the commissure (text-fig. 68*a*). Sometimes associated with a modification of the sculptural pattern.

Monolete mark: consists of a single laesura.

Reduced curvatura: a curvatura developed only at the distal ends of the laesura or laesurae (text-fig. 68).

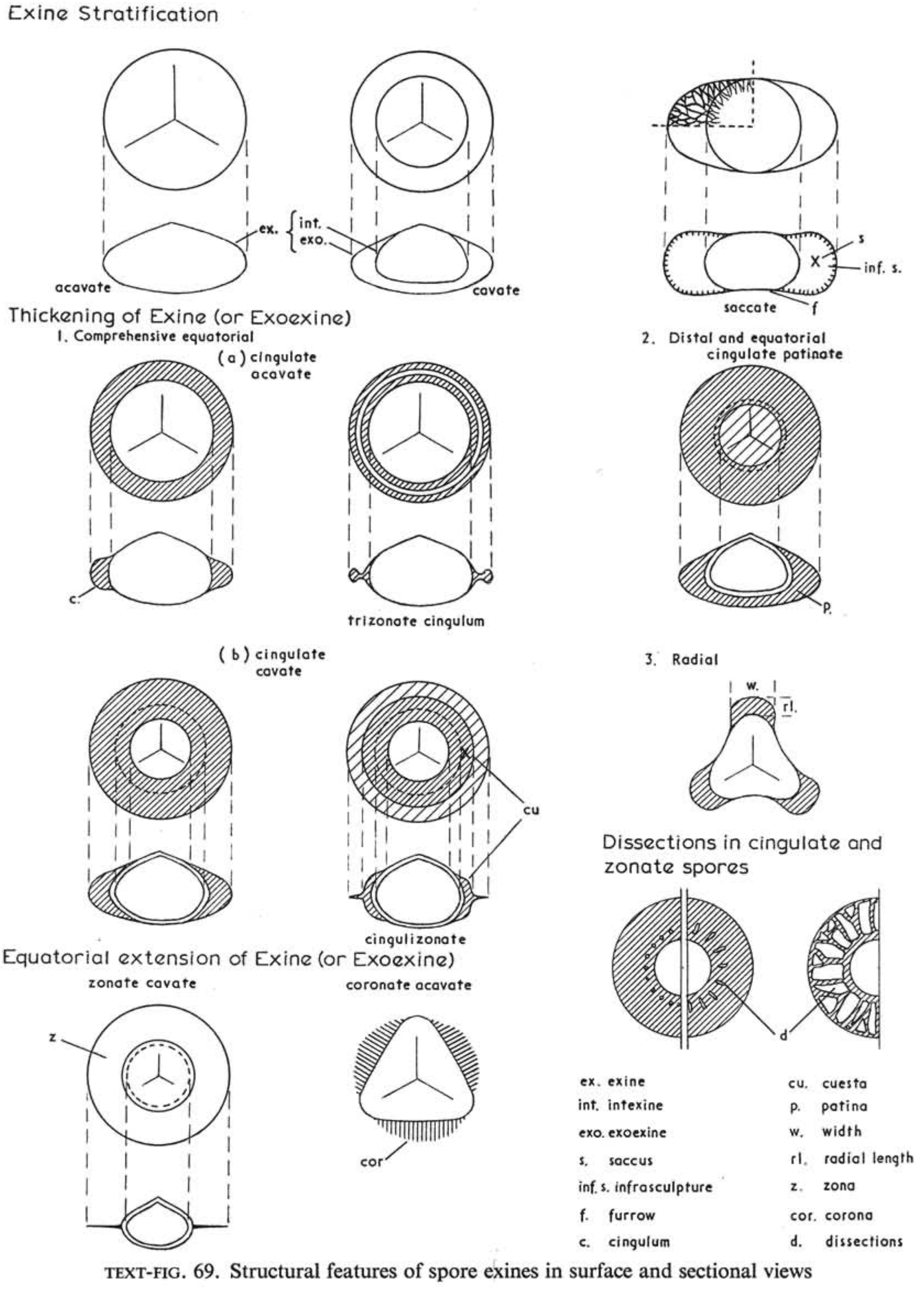
Tetrad mark: the mark, or marks, separating contact areas. Bilaterally symmetrical spores possess a single (monolete) mark (text-fig. 67*a*); those with radial symmetry possess three marks (trilete) radiating from the proximal pole (text-fig. 67*b*).

Trilete mark: consists of three laesurae radiating from their point of origin at the proximal pole.

3. *Terms used to describe structural features*

Cavate (Dettmann 1963, p. 18): asaccate spores in which the wall layers are partially, or almost completely, separated from each other by a cavity (text-fig. 69). The layers may remain in close contact as in *Densosporites*, or the outer layer may be expanded away from the inner layer to form a pseudosaccus as in *Endosporites*. The term also denotes the hollow condition of sculptural elevations and external thickenings and/or extensions.

Cingulum: a thickening of the exine (or exoexine) more or less confined to, and encircling, the equator (text-fig. 69), e.g. *Densosporites anulatus*. Spores with such a feature are described as cingulate. In



TEXT-FIG. 69. Structural features of spore exines in surface and sectional views cross-section the outer edge of the cingulum may be rounded, or cuneiform. Spores with a strongly tapering cingulum, which may be membraneous near its outer margin, are termed cingulizonate. The cingulum may extend some distance towards the poles, at the same time diminishing in thickness. (Staplin and Jansonius 1964 use the term zona for this type of structure and restrict the term cingulum to an abrupt, equatorial thickening.) The width of the cingulum is expressed as a ratio of the overall dimensions of the spore.

Corona: an equatorial extension of the exine (or exoexine) in the form of fimbriate structural elements which may be united laterally as in *Reinschospora*, or more or less separated as in *Diatomozonotriletes*. Usually reduced at, or absent from, radial regions (text-fig. 69).

Crassitude: localized thickening of exine. It may occur as a slight thickening encircling the spore at the equator, diminishing in thickness towards the poles (a cingulum is more massive and wedge-shaped in cross-section) or it may be more pronounced in, or confined to, the radial or interradial regions (radial or interradial crassitude). In a distal crassitude the thickening is continuous over the distal surface, reaching maximum thickness at the distal pole (cf. patina).

Cuesta (Staplin and Jansonius 1964, p. 98): the ridge marking an elevation of the surface of the cingulum above the surface of the central proximal area (text-fig. 69), e.g. *Cingulizonates loricatus*.

Dissections: rounded to elongate lumina in a cingulum or zona. The positions and extensions of the dissections are important (text-fig. 69).

Furrow: generally the thin, boat-shaped portion of the exine through which the pollen tube emerges; in bisaccate pollen grains the distal portion of the exine between the sacci (text-fig. 69), e.g. *Pityosporites*.

Kyrtome: an arcuate fold or thickening of the exine in compressed spores, which in trilete spores occurs in the angle formed by the laesurae. Two kyrtomes may join in the radial region and may project beyond the spore margin at the equator. In *Ahrensisporites* the kyrtomes are distal.

Limbus: a narrow, equatorial zone in certain pseudosaccate spores (monosaccate spores *sensu* Potonié and Kremp), formed by the fusion of the proximal and distal exoexine layers, e.g. *Endosporites globiformis*.

Patina (Butterworth and Williams 1958, p. 381): an exinal thickening which extends over the entire area of one hemisphere (text-fig. 69), e.g. the distal surface of *Tholisporites*.

Pseudosaccus: an air sac of trilete cavate spores formed by the separation and extension of the exoexine away from the intexine either equatorially or to a greater or lesser extent proximally, and/or distally. Spores possessing a pseudosaccus are referred to as pseudosaccate, e.g. *Endosporites*.

Radial crassitude: a thickening of the equatorial exine (or exoexine) restricted to the radial region (text-fig. 69), e.g. *Triquitrites*.

Saccus: an air sac with marked infrasculpture generally confined approximately to the equatorial region of spores which lack a proximal aperture but not necessarily a tetrad mark, which if present is usually vestigial, e.g. *Florinites*. Spores possessing a saccus are referred to as saccate.

Zona: an encircling membraneous extension of the exine (or exoexine) at the equator (the base of the zona is not thickened) (text-fig. 69), e.g. *Cirratriradites saturni*. (Microtome sections of *C. elegans* (Waltz) Potonié and Kremp in Hughes, Dettmann and Playford, 1962, pl. 38, figs. 6, 7 show that this species does not possess a typical zona.) Spores with a zona are described as zonate.

4. *Terms used to describe the external ornamentation of the exine* (*sculpture*)

Four types of exine ornament, can be recognized in Palaeozoic spores, viz. (i) minute sculpturing; (ii) pits in the general exine surface (foveolate elements and patterns); (iii) projections from the general surface (apiculate elements and patterns); (iv) elevations of the general surface (muronate elements and patterns). Projections, irrespective of height, are less than twice as long as broad, whereas elevations have their length more than twice their breadth. The sculptural elements and patterns associated with each of these types of exine sculpture are described below.

(i) Ornamention, where present, as minute sculpturing.

Laevigate: smooth.

Scabrate: flecked with minute pits or elevations less than 1 μ in greatest dimension giving the exine a rough appearance.

(ii) Foveolate elements and patterns.

Foveolae: rounded lumina, 1–2 μ in diameter, or, if larger, too widely spaced to form a reticulum, e.g. *Vestispora fenestrata*.

Foveolate sculpture: a sculptural pattern formed by foveolae. The sculpture is still described as foveolate (even if the diameter of the lumina is greater than 2 μ) when the diameter of the lumina is equal to, or less than, the distance between adjoining lumina.

Vermiculi: elongated, narrow, sinuate, and irregularly spaced lumina, not forming a definite pattern. Channels between rugulae may be referred to as vermiculi although not strictly formed by the depression of the general exine surface, e.g. *Convolutispora jugosa*.

Vermiculate sculpture: a sculptural pattern formed by vermiculi.

(iii) Apiculate elements and patterns.

(*a*) Those with unbranched, non-pointed terminations.

Bacula: projections in which the height is greater than the basal diameter; bases more or less rounded in plan view; sides parallel, or weakly converging; apices flat or partate, e.g. *Raistrickia saetosa*. (The term seta is used by some authors in the same sense as bacula.)

Baculate sculpture: a sculptural pattern formed by bacula.

Grana: more or less isodiametric projections with a maximum diameter not exceeding 1 μ, e.g. *Cyclogranisporites aureus*.

Granulate sculpture: a sculptural pattern formed by grana.

Pila: projections consisting essentially of a more or less spherical head carried on a neck or stalk. The ornament of *Verrucosisporites morulatus* is, in part, of this type.

Pilate sculpture: a sculptural pattern formed by pila.

Verrucae: larger and less uniform than grana; height equal to, or less than, the basal diameter; in plan view base irregular, round, polygonal, slightly elongated, or indented; sides more or less parallel to slightly rounded or tapering; can be slightly constricted towards base; apices truncate to rounded, e.g. *Verrucosisporites donarii*.

Verrucate sculpture: a sculptural pattern formed by verrucae.

(*b*) Those with unbranched, pointed terminations.

Coni: projections in which the height generally equals, or exceeds, the basal diameter, but is less than twice that diameter; in plan view, bases more or less rounded; apices pointed, e.g. *Apiculatisporis aculeatus*.

Conate sculpture: a sculptural pattern formed by coni.

Spinae: projections in which the height is at least twice the basal diameter; bases more or less rounded in plan view; apices pointed, e.g. *Acanthotriletes castanea*.

Spinose sculpture: a sculptural pattern formed by spinae.

(iv) Murornate sculptural elements and patterns.

(*a*) Those in which the elevations of the general surface leave no definite, regular, reticulate pattern of lumina between them.

Carinae (Spode, in press): small projections on the sides of primary muri which, when fused together, produce a weak secondary reticulum, e.g. *Vestispora pseudoreticulata*.

Carinate sculpture: a sculptural pattern formed by carinae.

Costae: rib-like elevations which sometimes more or less encircle the spore, e.g. *Vestispora costata*.

Costate sculpture: a sculptural pattern formed by costae.

Cristae: elevations of the surface with elongate, curved bases, occasionally fusing together to form an irregular reticulum; apices of elements more or less pointed, or serrated, to slightly rounded, e.g. *Cristatisporites indignabundus*.

Cristate sculpture: a sculptural pattern formed by cristae.

Rugulae: elevations with bases elongate, curved to irregular in plan view; apices flat to slightly rounded, e.g. *Convolutispora jugosa*.

Rugulate sculpture: a sculptural pattern formed by rugulae.

(*b*) Those in which the sculptural elements (muri, lumina) form a more or less definite reticulate pattern (reticulum).

Muri: the elevations bounding the lumina of reticulate sculptural patterns. In profile the sides of the elevations may be parallel, converging, or diverging and the apices rounded, flat, or pointed, e.g. *Dictyotriletes bireticulatus*.

Lumina: the pits (depressions) between the elevations of a reticulate sculptural pattern. The lumina of a reticulum may be either more or less rounded, or polygonal in plan view.

Reticulate sculpture: the sculptural pattern formed by the muri and adjoining lumina. When describing a reticulate sculptural pattern, the shape and relative size of the lumina compared with the intervening muri, together with the nature of the sides and apices of the muri, are, if possible, noted.

Hyphenated terms

Hyphenated terms are used to avoid a multiplicity of terms for describing ornament comprising more than one type of sculptural element, or ornament which, because of its variability, is difficult to assign to a single specified type. Examples of sculptural patterns described in this way are rugulate-verrucate, or costate-reticulate. The precise condition of the ornament should be clear from the context of the description.

THE DESIGNATION OF FIGURED SPECIMENS AND DESCRIPTIVE PROCEDURES

The holotypes of all new species, and those described by Butterworth and Williams (1958), are figured in the present paper. Lectotypes and neotypes of certain other species, notably those named by Knox (who did not designate holotypes), are also figured. All figured specimens are referred to by slide or type numbers (prefixed by T) and, excepting the majority of holotypes and isotypes prepared as single grain mounts, the 'E–W' and 'N–S' microscope vernier readings. These readings are based on a Leitz Ortholux microscope, No. 628237 at the Sheffield Coal Survey Laboratory of the National Coal Board. A master slide with the locations of two reference points is deposited with all figured specimens in the collection of the Sheffield Laboratory. The sources of all figured specimens, other than the holotypes, referred to by slide numbers are given in the appendix.

Deposition of type slides. Palynological work previously carried out at the Sheffield Coal Survey Laboratory is continuing at the National Coal Board's Scientific Laboratory, South Yorkshire Area, Golden Smithies Lane, Wath-upon-Dearne, Rotherham, Yorkshire. The collection of type slides now stored at this laboratory will eventually be deposited at the British Museum, Natural History, South Kensington, London.

Systematic procedure. Each species is provided with a diagnosis, the source of which is given in brackets. Where a diagnosis exists in the literature this has been accepted unless requiring emendation. The word 'translation' is added within the brackets only when the original diagnosis is in a foreign language and is given without emendation. When no diagnosis has been published, or it is inadequate, the authors have compiled one from data given in the descriptive account by the original author, or by subsequent workers. In these instances 'from' precedes the author's name and the source within the brackets. The same procedure has been followed in the few instances where the original diagnosis has been shortened, or when it is not clear whether a descriptive account is to be regarded as a diagnosis or a description. Except where a diagnosis has been quoted in full, the terminology used by the original authors may have been altered to that given in the present glossary. Such alterations have only been made where the original meaning is quite clear. When assigning a spore to a previously described species it has been considered desirable to use the published diagnosis wherever possible, particularly when type material was not available for re-examination. In this way the possibility of introducing an expanded, or emended, diagnosis based on a faulty assignment is avoided. This, however, has resulted in uneven treatment and in some instances in diagnoses which are inadequate by present standards (diagnoses are, however, supplemented by descriptive accounts).

The size ranges quoted by the present authors have been obtained from measurements made on at least twenty-five specimens reasonably well preserved in full polar compression unless otherwise stated. The mean size is shown in brackets between the limiting values. Measurements of the equatorial diameters of circular, oval, or elongate spores relate to the maximum dimensions. For triangular spores the maximum dimension from angle to opposite interradial margin is recorded as this value is more diagnostic of the species than the measurement from angle to angle. For cavate and saccate spores the measurements of their constituent parts are included, as specified in the text. All measurements exclude the heights of projecting ornament unless otherwise stated. Details of the reagents used in the maceration process are given, where known. The following abbreviations have been used: hydrochloric acid (dilute)—HCl; hydrofluoric acid (dilute)—HF; fuming nitric acid (S.G. 1·5)—fum. HNO_3; concentrated nitric acid—conc. HNO_3; Schulze reagent—Schulze. In aqueous solution: ammonium hydroxide—NH_4OH; potassium hydroxide—KOH; sodium hydroxide—NaOH; hydrogen peroxide—H_2O_2.

The source of the measured specimens is given after the methods of maceration. Where the size range is that of another author, the published designation, and geological age of the source material (often the same as that given under type locality), are given without regard to possible revision later.

The spore descriptions are generally based on specimens whose sizes have been measured. Where the number of measured specimens is small, reference has been made to material from other sources. Exine thickness is taken as the width of the usually faint marginal rim. If this is not apparent under oil, the thickness is recorded in qualitative terms.

The frequency of occurrence and stratigraphic range of each species in British coal seams are summarized under heading *Occurrence*. The former is based on the percentage occurrence of the species in all available counts made on samples of the whole seams excluding gross dirt and is expressed in terms of one or more of the following arbitrary frequency ranges:

Infrequent	$< 0{\cdot}5\%$
Frequent	0·5–2·0%
Common	2·1–5·0%
Very common	5·1–10·0%
Abundant	$> 10{\cdot}0\%$

Anteturma SPORONITES (R. Potonié) Ibrahim 1933
Genus CHAETOSPHAERITES Felix 1894

Type species. C. bilychnis Felix 1894.

Diagnosis (from description in Felix 1894, p. 272). Fungal spores, spindle-shaped with markedly blunt ends. Probably consist of four cells but the central septum may not be clearly visible because of the dark colouring of this portion of the spore. The two central cells are larger than the two end cells.

Affinity. Felix used *Chaetosphaerites* as a collective name for the fossil remains of Pyrenomycetes which conform to the living genus *Chaetosphaeria*. It only includes forms in which the central cells are coloured and the end cells are hyaline. *Chaetosphaerites pollenisimilis* somewhat resembles the Eocene form *C. bilychnis* Felix 1894 in being differentiated into darker and lighter portions.

Chaetosphaerites pollenisimilis (Horst) Butterworth and Williams 1958

Plate 1, figs. 1, 2

1907 Karczewski, pl. 1, figs. 5, 6.
1943 *Aletes pollenisimilis* Horst, (thesis) figs. 84–87.
1955 *Sporonites pollenisimilis* Horst, p. 150, pl. 24, figs. 84–87.
1957*a* *Sporonites cylindricus* (Horst); Dybová and Jachowicz, pp. 56–57, pl. 1, figs. 1–4.
1958 *Chaetosphaerites pollenisimilis* (Horst); Butterworth and Williams, p. 359, pl. 1, figs. 1–3.

Holotype. Horst 1955, pl. 24, fig. 84. Preparation IV 23, 27·0 77·9.

Type locality. Leopold Seam, Johann-Maria Colliery, Moravska-Ostrava; Namurian A.

Diagnosis. Spores oval to elongate with rounded ends, circular in section. Elements differentiated into two portions, usually of unequal size—a larger, more or less circular, colourless to pale yellow, translucent 'wing' and a smaller dark brown 'base'. There is no visible septum between the two portions. Elements may occur singly, but are usually found in pairs, joined together at an oblique angle at their bases. They may also occur in groups of three. Where joined in pairs the shorter sides of the bases are in contact, the 'wings' projecting at opposite ends of the fused elements.

Size in microns. (i) Holotype 32; 23–39 (30–35), fum. HNO_3 (Horst 1955). (ii) 21(36)52 Schulze (Playford 1962); Spitsbergen; Lower Carboniferous. (iii) Bicellular elements 18(25)30 × 12(16)20; single elements (5 specimens) 14–18 × 14–16, fum. HNO_3; Flex Seam at 3,866 ft. 2 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A. (iv) 18(27)33 × 14(18)24, fum. HNO_3; Fourlaws Seam, Fourlaws Hill Top Colliery, Northumberland Coalfield, England; Viséan.

Remarks. It is uncertain whether the fossil material referred to *Chaetosphaerites* by Butterworth and Williams originally possessed the structural characteristics of this genus. It has been retained in *Chaetosphaerites*, however, because of the colour differentiation within the elements.

Occurrence. Infrequent to frequent, Assemblages I to IV; Viséan and Namurian.

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch) Dettmann 1963
Suprasubturma ACAVATITRILETES Dettmann 1963
Subturma AZONOTRILETES (Luber) Dettmann 1963
Infraturma LAEVIGATI (Bennie and Kidston) Potonié 1956
Genus LEIOTRILETES (Naumova) Potonié and Kremp 1954

Type species. L. sphaerotriangulus (Loose) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 120; translation). 'Trilete isospores or microspores with smooth margin and triangular amb having distinctly concave, or slightly to rather strongly convex sides. Providing the triangular shape is still obvious or the three proximal pyramidal faces are rather steep, the spores belong to *Leiotriletes*. The angles of the amb are roughly rounded or blunt. Occasionally infrapunctate to infrareticulate. Trilete rays generally greater than one-half of radius.'

Remarks. Staplin (1960) referred spores of this type to the post-Palaeozoic genus *Deltoidospora* Miner 1935 in the belief that separation in time is not a valid reason for maintaining separate form genera. The authors, however, have retained the generally accepted nomenclature for Palaeozoic dispersed-spore genera since, as Playford (1962, p. 573) points out, the problem is not confined to *Leiotriletes*.

Affinity. Filicales, Remy and Remy (1957). Further evidence of filicinean affinity is given in Potonié (1962).

Leiotriletes inermis (Waltz) Ishchenko 1952

Plate 1, figs. 7, 8

1938 *Azonotriletes inermis* Waltz in Luber and Waltz, p. 11, pl. 1, fig. 3, pl. 5, fig. 58, and pl. A, fig. 2.
1952 *Leiotriletes inermis* (Waltz); Ishchenko, p. 9, pl. 1, figs. 2, 3.
1955 *Asterocalamotriletes inermis* (Waltz); Luber, p. 40, pl. 1, figs. 20, 21.
1955 *Leiotriletes inermis* (Waltz); Potonié and Kremp, p. 37.

EXPLANATION OF PLATE 1

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Chaetosphaerites pollenisimilis* (Horst) Butterworth and Williams 1958. 1, slide 1, 35·5 110·3. 2, slide 2, 36·1 110·0.

Figs. 3, 4. *Leiotriletes parvus* Guennel 1958. 3, slide 4, 21·0 109·8. 4, slide 5, 37·2 108·3.

Figs. 5, 6. *L.* cf. *priddyi* (Berry) Potonié and Kremp 1955. 5, slide 6, 40·3 100·5. 6, slide 7, 50·9 108·6.

Figs. 7, 8. *L. inermis* (Waltz) Ishchenko 1952. 7, slide 3, 31·8 112·2. 8, slide 3, 30·9 117·8.

Figs. 9, 10. *L. sphaerotriangularis* (Loose) Potonié and Kremp 1954. 9, slide 8, 57·5 107·1. 10, slide 9, 22·2 107·7.

Figs. 11, 12. *L. tumidus* Butterworth and Williams 1958. 11, Holotype; slide T32/1. 12, Isotype; slide T32/3.

Figs. 13, 14. *Punctatisporites nitidus* Hoffmeister, Staplin, and Malloy 1955. 13, slide 11, 51·2 101·3. 14, slide 12, 33·5 120·3.

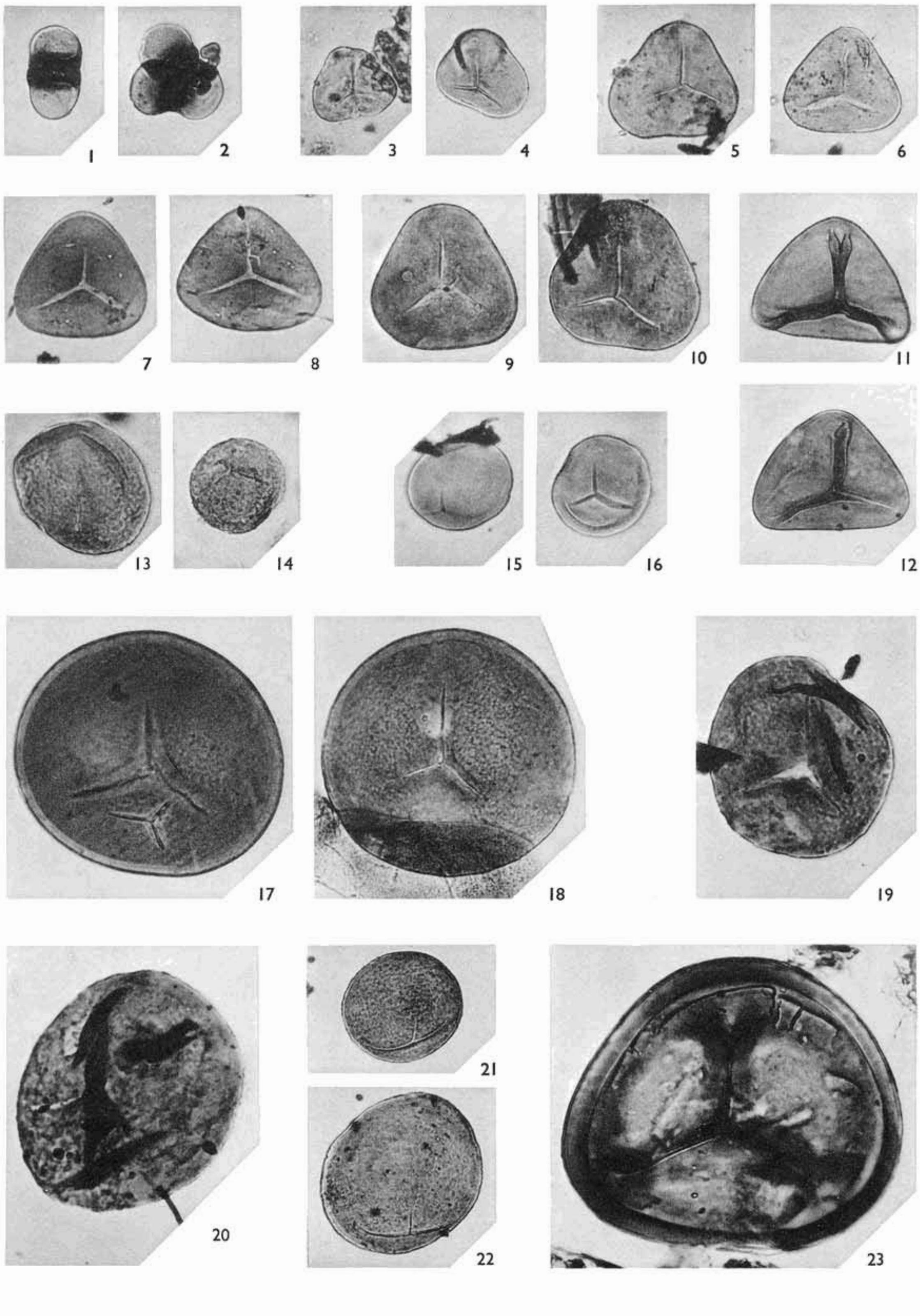
Figs. 15, 16. *P. minutus* Kosanke 1950. 15, slide 10, 35·6 114·3. 16, slide 10, 39·2 113·8.

Figs. 17, 18. *P. aerarius* Butterworth and Williams 1958. 17, Holotype; slide T33/1. 18, Isotype; slide T33/4.

Figs. 19, 20. *P. punctatus* Ibrahim 1932. 19, slide 16, 50·7 115·7. 20, slide 17, 52·6 115·4.

Figs. 21, 22. *P. obliquus* Kosanke 1950. 21, slide 14, 47·3 105·4. 22, slide 15, 54·6 112·8.

Fig. 23. *P. obesus* (Loose) Potonié and Kremp 1955. 23, slide 13, 35·6 112·5.



SMITH and BUTTERWORTH, British Carboniferous miospores

Holotype. Not designated by Waltz.

Diagnosis (Waltz 1938, from C.E.D.P. translation No. 1443 in French). Shape elongate-triangular. Surface of exine smooth. Lips of trilete dehiscence mark slightly raised; length of rays a little less than spore radius.

Size in microns. (i) 40–50, Schulze (Waltz 1938). (ii) 40–65 (Ishchenko 1958). (iii) 28(43)57, Schulze (Playford 1962). (iv) 30(38)55, fum. HNO_3; Shilbottle Seam at 201 ft. 1 in., New Moor Hall borehole, Northumberland Coalfield, England; Viséan.

Description. Amb subtriangular; sides straight to slightly convex. Laesurae simple, straight, reaching from three-quarters to whole of distance to amb. Exine moderately thick, laevigate, usually without folds, often darker in region of proximal pole.

Comparison. *Deltoidospora implumis* Staplin 1960 (p. 14, pl. 3, fig. 5) is smaller with a size range of 26–30 μ and has slightly concave sides.

Occurrence. Infrequent, occurs in Assemblage II but range is uncertain; Viséan.

Leiotriletes parvus Guennel 1958

Plate 1, figs. 3, 4

Holotype. Guennel 1958, p. 57; text-fig. 14. Sample 45, slide 851.

Type locality. Outcrop coal, Upper Block *b* zone, Owen County, Indiana, U.S.A.; Pottsville Series.

Diagnosis (from description in Guennel 1958, p. 57). Amb triangular; interradial margins concave or nearly straight, angles rounded. Laesurae distinct, extend more than half-way to margin; lips present. Exine unornamented and thin.

Size in microns. Holotype 22; 16(20)28, Schulze (Guennel 1958).

Comparison. *L. gracilis* Imgrund 1960 (p. 153, pl. 13, figs. 8, 9) and *L. sporadicus* Imgrund 1960 (p. 153, pl. 13, fig. 11 and pl. 14, fig. 40) are comparable in size with *L. parvus*. *L. gracilis* may be distinguished by its broad tectum. *Deltoidospora implumis* Staplin 1960 (p. 14, pl. 3, fig. 5) is also similar in size but exine in contact area is darker in colour.

Occurrence. Infrequent, Assemblages VIII to XI; Westphalian B to D.

Leiotriletes priddyi (Berry) Potonié and Kremp 1955

1937 *Zonales-sporites priddyi* Berry, p. 156, text-fig. 2.
1944 *Granulati-sporites*(?) *priddyi* (Berry); Schopf, Wilson, and Bentall, p. 33.
1950 *Plani-sporites priddyi* (Berry); Knox, p. 316, pl. 17, fig. 220.
1955 *Leiotriletes priddyi* (Berry); Potonié and Kremp, p. 38.

Holotype. Berry 1937, p. 159; text-fig. 2. Preparation L1, 91 49·4.

Type locality. Pennington Coal, Rhea County, Tennessee, U.S.A.; Upper Mississippian.

Diagnosis (from Berry 1937, p. 156). Amb triangular, often slightly convex between angles. Laesurae two-thirds of radius. Exine laevigate, clear (? without infrasculpture), and very thin.

Size in microns. Not more than 35 (Berry 1937).

Leiotriletes cf. *priddyi* (Berry) Potonié and Kremp 1955

Plate 1, figs. 5, 6

Description. Amb subtriangular, with well-rounded angles; interradial margins generally straight to convex. Laesurae simple, straight, two-thirds to three-quarters of radius. Exine laevigate without infrasculpture, rarely darker in area of proximal pole; compression folding of the 'gulaferus' type (Potonié and Kremp 1955, p. 40) occurs.

Size in microns. (i) 27(32)36, fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B. (ii) 20(27)35, conc. HNO_3 and 2% KOH (Sullivan 1964); Edgehills Coal, Forest of Dean Coalfield, England; ? Westphalian A.

Remarks. Laevigate, convex spores of this type, but without darkened contact area, from British coals have been referred to *L.* cf. *priddyi* by Sullivan (1964) as the type was inadequately described and illustrated. The authors have similarly assigned their forms to this species to avoid erecting further species in the present state of knowledge.

Comparison. L. inflatus (Schemel 1950, pl. 39, fig. 13) Potonié and Kremp and *L.* cf. *sphaerotriangulus* (Loose) Potonié and Kremp in Butterworth and Williams (1958, pl. 1, fig. 4) appear to be comparable in size, shape, and age with *L. priddyi* and may be conspecific with it. *L.* cf. *priddyi* is smaller and thinner than *L. inermis* and does not usually have a darker polar area.

Occurrence. Infrequent, Assemblages III to IX; Namurian to Westphalian B.

Leiotriletes sphaerotriangulus (Loose) Potonié and Kremp 1954

Plate 1, figs. 9, 10

1932 *Sporonites sphaerotriangulus* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 18, fig. 45.
1933 *Laevigati-sporites sphaerotriangulus* (Loose); Ibrahim, p. 20.
1944 *Punctati-sporites sphaerotriangulatus* (Loose); Schopf, Wilson, and Bentall, p. 31.
1950 *Plani-sporites sphaerotriangulatus* (Loose); Knox, p. 316, pl. 17, fig. 214.
1954 *Leiotriletes sphaerotriangulus* (Loose); Potonié and Kremp, p. 120.

Holotype. Potonié and Kremp 1955, pl. 11, fig. 107 after Loose. Preparation IV21, f_2 (m/ol).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 41; translation). 'Amb triangular, sides in part slightly convex. Laesurae extend nearly to equator. Exine weakly infrapunctate.'

Size in microns. (i) Holotype 43·5, Schulze. (ii) 40–60, Schulze (Potonié and Kr. 1955). (iii) 30–66, fum. HNO_3 (Horst 1955). (iv) 38(46)55, fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Sides straight to convex in proximal compression, angles rounded. Laesurae simple, straight, one-half to three-quarters of radius. Exine moderately thick, usually preserved without folds.

Remarks. Butterworth and Williams (1958, pl. 1, fig. 4) figure but do not describe a spore from the Namurian which they refer to *L.* cf. *sphaerotriangulus*. This specimen closely resembles in size and shape *L. inflatus* (Schemel 1950, pl. 39, fig. 13) Potonié and Kremp, with a size range of 30–47 μ.

Comparison. *L. ficilis* Ishchenko 1952 (pl. 1, fig. 5) and *L. falsus* Ishchenko 1952 (pl. 1, fig. 6) are considered by Dybová and Jachowicz (1957, p. 123) to be in part synonymous with *L. sphaerotriangulus*. *L. inermis* (Waltz) Ishchenko has a similar size range, but the exine is not infrapunctate as in *L. sphaerotriangulus*.

Occurrence. Infrequent, Assemblages VI to IX; Westphalian A to Lower Westphalian C.

Leiotriletes tumidus Butterworth and Williams 1958

Plate 1, figs. 11, 12

Holotype. Plate 1, fig. 11. Preparation No. T32/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Kilsyth Coking Seam at 1,097 ft. 0 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (Butterworth and Williams 1958, p. 359). '. . . elongated triangular in outline; spore coat smooth. Proximal hemisphere tumid; trilete rays long, typically with ray folds.'

Size in microns. Holotype 46; 34(42)52 (23 specimens), fum. HNO_3 (Butterworth and Will. 1958).

Description. Amb subtriangular, sides straight or convex, angles rounded. Laesurae simple, straight, two-thirds of radius or greater, frequently reaching almost to equator. Prominent folds, often of unequal length, frequently accompany the laesurae. Exine less than 2 μ in thickness.

Comparison. *L. inermis* (Waltz) Ishchenko is very similar but lacks the characteristic folds. *L. ornatus* Ishchenko 1956 (p. 22, pl. 2, figs. 18–21) is another species of comparable size [32(46)63 μ in Playford 1962] and shape, but differs in possessing prominent lips. *L. sphaerotriangulus* (Loose) Potonié and Kremp differs in its shape, thicker exine and in the absence of folds associated with the laesurae. *Granulatisporites triconvexus* Staplin 1960 (p. 15, pl. 3, figs. 11, 12), with a size range of 35–44 μ, may show folding along the laesurae, but is very finely granulate under oil.

Occurrence. Infrequent, Assemblages II to IV; Viséan and Namurian.

Genus PUNCTATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. *P. punctatus* Ibrahim 1933.

Diagnosis (Potonié and Kremp 1954, p. 120; translation). 'Trilete isospores or microspores having a circular, or near-circular, equatorial outline with a mere suggestion of triangular shape. Margin smooth, as exine devoid of ornamentation. Structure unrecognizable or only discernible owing to the presence of punctation, infrareticulation, or infragranulation (which must not be confused with a granulation causing roughness of the margin). On occasions, punctation is no more than locally visible, as, for instance, along the trilete rays. Rays generally longer than one-half the radius at the equator.'

Comparison. Exine thicker with fewer folds than in the majority of species of *Calamospora* Schopf, Wilson, and Bentall 1944. Differs from *Calamospora* and *Phyllothecotriletes* Luber in having longer laesurae, and no contact area.

Remarks. The genus contains many species, only a small number of which have so far been recorded sufficiently often from British coals to warrant description.

The diagnosis permits the inclusion within the genus of forms with smooth or rough exines. Guennel (1958, p. 66) suggests that the genus should be restricted to forms which resemble the type in having a rough exine. Such forms are in the majority. Judging the character of the exine, however, tends to be a subjective matter depending to some extent on the method of observation employed. For this reason, and because a number of small forms occurring in the coals would be particularly difficult to classify on this basis, the diagnosis given by Potonié and Kremp is accepted in the present work.

Affinity. Psilophytopsida, Filicales (Primofilices and Leptosporangiatae), and other Pteropsida in Potonié 1962.

Punctatisporites aerarius Butterworth and Williams 1958

Plate 1, figs. 17, 18

Holotype. Pl. 1, fig. 17. Preparation T33/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Lower Garscadden Ironstone Seam at 1,010 ft. 2 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (restated from Butterworth and Williams 1958, p. 360). Amb circular. Laesurae slightly longer than one-half of radius. Exine minutely granulate, up to 4 μ in thickness.

Size in microns. Holotype 83 × 75; 55(74)92 (21 specimens), fum. HNO_3 (Butterworth and Will. 1958).

Description. Margin smooth to minutely indented. Laesurae simple, or slightly ridged, straight (range 12–25 μ). Exine very finely granulate; grana only just visible at margin; sometimes with one or more compression folds.

Comparison. A number of species appear to be very similar to *P. aerarius*. The following comparisons are based only on the published descriptions and illustrations.

Small forms of *P. aerarius* fall within the size range of *P. glaber* (Naumova) Playford [32(52)70 μ], and cannot satisfactorily be distinguished morphographically from that species as broadly defined by Playford (1962, p. 576).

The spore figured by Horst 1955 (pl. 21, fig. 30) as *P.* cf. *obesus* (Loose) Potonié and Kremp is probably *P. aerarius*. *P. callosus* Hoffmeister, Staplin, and Malloy 1955 (p. 392, pl. 39, fig. 7) and *P. viriosus* Hacquebard 1957 (p. 308, pl. 1, fig. 14) both have laevigate exines; the former species has been compared with small forms of *P. obesus* (Loose) Potonié and Kremp. *P. calvus* Staplin 1960 (p. 8, pl. 1, fig. 26) is a species with a thin laevigate exine, frequently folded. *P. irrasus* Hacquebard 1957 (p. 308, pl. 1, figs. 7, 8) is thinner than *P. aerarius* and is often characterized by folds of major proportions. *P. mundus* Kosanke 1950 (p. 16, pl. 2, fig. 8) differs in being roundly triangular and in having a thinner exine. *P. planus* Hacquebard 1957 (p. 308, pl. 1, fig. 12) has slightly longer laesurae, two-thirds to three-quarters of spore radius. In *P. pseudolevatus* Hoffmeister, Staplin, and Malloy 1955 (p. 394, pl. 36, fig. 5) the exine ornament is pronounced (finely granulate). *P. punctatus* Ibrahim differs from *P. aerarius* in that the shape is less constantly circular, the exine thinner, and the laesurae longer.

Occurrence. Infrequent or frequent, Assemblages II to IV; Namurian.

Punctatisporites minutus Kosanke 1950

Plate 1, figs. 15, 16

Holotype. Kosanke 1950, pl. 16, fig. 3. Maceration 584, slide 7.

Type locality. ?Woodbury Coal, Jasper County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 15). Originally spherical in shape with the spore coat variously folded. Laesurae distinct, two-thirds of radius, lips slightly developed. Exine $1–1{\cdot}5\,\mu$ thick and minutely punctate.

Size in microns. (i) Holotype 29; 27–33, Schulze and 10% KOH (Kosanke 1950). (ii) 22(27)32 (18 specimens) fum. HNO_3; Shale Seam at 663 ft. 6 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Laesurae usually straight ($6–11\,\mu$), unless spore is compressed obliquely; contact areas sometimes slightly darkened. No detectable sculpture at spore margin; very finely granulate or punctate. Appearance of exine may be due to infrasculpture. Folding slight or absent.

Remarks. Superficially some specimens resemble a small, relatively thick-walled *Calamospora. Calamospora minutus* Knox, *non sensu* Potonié and Kremp is probably conspecific with *P. minutus*. The forms figured as *P.* cf. *nitidus* by Butterworth and Williams 1958 (pl. 1, figs. 7, 8) are this species.

The species was first described from coals of Stephanian age but subsequently it was recorded from the Upper Westphalian B by Potonié and Kremp 1955 and from the Viséan of Scotland by Love 1960. It is apparent, therefore, that spores indistinguishable from Kosanke's species have a considerable stratigraphic range. The present forms from coals of Namurian age are consequently assigned to Kosanke's species.

Comparison. Several species have a similar size range. The smaller specimens of *P. curviradiatus* Staplin 1960 (p. 7, pl. 1, figs. 17, 20) resemble those specimens of *P. minutus* preserved in oblique compression. *P. densiminutus* Staplin 1960 (p. 7, pl. 1, fig. 19) differs in having a very thick exine and compression folds simulating a girdle. The smaller varieties of *Cyclogranisporites parvulus* Staplin 1960 (p. 9, pl. 1, figs. 16, 21) appear to have a coarser sculpture than *P. minutus*.

Occurrence. Infrequent, Assemblages II to IV; Namurian. Recorded from coal and other rocks of Viséan age from Scotland by Love 1960.

Punctatisporites nitidus Hoffmeister, Staplin, and Malloy 1955

Plate 1, figs. 13, 14

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 4. Preparation 9, ser. 18,659.

Type locality. Shale at 2,072 ft. Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 393). Amb circular. Laesurae simple, about two-thirds of radius. Arcuate compression folds common. Exine laevigate to faintly granulose, about 2 μ thick.

Size in microns. (i) Holotype 34 31–43, HF; (Hoffmeister, Stap., and Mall. 1955). (ii) 30–38, Schulze (Hacquebard and Barss 1957). (iii) 30(43)57, fum. HNO_3; Shale Seam at 663 ft. 6 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Shape sometimes oval, margin may be smooth or minutely indented. Laesurae two-thirds to three-quarters of radius (range 7–17 μ), generally straight, but may be curved as result of oblique compression. Exine scabrate to finely granulate; type of ornament is independent of size of spore. Compression folds usually narrow and few in number.

Remarks. Playford (1962, p. 576) considers *P. nitidus* to be conspecific with *P. glaber* (Naumova) Playford. *P. glaber* is, however, described by Playford as being laevigate and rarely folded and the specimens illustrated by him (pl. 78, figs. 15, 16) possess a relatively thick exine. *P. nitidus*, on the other hand, has a distinct, finely granulate sculpture and a thinner exine which commonly develops folds on compression (Hoffmeister, Staplin, and Malloy, pl. 36, fig. 4; Hacquebard and Barss, pl. 2, fig. 3). The size range is also less than that given by Playford for *P. glaber*. For these reasons *P. nitidus* is considered as a distinct species from *P. glaber*. The size range of spores referred to *P. nitidus* from British coals is larger than that given by Hoffmeister, Staplin, and Malloy but in other respects the spores closely resemble this species.

Comparison. Cyclogranisporites orbicularis (Kosanke) Potonié and Kremp is slightly thicker and is rarely folded. *P. parvipunctatus* Kosanke is more finely sculptured than most specimens of *P. nitidus.*

Occurrence. Infrequent or frequent, Assemblages II to IV; Namurian.

Punctatisporites obesus (Loose) Potonié and Kremp 1955

Plate 1, fig. 23

1932 *Sporonites obesus* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 19, fig. 49.
1934 *Laevigatisporites obesus* Loose, p. 145.
1944 ?*Calamospora obesus* (Loose); Schopf, Wilson, and Bentall, p. 52.
1955 *Punctatisporites obesus* (Loose); Potonié and Kremp, p. 43, pl. 11, fig. 124.

Holotype. Loose 1932, pl. 19, fig. 49. Preparation III 6, e_4 (m).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from description in Loose 1934, p. 145). Amb circular to oval. Laesurae one-third of radius. Exine laevigate to punctate, up to 5 μ in thickness.

Size in microns. (i) Holotype 117, Schulze. (ii) 100–130, Schulze (Potonié and Kr. 1955). (iii) 94(106)125 (8 specimens) fum. HNO_3; various horizons, Great Britain; Westphalian B to D.

Description. Amb circular, subcircular, rounded-triangular or oval. Laesurae simple, straight, one-half to two-thirds of radius (range 25–37 μ); commissure sometimes open; occasionally the exine parallel to the commissures is darkened giving the appearance of broad lips. Exine thick, 5–10 μ; compression folds sometimes occur.

Remarks. Some of the British specimens are smaller and most have longer laesurae than the specimens described by Loose. Potonié and Kremp assign such forms to *P.* cf. *obesus* but these differences in overall size may only be due to the different methods of maceration. The exine thickness, as judged by the width of the prominent marginal rim, mostly exceeds the 5 μ quoted by Loose 1934. It is probable that Loose's description was based on the examination of too few specimens.

Comparison. *P. callosus* Hoffmeister, Staplin, and Malloy 1955 (p. 392, pl. 39, fig. 7) and *P. viriosus* Hacquebard 1957 (p. 308, pl. 1, fig. 14) are smaller and thinner. The spores described by Neves (1958, p. 6, pl. 3, fig. 1) as *P.* cf. *obesus* have similar size (95–135 μ) but appear rather different, frequently having small folds running along the laesurae. *P. flavus* (Kosanke) Potonié and Kremp 1955 is similar in size and appearance to *P. obesus* but Kosanke (1950, p. 41) stated that the two species are distinct.

Occurrence. Infrequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Punctatisporites obliquus Kosanke 1950

Plate 1, figs. 21, 22

Holotype. Kosanke 1950, pl. 2, fig. 5. Maceration 603-B, slide 5.

Type locality. No. 2 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 16). Amb oval to circular. Laesurae distinct with lips and not equally spaced. Exine minutely punctate, 1·25 to 1·5 μ thick.

Size in microns. Holotype 35 × 40; 31–46, Schulze and 10% KOH (Kosanke 1950).

Description. Laesurae greater than one-half of radius and frequently curved due to oblique compression; in some cases, as noted by Kosanke, one laesura is reduced in length and prominence. Exine scabrate to minutely granulate. Margin minutely indented. Exine generally without folds.

Remarks. The spore has only been recognized when compressed obliquely. Playford (1962, p. 577) points out that off-polar compression resulting in curvature of two laesurae is a questionable basis for specific distinction. The species has, however, been retained in the absence of data from British coals concerning associated forms lacking these features.

Comparison. Two other species described by Kosanke, namely *Cyclogranisporites orbicularis* (Kosanke) Potonié and Kremp 1955 and *P. parvipunctatus*, somewhat resemble *P. obliquus* and might be confused with it when obliquely compressed; their laesurae, however, are equally developed.

Occurrence. Infrequent or frequent, Assemblages X and XI; Westphalian C and D.

Punctatisporites punctatus Ibrahim 1932

Plate 1, figs. 19, 20

1932 *Sporonites punctatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 448, pl. 15, fig. 18.

1933 *Punctati-sporites punctatus* Ibrahim, p. 21, pl. 2, fig. 18.

Holotype. Ibrahim 1932, pl. 15, fig. 18. Preparation B29, f1 (ul).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Ibrahim 1933, p. 21). Amb circular to triangular. Laesurae reach to the equator. Exine 1–2 μ thick; punctate; margin somewhat rough.

Size in microns. (i) Holotype 77, Schulze and KOH. (ii) 50–80, Schulze (Potonié and Kr. 1955). (iii) 59(74)89 (14 specimens) fum. HNO_3; Swallow Wood Seam at 1,475 ft. 0 in., Kellingley borehole, Yorkshire Coalfield, England; Westphalian B.

Description. Most of the specimens examined tended to be circular or subcircular in proximal distal orientation. Laesurae straight and simple, two-thirds to three-quarters of radius (range 20–37 μ). Scabrate, sculpture scarcely detectable at margin. Often folded.

Remarks. Ibrahim in his drawing of *P. punctatus* shows the laesurae extending to the margin of the spore but this is not so in the holotype, or in the spore photographed by Potonié and Kremp (1955, pl. 11, fig. 123).

Comparison. There are a number of species described in the literature which superficially resemble *P. punctatus*. In *P. callosus* Hoffmeister, Staplin, and Malloy 1955 (p. 392, pl. 39, fig. 7) the exine is more translucent and laevigate. *P. calvus* Staplin 1960 (p. 8, pl. 1, fig. 26) has a thinner exine. *P. irrasus* Hacquebard 1957 (p. 308, pl. 1, figs. 7, 8) often has major, arcuate compression folds. *P. mundus* Kosanke 1950 (p. 16, pl. 2, fig. 8) appears to have a rather coarser sculpture than *P. punctatus* and the laesurae are shorter. *P. planus* Hacquebard 1957 (p. 308, pl. 1, fig. 12) is difficult to distinguish from some forms of *P. punctatus* seen in British coals. *P. pseudolevatus* Hoffmeister, Staplin, and Malloy 1955 (p. 394, pl. 36, fig. 5) is characterized by heavy, arcuate folding and a finely granulate surface. *P. viriosus* Hacquebard 1957 (p. 308, pl. 1, fig. 14) is said to resemble *P. callosus* Hoffmeister, Staplin, and Malloy except for larger size and lip development.

Occurrence. Infrequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Punctatisporites sinuatus (Artüz) Neves 1961

Plate 2, figs. 1, 2

1957 *Sinuspores sinuatus* Artüz, p. 254, pl. 7, fig. 48.

1958 *Punctatisporites densoarcuatus* Neves, p. 6, pl. 2, fig. 7.

1958 *Punctatisporites coronatus* Butterworth and Williams, p. 360, pl. 1, fig. 12.

1961 *Punctatisporites sinuatus* (Artüz); Neves, p. 252.

Holotype. Artüz 1957, pl. 7, fig. 48. Preparation I, 30, 1c.

Type locality. Büyük Seam, Zonguldak Coalfield, Turkey; Westphalian A.

Diagnosis (from Artüz 1957, p. 254). Amb circular. Laesurae straight, distinct, three-quarters of radius. Surface of exine covered by 'sine-curve-like' infrastructures. A dark coloured, structureless girdle zone ('Gürtelzone'), 15–17 μ broad, occurs at the margin of the spore.

Size in microns. (i) Holotype 120; 90–130, maceration method not known (Artüz 1957). (ii) 80(117)140, Schulze and KOH (Neves 1958); roof shales of Six Inch Seam, North Staffordshire Coalfield, England; Namurian C. (iii) 75(102)116 (13 specimens) fum. HNO_3 (Butterworth and Will. 1958); Shale Seam at 663 ft. 6 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Amb circular to subcircular, margin smooth. Laesurae simple, or slightly ridged, commissure sometimes slightly open. Exine laevigate and with fine infrasculpture up to 5 μ in thickness, usually highly folded. Characteristically the folds are broad and situated around the periphery of the spore but they sometimes follow the laesurae, when they give the appearance of broad lips; occasionally the exine is thrown into low, broad, sinuous corrugations in addition to the marginal folds.

Remarks. *Sinuspores sinuatus* was described by Artüz as possessing a dark peripheral 'Gürtelzone' and 'sine curve' structures. The material examined by Neves (1958) and Butterworth and Williams (1958) showed that these structures are due to simple folding, or corrugation of the exine, and are variable in their development. For this reason the species was transferred to *Punctatisporites* by Neves (1961) without emending the diagnosis.

Occurrence. Scotland, infrequent, Assemblages III and IV; Central Province, infrequent, V and VI; Namurian A to Westphalian A.

Genus CALAMOSPORA Schopf, Wilson, and Bentall 1944

Type species. *C. hartungiana* Schopf in Schopf, Wilson, and Bentall 1944 [?synonym of *C. mutabilis* (Loose 1932)].

Diagnosis (Potonié and Kremp 1955, p. 46; translation). 'Trilete miospores, that is isospores, microspores, and small megaspores, the latter possibly up to 350 μ (cf. Hartung 1933, p. 106). Laesurae generally shorter, or only slightly longer, than one-half the radius of the equatorially flattened spore; occasionally indistinct. Suture sometimes open. Faint contact areas often present; usually no curvaturae, but only different coloration of these areas. Outline more or less smooth. Thin exine without sculpture. Structure not recognizable, or appearing as faint internal punctation, mottling, etc. Conspicuous secondary folds frequent due to fairly thin exine.'

EXPLANATION OF PLATE 2

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Punctatisporites sinuatus* (Artüz) Neves 1961. 1, slide T34/1. 2, slide 18, 60·0 109·0.

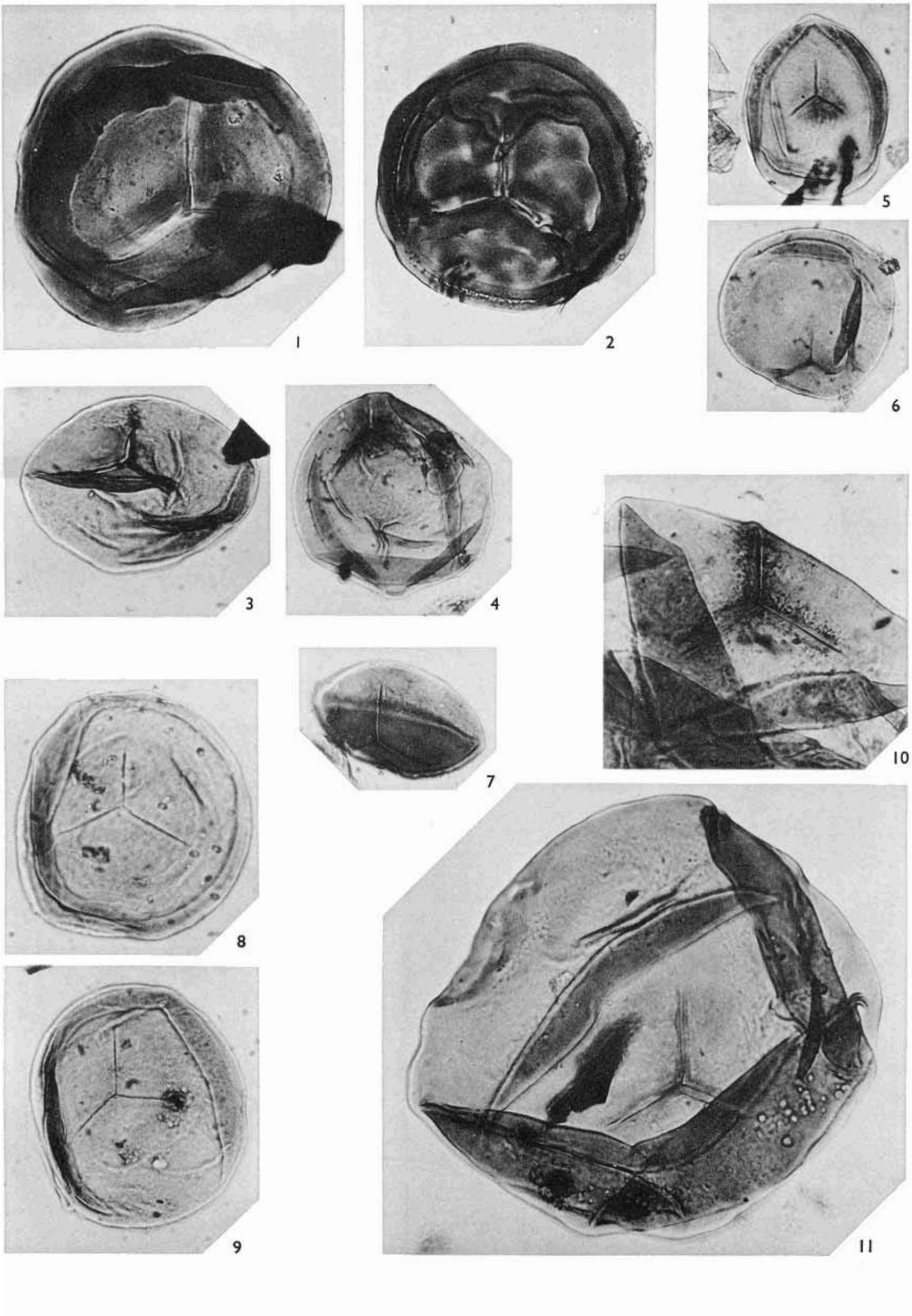
Figs. 3, 4. *Calamospora breviradiata* Kosanke 1950. 3, slide 19, 60·7 107·8. 4, slide 20, 47·4 113·6.

Figs. 5, 6. *C.* cf. *breviradiata* Kosanke 1950. 5, slide 21, 44·0 106·3. 6, slide 21, 18·0 106·6.

Fig. 7. *C. pedata* Kosanke 1950. Slide 32, 33·9 105·6.

Figs. 8, 9. *C. mutabilis* (Loose) Schopf, Wilson, and Bentall 1944. 8, slide 26, 29·8 108·2. 9, slide 27, 35·6 115·5.

Figs. 10, 11. *C.* cf. *laevigata* (Ibrahim) Schopf, Wilson, and Bentall 1944. 10, thickened lips and adjacent contact areas; slide 22, 40·4 106·1. 11, slide 23, 38·4 114·1.



SMITH and BUTTERWORTH, British Carboniferous miospores

Remarks. Typical forms of the genus are easily recognized but for a genus with so few distinguishing characters a surprising number of species have been erected. Apart from size, speciation has been based on such features as extent and tendency to unequal development of laesurae, presence of differentiated contact areas, nature and extent of folding, thickness of exine, and 'off-centre' compression.

It is not yet apparent from palaeobotanical studies of fructifications and their contained spores how far such features are genetically determined and diagnostic of species. In a system of classification based on purely morphographic characters there may be a tendency to multiply the number of species without increasing the value of the genus for stratigraphical purposes. It is probable that in this genus there are a number of botanical species which differ only in their size ranges, and these ranges may show a considerable degree of overlap. For practical purposes a limited number of species have been recognized whose size ranges show the minimum of overlap and whose members are normally distributed about a modal size value. Species with intermediate size ranges, if they exist, must of necessity be assigned to one or other of the recognized species. In practice, arbitrary size limits (indicated in the text) must be used in counts to distinguish those species whose size ranges overlap to a small extent. Some species of *Calamospora* are less difficult to recognize since the sum of their characters gives them a distinctive appearance.

Comparison. *Calamospora* differs from *Phyllothecotriletes* Luber 1955 in having a thinner exine and from *Punctatisporites* (Ibrahim) Potonié and Kremp in possessing contact areas, and shorter laesurae. *Calamospora* differs from both genera in possessing pronounced secondary folding.

Affinity. Eleutherophyllaceae, Sphenophyllaceae, Calamitaceae, Equisetaceae, and Noeggerathiineae in Potonié (1962), Protopityales (Walton 1957).

Calamospora breviradiata Kosanke 1950

Plate 2, figs. 3, 4

Holotype. Kosanke 1950, pl. 9, fig. 4. Maceration 579-B, slide 1.

Type locality. No. 2 Coal, Bureau County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 41). Amb circular, or irregular through folding. Laesurae ridged, one-third to one-half of radius. Contact area developed.

Size in microns. Holotype 65·1 × 57·7; 52–71, Schulze and 10% KOH (Kosanke 1950).

Description. Amb circular, shape often distorted by compression. Laesurae prominent and slightly flexuose. (This latter character is not mentioned by Kosanke but it is apparent in the figure of the holotype.) Laesurae sometimes of unequal length. Radius of darker contact area less than length of laesurae. Exine less than 1 μ in thickness; compression folds well-developed, often parallel to the margin of the spore.

Comparison. Easily distinguished from most other forms of *Calamospora* of similar size by ridged and relatively short laesurae and darkened contact areas.

Occurrence. Infrequent, not recorded from all coals, Assemblages III to IX; Namurian A to Lower Westphalian C.

Calamospora cf. *breviradiata* Kosanke 1950

Plate 2, figs. 5, 6

Description. Amb generally circular. Laesurae distinct and straight, one-third to one-half of radius (average 10 μ). Darkening of exine around proximal pole, not extending to limit of laesurae. Exine thin, but more robust than in some other species of genus. Limited number of compression folds, generally occurring towards margin; sometimes virtually without folds.

Size in microns. 42(49)57, fum. HNO_3; Tillery Rider Seam, Tirpentwys Colliery, South Wales Coalfield; Lower Westphalian D.

Remarks. Appears to be smaller form of the type.

Occurrence. Infrequent, Assemblages VI to X; frequent to common, Assemblage XI; Upper Westphalian A to Westphalian D.

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

1933 *Laevigati-sporites laevigatus* Ibrahim, p. 17, pl. 6, fig. 46.
1944 *Calamospora laevigatus* (Ibrahim); Schopf, Wilson, and Bentall, p. 52.

Holotype. Ibrahim 1933, pl. 6, fig. 46. Preparation E92, c.

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from diagnosis and description in Potonié and Kremp 1955, p. 48). Amb more or less circular. Laesurae distinct, simple, and less than one-third of radius; no contact area or curvaturae recognizable. Exine 4–7 μ thick, shows little or no structure.

Size in microns. (i) Holotype 490, Schulze and KOH. (ii) 250–500, Schulze (Potonié and Kr. 1955).

Calamospora cf. *laevigata* (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 2, figs. 10, 11

Description. Amb more or less rounded, but may be irregular in shape due to folding. Laesurae ? ridged, straight, about one-third of radius (30–42 μ), usually bordered by lips for part, or all, of length; width of lips about 2·5 μ; contact area more or less differentiated due to coarsening of exine ? structure (exine appears mottled or even granulose). Exine about 2·5 μ thick and darker in colour than in other species of *Calamospora*. Folding variable and usually of major dimensions.

Size in microns. 150–260 (7 specimens) fum. HNO_3; various localities, Great Britain; Westphalian A and B.

Remarks. The smaller size, the ? ridged laesurae, and the differentiated contact area are features which distinguish this form from the type. These differences are, however, not considered sufficient reason to create a new species since the earlier descriptions are brief and there are some anomalies in the literature. The illustration of Loose's specimen in Potonié and Kremp (1955, pl. 12, fig. 136*b*) shows a spore with a diameter of about 175 μ, which is smaller than the published range, but agrees with the spores from British coals.

Comparison. Loose (1934) states that the folding in the type is reminiscent of that in *C. mutabilis*.

Occurrence. Infrequent, Assemblages V to IX; Westphalian A to Lower Westphalian C. Recorded from all the major coalfields but only from a few coals.

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

Plate 3, figs. 1, 2

1932 *Sporonites microrugosus* Ibrahim in Potonié, Ibraham, and Loose, p. 447, pl. 14, fig. 9.
1933 *Laevigati-sporites microrugosus* (Ibrahim); Ibrahim, p. 18, pl. 1, fig. 9.
1938 *Azonotriletes microrugosus* (Ibrahim); Waltz in Luber and Waltz, p. 10, pl. 1, fig. 1 and pl. A, fig. 1.
1944 *Calamospora microrugosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 52.
1952 *Leiotriletes microrugosus* (Ibrahim); Ishchenko, p. 15, pl. 2, fig. 19.
1955 *Calamotriletes microrugosus* (Ibrahim); Luber, p. 36, pl. 1, figs. 1–3.

Holotype. Ibrahim 1932, pl. 14, fig. 9. Preparation A42, c6 (l).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1955, p. 49). Amb more or less circular, often very irregular due to compression folding. Laesurae weakly ridged, straight or flexuose, one-third of radius. Exine structureless, about $\frac{2}{3}\,\mu$ in thickness. Secondary compression folds numerous.

Size in microns. (i) Holotype 77, Schulze and KOH. (ii) 70–100, Schulze (Potonié and Kr. 1955). (iii) 62(82)104 Schulze and NH_4OH (Playford 1962); Spitsbergen; Lower Carboniferous. British specimens have been recorded up to 110.

EXPLANATION OF PLATE 3

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Calamospora microrugosa* (Ibrahim) Schopf, Wilson, and Bentall 1944. 1, slide 9, 39·0 107·6. 2, slide 24, 59·6 108·3.

Figs. 3, 4. *C*. cf. *microrugosa* (Ibrahim) Schopf, Wilson, and Bentall 1944. 3, slide 25, 51·3 105·9. 4, slide 25, 27·8 108·8.

Figs. 5, 6. *C. pallida* (Loose) Schopf, Wilson, and Bentall 1944. 5, slide 28, 35·8 117·6. 6, slide 29, 52·3 117·6.

Figs. 7, 8. *C. parva* Guennel 1958. 7, slide 30, 22·7 105·5. 8, slide 31, 26·6 105·8.

Fig. 9. *C. perrugosa* (Loose) Schopf, Wilson, and Bentall 1944. Specimen not preserved.

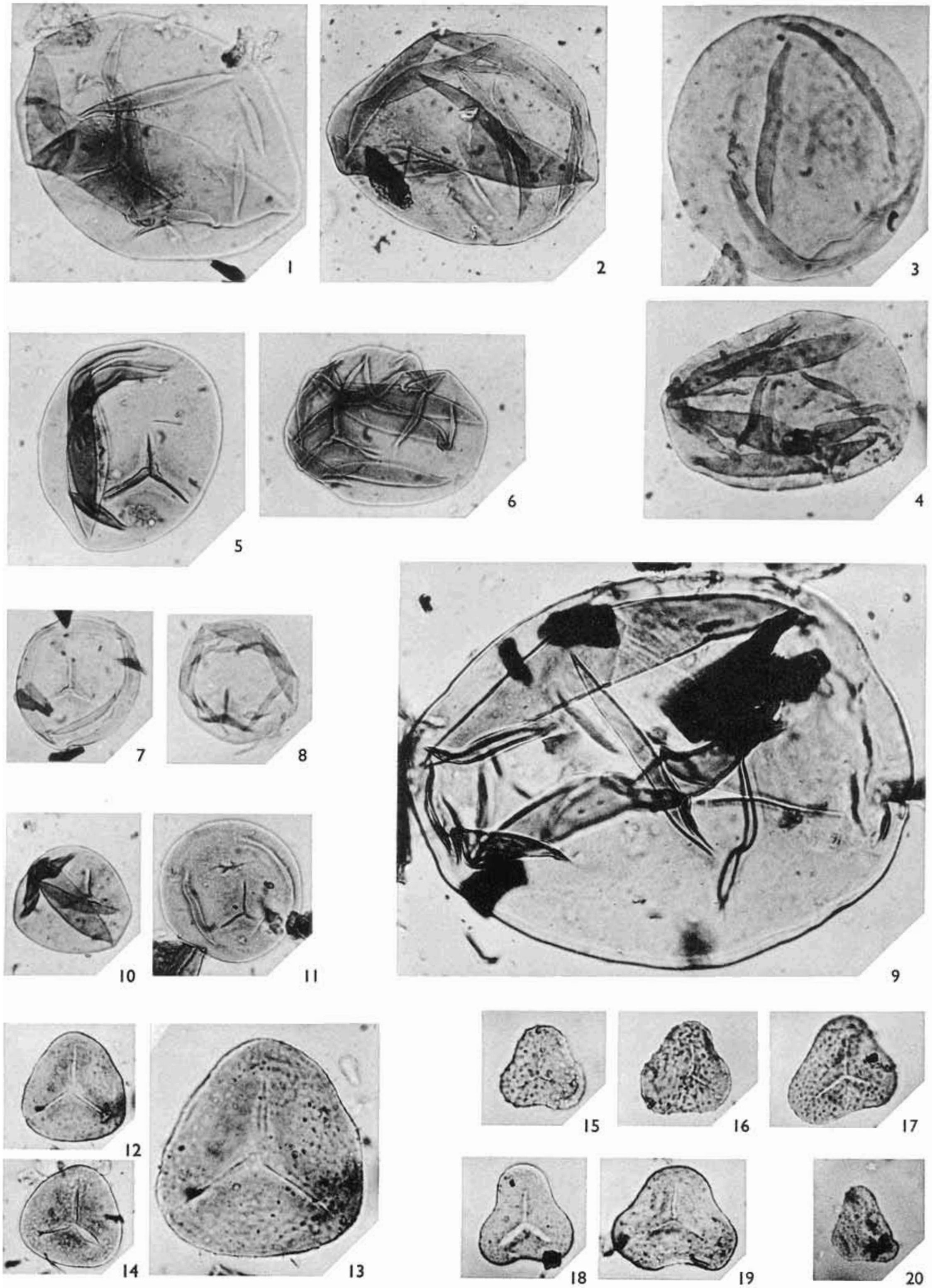
Figs. 10, 11. *C. straminea* Wilson and Kosanke 1944. 10, slide 33, 33·3 101·9. 11, slide 33, 24·5 103·1.

Figs. 12–14. *Granulatisporites adnatoides* (Potonié and Kremp) comb. nov. emend. 12, 13, slide 34, 42·2 107·8. 13, ×1,000. 14, slide 4, 32·1 103·6.

Figs. 15–17. *G. granulatus* Ibrahim 1933. 15, distal surface; slide 35, 49·1 109·4. 16, slide 36, 42·5 104·3. 17, slide 37, 33·0 112·6.

Figs. 18, 19. *G. microgranifer* Ibrahim 1933. 18, slide 35, 43·9 101·9. 19, slide 35, 25·4 109·4.

Fig. 20. *G. minutus* Potonié and Kremp 1955. Slide 38, 32·8 106·8.



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Comparison. Calamospora liquida Kosanke 1950 appears to differ only in possessing longer laesurae (26–32 μ). Potonié and Kremp (1955) quote a length of about 20 μ for *C. microrugosa* but Imgrund (1960) and Playford (1962) state for this latter species proportions up to two-thirds of radius. Records of *C. microrugosa* in the literature are listed by Playford (1962, p. 580) together with forms which are very similar and which may upon examination be found to be synonymous with *C. microrugosa*.

Remarks. Since there are individual variations in lengths of laesurae, this criterion is not considered a sufficient basis for creating more than one species in the absence of any other distinguishing character.

Occurrence. Infrequent to frequent, Assemblages I to X; Viséan to Upper Westphalian C. Recorded from coal and other rocks of Viséan age in Scotland (Love 1960).

Calamospora cf. *microrugosa* (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 3, figs. 3, 4

Description. Amb oval, less commonly round. Laesurae simple and straight, about 20 μ, but rarely seen. Exine thin. Numerous relatively narrow folds, sometimes restricted to the peripheral region of the spore, but usually irregularly distributed.

Size in microns. 57(77)99, fum. HNO_3; Possil Wee Seam at 1,606 ft. 10 in., Queenslie Bridge borehole, Central Coalfield, Scotland; Namurian A.

Comparison. Differs from the type in shape, greater size range, and in that the laesurae appear to be concealed by the folds in most specimens. *Calamospora* sp. A Staplin 1960 (pl. 1, fig. 11) appears similar in that the laesurae were not seen.

Occurrence. Infrequent, Scotland (Central Group of Coalfields), Assemblage III; Namurian A. Only recorded from a few coals in the range and not always distinguished from the type in counts.

Calamospora mutabilis (Loose) Schopf, Wilson, and Bentall 1944

Plate 2, figs. 8, 9

1932 Calamiti?-*Sporonites mutabilis* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 19, figs. 50*a–c*.
1934 *Calamiti?-sporites mutabilis* Loose, p. 145.
1944 *Calamospora mutabilis* (Loose); Schopf, Wilson, and Bentall, p. 52.

Holotype. Loose 1932, pl. 19, fig. 50*b*. Preparation I36, m.

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1955, p. 49). Amb round to oval with occasional tendency to triangular shape. Laesurae slightly flexuose, about one-half of radius. Contact area recognizable. Exine about 1 μ in thickness.

Size in microns. (i) Holotype 126, Schulze. (ii) 65–130, Schulze (Potonié and Kr. 1955). (iii) 75–100, Schulze (Bharadwaj 1957*a*).

Description. Shape somewhat variable due to compression, but generally more or less circular. Laesurae simple, or slightly ridged, generally straight. The contact areas, as observed by Bharadwaj (1957*a*), are bounded by faint curvaturae. The circular area of exine thus demarcated is not generally darker in colour, as stated by Potonié and Kremp (1955, p. 50) and as is often the case in other species in which the contact areas are differentiated, but does appear coarser in texture. Several narrow compression folds usually occur near the margin of the spore more or less parallel to the amb.

Remarks. Smaller forms with darkened contact areas and flexuose laesurae have been referred to *C. breviradiata* in this work.

Comparison. Distinguished from forms of similar size by presence of curvaturae. Potonié and Kremp (1955, p. 50) remark on the close similarity between *C. mutabilis* and *C. hartungiana* Schopf. Spores referred to *C. mutabilis* in the present work, however, lack the short, ridged, flexuose laesurae and darkened contact areas of *C. hartungiana*.

Occurrence. Infrequent, Assemblages VIII and IX; Westphalian B and Lower Westphalian C.

Calamospora pallida (Loose) Schopf, Wilson, and Bentall 1944

Plate 3, figs. 5, 6

1932 *Sporonites pallidus* Loose in Potonié, Ibrahim, and Loose, p. 449, pl. 18, fig. 31.
1934 *Punctatisporites pallidus* Loose, p. 146.
1944 *Calamospora pallidus* (Loose); Schopf, Wilson, and Bentall, p. 52.

Holotype. Loose 1932, pl. 18, fig. 31. Preparation IV26, d_4 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1955, p. 50). Amb circular to oval. Laesurae weakly ridged, straight, up to one-third of radius. Exine about 1 μ thick.

Size in microns. (i) Holotype 58·5, Schulze. (ii) 55–70, Schulze (Potonié and Kr. 1955). (iii) 49(65)79, fum. HNO_3; Cannel Seam, Bagworth Colliery, Leicestershire Coalfield, England; Lower Westphalian B. In practice the size limits are fixed at 55 and 75 μ to separate the species from the smaller *C. parva* and the larger *C. microrugosa*.

Description. Amb more or less circular, but often distorted due to compression folding. Laesurae distinct, up to one-half of radius (average 15 μ) in length. No contact areas recognizable.

Remarks. Spores from British coals, included under *C. pallida*, in general possess longer laesurae than stated by Potonié and Kremp (10–14 μ).

Comparison. *C. flexilis* Kosanke is very similar to the form described, with a size range from 58 to 70 μ and laesurae which vary in length from 14 to 17 μ. *C. flexilis* is, however, characterized by occasional folds running parallel with the laesurae. In *C. pallida* the laesurae are sometimes concealed by folds. *C. microrugosa* is considerably larger, but is otherwise like the form described. *C. saariana* Bharadwaj 1957*a* (p. 81, pl. 22, figs. 13–15) is somewhat smaller and has darkened contact areas. *C. membrana* Bharadwaj 1957*a* (p. 81; pl. 22, fig. 11) possesses a characteristic thinning of the exine towards the equator.

Occurrence. Infrequent to common, Assemblages I to X; infrequent, Assemblage XI; Viséan to Westphalian D. Generally the most frequently recorded species of *Calamospora* in British coals.

Calamospora parva Guennel 1958

Plate 3, figs. 7, 8

Holotype. Guennel 1958, fig. 16, p. 71. Sample 66, slide 4104.

Type locality. Outcrop coal, Upper Block *b* zone, Daviess County, Indiana, U.S.A.; Pottsville Series.

Diagnosis (from description in Guennel 1958, p. 70). Amb circular to elliptical. Laesurae one-third of radius. Exine thicker and darker in contact areas. Folding common.

Size in microns. (1) Holotype 38; 32(37)45, Schulze (Guennel 1958). (ii) 37(45)55, fum. HNO_3; Cannel Seam, Bagworth Colliery, Leicestershire Coalfield, England; Lower Westphalian B. (iii) 40(45)52, fum. HNO_3; Flockton Thick Seam, West Riding Colliery, Yorkshire Coalfield, England; Upper Westphalian A.

Description. Laesurae simple, sometimes flexuose, one-third to one-half of radius (average 9 μ). Slight darkening of exine in the angles between the laesurae in some specimens; commissures sometimes open. Exine thin, about 0·5 μ; compression folds narrow and, in polar compression, more or less parallel to the margin and confined to the equatorial portion of the spore. Spores frequently preserved in lateral compression, when the laesurae may be concealed in folds.

Remarks. In general the laesurae and spore dimensions are larger than those of the type. Guennel records laesurae of 5–7 μ.

Comparison. *C. exigua* Staplin 1960 (p. 7, pl. 1, fig. 5) is characterized by the unequal length of the laesurae, but in other respects is identical with *C. parva* Guennel. The specimens figured by Butterworth and Williams (1958, pl. 1, figs. 21, 22) as *C. macer* Williams are indistinguishable from *C. parva*. *C. macer* is not a valid species since it was described by Williams in an unpublished thesis (1956).

Occurrence. Infrequent to common, Assemblages I to XI; Viséan to Westphalian D.

Calamospora pedata Kosanke 1950

Plate 2, fig. 7

Holotype. Kosanke 1950, pl. 9, fig. 3. Maceration 542-C, slide 3.

Type locality. No. 8 Coal, Peoria County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 42). Amb circular to sharply lenticular as a result of compression. Laesurae thin, but distinct, two-thirds of radius, or more. Exine relatively thick, 2–3 μ.

Size in microns. Holotype $70·3 \times 44·1$; 41–75, Schulze and 10% KOH (Kosanke 1950).

Description. Compression folds are generally broad and few in number; often only one major fold is present.

Comparison. The length of the laesurae, the relatively thick exine, and the nature of the folding serve to distinguish this species from others of similar size.

Occurrence. This species was not at first distinguished in the present investigations. Data are few but the species has been recorded from certain coals of Namurian and Westphalian age.

Calamospora perrugosa (Loose) Schopf, Wilson, and Bentall 1944

Plate 3, fig. 9

1934 *Laevigati-sporites perrugosus* Loose, p. 145, pl. 7, fig. 13.
1944 *Calamospora perrugosus* (Loose); Schopf, Wilson, and Bentall, p. 52.

Holotype. Loose 1934, pl. 7, fig. 13. Preparation IV9, e_4 (l/ol).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (expanded from diagnosis in Potonié and Kremp 1955, p. 51). Amb oval to round. Laesurae simple, straight, one-third of radius or more. Exine relatively thin, markedly folded.

Size in microns. (i) Holotype 133, Schulze and KOH. (ii) 130–60, Schulze (Potonié and Kr. 1955).

Remarks. Horst (1955) extended the size range to include forms down to 46 μ.

Comparison. Horst (1955) and Potonié and Kremp (1955) compared this species to a large form of *C. microrugosa* but too few specimens of these large forms have been found to determine the population statistics. In the present work large forms of *Calamospora* within the size range given by Potonié and Kremp and resembling *C. microrugosa* have been recorded as *C. perrugosa*.

Occurrence. Infrequent. Has been recorded from the Namurian A and Westphalian A but there are too few data from British coals to give precise limits.

Calamospora straminea Wilson and Kosanke 1944

Plate 3, figs. 10, 11

1944 *Calamospora straminea* Wilson and Kosanke, p. 329, pl. 1, fig. 1.
1958 *Punctatisporites stramineus* (Wilson and Kosanke); Guennel, p. 68, pl. 4, figs. 5–8.

Holotype. Wilson and Kosanke 1944, pl. 1, fig. 1. Slide No. 276 P, circle 2.

Type locality. Coal from Angus Coal Company Mine, Iowa, U.S.A.; Des Moines Series.

Diagnosis (from description in Wilson and Kosanke 1944, p. 329). Amb circular. Laesurae about one-half of radius. Frequent tapering and pointed compression folds. Exine 3 μ thick.

Size in microns. (i) 30–45, maceration method not known (Wilson and Kos. 1944). (ii) 31(39)47, fum. HNO_3; seam at 56 ft. 4 in., Murton Colliery borehole, Durham Coalfield, England; Upper Westphalian B.

Description. Shape sometimes oval due to folding. Laesurae simple and usually distinct, sometimes flexuose and of unequal length (average 9 μ). Some part, or all, of contact area often darker in colour. Exine about 1 μ thick; compression folds few, tend to follow margin of spore; occasional specimens without folds.

Remarks. This species was referred to *Punctatisporites* by Guennel 1958 on account of its relatively thick exine, although this author did not confirm the measurement of 3 μ given by Wilson and Kosanke. The spores referred to this species in the present work have thinner exines. Wilson and Kosanke in their description refer to a smooth, translucent, colourless spore with frequent tapering and pointed folds. These features suggest a relatively thin exine and are characteristic of the genus *Calamospora* as are the relatively short laesurae and the contact area. The latter is not known in species of *Punctatisporites*. It is clearly visible in some of the specimens photographed by Guennel. The species should, perhaps, be transferred to the genus *Phyllothecotriletes* Luber which includes forms in which the wall is thicker than in *Calamospora*, with minor secondary folding and with a darkened contact area. This must, however, await examination of spores from the type locality.

Comparison. Exine slightly thicker and with fewer folds than *C. parva*, which is of similar size.

Occurrence. The precise distribution in British coals is not known as the species was not recognized until a late stage in the investigations. It has, however, been recorded from some coals in Assemblages VIII to XI (Westphalian B to D) of the Central and Southern Provinces.

Infraturma APICULATI (Bennie and Kidston) Potonié 1956
Subinfraturma GRANULATI Dybová and Jachowicz 1957
Genus GRANULATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. G. granulatus Ibrahim 1933.

Diagnosis (Potonié and Kremp 1954, p. 126; translation). 'Trilete isospores or microspores, more or less triangular, and with no differentiation other than a closely granular ornament of the exoexine. The grana are approximately circular, more or less of identical size within each species, and sometimes arranged in a fairly well-defined pattern. In profile the grana are flat or rounded.'

Remarks. Potonié and Kremp (1954) observe that they are in agreement with the diagnosis of the genus *Granulatisporites* as given by Schopf, Wilson, and Bentall (1944) in so far as that it should include triangular forms with a granulate ornament, but they do not agree that forms with laevigate, punctate, reticulate, or apiculate ornament should also be included.

Comparison. Distinguished from other genera by its triangular amb and the regular, granulate nature of the ornament. The grana have circular bases and rounded or flat apices, so that they barely modify the equator of the spore.

Affinity. Filicales in Potonié (1962).

Granulatisporites adnatoides (Potonié and Kremp) comb. nov. emend.

Plate 3, figs. 12–14

1955 *Leiotriletes adnatoides* Potonié and Kremp, p. 38, pl. 11, figs. 112–15.

Holotype. Potonié and Kremp 1955, pl. 11, fig. 112. Preparation 607/2.

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

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 38). Amb triangular, sides slightly concave to slightly convex, angles broadly rounded. Laesurae simple, straight, reaching almost to amb. Exine very finely granulate.

Size in microns. (i) Holotype 36; 30–40, Schulze (Potonié and Kremp 1955). (ii) 27(31)35 (18 specimens) fum. HNO_3; Sharlston Top Seam, Cross Hill borehole, Yorkshire Coalfield, England; Westphalian C. (iii) 27(31)38, fum. HNO_3; Kilnhurst Seam, Cadeby Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Shape of sides very often varies in any one specimen. Laesurae may vary in length, but at least one laesura usually extends to, or nearly to, margin. Exine thin, and finely granulate (oil), grana less than 0·5 μ in height. Exine sometimes darker in region of proximal pole. Folding sometimes occurs as in *Leiotriletes gulaferus* Potonié and Kremp 1955.

Remarks. The species has been assigned to *Granulatisporites* because examination in oil shows the exine to possess a finely granulate ornament and not an infrasculpture as stated by Potonié and Kremp (1955). According to Kosanke *L. adnatus* (Kosanke 1950, p. 20, pl. 3, fig. 9) Potonié and Kremp possesses a slightly granulate ornament in the region of the tetrad scar. According to Potonié and Kremp (1955) the main distinction between these two species is in their shape in proximal compression. The proportions of convex and concave forms in British coals vary but neither form has been found exclusively in any coal. Many specimens are difficult to assign to either species on a basis of shape. The presence of a definite contact area is uncommon in British specimens of the spore. While it is legitimate to make a distinction of this kind in a morphographic classification, it is of doubtful value for stratigraphic purposes if the forms show considerable variation in shape and have similar stratigraphic ranges. For this reason the British specimens are referred to *G. adnatoides*, which they most closely resemble.

Comparison. *G. parvigranulatus* Staplin 1960 (p. 15, pl. 3, figs. 8, 9) with a size range of 30–38 μ appears identical to forms of *G. adnatoides* with slightly concave margins. Specimens of *G.* cf. *parvus* (Ibrahim) Potonié and Kremp illustrated in Imgrund (1960, pl. 13, figs. 25, 26) are smaller but otherwise appear similar to *G. adnatoides*. *Leiotriletes subadnatoides* Bharadwaj 1957*a* (p. 80, pl. 22, figs. 5–7) is also smaller (24–29 μ) than *G. adnatoides* which it otherwise resembles.

Occurrence. Infrequent, Assemblages VI to X; Westphalian A to Upper Westphalian C. Recorded most frequently from seams in the Westphalian A and B.

Granulatisporites granulatus Ibrahim 1933

Plate 3, figs. 15–17

1933 *Granulati-sporites granulatus* Ibrahim, p. 22, pl. 6, fig. 51.
1955 *Granulatisporites granulatus* Ibrahim; Potonié and Kremp, p. 58, pl. 12, figs. 157–60.

Holotype. Ibrahim 1933, pl. 6, fig. 51. Preparation D57, b7 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 58; translation). 'Amb triangular; sides generally slightly convex, rarely concave. About 55 grana on the margin; grana rather more than 1 μ in diameter.'

Size in microns. (i) Holotype 31, Schulze and KOH. (ii) 25–35, Schulze (Potonié and Kr. 1955). (iii) 24(28)33, fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 23(27)33, fum. HNO_3; Seam at 253 ft. 10 in., Broad Law Deep No. 36 borehole, Northumberland Coalfield, England; Namurian B/C. (v) 22(27)35, fum. HNO_3; Shilbottle Seam at 201 ft. 1 in., New Moor Hall borehole, Northumberland Coalfield, England; Viséan.

Description. Amb triangular, angles rounded, sides concave, rarely convex. Laesurae simple, one-half to three-quarters of spore radius. Ornament of grana about 1 μ in diameter, bases not touching; number projecting at equator varies from 30 to 60. Exine very thin, folding infrequent.

Remarks. The spores of the present assemblages differ from the type in having concave rather than convex sides but the former are not uncommon in the specimens photographed by Potonié and Kremp (1955, pl. 12, figs. 157–60).

Comparison. *G. granulatus* is more coarsely granulate than *G. adnatoides*.

Occurrence. Infrequent, Assemblages I to IX; Viséan to Lower Westphalian C.

Granulatisporites microgranifer Ibrahim 1933

Plate 3, figs. 18, 19

1933 *Granulati-sporites microgranifer* Ibrahim, p. 22, pl. 5, fig. 32.
1938 *Azonotriletes microgranifer* (Ibrahim); Luber in Luber and Waltz, pl. 7, fig. 92.
1955 *Granulatisporites microgranifer* Ibrahim; Potonié and Kremp, p. 58, pl. 12, figs. 149–151.

Holotype. Ibrahim 1933, pl. 5, fig. 32, Potonié and Kremp 1955, pl. 12, fig. 149 after Ibrahim. Preparation B29, a2 (o/l).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 58; translation). 'Amb triangular with more or less concave sides. Approximately 100 grana on the margin.'

Size in microns. (i) Holotype 32·5, Schulze and KOH. (ii) (25?)30–40, Schulze (Potonié and Kr. 1955). (iii) 18(23)28, fum. HNO_3; Chemiss Seam, Michael Colliery, East Fife Coalfield, Scotland; Westphalian B.

Description. Amb triangular, angles narrowly rounded, sides concave. Laesurae simple, straight, one-half to two-thirds of spore radius. Ornament of minute grana, bases touching; barely discernible at the equator; fairly even in distribution. Exine very thin, folding frequent.

Comparison. Distinguished from other species by the fine grade of its ornament.

Occurrence. Infrequent, Assemblages VI to X; Upper Westphalian A to Upper Westphalian C.

Granulatisporites minutus Potonié and Kremp 1955

Plate 3, fig. 20

Holotype. Potonié and Kremp 1955, pl. 12, fig. 147. Preparation 607/5, KT 14.4.123,9.

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

Diagnosis (expanded from Potonié and Kremp 1955, p. 59). Amb triangular, angles broadly rounded, sides concave. Laesurae straight, simple, sometimes open, one-half to three-quarters of spore radius in length; contact areas sometimes darker. Ornament of discrete grana, slightly less than 1 μ in diameter; uneven in distribution; 35 to 40 project at the equator. Exine very thin, folding frequent.

Size in microns. (i) Holotype 23, approximately 20–25, Schulze (Potonié and Kr. 1955). (ii) 18(23)27, fum. HNO_3; Seam at 1,647 ft. 4 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Westphalian A. (iii) 18(24)28, fum. HNO_3; Rushy Park Seam, Sutton Manor Colliery, Lancashire Coalfield, England; Westphalian A. (iv) 18(23)27, fum. HNO_3; Seam at 696 ft. 8 in., Tynemouth Pier borehole, Durham Coalfield, England; Westphalian A. (v) 16(21)25, fum. HNO_3; Seam at 1,588 ft. 4 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Westphalian B.

Comparison. Distinguished from *Granulatisporites microgranifer* by its small size and coarser, more widely spaced ornament.

Occurrence. Infrequent or frequent, Assemblages V to X; Lower Westphalian A to Upper Westphalian C.

Granulatisporites piroformis Loose 1934

Holotype. Loose 1934, pl. 7, fig. 19, Potonié and Kremp 1955, pl. 12, fig. 152 after Loose. Preparation IV50, d_1 (m/r).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 60; translation). 'Amb triangular with more or less concave sides; approximately 65 grana of about 1 μ diameter on the margin.'

Size in microns. (i) Holotype 28·5, Schulze and KOH. (ii) 25–40, Schulze (Potonié and Kr. 1955).

Granulatisporites cf. *piroformis* Loose 1934

Plate 4, figs. 1–3

Size in microns. (i) 19(27)38, fum. HNO_3; Great Seam at 3,926 ft. 7 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A. (ii) 17(25)32, fum. HNO_3; Seam at 4,316 ft. 6 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A.

Description. Amb triangular, angles broadly rounded, sides concave. Laesurae simple, one-half to two-thirds of spore radius, sometimes open. Ornament of closely packed, rounded grana, less than 1 μ in diameter, bases touching; 40 to 50 project at the equator. Exine thin, folding infrequent.

Comparison. The ornament is more closely packed and regularly disposed than that of the type material. The ornament is larger than that of *Granulatisporites microgranifer* and more dense than that of *G. granulatus* or *G. minutus*.

Occurrence. Infrequent to common, Assemblage III; Namurian A.

Genus CYCLOGRANISPORITES Potonié and Kremp 1954

Type species. *C. leopoldi* (Kremp 1952) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1955, p. 60; translation). 'Trilete isospores or microspores, generally with a circular amb, which in extreme cases may approach a triangular shape. Except for the generally circular amb, the genus possesses the same characteristics as *Granulatisporites*.'

Affinity. Psilophytopsida, Noeggerathiopsida, Filices, and other Pteropsida in Potonié (1962).

Cyclogranisporites aureus (Loose) Potonié and Kremp 1955

Plate 4, figs. 8, 9

1934 *Reticulati-sporites aureus* Loose, p. 155, pl. 7, fig. 24.
1944 *Punctati-sporites aureus* (Loose); Schopf, Wilson, and Bentall, p. 30.
1950 *Plani-sporites aureus* (Loose); Knox, p. 315.
1955 *Cyclogranisporites aureus* (Loose); Potonié and Kremp, p. 61, pl. 13, figs. 184–6.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 184 after Loose. Preparation IV1, e_5 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 61; translation). 'Amb circular. Laesurae one-half to two-thirds of radius. Grana over 1 μ diameter; 70 to 100 project at the margin.'

Size in microns. (i) Holotype 55·5, Schulze and KOH. (ii) 50–80, Schulze (Potonié and Kr. 1955). (iii) 59(72)82 (22 specimens) fum. HNO_3; unnamed seam, Bickershaw Colliery, Lancashire Coalfield, England; Westphalian B. (iv) 54(65)74, fum. HNO_3 ; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England; Westphalian A. Occasional specimens up to 99 μ have been recorded.

Description. Margin minutely notched. Laesurae simple, straight, sometimes curved in off-centre compression, often of unequal length, may be more than three-quarters of

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EXPLANATION OF PLATE 4

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Granulatisporites* cf. *piroformis* Loose 1934. 1, slide 39, 54·1 114·4. 2, slide 39, 42·3 111·7. 3, slide 40, 30·0 109·7.

Figs. 4–7. *Cyclogranisporites* cf. *minutus* Bharadwaj 1957. 4, slide 43, 45·3 109·7. 5, slide 43, 32·3 109·4. 6, 7, slide 44, 51·2 108·8. 7, ×1,000.

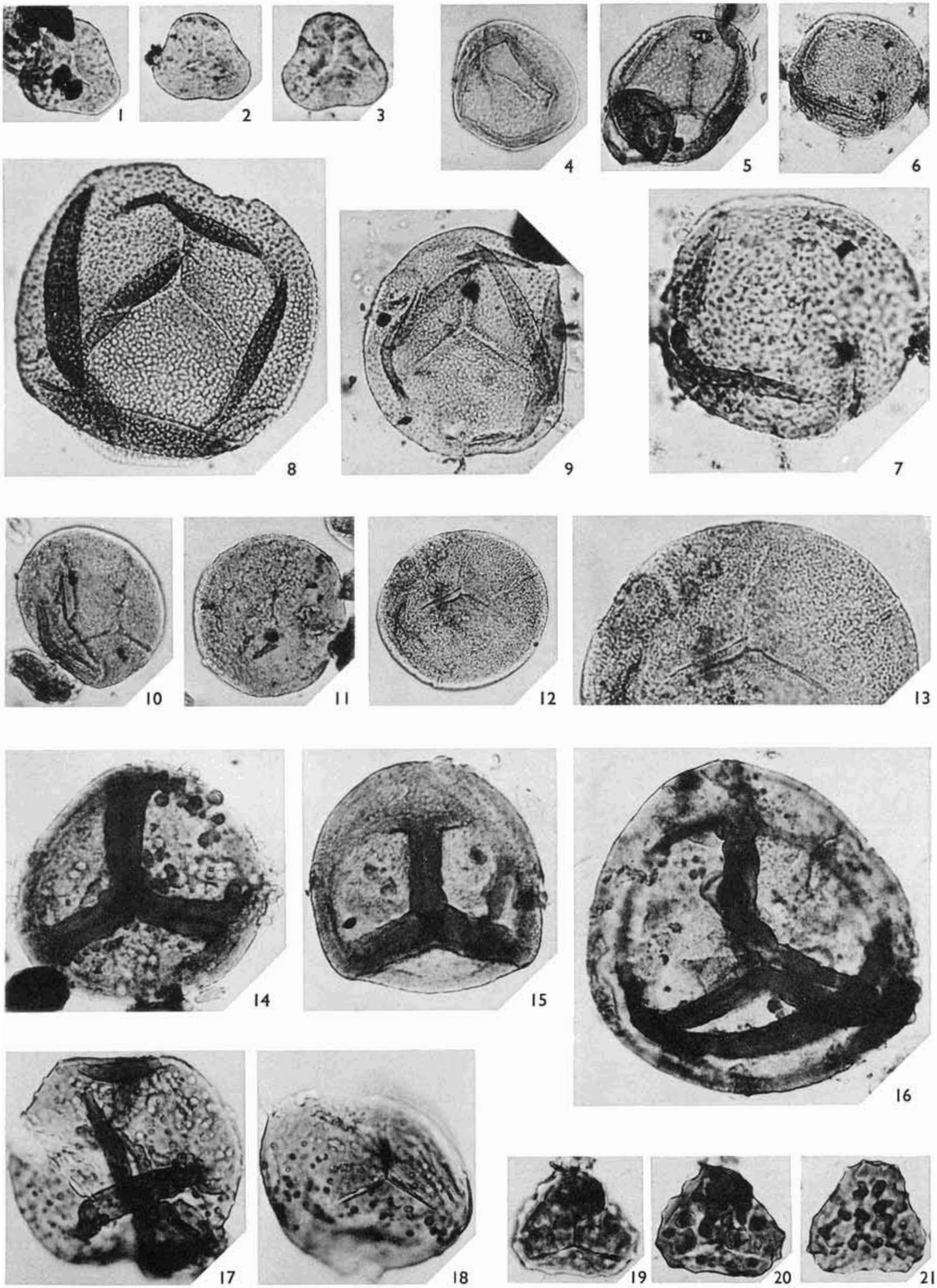
Figs. 8, 9. *C. aureus* (Loose) Potonié and Kremp 1955. 8, slide 42, 51·7 112·7. 9, slide 41, 34·9 115·9.

Figs. 10–13. *C. multigranus* sp. nov. 10, Isotype; slide T91/2, 53·6 107·3. 11, Isotype; slide T91/3, 34·9 110·3. 12, 13, Holotype; slide T91/1. 13, ×1,000.

Figs. 14–16. *Cadiospora magna* Kosanke 1950. 14, slide 45, 53·4 111·5. 15, slide 46, 32·5 106·0. 16, slide 47, 33·5 116·4.

Figs. 17, 18. *Verrucosisporites baccatus* Staplin 1960. 17, slide 49, 40·1 109·5. 18, slide 49, 39·5 113·7.

Figs. 19–21. *Converrucosisporites armatus* (Dybová and Jachowicz) comb. nov. 19, 20, proximal and distal surfaces respectively; slide 48, 49·4 105·4. 21, slide 48, 42·9 113·9.



SMITH and BUTTERWORTH, British Carboniferous miospores

radius. Exine bordering laesurae sometimes darker. Ornament of closely packed grana, approximately 1 μ in diameter and height, covers the entire exine. Exine thin, compression folds few and narrow.

Remarks. The colour of *C. aureus*, which is typically yellowish brown, serves to distinguish the species from the smaller and paler *C. minutus*. Small forms of *C. aureus* with paler coloration may result, however, from the maceration process and identification is then difficult.

Comparison. *C. aureus* has a thinner exine than *C. microgranus* Bharadwaj 1957*a* (p. 84, pl. 22, figs. 29–32), which is of comparable size (55–70 μ).

Occurrence. Infrequent or occasionally frequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Cyclogranisporites minutus Bharadwaj 1957

Holotype. Bharadwaj 1957*a*, pl. 22, fig. 22. Preparation 7314/2.

Type locality. Wahlschied Seam, Gottelborn Colliery, Saar Coalfield, Germany; Stephanian A.

Diagnosis (Bharadwaj 1957*a*, p. 83). 'Circular (subcircular due to secondary folds), Y-mark having two rays distinct but one faint and small, rays one-half radius long, extrema lineamenta rough due to minute grana, regularly distributed all over the surface and appearing minutely punctate. Spore coat medium thin, 90 grana along the circumference.'

Size in microns. Holotype 40; 34–43, Schulze (Bharadwaj 1957*a*).

Cyclogranisporites cf. *minutus* Bharadwaj 1957

Plate 4, figs. 4–7

Description. Amb circular unless distorted by compression; margin minutely notched to almost smooth. Laesurae simple, straight, sometimes faint, two-thirds to three-quarters of spore radius. Ornament of grana 0·5–1·0 μ in diameter and height; spaces between grana irregular and less than their diameter; 50 to 70 project from margin. Exine thin, compression folds generally developed close to margin.

Size in microns. (i) 39(42)45 (5 specimens) fum. HNO_3; Low Hutton Seam at 223 ft. 1 in., Metal Bridge borehole (35 NW. 34), Durham Coalfield, England; Westphalian B. (ii) 37(47)57 (11 specimens) fum. HNO_3; seam at 491 ft. 10 in., Seafield No. 2 borehole, East Fife Coalfield, Scotland; Westphalian B. (iii) 41–52 (6 specimens) fum. HNO_3; various localities, Yorkshire and Durham Coalfields, England; Westphalian A and B.

Remarks. Spores of this general form have been recorded throughout the Carboniferous and speciation of the British material has proved difficult. In the present work all forms intermediate in size between *C. minutus* Bharadwaj and *C. aureus* (Loose) Potonié and Kremp have been assigned to *C.* cf. *minutus*. Species with similar ornament but which are in general larger than the forms referred to *C.* cf. *minutus* are *C. lasius* (Waltz) Playford 1962 (p. 585, pl. 79, figs. 19, 20) from the Lower Carboniferous, *C. carinatus*

Artüz 1957 (p. 242, pl. 1, fig. 7) from the Namurian and Westphalian A of Turkey (laesurae shorter), and *C. micaceus* Imgrund 1960 (p. 158, pl. 13, figs. 17, 18) from the Lower Permian of China and the Stephanian of the Kladno-Rakovnik basin (Kalibová 1962, p. 85, pl. 1, figs. 11, 12). Staplin (1960, p. 9, pl. 1, fig. 28) and Sullivan (1964, p. 360, pl. 57, figs. 17, 18) also assign spores of similar appearance to *C.* cf. *minutus*.

Occurrence. Infrequent, Assemblages III to XI; Namurian A to Westphalian D.

Cyclogranisporites multigranus sp. nov.

Plate 4, figs. 10–13

Holotype. Plate 4, fig. 12. Preparation T91/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 491 ft. 10 in., Seafield No. 2 borehole, East Fife Coalfield, Scotland; Westphalian B.

Diagnosis. Amb circular; margin minutely notched. Laesurae simple, faint, often of unequal length, one-third to two-thirds of radius. Exine covered by minute grana less than 0·5 μ in diameter and height, tightly packed; more than 100 project at margin. Narrow compression folds usually occur.

Size in microns. Holotype 53; 38(47)55, fum. HNO_3; type locality.

Description. Compression often results in distortion of the outline. Grana somewhat variable in size; in plan view the ornament is distinct, but the appearance at the margin, using dry objectives, is variable; sometimes the margin is scarcely modified by the grana. Exine about 1·5 μ thick.

Remarks. The ornament of this species approaches that of *Punctatisporites*.

Comparison. Only three other species have a comparable size range, *C. carinatus* Artüz 1957 (p. 242, pl. 1, fig. 7), from the Namurian and Westphalian A of Turkey, and *C. densus* Bharadwaj 1957*a* (p. 85, pl. 23, figs. 1, 2) and *C. parvus* Bharadwaj 1957*a* (p. 85, pl. 23, figs. 7, 8), both from the Stephanian of the Saar Coalfield. *C. carinatus* has coarser ornament and short laesurae. *C. densus* has a thicker exine and is characterized by one or two large, crescentic folds. *C. parvus* is thinner than *C. multigranus* and there is a darkening of the exine in the region of the laesurae. The exine in *C. multigranus* is thicker than in *C.* cf. *minutus*, the ornament is of a finer grade, and the bases of the grana are in contact all round. Also the laesurae are often shorter in *C. multigranus*.

Occurrence. Scotland, Assemblage VIII; Westphalian B. Range uncertain.

Genus CADIOSPORA (Kosanke) Venkatachala and Bharadwaj 1964

1954 *Gravisporites* Bharadwaj, p. 513.

Type species. *C. magna* Kosanke 1950.

Diagnosis (Venkatachala and Bharadwaj 1964, p. 166). 'Radial sub-spherical to roundly triangular miospores. Trilete-rays distinct, up to threequarters radius in length, ray-ends apparently bifurcating, *area contagionis* differentiated by its thinner exine, labra well developed. Exine surface laevigate, punctate to infrapunctate, exine normally 5–10 μ thick, usually thicker beyond the ray-ends and developing one or more, large mounds.'

Remarks. Bharadwaj (1955, p. 129) distinguished *Gravisporites* by its 'massive equatorial crassitudo' and considered that *Cadiospora* had a cingulum of the type present in *Lycospora* Schopf, Wilson, and Bentall. The present authors are of the opinion that there is no constant equatorial thickening in *C. sphaera* (designated as type species of *Gravisporites* by Bharadwaj 1954), and that *C. magna* is not cingulate. Venkatachala and Bharadwaj (1964, p. 167) also state that *Cadiospora* lacks a cingulum but has a thick exine which appears like a cingulum in optical section. Contrary to the statement by Venkatachala and Bharadwaj (loc. cit.), that no curvaturae have been seen in *Cadiospora*, spores referred to this genus by the authors possess curvaturae which are variable in their development and which connect the extremities of the laesurae.

Affinity. Unknown.

Cadiospora magna Kosanke 1950

Plate 4, figs. 14–16

1950 *Cadiospora magna*, Kosanke, p. 50, pl. 16, fig. 1.
1954 *Cadiospora sphaera* Butterworth and Williams, p. 761, pl. 19, figs. 1, 2, text-fig. 2.
1954 *Gravisporites sphaera* (Butterworth and Williams); Bharadwaj, p. 514, text-fig. 2.

Holotype. Kosanke 1950, pl. 16, fig. 1. Preparation 600, slide 15.

Type locality. La Salle Coal, Bureau County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (description in Kosanke 1950, p. 50). '. . . The trilete rays vary in length from 40–44 microns. The suture is distinct and the lips vary in thickness from 4–5 microns on either side of the suture. The lips appear to continue as thickenings in association with the arcuate ridge. The apex of the rays (trilete aperture) is open or closed. The rays divide at the terminus of the rays and interradially become the arcuate ridge. The spore coat is minutely punctate to finely granulose, and measures 6–8 microns in thickness.'

Size in microns. (i) Holotype 117·6 × 111·3; 100–117·6, Schulze and 10% KOH (Kosanke 1950). (ii) 67(98)119 (10 specimens) Schulze; various Westphalian D coals. (iii) 58(78)96 (20 specimens) fum. HNO_3, 85(98)111 (21 specimens) Schulze and 5% KOH, for *C. sphaera* (Butterworth and Will. 1954).

Description. Laesurae ridged, more than two-thirds of spore radius; lips prominent, margins often crenulate; individual lips remain discrete after separation and do not form part of the slightly thickened curvaturae. Ornament of small closely spaced grana of variable size, height less than 0·5 μ. In some specimens verrucate projections up to 4 μ in width and height may occur singly or in clusters scattered over the exine; these projections may be resin droplets adhering to the surface of the spore. A single compression fold sometimes occurs in the region of the curvaturae.

Remarks. The authors consider that there is no basis for continuing to recognize *C. sphaera* as a separate species. In their diagnosis of *C. sphaera* Butterworth and Williams (1954, p. 761) state that the distal surface is laevigate but subsequent examination of

British specimens shows the exine to be densely granulate as indicated by Bharadwaj (1955, p. 128).

Occurrence. Infrequent, Assemblage XI; Etruria Marl of North Staffordshire (? Westphalian C) and Westphalian D.

Subinfraturma VERRUCATI Dybová and Jachowicz 1957
Genus CONVERRUCOSISPORITES Potonié and Kremp 1954

Type species. *C. triquetrus* (Ibrahim) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 137; translation). 'Trilete isospores and microspores in which the ornament corresponds to that of the genus *Verrucosisporites*, although the amb is more or less triangular. The sides can be slightly concave, or slightly to markedly convex, without, however, the spore losing its essentially triangular shape.'

Affinity. Unknown.

Converrucosisporites armatus (Dybová and Jachowicz) comb. nov.

Plate 4, figs. 19–21

1957*a* *Converrucitriletes armatus* Dybová and Jachowicz, p. 128, pl. 32, fig. 1.

Holotype. Dybová and Jachowicz 1957*a*, pl. 32, fig. 1. Preparation Cv 1/25.

Type locality. Seam 12, Václav Colliery, Czechoslovakia; Namurian A.

Diagnosis (English summary in Dybová and Jachowicz 1957*b*, p. 182). 'Spores with a thick membrane, of triangular outline in transverse plane, passing into three wing outline. Surface of exine covered with large flat projections. Trilete mark fairly clearly visible, rays reaching to three-fourths of radius of spore. . . .'

Size in microns. (i) Holotype not specified. (ii) Average 30, fum. HNO_3 and 30% NH_4OH (Dybová and Jachowicz 1957*a*); 45 (Dybová and Jachowicz 1957*b*). (iii) 26(36)43, fum. HNO_3; seam at 550 ft. 3 in., Spanish Battery borehole, Durham Coalfield, England; Westphalian A. (iv) 33(36)42 (17 specimens) fum. HNO_3; Wheatley Lime Seam at 2,136 ft. 11 in., Stubbs Lane borehole, Yorkshire Coalfield, England; Westphalian A.

Description. Amb triangular, sides straight or concave, angles broadly rounded, outline irregular. Laesurae simple, straight, one-half to two-thirds radius. Distally, exine covered by verrucae with more or less rounded bases and apices. Size of verrucae variable within a single spore, up to 6 μ in width and 2·5 μ in height; number projecting from margin, 15 to 22. Proximally the number and size of the verrucae is reduced. In some specimens the ornament is uniformly small, scarcely modifying the margin, in others it is much coarser. Sometimes coarse and fine verrucae occur on a single specimen. Exine about 2·5 μ thick.

Remarks. The species has been transferred to *Converrucosisporites* since *Converrucitriletes* is not a valid name (Potonié 1960, p. 36).

Comparison. Converrucosisporites mosaicoides Potonié and Kremp 1955 (p. 64, pl. 13, fig. 192) is smaller (about 30 μ) and has a correspondingly finer ornament than *C. armatus. Tuberculatisporites triangulatus* Dybová and Jachowicz in Jachowicz 1958 (pl. 2, fig. 11) appears similar to *C. armatus* but its description has not been available to the authors for comparison. *C. triquetrus* (Ibrahim) Potonié and Kremp 1955 (p. 65, pl. 13, fig. 191) is larger (40–60 μ), with convex margins and sharper angles.

Occurrence. Infrequent, Assemblages V to VII; Westphalian A.

Genus VERRUCOSISPORITES (Ibrahim) emend.

Type species. V. verrucosus (Ibrahim) Ibrahim 1933.

Diagnosis. Trilete isospores, or microspores. Amb circular, subtriangular or roundly triangular. Margin generally crenulate but may be undulate to irregularly lobate. Laesurae generally simple, if ridged, lips not exceeding height of ornament, length variable from one-half to length of spore radius. Exine predominantly verrucate but sculptural elements may include some small proportion of rugulae, coni or bacula. Sculpture generally comprehensive but size of elements may be reduced in contact areas. In plan view shape circular, polygonal, phaseolate or irregular; in profile may be dome-shaped or sides may taper to varying degrees and the apices may be flat, obliquely truncate or well rounded, height equal to or less than breadth. Sculptural elements generally closely spaced but distance variable, generally not greater than maximum diameter of verrucae. Number of elements projecting from margin usually greater than 10 but rarely exceeding 100. Exine thickness (including sculpture) rarely exceeds 10 μ.

Remarks. The diagnoses of earlier authors (Ibrahim 1933, p. 25, Potonié and Kremp 1954, p. 137, Bharadwaj 1955, p. 123 and Smith *et al.* 1964, p. 1071) have been emended to cover the characters of the large number of recently published species of *Verrucosisporites.*

Comparison. Differs from *Apiculatisporis* Potonié and Kremp in possessing ornament in which basal width is equal to or greater than height, and from *Camptotriletes* Naumova and *Convolutispora* Hoffmeister, Staplin, and Malloy in possessing ornamentation of more or less discrete elements, which may sometimes be confluent at their bases but never anastomose to form a system of open or closely packed ridges. In *Dibolisporites* Richardson the sculptural elements which include verrucae possess apical papillae.

Affinity. Filicales, Remy and Remy (1955*a*, 1957).

Verrucosisporites baccatus Staplin 1960

Plate 4, figs. 17, 18

Holotype. Staplin 1960, pl. 2, fig. 4. Preparation Imp. 1708, A–24·7 116·7.

Type locality. Coal at 4,389 ft., Imperial Belloy borehole 12–14, Alberta, Canada; Golata Formation, Chester Series.

Diagnosis (Staplin 1960, p. 12). '. . . circular; granulose, irregular size and spacing, some coalesced, crowded and wart-like, remainder of surface minutely granulose (oil);

proximal polar area lacks large granules; sutures distinct, simple, ratio one-half to two-thirds (varies from specimen to specimen); wall thickness moderate but secondary folding . . . common. . . .'

Size in microns. (i) Holotype 87; 70–104, maceration method not known (Staplin 1960). Staplin (pers. comm.) states that the lower size limit should be 60. (ii) 65–80 (5 specimens) fum. HNO_3; Oakshaw Ford Seam, Oakshaw Ford Colliery, Cumberland, England; Viséan.

Description. Exine infragranulate, or infrapunctate. Ornament of irregularly disposed grana and verrucae; outer surface otherwise laevigate. In plan view verrucae are circular, in profile they have well-rounded apices; they are less than 3·5 μ in width and 2 μ in height. The verrucae project from the margin at irregular intervals. Considerable areas of exine may be without ornament. The density of ornament varies considerably between specimens. Exine 2–2·5 μ thick.

Remarks. The ornament in this species is not typical of the genus but the species is less satisfactorily assigned to any other published genus.

Comparison. V. baccatus shows a superficial resemblance to *Apiculatisporis irregularis* (Alpern) comb. nov. in the irregular distribution of its ornament.

Occurrence. Infrequent, Assemblage I. Recorded only from the Oakshaw Ford Seam, Cumberland. Viséan.

Verrucosisporites cerosus (Hoffmeister, Staplin, and Malloy) Butterworth and Williams 1958

Plate 5, figs. 1–3

1955 *Punctati-sporites? cerosus* Hoffmeister, Staplin, and Malloy, p. 392, pl. 36, fig. 6.
1958 *Verrucosisporites cerosus* (Hoffmeister, Staplin, and Malloy); Butterworth and Williams, p. 361, pl. 1, figs. 42, 43.

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 6. Preparation 10, ser. 18,823.

Type locality. Shale at 2,071 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 392). Amb circular. Laesurae simple, two-thirds of radius. Ornament of poorly defined granula-

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EXPLANATION OF PLATE 5

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Verrucosisporites cerosus* (Hoffmeister, Staplin, and Malloy) Butterworth and Williams 1958. 1, 2, proximal and distal surfaces respectively; slide 50, 38·7 110·1. 3, slide 51, 37·1 109·6.

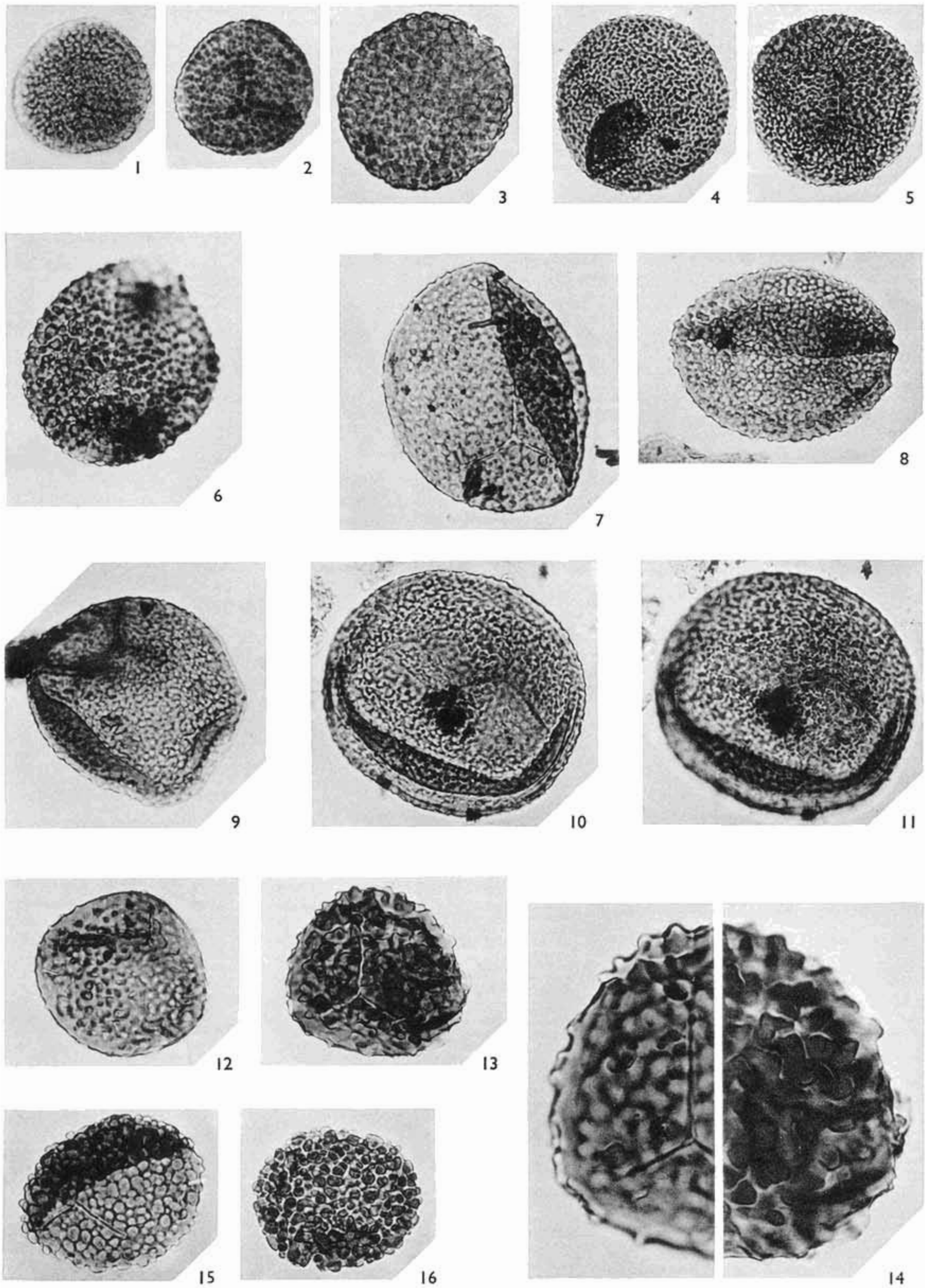
Figs. 4–6. *V. donarii* Potonié and Kremp 1955. 4, slide 52, 37·6 109·8. 5, slide 53, 38·6 110·4. 6, distal surface; slide 54, 36·7 108·9.

Figs. 7, 8. *V. verrucosus* (Ibrahim) Ibrahim 1933. 7, slide 61, 23·1 105·9. 8, slide 56, 20·9 102·1.

Figs. 9–11. *V. microtuberosus* (Loose) comb. nov. 9, slide 56, 40·0 110·1. 10, 11, proximal and distal surfaces respectively; slide 55, 33·8 117·0.

Figs. 12–14. *V. microverrucosus* Ibrahim 1933. 12, slide 57, 13·8 112·4. 13, slide 58, 27·3 111·3. 14, left and right halves proximal and distal surfaces respectively; slide 58, 27·3 111·3.

Figs. 15, 16. *V. morulatus* (Knox) emend. 15, Lectotype; slide T85/1, 43·1 104·3. 16, slide 59, 38·7 110·4.



SMITH and BUTTERWORTH, British Carboniferous miospores

tions simulating tubercles at the equator. Exine translucent, approximately 3 μ thick. Waxy lustre. Compressed zone near equator appears smooth.

Size in microns. (i) Holotype 48, 37–53, HF (Hoffmeister, Stap., and Mall. 1955). (ii) 34–52, fum. HNO_3; various localities, Scotland; Namurian A.

Description. Laesurae 15–18 μ, extremities not always distinct. Ornament comprises closely packed verrucae mostly not exceeding 2 μ in height and 4 μ in breadth with flat, indented, or well-rounded apices; includes a proportion of pila which can only be seen at the margin. Intervening spaces less than 1 μ. 35 to 45 verrucae project at margin.

Occurrence. Infrequent or frequent, Assemblages II to IV; Viséan and Namurian. Recorded from rocks other than coal in Viséan of Scotland (Love 1960).

Verrucosisporites donarii Potonié and Kremp 1955

Plate 5, figs. 4–6

Holotype. Potonié and Kremp 1955, pl. 13, fig. 193. Preparation 31/1.

Type locality. Donar Seam, Brassert Colliery, Ruhr Coalfield, Germany; Lower Westphalian C.

Diagnosis (from diagnosis in Potonié and Kremp 1955, p. 67). Amb circular. Laesurae two-thirds of radius. Entire surface covered by verrucae of irregular shape, measuring about 2–3 μ. More than 50 verrucae project at equator.

Size in microns. (i) Holotype 71; about 70, Schulze (Potonié and Kr. 1955). (ii) 55–70, fum. HNO_3 and KOH (Piérart 1958). (iii) 43(60)79, fum. HNO_3; Slyving Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. Amb sometimes oval. Laesurae simple, one-half to two-thirds of radius, range 15(19)25 μ, not always visible; extremities indistinct and merging with pattern of channels between verrucae (negative reticulum). Verrucae up to 3 μ in breadth and 2 μ in height; in profile apices well-rounded, in plan rounded, polygonal, or irregular in shape, closely packed. Intervening channels are of uniform width. Folds absent, or of minor proportions. Exine moderately thick.

Comparison. The verrucae of *V. donarii* are smaller in diameter and more numerous than in *V. cerosus*. Certain large specimens in which the ornament tends to be parallel-sided with truncated apices have been tentatively included in *V. donarii*. These spores resemble those figured by Bharadwaj (1955, pl. 1, figs. 1*a*, *b*, *c*) from the Saar Coalfield and referred to *Cyclobaculisporites grandiverrucosus* (Kosanke) Bharadwaj. The ornament of these specimens is different from that of the holotype of *Punctatisporites grandiverrucosus*.

Occurrence. Infrequent or frequent, Assemblages VIII to XI; Westphalian B to D.

Verrucosisporites microtuberosus (Loose) comb. nov.

Plate 5, figs. 9–11

1932 *Sporonites microtuberosus* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 33.
1934 *Tuberculati-sporites microtuberosus* Loose, p. 147.
1944 *Punctatisporites microtuberosus* (Loose); Schopf, Wilson, and Bentall, p. 31.
1950 *Plani-sporites microtuberosus* (Loose); Knox, p. 316, pl. 17, fig. 211.
1955 *Microreticulatisporites microtuberosus* (Loose); Potonié and Kremp, p. 100, pl. 15, figs. 273–7.
1957*a* *Planisporites microtuberosus* (Loose) Knox in Bharadwaj, p. 87, pl. 23, figs. 13, 14.

Holotype. Potonié and Kremp 1955, pl. 15, fig. 273 after Loose. Preparation III50, C_6 (or).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 100). Amb oval to circular; outline regularly notched. Laesurae simple, one-half to three-quarters of radius. Exine covered by small, bluntly conical verrucae, not exceeding 2μ in height, or breadth; closely packed; 70 to 100 project from margin. Exine thin with compression folds.

Size in microns. (i) Holotype 67·5, Schulze. (ii) 55–85, Schulze (Potonié and Kr. 1955). (iii) 55(72)84 (20 specimens), H_2O_2; lower bed of Chislet No. 2 Seam at 58 ft. 9 in., No. 30 upborehole, Chislet Colliery, Kent Coalfield, England; Westphalian B. (iv) 55(68)79, fum. HNO_3; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England; Westphalian A.

Description. Laesurae range $17(21)25\ \mu$; extremities not always well-defined. Verrucae variable in size; in profile apices often rather pointed, in plan rounded, polygonal, or irregular; bases of adjacent verrucae may be more or less confluent giving microreticulate pattern in certain planes of focus; channels between verrucae narrow. Compression folds similar to those developed in *Calamospora*.

Remarks. The authors have examined photographs ($\times 1000$) of the holotype taken with high-power oil-immersion objectives (Smith *et al.* 1964, pl. 2, figs. 4, 6). These leave no doubt as to the nature of the ornament and indicate that Bharadwaj (1955, p. 127) was correct in suggesting that the species should be assigned to *Verrucosisporites*. He subsequently, however, (1957*a*, p. 87, pl. 23, figs. 13, 14) placed the species in *Planisporites*, as had Knox in 1950, and provided a new diagnosis. The specimens figured by Bharadwaj at this time do not resemble the type of Loose.

The population measured from the Westphalian A of the Yorkshire Coalfield comprised 43 specimens. As will be seen from text-fig. 70 the histogram of size variation is bimodal. The appearance of specimens from the two size classes is shown in Plate 5, figs. 9–11.

Comparison. Occasional specimens have been recorded which slightly exceed the size range quoted above and have about 100 verrucae projecting from the equator. Another form with about 60 marginal projections is referred to *Microreticulatisporites* cf. *microtuberosus* by Potonié and Kremp 1955. These authors compare their form with *V. sinensis* Imgrund. *V.* (*Microreticulatisporites*) *verus* (Potonié and Kremp 1955, p. 102, pl. 15, fig. 286) Smith *et al.* 1964 (pl. 3, fig. 8) also appears very similar. The identification of these species would appear to be difficult in practice. *Tuberculatisporites regularis* Dybová and Jachowicz 1957*a* (p. 114, pl. 26, figs. 1–4) is probably a synonym of *V. microtuberosus*. *V. microtuberosus* differs from *V. donarii* in having slightly smaller and more pointed verrucae; the amb is also usually oval rather than circular and compression folds are well developed.

Occurrence. Infrequent or occasionally frequent, Assemblages V to XI; Westphalian A to D.

Verrucosisporites microverrucosus Ibrahim 1933

Plate 5, figs. 12–14

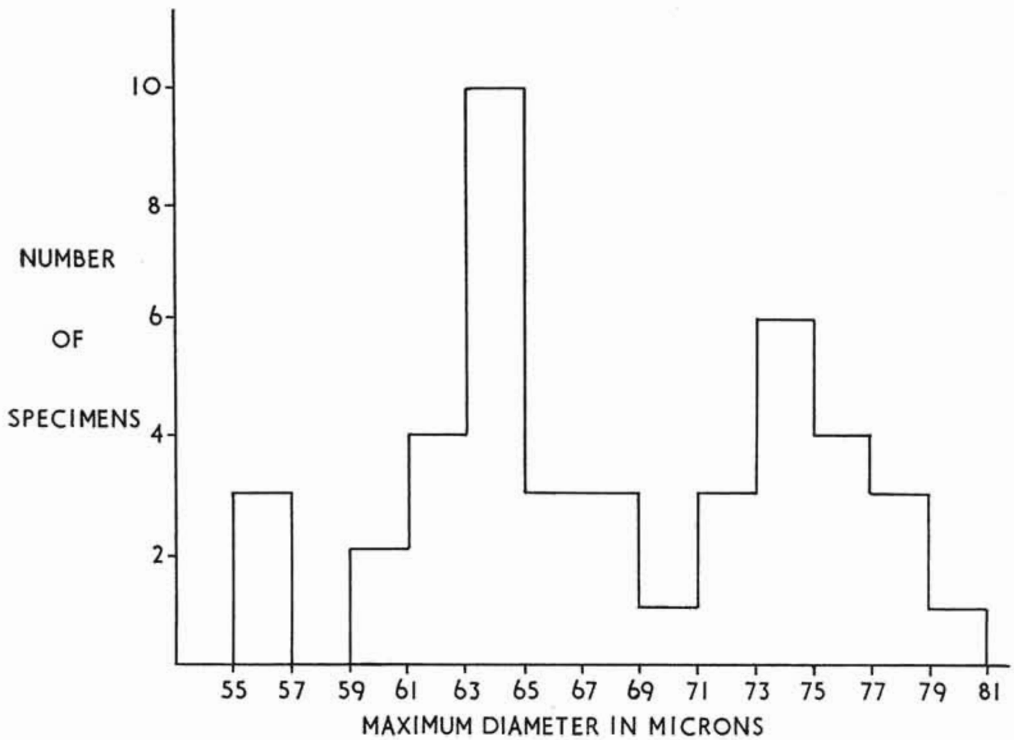
1933 *Verrucosi-sporites microverrucosus* Ibrahim, p. 25, pl. 7, fig. 60.
1944 *Punctati-sporites microverrucosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 31.
1950 *Verrucoso-sporites microverrucosus* (Ibrahim); Knox, p. 318, pl. 17, fig. 228.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 200 after Ibrahim. Preparation B26, c2 (ur).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Ibrahim 1933, p. 25 and Potonié and Kremp 1955, p. 68). Amb oval to circular. Laesurae extend almost to equator. Verrucae round to slightly elongated, and 3–7 μ in diameter, cover entire exine.

Size in microns. (i) Holotype 56·5, Schulze and KOH. (ii) 45–75, Schulze (Potonié and Kr. 1955).



TEXT-FIG. 70. Spore size of *Verrucosisporites microtuberosus* from the Parkgate Seam, Yorkshire Coalfield

Description. Amb circular, subcircular, or oval; outline uneven. Laesurae distinct and simple, two-thirds to three-quarters of radius. Verrucae vary in size and shape on any one specimen; in profile more or less conical to low and well rounded; in plan rounded, polygonal, or irregular; channels between verrucae irregular in size. In some specimens the ornament is reduced in size on the contact area. 25 to 30 verrucae project at the margin.

Comparison. The irregular shape and disposition of the verrucae and their comparatively large size are diagnostic of this species.

Occurrence. Infrequent, Assemblages V to X; Westphalian A to Upper Westphalian C.

Verrucosisporites morulatus (Knox) emend.

Plate 5, figs. 15, 16

1948 Type 20K Knox, text-fig. 23.
1950 *Verrucoso-sporites morulatus* Knox, p. 318, pl. 17, fig. 235.
1955 *Verrucosisporites morulatus* (Knox); Potonié and Kremp, p. 65.

Lectotype. Plate 5, fig. 15 after Knox. Preparation 369A (T85/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Sulphur Seam, Lindsay Colliery, East Fife Coalfield, Scotland; Namurian A.

Diagnosis (emended from diagnosis in Butterworth and Williams 1958, p. 362). Amb circular to oval; margin modified by ornament. Laesurae simple, one-half to two-thirds of radius. Exine covered by well-defined, discrete verrucae, relatively loosely packed and numbering 30 to 40 at the margin. Verrucae more or less parallel-sided with flat to rounded apices; variable in size, up to 6 μ in diameter and 4 μ in height. Exine relatively thin.

Size in microns. (i) Lectotype 58, Schulze. (ii) 50–80, Schulze and 5% KOH (Butterworth and Will. 1958).

Description. Laesurae seldom seen. In profile verrucae mostly approach squares but a proportion of pila shapes also occurs; in plan view they are polygonal or irregular; in some specimens spaces between verrucae may equal the width of the verrucae.

Remarks. Knox did not name a holotype but the authors have designated as lectotype a specimen marked by Knox on an original preparation.

Comparison. *V. morulatus* is very similar to *V. firmus* Loose, but differs in having a more regular pattern of ornament of a slightly finer grade. *V.* (*Azonotriletes*) *scrobiculatus* Luber and Waltz 1938 (pl. 5, fig. 70) Potonié and Kremp 1955 is a comparable form.

Occurrence. Infrequent, Assemblages I to IV; Viséan and Namurian.

Verrucosisporites sifati (Ibrahim) comb. nov. emend.

Plate 6, fig. 1

1933 *Reticulati-sporites sifati* Ibrahim, p. 35, pl. 8, fig. 67.
1955 *Microreticulatisporites sifati* (Ibrahim); Potonié and Kremp, p. 102, pl. 15, figs. 282–5.

Holotype. Potonié and Kremp 1955, pl. 15, fig. 283 after Ibrahim. Preparation B5, a6 (m).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 102). Amb oval to circular; margin gently undulating. Laesurae simple, one-third to one-half of radius (longest axis). Exine covered by verrucae mostly with low, well-rounded apices; height less than 2·5 μ, breadth not exceeding 5 μ; 50 to 70 verrucae project at margin. Exine thin, and usually with narrow compression folds.

Size in microns. (i) Holotype 100, Schulze and KOH. (ii) 80–140, Schulze (Potonié and Kr. 1955). (iii) 77(97)114, H_2O_2; lower bed of Chislet No. 2 Seam at 58 ft. 9 in., No. 30 upborehole, Chislet Colliery, Kent Coalfield, England; Westphalian B.

Description. Laesurae range 15–30 μ. In profile verrucae mostly broader than high, and well rounded; in plan view circular, polygonal, irregular, and sometimes elongate; to some extent adjacent verrucae may be confluent. Channels between verrucae of varying width. Outline for most part gently undulating but degree of prominence of verrucae at margin varies in different individuals.

Remarks. Examination of photographs ($\times$1000) of holotype (Smith *et al.* 1964, pl. 3, fig. 1) leaves no doubt that the species should be assigned to *Verrucosisporites*.

Comparison. There is a considerable overlap in the size ranges of *V. sifati*, *V. microtuberosus*, and *V. verrucosus*. *V. sifati* differs from *V. verrucosus* in having relatively broad, low, and well-rounded verrucae, and from *V. microtuberosus* in having slightly larger and less tightly packed verrucae. *Tuberculatisporites permagnus* Dybová and Jachowicz 1957*a* (p. 113, pl. 25, figs. 1–4) is probably a synonym of *V. sifati*.

Occurrence. Infrequent, or occasionally frequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

EXPLANATION OF PLATE 6

All figures $\times$500, and of proximal surface, unless otherwise stated.

Fig. 1. *Verrucosisporites sifati* (Ibrahim) comb. nov. emend. Slide 60, 41·1 118·5.

Fig. 2. *Schopfites dimorphus* Kosanke 1950. Specimen not preserved.

Figs. 3, 4. *Lophotriletes granoornatus* Artüz 1957. 3, slide 64, 53·9 106·2. 4, slide 64, 23·9 110·4.

Figs. 5–8. *L. commissuralis* (Kosanke) Potonié and Kremp 1955. 5, slide 62, 45·0 120·9. 6, 7, slide 62, 29·3 114·0. 8, slide 62, 39·3 106·7. 7, 8, pointed apices of sculpture visible at margin; $\times$1,000.

Fig. 9. *L.* cf. *gibbosus* (Ibrahim) Potonié and Kremp 1954. Slide 63, 43·2 113·7.

Figs. 10, 11. *L.* cf. *microsaetosus* (Loose) Potonié and Kremp 1955. 10, slide 66, 52·5 104·5. 11, slide 66, 57·9 110·8.

Figs. 12, 13. *L. microsaetosus* (Loose) Potonié and Kremp 1955. 12, slide 65, 33·5 119·9. 13, slide 65, 41·2 108·1.

Fig. 14. *Waltzispora polita* (Hoffmeister, Staplin, and Malloy) comb. nov. Slide 11, 39·5 111·5.

Figs. 15, 16. *Anapiculatisporites concinnus* Playford 1962. 15, slide 67, 32·1 115·1. 16, slide 68, 50·0 102·1.

Figs. 17, 18. *A. hispidus* Butterworth and Williams 1958. 17, Holotype; slide T39/1. 18, Isotype, equatorial view showing laevigate proximal surface; slide T39/2.

Figs. 19, 20. *A. spinosus* (Kosanke) Potonié and Kremp 1955. 19, slide 71, 36·2 114·2. 20, slide 72, 20·0 107·1.

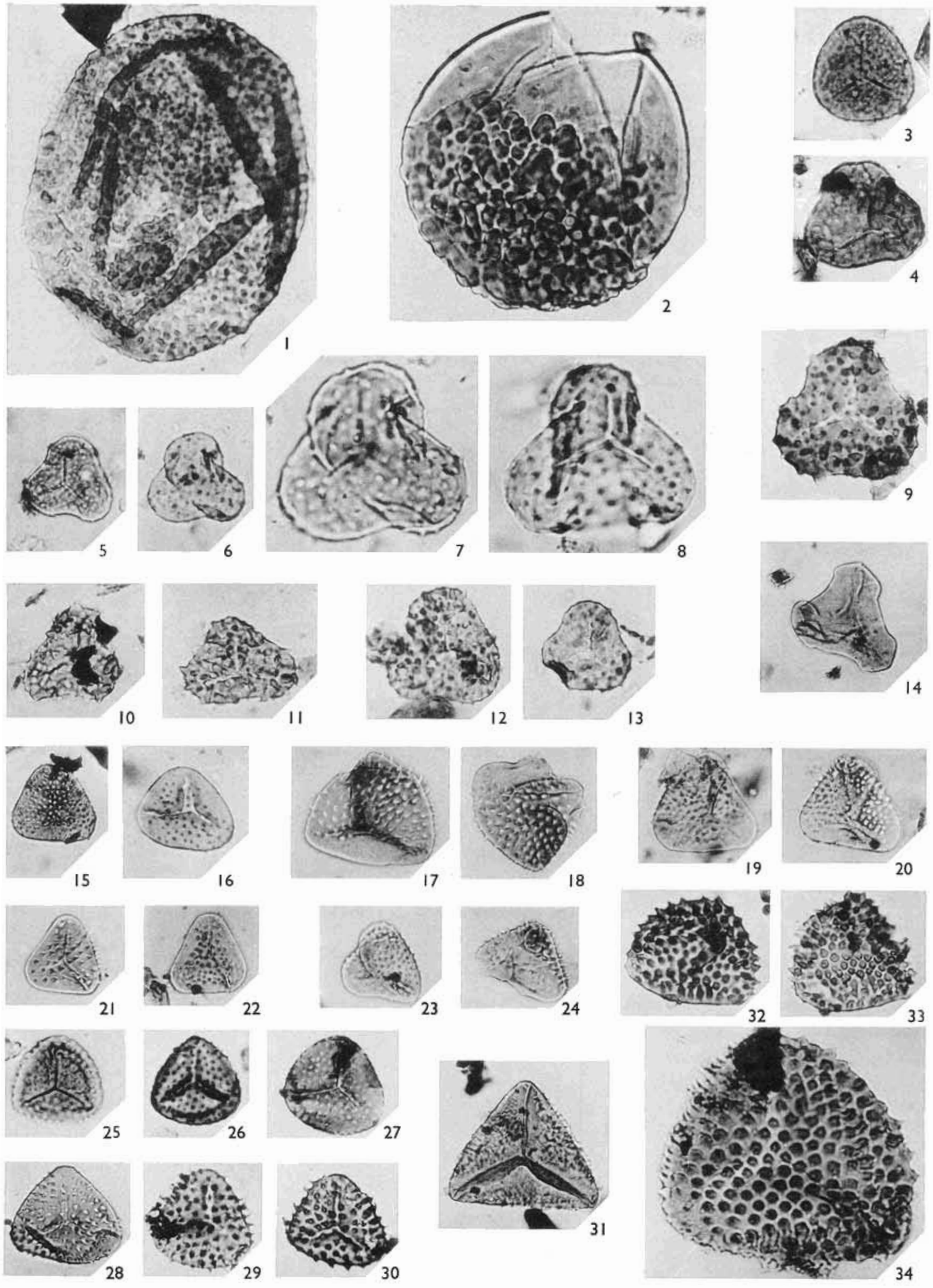
Figs. 21–24. *A. minor* (Butterworth and Williams) emend. 21, Holotype; slide T40/1. 22, slide 69, 27·1 110·5. 23, slide 69, 40·8 108·3. 24, slide 70, 32·8 111·5.

Figs. 25–27. *Procoronaspora ambigua* (Butterworth and Williams) emend. 25, 26, Holotype, proximal and distal surfaces respectively; slide T64/1. 27, Isotype; slide T64/4.

Figs. 28–30. *P. dumosa* (Staplin) comb. nov. 28, slide 73, 34·5 113·3. 29, slide 74, 47·7 102·8. 30, distal surface; slide 75, 29·7 115·0.

Fig. 31. *P. fasciculata* Love 1960. Slide 76, 28·3 101·7.

Figs. 32–34. *P. serrata* (Playford 1962) comb. nov. 32, distal surface; slide 73, 26·8 120·3. 33, distal surface; slide 73, 44·3 119·4. 34, distal surface, mammoid character of sculpture visible at margin, $\times$1,000; slide 74, 42·5 105·6.



SMITH and BUTTERWORTH, British Carboniferous miospores

Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933

Plate 5, figs. 7, 8

1932 *Sporonites verrucosus* Ibrahim in Potonié, Ibrahim, and Loose, p. 448, pl. 15, fig. 17.
1933 *Verrucosi-sporites verrucosus* Ibrahim, p. 25, pl. 2, fig. 17.
1938 *Azonotriletes verrucosus* (Ibrahim); Luber in Luber and Waltz, pl. 7, fig. 95.
1944 *Punctati-sporites verrucosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 32.
1950 *Verrucoso-sporites verrucosus* (Ibrahim); Knox, p. 319, pl. 17, fig. 230.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 196 and Smith *et al.* 1964, pl. 3, fig. 7 after Ibrahim. Preparation B29, d1 (o).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from diagnosis and description, Potonié and Kremp 1955, p. 69). Amb roughly oval to circular; outline with irregular protuberances ('grob-höckerig'). Laesurae two-thirds of radius. Surface densely covered by verrucae of irregular shape, 2–4 μ in diameter; 45 to at least 50 verrucae project at margin. Spaces between verrucae less than their basal width.

Size in microns. (i) Holotype 77, Schulze and KOH. (ii) 70–100, Schulze (Potonié and Kr. 1955). (iii) 52(69)94, H_2O_2; lower bed of Chislet No. 2 Seam at 58 ft. 9 in., No. 30 upborehole, Chislet Colliery, Kent Coalfield, England; Westphalian B.

Description. Laesurae simple, from less than one-half to nearly three-quarters of radius in length, range 15(20)25 μ, not always visible; extremities indistinct, merging with pattern of channels between verrucae (negative reticulum). Verrucae up to 4 μ in breadth and 2·5 μ in height. Variation occurs in the size and shape of the verrucae within and between specimens of the same population. Thus in profile the apices may be more or less conical, flat, or well rounded. The degree of prominence and density also varies. Most specimens have one or more compression folds.

Remarks. The difference in the size ranges quoted above may, in part, be due to the different methods of maceration.

Comparison. *V. verrucosus* differs from *V. donarii* in having slightly larger verrucae. The width of the channels between the verrucae is also more variable. *Tuberculatisporites gigantonodatus* Dybová and Jachowicz 1957*a* (p. 116, pl. 27, figs. 1–4) is a probable synonym of *V. verrucosus*.

Occurrence. Infrequent, Assemblages V to XI; Westphalian A to D.

Genus SCHOPFITES Kosanke 1950

Type species. *S. dimorphus* Kosanke 1950.

Diagnosis (from description in Kosanke 1950, p. 52). Spores radial, trilete; outline circular. Trilete mark plainly visible, thin lips may be developed. Proximal surface entirely laevigate or laevigate for four-fifths of its area. Distal surface with closely spaced, imbricating, blunt to round projections ranging in length from 2 to 12 μ. Exine variable in thickness, up to 3 μ on proximal surface, thickening to 4 μ at the point where ornament begins. Folding rare except on the thinner, proximal surface.

Comparison. Anapiculatisporites Potonié and Kremp has a triangular amb and a much finer grade of ornament. In *Anaplanisporites* Jansonius the amb is circular but the ornament is small, seldom greater than 2 μ in height, and is regularly disposed.

Affinity. Unknown.

Schopfites dimorphus Kosanke 1950

Plate 6, fig. 2

Holotype. Kosanke 1950, pl. 13, fig. 3. Preparation 537–L_3, slide 5.

Type locality. No. 2 Coal, Franklin County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 52). Outline circular. Trilete mark distinct, rays 30–35 μ long, lips only slightly developed. Proximal surface laevigate for four-fifths of the area; distal surface covered with imbricating, blunt to round projections, 3–12 μ long, 3–15 μ wide. Proximal exine at least 3 μ in thickness, distal exine without ornament at least 4 μ in thickness.

Size in microns. (i) *Holotype* 113·2 × 105; 78–115, Schulze and 10% KOH (Kosanke 1950). (ii) 70(81)100 × 70(80)98, fum. HNO_3, 75(87)109 × 74(81)100, Schulze and 5% KOH; seam at 3,388 ft. 2 in., Upton borehole, Oxfordshire Coalfield, England; Westphalian D (Butterworth and Will. 1954).

Remarks. Kosanke (1950) describes two species of *Schopfites*, *S. dimorphus* and *S. colchesterensis*, the latter differing in its slightly smaller size and shorter and less closely spaced distal projections. The two species are recorded from similar horizons and the measurement given for *S. colchesterensis* falls within those given for *S. dimorphus*. The spores measured by Butterworth and Williams (loc. cit.) showed no discontinuity and yielded no evidence of there being more than one species present. Kosanke (personal communication) has agreed that the spores seen during the present investigations should be assigned to *S. dimorphus*.

Occurrence. Infrequent, Assemblage XI; Etruria Marl of North Staffordshire (? Westphalian C) and Westphalian D.

Subinfraturma NODATI Dybová and Jachowicz 1957*a*
Genus LOPHOTRILETES (Naumova) Potonié and Kremp 1954

Type species. *L. gibbosus* (Ibrahim) Potonié and Kremp.

Diagnosis (Potonié and Kremp 1954, p. 129; translation). 'Trilete isospores or microspores, of similar structure to *Apiculatisporis*, but with the equatorial outline distinctly triangular rather than circular; sides generally convex, sometimes concave. Forms with very convex sides approaching a circle in equatorial outline are included in *Apiculatisporis*.'

Affinity. The spores of the fern *Sphyropteris* cf. *boenischi* Stur figured by Remy and Remy (1957, pl. 2, fig. 7) appear to be of *Lophotriletes* type.

Lophotriletes commissuralis (Kosanke) Potonié and Kremp 1955

Plate 6, figs. 5–8

1950 *Granulatisporites commissuralis* Kosanke, p. 20, pl. 3, fig. 1.
1955 *Lophotriletes commissuralis* (Kosanke); Potonié and Kremp, p. 73, pl. 14, figs. 222, 223.
non 1960 *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp; Imgrund, p. 164, pl. 15, figs. 66–68.

Holotype. Kosanke 1950, pl. 3, fig. 1. Preparation 486–B, slide 22.

Type locality. Friendsville Coal, Wabash County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 20). Outline triangular, angles rounded, sides concave. Tetrad mark distinct, extending for three-quarters of spore radius; margin of commissure slightly raised, in part broken by granulations. Exine (1–2 μ thick), coarsely granulate, grana closely spaced.

Size in microns. (i) Holotype 29·5×26; 25–34, Schulze and 10% KOH (Kosanke 1950). (ii) 24(29)35 (18 specimens) Schulze and 5% KOH; seam at 739 ft. 10 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England; Westphalian D.

Remarks. Potonié and Kremp (1955) transferred this species from *Granulatisporites* because the ornament consists of small coni rather than grana.

Comparison. Distinguished from other species by its finer grade of ornament. Potonié and Kremp (1955, p. 73) record about 45 coni projecting from the margin, but in British specimens the number is smaller. Distinguished from species of *Granulatisporites* by the nature of its ornament, which is large enough to modify the outline of the spore. Potonié and Kremp (1955) likened the ornament to that of *Planisporites* among circular spores. The specimens figured by Imgrund (1960, pl. 15, figs. 66–68) have longer, more pointed coni and are considered to be more akin to *Lophotriletes microsaetosus*.

Occurrence. Infrequent, Assemblages V to XI; Namurian to Westphalian D.

Lophotriletes gibbosus (Ibrahim) Potonié and Kremp 1954

1933 *Verrucosi-sporites gibbosus* Ibrahim, p. 25, pl. 6, fig. 49.
1938 *Azonotriletes gibbosus* (Ibrahim); Luber in Luber and Waltz, pl. 7, fig. 91.
1944 *Granulati-sporites gibbosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 33.
1950 *Verrucoso-sporites gibbosus* (Ibrahim); Knox, p. 317, pl. 17, fig. 232.
1954 *Lophotriletes gibbosus* (Ibrahim); Potonié and Kremp, p. 129.
non 1958 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp; Guennel, p. 62, pl. 3, fig. 9.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 220 after Ibrahim. Preparation B61, e5 (ul).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1955, p. 74). Amb triangular; sides more or less concave; angles markedly rounded. Trilete rays more than two-thirds of radius; tecta rather high, vertex sharp, slightly flexuose. Ornament of small coni differing slightly in size; apices rounded, seldom flat, about 40 project at the equator. Width of coni generally equal to height, but may sometimes be greater. The narrow spaces between the coni give rise to a negative reticulum.

Size in microns. (i) Holotype 46, Schulze and KOH. (ii) 40–50, Schulze (Potonié and Kr. 1955).

Remarks. Guennel (1958) assigned to *Lophotriletes gibbosus* spores with a size range 30–40 μ which the present authors consider should have been assigned to *L. microsaetosus*.

Lophotriletes cf. *gibbosus* (Ibrahim) Potonié and Kremp 1954

Plate 6, fig. 9

Size in microns. 29(34)41 (in an assemblage of 31 specimens three were found with diameters approaching 50μ), fum. HNO_3; lower bed of Brockwell Seam at 635 ft. 3 in., Sharpness Point borehole, Durham Coalfield, England; Westphalian A.

Description. Amb triangular, sides concave, angles broadly rounded. Laesurae indistinct, extending about two-thirds of spore radius. Ornament of sharply tapering coni, 3–4 μ high, 2–3 μ wide at the base, unequal in size; about 35 project from the amb. Height of coni approaches that of spinae of *Acanthotriletes*. Exine moderately thick, seldom folded.

Comparison. The size range of *L.* cf. *gibbosus* is smaller than that of the type. The angles are broader and the coni are fewer, longer, and more pointed than in *Lophotriletes mosaicus* Potonié and Kremp 1955, the only other species with a comparable size range.

Occurrence. Infrequent, Assemblage VI; Westphalian A.

Lophotriletes granoornatus Artüz 1957

Plate 6, figs. 3, 4

Holotype. Artüz 1957, pl. 2, fig. 13. Preparation II14, 2e.

Type locality. Büyük Seam, Zonguldak Coalfield, Turkey; Westphalian A.

Diagnosis (from Artüz 1957, p. 244; translation). 'Triangular with angles rounded; sides slightly concave. . . . Tetrad mark about two-thirds of radius, rays regular. Exine ornamented with discrete grana which are also evident at the equator.'

Size in microns. (i) Holotype 37, 35–41, method of maceration not known (Artüz 1957). (ii) 27(35)44, fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb triangular, angles broadly rounded, sides slightly concave or straight. Laesurae simple, one-half to two-thirds of spore radius. Ornament of coni, 1–2 μ in diameter; apices pointed, rounded, or slightly flattened, bases not touching; about 50 project at the equatorial margin. Exine moderately thick. Folding fairly frequent.

Comparison. The ornament of *L. granoornatus* is smaller than in other species of comparable size.

Occurrence. Infrequent, Assemblages VI to VIII; Upper Westphalian A and Westphalian B.

Lophotriletes microsaetosus (Loose) Potonié and Kremp 1955

Plate 6, figs. 12, 13

1932 *Sporonites microsaetosus* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 40.
1933 *Setosi-sporites microsaetosus* (Loose) Ibrahim, p. 26.
1934 *Setosisporites microsaetosus* (Loose) Loose, p. 148.
1944 *Granulatisporites microsaetosus* (Loose); Schopf, Wilson, and Bentall, p. 33.
1950 *Spinoso-sporites microsaetosus* (Loose); Knox, p. 314, pl. 17, fig. 203.
1955 *Lophotriletes microsaetosus* (Loose); Potonié and Kremp, p. 74, pl. 14, figs. 229–30.
1958 *Lophotriletes gibbosus* (Ibrahim) Potonié and Kremp; Guennel, p. 62, pl. 3, fig. 9.

Holotype. Potonié and Kremp, 1955, pl. 14, fig. 229 after Loose. Preparation IV6 f_2 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from diagnosis and description in Potonié and Kremp 1955, p. 74). Amb triangular with more or less concave sides and markedly rounded angles. Trilete rays weakly flexuose, almost reach equator. Coni moderately pointed, height about equal to basal width, 2–2·5 μ; about 35 project at equator. The coni are so closely spaced as to give the appearance of a negative reticulum.

Size in microns. (i) Holotype 39, Schulze. (ii) 25–40, Schulze (Potonié and Kr. 1955). (iii) 21(30)39, fum. HNO_3; seam at 1,754 ft. 11 in., Sandon Bank borehole, Cannock Chase Coalfield, England; Westphalian C.

Remarks. Spores corresponding to the above diagnosis have been noted from several horizons in the Westphalian C. It is thought that the assemblage from the seam at 1,754 ft. 11 in. in the Sandon Bank borehole might contain this species and the smaller *Lophotriletes* cf. *microsaetosus*, described below. Guennel (1958, p. 63) found two size ranges (20–30 μ and 30–40 μ) for spores of this type, which he referred to *L. microsaetosus sensu stricto* and *L. gibbosus* respectively. According to Potonié and Kremp (1955) *L. gibbosus* has a size range of 40–50 μ but Guennel did not find any spores of this size.

Occurrence. Infrequent to frequent, Assemblages IX and X; Upper Westphalian B and Westphalian C.

Lophotriletes cf. *microsaetosus* (Loose) Potonié and Kremp 1955

Plate 6, figs. 10, 11

1955 *Lophotriletes microsaetosus* (partim) (Loose) Potonié and Kremp, p. 74, pl. 14, fig. 230.
?1958 *Lophotriletes microsaetosus* (Loose) Potonié and Kremp in Guennel, p. 63, pl. 3, fig. 10.
?1960 *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp; Imgrund, p. 164, pl. 15, figs. 66–68.

Size in microns. (i) 19(23)29, fum. HNO_3; Barncraig Seam, Michael Colliery, East Fife Coalfield, Scotland; Westphalian B. (ii) 21(25)32, fum. HNO_3; Jewel Seam at 2,923 ft. 9 in., Slatehole Farm borehole, Ayrshire Coalfield, Scotland; Westphalian B. (iii) 20(26)32, fum. HNO_3; Rams Seam, Wheatsheaf Colliery, Lancashire Coalfield, England; Westphalian B. (iv) 16(20)24 (13 specimens) fum. HNO_3; Slyving Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. Amb triangular, sides concave, angles rounded. Laesurae partly concealed by ornament, about two-thirds of spore radius in length. Ornament of coni up to 2 μ in height and basal width, tapering or rounded, sometimes varying on single specimens; 30 to 35 coni project from amb.

Remarks. Apart from their smaller size these spores are similar to *Lophotriletes microsaetosus*. They invariably have concave sides. The Westphalian B specimens are probably those which Guennel (1958, p. 63) referred to *L. microsaetosus*. The smallest specimens, from the Westphalian D, are too few to be treated systematically; they may be equivalent to the spore which Imgrund (1960, pl. 15, figs. 66–68) refers to *Lophotriletes commissuralis* (Kosanke) Potonié and Kremp.

Comparison. Lophotriletes commissuralis (Kosanke) Potonié and Kremp is slightly larger and the ornament is of a finer grade and more closely spaced.

Occurrence. Infrequent or occasionally frequent, Assemblage VIII; infrequent, Assemblages IX to XI; Upper Westphalian B to Westphalian D.

Genus WALTZISPORA Staplin 1960

The genus Waltzispora at present includes forms with exine ornament ranging from laevigate to apiculate. Sullivan (1964) transferred the genus to the infraturma Apiculati on the basis of the prominent ornament of the type species *W. lobophora* (Waltz) Staplin 1960.

Type species. W. lobophora (Waltz) Staplin 1960.

Diagnosis (Staplin 1960, p. 18). 'Spores radial; trilete; triangular in proximal view; shape lenticular; radial extremities of spore reflexed and expanded into mushroom, saddle or T-shaped outline; entire spore cavity continuous without differentiation or appression; sutures distinct, with or without lip development; sculpture fine or lacking on known species; spore wall relatively thick. . . .'

Affinity. Unknown.

Waltzispora polita (Hoffmeister, Staplin, and Malloy) comb. nov.

Plate 6, fig. 14

1955 *Granulati-sporites politus* Hoffmeister, Staplin, and Malloy, p. 389, pl. 36, fig.13.
non 1960 *Leiotriletes politus* (Hoffmeister, Staplin, and Malloy); Love, p. 111, pl. 1, fig. 1.

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 13. Preparation 6, ser. 15,718.

Type locality. Shale at 2,077 ft., Carter No. 3 borehole (TCO-82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 389). Amb subtriangular; interradial margins concave or slightly convex, radial margins rounded. Trilete suture broad, two-thirds to three-quarters of radius. Surface smooth to infrapunctate. Exine moderately thin.

Size in microns. Holotype 37·5; 26–38, HF (Hoffmeister, Stap., and Mall. 1955).

Description. Tendency for rounded apices to project laterally gives an angular junction of radial and interradial margins in proximal view; exine weakly granulate, grana scarcely modifying margin (under oil).

Remarks. The characteristic feature of this species, namely the angular junction between the radial and interradial margins, was pointed out by Butterworth and Williams (1958). This feature, however, is less well defined in this species than in others assigned to the genus. The character is not mentioned by Hoffmeister, Staplin, and Malloy although it is evident in their photograph (pl. 36, fig. 13). The specimen figured by Love (1960, pl. 1, fig. 1) as *Leiotriletes politus* (Hoffmeister, Staplin, and Malloy) Love from the Viséan of Scotland appears identical with *W. sagittata* Playford 1962 (p. 582, pl. 79, fig. 12, text-fig. 5*c*).

Occurrence. Infrequent, Assemblages II and III; Viséan and Namurian A.

Genus ANAPICULATISPORITES (Potonié and Kremp) emend.

Type species. *A. isselburgensis* Potonié and Kremp 1954.

Diagnosis (emended from Potonié and Kremp 1954, p. 133). Trilete isospores or microspores. Amb triangular, very occasionally circular. Laesurae prominent, simple. Proximal surface laevigate; distal surface with grana, coni, or spinae, which do not extend to the interradial portions of the equator. Coni and spinae generally of similar size over distal surface, but they may increase in size slightly towards the distal pole.

Remarks. The generic diagnosis is emended to exclude Namurian and Viséan species of *Procoronaspora* (*P. dumosa*, *P. vegeta*, and *P. serrata*) in which the distal ornament extends to the interradial margins of the equator.

Comparison. In *Acanthotriletes*, *Apiculatisporis*, *Granulatisporites*, and *Lophotriletes* the ornament is distributed over the whole exine. In *Anaplanisporites* Jansonius 1962 the ornament is restricted to, and evenly distributed over, the distal surface and projects evenly round the equator.

Affinity. Unknown.

Anapiculatisporites concinnus Playford 1962

Plate 6, figs. 15, 16

Holotype. Playford 1962, pl. 80, figs. 9, 10. Preparation P145B/37, 40·2 103·0 (L. 995).

Type locality. Triungen (Sample G1466), Spitsbergen; Lower Carboniferous.

Diagnosis (Playford 1962, p. 587). 'Spores radial, trilete; amb triangular with rounded apices and convex to almost straight sides. Laesurae distinct, simple, more or less straight, length three-quarters to four-fifths spore radius. Proximal surface laevigate. Distal surface bearing scattered, small, uniform coni, 1–2 μ in length and 1–1·5 μ in basal diameter. Coni about 2–3 μ apart, fairly evenly distributed, but characteristically absent, or markedly reduced in numbers, at and around equatorial margin, particularly of interradial areas. Exine (excluding projections) about 1 μ thick; rarely folded.

Equatorial margin mainly smooth with only a few projecting coni, and these generally in the vicinity of the triangular apices.'

Size in microns. (i) Holotype 35; 23(32)44, Schulze (Playford 1962). (ii) 24(28)35 (20 specimens) fum. HNO_3; Oakshaw Ford Seam, Oakshaw Ford Colliery, Cumberland, England; Viséan.

Comparison. Distinguished from other species by the smallness of the ornament relative to the overall size, and by the characteristic distribution of the ornament.

Occurrence. Infrequent, Assemblages I and II; Viséan.

Anapiculatisporites hispidus Butterworth and Williams 1958

Plate 6, figs. 17, 18

Holotype. Plate 6, fig. 17. Preparation T39/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. 4 in. coal at 191 ft. 3 in., Darnley No. 3 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 364). Amb rounded-triangular, sides straight or convex. Laesurae slightly ridged, extending one-half to three-quarters of spore radius. Ornament of spinae up to 3 μ long which are sometimes falcate; about 27 to 36 spinae occur in outermost zone of ornamentation; ornament regularly and widely spaced. Folding frequent.

Size in microns. Holotype 39; 30(33)39, fum. HNO_3 (Butterworth and Will. 1958).

Description. Spores generally found in lateral compression. 70 to 90 spinae on the distal surface. Spinae reduced in size at radial equatorial positions. Exine thin.

Comparison. Larger and with more spinae than *A. concinnus.*

Occurrence. Infrequent, Assemblages III and IV; Namurian.

Anapiculatisporites minor (Butterworth and Williams) emend.

Plate 6, figs. 21–24

Holotype. Plate 6, fig. 21. Preparation T40/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Lyoncross Seam at 558 ft. 10., Darnley No. 4 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (emended from Butterworth and Williams 1958, p. 365). Amb triangular, sides straight, concave, or slightly convex, angles rounded, narrow, or truncate. Laesurae distinct, simple, one-half to three-quarters of spore diameter, sutures often open. Ornament variable, 40 to 70 small spinae up to 2·5 μ long, restricted to distal surface; arrangement random or, occasionally, in arcs following the direction of the laesurae. Exine thin; folding along the laesurae fairly frequent.

Size in microns. (i) Holotype 23; 14(22)28, fum. HNO_3 (Butterworth and Will. 1958). (ii) 20(23)27, fum. HNO_3; Lower Florida Seam, Golborne Colliery, Lancashire Coalfield, England; Westphalian B. (iii) 20(25)29, fum. HNO_3; seam at 1,758 ft. 2 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Westphalian A. (iv) 18(21)25, fum. HNO_3; Lower Three Quarters Seam, Solway Colliery (No. 1

Shaft), Cumberland Coalfield, England; Westphalian A. (v) 15(19)22, fum. HNO_3; seam at 3,833 ft. 0 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A. (vi) 14(19)28, fum. HNO_3; seam at 2,138 ft. 10 in., Blairmains No. 2 borehole, West Fife Coalfield, Scotland; Namurian A.

Remarks. The diagnosis of *A. minor* has been emended to accommodate specimens found in the Westphalian. These tend to have a larger number of grana or spinae on the distal surface which extend closer to the equatorial margin. In other respects the spores of this type from the Namurian A and the Westphalian are very similar.

Comparison. Smaller and with fewer spinae than *A. hispidus*, which does not have a concave margin.

Occurrence. Infrequent to frequent, Assemblages II to X; Viséan to Upper Westphalian C.

Anapiculatisporites spinosus (Kosanke) Potonié and Kremp 1955

Plate 6, figs. 19, 20

1950 *Granulatisporites spinosus* Kosanke, p. 22, pl. 3, fig. 7.
1955 *Anapiculatisporites spinosus* (Kosanke); Potonié and Kremp, p. 82, pl. 14, figs. 253–5.

Holotype. Kosanke 1950, pl. 3, fig. 7. Preparation 579-A, slide 1.

Type locality. No. 2 Coal, Bureau County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from Kosanke 1950, p. 22). Outline triangular, sides convex; angles bluntly pointed. Laesurae almost length of spore radius; lips slightly developed. Ornament of spinae $4\,\mu$ long, $1{\cdot}5\,\mu$ wide, covering distal and part of proximal surface.

Size in microns. (i) Holotype 31×30; 26–38, Schulze and 10% KOH (Kosanke 1950). (ii) 26(30)36, Schulze and 5% KOH; seam near base of Newcastle Beds, Penkhull, North Staffordshire Coalfields, England; Westphalian D.

Description. Specimens are generally preserved in lateral compression; in the occasional specimen in polar compression the ornament is seen to extend almost to the equator in the interradial regions. Ornament consists of approximately 100 fine, closely spaced spinae on the distal surface; spinae somewhat smaller than those recorded by Kosanke; arrangement random. Exine thin, folding frequent.

Comparison. Distinguished from other species by the greater number of distal spinae; spore larger than other Westphalian species.

Occurrence. Infrequent, Assemblage XI; Westphalian D.

Genus PROCORONASPORA (Butterworth and Williams) emend.

Type species. *P. ambigua* Butterworth and Williams 1958.

Diagnosis (emended from Butterworth and Williams 1958, p. 383). Trilete isospores or microspores. Amb triangular, angles rounded, sides straight or convex. Laesurae distinct, extending for about three-quarters spore radius, sometimes ridged. Exine thin, moderately thick, or thick. Ornament of small spinae, coni, or bacula on distal surface, extending to interradial areas of equator, where they may be greater in size; angles smooth or finely granulose. Folding infrequent but may be present in the area of the laesurae.

Remarks. Love (1960, p. 112) has indicated that the ornament in this genus is restricted to the distal surface and to the interradial parts of the equator. He has also noted that an incipient corona structure is not present in species of *Procoronaspora* and that the genus should be transferred to the Apiculati; the present authors are in agreement with this.

Comparison. Distinguished from *Anapiculatisporites* Potonié and Kremp emend. by the extension of the distal ornament to the interradial areas of the equator and by its greater prominence there than at the distal pole. Distinguished from *Diatomozonotriletes* (Naumova) Playford by the absence of a corona, by its smaller ornamental elements, and by the invariable presence of the latter on the distal surface. Distinguished from *Anaplanisporites* Jansonius 1962 by the absence or presence of a finer grade of ornament at the angles.

Affinity. Unknown.

Procoronaspora ambigua (Butterworth and Williams) emend.

Plate 6, figs. 25–27

1958 *Procoronaspora ambigua* Butterworth and Williams, p. 384, pl. 4, figs. 1–3, text-fig. 4.

Holotype. Plate 6, figs. 25, 26. Preparation T64/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Jubilee Seam at 682 ft. 0 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (emended from Butterworth and Williams 1958, p. 384). Amb triangular, angles rounded, sides convex or straight. Laesurae distinct, slightly ridged, extending for three-quarters of spore radius. Ornament of regularly spaced, parallel-sided elements 1 μ in diameter and 1·5 μ long; generally flat-topped but may also be small spinae; about 12 occur along each interradial margin; 15 to 20 are discernible in each interradial segment. Exine thick, apparently thinner at angles but thicker at interradial parts of equator. Folding infrequent.

Size in microns. Holotype 27; 26(34)40, fum. HNO_3 (Butterworth and Will. 1958).

Remarks. Sullivan (personal communication) considers that the holotype of *P. ambigua* possesses a cingulum, widest in the interradial areas, and has suggested that because of this the species should be transferred to the genus *Rotaspora*. The authors, however, are not entirely convinced that the spore is cingulate, and do not think it has the type of zona characteristic of *Rotaspora*. For the present, therefore, they have decided to retain the genus *Procoronaspora*.

Occurrence. Infrequent to frequent, Assemblages II to IV; Viséan and Namurian.

Procoronaspora dumosa (Staplin) comb. nov.

Plate 6, figs. 28–30

1960 *Granulatisporites? dumosus* Staplin, p. 16, pl. 3, figs. 15–17.

Holotype. Staplin 1960, pl. 3, figs. 15, 16. Imp. 1707, 5–40·3, 118·2.

Type locality. Shale at 4,385 ft., Imperial Belloy borehole 12–14, Alberta, Canada; Golata formation, Chester Series.

Diagnosis (Staplin 1960, p. 16). 'Spores trilete; convexly triangular; distal surface in part covered with scattered spines, reduced to granulations or absent at radial corners, small at the distal pole, largest along interradial portions of the equator where they are up to 2 μ long, 2–3·5 μ apart; proximal surface laevigate; sutures distinct, lips faintly thickened, often slightly gaping, ratio slightly over two-thirds; spore wall thickness moderate; . . .'

Size in microns. (i) Holotype 30; 26–30, maceration method not known (Staplin 1960). (ii) 20(28)32, fum. HNO_3; Houston Coal, Coalheughhead Mine, Central Coalfield, Scotland; Viséan.

Description. Exine thin. Spinae up to 3 μ long; 8 to 9 project along each interradial margin and 10 to 14 are visible in each interradial segment; arrangement random, well spaced; occasionally falcate.

Remarks. This species is transferred to the genus *Procoronaspora* because of the characteristic distribution of its ornament. In the specimens examined the size of the ornament was constant over the distal surface but much reduced in the radial, equatorial areas.

Comparison. The exine of *P. dumosa* is thinner than that of other species of the genus. *Lophotriletes vegetus* Ishchenko 1956 (p. 37, pl. 5, figs. 63–65) is larger and has a thicker exine.

Occurrence. Infrequent, Assemblages II and III; Viséan and Namurian A.

Procoronaspora fasciculata Love 1960

Plate 6, fig. 31

Holotype. Love 1960, pl. 1, fig. 2; slide PSB 296 m/6.

Type locality. Pumpherston Shell Bed, South Queensferry, Lothians Coalfield, Scotland; Viséan.

Diagnosis (Love 1960, p. 112). 'Triangular with almost straight interradial sides, apices narrowly rounded; trilete rays almost to the apices, lips thickened; ornament of granules only on distal surface and on the interradial equatorial margins where about 15 granules appear on each one; equatorial apices and proximal surface laevigate.'

Size in microns. (i) Holotype 50; 35–50, Schulze and KOH (Love 1960). (ii) 37, 44, fum. HNO_3; Shilbottle Seam at 201 ft. 1 in., New Moor Hall borehole, Northumberland Coalfield, England; Viséan.

Comparison. Distinguished from other species by the disposition of the ornament, which is almost restricted to the interradial areas and absent from the distal pole.

Occurrence. Two specimens corresponding exactly to the above diagnosis were found in Assemblage II, Middle Limestone Group, Northumberland Coalfield, England; Viséan. Recorded from rocks other than coal from Viséan of Scotland (Love 1960).

Procoronaspora serrata (Playford 1962) comb. nov.

Plate 6, figs. 32–34

1938 *Zonotriletes curiosus* (partim) Waltz in Luber and Waltz, pl. A, fig. 13 (*non* pl. 4, fig. 49).
1962 *Anapiculatisporites serratus* Playford, p. 589, pl. 80, figs. 16–19, text-fig. 5*j*.

Holotype. Playford 1962, pl. 80, fig. 16. Preparation P149A/3, 27·0 109·2 (L. 999).

Type locality. Triungen (sample G1470), Spitsbergen; Lower Carboniferous.

Diagnosis (Playford 1962, p. 589). 'Spores radial, trilete; amb sub-triangular with straight to slightly convex sides and rounded apices. Laesurae indistinct to perceptible, simple, straight, almost reaching to equatorial margin. Proximal surface laevigate. Distal surface strongly and uniformly sculptured with closely packed, broadly based, sharply tapering spines, which are also evident at the equator (projecting as a conspicuous pseudo-flange). Spines have characteristically hexagonal bases (diameter 2–4 microns) and range in length from 2·5 to 6 microns; somewhat diminished in size and density around the triangular apices. Exine (excluding spinae) 1–1·5 microns thick.'

Size in microns. (i) Holotype 42; equatorial diameter (excluding spinae) 38(49)61 (15 specimens), HF and Schulze (Playford 1962). (ii) Equatorial diameter (excluding spinae) 33–40 (5 specimens) fum. HNO_3; Shilbottle Seam at 201 ft. 1 in., New Moor Hall borehole, Northumberland Coalfield, England. Viséan.

Remarks. This species is transferred to the genus *Procoronaspora* because of the prominence of the ornament in the interradial areas of the equator and the reduction in size of this ornament at the angles.

Comparison. Distinguished from other species by the greater length and density of the spinae.

Occurrence. Infrequent, Assemblages I and II, Northumberland Coalfield and East Fife Coalfield, Scotland; Viséan.

Genus ANAPLANISPORITES Jansonius 1962

Type species. *A. telephorus* Klaus 1960.

Diagnosis (Jansonius 1962). 'Trilete spores; equatorial outline circular to subcircular; exine relatively thin, distally with numerous warts, granules or low coni, usually not more than 2 μ; ornaments regularly disposed, uniform in size and shape, showing on equatorial outline but only barely extending into proximal face; dehiscence area without ornamentation, essentially laevigate; sutures more or less distinct, mostly over half radius in length; dehiscence area relatively large.'

Comparison. The genus differs from *Anapiculatisporites* Potonié and Kremp emend. and *Procoronaspora* Butterworth and Williams emend. in that the regular and uniform ornament projects evenly beyond the amb and does not include spinae.

Affinity. Unknown.

Anaplanisporites baccatus (Hoffmeister, Staplin, and Malloy) comb. nov. emend.

Plate 7, figs. 1–5

1955 *Punctatisporites*? *baccatus* Hoffmeister, Staplin, and Malloy, p. 392, pl. 36, fig. 2.
1958 *Apiculatisporis baccatus* (Hoffmeister, Staplin, and Malloy); Butterworth and Williams, p. 363, pl. 1, fig. 25.

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 2. Preparation 8, ser. 19,087.

Type locality. Shale at 2,075 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (emended from Hoffmeister, Staplin, and Malloy 1955, p. 392). Amb circular to subcircular; laesurae slightly ridged, equal in length to spore radius. Ornamentation confined to distal surface; comprises numerous discrete coni with tapered to narrowly pointed apices; these number 35 to 45 at margin; height of coni 0·5–2 μ, basal diameter 0·5–1·5 μ. Exine thin.

Size in microns. (i) Holotype 29; 26–46, HF (Hoffmeister, Stap., and Mall. 1955). (ii) 22(26)30, fum. HNO_3; Bottom Busty Seam at 419 ft. 6 in., Houghton Colliery borehole (14 SW. 3), Durham Coalfield, England; Westphalian A. (iii) 20(26)30, fum. HNO_3; Shale Seam at 663 ft. 6 in., Cawder Cuilt No. 1 borehole, Central Coalfield, Scotland; Namurian A.

Description. Amb usually somewhat distorted by compression. Laesurae less than 0·5 μ high. Narrow, arcuate compression folds sometimes occur.

Remarks. This species was tentatively assigned to *Punctatisporites* by Hoffmeister, Staplin, and Malloy, but was subsequently placed in *Apiculatisporis* by Butterworth

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EXPLANATION OF PLATE 7

All figures × 500, and of roximal surface unless, otherwise stated.

Figs. 1–5. *Anaplanispoprites baccatus* (Hoffmeister, Staplin, and Malloy) comb. nov. emend. 1, distal surface with projecting portion of laevigate proximal surface; slide 77, 37·6 104·8. 2, equatorial view showing laevigate proximal surface; slide 77, 30·2 104·5. 3, slide 77, 45·0 116·4. 4, equatorial view showing laevigate proximal surface; slide 78, 46·5 105·9. 5, distal surface; slide 79, 28·7 107·6. 4, 5, specimens from Westphalian with finer sculpture.

Figs. 6–8. *A. globulus* (Butterworth and Williams) emend. 6, Holotype, distal surface; slide T38/1. 7, Isotype, distal surface; slide T38/2. 8, equatorial view showing laevigate proximal surface; slide 80, 29·7 105·9.

Figs. 9, 10. *Pustulatisporites papillosus* (Knox) Potonié and Kremp 1955. 9, Lectotype; slide T84/1, 45·3 106·8. 10, distal surface; slide 81, 36·9 109·9.

Fig. 11. *P. pustulatus* Potonié and Kremp 1954. Slide 82, 31·1 112·4.

Figs. 12, 13. *Apiculatisporis aculeatus* (Ibrahim) emend. 12, slide 85, 23·7 104·8. 13, slide 86, 44·9 115·6.

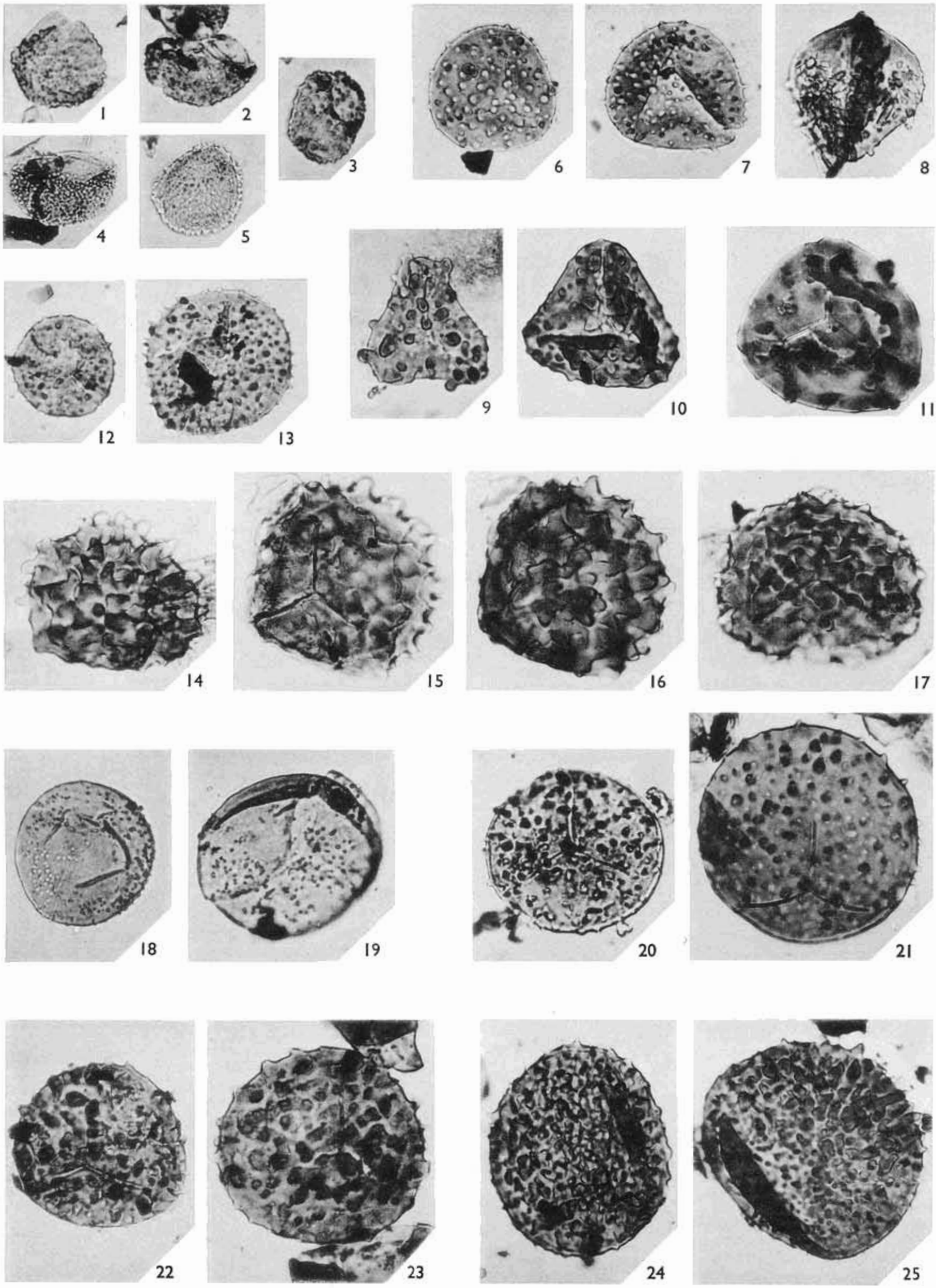
Figs. 14–17. *A. abditus* (Loose) Potonié and Kremp 1955. 14, distal surface; slide 235, 30·8 114·5. 15, 16, proximal and distal surfaces respectively; slide 83, 36·2 109·0. 17, distal surface; slide 84, 38·2 108·5.

Figs. 18, 19. *A. irregularis* (Alpern) comb. nov. 18, slide 87, 42·6 105·0. 19, slide 88, 52·6 112·5.

Figs. 20, 21. *A.* cf. *latigranifer* (Loose) Potonié and Kremp 1955. 20, slide 170, 30·5 105·2. 21, slide 89, 29·9 111·0.

Figs. 22, 23. *A. spinososaetosus* (Loose) emend. 22, slide 90, 40·1 106·4. 23, slide 91, 38·3 109·8.

Figs. 24, 25. *A. variocorneus* Sullivan 1964. 24, distal surface; slide 92, 51·2 116·6. 25, distal surface; slide 93, 25·4 115·9.



SMITH and BUTTERWORTH, British Carboniferous miospores

and Williams in view of its distinctly conate ornament. As the spore is usually preserved in polar compression the laevigate proximal face is not often apparent and can only be seen when the spore is laterally preserved.

Comparison. When the proximal face is not apparent this species can be distinguished from *Cyclogranisporites leopoldi* (Kremp) Potonié and Kremp by its more open and distinctly conate ornament.

Occurrence. Infrequent, or sometimes frequent, Assemblages I to VII; infrequent and only recorded from a small number of seams, Assemblages VIII and IX; Viséan to Lower Westphalian C. Recorded from rocks other than coal from Viséan of Scotland (Love 1960).

Anaplanisporites globulus (Butterworth and Williams) emend.

Plate 7, figs. 6–8

1948 Knox, p. 158, fig. 19.
1958 *Apiculatisporis globulus* Butterworth and Williams, p. 363, pl. 1, figs. 26, 27.

Holotype. Plate 7, fig. 6. Preparation T38/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Cloven Seam at 1,764 ft. 2 in., Queenslie Bridge borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (emended from Butterworth and Williams 1958, p. 363). Amb broadly rounded to triangular. Laesurae simple, straight, one-half to two-thirds of radius. Ornament restricted to distal surface, variable, consisting of small coni or verrucae, widely and irregularly spaced; approximately 15 to 30 project at equator. Proximal face laevigate.

Size in microns. Holotype 38; 32(36)46, fum. HNO_3 (Butterworth and Will. 1958).

Description. Amb tends to be triangular, but with broadly rounded angles. Commissures frequently open. Ornament very variable in individual spores and often in any one spore, but essentially consists of widely spaced, short, pointed or blunt coni up to 3 μ in height and 1–3 μ in diameter at base. It may also take the form of short, narrow bacula or broad, globular protuberances up to 6 μ in diameter. Exine thin, slightly darker in region of tetrad mark.

Remarks. This species has been assigned to *Anaplanisporites* because of the distal ornament, which projects beyond the amb, and the laevigate proximal face. On the other hand, the tendency to triangular shape, and the relatively coarse ornament, are not specified in the diagnosis of the genus.

Comparison. *Anapiculatisporites concinnus* Playford 1962 (p. 587, pl. 80, figs. 9–12) possesses less prominent distal ornament, which is absent or reduced at and around the equatorial margin, particularly of interradial areas.

Occurrence. Infrequent, Assemblage III; Namurian A.

Genus PUSTULATISPORITES Potonié and Kremp 1954

Type species. P. pustulatus Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 134; translation). 'Trilete isospores or microspores. Exoexine with individual widely spaced grana, warts, or short, blunt coni. The intervals between the sculptural elements are generally so wide that more than sufficient space is left for additional ornamentation elements of the same size. The bases of these elements are in contact only here and there and therefore never assume a polygonal shape.'

Affinity. Unknown.

Pustulatisporites papillosus (Knox) Potonié and Kremp 1955

Plate 7, figs. 9, 10

1948 Type 16K Knox, text-fig. 13.
1950 *Triquitrites papillosus* Knox, p. 327, pl. 17, fig. 234.
1955 *Pustulatisporites papillosus* (Knox); Potonié and Kremp, p. 82.

Lectotype. Plate 7, fig. 9. Knox did not designate a holotype. A specimen marked by Knox on her preparation 360A has been chosen as the lectotype (T84/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Dunfermline Splint Seam, Lumphinnans No. 1 borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 365). Amb triangular, sides slightly concave, straight, or slightly convex, angles rounded or truncate, outline modified to varying degree by ornament. Laesurae simple, straight, extending almost to margin. Ornament distal, of widely spaced verrucae, or short bacula, up to 5 μ in diameter and 8 μ in height, slightly tapering with blunt or well-rounded apices; ornamentation variable on any one specimen; proximal surface laevigate. Exine moderately thick.

Size in microns. (i) Lectotype 45, Schulze. (ii) 37(50)65, Schulze (Butterworth and Will. 1958); Namurian A.

Description. Tendency for larger ornamentation elements to be distributed in polar region, so that outline is often only slightly modified.

Occurrence. Infrequent or frequent, Assemblage III; Namurian A.

Pustulatisporites pustulatus Potonié and Kremp 1954

Plate 7, fig. 11

Holotype. Potonié and Kremp 1955, pl. 14, fig. 256. Preparation 485 VII.

Type locality. Ägir Seam, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1954, p. 134; translation). 'Amb rounded-triangular. Laesurae two-thirds radius, sometimes open. Outline smooth, apart from the well-spaced, very low pyramidal protuberances on the exine, which number about 15 at the equator and which are rarely pointed and only faintly recognizable. Exine thin.'

Size in microns. (i) Holotype 66; approximately 70, Schulze (Potonié and Kr. 1955). (ii) 50–70 (6 specimens) fum. HNO_3; various localities and horizons, British coalfields.

Remarks. Spores from British coals assigned to this species have moderately thick exines and are smaller than the 70 μ quoted by Potonié and Kremp. These differences may be due to the methods of maceration. Ornament probably reduced, or absent, from proximal face, but too few specimens mounted with proximal surface uppermost have been available for examination under oil.

Comparison. Amb of *P. pustulatus* is more rounded and ornament is less prominent than that of *P. papillosus*.

Occurrence. Infrequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Genus APICULATISPORIS Potonié and Kremp 1956

1933 *Apiculati-sporites* Ibrahim, p. 23, *non* Bennie and Kidston 1886.
1956*b* *Apiculatisporis* Potonié and Kremp, p. 94.

Type species. A. aculeatus Ibrahim 1933.

Diagnosis (Potonié and Kremp 1954, p. 130; translation). 'Trilete isospores, or microspores, displaying few distinctive features. Approximately circular at the equator. Surface fairly thickly covered with approximately conical elements. Often, these coni are fairly broad at the base and may have a slightly greater height than basal width. Their relative heights, which are generally slight, may sometimes approximate to double the basal diameters. The ornament on any one individual varies somewhat in size and shape. In some specimens the surface is fairly closely covered with these elements. Where they are more openly spaced the intervals between them are not large enough to accommodate further ornamentation. Where the ornamentation is so dense that individual elements touch at their bases, this occasionally causes the bases to deform to polygonal shapes.'

Remarks. Forms at present included in the genus without emendation include some in which sculptural elements are widely spaced. This is considered preferable to assigning them to genera distinguished only on the basis of density of ornament. Other species not included in the present work are among the less common spores in British coals and still require detailed study.

Comparison. In *Planisporites* (Knox) Potonié 1960 the ornament is smaller and more uniform. Distinctly triangular forms with apiculate ornament are referred to *Lophotriletes*.

Affinity. Unknown.

Apiculatisporis abditus (Loose) Potonié and Kremp 1955

Plate 7, figs. 14–17

1932 *Sporonites abditus* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 19, fig. 53.
1934 *Verrucosi-sporites abditus* Loose, p. 154.
1944 ? *Raistrickia abditus* (Loose); Schopf, Wilson, and Bentall, p. 55.
1950 *Verrucoso-sporites abditus* (Loose); Knox, p. 317.
1955 *Apiculatisporites abditus* (Loose); Potonié and Kremp, p. 78, pl. 14, figs. 237–9.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 237 after Loose. Preparation IV29, e_4 (m/or).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. Amb round to oval or rounded-triangular. Laesurae simple, straight, one-half to three-quarters of radius. Sculpture reduced or absent from proximal face. Coni with rounded apices, variable in size; mostly 5–10 μ in height, diameter at base more or less equal to height. Bases of coni almost touch. 20 to 30 project from margin.

Size in microns. (i) Holotype 78 × 55·5, Schulze. (ii) 50–70, tentative range based on six specimens isolated from British coals of varying age by fuming nitric acid.

Description. The ornament in any one individual spore comprises coni of varying size, the majority being relatively large. There is not usually space between the coni for further elements of similar size. Exine relatively thick.

Remarks. No satisfactory diagnosis has previously been published for this species.

Comparison. *A. pineatus* Hoffmeister, Staplin, and Malloy 1955 (p. 381, pl. 38, fig. 3) appears smaller (36–56 μ) but otherwise similar.

Occurrence. Infrequent, Assemblages V to XI (one occurrence in Assemblage XI, Somerset Coalfield); Westphalian A to D.

Apiculatisporis aculeatus (Ibrahim) emend.

Plate 7, figs. 12, 13

1933 *Apiculati-sporites aculeatus* Ibrahim, p. 23, pl. 6, fig. 57.
1944 *Punctati-sporites aculeatus* (Ibrahim); Schopf, Wilson, and Bentall, p. 30.
1950 *Spinoso-sporites aculeatus* (Ibrahim); Knox, p. 313.
1955 *Apiculatisporites aculeatus* (Ibrahim); Potonié and Kremp, p. 78, pl. 14, figs. 235, 236, 241.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 235 after Ibrahim. Preparation A27, d6 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from diagnosis and description in Potonié and Kremp 1955, p. 78). Amb circular, subcircular, or rounded-triangular. Laesurae simple and straight, about one-half of radius. Coni narrow and pointed, about 2·5 μ in height; basal diameter somewhat less, bases not in contact. Number of coni projecting from margin variable, mostly between 25 and 35.

Size in microns. (i) Holotype 53; Schulze and KOH. (ii) 50–60, Schulze (Potonié and Kr. 1955). (iii) 32(43)58, fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 32(42)50, fum. HNO_3; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England; Westphalian A.

Description. Precise length of laesurae (seldom seen) often difficult to determine due to ornament. Coni somewhat variable in size and shape; spaces between coni generally somewhat more than basal diameter. A single compression fold is often present. Exine thin.

Remarks. The form described overlaps the size ranges of *A. spinosus* (Loose) and *A. aculeatus* as given by Potonié and Kremp 1955, the modal value lying between the published ranges. Only one species has therefore been recognized in the present work and in assigning a name priority has been given to the first-named species. The brief diagnosis of *A. aculeatus* given by Potonié and Kremp (1955, p. 78) has been emended.

Comparison. *A. punctaornatus* Artüz 1957 (p. 245, pl. 3, fig. 15) differs mainly in its oval shape and in possessing longer laesurae. *A. spinosus* (Naumova) Potonié and Kremp is stated by Potonié and Kremp (1955, p. 78) not to be the same as Loose's species. From Luber and Waltz (1938, pl. 1, fig. 13) it appears that the ornament is more prominent and the apiculate elements more sharply pointed than in *A. aculeatus*. *Filicitriletes curvispinus* Luber 1955 (pl. 3, fig. 53), size 30 μ, resembles small forms of *A. aculeatus*.

Occurrence. Infrequent to frequent, Assemblages V to XI; above Assemblage IX, infrequent and only recorded from a few seams; Westphalian A to D.

Apiculatisporis irregularis (Alpern) comb. nov.

Plate 7, figs. 18, 19

1959 *Granasporites irregularis* Alpern, p. 139, pl. 1, figs. 7–9.
non 1955 *Apiculatisporites* (*Raistrickia*) *irregularis* (Kosanke); Potonié and Kremp, p. 77.

Holotype. Alpern 1959, pl. 1, fig. 8. Slide 509b, 38·5, 113·4.

Type locality. 1st Seam Morsbach, Lorraine Coalfield, France; Lower Stephanian.

Diagnosis (from description in Alpern 1959, p. 139). Spores round, oval, or more or less quadrangular. Exine partly covered by round grana 0·5–1·5 μ in diameter; grana openly spaced and irregularly distributed. No fissure apparent. Exine sometimes folded.

Size in microns. (i) Holotype 52 × 44; 50–75 (Alpern 1959), 45–65 (Alpern, pers. comm.), Schulze and KOH. (ii) 40(48)56, fum. HNO_3; Hafod Seam at 162 ft. 10 in., Margam No. 4 borehole, South Wales Coalfield; Westphalian C. (iii) 37(46)52, fum. HNO_3; Low Beamshaw Seam, Woolley Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Shape round, oval, or irregular, owing to folding on compression. Generally appears alete although some specimens show a triangular-shaped tear, which may indicate triradiate lines of weakness in the exine. Exine bears small coni, visible at margin, mostly less than 1·5 μ in height and breadth; not randomly distributed in most specimens but occurring in localized patches, sometimes leaving considerable areas of exine without ornament. Exine thin without infrasculpture. Compression folds common, often of major proportions, sometimes peripheral, but often randomly orientated. Tendency for exines without major folds to be ruptured.

Remarks. This species is transferred to *Apiculatisporis* since there is evidence that it is trilete. One specimen has been seen with open sutures and it is not uncommon to find specimens with a triangular-shaped tear in the exine. The spores from British coals referred to *A. irregularis* are in general smaller than those described by Alpern but this may in part be due to the different methods of maceration used. Specimens from the Lorraine Coalfield have been examined by the authors.

Composition. Dybová and Jachowicz (1957*a*, pl. XI, figs. 1, 2) illustrate two specimens of *Granisporites medius*, which apart from their larger size are similar in appearance to the above form. *G. medius* is stated to possess a tetrad mark.

Occurrence. Infrequent or frequent, Assemblages V to XI; occasionally common in Assemblages VI to IX; Westphalian A to D.

Apiculatisporis latigranifer (Loose) Potonié and Kremp 1955

1932 *Sporonites latigranifer* Loose in Potonié, Ibrahim, and Loose, p. 452, pl. 19, fig. 54.
1934 *Granulati-sporites latigranifer* Loose, p. 147.
1944 *Punctati-sporites latigranifer* (Loose); Schopf, Wilson, and Bentall, p. 31.
1950 *Spinoso-sporites latigranifer* (Loose); Knox, p. 314.
1955 *Apiculatisporites latigranifer* (Loose); Potonié and Kremp, p. 79, pl. 14, figs. 244, 245.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 244 after Loose. Preparation III36, b_1 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 79; translation). '. . . laesurae greater than one-half radius. Coni somewhat openly distributed.'

Size in microns. (i) Holotype 78, Schulze. (ii) 55–90, Schulze (Potonié and Kr. 1955).

Apiculatisporis cf. *latigranifer* (Loose) Potonié and Kremp 1955

Plate 7, figs. 20, 21

Description. Amb circular. Laesurae simple, straight, sometimes of unequal length, largest dimension between two-thirds and three-quarters of radius. Coni slightly variable in shape and size, bases usually equal to, or less than, heights which are generally between 1 μ and 2·5 μ. Coni well separated; number projecting from margin 15 to 25. Long portions of amb may be without ornament due to the localized distribution of coni. Generally without folds. Exine about 1·5–2 μ thick.

Size. British specimens fall within the limits given by Potonié and Kremp for *A. latigranifer*.

Remarks. Differs from type in possessing rather more prominent ornament. Loose originally designated the ornament as granulate to spinose and Potonié and Kremp 1955 (p. 79) state that the ornament consists of broad-based cones approximately 1 μ in height.

Comparison. In *A*. cf. *setulosus* (Kosanke) Potonié and Kremp 1955 (p. 79, pl. 14, figs. 246–8) the coni are of similar size but are more evenly and densely distributed; they number 40 to 50 at the margin.

Occurrence. Infrequent and not recorded from all seams, Assemblages V to XI; Westphalian A to D.

Apiculatisporis spinososaetosus (Loose) emend.

Plate 7, figs. 22, 23

1932 *Sporonites spinososaetosus* Loose in Potonié, Ibrahim, and Loose, p. 452, pl. 19, fig. 55.
1933 *Apiculati-sporites spinososaetosus* (Loose); Ibrahim, p. 24.
1944 *Raistrickia spinososaetosus* (Loose); Schopf, Wilson, and Bentall, p. 56.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 249; after Loose. Preparation I2, h.

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 80). Amb rounded-triangular. Laesurae one-half to two-thirds of radius. Ornament of loosely packed coni and bacula having heights more or less the same as basal diameters and generally less than 5 μ. Between 15 and 30 elements project from margin.

Size in microns. (i) Holotype 74, Schulze. (ii) 50–80, Schulze (Potonié and Kr. 1955). (iii) 38(50)60, fum. HNO_3; Dunsil Seam, Frickley Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb generally rounded-triangular, but sometimes circular. Laesurae frequently of unequal length, although their course is often partly obscured by ornament; laesurae (not always apparent) occasionally reach the margin of the spore. Ornament variable in size and shape, height generally between 2 and 3 μ; basal diameter sometimes exceeds height. In any one individual, ornament may comprise short squat processes and pointed coni; in profile the former often show converging sides and more or less truncated apices, which are often partate; the coni are sometimes falcate. In plan view all projections have a very irregular shape but their bases do not touch. Exine 2–3 μ thick, rarely folded.

Remarks. The diagnosis of Potonié and Kremp is emended with respect to the shape and the number of elements projecting from the margin of the spore and is in agreement with Loose's figure (1932, pl. 19, fig. 55). The laesurae, in general, are shorter than indicated by these authors.

Comparison. As pointed out by Potonié and Kremp, *A. irregularis* (Kosanke 1950, pl. 11, fig. 5) Potonié and Kremp 1955 is morphologically similar, but the ornament is more prominent than in *A. spinososaetosus*. Differs from other forms of *Apiculatisporis* described here in possessing ornament of coni and bacula.

Occurrence. Infrequent, or very occasionally frequent, Assemblages V to X; Westphalian A to C.

Apiculatisporis variocorneus Sullivan 1964

Plate 7, figs. 24, 25

Holotype. Sullivan 1964, pl. 58, fig. 4. Preparation SMUD/1.

Type locality. Edgehills Coal, Drybrook Sandstone, Forest of Dean Coalfield, England; ?Westphalian A.

Diagnosis (Sullivan 1964, p. 363). '. . . amb irregularly circular to oval; exine ornamented with cones and spines which range from 0·5 to 5·5 μ in height; ornament variable in size, shape and density even on individual specimens, usually absent from intertectal areas.'

Size in microns. (i) 40(60)78, HF and 2% KOH (Sullivan 1964). (ii) 52(60)77, fum. HNO_3; Belper Lawn Seam at 606 ft. 0 in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England; Westphalian A. (iii) 45(60)77, fum. HNO_3; seam at 455 ft. 2 in., Denby (Drury Lowe) borehole, Nottinghamshire Coalfield, England; Westphalian A. (iv) 41(59)80, fum. HNO_3; Ganister Clay Seam at 214 ft. 10 in., Keverstone borehole (47 NE. 17), Durham Coalfield, England; Westphalian A.

Description. Laesurae simple, one-half to two-thirds radius, only occasionally visible. The proportions of coni and spinae vary in different specimens. Proximal ornament usually less than 2·5 μ in height. The distal ornament may attain a height of 5 μ, or more, with similar basal dimensions. The projecting elements are closely spaced but their bases are discrete; about 35 to 45, or occasionally more, project from margin. Exine 1·5–2·5 μ thick, sometimes shows one or more major compression folds.

Comparison. There is a superficial resemblance to *A.* cf. *latigranifer* (Loose) Potonié and Kremp, *A.* cf. *setulosus* (Kosanke) Potonié and Kremp, and *Apiculatasporites spinulistratus* (Loose) Ibrahim 1933, but none of these species show the uneven development of ornament which characterizes *A. variocorneus*. *A. subspinosus* Artüz 1957 (p. 245, pl. 3, fig. 16) is of similar size (63–73 μ), but thinner to judge by the compression folds which led Artüz to compare her form with *Calamospora*-type spores. *Cycadofilicitriletes testiculatus* Luber 1955 (pl. 2, figs. 35–38) is of similar size and also possesses variable ornament.

Occurrence. Occasionally frequent, Assemblage V; infrequent, Assemblages VI and VII and in South Wales and Bristol and Somerset Coalfields at base of Assemblage VIII; Namurian C to Lower Westphalian B.

Genus PLANISPORITES (Knox) Potonié 1960

Type species. P. granifer (Ibrahim) Knox 1950.

Diagnosis (Potonié and Kremp 1954, p. 129, emend. Potonié 1960, p. 39; translation). 'Trilete isospores and microspores, roughly triangular at equator. Exine completely covered by small coni of approximately equal size, although there are slight differences in these sizes as between the proximal and the distal sides. The coni are roughly arranged in rows and their bases, where they are broadest, only just touch and tend to be deformed polygonally. Although they are sometimes round in plan view, the coni should not be considered as grana since their apices are not flat or slightly rounded. They are very small and short coni (at most with a height/breadth ratio of about 2:1) and they may be moderately pointed, or truncated. Their size is not much greater than that of grana and less than that of the ornament found in *Apiculatisporis*.'

Comparison. Planisporites differs from *Apiculatasporites* only in the triangular shape of the spores. *Apiculatisporis* and other genera with similar ornament have larger coni which, moreover, differ from those found in *Planisporites* by reason of their greater variety of shape and size. In general, the ornamentation of *Planisporites* is very uniform.

Affinity. Unknown.

Planisporites granifer (Ibrahim) Knox 1950

Plate 8, figs. 1–3

1933 *Granulati-sporites granifer* Ibrahim, p. 22, pl. 8, fig. 72.
1944 *Punctati-sporites granifer* (Ibrahim); Schopf, Wilson, and Bentall, p. 31.
1950 *Planisporites granifer* (Ibrahim); Knox, p. 315.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 207 after Ibrahim. Preparation B29, e5 (o).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 71; translation). '. . . amb tending to a triangular shape. Laesurae two-thirds radius.'

Size in microns. (i) Holotype 96, Schulze and KOH. (ii) 85–100, Schulze (Potonié and Kr. 1955). (iii) A small number of specimens referred to this species from British coals, treated with fuming nitric acid, are smaller with a minimum size of 60 μ.

Description. Amb triangular with broad rounded angles and straight to convex sides. Margin scarcely modified by ornament. Laesurae simple, two-thirds radius. Exine covered by grana, and low broad-based verrucae, with rounded apices, mostly 2–4 μ in basal dimensions and 1 μ in height; larger elements sometimes occur; spaces between projecting elements equal to or somewhat greater than their basal diameter. Exine about 2 μ thick; compression folds may occur.

Remarks. The ornament of the holotype, as seen at the margin (see also Ibrahim 1933, pl. 8, fig. 72), appears conate, rather than verrucate, as in the spores referred to this species from British coals.

Occurrence. Infrequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

EXPLANATION OF PLATE 8

All figures $\times$ 500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Planisporites granifer* (Ibrahim) Knox 1950. 1, slide 94, 42·4 114·3. 2, slide 95, 21·3 105·6. 3, slide 96, 23·1 100·6.

Figs. 4–6. *Apiculatasporites spinulistratus* (Loose) Ibrahim 1933. 4, slide 97, 50·5 101·5. 5, slide 98, 46·0 114·4. 6, slide 99, 44·9 108·6.

Figs. 7, 8. *Acanthotriletes castanea* Butterworth and Williams 1958. 7, Holotype; slide T42/1. 8, Isotype; slide T42/3.

Figs. 9, 10. *A. echinatus* (Knox) Potonié and Kremp 1955. 9, Neotype, $\times$ 1,000; slide T86/1, 30·4 117·2. 10, slide T86/1, 30·8 109·7.

Figs. 11, 12. *A. falcatus* (Knox) Potonié and Kremp 1955. 11, Neotype; slide T41/1. 12, Isotype; slide T41/2.

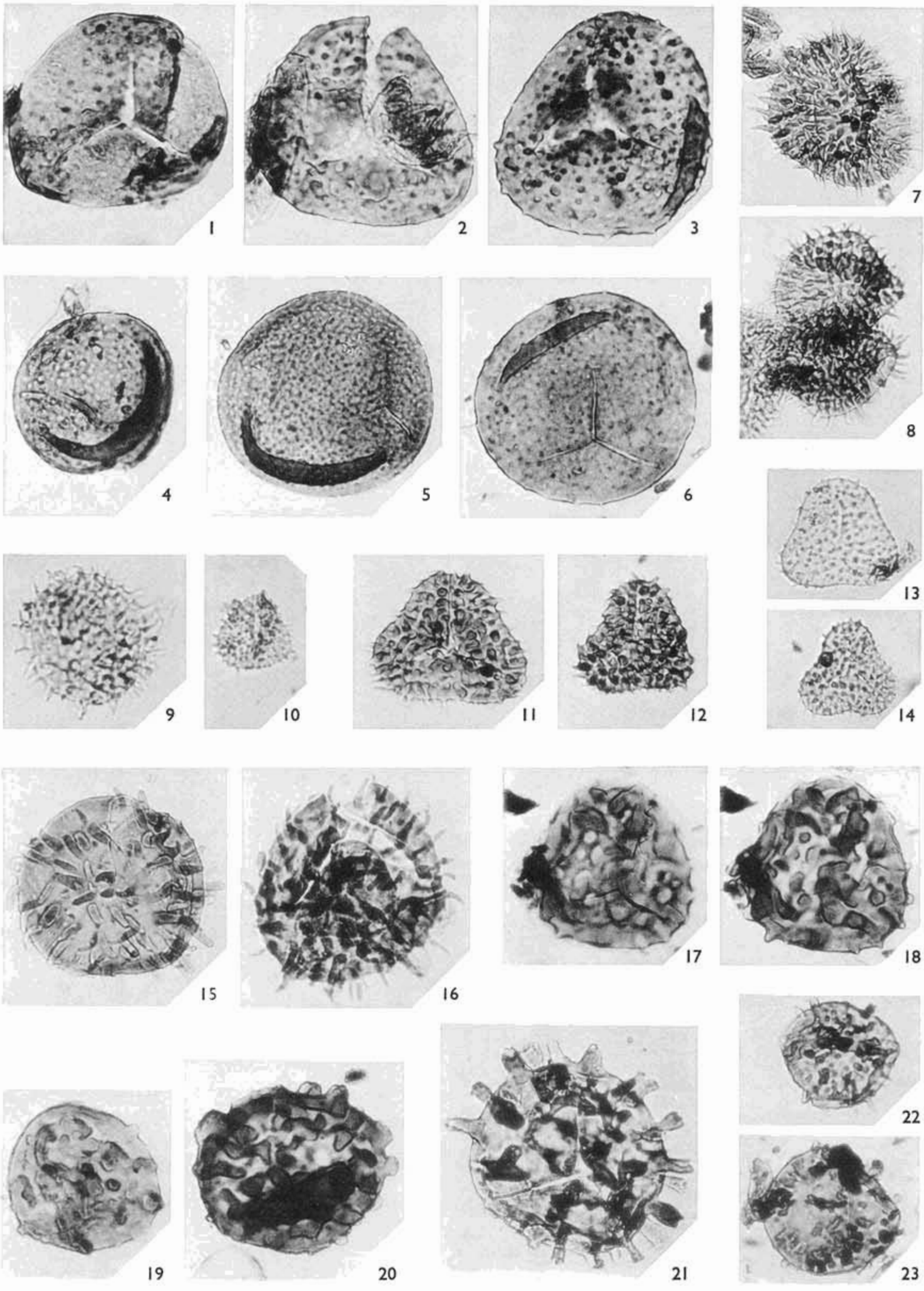
Figs. 13, 14. *A. triquetrus* sp. nov. 13, Holotype; slide T92/1, 29·7 107·9. 14, Isotype; T92/2, 29·0 100·3.

Figs. 15, 16. *Raistrickia aculeata* Kosanke 1950. 15, slide 100, 37·1 110·8. 16, slide 101, 39·3 109·6.

Figs. 17–20. *R. fulva* Artüz 1957. 17, 18, proximal and distal surfaces respectively; slide 102, 40·6 108·9. 19, slide 102, 49·7 117·8. 20, distal surface; slide 102, 50·2 118·3.

Fig. 21. *R. saetosa* (Loose) Schopf, Wilson, and Bentall 1944. Slide 103, 49·6 114·9.

Figs. 22, 23. *R.* cf. *superba* (Ibrahim) Schopf, Wilson, and Bentall 1944. 22, slide 104, 36·2 114·5. 23, slide 104, 46·0 107·9.



SMITH and BUTTERWORTH, British Carboniferous miospores

Genus APICULATASPORITES (Ibrahim) emend.

Type species. A. spinulistratus (Loose) Ibrahim 1933.

Diagnosis. Radial, trilete isospores or microspores. Amb circular. Exine covered by small coni of approximately the same size. The size of ornament is not much greater than that of grana, and less than that of the ornament of *Apiculatisporis*.

Remarks. Potonié excludes *A. spinulistratus* from *Planisporites* which is reserved for triangular spores (Potonié 1960, p. 39) and has re-established the species as the type of *Apiculatasporites*. In creating this genus Ibrahim considered the spores to be alete although the holotype of *A. spinulistratus* has a distinct trilete mark. The genus has accordingly been emended.

Affinity. ? Filicales. Spores of *Crossotheca hughesiana* Kidston are possibly of this type (after Potonié 1962, p. 125).

Apiculatasporites spinulistratus (Loose) Ibrahim 1933

Plate 8, figs. 4–6

1932 *Sporonites spinulistratus* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 47.
1933 *Apiculata-sporites spinulistratus* (Loose), Ibrahim, p. 37.
1934 *Apiculati-sporites spinulistratus* Loose, p. 153.
1934 *Apiculati-sporites globosus* Loose, p. 152, pl. 7, fig. 14.
1944 *Punctati-sporites spinulistratus* (Loose); Schopf, Wilson, and Bentall, p. 31.
1950 *Spinoso-sporites spinulistratus* (Loose); Knox, p. 314.
1955 *Planisporites spinulistratus* (Loose); Potonié and Kremp, p. 71, pl. 14, figs. 214–19.
1960 *Apiculatasporites spinulistratus* (Loose) Ibrahim; Potonié, p. 38.

Holotype. Potonié and Kremp 1955, pl. 14, fig. 214 after Loose 1932. Preparation IV9, d_4 (m/or).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 71; translation). '. . . amb circular. Laesurae about two-thirds radius. Over 90 coni on the equatorial margin.'

Size in microns. (i) Holotype 53, Schulze. (ii) 45–75, Schulze (Potonié and Kr. 1955). (iii) 32(70–90)160, fum. HNO_3 (Horst 1955). (iv) 38(57)87, fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb generally circular, rarely rounded-triangular. Laesurae simple, often of unequal length, with one or more laesurae curved; maximum length, two-thirds to full radius length; range 14–30 μ (average 20 μ). Height of coni generally about 1 μ but may reach about 2·5 μ; diameter of base generally equals or exceeds height; on any individual spore the ornament is more or less uniform in size. Density of ornament also varies between individuals; the space between coni may equal, or somewhat exceed, their base dimensions. Exine 1·5 μ thick, often with single compression fold.

Remarks. There is a fairly wide variation in size and character of ornament in this species. This is illustrated by Potonié and Kremp (1955, pl. 14, figs. 214–19). In general it appears that the smaller forms, similar to the holotype, have a somewhat coarser ornament and a thicker exine than the larger forms.

In his study of the size variation in the species Bharadwaj (1957*a*, p. 86) considered that the range given by Potonié and Kremp was too large and accordingly restricted the size to 40–54 μ. The larger forms (Bharadwaj 1957*a*, pl. 23, figs. 13, 14) were referred to *P. microtuberosus* Loose, although in 1955 Bharadwaj proposed that this species should be referred to *Verrucosisporites*. *V. microtuberosus* is in fact quite different from the form to which he applied this name. Studies of specimens from British coals have shown that the histogram of size distribution is not significantly bimodal and provides no evidence for splitting the species. The species referred to *Spinoso-sporites spinulistratus* in Balme and Butterworth 1952 is *Crassispora kosankei* (Potonié and Kremp) Bharadwaj 1957 emend.

Comparison. *A. spinulistratus* differs from *C. kosankei*, which has a similar type of ornament, in the presence of a definite trilete mark, the absence of crassitudo, and in possessing a thicker exine. A specimen figured by Wilson and Hoffmeister (1956, pl. 1, fig. 8) as *Punctati-sporites latigranifer* is probably *A. spinulistratus*. *Punctatisporites nahannensis* Hacquebard and Barss 1957 (p. 14, pl. 2, fig. 6; size 38–52 μ) appears similar to small forms of *A. spinulistratus*.

Occurrence. Infrequent or sometimes frequent, Assemblages V to XI; Westphalian A to D.

Genus ACANTHOTRILETES (Naumova) Potonié and Kremp 1954

Type species. *A. ciliatus* (Knox) Potonié and Kremp.

Diagnosis (Potonié and Kremp 1954, p. 133; translation). 'Trilete isospores or microspores. Exine ornamented with spinae between which there is little, or no, space. Scarcely any blunting of the gradually tapered spinae, the length of which is more than twice their diameter.'

Comparison. Potonié and Kremp (1954) state that in most species the length of the spinae clearly exceeds the above ratio so that the genus may be distinguished from *Lophotriletes* and *Apiculatisporis* by the greater length and by the tapering of the generally strongly pointed ornamental elements.

Affinity. Unknown.

Acanthotriletes castanea Butterworth and Williams 1958

Plate 8, figs. 7, 8

1948 Knox, p. 158, fig. 18.
1958 *Acanthotriletes castanea* Butterworth and Williams, p. 365, pl. 1, fig. 35.

Holotype. Plate 8, fig. 7. Preparation T42/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Garibaldi Ironstone Seam at 1,058 ft. 3 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis and description in Butterworth and Williams 1958, p. 365). Outline circular or broadly rounded-triangular. Laesurae simple, not always visible, never prominent, extending for two-thirds to three-quarters of spore radius. Ornament of spinae having basal diameter 2 μ or less and length up to 8 μ tapering uniformly to a sharp point, generally slightly bent and occasionally sharply incurved. Distance between spinae about 2–5 μ; 30 to 50 occur round the margin. Exine thin.

Size in microns. Holotype 46 × 40; 31–47 (10 specimens), Schulze and 5% KOH (Butterworth and Will. 1958).

Remarks. Knox (1948) figured this spore but did not name it.

Occurrence. Infrequent, Assemblages I to III; Viséan and Namurian A.

Acanthotriletes echinatus (Knox) Potonié and Kremp 1955

Plate 8, figs. 9, 10

1950 *Spinoso-sporites echinatus* Knox, p. 313, pl. 17, fig. 208.
1955 *Acanthotriletes echinatus* (Knox); Potonié and Kremp, p. 84.

Neotype. No holotype was cited by Knox (1950) and the authors have therefore selected a neotype (T86/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Splint Seam, Cadzow Colliery, Central Coalfield, Scotland; Westphalian B.

Diagnosis (from Knox 1950, p. 313). Outline circular. Triradiate mark one-third of spore radius. Ornament of spinae 5–8 μ long, 5 μ apart.

Size in microns. (i) Neotype 26, fum. HNO_3. (ii) 25, Schulze (Knox 1950). (iii) 12(20)28, fum. HNO_3; type locality.

Description. Amb circular, oval, or rounded-triangular. Laesurae indistinct, up to two-thirds of spore radius. Ornament of fine, tapering spinae, less than 1 μ in diameter, 2–5 μ long, occasionally falcate; 25 to 35 project round the equatorial margin. Exine very thin, folding infrequent.

Comparison. This is the smallest species of *Acanthotriletes* recorded.

Occurrence. Infrequent, Assemblages V to IX; Namurian to Westphalian C.

Acanthotriletes falcatus (Knox) Potonié and Kremp 1955

Plate 8, figs. 11, 12

1948 18K, Knox, p. 157, fig. 15.
1950 *Spinoso-sporites falcatus* Knox, p. 313, pl. 17, fig. 205.
1955 *Acanthotriletes falcatus* (Knox); Potonié and Kremp, p. 84.
1958 *Acanthotriletes falcatus* (Knox) Potonié and Kremp; Butterworth and Williams, p. 366, pl. 1, figs. 37, 38.

Neotype. Plate 8, fig. 11. Preparation T41/1 in collection of Coal Survey Laboratory, Sheffield. [This specimen was wrongly designated as the holotype in Butterworth and Williams (1958).]

Type locality. Possil Main Seam at 600 ft. 2 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (Knox 1950, p. 313). 'Triangular, ... Triradiate mark extending to the margin. Surface with spinose processes, 5–7 μ long, straight or curved and spaced 3–5 μ apart.'

Size in microns. (i) Neotype 42, fum. HNO_3. (ii) 55, Schulze (Knox 1950). (iii) 29(36)47, fum. HNO_3 (Butterworth and Will. 1958).

Description. Amb triangular, angles broadly rounded, sides concave. Laesurae not always visible, length two-thirds to three-quarters of spore radius, occasionally reaching equator. Ornament of spinae 4 μ wide at base, tapering sharply, or occasionally very sharply, from about half-way along their length; these are up to 7 μ long, 3–5 μ apart, and frequently incurved; about 40 are apparent round the equatorial margin. Exine thin, folding infrequent.

Comparison. Acanthotriletes falcatus is distinguished from *A. castanea* by the triangular outline and the abruptly tapering, incurved spinae.

Occurrence. Infrequent, Assemblages II and III; Viséan and Namurian A.

Acanthotriletes triquetrus sp. nov.

Plate 8, figs. 13, 14

Holotype. Plate 8, fig. 13. Preparation T92/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 1,413 ft. 6 in., Darkslade borehole, Cannock Chase Coalfield, England; Westphalian C.

Diagnosis. Amb triangular, angles rounded, sides concave. Laesurae distinct, simple, frequently open; length one-half to two-thirds of spore radius. Ornament of hair-like spinae, approximately 2 μ long, slightly tapering, or truncate 2–3 μ apart. Exine very thin, occasionally folded.

Size in microns. Holotype 37; 19(26)37, Schulze; type locality.

Comparison. This species is larger than *Acanthotriletes echinatus* and consistently triangular. It also has shorter spinae. *A. microspinosus* (Ibrahim) Potonié and Kremp 1955 (p. 84, pl. 14, fig. 258) is larger and has more numerous and longer spinae.

Occurrence. Infrequent, Assemblages IX and X; Upper Westphalian B and Westphalian C.

Subinfraturma BACULATI Dybová and Jachowicz 1957*a*

Genus RAISTRICKIA (Schopf, Wilson, and Bentall) Potonié and Kremp 1954

Type species. R. grovensis Schopf in Schopf, Wilson, and Bentall 1944.

Diagnosis (Potonié and Kremp 1955, p. 85; translation). Trilete isospores and ? microspores. Exine largely covered with bacula, that is roughly cylindrical ornamentation. In some cases fairly distinct cone-shaped elements appear interspersed with bacula. The individual bacula are thinner, or barely thicker, at the base than over their entire length; alternatively, they show marked broadening at the root only. At their top ends the bacula are generally unpointed, only slightly pointed, or rounded; they are in fact often abruptly truncated. This truncation is apparently partly a secondary phenomenon, as seems to be borne out by the irregular fracture, sometimes by the raggedness at the ends, and frequently by a distinct variation in bacula length. The bacula vary appreciably in thickness, by as much as a factor of two. Frequently the bacula tend to split at their ends into two or more papillae.

Remarks. There is no reference to shape in the above diagnosis. Among the forms which are included in the genus by Potonié and Kremp 1955 are some in which the outline is circular and others in which it is rounded-triangular. In 1956 Potonié created the genus *Neoraistrickia* for rounded-triangular baculate spores, but the genus is narrowly circumscribed and the diagnosis excludes forms with closely spaced and variable ornament of coni and bacula. The rounded-triangular forms with this type of ornament are therefore retained in *Raistrickia*.

Affinity. Filices, Radforth 1938, 1939; Mamay 1950; Remy and Remy 1955*a*.

Raistrickia aculeata Kosanke 1950

Plate 8, figs. 15, 16

Holotype. Kosanke 1950, pl. 10, fig. 9. Preparation 490–A, slide 5.

Type locality. McCleary's Bluff Coal, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 46). Laesurae simple, about two-thirds radius, inconspicuous. Ornament of numerous, long, and slightly tapering, blunt spines, 7–10 μ in length and 2–2·5 μ in breadth.

Size in microns. (i) Holotype 69 × 65, 62–74, Schulze and 10% KOH (Kosanke 1950). (ii) 40(51)60 (23 specimens) fum. HNO_3; seam at 3,199 ft., Upton borehole, Oxfordshire Coalfield, England; Westphalian D.

Description. Amb circular to rounded-triangular. Laesurae not always visible. The processes almost cover the entire exine; they taper gently from the base, or about the mid-point of the length; apices pointed, rounded, or truncate, not usually apiculate. Exine thin and frequently with minor folds.

Comparison. *R. aculeolata* Wilson and Kosanke 1944 (p. 331, pl. 1, fig. 5) possesses broader processes, which are more variable in form and slightly apiculate at their tips. *R. crinita* Kosanke 1950 (p. 46, pl. 11, fig. 7) also differs from *R. aculeata* mainly in the possession of broader processes.

Occurrence. Infrequent, Assemblage XI; Westphalian D.

Raistrickia fulva Artüz 1957

Plate 8, figs. 17–20

Holotype. Artüz 1957, pl. 3, fig. 19. Preparation 1I15, 6d.

Type locality. Sülü Seam, Zonguldak Coalfield, Turkey; Westphalian A.

Diagnosis (from description in Artüz 1957, p. 246). Rounded-triangular. Laesurae reach to margin. Exine covered by 4–5 μ, finger-shaped warts which are distinctly recognizable at the amb.

Size in microns. (i) Holotype 45, 40–55, maceration method not stated (Artüz 1957). (ii) 39(51)66, fum. HNO_3; Ganister Clay Seam at 2,095 ft. 11 in., No. 1 Off-shore borehole, Durham Coalfield, England; Westphalian A. (iii) 39(49)62, fum. HNO_3; Belper Lawn Seam at 606 ft. 0 in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England; Westphalian A. (iv) 38(52)69, fum. HNO_3; Woodfield Seam at 1,468 ft. 10 in., Caldwell Ashley House borehole, South Derbyshire Coalfield, England; Westphalian A.

Description. Amb rounded-triangular. Laesurae simple, two-thirds to three-quarters of radius; full extent of laesurae often obscured by ornament. Ornament predominantly of bacula, but also comprises coni and verrucae. Bacula rarely exceed 3 μ in height; basal diameter up to 10 μ in exceptional cases; tips truncate and often apiculate. Density of ornament variable; generally 15 to 20 processes project from margin. Exine between processes laevigate. Excluding ornament, exine is up to 5 μ in thickness and generally without folds.

Remarks. A number of species have been described which appear morphologically somewhat similar to these British specimens. Of these *R. fulva* has been recorded from coal of comparable age from Turkey and Artüz has confirmed that the British material is her species.

Comparison. *Raistrickia irregularis* Kosanke 1950 (p. 47, pl. 11, fig. 5) is larger although allowance should be made for size differences due to maceration methods. In *R. macra* Bharadwaj 1957*a* (p. 89, pl. 23, fig. 23) the bacula are stated to be closely spaced so that the intervening spaces give the impression of a negative reticulum. *Filicitriletes phaleratus* Luber 1955 (pl. 3, fig. 76) is another comparable species. The holotype of *R. rubida* Kosanke 1950 (p. 48, pl. 12, fig. 1) has been examined by the authors. The ornament was found to comprise coni and verrucae but bacula with apiculate tips were lacking. There is a superficial resemblance to *Apiculatisporis spinososaetosus* Loose and *A. verrucifer* (Kosanke) Potonié and Kremp (Kosanke p. 17, pl. 2, fig. 6) but the ornament in *R. fulva* is generally of a much coarser grade.

Occurrence. Infrequent, or occasionally frequent, Assemblages V to VII; infrequent, Assemblage VIII; two records from Assemblage IX (Durham and Yorkshire Coalfields); Westphalian A to C.

Raistrickia saetosa (Loose) Schopf, Wilson, and Bentall 1944

Plate 8, fig. 21

1932 *Sporonites saetosus* Loose in Potonié, Ibrahim, and Loose, p. 452, pl. 19, fig. 56.
1933 *Setosi-sporites saetosus* (Loose); Ibrahim, p. 26.
1944 *Raistrickia saetosus* (Loose); Schopf, Wilson, and Bentall, p. 56.

Holotype. Potonié and Kremp 1955, pl. 15, fig. 264 after Loose 1932. Preparation I11, c.

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 87; translation). '. . . laesurae two-thirds radius; bacula up to 14 μ in length, varying in size, ends partly cleaved.'

Size in microns. (i) Holotype 78, Schulze. (ii) 60–90, Schulze (Potonié and Kr. 1955). (iii) 41(50)62 (20 specimens) fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb round to oval. Laesurae simple, greater than one-half radius; usually not apparent or partly concealed by bacula. Exine mostly covered by bacula whose length depends on spore size but may reach 14 μ in large specimens. Bases and tips of bacula sometimes expanded; maximum width seldom exceeds 5 μ; apices usually truncate and apiculate but may be rounded. The majority of the bacula are of the same size and form on any one individual. Surface of exine and bacula laevigate. Exine moderately thick; major compression folds usually absent.

Remarks. Bharadwaj 1957*a* (p. 89) states that the bacula on the proximal side are reduced in size and density but this observation has proved difficult to confirm.

Comparison. *R. crocea* Kosanke 1950 (p. 47, pl. 11, fig. 6) is probably a synonym of *R. saetosa*.

Occurrence. Infrequent or occasionally frequent, Assemblages V to XI; Westphalian A to D.

Raistrickia superba (Ibrahim) Schopf, Wilson, and Bentall 1944

1933 *Setosi-sporites superbus* Ibrahim, p. 27, pl. 5, fig. 42.
1944 *Raistrickia superbus* (Ibrahim); Schopf, Wilson, and Bentall, p. 56.

Holotype. Potonié and Kremp 1955, pl. 15, fig. 262 after Ibrahim. Preparation B25, a5 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 88; translation). '. . . laesurae reach nearly to equator. Bacula 4–8 μ long, in part fairly thick; some of them conical in shape.'

Size in microns. Holotype 54, Schulze and KOH. 40–60, Schulze (Potonié and Kr. 1955).

Raistrickia cf. *superba* (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 8, figs. 22, 23

Description. Amb round to oval. Laesurae simple, two-thirds to nearly length of radius, sometimes obscured by ornament. Bacula 5–10 μ in height and 2–4 μ in breadth; thinner forms predominate; somewhat irregularly distributed. Density of bacula very variable, in some specimens they may be separated by as much as 20 μ. In profile the maximum width of the bacula occurs about the mid-point or near the top, or they may be of uniform width; tips rounded or truncate and slightly apiculate. Exine thin to moderately thick; narrow marginal folds usually apparent.

Size in microns. 37(47)55 (13 specimens) fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B.

Remarks. In view of the considerable variation in the ornament of certain forms of *Raistrickia* in British coals the descriptions and illustrations of *R. fibrata* and *R. superba* given by Potonié and Kremp 1955 are not an adequate basis for the morphological separation of species. Bharadwaj 1957*a* (p. 88) illustrates the sculptural elements of species of *Raistrickia*, but as regards *R. fibrata* his illustration is at variance with the measurements given by Potonié and Kremp 1955 (p. 87). For *R. fibrata* Bharadwaj depicts a broad, squat baculum with height and breadth approximately equal, whereas from the measurements given by Potonié and Kremp the height-to-breadth ratio is about 2:1. To some extent the spores mentioned above include characters that have been described for *R. fibrata* and *R. superba* by Potonié and Kremp. They agree with

R. superba in possessing various types of ornament, including cone-shaped (tapering) bacula, which are locally distributed, but differ in possessing a relatively thin exine. Potonié and Kremp refer to the colour as distinctly brown, which implies a relatively thick exine. The spore figured as *R.* cf. *superba* by Bharadwaj 1957*b* (p. 114, pl. 23, fig. 31) is typical of many of the specimens in British coals.

Comparison. Compared with *R. saetosa* the bacula are shorter, generally thinner, and more varied. A small proportion of typical *R. saetosa*-type bacula may occur on some individuals. The exine, however, is thinner and the triradiate mark is more often seen. The number of bacula projecting from the margin is also less.

Occurrence. Infrequent and not recorded from all seams, Assemblages VI to X; Upper Westphalian A to Westphalian C.

Infraturma MURORNATI Potonié and Kremp 1954

Genus CONVOLUTISPORA Hoffmeister, Staplin, and Malloy 1955

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

Diagnosis (description in Hoffmeister, Staplin, and Malloy 1955, p. 384). 'Spores radial, trilete; circular to subcircular, probable original spherical shape indicated by lack of orientation preference; ornamentation closely packed overlapping anastomosing vermiculate or obervermiculate ridge-like processes, often causing a convoluted or coarsely reticulate-punctate appearance; trilete rays short, usually simple, but may have distinct lips, often obscured by the overlapping ridges; spore coat thick, lacking conspicuous folding, translucent; diameter 40–150 microns.'

Remarks. The character of the ornament within the genus is variable. It may comprise rugulae with a proportion of isolated verrucae, anastomosing verrucae, or muri. Species with long laesurae are at present included within the genus.

Affinity. The dispersed spores of *Senftenbergia pennaeformis* Brongniart, figured by Radforth (1938, pl. 1, figs. 2, 6, and 7) would appear to belong to *Convolutispora* rather than to *Camptotriletes* Naumova as suggested by Potonié (1962, p. 106.)

Convolutispora ampla Hoffmeister, Staplin, and Malloy 1955

Plate 9, figs. 1, 2

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 38, fig. 12. Preparation 3, ser. 19,280.

Type locality. Outcrop area (TCO–143), Christian County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 384). Amb circular to subcircular. Laesurae obscure, two-thirds of radius. Ornamentation crowded, vermiculate, anastomosing ridges; depressed areas vary from small lacunae to irregularly radiating depressions. Ridges 1–2·8 μ wide, 1–2·8 μ high. Exine relatively thick.

Size in microns. (i) Holotype 64 × 62; 40–75, HF (Hoffmeister, Stap., and Mall. 1955). (ii) 52(74)89, fum. HNO_3; seam at 1,801 ft. 5 in., Queenslie Bridge borehole, Central Coalfield, Scotland; Namurian A. 52(67)79 (21 specimens) fum. HNO_3; seam at 658 ft. 0 in., Darnley No. 3 borehole, Central Coalfield, Scotland; Namurian A. (iii) 59(85)102 (15 specimens) Schulze and KOH; Calpatie Seam at 2851 ft. 3 in., Monkton House borehole, Lothians Coalfield, Scotland; Namurian A.

Description. Margin notched. Laesurae simple, straight, except in off-centre compression, extremities often indistinct, one-half to three-quarters or more of radius, often obscure. Proximal and distal ornament of closely spaced rugulae and verrucae with more or less parallel, or converging sides and well-rounded apices; basal width of ornament at margin 2–4 μ; ornament projects 1–2 μ from margin; in plan view it comprises a mosaic pattern of circular, polygonal, or irregularly rounded, closely fitting shapes, seldom exceeding 6 μ in length; vermiculi often less than 1 μ in width, although spaces between elevations may attain a maximum of about 3 μ and form a continuous network; generally between 45 and 60 elevations project at margin. Exine, including ornament, 2–3 μ thick; narrow compression folds sometimes occur.

Remarks. The specimens examined from British coals are, in general, larger than those described by Hoffmeister, Staplin, and Malloy.

Comparison. According to Love (1960, p. 116, pl. 1, fig. 7), *C. finis* Love (85–110 μ) differs from *C. ampla* in possessing a finer, lower, more regular and closely packed ornament. It is also larger and possesses a thicker exine.

Occurrence. Infrequent, Assemblages III and IV; Namurian. Also recorded from Scotland from coals and other rocks of Viséan age by Love (1960).

Convolutispora cerebra Butterworth and Williams 1958

Plate 9, figs. 5, 6

1942 2K Knox, p. 3, text-fig. 3.

Lectotype. Plate 9, fig. 5. Preparation T48/3 in collection of Coal Survey Laboratory, Sheffield (the holotype is missing).

Type locality. Shale Seam at 663 ft. 6 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (restated from diagnosis in Butterworth and Williams 1958, p. 371). Amb circular to subcircular, margin smooth to undulating, incisions few or none. Laesurae simple, commissures straight, or curved, in off-centre compression, length three-quarters of, or approximately equal to, internal radius. Proximal and distal ornament of closely spaced low sinuose and branching muri of variable width, separated by vermiculi and

EXPLANATION OF PLATE 9

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Convolutispora ampla* Hoffmeister, Staplin, and Malloy 1955. 1, slide 105, 39·7 109·3. 2, slide 106, 48·6 101·2.

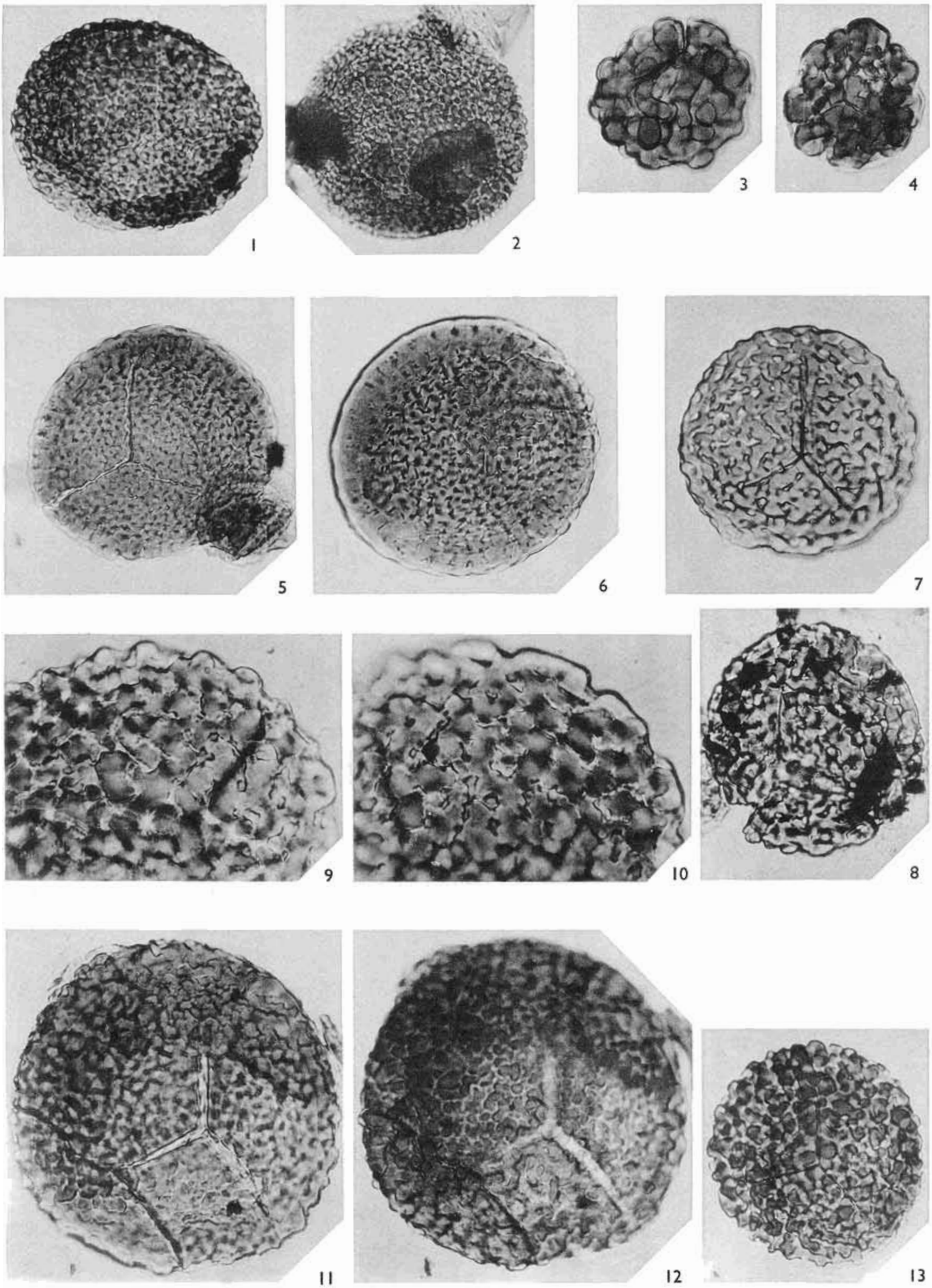
Figs. 3, 4. *C. florida* Hoffmeister, Staplin, and Malloy 1955. 3, slide 107, 36·2 109·7. 4, slide 108, 38·5 108·7.

Figs. 5, 6. *C. cerebra* Butterworth and Williams 1958. 5, Lectotype; slide T48/3. 6, slide T48/4.

Figs. 7, 8. *C.* cf. *usitata* Playford 1962. 7, slide 111*a*, 40·4 111·5. 8, slide 111*b*, 49·1 101·7.

Figs. 9, 10. *C. usitata* Playford 1962. Holotype, low and high focus respectively, ×750.

Figs. 11–13. *C. tessellata* Hoffmeister, Staplin, and Malloy 1955. 11, 12, proximal and distal surfaces respectively; slide 109, 39·1 109·8. 13, slide 110, 35·9 110·4.



SMITH and BUTTERWORTH, British Carboniferous miospores

enclosing small lumina. Muri variable in outline in plan view, mostly 2–5 μ in width and about 2 μ in height; well rounded in profile; vermiculi less than 1 μ in width and lumina rarely exceeding 3 μ in maximum dimension. Tendency for peripheral vermiculi to become radially aligned; marginal portion of exine, about 2 μ in width, generally appears structureless. Exine including muri 5–9 μ thick.

Size in microns. (i) Lectotype 82; 55(72)83, fum. HNO_3 (Butterworth and Will. 1958). (ii) Measurements of another assemblage from the type locality extend the range to 92 μ.

Description. Proximally there is a parting of the ornament over the commissures. At low magnification the course of a laesura often appears flexuose due to the undulating outline of the bordering muri.

Remarks. The structure of the species has been re-interpreted following examination at high magnification under oil. The marginal zone referred to by Butterworth and Williams is not a structural feature but can be seen in any plane of compression. It probably results from narrow vermiculi becoming obscure as the muri pass over the equator because they are viewed obliquely. There may also be some distortion due to the compression of a very thick exine which may result in the radial alignment of the vermiculi.

Comparison. C. cerebra resembles *C. crassa* Playford 1962 (p. 594, pl. 81, figs. 10–12) in appearance but *C. crassa* is in part larger with a size range of 61(85)115 μ and has a thicker exine. These differences may in part be due to the maceration methods.

Occurrence. Infrequent, Assemblages III and IV; Namurian. The species is recorded by Love (1960) from coal and other rocks of Viséan age.

Convolutispora florida Hoffmeister, Staplin, and Malloy 1955

Plate 9, figs. 3, 4

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 38, fig. 6. Preparation 1, ser. 16,551.

Type locality. Shale at 2,086 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 384). Amb circular to subcircular. Laesurae slightly exceed one-half radius, usually obscured, lips raised. Ornamentation of closely packed, coarse, obervermiculate, convoluted ridges, often flattened by compression; ridges 2·8–6·3 μ wide. Exine relatively thick.

Size in microns. (i) Holotype 49; 39–50, HF (Hoffmeister, Stap., and Mall. 1955). (ii) 36(47)56 (15 specimens) fum. HNO_3; Cloven Seam at 621 ft. 10 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Sometimes preserved in lateral compression, when proximal and distal profiles are convex; margin irregularly undulating to lobate. Laesurae simple, straight, three-quarters of, to approximately equal to, internal radius of spore. Ornament essentially consists of anastomosing, well-rounded or flat-topped verrucae, generally not exceeding 5 μ in height and 7 μ in basal width. Ridges connecting verrucae narrower in width.

Ornament generally closely spaced, but sometimes with more open structure, the elevations enclosing irregularly shaped lumina generally not exceeding 3 μ in maximum dimension. 9 to 15 elevations project from margin; width of projections at margin very variable due to variable direction in which ridges traverse equator.

Comparison. Distinguished from other species of genus by smaller size and relatively coarse ornament.

Occurrence. Infrequent, Assemblage III; Namurian A. Recorded by Love (1960) from rocks other than coal in Viséan of Scotland.

Convolutispora jugosa sp. nov.

Plate 10, figs. 1–3

1958 *Convolutispora* cf. *mellita* Hoffmeister, Staplin, and Malloy; Butterworth and Williams, p. 372, pl. 2, figs. 20, 21.

Holotype. Plate 10, figs. 1, 2. Preparation T49/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. 4 in. coal at 191 ft. 3 in., Darnley No. 3 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis. Amb circular, margin irregularly undulose. Laesurae simple, straight or curved, one-half to two-thirds of radius. Proximal and distal ornament of closely spaced, broad, and low verrucae and branched rugulae with well-rounded apices; ornament mostly 5–10 μ in basal width at margin and projecting 1·5–5 μ from margin; length not exceeding 30 μ in plan view. Width of ornament very variable due to anastomosing and branching; vermiculi about 1 μ, angular spaces 2–3 μ in width; 25 to 35 elevations project at margin. Exine, including sculpture, 8–10 μ thick.

Size in microns. (i) Holotype 112; 84(102)119 (21 specimens), fum. HNO_3; type locality. (ii) Butterworth and Williams 1958 quote a minimum size of 72 μ for an assemblage from the type locality.

Description. Outline often in part smooth due to alignment of long axes of elevations along margin, or to overlap of adjacent sculptural elements. Laesurae perceptible. Elevations in plan view somewhat variable from closely fitting, branched, and elongate, to relatively more open, less branched, and extended condition.

Remarks. Specimens referred to *C. mellita* and *C.* cf. *mellita* by Butterworth and Williams are now considered to be the same species and distinct from *C. mellita* Hoffmeister, Staplin, and Malloy.

Comparison. *C. jugosa* sp. nov. differs from *C. mellita* and *C.* cf. *usitata* Playford in larger size and thicker exine. In plan view the rugulae in *C. jugosa* are more extended

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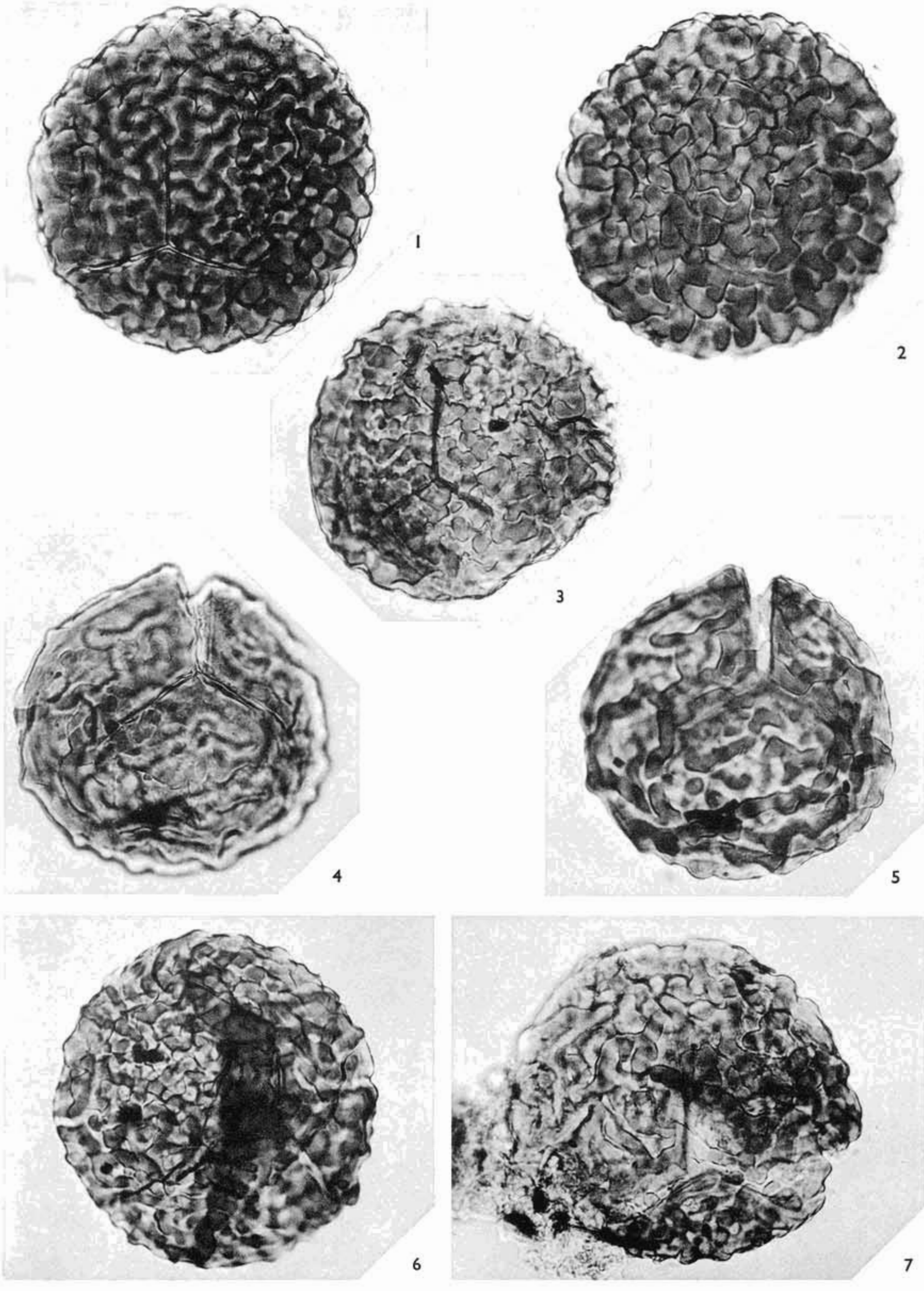
EXPLANATION OF PLATE 10

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Convolutispora jugosa* sp. nov. 1, 2, Holotype, proximal and distal surfaces respectively; slide T49/1. 3, Isotype; slide T49/3.

Figs. 4–7. *C. varicosa* Butterworth and Williams 1958. 4, 5, Holotype, proximal and distal surfaces respectively; slide T51/1. 6, Isotype; slide T51/2. 7, Isotype; slide T51/5.

PLATE 10



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and branched than in *C. tessellata* Hoffmeister, Staplin, and Malloy 1955 (p. 385, pl. 38, fig. 9). *C. jugosa* is similar in size to *C. usitata* Playford, but differs in having shorter laesurae, a rugulate rather than a murinate ornament, and a thicker exine.

Occurrence. Infrequent, Assemblage III; Namurian A.

Convolutispora tessellata Hoffmeister, Staplin, and Malloy 1955

Plate 9, figs. 11–13

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 38, fig. 9. Preparation 1, ser. 16,527.

Type locality. Shale at 2087–8 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 385). Amb circular to subcircular. Laesurae obscure. Ornamentation thick, irregular, consisting of partly anastomosing, broad ridges of variable width and height, narrow to rounded in profile, 2·8–6·5 μ wide, 2–5·6 μ high. Exine relatively thick.

Size in microns. Holotype 86; 45–86, HF (Hoffmeister, Stap., and Mall. 1955).

Description. Proximal and distal ornament of closely packed, anastomosing verrucae with ridges seldom exceeding 10 μ in length and 5 μ in width which project 1–2 μ beyond margin; spaces between elevations may be as much as 5 μ; 30 to 40 elevations project at margin. Exine thickness, including ornament, about 5 μ.

Remarks. Only isolated specimens referable to *C. tessellata* have so far been examined from British coals so that comparison with other species is difficult. Playford (1962, p. 592) considers that the ornament of *C. tessellata* and *C. punctatimura* Staplin 1960 (p. 12, pl. 2, figs. 12, 20, 21) falls within the range of variation of that of *C. tuberculata* (Waltz 1938, pl. 1, fig. 12; pl. 5, fig. 68; and pl. A, fig. 6) Hoffmeister, Staplin, and Malloy, with which species the former may be synonymous.

Comparison. Forms assigned to *C. tessellata* from British coals resemble *C. ampla* in shape and pattern of ornament; they have been distinguished from the latter species on the basis of the coarser ornament with correspondingly fewer projecting elements at the margin.

Occurrence. Infrequent, Assemblage III; Namurian A. Recorded by Love (1960) from rocks other than coal in Viséan of Scotland.

Convolutispora usitata Playford 1962

Plate 9, figs. 9, 10

Holotype. Plate 9, figs. 9, 10 after Playford 1962, pl. 82, figs. 7, 8. Preparation P149A/30, 36·7 102·5 (L. 1028).

Type locality. Triungen (sample G1470), Spitsbergen; Lower Carboniferous.

Diagnosis (Playford 1962, p. 595). '... amb circular or subcircular. Laesurae perceptible, simple, straight, length almost equal to spore radius. Exine 6–8 μ thick, including dense, comprehensive sculpture of broad, rounded, crowded, frequently anastomosing muri, 4–10 μ wide and 2–4 μ high; lumina highly irregular in shape and size, greatly subordinate to enclosing muri. Equatorial margin undulating to incised.'

Size in microns. Holotype 91, 84(100)112 (20 specimens), Schulze (Playford 1962).

Convolutispora cf. *usitata* Playford 1962

Plate 9, figs. 7, 8

Description. Amb circular or subcircular. Laesurae simple, straight or curved, two-thirds to three-quarters, or more, of radius, not always visible. Proximal and distal ornament of closely spaced muri with low, well-rounded apices. Muri branch and terminate freely and are separated by narrow vermiculi, or enclose small, irregularly shaped lumina. Muri do not cover commissure proximally. Width of muri in plan view 2–7 μ; height at margin 1·5–2 μ; vermiculi and lumina do not exceed width of muri; 20 to 30 muri project at margin. Exine including ornament 3–5 μ thick.

Size in microns. 58(71)79 (10 specimens) fum. HNO_3; Oakshaw Ford Seam, Oakshaw Ford Colliery, Cumberland, England; Viséan.

Comparison. The surface sculpture of the holotype is shown at two levels of focus in Plate 9, figs. 9, 10, and appears similar to that of the spores assigned to *C.* cf. *usitata* shown in Plate 9, figs. 7, 8. The British specimens differ from the type only in having a smaller size and thinner exine. It is possible that these differences may be due to method of maceration. The species is similar in size but not in appearance to *C. mellita* Hoffmeister, Staplin, and Malloy 1955 (p. 384, pl. 38, fig. 10). Specimens have been examined of *Convolutispora* isolated from type material and identified as *C. mellita* in the collection of Sheffield University Geology Department. Compared with the spores described above these specimens appear smoother in outline with fewer projections and possess an ornament of muri which are variable in width and impart a distinctly reticulate appearance. Since alkali was used in the maceration of the Sheffield University material no useful comparison with the present material or with the measurements given by Hoffmeister, Staplin, and Malloy is possible.

Occurrence. Infrequent, Assemblage I; Viséan.

Convolutispora varicosa Butterworth and Williams 1958

Plate 10, figs. 4–7

Holotype. Plate 10, figs. 4, 5. Preparation T51/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Ashfield Coking Seam at 1,717 ft. 5 in., Queenslie Bridge borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 372). Amb circular, subcircular, or oval; outline smooth, uneven, or irregular. Laesurae one-half to two-thirds of radius. Ornament of large, irregular vermiculi (muri), usually well spaced. Exine thick.

Size in microns. Holotype 96; 77(101)136 (18 specimens), fum. HNO_3 (Butterworth and Will. 1958).

Description. Laesurae simple, straight, sometimes exceeding three-quarters of radius. Ornament of discontinuous, low-branched, sinuose muri, well rounded in profile, 3–5 μ in width in plan view and projecting 1–3 μ from margin. Muri enclose irregularly shaped lumina of variable size but seldom exceeding 25 μ in maximum dimension. Density of muri varies considerably in different specimens. Verrucae and rugulae may partly replace muri proximally. Number of marginal projections 25 to 35. Exine in lumina about 2 μ thick.

Comparison. *C. varicosa* is similar in size to *C. jugosa* sp. nov. but differs in the more open pattern of the ornament, although occasional specimens may be found which cannot be assigned to either species with certainty. It is considered that *C. varicosa* is not an extreme variant of *C. jugosa* since it is only sometimes found in assemblages of *C. jugosa* and can be more abundant than this species.

Occurrence. Infrequent, Assemblage III; Namurian A. Recorded by Love (1960) in rocks other than coal in Viséan of Scotland.

Genus MICRORETICULATISPORITES (Knox) Potonié and Kremp 1954 *non sensu* Bharadwaj

Type species. *M. lacunosus* (Ibrahim) Knox 1950.

Diagnosis (Potonié and Kremp 1954, p. 143; translation). 'Trilete isospores and microspores. Amb triangular to circular. Exine extra-reticulate with small lumina not much greater than 6 μ in diameter, mostly smaller. Muri sometimes imperfect and branched, with lumina having a corresponding shape. Occasionally muri vary in height and are sometimes inclined to the perpendicular. Margin finely notched to undulating.'

Remarks. It is unfortunate that Potonié and Kremp designated a triangular species as the type of the genus since, in general, the circular forms which Knox has described from the Lower Carboniferous of Scotland and for which she proposed the genus are more obviously microreticulate.

In an attempt to provide a more closely circumscribed genus Bharadwaj (1955, p. 127) emended the genus to include only triangular forms. This also conforms with the principle, used by Potonié and Kremp in their morphographic classification of dispersed spores, that shape as well as ornament is made the basis for the erection of genera. However, with the exception of spores with foveolate exines and certain other forms, Bharadwaj gave no indication where the remaining circular forms included in *Microreticulatisporites* by Potonié and Kremp should be assigned. Since then further circular-shaped species have been added to the genus.

The classification of these species presents a problem; they show a range of ornament from poorly defined to well-defined reticulation and in practice the separation of these species into two or more genera based on the character of the ornament is a subjective procedure. For these reasons the authors have reverted to the use of the broader diagnosis of Potonié and Kremp.

Affinity. ? Filicales. Spores of *Scolecopteris iowensis* Mamay 1950 (p. 249, pl. 5, fig. 25) may belong to *Microreticulatisporites* according to Potonié (1962, p. 99).

Microreticulatisporites concavus Butterworth and Williams 1958

Plate 11, figs. 1, 2

Holotype. Plate 11, fig. 1, after Butterworth and Williams, pl. 1, fig. 56. Preparation T45/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 1,872 ft. 7 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 367). Amb triangular, angles broadly rounded, interradial margins concave. Laesurae two-thirds radius. Ornamentation finely microreticulate, distinct, and regular.

Size in microns. Holotype 44; 30(40)52, Schulze and KOH (Butterworth and Will. 1958).

Description. Interradial margins concave. Laesurae simple, straight; commissure frequently open. Lumina approximately 2 μ in diameter. Muri up to 3 μ in width, slightly arched, giving rise to a regularly notched margin; 40 to 60 muri project at amb. The muri tend to be less prominent in the interradial areas. Exine thin.

Occurrence. Infrequent, Assemblages III and IV; Namurian.

Microreticulatisporites? *microreticulatus* Horst 1943

Plate 11, figs. 3, 4

1943 *Aletes microreticulatus* Horst (thesis), fig. 83.
1955 *Microreticulatisporites*? *microreticulatus* Horst, p. 166, pl. 24, fig. 83.

Holotype. Horst 1955, pl. 24, fig. 83. Preparation IV25, 20·8 72·6.

Type locality. Leopold Seam, Johann-Maria Colliery, Moravska-Ostrava; Namurian A.

Diagnosis (from Horst 1955, p. 166). Very small, spherical to oval microspores with fine, 1–3 μ, reticulum.

Size in microns. (i) Holotype 17; 14–23, fum. HNO_3 (Horst 1955). (ii) 15(16)17, fum. HNO_3; seam at 31 ft. 4 in., Culross No. 2 borehole, West Fife Coalfield, Scotland; Namurian A.

Description. Shape generally circular. Spinae up to 2·5 μ in height and 0·5 μ in width may project from some part, or all, of the spore margin. These spinae appear to be located at the junction of the muri but are only clearly seen at the margin. Lumina number about 12 to 15. Exine thin.

Remarks. This spore appears to be alete and for this reason Horst assigned the species only tentatively to *Microreticulatisporites*.

Comparison. A specimen of *M. minutus* Knox 1950 (Knox 32K, 1948, fig. 38) supplied by her was compared with the figure of *M.*? *microreticulatus* in Horst (1955, pl. 24, fig. 83) and with somewhat similar spores obtained by the authors. Knox's specimen had more and smaller lumina and slightly broader muri than the other specimens. The margin was also more undulose with no trace of projecting spinae. The two species must be considered separate until further specimens of each, macerated in the same way, are available for comparison. *M.? microreticulatus* is generally smaller than *Dictyotriletes castaneaeformis* which has a more prominent and larger reticulum and is generally oval in shape.

Occurrence. Infrequent, Assemblages III and IV; Namurian.

Microreticulatisporites microreticulatus Knox 1950

Plate 11, figs. 5, 6

1948 36K Knox, p. 159, text-fig. 42.
1950 *Microreticulati-sporites microreticulatus* Knox, p. 321.

Neotype. Plate 11, fig. 5, after Butterworth and Williams 1958 (erroneously referred to by these authors as the holotype). Preparation T43/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. A bed of Milton Main Seam at 1,735 ft. 3 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis and description in Butterworth and Williams 1958, p. 367). Amb round to oval. Laesurae indistinct, two-thirds radius. Exine finely, and rather irregularly, microreticulate; margin undulating.

Size in microns. Neotype 38, 28(35)41, Schulze and KOH (Butterworth and Will. 1958).

Description. Laesurae are faint and usually obscured by surface ornamentation. Lumina 3–5 μ in diameter. Muri approximately 2 μ in breadth; muri are low and the reticulation is therefore not well defined. Exine thin.

Remarks. This species is not the same as that described under the same name by Horst 1955, or by Loose 1932. If Loose's species is correctly assigned to *Microreticulatisporites* by Potonié and Kremp it has priority over Knox's species. However, it appears

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EXPLANATION OF PLATE 11

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Microreticulatisporites concavus* Butterworth and Williams 1958. 1, Holotype; slide T45/1, 43·6 107·4. 2, distal surface; slide 112, 61·2 113·9.

Figs. 3, 4. *M.? microreticulatus* Horst 1943. 3, ×1,000; slide 113, 51·5 100·9. 4, ×1,000; slide 113, 38·3 112·5.

Figs. 5, 6. *M. microreticulatus* Knox 1950. 5, Neotype; slide T43/1, 46·5 108·0. 6, slide 114, 30·9 105·7.

Figs. 7, 8. *M. nobilis* (Wicher) Knox 1950. 7, slide 115, 57·5 103·6. 8, slide 116, 46·2 118·0.

Figs. 9, 10. *M. sulcatus* (Wilson and Kosanke) comb. nov. 9, slide 118, 37·0 109·8. 10, slide 119, 37·3 110·9.

Figs. 11–13. *M. punctatus* Knox 1950. 11, slide 117, 47·8 105·0. 12, 13, Neotype, proximal and distal surfaces respectively; slide T44/1, 35·3 111·4.

Figs. 14, 15. *Dictyotriletes bireticulatus* (Ibrahim) emend. 14, slide 127, 39·8 98·8. 15, oblique compression showing laevigate proximal surface; slide 127, 12·5 114·7.

Figs. 16–18. *D. castaneaeformis* (Horst) Sullivan 1964. 16, 17, slide 120, 31·0 112·1. 17, ×1,000. 18, ×1,000; slide 120, 16·7 106·1.

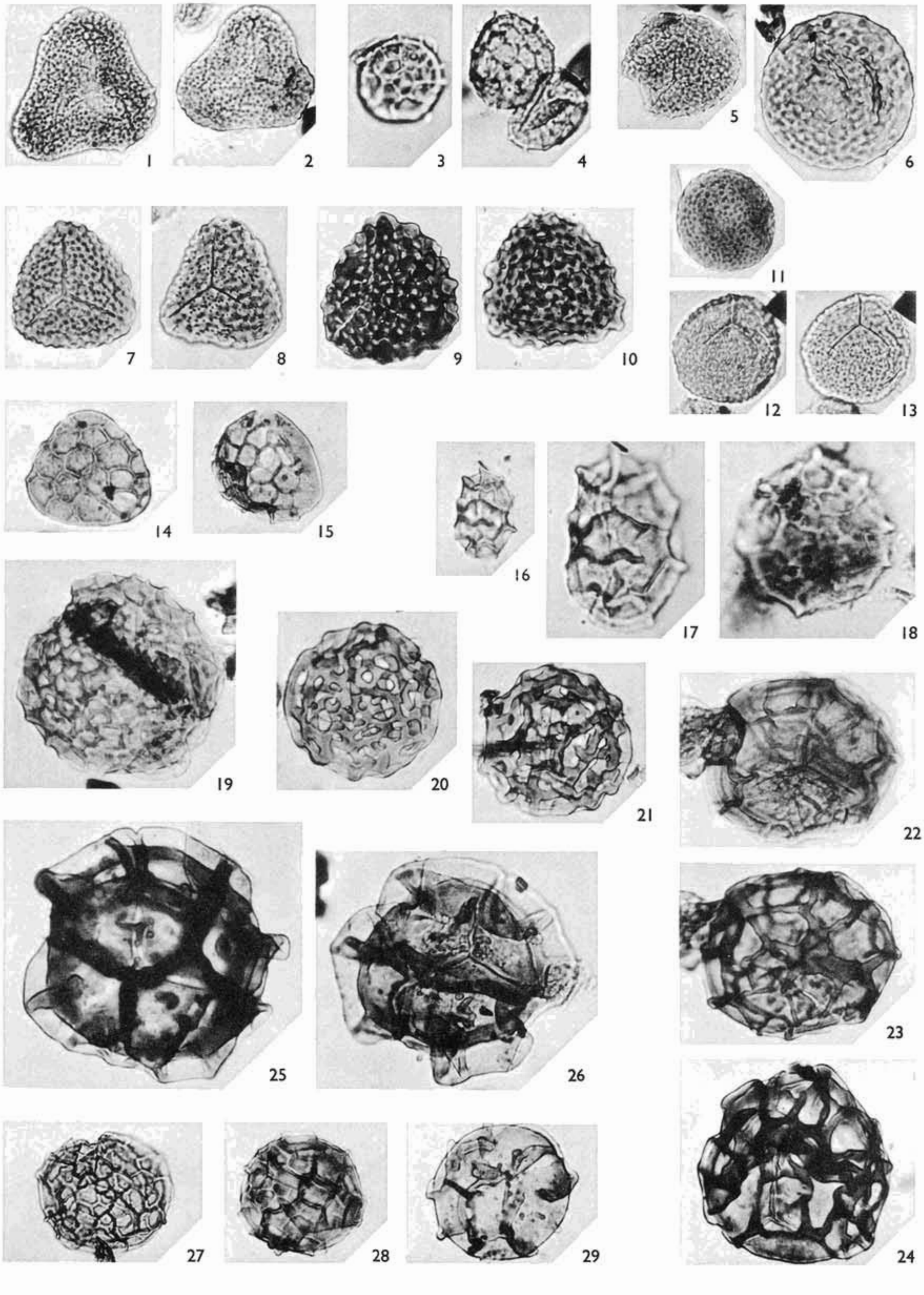
Fig. 19. *D. densoreticulatus* Potonié and Kremp 1955. Slide 129, 52·8 113·1.

Figs. 20, 21. *D. falsus* Potonié and Kremp 1955. 20, slide 128, 30·8 114·1. 21, slide 128, 18·8 112·7.

Figs. 22–24. *D. mediareticulatus* (Ibrahim) emend. 22, 23, proximal and distal surfaces respectively; slide 121, 51·5 106·0. 24, slide 121, 26·5 112·7.

Figs. 25, 26. *D. muricatus* (Kosanke) comb. nov. 25, distal surface; slide 122, 40·7 115·5. 26, slide 123, 43·3 115·0.

Figs. 27–29. *D. reticulocingulum* (Loose) comb. nov. 27, slide 124, 44·0 102·9. 28, slide 125, 45·9 105·8. 29, slide 126, 30·7 116·9.



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doubtful whether the specimens figured by Loose (1932, pl. 18, fig. 37) should be regarded as belonging to this genus. Knox's name would also be illegitimate if Horst's tentative assignment of his species to *Microreticulatisporites* is affirmed. Knox's name is therefore retained while these uncertainties remain.

Occurrence. Infrequent or sometimes frequent, Assemblages III and IV; Namurian.

Microreticulatisporites nobilis (Wicher) Knox 1950

Plate 11, figs. 7, 8

1934 *Sporites nobilis* Wicher, p. 186, pl. 8, fig. 30.
1944 *Punctati-sporotes nobilis* (Wicher); Schopf, Wilson, and Bentall, p. 31.
1950 *Microreticulatisporites nobilis* (Wicher); Knox, p. 321, pl. 18, fig. 242.

Holotype. Potonié and Kremp 1955, pl. 15, fig. 279 after Wicher. Preparation IV X5, a_2 (u/r).

Type locality. Seam R_1, Wehofen Colliery, Ruhr Coalfield, Germany; Westphalian C. (Seam R_1 in Wicher 1934 is a thin coal between the Seams Kobold and Loki and is not the authentic R_1 of the Ruhr Coalfield.)

Diagnosis (Potonié and Kremp 1955, p. 101; translation). 'Amb rounded-triangular. Laesurae distinct, at least two-thirds radius; approximately 50 crenulations at margin. Muri rather broad.'

Size in microns. (i) Holotype 36, Schulze and KOH. (ii) 30–45, Schulze (Potonié and Kr. 1955). (iii) 32(37)43, fum. HNO_3; Sharlston Top Seam at 1,168 ft. 8 in., Cross Hill borehole, Yorkshire Coalfield, England; Westphalian C.

Description. Amb triangular, sides straight or convex, angles rounded; when not in proximal/distal compression shape may be circular or oval. Laesurae simple, often partly obscured by ornament; length from three-quarters to full length of radius. Ornament distinctly reticulate, of polygonal lumina, 1 μ in diameter, and high muri with rounded apices. The margin is finely notched, the number of projecting elements varying from 25 to 40, or occasionally more. Exine moderately thick and generally without folds in polar compression.

Comparison. The convexity of the interradial margins distinguishes *M. nobilis* from *M. concavus*. The lumina are more numerous and the muri are smaller than in *M. sulcatus*. *M. novicus* Bharadwaj 1957*a* (p. 92, pl. 25, fig. 3) possesses muri which are pointed in profile.

Occurrence. Infrequent (not recorded from many seams), Assemblages VIII to X; Westphalian B and C.

Microreticulatisporites punctatus Knox 1950

Plate 11, figs. 11–13

1948 37K Knox, p. 159; text-fig. 43.
1950 *Microreticulati-sporites punctatus* Knox, p. 321.

Neotype. Plate 11, figs. 12, 13 after Butterworth and Williams 1958 (erroneously referred to by these authors as the holotype). Preparation T44/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. A bed of Milton Main Seam at 1,735 ft. 3 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis and description in Butterworth and Williams 1958, p. 368). Amb round to oval. Laesurae simple, two-thirds radius. Exine with an extremely fine and regular microreticulation; margin finely crenulate.

Size in microns. Neotype 34; 26(34)39, Schulze and KOH (Butterworth and Will. 1958).

Description. Lumina less than 2μ in diameter. Muri less than 2μ in width, but sufficiently high to project slightly at the margin and produce a regular crenulation. Exine thin.

Comparison. The microreticulation in *M. punctatus* is more regular and better defined and the lumina are smaller than in *M. microreticulatus*. The authors have compared *M. punctatus* with two specimens of *M. parvirugosus* Staplin 1960 (p. 10, pl. 2, fig. 11) from the type locality. The lumina in the latter species are of the same order of size, but the microreticulation is less well defined than in *M. punctatus*.

Occurrence. Infrequent, or occasionally frequent, Assemblages III and IV; Namurian.

Microreticulatisporites sulcatus (Wilson and Kosanke) comb. nov.

Plate 11, figs. 9, 10

1944 *Punctati-sporites sulcatus* Wilson and Kosanke, p. 331, pl. 1, fig. 4.
1955 *Converrucosisporites sulcatus* (Wilson and Kosanke); Potonié and Kremp, p. 64.

Cotypes. Wilson and Kosanke 1944. Preparation 265 P, circle 1 and 266 P.

Type locality. Unspecified coal from Angus Coal Co. Colliery, Iowa, U.S.A.; Des Moines Series.

Diagnosis (from Wilson and Kosanke 1944, p. 331). Amb triangular to round. Laesurae simple, reaching to equator. Ornament of a dense, coarse, irregular reticulation enclosing minute areas (lumina) between them; some of reticulations may end in pronounced verrucate processes.

Size in microns. (i) 30–40, maceration method not known (Wilson and Kos. 1944). (ii) 36(42)51, fum. HNO_3; Trenchard Seam, Princess Royal Colliery, Forest of Dean Coalfield, England; Upper Westphalian C.

Description. Amb rounded-triangular; shape circular or oval when not preserved in polar orientation. Laesurae reach nearly to equator when not concealed by ornament; not apparent when viewed from distal side or in lateral compression. The exine is covered by verrucate processes which are developed on the outer surface of the muri. The lumina are circular or polygonal and may be just over 1μ in maximum dimension. The development of the verrucae and the extent to which the lumina are visible vary considerably in different specimens. The verrucae give rise to broad crenulations at the margin of the spore which number between 20 and 25. The marginal crenulations are 2–3μ in height and 5–7μ in breadth at their bases. The exine is moderately thick and rarely folded.

Remarks. In British coals there are two forms of rounded-triangular spores with verrucate-reticulate ornamentation which are liable to be confused. Although their size ranges overlap they differ in the degree of development of the muri. The form with coarse ornament (less than 25 crenulations at margin) is figured by Wilson and Kosanke

(1944, pl. 1, fig. 4) and by Wilson and Hoffmeister (1956, pl. 1, fig. 11) as *Punctatisporites sulcatus*. The specimen figured by Guennel (1958, pl. 3, fig. 7) as *Converrucosisporites sulcatus* has more than 25 crenulations at the margin and in the authors' opinion is *M. nobilis*. Similarly, it is considered that the spore illustrated as *C. sulcatus* by Love (1960, pl. 1, fig. 6) from the Viséan of Scotland is not correctly assigned.

Occurrence. Infrequent, Assemblages IX to XI; Westphalian C and D.

Genus DICTYOTRILETES (Naumova) emend.

Type species. D. bireticulatus (Ibrahim) Potonié and Kremp 1954.

Diagnosis (emended from Potonié and Kremp 1954, p. 144). Radial, trilete miospores. Exine with reticulate sculpture. Arrangement of muri may give a well-defined or poorly defined reticulum. The muri may project at the amb, or may be low and scarcely recognizable. Lumina regular, or highly variable in shape, generally greater than 6 μ in diameter. Reticulum may be confined to distal surface.

Remarks. The diagnosis of Potonié and Kremp has been emended to include certain spores formerly assigned to *Reticulatisporites*. This follows the demonstration of a cingulum in the type species of *Reticulatisporites*. *Dictyotriletes* as now constituted comprises species of several morphographic types. Subsequently it may be desirable to restrict the genus to forms resembling the type species.

Affinity. Reticulate spores have been recovered from *Sclerocelyphus oviformis* Mamay (1954*b*) but the systematic position of this fructification is uncertain.

Dictyotriletes bireticulatus (Ibrahim) emend.

Plate 11, figs. 14, 15

1932 *Sporonites bireticulatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 1.
1933 *Reticulati-sporites bireticulatus* Ibrahim, p. 35, pl. 1, fig. 1.
1934 *Reticulata-sporites bireticulatus* Ibrahim; Loose, pl. 7, fig. 28.
1950 *Reticulatisporites mediareticulatus* Ibrahim; Knox, p. 323, pl. 18, fig. 253.
1952 *Reticulatisporites mediareticulatus* Ibrahim; Balme, p. 176, text-fig. 1*c*.
1952 *Reticulati-sporites* cf. *mediareticulatus* Ibrahim; Balme and Butterworth, pl. 48, figs. 4*a*, *b*.
1954 *Dictyotriletes bireticulatus* (Ibrahim); Potonié and Kremp 1954, p. 108.
1954 *Reticulati-sporites* cf. *mediareticulatus* Ibrahim; Butterworth and Millott, pl. 21, fig. 8*b*.
1956 *Reticulatisporites mediareticulatus* Ibrahim; Butterworth and Millott, text-fig. 3(8).

Holotype. Potonié and Kremp 1955, pl. 16, fig. 296 after Ibrahim. Preparation B33, a4 (r).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 108). Amb rounded-triangular with convex sides and rounded angles; in equatorial view proximal profile slightly, distal profile strongly, convex; outline in polar view smooth to gently undulate, but in other compressions the muri project about 2 μ from margin. Laesurae not often visible, simple, straight, three-quarters or more of the spore radius. Reticulation covers entire distal surface but does not extend beyond equator. Polygonal-shaped lumina number between 15 and 25, size 2·5–12 μ. Except in the peripheral region the shape and size of the lumina are very regular, diameter about 10 μ. Muri approximately square in section; width somewhat less than 1·5 μ. Exine thin, proximally laevigate, distally in lumina punctate (?infrasculpture).

Size in microns. (i) Holotype 57·5, Schulze and KOH. (ii) 40–60, Schulze (Potonié and Kr. 1955). (iii) 40(47)56, Schulze (Balme 1952). (iv) 30(34)40, fum. HNO_3; Beamshaw Seam, South Kirkby Colliery, Yorkshire Coalfield, England; Westphalian B. (v) 27(35)39, fum. HNO_3; Harvey Seamat 564 ft. 2 in., New Shildon borehole (42 SW. 20), Durham Coalfield, England; Westphalian A. (vi) 37(50)60, fum. HNO_3; 2 in. coal at 100 ft. 2 in., Common Gate borehole No. 1, Northumberland Coalfield, England; Lower Westphalian A.

Remarks. The diagnosis of Potonié and Kremp has been emended since it is not clear whether the authors recognized that the ornament is confined to the distal surface.

Occurrence. Infrequent to very common, Assemblages V to IX (lower part); most abundant in seams of Assemblages VII and VIII; Westphalian A to lowest part of Westphalian C.

Dictyotriletes castaneaeformis (Horst) Sullivan 1964

Plate 11, figs. 16–18

1943 *Aletes castaneaeformis* Horst (thesis) p. 124, fig. 82.
1955 *Reticulatisporites castaneaeformis* (Horst) Potonié and Kremp; Horst, p. 169.
1964 *Dictyotriletes castaneaeformis* (Horst); Sullivan, p. 367.

Holotype. Horst 1955, pl. 24, fig. 82. Preparation III91, 16·3 68·4.

Type locality. Peterswalder Seam, Eugen Colliery, Moravska-Ostrava; Namurian A.

Diagnosis (from Horst 1955, p. 169). Amb round to oval. Exine irregularly reticulate (reticulum not always distinct); lumina 2–7 μ in diameter, muri about 0·5 μ in width. Where the muri meet they appear to give rise to pointed projections up to 2 μ in size, which are best seen at the margin.

Size in microns. (i) Holotype 20; 11–29, fum. HNO_3 (Horst 1955). (ii) 21(26)32, fum. HNO_3; High Hazel of Hatfield Seam, Askern Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Shape generally oval, outline modified by projecting muri. Apparently alete. Exine distinctly reticulate on both proximal and distal faces; about 9 to 12 muri project at margin.

Comparison. Microreticulatisporites fundatus Hoffmeister, Staplin, and Malloy 1955 (p. 391, pl. 36, fig. 3) differs only in possessing smaller lumina. Staplin (1960, p. 11) suggests that the form designated as *R. castaneaeformis* by Dybová and Jachowicz (1957*a*, p. 110, pl. 23, fig. 4) is probably the same as *M. fundatus* and different from *R. castaneaeformis* of Horst. *Dictyotriletes clatriformis* (Artüz 1957, p. 248, pl. 4, fig. 25) Sullivan 1964 (p. 367) and *D. crassireticulatus* (Artüz 1957, p. 248, pl. 4, fig. 26) comb. nov. are probably conspecific according to Sullivan (1964). These species differ from the forms here assigned to *D. castaneaeformis* only in their larger size (30–45 μ). Forms from the Edgehills Coal of the Forest of Dean Coalfield which are identical in size and ornament with those considered here as *D. castaneaeformis* have been assigned by Sullivan to *D.* cf. *clatriformis.*

Occurrence. Infrequent, Assemblages III to VIII; Namurian A to Westphalian B.

Dictyotriletes densoreticulatus Potonié and Kremp 1955

Plate 11, fig. 19

Holotype. Potonié and Kremp 1955, pl. 16, fig. 313. Preparation 485/5.

Type locality. Ägir Seam, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1956, p. 109). Amb circular; outline rendered irregular by more than 20 slight projections. Laesurae reaching nearly to the amb, scarcely recognizable. Muri rather narrow.

Size in microns. Holotype 72; 60–80, Schulze (Potonié and Kr. 1955).

Description. Laesurae simple, straight. Both proximal and distal faces reticulate. Muri about 1–1·5 μ in width and height, somewhat broader at corners of lumina. Lumina mostly between 5 and 10 μ in diameter.

Comparison. This species is characterized by its relatively large size and the well-defined reticulum comprising a large number of small lumina on both hemispheres.

Occurrence. Infrequent; range uncertain. Specimens recorded from Westphalian B.

Dictyotriletes falsus Potonié and Kremp 1955

Plate 11, figs. 20, 21

Holotype. Potonié and Kremp 1955, pl. 16, fig. 303. Preparation 485/X.

Type locality. Ägir Seam, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 109; translation). 'Amb roughly circular, with 14 to 17 marginal bulges or projecting muri ('Randstrahlen'). Reticulum with broad muri and occasionally with small rounded projections at the corners of the lumina.'

Size in microns. (i) Holotype 48; 45–55, Schulze (Potonié and Kr. 1955). (ii) 40(46)52 (six specimens) fum. HNO_3; various localities, Yorkshire and Nottinghamshire Coalfields, England; Westphalian A and B.

Description. Outline irregularly undulate. Laesurae not always visible, simple, straight, two-thirds to over three-quarters of radius. Reticulation on both hemispheres. Muri relatively broad, about 2·5 μ, their outer surfaces well rounded, scarcely projecting more than 2·5 μ at the margin. At certain levels of focus, possibly due to the curvature of the outer surfaces, the muri appear to be differentiated into a dark inner and light outer portion, comparable in appearance to the middle lamellae of xylem tissue. There is considerable variation in size and shape of the lumina on any individual; they range from 1 to 10 μ in diameter. Exine thin.

Remarks. The small projections which Potonié and Kremp refer to as occurring on the muri at the corners of the lumina have not been seen. The muri are, however, sometimes distorted, when the outer surface may appear somewhat wrinkled.

Occurrence. Infrequent, only recorded from a few seams, Assemblages V to IX; Westphalian A to Lower Westphalian C.

Dictyotriletes mediareticulatus (Ibrahim) emend.

Plate 11, figs. 22–24

1933 *Reticulati-sporites mediareticulatus* Ibrahim, p. 34, pl. 7, fig. 62.
1938 *Azonotriletes mediareticulatus* (Ibrahim); Luber and Waltz, pl. 8, fig. 107.
1944 *Reticulati-sporites mediareticulatus* Ibrahim; Schopf, Wilson and Bentall, p. 35.
1955 *Dictyotriletes mediareticulatus* (Ibrahim); Potonié and Kremp, p. 110, pl. 16, figs. 314, 315.

Holotype. Potonié and Kremp 1955, pl. 16, fig. 314 after Ibrahim. Preparation B20, a5 (ol).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from diagnosis in Potonié and Kremp 1955, p. 110). Amb circular; outline undulate. Laesurae weakly ridged, one-half to two-thirds radius; width narrow, height low. Exine approximately 2·5 μ in thickness, distinctly reticulate distally and proximally, except on contact areas where laevigate; 10 to 18 muri project at margin.

Size in microns. (i) Holotype 65·5, Schulze and KOH. (ii) 50–80, Schulze (Potonié and Kr. 1955). (iii) 55(63)72, fum. HNO_3; seam at 903 ft. 4 in., Harry Stoke 'B' borehole, Bristol and Somerset Coalfield, England; Lower Westphalian C.

Description. Ridged laesurae, 17–25 μ in length, sometimes flexuose, often not apparent. Distal lumina polygonal, varying in number and size within and between individuals; size 5–25 μ. Muri straight, or slightly sinuate, 2–4 μ in width, projecting up to 4 μ at margin. Where muri lie along equator they appear in polar compression as narrow flanges connecting two or more radially directed muri. Seen thus, the muri appear more translucent than in plan view where they are viewed through the spore exine. Proximally the radially directed muri may extend polewards for a distance up to about one-third of the spore radius. The ends of these muri are often connected laterally to give a more or less complete ring demarcating the contact areas. Exine finely granulate (or punctate) to laevigate.

Remarks. The spore figured by Potonié and Kremp (1955, pl. 16, fig. 315) and that drawn by Ibrahim (1933, pl. 7, fig. 62) possess more lumina than are typical of the species.

Occurrence. Infrequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Dictyotriletes muricatus (Kosanke) comb. nov.

Plate 11, figs. 25, 26

1950 *Reticulati-sporites muricatus* Kosanke, p. 27, pl. 4, fig. 7.

Holotype. Kosanke 1950, pl. 4, fig. 7. Preparation 600, slide 2.

Type locality. La Salle Coal, Bureau County, Illinois, U.S.A.; Upper McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 27). Amb circular, outline irregularly crenulate. Laesurae distinct, about two-thirds radius. Exine reticulate with large lumina and thin, but high, and frequently folded, twisted muri. Exine, exclusive of muri, 2–4 μ thick.

Size in microns. (i) Holotype 91 × 84; 82–97, Schulze and 10% KOH (Kosanke 1950). (ii) 68(77)89, fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Laesurae often concealed by ornament. Muri 1–2 μ in thickness extend 6–12 μ beyond the body. Number and size of lumina often difficult to determine but size appears to be up to 25 μ in diameter. The high muri cover entire spore with the exception of the contact area where they are either absent or reduced in height. Apiculate elements, which do not exceed the height of fully developed muri, sometimes occur on the muri and on the lumina. The high muri give the compressed spore body the appearance of having a membranous flange. The body often shows a darker peripheral zone due to the overlapping of the body by the muri arising near the equator. Exine of lumina generally laevigate, but may be pustulate or granulate.

Comparison. Reticulatisporites reticuliformis Ibrahim 1933 (p. 34, pl. 7, fig. 63), *R. evolvens* (Waltz in Luber and Waltz 1938, pl. 1, fig. 9) Potonié and Kremp, and *R. velatus* (Waltz in Luber and Waltz 1938, pl. 3, fig. 35 and pl. A, fig. 18) Potonié and Kremp appear morphologically similar. *D. muricatus* may be conspecific with one or more of these species. *D. muricatus* is considered by Potonié and Kremp (1955) to be indistinguishable from *Reticulatisporites reticulatus* but the latter possesses a differentially thickened cingulum. The size range of the British specimens isolated by fuming nitric acid lies between the ranges of *R. muricatus* Kosanke and *R. annulatus* Guennel (55–75 μ). Both these authors used Schulze reagent followed by potassium hydroxide so that the two forms must at present be regarded as distinct. The British specimens appear nearer to *R. muricatus* in size, the difference probably being due to the different macerating agents used.

Occurrence. Infrequent, rarely frequent, Assemblage VI to IX; Upper Westphalian A to Lower Westphalian C.

Dictyotriletes reticulocingulum (Loose) comb. nov.

Plate 11, figs. 27–29

1932 *Sporonites reticulocingulum* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 41.
1934 *Reticulati-sporites reticulocingulum* Loose, p. 156.
1944 ? *Punctati-sporites reticulocingulum* (Loose); Schopf, Wilson, and Bentall, p. 31.
1950 *Microreticulatisporites reticulocingulum* (Loose); Knox, p. 321.

Holotype. Potonié and Kremp 1955, pl. 16, fig. 306 after Loose. Preparation IV44, a_2 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from diagnosis in Potonié and Kremp 1955, p. 113). Amb more or less circular with about 15 to 20 small, membranous-linked marginal rays. Laesurae about two-thirds radius. Well-developed distal reticulum; proximal ornament more striate.

Size in microns. (i) Holotype 45, Schulze. (ii) 40–60, Schulze (Potonié and Kr. 1955). (iii) 37(46)52, fum. HNO_3; High Hazel of Hatfield Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 38(42)48, fum. HNO_3; seam at 2,015 ft. 4 in., Cotgrave Wolds borehole, Nottinghamshire Coalfield, England; Westphalian A.

Description. Laesurae simple, straight, not often apparent. Reticulation often less well-defined proximally. Number and size of lumina vary between individuals; lumina relatively small, more or less polygonal; range in size from 4 to 15 μ. Muri 1–2·5 μ in width, project 1–2·5 μ from margin; occasionally the muri skirt the margin of the spore between two or more radially directed muri. Number of muri projecting from margin may be as low as 10. Exine of lumina laevigate and thin.

Remarks. The variation in the character of the reticulum in spores referred to *D. reticulocingulum* is shown in Plate 11, figs. 27–29. Further study may reveal the existence of more than one species. Specimens resembling the holotype of *D. reticulocingulum* were not often seen; these spores possess a well-defined proximal and distal reticulation and a larger number of lumina than the specimens more commonly included in this species. They grade into larger specimens resembling *D. densoreticulatus* Potonié and Kremp 1955.

Comparison. Differs from *D. mediareticulatus* in being distinctly smaller and in having a more or less reticulate proximal face. *D. areolatus* (Guennel 1958, p. 83, pl. 6, fig. 7, text-fig. 19) comb. nov. is morphologically similar but is smaller with a size range of 26(32)38 μ.

Occurrence. Infrequent, rarely frequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Genus CAMPTOTRILETES (Naumova) Potonié and Kremp 1954

Type species. *C. corrugatus* (Ibrahim) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 142; translation). 'Trilete isospores or microspores with a sculpture of irregular ridges of unequal height (rudimentary cristae) or of irregular, partly branching striae. There are occasionally distinct cristae on the tecta. The striae merge into rudimentary cristae.'

Affinity. Filices. Spores of *Botryopteris fecunda* Mamay and *B. illinoensis* Mamay are of the type of *Camptotriletes* (Mamay 1950). Potonié (1962) refers the spores of *Senftenbergia pennaeformis* Brongniart to this genus of dispersed spores but Marshall and Smith (1965) suggest that the specimens of this species figured by Radforth (1939, pl. 1, figs. 2, 6, 7) are referable to *Convolutispora*.

Camptotriletes bucculentus (Loose) Potonié and Kremp 1955

Plate 12, fig. 1, 2

1934 *Verrucosi-sporites bucculentus* Loose, p. 154, pl. 7, fig. 15.
1944 *Punctati-sporites bucculentus* (Loose); Schopf, Wilson, and Bentall, p. 30.
1950 *Verrucoso-sporites bucculentus* (Loose); Knox, p. 317.
1955 *Camptotriletes bucculentus* (Loose); Potonié and Kremp, p. 104, pl. 16, figs. 287, 288.

Holotype. Potonié and Kremp 1955, pl. 16, fig. 287 after Loose. Preparation III94, d_2 (m/or).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from diagnosis and description in Potonié and Kremp 1955, p. 104). Amb round to triangular. Laesurae more or less reach to equator. Exine with loosely arranged striae and wart-like projections which appear at the amb as 20 or more stout ridges. The ornament is best developed distally.

Size in microns. (i) Holotype 47·5, Schulze and KOH. (ii) 45–75, Schulze (Potonié and Kr. 1955). (iii) 50(56)67 (7 specimens) fum. HNO_3; various localities; Westphalian A and B.

Description. Margin modified by ornament. Laesurae simple, straight or slightly flexuose, one-half to three-quarters radius. Ornament of low ridges and isolated verrucae, less than 2·5 μ in height and 4 μ in breadth at base; where these elements project at amb the apices are pointed, rounded, truncate, or occasionally partate. The ridges fluctuate in height and do not form a reticulate pattern in high focus. Exine moderately thick.

Comparison. A somewhat smaller form (40–50 μ) in which the ridges tend to form a reticulate pattern has been assigned to *C. corrugatus* (Ibrahim) Potonié and Kremp 1955 (p. 104, pl. 16, figs. 289, 290).

Occurrence. Infrequent, Assemblages VI to IX (not above horizon of Mansfield Marine Band and its equivalents); Upper Westphalian A and Westphalian B.

Subturma ZONOTRILETES Waltz 1935
Infraturma AURICULATI (Schopf) Dettmann 1963
Genus AHRENSISPORITES Potonié and Kremp 1954

Type species. A. guerickei (Horst) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 155; translation). 'Isospores or microspores. Amb roughly triangular; angles with exine protuberances connected by semicircular, arcuate folds (kyrtomes) curving towards the distal pole of the spore and open to the equator; the triangular sides at the equator form the chords of three arcs.'

Affinity. Unknown.

EXPLANATION OF PLATE 12

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Camptotriletes bucculentus* (Loose) Potonié and Kremp 1955. 1, slide 130, 34·4 108·3. 2, slide 131, 45·7 111·6.

Figs. 3, 4. *Ahrensisporites guerickei* (Horst) Potonié and Kremp 1954. 3, distal surface; slide 132, 19·8 105·1. 4, slide 132, 27·5 111·8.

Figs. 5–7. *Triquitrites bransonii* Wilson and Hoffmeister 1956. 5, slide 133, 21·0 109·5. 6, slide 133, 25·5 110·3. 7, equatorial view; slide 133, 55·1 115·2.

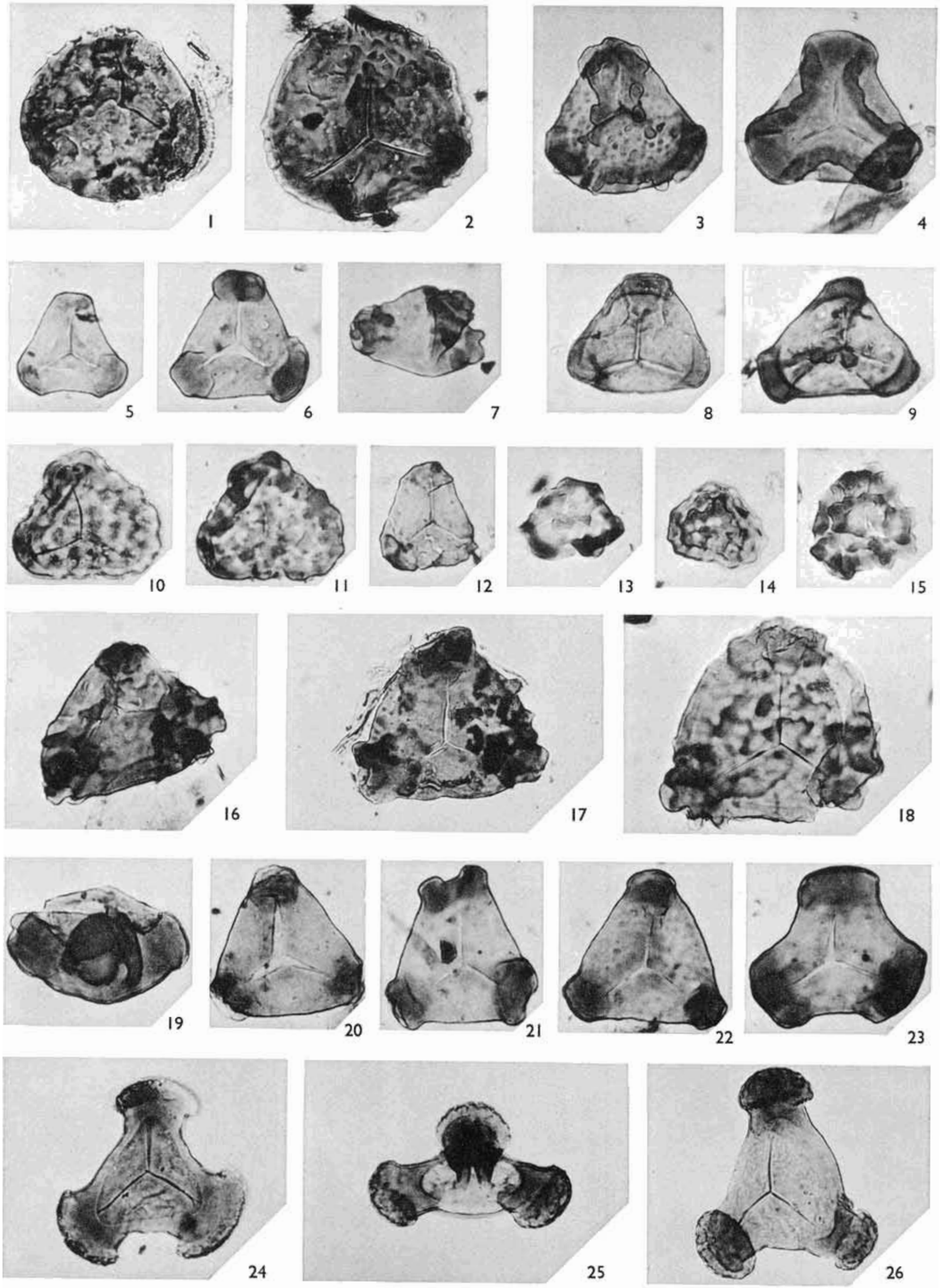
Figs. 8, 9. *T.* cf. *protensus* Kosanke 1950. 8, distal surface; slide 134, 20·2 107·8. 9, distal surface; slide 134, 48·8 113·4.

Figs. 10–15. *T. sculptilis* (Balme) emend. 10, 11, Lectotype, proximal and distal surfaces respectively; slide T70/1. 12, slide 135, 19·6 106·9. 13. slide 136, 44·0 107·9. 14, distal surface; slide 137, 42·7 113·1. 15, slide 136, 51·9 113·3.

Figs. 16–18. *T. spinosus* Kosanke 1943. 16, slide 138, 41·8 113·2. 17, slide 139, 34·4 113·8. 18, slide 139, 47·9 111·0.

Figs. 19–23. *T. tribullatus* (Ibrahim) Schopf, Wilson, and Bentall 1944. 19, equatorial view; slide 102, 35·4 107·4. 20, slide 102, 50·5 104·7. 21, slide 102, 29·5 107·3. 22, slide 102, 43·7 105·5. 23, slide 102, 39·7 117·8.

Figs. 24–26. *T. trivalvis* (Waltz) Potonié and Kremp 1956. 24, slide 140, 38·3 110·5. 25, oblique compression; slide 141, 38·9 110·3. 26, slide 142, 38·8 109·9.



SMITH and BUTTERWORTH, British Carboniferous miospores

Ahrensisporites guerickei (Horst) Potonié and Kremp 1954

Plate 12, figs. 3, 4

1943 *Triletes guerickei* Horst, (thesis) pl. 7, figs. 58, 59, 61–64.
1954 *Ahrensisporites guerickei* (Horst); Potonié and Kremp, p. 155.

Holotype. Horst 1955, pl. 23, fig. 63. Preparation I6, 28·7 71·4.

Type locality. Seam VI, Karsten Central Colliery, Beuthen, Upper Silesia; Westphalian A.

Diagnosis (expanded from Horst 1955, p. 178). Amb triangular; sides straight or slightly convex; angles truncate, rounded, or sometimes undulate. Laesurae straight, simple, may extend to kyrtome. Kyrtomes prominent, forming an unbroken ridge, or crest, which at the angles of the spore may project beyond the amb. Kyrtomes about 5–7·5 μ in width and height (measured as the projection beyond the amb in radial region); the roughly truncate radial projection of the kyrtomes is 20–30 μ in width. Margin of kyrtome smooth to undulate, sometimes modified by ornament. Exine laevigate or more usually coarsely granulate. Grana loosely distributed, sometimes with scattered verrucae on, or between, kyrtomes. Exine about 2·5 μ thick.

Size in microns. (i) Holotype 68; 50–84 (50–68), fum. HNO_3 (Horst 1955). (ii) 42(51)61, fum. HNO_3; seam at about 2,776 ft., Colston Bassett (British Petroleum Co. Ltd.) borehole, Nottinghamshire Coalfield, England; Westphalian A.

Description. There is a considerable variation in the shape and prominence of the kyrtomes particularly at the angles of the spore.

Remarks. Horst's diagnosis has been expanded to provide a more satisfactory basis for comparison.

Comparison. *A. angulatus* (Kosanke) Potonié and Kremp (Kosanke 1950, p. 38, pl. 8, fig. 8) is larger (66–75 μ) but appears morphologically similar, although Kosanke refers to proximal, arcuate thickenings. The difference in size may be due to the method of maceration. *A. guerickei* var. *ornatus* Neves 1961 (p. 263, pl. 32, fig. 11) is also larger (65–80 μ) and possesses irregular thickenings of a wart-like nature on the distal surface. This variety is figured by Horst (1955, pl. 23, fig. 61) and Butterworth and Williams (1958, pl. 3, fig. 18). The variety has not been distinguished from the type in the present work.

Occurrence. *A. guerickei* and *A. guerickei* var. *ornatus*. Infrequent, Assemblages III to VIII. Recorded from most seams of Assemblage V. Namurian to Westphalian B. Neves (1961, p. 263) records the following ranges: *A. guerickei* Upper Namurian B to Westphalian A; *A. guerickei* var. *ornatus* Namurian A to Lower Westphalian.

Genus TRIQUITRITES (Wilson and Coe) Potonié and Kremp 1954

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

Diagnosis (Potonié and Kremp 1954, p. 153; translation). 'Trilete isospores, or microspores; amb approximately triangular. Exine at angles only slightly thickened and therefore appears to be darker (valvae) or shows fairly small projections, which are either pointed or rounded, the rounded projections being described as auriculae. These auriculae tend to become inflated and more or less to protrude cushion-wise beyond the contour of the spore in contrast to the auriculae of *Tripartites*. Occasionally the three valvae, or auriculae, may be found joined by a narrow flange at the equator.'

Remarks. The considerable variation in the development of the radial crassitudes has been made the basis for the erection of a large number of species. A study of assemblages of *Triquitrites* from different horizons has led the authors to conclude that relatively few natural species are involved in this plexus of forms and that for stratigraphic purposes there is little advantage in recognizing so many morphological species.

Comparison. The auriculae of *Tripartites* (Schemel) Potonié and Kremp 1954 are more flange-like and generally larger than those of *Triquitrites*; they are also crinkled. *Ahrensisporites* is distinguished by the presence of a kyrtome.

Affinity. Potonié (1962) provides no definite evidence for the palaeobotanical affinities of this type of spore. A possible filicean relationship has been suggested by Schopf, Wilson, and Bentall (1944, p. 46).

Triquitrites bransonii Wilson and Hoffmeister 1956

Plate 12, figs. 5–7

Holotype. Wilson and Hoffmeister, pl. 3, fig. 1. Preparation No. 12A, WH6.

Type locality. Croweburg Coal, Stewart Mine, Oklahoma, U.S.A.; Des Moines Series.

Diagnosis (from description in Wilson and Hoffmeister 1956, p. 24). Shape triangular-oblate. Laesurae distinct, extending to equator; lips slightly raised. Exine laevigate. Arcuate thickenings distinct, broadly oval to angular, and of variable height, 4·5–7·0 μ, width 9–16·5 μ. Exine 1–1·5 μ thick.

Size in microns. (i) Holotype 35 × 37·5; 30–42, Schulze and NH_4OH (Wilson and Hoff. 1956). (ii) 31(35)41, fum. HNO_3; seam at 1,252 ft. 1 in., Apley Barn borehole, Oxfordshire, England; Westphalian D.

Description. Interradial margin varies from slightly convex to slightly concave, rarely undulating. Laesurae simple, straight, extending from two-thirds radius to polar margin of radial crassitudes; range 10–16 μ. Extent and development of radial crassitudes vary considerably from a mere darkening of the angles of the spore body to dense thickenings, which protrude from the equator, and are smooth and rounded, truncate, or sometimes lobed; the radial crassitudes often vary considerably on any one individual; average maximum width of crassitudes 13 μ, average maximum length from inner margin 7 μ.

Remarks. Wilson and Hoffmeister (1956, p. 25) state that *T. bransonii* is smaller than *T. pulvinatus* Kosanke 1950 (p. 39, pl. 8, fig. 1), which is 41–52 μ, and which it otherwise resembles. The larger size of *T. pulvinatus* may, in part, be due to the use of potassium hydroxide in maceration but at the same time Kosanke (1950, pl. 17) gives *T. pulvinatus* a longer stratigraphic range than is known for *T. bransonii*. It is also possible that *T. pulvinatus* may, in part, include other forms such as *T. triturgidus* as suggested by Potonié and Kremp (1956, p. 88).

Comparison. *T. exiguus* Wilson and Kosanke 1944 (p. 332, pl. 1, fig. 2), size 22–30 μ, is similar, but smaller. *T. arculatus* Wilson and Coe 1940 (p. 185, pl. 1, fig. 8), size 40–49 μ, and *T. dividuus* Wilson and Hoffmeister 1956 (p. 25, pl. 3, figs. 10, 11), size 40–49 μ, also appear similar to certain forms of *T. bransonii* but are larger and the exine, particularly in *T. arculatus*, is thicker (the 'equatorial flange' of Wilson and Coe). Certain forms included in *T. bransonii* resemble *T. truncatus* Bharadwaj and Kremp 1955 (p. 53, pl. 4, figs. 4–6) and *T. leiolitus* Bharadwaj 1957*b* (p. 122, pl. 25, figs. 61, 62). *T. protensus* Kosanke 1950 (p. 40, pl. 8, fig. 2), which is not a species of *Ahrensisporites* as suggested by Potonié and Kremp (1956, p. 97), differs from *T. bransonii* in possessing radial crassitudes which appear angular rather than as inflated cushions (Kosanke pers. comm.).

Occurrence. Infrequent, or occasionally frequent, Assemblages X and XI; Upper Westphalian C and Westphalian D.

Triquitrites protensus Kosanke 1950

Holotype. Kosanke 1950, pl. 8, fig. 2. Preparation 519–B, slide 1.

Type locality. Dekoven Coal, Williamson County, Illinois, U.S.A.; Tradewater Group.

Diagnosis (from description in Kosanke 1950, p. 40). Amb triangular, interradial margins slightly concave to convex with arcuate thickenings. Laesurae fairly distinct, extending almost to margin. Exine laevigate, 2–3 μ thick.

Size in microns. Holotype 38 × 36·5; 33·5–39, Schulze and 10% KOH (Kosanke 1950).

Triquitrites cf. *protensus* Kosanke 1950

Plate 12, figs. 8, 9

Description. Amb triangular; sides straight or slightly convex; angles truncate, rounded, or sometimes undulate. Laesurae straight, simple, extend nearly to inner margin of radial crassitude. Radial crassitudes vary in prominence but are rarely more than 7 μ in radial length or 20 μ in width. Arcuate ridges on distal surface also variable in prominence; they may extend polewards to form a continuous structure resembling a kyrtome; generally 2–4 μ in height and width. Exine laevigate, or scabrate, occasionally with wart-like projections or verrucae; exine 1·5–2·5 μ thick.

Size in microns. 38(43)51 (10 specimens) fum. HNO_3; seam at 79 ft. 4 in., Ferrers Opencast borehole, Leicestershire Coalfield, England; Westphalian A.

Remarks. Although the species possesses distal arcuate ridges resembling kyrtomes the presence of radial crassitudes excludes the species from *Ahrensisporites*, to which genus Potonié and Kremp (1956, p. 97) suggest it might belong. Kosanke (pers. comm.) states that 'the interradial thickenings are merely an extension of the arcuate thickenings (radial crassitudes) for a short distance interradially'.

Comparison. Specimens referred to *T.* cf. *protensus* from British coals are larger than the type which they otherwise resemble.

Occurrence. Infrequent, Assemblage V; Lower Westphalian A. Stratigraphic range uncertain owing to too few data.

Triquitrites sculptilis (Balme) emend.

Plate 12, figs. 10–15

1952 *Triquitrites sculptilis* Balme, p. 181, text-fig. 1*g*.
1957*b* *Triquitrites coesfeldens* Bharadwaj, p. 123, pl. 25, figs. 66, 67.
1958 *Triquitrites bucculentus* Guennel, p. 73, pl. 5, figs. 1, 2, text-fig. 17.

Lectotype. Plate 12, figs. 10, 11. Selected by Balme from his original preparation No. 234 (T70/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Seam at 670 ft. 10 in., Manton Colliery No. 4 Shaft, Yorkshire Coalfield, England; Westphalian C.

Diagnosis (emended from Balme 1952, p. 181). Amb irregularly triangular, sides more or less straight; angles sharply rounded, flat, or lobed. In equatorial view proximal surface pointed; distal surface convex. Equatorial and distal margin in equatorial view irregularly undulate. Laesurae simple, straight, extend two-thirds radius to inner margin of radial crassitudes. Exine laevigate proximally, but distally variously ornamented by an irregular network of ridges and/or verrucae. Thickening of exine at angles variable; sometimes extends interradially to give narrow, equatorially thickened zone of uniform width. Exine moderately thick.

Size in microns. (i) Lectotype 45; 25(37)45, Schulze and KOH; type locality. (ii) 27(31)37, fum. HNO_3; Sharlston Top Seam at 1,168 ft. 8 in., Cross Hill borehole, Yorkshire Coalfield, England; Westphalian C. (iii) 25(27)35, H_2O_2; Lower bed of Chislet No. 2 Seam at 58 ft. 9 in., No. 30 upborehole, Chislet Colliery, Kent Coalfield, England; Westphalian B.

Description. Shape very variable depending on degree of development of ornament. Laesurae range in length from 10 to 15μ. Verrucae very variable in height and distribution; bases broad and more or less confluent. Their arrangement may give a poorly defined reticulate pattern particularly in high focus. Development of radial crassitudes variable. They scarcely project from the equatorial margin unless bearing verrucae and are sometimes absent; radial length 2·5–7·5 μ; width 10–17 μ.

Remarks. Balme did not recognize the laevigate character of the proximal surface. The distal ornament is more variable than is suggested by Balme (1952), and other workers have given species status to the more extreme forms. Thus *T. bucculentus* Guennel 1958 and *T. coesfeldens* Bharadwaj 1957*b* correspond to forms with broad and conspicuous verrucae and with a conspicuous equatorial flange respectively.

Comparison. Balme mentions the resemblance to *Reticulati-sporites trigonus* Ibrahim 1933 (p. 37, pl. 5, fig. 34) although no mention is made of any exinal thickening in the original description of this species.

Occurrence. Infrequent or frequent, Assemblages IX to XI (lower part of Assemblage XI only); Upper Westphalian B to Lower Westphalian D.

Triquitrites spinosus Kosanke 1943

Plate 12, figs. 16–18

Holotype. Kosanke 1943; preparation No. 8004.

Type locality. Pomeroy No. 8A Seam, Princess Pat Colliery, Ohio, U.S.A.; Monongahela Series.

Diagnosis (from description in Kosanke 1943, p. 128). Oval to elliptical in equatorial view, triangular in polar view; angles rounded or truncate. Laesurae extend nearly to margin of body, lips prominent. Exine laevigate and interspersed with spinae; conspicuous thickening of exine at angles; exine, except at angles, 1–2 μ thick.

Size in microns. (i) Holotype (not stated). (ii) 45–55, Schulze (Kosanke 1943). (iii) 37(48)57 (15 specimens) fum. HNO_3; Coleford High Delf Seam, Northern United Colliery, Forest of Dean Coalfield, England; boundary Westphalian C/D.

Description. Interradial margins excluding ornament, from convex to slightly concave. Laesurae distinct, straight, simple, extend two-thirds radius to radial crassitudes; range 15–24 μ. Ornament, confined to distal surface and sometimes proximal surface of radial crassitudes, consists of low, broad-based verrucae and coni with rounded apices; basal diameter up to 7 μ and height up to 5 μ. Considerable variation in type and distribution of ornament exists within, and between, individuals. Thickening at angles also variable in extent and development; but consists usually of broad, truncate, lobed, or indented bosses, developed proximally and distally from equator on one or more of the angles; sometimes partly obscured by apiculate ornament. Exine 2–2·5 μ thick.

Comparison. In *T. additus* Wilson and Hoffmeister 1956 (p. 24, pl. 3, figs. 6–9) the ornament is more or less confined to lobed projections developed on the radial crassitudes. *T. crassus* Kosanke 1950 (p. 38, pl. 8, fig. 6), size 61–73 μ, and *T. discoideus* Kosanke 1950 (p. 39, pl. 8, fig. 3), size 63–75 μ, have a somewhat similar morphology but are considerably larger in size than *T. spinosus*. Certain forms included here in *T. spinosus* but with ornament mainly of low verrucae can be referred to *T. mamosus* Bharadwaj 1957*a* (p. 96, pl. 25, figs. 29–32).

Occurrence. Infrequent, Assemblages X and XI; Upper Westphalian C and Westphalian D.

Triquitrites tribullatus (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 12, figs. 19–23

1932 *Sporonites tribullatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 448; pl. 15, fig. 13.
1933 *Laevigati-sporites tribullatus* Ibrahim, p. 20, pl. 2, fig. 13.
1934 *Valvisi-sporites tribullatus* (Ibrahim); Loose, p. 152, pl. 7, fig. 21.
1938 *Azonotriletes tribullatus* (Ibrahim); Luber in Luber and Waltz, pl. 7, fig. 88.
1944 *Triquitrites tribullatus* (Ibrahim); Schopf, Wilson, and Bentall, p. 47.

Holotype. Potonié and Kremp 1955, pl. 17, fig. 319 after Ibrahim. Preparation B47, c3 (ul).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 90; translation). 'Amb triangular. Laesurae reach more or less to the auriculae; auriculae only slightly inflated and more or less bilobed.'

Size in microns. (i) Holotype 62, Schulze and KOH. (ii) 40–70, Schulze (Potonié and Kr. 1966). (iii) 37(43)52, fum. HNO_3; seam at 436 ft. 4 in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England; Westphalian A.

Description. Amb triangular with well-rounded or flat angles; sides generally straight, but may be slightly convex or concave. In equatorial view proximal profile pointed, distal profile convex; interradial margins smooth. Laesurae distinct, simple, and straight, extend from two-thirds radius to inner margin of spore body, range 15–22 μ. The radial crassitudes vary from slight equatorial thickenings, which do not modify outline of spore, to conspicuously rounded or truncate processes, which are only occasionally lobed, and which may project slightly beyond margin; average maximum width 18 μ, maximum radial length from inner margin averages 11 μ; tendency for thickening to be developed more towards distal than proximal pole. Exine scabrate to weakly granulate and up to 2·5 μ in thickness.

Remarks. The forms with weakly developed radial crassitudes tend to be smaller than those in which this feature is well developed. These smaller forms give the size histogram an asymmetrical distribution, but in practice it is not possible to accord these forms species status since the various forms grade into one another imperceptibly.

Comparison. *T. bransonii* Wilson and Hoffmeister is somewhat similar but smaller. *T. triturgidus* (Loose) Potonié and Kremp 1956 (p. 91, pl. 17, fig. 325), size 45–60 μ, has a more extreme development of radial crassitudes, which are well rounded in profile.

Occurrence. Infrequent, occasionally frequent, not recorded from all seams, Assemblages III to X; Namurian A to Westphalian C.

Triquitrites trivalvis (Waltz) Potonié and Kremp 1956

Plate 12, figs. 24–26

1938 *Zonotriletes trivalvis* Waltz in Luber and Waltz, pl. 4, fig. 41.
1956 *Triquitrites trivalvis* (Waltz); Potonié and Kremp, p. 88.
1956 *Trilobozonotriletes trivalvis* (Waltz); Ishchenko, p. 97, pl. 19, figs. 231–3.
1958 *Tripartites incisotrilobus* (Naumova) Potonié and Kremp; Butterworth and Williams, p. 373, pl. 3, figs. 2, ?3, ?4.

Holotype. Not designated.

Diagnosis. (Waltz in Luber and Waltz 1938; C.E.D.P. French translation No. 1443). Spore body of triangular shape with markedly rounded angles. Surface smooth; width of equatorial margin variable, on the sides of the body it is thin and less than 7 μ and at the angles it forms lobes, which are much thicker. Dehiscence mark with smooth edges. Length of rays, at most two-thirds of radius.

Size in microns. (i) 45–65, body 25–37·5, Schulze and KOH (Waltz 1938); Tournaisian and Viséan. (ii) 40–70 (Butterworth and Will. 1958); Namurian A. (iii) 38(51)66, body 24(34)44, Schulze and NH_4OH (Playford 1962); Spitsbergen; Tournaisian and Viséan.

Description. Amb subtriangular with rounded angles and convex to slightly concave sides. Laesurae simple, straight, reaching to, or nearly to, the inner margin of cingulum. Body laevigate to finely granulate. Radial crassitudes prominent, extending in radial direction for as much as 20 μ from inner margin of crassitude; outer margin thickened and expanded laterally, convex, smooth to crenulate, sometimes exceeding 30 μ in length. Spore body-wall thick.

Remarks. The authors agree with Playford (1962, p. 603) that spores previously referred to *Tripartites incisotrilobus* by Butterworth and Williams (1958) belong to *T. trivalvis*.

Occurrence. Infrequent, Assemblages II to IV; Upper Viséan and Namurian.

Genus TRIPARTITES (Schemel) Potonié and Kremp 1954

Type species. *T. vetustus* Schemel 1950.

Diagnosis (from Potonié and Kremp 1954, p. 154. Translation). Trilete isospores, or microspores, approximately triangular at equator. Exine at the angles broadens to form auriculae (radial crassitudes) generally much larger and more lobate (or spatulate) than in *Triquitrites*—hence virtually tri-lobal at equator, not unlike trefoil. Auriculae are often found to be radially plicated (unlike *Triquitrites*) due to their more membranous character, when they may sometimes also be rather short and broad. The auriculae may be joined at the equator by a flange.

Remarks. Prior to 1950 recognized by Reinsch, Naumova, and other workers. For discussion of the early history of these forms see Schemel (1950, p. 243) and Potonié (1956, p. 55). Staplin (1960, p. 26) has tentatively subdivided the genus into two groups—Section A: forms in which the margin of the spore body does not bear a thickened continuous girdle, but may be limbate, or bear a narrow flange interradially that, in part, can be distally attached. Section B: forms in which the auriculae are part of a distinct continuous girdle surrounding and slightly overlapping the central body.

Comparison. Differs from *Triquitrites* in shape, size, and plication of radial crassitudes.

Affinity. Unknown.

Tripartites nonguerickei Potonié and Kremp 1956

Plate 13, figs. 1–3

1943 *Triletes* (*Zonales*) *guerickei* Horst (thesis), pl. 7, fig. 60.
1955 *Ahrensisporites guerickei* Potonié and Kremp; Horst, p. 178, pl. 23, fig. 60.
1956 *Tripartites nonguerickei* Potonié and Kremp, p. 92.

Holotype. Horst 1955, pl. 23, fig. 60. Preparation III41, 14·7 65·3.

Type locality. Hermann Seam, Porubaer Beds, Moravska-Ostrava; Namurian A.

Diagnosis. Amb subtriangular, angles broadly rounded with crenulate margins; sides straight or concave with smooth to irregularly undulate margins. Laesurae simple, straight, approximately two-thirds radius. Radial crassitudes with distal radial plications. Radial length, or height 5–12 μ; width 20–30 μ, often connected interradially by a flange about 2–3 μ in width (not to be confused with marginal rim due to exine thickness) attached distally, but more or less coinciding with margin of the spore. Exine finely to coarsely granulate, or even verrucate; ornament reduced on contact face. Exine about 2·5 μ thick.

Size in microns. (i) Holotype (not stated). (ii) 37(42)50, fum. HNO_3; Shale Seam at 663 ft. 6 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Distal ornament of radial crassitudes often of ridges or plications which are predominantly aligned radially and which may extend polewards for a short distance from the inner margin of the equatorial structure.

Remarks. One of the specimens figured by Horst (1955, pl. 23, fig. 60) as *Ahrensisporites guerickei* was made the type of *Tripartites nonguerickei* by Potonié and Kremp 1956. These authors did not, however, provide a diagnosis of the species.

Occurrence. Infrequent, sometimes frequent, Assemblages II to IV; Upper Viséan and Namurian.

Tripartites trilinguis (Horst) emend.

Plate 13, figs. 6–9

1943 *Triletes (Zonales) trilinguis* Horst (thesis), pl. 7, figs. 55, 56.
1955 *Tripartites trilinguis* (Horst) Potonié and Kremp; Horst, p. 176, pl. 23, figs. 55, 56.
1956 *Tripartites trilinguis* (Horst); Potonié and Kremp, p. 92.
1957*a* *Tripartites cristatus* Dybová and Jachowicz, p. 141, pl. 36, figs. 3, 4.
1957*a* *Tripartites rugosus* Dybová and Jachowicz, p. 139, pl. 35, figs. 1–4.
1957*a* *Tripartites trifoliatus* Dybová and Jachowicz, p. 140, pl. 36, figs. 1, 2.
1958 *Tripartites ianthina* Butterworth and Williams, p. 373, pl. 3, figs. 7, 8.

Holotype. Horst 1955, pl. 23, fig. 56. Preparation IV39, 30·4 68·2.

Type locality. Flora Seam, Michael Colliery, Moravska-Ostrava; Namurian A.

Diagnosis (emended from Horst 1955, p. 176). Amb trifoliate, margin crenulate. Laesurae simple, straight or slightly flexuose, one-half to two-thirds radius. Radial crassitudes prominent, rounded, plicated or corrugated, occupying greater part of the amb; radial length or height 2·5–6 μ; width 24–32 μ. Interradial areas short and deeply incised. Radial thickenings often distinctly connected by a narrow interradial marginal zone. Exine laevigate proximally; distally, small, well-spaced grana occur in radial areas in an arc between ends of laesurae and thickenings. Exine of spore body thin.

Size in microns. (i) Holotype 51; 41–80, fum. HNO_3 (Horst 1955). (ii) 32(44)51, fum. HNO_3 (Butterworth and Will. 1958); Namurian A.

EXPLANATION OF PLATE 13

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Tripartites nonguerickei* Potonié and Kremp 1956. 1, slide 143, 37·1 109·4. 2, slide 144, 38·2 110·3. 3, slide 145, 52·8 110·6.

Figs. 4, 5. *T. vetustus* Schemel 1950. 4, slide 3, 32·3 108·4. 5, slide 148, 37·8 109·6.

Figs. 6–9. *T. trilinguis* (Horst) emend. 6, slide 146, 45·8 106·5. 7, distal surface; slide 146, 31·5 112·9. 8, distal surface; slide 146, 20·5 108·9. 9, slide 147, 33·9 110·9.

Fig. 10. *Mooreisporites fustis* Neves 1958. Distal surface; slide 149, 39·7 105·2.

Figs. 11, 12. *M.* cf. *inusitatus* (Kosanke) Neves 1958. 11, slide 133, 36·8 118·0. 12, slide 133, 27·5 103·5.

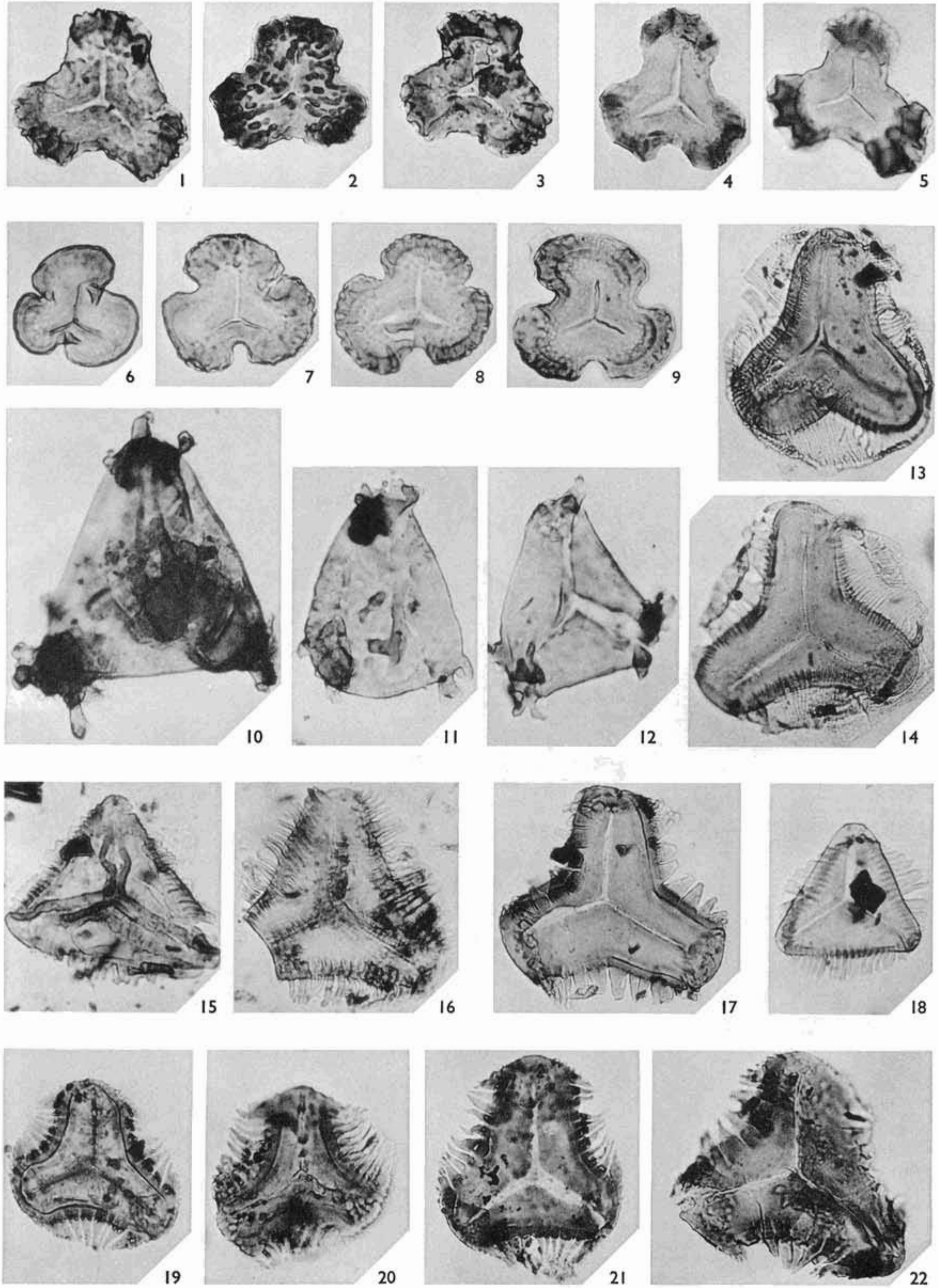
Figs. 13, 14. *Reinschospora speciosa* (Loose) Schopf, Wilson, and Bentall 1944. 13, slide 150, 25·0 114·1. 14, slide 151, 57·8 103·0.

Figs. 15, 16. *R. triangularis* Kosanke 1950. 15, slide 152, 40·3 115·4. 16, distal surface; slide 153, 36·8 102·4.

Fig. 17. *Diatomozonotriletes saetosus* (Hacquebard and Barss) Hughes and Playford 1961. Slide 73, 35·3 106·8.

Fig. 18. *D. ubertus* Ishchenko 1956. Slide 76, 38·4 119·8.

Figs. 19–22. *D. cervicornutus* (Staplin) Playford 1963. 19, slide 154, 38·1 107·6. 20, slide 155, 31·2 111·9. 21, slide T93/1, 48·8 103·1. 22, slide 156, 40·5 112·6.



SMITH and BUTTERWORTH, British Carboniferous miospores

Remarks. Dybová and Jachowicz subdivided *T. trilinguis* into two species *T. rugosus* and *T. trifoliatus* on a basis of exine ornamentation. Sullivan and Neves (1964, p. 1089) consider that a third species, *T. cristatus* Dybová and Jachowicz, is also within the limits of specific variation of *T. trilinguis* and suggest that the retention of the three species of Dybová and Jachowicz is unnecessary. *T. ianthina* is considered to be a synonym of *T. trilinguis* despite the difference in size, noted by Butterworth and Williams. According to Staplin (1960, p. 26) spores of this type do not possess 'a thickened continuous girdle but may be limbate or bear a narrow flange interradially that in part can be distally attached'.

Comparison. *Trilobozonotriletes aductus* Ishchenko 1956 (p. 95, pl. 18, figs. 223, 224) appears very similar to *Tripartites trilinguis* and the two forms may be conspecific. In *T. trilinguis* the radial crassitudes project less, but occupy a greater proportion of the amb than in *T. nonguerickei* Potonié and Kremp. The exine is thinner in *T. trilinguis*.

Occurrence. Infrequent or sometimes frequent, Assemblages II to IV; Upper Viséan and Namurian.

Tripartites vetustus Schemel 1950

Plate 13, figs. 4, 5

Holotype. Schemel 1950, pl. 40, fig. 11. Preparation in collection of Missouri Geological Survey.

Type locality. 24 in. coal about 550 ft. above top of Madison Formation, Daggett County, Utah, U.S.A.; Mississippian.

Diagnosis (from description in Schemel 1950, p. 242). Amb subtriangular, angles broadly rounded or blunt, interradial margins moderately to strongly concave. Laesurae 1–2 μ shorter than radius in length. Equatorial flange widest at corners and very narrow, or absent, in the interradial regions; plicated in the widest portions. Flange laevigate; remainder of exine laevigate to minutely punctate.

Size in microns. (i) Holotype (not stated): 30–40; body 19–25; height of flange 10–15, maceration method not known (Schemel 1950). (ii) 30(42)50 equatorial flange, height 6–12; length 20–40 (15 specimens) fum. HNO_3; upper bed of Kittlepurse Seam at 4,108 ft. 11 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A.

Description. The sculptural elements of the equatorial flange are not always clearly aligned radially. Sullivan and Neves (1964, p. 1088), following an examination of specimens of *T. vetustus* from the type preparation, states that the folding of the exine at the angles is confined to the distal surface of the equatorial flange.

Comparison. *T. vetustus* differs from *T. nonguerickei* Potonié and Kremp in possessing a thinner, laevigate exine and in the absence of a marked interradial connexion between the radial crassitudes. *Trilobozonotriletes annosus* Ishchenko 1956 (p. 96, pl. 18, fig. 227) and *T. apartus* Ishchenko 1958 (p. 93, pl. 12, fig. 156) appear to fall within the range of variation recorded for *Tripartites vetustus* in British coals. *T. trilinguis* (Horst) emend. possesses a distinct interradial marginal zone and localized granulate ornament.

Occurrence. Infrequent, Assemblages II to IV; Upper Viséan and Namurian.

Genus MOOREISPORITES Neves 1958

Type species. M. fustis Neves 1958.

Diagnosis (Neves 1958, p. 7). 'Trilete isospores or microspores, equatorial outline triangular. The apices bear baculae or blunted cone-like projections. The bases of these elements are often fused into a thickened bar or pad which may lie at the equator or be displaced slightly on to one of the polar hemispheres, more frequently the distal hemisphere. Where the thickening is seen at the equator it may simulate apical thickening. Baculae or cones are commonly dispersed irregularly over both proximal and distal surfaces of the spore.'

Comparison. Triquitrites may have radially projecting ornament but the angles are invariably thickened to form radial crassitudes.

Affinity. Unknown.

Mooreisporites fustis Neves 1958

Plate 13, fig. 10

Holotype. Neves 1958, pl. 1, fig. 1. Preparation F 746, reference 648134.

Type locality. Gastrioceras subcrenatum marine shales, The Wash, Quarnford, North Staffordshire Coalfields, England; Namurian C.

Diagnosis (Neves 1958, p. 7). '. . . tetrad rays up to one-half radius of spore body, apices ornamented with well-developed, thick baculae, similar elements may be dispersed on remainder of spore body.'

Size in microns. (i) Holotype 88 × 76; 60–90, Schulze and KOH (Neves 1958). (ii) 40(46)54 (7 specimens) fum. HNO_3; Gubeon Seam at 100 ft. 2 in., Common Gate No. 1 borehole, Northumberland Coalfield, England; Westphalian A. (iii) 46 μ (1 specimen) fum. HNO_3; Norton Seam at 2684 ft., Colston Bassett (British Petroleum Co. Ltd.) borehole, Nottinghamshire Coalfield, England; Westphalian A. (iv) 63, 70 (2 specimens) fum. HNO_3; Lethemwell Seam, Frances Colliery, East Fife Coalfield, Scotland; ? Namurian.

Description. Amb triangular, sides straight, angles narrowly rounded. Laesurae about one-half of spore radius, flexuose, frequently open. Triangular angles with bacula, up to 16 μ long, 5–9 μ wide, branching; bases frequently joined to form a thickened pad either on the amb, or slightly towards the distal pole; similar bacula and verrucae present on distal and proximal surfaces of the exine, particularly at the distal pole. Exine approximately 2 μ thick, occasionally folded.

Remarks. The specimens from the Gubeon Seam, Northumberland Coalfield, are smaller than those from the type locality but are otherwise similar.

Occurrence. Infrequent, Assemblages V to VIII; ? Namurian to Westphalian B.

Mooreisporites inusitatus (Kosanke) Neves 1958

1950 *Triquitrites inusitatus* Kosanke, p. 39, pl. 8, fig. 7.
1958 *Mooreisporites inusitatus* (Kosanke); Neves, p. 8.

Holotype. Kosanke 1950, pl. 8, fig. 7. Preparation 603–C, slide 4.

Type locality. No. 2 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 39). Amb triangular, sides straight. Trilete mark, lips and commissure distinct; rays of holotype 15–17 μ in length. Radial ? thickening of several processes averaging rather more than 8 μ in length; width variable due to fusion of two processes. Exine laevigate to minutely granulate; 2–3 μ in thickness.

Size in microns. Holotype 67·2×65·1; 60·5–73, Schulze and 10% KOH (Kosanke 1950).

Mooreisporites cf. *inusitatus* (Kosanke) Neves 1958

Plate 13, figs. 11, 12

Size in microns. 43(51)59 (10 specimens) fum. HNO_3; seam at 1,252 ft. 1 in., Apley Barn borehole, Oxfordshire Coalfield, England; Westphalian D.

Description. Amb triangular, sides straight or slightly convex. Laesurae simple, three-quarters of spore radius in length. Ornament of bacula, up to 10 μ long, 5 μ wide, mainly on the angles; bacula may bifurcate and up to 6 be joined at their bases to simulate a radial thickening of the exine.

Comparison. Differs from the type only in its smaller size, which may be in part due to the use of different reagents in maceration. *M. fustis* has a more pronounced ornament and frequently has a baculum, or group of bacula, on the distal pole. *Triquitrites additus* Wilson and Hoffmeister 1956 (p. 24, pl. 3, figs. 6–9) also has bacula at the angles, but is smaller (35–45 μ) than the present specimens and has arcuate thickenings at the angles and ridged laesurae.

Occurrence. Infrequent, Assemblage XI; Etruria Marl of North Staffordshire (? Westphalian C) and Westphalian D.

Infraturma TRICRASSATI Dettmann 1963
Genus REINSCHOSPORA Schopf, Wilson, and Bentall 1944

Type species. *R. speciosa* (Loose) Schopf, Wilson, and Bentall 1944.

Diagnosis (Potonié and Kremp 1956, p. 131; translation). 'Trilete isospores or microspores. Amb subtriangular, angles rounded. A zona (corona), formed of more or less free to coalescing fimbriae, is attached a little to the proximal side of the equator. The zona is broadest at the centre of the sides and narrowest or entirely absent at the angles of the triangular spore body.'

Comparison. *Diatomozonotriletes* (Naumova) Playford possesses a corona of relatively coarse, strongly developed setae but is otherwise similar to *Reinschospora*.

Affinity. Unknown.

Reinschospora speciosa (Loose) Schopf, Wilson, and Bentall 1944

Plate 13, figs. 13, 14

1934 *Alati-sporites speciosus* Loose, p. 151, pl. 7, fig. 1.
non 1938 *Zonotriletes speciosus* (Loose); Waltz in Luber and Waltz, pl. 4, fig. 48 and pl. A, fig. 9.
1944 *Reinschospora bellitas* Bentall in Schopf, Wilson, and Bentall, p. 53, fig. 2.

Holotype. Potonié and Kremp 1956, pl. 19, fig. 419, after Loose. Preparation IV45, f_4 (ul).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from Potonié and Kremp 1956, p. 132). Amb of corona roughly circular; amb of laevigate central body distinctly triangular with well-rounded angles and more or less concave sides. Laesurae reach almost to the equator of central body. The equator has a fairly delicate membranous corona decreasing in width towards the angles of the body. The corona tends to be attached proximally, especially interradially. The corona has marked radial striations and is composed of fibres which are prone to radial tearing. At its broadest the corona measures about one-half the maximum radius of the central body.

Size in microns. (i) Holotype 81, Schulze and KOH (the size of 54 given in Loose 1934 is a printing error according to Potonié and Kremp 1956, p. 132). (ii) Spore body 56(58)60 (8 specimens) fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb of corona rounded-triangular to circular, spore body triangular with markedly concave sides and rounded angles. Laesurae simple, straight, slightly shorter than maximum body radius, range 28–32 μ. Corona composed of narrow setae about 1 μ in width and more or less in lateral contact throughout their length. Corona attached to spore body just proximally of the equator but in compressed spores its inner edge may lie interradially up to 7 μ from the amb. Maximum width of corona (including overlap) 17–28 μ. Radially the corona may be as narrow as 2 μ and be attached nearer the proximal pole so that on compression it may lie across the angles of the body. Exine moderately thick; laevigate or scabrate. Folding of body infrequent.

Comparison. In *R. magnifica* Kosanke 1950 (p. 42, pl. 10, fig. 2) the corona comprises discrete elements and the angles are broader than in *R. speciosa*. *R. punctata* Kosanke 1950 (p. 43, pl. 10, fig. 1) has a spore body with punctate ornament.

Occurrence. Infrequent, Assemblages V to IX; Westphalian A to C.

Reinschospora triangularis Kosanke 1950

Plate 13, figs. 15, 16

Holotype. Kosanke 1950, pl. 9, figs. 6, 7. Preparation 573, slide 2.

Type locality. Carlinville Coal, Macoupin County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from Kosanke 1950, p. 43). Amb of corona subcircular, amb of spore body triangular; sides of body slightly convex, angles pointed; in equatorial view spore body flattened to elliptical. Laesurae with lips, extend nearly to margin of spore body. Setae in radial positions extend 5–6 μ beyond spore wall; interradially setae up to 12·6 μ long and 1–1·5 μ wide at base, extending as much as 7·3 μ into spore coat just above the equator proximally, frequently partate with apical knobs. Exine laevigate (slightly granulate under oil).

Size in microns. (i) Holotype (including corona) 74×74; 79×78 to 66×66, Schulze and 10% KOH (Kosanke 1950). (ii) Body dimensions 56, 56, and 60 (3 specimens) fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Sides of body straight or slightly concave. Each commissure is accompanied by two low parallel bands of thickening (?folds) each 2–3 μ in width. Setae occur as a corona and as a single row along each radius from the distal pole to each angle, almost reaching the margin of the spore body. In the interradial positions the setae of the corona are in contact at their bases but taper so that they are free throughout their length and sometimes partate; maximum length up to 17 μ, overlapping body by as much as 7 μ. In the radial positions the setae are greatly reduced or absent. Distal setae are shorter, up to 6·5 μ in length.

Remarks. Kosanke does not mention the distal setae although they can be detected in the photograph of the holotype (Kosanke 1950, pl. 9, fig. 6). The setae in the small number of British spores of this type which have been examined did not possess apical knobs.

Comparison. *R. triangularis* differs from *R. speciosa* in possessing fairly straight sides, ridged laesurae, and setae which are discrete, often partate, and which also occur as distal ornament.

Occurrence. Infrequent. Range uncertain but has been recorded from Assemblage VIII from the South Wales and Yorkshire Coalfields; Westphalian B.

Genus DIATOMOZONOTRILETES (Naumova) Playford 1963

Type species. *D. saetosus* (Hacquebard and Barss) Hughes and Playford 1961.

Diagnosis (Playford 1963, p. 646). 'Microspores radial, trilete; spore body triangular or subtriangular in equatorial outline. Laesurae usually well defined and long; simple or accompanied by lips. Spore body almost entirely encompassed by prominent zona (corona) consisting of numerous strongly developed, mainly discrete saetae (fimbriae) emanating radially from equatorial margin of spore body. Saetae are particularly well developed in central interradial equatorial regions, characteristically exhibiting a gradual diminution in size towards the triangular apices of the spore, where they may be either absent or considerably reduced. Saetae pointed or blunt; sometimes fused, at least in part, but always remain recognizable individually within the corona as distinct structural entities. Spore body often sculptured, particularly on distal surface.'

Comparison. Distinguished from *Reinschospora* Schopf, Wilson, and Bentall by the coarser setae comprising its corona. *Procoronaspora* Butterworth and Williams has a prominent ornament on the distal surface and on the interradial regions of the equatorial margin, but has no corona.

Affinity. Unknown.

Diatomozonotriletes cervicornutus (Staplin) Playford 1963

Plate 13, figs. 19–22

1960 *Reinschospora cervicornuta* Staplin, p. 24, pl. 5, figs. 1–3.

Holotype. Staplin 1960, pl. 5, figs. 1, 2. Preparation Imp. 1707, 4–35·3 122·4.

Type locality. Shale at 4,385 ft., Imperial Belloy borehole 12–14, Alberta, Canada; Golata Formation, Chester Series.

Diagnosis (Staplin 1960, p. 24). 'Spores trilete; outline circular to subtriangular; spore body concavely triangular with narrow thickened margin; fimbriae fused except for 4–5 at each interradial position, the shorter fimbriae towards the radial corner fused into a mass that bears numerous apiculae (resembling the neck of a moose); on the distal face, wedge-shaped patches of apiculae at each radial corner point towards the distal pole and may be continued as a single line of apiculae to a central distal mass of 15–20 apiculae; proximal face laevigate; sutures distinct, ratio four-fifths, lips very narrow and slightly raised, the trilete mark often gaping. . . .'

Size in microns. (i) Holotype 55, body 48; total diameter 50–58, maceration method not known (Staplin 1960). (ii) Total diameter 56–66; body 44–54 (6 specimens) fum. HNO_3; Shilbottle and Greenses Seams, Northumberland Coalfield, England and from the seam at 191 ft. 3 in., No. 1 Shaft, Seafield Colliery, East Fife Coalfield, Scotland; Viséan.

Description. Amb triangular, angles rounded. Sides concave. Laesurae distinct, extending almost to angles, margins slightly thickened, frequently open. Corona of broad setae, up to 5 μ in diameter at base and up to 16 μ long in interradial areas; bases and tips sometimes bifurcated; attached to distal surface. The five or six longest setae in median interradial position discrete, radially disposed to spore body; setae nearest angles shorter, disposed tangentially to the angles and drawn in towards the distal pole, leaving a wedge-shaped area at each angle free from setae; wedge-shaped area conate, coni sometimes extending over distal surface, roughly following lines of laesurae; variable number of coni present at distal pole. Exine thick, folding infrequent.

Remarks. The species was transferred to *Diatomozonotriletes* by Playford (1963, p. 646) on account of the coarseness of its setae. Five of the six specimens noted in the present investigations are larger than those described by Staplin and have less concave sides than the specimens he figures; in other repects they are similar.

Occurrence. Infrequent, Assemblage II; Northumberland and East Fife Coalfields; Viséan.

Diatomozonotriletes saetosus (Hacquebard and Barss) Hughes and Playford 1961

Plate 13, fig. 17

1938 *Zonotriletes speciosus* (*non* Loose) Waltz in Luber and Waltz, p. 14, pl. 4, fig. 48 and pl. A, fig. 9.
1956 *Diatomozonotriletes speciosus* (*non* Loose); Ishchenko, p. 99, pl. 19, figs. 239–41.
1957 *Reinschospora saetosus* Hacquebard and Barss, p. 41, pl. 6, fig. 3.
1961 *Diatomozonotriletes saetosus* (Hacquebard and Barss); Hughes and Playford, p. 40, pl. 4, figs. 14, 15.

Holotype. Hacquebard and Barss 1957, pl. 6, fig. 3. Preparation NAH—slide 7A, 47·4 126·8.

Type locality. 4 ft. coal, South Nahanni River area, Northwest Territories, Canada; Upper Mississippian.

Diagnosis (description in Playford 1963, p. 647). 'Spores radial, trilete; spore body subtriangular with concave sides and rounded to truncated apices. Laesurae distinct, straight, extending almost to equatorial margin; simple or bordered by narrow, slightly thickened lips. Prominent corona comprising nine to fifteen discrete, typically pointed saetae projecting laterally from each interradial portion of the spore-body equator. Saetae 2·5–5 μ broad at base, 3–22 μ long; attain maximum length in central interradial region, diminishing uniformly towards smooth triangular apices. Spore body usually entirely laevigate, occasionally finely granulate on distal surface. Exine thick (2–4 μ), often distinctly thinner at apices.'

Size in microns. (i) Holotype 44·8 × 41·6; longest diameter 45–58, Schulze and KOH (Hacquebard and Barss 1957). (ii) Equatorial diameter of spore body 36(49)63, Schulze and NH_4OH (Playford 1963). (iii) Body diameter 48–55 (6 specimens) fum. HNO_3; Shilbottle Seam, several localities, Northumberland Coalfield, England; Viséan.

Remarks. The specimens from the Shilbottle Seam approximate fairly closely to the diagnosis but the triangular angles of the spore bodies are invariably truncated. The setae diminish in size towards the angles, where they are absent; they are connected by a line of residual setae or coarse grana, crossing the angles and deflected slightly polewards; the grana appear to be present on both the distal and proximal surfaces of the spore body and may represent the limits of 'caps' at the angles. This feature is apparent on two of the specimens figured by Playford (1963, pl. 93, figs. 4, 5). It is not so marked as the granulate, wedge-shaped areas at the angles of *D. cervicornutus* (Staplin) Playford 1963.

Comparison. Distinguished from other species by its laevigate distal surface and coarse setae.

Occurrence. Infrequent, Assemblage II; Northumberland Coalfield and Central Coalfield, Scotland; Viséan.

Diatomozonotriletes ubertus Ishchenko 1956

Plate 13, fig. 18

Holotype. Not specified.

Type locality. Western extension of Donetz Basin, U.S.S.R.; Viséan.

Diagnosis (from Ishchenko 1958, p. 96; translation). 'Outline of spore body triangular, angles more or less rounded, sides almost straight or weakly convex. Suture triradiate with slightly thickened margin. Length of rays a little less than the spore body radius. Corona consists of separate segments, like sharp teeth, radially disposed around the spore equator. . . . Exine smooth. . . . Length of separate segments of corona attains 5 μ. Length of setae unequal, greatest at the middle parts of the sides, least close to the angles of the spore body. No corona present at the angles.'

Size in microns. (i) 35–40 (Ishchenko 1958). (ii) 28(35)42 (24 specimens) fum. HNO_3; Shilbottle Seam at 201 ft. 1 in., New Moor Hall borehole, Northumberland Coalfield, England; Viséan.

Description. Amb triangular, angles narrow, sides slightly convex. Laesurae straight; extent almost that of spore radius; margins slightly thickened. Corona of narrow, tapering setae, occasionally bifurcating, blunt or swollen at tips; these are up to 2 μ wide at base and up to 7–12 μ long in the interradial areas; they are much reduced at the angles, 12 to 20 being present on each interradial margin. The corona is attached to the distal surface of the body, extending across, rather than around, the angles, which may be granulate. Proximal surface laevigate; distal surface laevigate apart from a single boss, which is triangular in basal outline. Forked spina, or small group of spinae, form a triangle at the distal pole. Folding infrequent; exine frequently torn.

Remarks. Ishchenko does not mention any ornament at the distal pole but there is some indication of this in his drawing (Ishchenko 1958, pl. 13, fig. 164); between 15 and 20 setae are represented along each interradial margin.

Comparison. D. ubertus has a distinctive form of distal ornament and is smaller than most other species of the genus.

Occurrence. Infrequent, Assemblage II, Northumberland Coalfield; Viséan.

Infraturma CINGULATI (Potonié and Klaus) Dettmann 1963
Genus STENOZONOTRILETES (Naumova) Potonié 1958

Type species. S. conformis Naumova 1953.

Diagnosis (Hacquebard 1957, p. 313). 'Spores radial, trilete; triangular, subcircular or circular in proximal view; trilete not always distinct, rays long, at least three-fourths radius of central area; rim narrow, rounded (not cuneiform) surrounding central area like a tire around a wheel; ornamentation of central area infragranulose, punctate or smooth, rim essentially smooth to slightly rough. . . .'

Comparison. Stenozonotriletes differs from *Lycospora* and *Densosporites* in that in polar section the cingulum is of more or less uniform thickness and does not show any flange development.

Remarks. Naumova used *Stenozonotriletes* in 1937 without naming a type. As originally defined the genus included spores without perispore and possessing a narrow rim. It probably included forms assigned by other workers to *Lycospora* and in order to exclude such forms Hacquebard (1957) emended Naumova's definition of *Stenozonotriletes* to include only forms in which the cingulum is rounded rather than cuneiform in polar section. Hacquebard did not, however, name a type.

Potonié in 1958, apparently without knowing of Hacquebard's treatment of *Stenozonotriletes*, named a type and provided a further diagnosis which, however, does not differ significantly from that of Hacquebard. In comparing *Lycospora* with *Stenozonotriletes* Potonié refers to the absence of prominent ornament in *Stenozonotriletes* but does not mention the structure of the cingulum.

In assigning spores to this genus care must be taken to avoid confusing the appearance of a cingulum in polar compression with the marginal rim of thick-walled spores. The distinction is best made by observing spores preserved in equatorial compression.

Affinity. Unknown.

?*Stenozonotriletes bracteolus* (Butterworth and Williams) comb. nov.

Plate 14, figs. 1–4

1958 *Lycospora bracteola* Butterworth and Williams, p. 375, pl. 3, figs. 26, 27.

Holotype. Plate 14, fig. 1. Preparation T57/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Lower Hirst Seam at 1,854 ft. 2 in., Kincardine borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 375). Amb circular to rounded-triangular, outline smooth to denticulate. Laesurae straight, extending to inner margin of cingulum. Exine covered by small grana. Cingulum approximately one-quarter of total spore radius.

Size in microns. Holotype 45; 36(43)54, Schulze (Butterworth and Will. 1958).

Description. Laesurae weakly ridged, not exceeding 2 μ in width and about 1 μ in height; one or more of the laesurae may be flexuose, sometimes extending beyond inner margin of cingulum. Grana do not exceed 1 μ in height; may be densely or relatively loosely distributed. Cingulum without flange-like extension; in polar compression 3–6 μ in width or one-quarter to one-sixth of radius; inner margin sometimes sharply defined. Narrow, arcuate folds, or ridges, may connect laesurae to the cingulum or to each other. Exine moderately thick.

Remarks. This species is tentatively assigned to *Stenozonotriletes* on account of the structure of the cingulum, which shows no centrifugal development and which in section is assumed to be more or less uniform in thickness. The ornament, however, is possibly too coarse for the species to be retained in *Stenozonotriletes* as defined at present. An ornamented cingulum is found in *Aneurospora* Streel 1964, but in this genus the cingulum is less strongly developed than in *S. bracteolus*.

EXPLANATION OF PLATE 14

All figures $\times$500, and of proximal surface, unless otherwise stated.

Figs. 1–4. ?*Stenozonotriletes bracteolus* (Butterworth and Williams) comb. nov. 1, Holotype; slide T57/1, 35·2 111·0. 2, oblique compression showing slight projection of cingulum at equator; slide T57/1, 36·4 110·2. 3, 4, Isotype, proximal and distal surfaces respectively; slide T57/2.

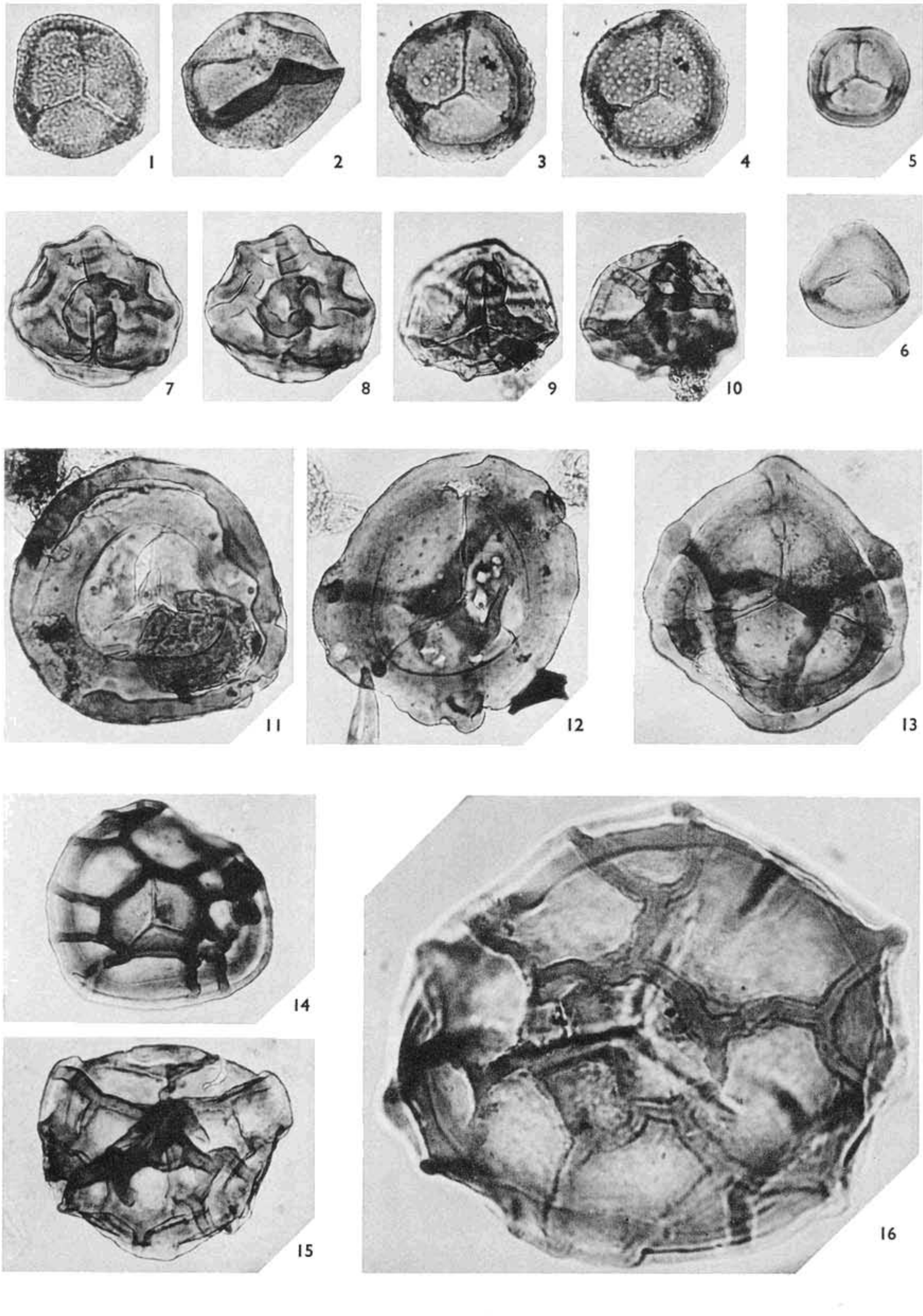
Figs. 5, 6. *S. lycosporoides* (Butterworth and Williams) comb. nov. 5, Holotype; slide T58/1. 6, Isotype, oblique compression, no marked projection of cingulum at equator; slide T58/3.

Figs. 7–10. *Knoxisporites cinctus* (Waltz) Butterworth and Williams 1958. 7, 8, proximal and distal surfaces respectively; slide 157, 38·3 110·2. 9, 10, proximal and distal surfaces respectively; slide 158, 27·3 106·2.

Figs. 11, 12. *Reticulatisporites carnosus* (Knox) Neves 1964. 11, Neotype; slide T47/1. 12, slide 159, 46·0 115·3.

Fig. 13. *R. polygonalis* (Ibrahim) emend. Slide 162, 51·8 114·1.

Figs. 14–16. *R. reticulatus* (Ibrahim) Ibrahim 1933. 14, slide 160, 26·6 111·5. 15, oblique compression showing projection of cingulum beyond laevigate proximal surface; slide 161, 40·7 105·6. 16, Holotype, medium focus, $\times$1,000.



SMITH and BUTTERWORTH, British Carboniferous miospores

Comparison. Spores referred to *Lycospora* cf. *micrograna* Hacquebard and Barss in Staplin 1960 (p. 19, pl. 4, fig. 12) and *L. tenebricosa* Staplin 1960 (p. 20, pl. 4, figs. 15, 16) fall within the morphological variation of specimens referred here to *S. bracteolus*.

Occurrence. Infrequent or frequent, Assemblages III and IV; Namurian. Recorded from coal and shale in Lower Oil Shale Group of Scotland (Love 1960); Viséan.

Stenozonotriletes lycosporoides (Butterworth and Williams) comb. nov.

Plate 14, figs. 5, 6

1958 *Anulatisporites lycosporoides* Butterworth and Williams, p. 378, pl. 3, figs. 28, 29.

Holotype. Plate 14, fig. 5. Preparation T58/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Chapelgreen Seam at 314 ft. 2 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 378). Amb circular to subcircular; margin smooth or very finely notched. Laesurae generally simple and straight, but may be ridged up to 1 μ in width; extend to polar margin of cingulum. Cingulum 2·5–6 μ in width or one-fifth to one-quarter of spore radius. Exine, including cingulum, laevigate or faintly granulate distally. Exine, except for cingulum, thin.

Size in microns. Holotype 33; 26(34)42 (23 specimens), fum. HNO_3 (Butterworth and Will. 1958).

Description. Laesurae vary in prominence; in the holotype they are distinctly ridged and one laesura is flexuose; in some specimens they are faint. Laesurae may extend on to cingulum.

Remarks. Butterworth and Williams (1958) refer to a narrow, solid cingulum but in polar section the cingulum is considered to be thin and approximately uniform in thickness since in lateral compression it does not project beyond the outline of the spore body.

Comparison. Although there is some overlap in the size ranges of *S. lycosporoides* and *S. bracteolus*, the cingulum in the latter is generally distinctly granulate. *Lycospora granianellatus* Staplin 1960 (p. 19, pl. 4, fig. 10) possesses a minutely granulate cingulum and Staplin uses this character to separate the species from *S. lycosporoides*. The cingulum in the latter sometimes appears minutely granulate. The two species may be conspecific although the British specimens considerably exceed the size range of 22–28 μ quoted by Staplin for *L. granianellatus*.

Occurrence. Infrequent, Assemblages III and IV; Namurian. Recorded from Lower Oil Shale Group of Scotland (Love 1960); Viséan.

Genus KNOXISPORITES (Potonié and Kremp) Neves and Playford 1961

Type species. K. hageni Potonié and Kremp 1954.

Diagnosis (Neves and Playford 1961, Report to Commission Internationale de Microflore du Paléozoïque). 'Trilete isospores or microspores with an equatorial flange (cingulum) which is of more or less uniform thickness throughout its width, possibly tapering slightly in the immediate vicinity of the equator. The distal hemisphere of the spores is characterised by variably disposed radial and/or concentric bands of thickening. The equatorial outline of the cingulum is circular to rounded-triangular, more or less conformable with that of the spore body, departing from it locally where the fusion of radial elements and the flange produces a swollen node of thickening. Small thickened lobes may project from the cingulum on to the proximal surface of the spore body.'

Comparison. Differs from *Stenozonotriletes* (with similar equatorial structure) in possessing distal bars of thickening and from *Cincturasporites* by the absence of an appreciable poleward overlap of the spore body.

Remarks. Neves and Playford (1961) have drawn attention to the existence of two basic structural patterns of flange development within the forms formerly assigned to *Knoxisporites*. They accordingly emended the diagnosis of Potonié and Kremp (1954, p. 147) to restrict the genus to forms closely resembling the type of construction found in the type species, *K. hageni*. The above diagnosis is almost identical with that of Neves 1961.

Affinity. Unknown.

Knoxisporites cinctus (Waltz) Butterworth and Williams 1958

Plate 14, figs. 7–10

1938 *Zonotriletes cinctus* Waltz in Luber and Waltz, pl. 2, fig. 27.
1956 *Anulatisporites cinctus* (Waltz); Potonié and Kremp, p. 111.
1958 *Euryzonotriletes cinctus* (Waltz); Ishchenko, Table 3.
1958 *Knoxisporites cinctus* (Waltz); Butterworth and Williams, p. 370, pl. 2, figs. 11–13.

Holotype. None designated in the literature.

Diagnosis (from Butterworth and Williams 1958, p. 370). Amb subcircular, subangular, or polygonal; margin smooth to undulate. Laesurae straight, extend for three-quarters of radius reaching inner margin of cingulum. Proximally six broad muri radiate from proximal pole in three pairs, each enclosing a laesura. Distal reticulation comprises relatively broad muri, rounded in cross-section. Lumina variable in shape. Ornament covers considerable part of surface of spore. Exine moderately thick.

Size in microns. (i) 40–60, fum. HNO_3 (Butterworth and Will. 1958); Scotland; Namurian A. (ii) 58(75)92 (16 specimens) HF, dil. HCl, and conc. HNO_3 (Hughes and Play. 1961); Spitsbergen; Lower Carboniferous.

Description. Muri and cingulum (in polar compression) of similar width, 5–11 μ. Distal lumina range up to 15 μ in diameter.

Comparison. *Knoxisporites literatus* (Waltz) Playford 1963 (p. 634, pl. 90, figs. 7, 8) also has laesurae bordered by broad, flat 'lips' but differs from *K. cinctus* in possessing irregularly disposed and often loosely connected distal muri.

Occurrence. Infrequent, Assemblage III; Namurian A.

Genus RETICULATISPORITES (Ibrahim) Neves 1964

Type species. R. reticulatus Ibrahim 1932.

Diagnosis (Neves 1964, p. 1066). 'Trilete isospores or microspores with a differentially thickened cingulum. Equatorial outline rounded triangular to somewhat polygonal; irregular embayments in the outline may occur particularly in poorly preserved, larger specimens. Outline of spore cavity triangular to sub-circular.

'Cingulum has a peripheral zone of thickening and a further band of thickening adjacent to, and slightly overlapping the spore cavity outline. Between the thickened bands the cingulum has a concentric zone in which the exine is relatively thinner. Thickened nodes commonly develop in the peripheral band of thickening, particularly in the inter-radial positions.

'The distal surface of the spores is distinguished by a network of muri [*R. reticulatus* and *R.* (*Knoxisporites*) *margarethae* (Hughes and Playford) comb. nov.] or by linear bars of exinal thickening [i.e. *Reticulatisporites polygonalis* (Ibrahim) Loose, 1934]. Bifurcation of the muri and linear thickenings is common and various patterns are to be found on the distal surface.'

Comparison. Knoxisporites and *Cincturasporites* differ from *Reticulatisporites* in possessing cinguli which do not show a tripartite structure in polar compression.

Remarks. Apart from the type species, spores corresponding to the above diagnosis were formerly included in *Knoxisporites*. They have been separated from that genus on the basis of the structure of the cingulum (Neves and Playford 1961, Report to Commission Internationale de Microflore du Paléozoïque).

The structure of the cingulum in this genus and in *Cincturasporites* has been demonstrated by Hughes, Dettmann, and Playford (1962) from polar microtome sections.

Affinity. Unknown.

Reticulatisporites carnosus (Knox) Neves 1964

Plate 14, figs. 11, 12

1939 Type 1 Millott, p. 15, fig. 1, text-fig. 6.
1942 C6 Knox, p. 6, text-fig. 3.
1950 *Cirratriradites carnosus* Knox, p. 329, pl. 19, fig. 290.
1958 *Knoxisporites carnosus* (Knox); Butterworth and Williams, p. 369, pl. 2, figs. 8–10.
1964 *Reticulatisporites carnosus* (Knox); Neves, p. 1067.

Neotype. Plate 14, fig. 11. Preparation T47/1 in collection of Coal Survey Laboratory, Sheffield. (This specimen was wrongly designated as the holotype by Butterworth and Williams 1958.)

Type locality. 9 in. coal at 256 ft. 11 in., Darnley No. 3 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 369). Amb broadly rounded-triangular to subcircular; margin usually smooth, occasionally undulate to uneven or highly involute. Laesurae simple, straight, reaching almost to inner margin of cingulum. Cingulum differentiated into three zones which vary in their proportions within a single spore. Area enclosed by cingulum circular to rounded-triangular. Exine laevigate to infragranulate, radial thickenings may be developed; exine moderately thick.

Size in microns. Neotype 92; 67(80)94, fum. HNO_3 (Butterworth and Will. 1958). Size of neotype in Butterworth and Williams (1958) is in error.

Description. Cingulum varies in width from 10 to 25 μ; the individual zones of thickening vary from 5 to 17 μ in width, the inner zone being broader and more prominent than the marginal zone. The thinner, median region may be reduced to a mere line. The radial thickenings, sometimes present on the distal surface, may take the form of a Y attached to the cingulum at interradial positions. Faint proximal thickenings may arise from the radial positions but they scarcely extend polewards beyond the cingulum.

Comparison. Distinguished from other species of the genus described here by the absence of any elaborate distal pattern of thickenings, although some specimens approach closely to the type of ornament found in *R. polygonalis*.

Occurrence. Infrequent, Assemblages III and IV; a single occurrence in Assemblage V, Nottinghamshire Coalfield; Namurian A to Lower Westphalian A.

Reticulatisporites polygonalis (Ibrahim) emend.

Plate 14, fig. 13

1932 *Sporonites polygonalis* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 8.
1933 *Laevigati-sporites polygonalis* Ibrahim, p. 19, pl. 1, fig. 8.
1934 *Reticulati-sporites polygonalis* Ibrahim; Loose, p. 155, pl. 7, fig. 16.
1955 *Knoxisporites polygonalis* (Ibrahim); Potonié and Kremp, p. 117, pl. 16, fig. 318, text-fig. 33.
1964 *Reticulatisporites polygonalis* (Ibrahim); Neves, p. 1066.

Holotype. Potonié and Kremp 1955, pl. 16, fig. 318 after Ibrahim. Preparation A40, b5 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from Potonié and Kremp 1955, p. 117). More or less polygonal in polar compression, but shape very variable due to oblique compression and folding; outline smooth and undulate, due to radial thickenings. Laesurae simple or, if ridged, elevation slight; one-half to two-thirds of radius. Three zones of cingulum clearly defined, the inner broader than the outer zone. The degree of separation of these thickened zones varies. Exine ornament on distal surface prominent, but reduced proximally; pattern varies in detail but distally consists essentially of a single triangle, or a more or less polygonal structure formed by the bands which connect to the cingulum at interradial positions by three prominent muri. Proximally three bands arising in radial positions pass polewards from the cingulum to meet the laesurae; bands of thickening may also pass towards the proximal pole for short distances from other positions on the cingulum. Exine laevigate or scabrate (?infrasculpture); moderately thick.

Size in microns. (i) Holotype 108, Schulze and KOH. (ii) 80–110, Schulze (Potonié and Kr. 1955). (iii) 79(91)102 (11 specimens) fum. HNO_3; seam at 2,015 ft. 4 in., Cotgrave Wolds borehole, Nottinghamshire Coalfield, England; Westphalian A.

Description. Laesurae may reach nearly to inner thickened margin of cingulum. In polar compression cingulum generally 10–15 μ in width, inner zone 3·5–7 μ, marginal zone 3·5–6 μ; the two zones may be almost in juxtaposition, or up to 5 μ apart. Width of distal bands 4–10 μ; width varies in any individual. Pattern of distal muri often distorted by folding.

Remarks. Potonié and Kremp (1955) probably examined few specimens since they record that the species was not found subsequent to Loose's work. It is necessary to emend and expand their diagnosis to take account of our present knowledge of the structure of the genus.

Comparison. *R. polygonalis* differs from *R. corporeus* (Loose) Neves 1964 in being somewhat larger and in possessing a distal ornament which does not form a reticulate pattern. *R. polygonalis* differs from *R. carnosus* in being more or less polygonal rather than round in shape, in lacking the involute margin, and in the narrower inner zone of the cingulum.

Occurrence. Infrequent, Assemblages V to IX (lowest seams); Westphalian A, B, and lowest part of C.

Reticulatisporites reticulatus (Ibrahim) Ibrahim 1933

Plate 14, figs. 14–16

1932 *Sporonites reticulatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 3.
1933 *Reticulati-sporites reticulatus* Ibrahim, p. 33, pl. 1, fig. 3.
1938 *Azonotriletes reticulatus* (Ibrahim); Luber in Luber and Waltz, pl. 7, fig. 99.

Holotype. Plate 14, fig. 16 after Ibrahim. Preparation B5, b2 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (expanded from Potonié and Kremp 1955, p. 112). Amb subcircular, subangular, or more or less polygonal. Outline smooth, somewhat modified by radial ornament. Laesurae simple, straight, one-half to two-thirds of radius. In polar compression cingulum clearly differentiated into three zones. Exine ornament comprises bands of thickening which extend a short distance from equator to proximal pole and form a reticulate pattern distally. Muri broader than high; number of distal muri reaching equator 6 to 15, rarely more. Exine of proximal face and distal lumina laevigate, moderately thick.

Size in microns. (i) Holotype 81, Schulze and KOH. (ii) 75–90, Schulze (Potonié and Kr. 1955). (iii) 74(82)94, Schulze and 5% KOH, 59(73)89, fum. HNO_3, Clown Seam, Shireoaks Colliery, Yorkshire Coalfield, England; Upper Westphalian B.

Description. In polar compression inner thickened zone of cingulum, 2·5–5 μ in width, separated from narrower, marginal zone by a thinner region 2–4 μ in width. Muri up to 5 μ in width and 2 μ in height. The distal pattern is very variable. In its simplest form the muri delimit a central polygonal area and six or seven surrounding marginal areas; the latter are formed by muri connecting the angles formed by the muri at the centre to the cingulum. A more complex pattern comprises several polygonal lumina and a correspondingly greater number of marginal lumina; the radiating muri may branch before reaching the equator. Lumina vary from 8 to 40 μ in diameter. The inner margin of the cingulum is often sharply delimited.

Remarks. Dr. Krutzsch of the Central Geological Institute in Berlin provided the authors with photographs of the holotype taken at different levels of focus under oil. These photographs, one of which is shown as Plate 14, fig. 16, clearly show the presence of a cingulum with the type of structure possessed by species formerly included in *Knoxisporites* and now assigned to *Reticulatisporites*. It is therefore necessary to expand the diagnosis of Potonié and Kremp to take account of our present knowledge of the structure of the species. In its original state the polar axis of this spore must have been considerably shorter than the equatorial axis since the spore is nearly always preserved in polar compression and is rarely folded.

Comparison. The paratype of *R. annulatus* Guennel 1958 (pl. 6, fig. 1, 2) appears to be cingulate and comparable to *R. reticulatus* although the holotype (p. 81, fig. 18) does not appear to possess a cingulum [although smaller it is otherwise similar to *Dictyotriletes muricatus* (Kosanke) comb. nov.].

Occurrence. Infrequent, Assemblages VI to XI; occasionally frequent in Assemblage X in the coalfields of the Southern Province; Westphalian A to D.

Genus SAVITRISPORITES Bharadwaj 1955

1958 *Callisporites* Butterworth and Williams, p. 376.

Type species. S. triangulus Bharadwaj 1955.

Diagnosis (Bharadwaj 1955, p. 127). 'Triangular miospores having broad angles. Trilete mark distinct, rays not reaching equator but ending at the inner margin of a prominent cingulum. Exine irregularly thickened, glossy on the proximal surface but ornamented on the distal side. The angles are slightly thickened.'

Remarks. Sullivan (1964, p. 373) considers *Callisporites* to be congeneric with *Savitrisporites* following his re-examination of the type species of *C. nux* Butterworth and Williams, which established that the ornament in this species is confined to the distal surface except for the broad, lip-like thickenings which accompany the laesurae and which are not always apparent. The present authors agree with this conclusion.

Affinity. Filicales. Radforth (1939, pl. 1, fig. 14) figures a spore of this type from *Senftenbergia sturi* Sterzel.

Savitrisporites nux (Butterworth and Williams) emend.

Plate 15, figs. 1–3

1958 *Callisporites nux* Butterworth and Williams, p. 377, pl. 3, figs. 24, 25.
1964 *Savitrisporites nux* (Butterworth and Williams); Sullivan, p. 373, pl. 60, figs. 1–5.

Lectotype. Plate 15, figs. 1, 2. Preparation T55/1 in collection of Coal Survey Laboratory, Sheffield. The holotype could not be located on the type slide so another specimen from this slide has been designated as the lectotype by the authors.

Type locality. Upper Hirst Seam at 2,310 ft. 4 in., Brucefield borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (emended from Butterworth and Williams 1958, p. 377). Amb triangular with slightly convex to concave sides and broad rounded angles. Outline smooth to irregularly crenate. Laesurae simple, distinct, extending to inner margin of cingulum. Cingulum up to about one-half of spore radius in width. Proximal ornament confined to a broad, low band of thickening on either side of each commissure. Distal ornament comprises coni and verrucae, or ridges of irregular height, formed by the coalescence of the bases of the individual elements.

Size in microns. (i) Lectotype 58; 45(56)64, Schulze and 5% KOH (Butterworth and Will. 1958). (ii) 30(47)60, fum. HNO_3 (Sullivan 1964); Edgehills Coal, Forest of Dean Coalfield, England; ? Westphalian A.

Description. The ornament is variable in form and development; height not exceeding 4 μ. It may comprise discrete elements, or ridges, which may be random in their occurrence, or arranged in concentric zones running more or less parallel to the sides of the spore. The proximal ridges associated with the laesurae simulate the appearance of lips and are usually only apparent by careful focusing under oil. The individual width of these proximal bands is 3–4 μ; their equatorial extremities may be slightly expanded in width and their margins smooth, or sinuose. Cingulum usually less coarsely ornamented than remainder of distal surface.

Comparison. Savitrisporites nux resembles *S. triangulus* Bharadwaj 1955 (p. 128, pl. 1, fig. 5) and 1957*a* (p. 97, pl. 26, figs. 6, 7) in size, shape, and in the character of the distal ornament. Minor points of difference appear to be that the cingulum in *S. triangulus* is slightly more developed at the angles and the commissures apparently lack the accompanying broad bands of thickening. Probable specimens of *S. nux* figured in the literature and referred to by Sullivan (1964) are the spores figured as *Converrucosisporites triquetrus* (Ibrahim) Potonié and Kremp in Artüz (1959, pl. 2, fig. 14) and the holotype of *Lycospora percusa* (Horst) Potonié and Kremp in Horst (1955, pl. 24, fig. 74). *S. concavus* Marshall and Smith (1965) is smaller with usually strongly concave margins. *S. majus* Bharadwaj 1957*a* (p. 97, pl. 26, figs. 6, 7), a species which was only provisionally assigned to *Savitrisporites* by Bharadwaj, and its probable synonym *Dictyo-*

EXPLANATION OF PLATE 15

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Savitrisporites nux* (Butterworth and Williams) emend. 1, 2, Lectotype, proximal and distal surfaces respectively, ×1,000; slide T55/1, 47·7 117·8. 3, slide T55/2, circle 3.

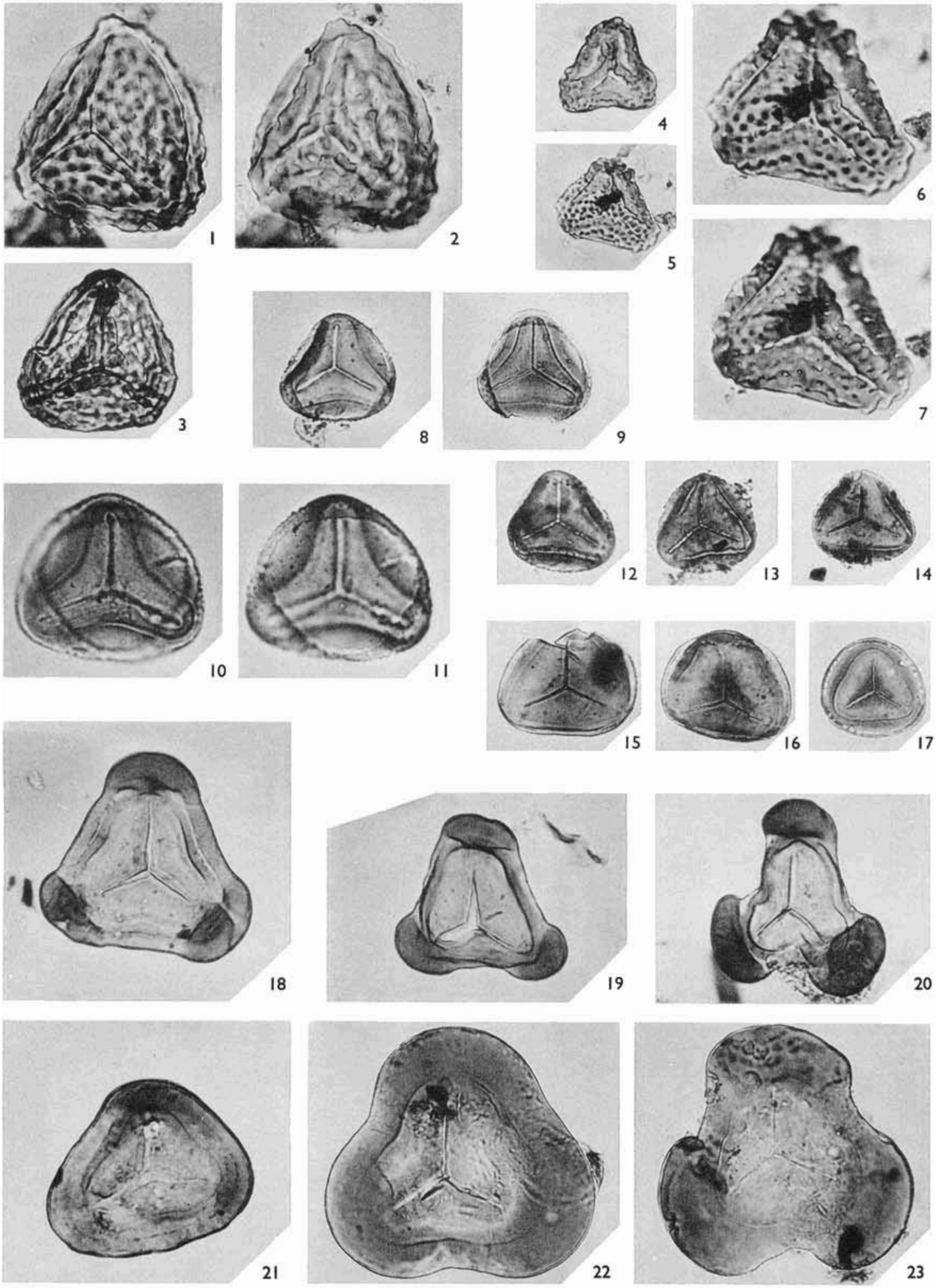
Figs. 4–7. *Bellispores nitidus* (Horst) Sullivan 1964. 4, distal surface; slide 163, 35·8 119·5. 5–7, slide 163, 20·3 106·4. 6, 7, proximal and distal surfaces respectively, ×1,000.

Figs. 8–11. *Rotaspora fracta* (Schemel) emend. 8, slide 164, 40·2 108·6. 9, slide 165, 36·2 111·5. 10, 11, proximal and distal surfaces respectively, ×1,000; slide 166, 36·0 110·8.

Figs. 12–14. *R. crenulata* sp. nov. 12, Holotype; slide T93/1, 52·8 105·7. 13, Isotype; slide T93/2, 54·3 109·8. 14, Isotype; slide T93/3, 30·8 102·2.

Figs. 15–17. *R. knoxi* Butterworth and Williams 1958. 15, Holotype; slide T56/1. 16, Isotype; slide T56/3. 17, Isotype; slide T56/4.

Figs. 18–23. *Simozonotriletes intortus* (Waltz) Potonié and Kremp 1954. 18, slide 175, 30·5 104·7. 19 slide 175, 36·7 103·5. 20, slide 175, 26·2 109·7. 21, slide 176, 40·0 109·0. 22, slide 177, 43·3 106·2. 23, slide 177, 37·1 108·9.



SMITH and BUTTERWORTH, British Carboniferous miospores

triletes camptotus Alpern 1958 (p. 77; pl. 1, figs. 3, 4) are larger and have rounded outlines.

Occurrence. Infrequent, Assemblages III to VIII; Namurian A to Westphalian B.

Genus BELLISPORES (Artüz) Sullivan 1964

Type species. B. nitidus (Horst) Sullivan 1964.

Diagnosis (generic description in Sullivan 1964, p. 374). 'Spores radial, trilete, lenticular in polar section. Amb triangular with straight or concave sides. Trilete rays prominent, tecta long and straight. Three radial thickenings are located on the distal surface. Equatorial border narrow, of uniform thickness.'

Remarks. The above generic description given by Sullivan is considered by the authors to constitute an emendation of Artüz's diagnosis (1957, p. 254). It clarifies the position of the radial thickenings, which are a distal and not a proximal feature as implied by Artüz.

Affinity. Unknown.

Bellispores nitidus (Horst) Sullivan 1964

Plate 15, figs. 4–7

1943 *Triletes nitidus* Horst (thesis), pl. 8, fig. 81.
1948 D 11 Knox, p. 157, fig. 8.
1955 *Lycospora nitida* (Horst); Potonié and Kremp in Horst, p. 181, pl. 24, fig. 81.
1957 *Bellispores bellus* Artüz, p. 255, pl. 7, fig. 49.
1957 *Simozonotriletes trilinearis* Artüz, p. 251, pl. 5, fig. 36.
1964 *Bellispores nitidus* (Horst); Sullivan, p. 375.

Holotype. Horst 1955, pl. 24, fig. 81. Preparation IV53, 23·4 73·8.

Type locality. Justa Seam, Michael Colliery, Moravska-Ostrava; Namurian A.

Diagnosis (expanded from Horst 1955, p. 181 and Artüz 1957, p. 255). Amb triangular with rounded angles and straight or, more commonly, concave sides. Outline undulate to crenulate, crenulations often more marked at angles. Laesurae simple, extending to inner margin of cingulum. In polar compression cingulum is 2·5–5 μ in width. Relatively broad distal radial thickenings present, which extend from pole to equator and have more or less well-defined, crenulate margins; these are up to 10 μ in width. Proximal surface laevigate, distal surface, including the cingulum, foveolate; lumina do not exceed 2 μ in diameter.

Size in microns. (i) Holotype 42; 33–43, fum. HNO_3 (Horst 1955). (ii) 28(36)45, HF and 2% KOH (Sullivan 1964 for *B. bellus*); Edgehills Coal, Forest of Dean Coalfield, England; ? Westphalian A. (iii) 27(29)32 (8 specimens) fum. HNO_3; ? Lyon cross Seam at 558 ft. 10 in., Darnley No. 4 borehole, Central Coalfield, Scotland; Namurian A. (iv) 31(34)36 (9 specimens) fum. HNO_3; seam at 253 ft. 10 in., Broad Law Deep borehole No. 36, Northumberland Coalfield, England; Namurian.

Description. The crenulate margin is due to the sculpturing of the cingulum, which is often poorly defined; this sculpture varies in prominence. The distal foveolae may be randomly distributed, or may be arranged in rows running from the distal pole to the angles, as well as more or less parallel to the amb. There are not usually more than two rows of foveolae on the distal thickenings. Viewed from the proximal surface at low magnification the distal radial thickenings appear to accompany the laesurae.

Remarks. Potonié and Kremp presumably assigned this spore to *Lycospora* on account of the cingulum and the length of the laesurae, but the structure, shape, and ornament are clearly not features of this genus. In creating the genus *Bellispores* Artüz did not recognize that spores of this type had already been figured by Horst as *Triletes nitidus* Horst. However, Sullivan (1964, p. 375) considers that *B. bellus* and *B. nitidus* are distinct species, distinguished by the degree of concavity of the radial thickenings. This distinction is not always easy to make in practice and for this reason the authors regard the two forms as conspecific. The authors agree with Sullivan that *Simozonotriletes trilinearis* Artüz 1957 (p. 251) is conspecific with *Bellispores bellus* Artüz. The probable synonymy of *Zonotriletes arcuatus* Waltz in Luber and Waltz 1938 (pl. 3, fig. 36) is suggested by Butterworth and Williams (1958, p. 375). Potonié (1960, p. 63) notes the close similarity of *Bellispores* to *Savitrisporites* Bharadwaj 1955.

The smaller dimensions given for the few British specimens examined may, in part, be due to the concavity of the interradial margins; this is reflected in the measurements given for triangular spores.

Occurrence. Infrequent, Assemblages III to V; Namurian to Lower Westphalian A.

Genus ROTASPORA Schemel 1950 emend.

Type species. *R. fracta* Schemel 1950.

Diagnosis (emended from description in Schemel 1950, p. 241). Spores radial, trilete, zonate. Amb circular to subcircular; body triangular to subtriangular. Laesurae simple, generally almost equal to body radius in length. Zona may be reduced in width radially. In the uncompressed state the zona, if broad, may be directed downwards from the equator in a distal direction thereby forming a 'collar'. Compression results in a broad zona in the radial positions lying distally over the angles of the spore body while projecting horizontally in the interradial regions. Ornament, laevigate to verrucate, may be different on body and zona. Exine relatively thick.

Remarks. The authors consider that the equatorial extension of the exine is more in the nature of a zona, as originally described by Schemel, than of a cingulum as suggested by Potonié and Kremp (1954, p. 159).

Comparison. In *Camarozonotriletes* Naumova the zona bears one or more rows of ornament. In his description of *Rotaspora*, Schemel (1950, p. 242) mentions differential ornament of the body and flange and the present authors therefore agree with Potonié (1956, p. 65) that *Camarozonotriletes*, for which no type was defined, should be included in *Rotaspora*. *Diatomozonotriletes* (Naumova) Playford possesses a setose corona interradially instead of a comprehensive zona.

Affinity. Unknown.

Rotaspora crenulata sp. nov.

Plate 15, figs. 12–14

Holotype. Plate 15, fig. 12; T93/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Greenses Seam at 147 ft. 8 in., Stamford borehole, Northumberland Coalfield, England; Viséan.

Diagnosis. Amb subtriangular, sides convex, angles broadly rounded; body triangular, sides more or less straight, angles rounded. Laesurae simple, extending almost to margin of body. Zona narrow at apices, broad and crenulate in interradial areas. Body laevigate or punctate. Zona with 8 to 12 small verrucae along each interradial margin. Body moderately thick.

Size in microns. Holotype 34; 29(35)41, fum. HNO_3.

Comparison. Similar in size and shape to *R. knoxi* but differs in having verrucate ornament on interradial areas of the zona. *Camarozonotriletes circumligus* Staplin 1960 (p. 23; pl. 4, figs. 31, 35), which this author (in correspondence) believes should be transferred to the genus *Rotaspora*, has a body with markedly concave sides, and zona ornament consisting of two rows of small spinae. *Camarozonotriletes devonicus* Naumova 1953 (pl. 14, fig. 9) has spinae on the zona and *C. obtusus* Naumova 1953 (pl. 14, fig. 9*a*) has spinae on the zona and also on the body.

Occurrence. Infrequent, Assemblage II; Viséan.

Rotaspora fracta (Schemel) emend.

Plate 15, figs. 8–11

Holotype. Schemel 1950, pl. 40, fig. 8. In collection of Missouri Geological Survey.

Type locality. 24 in. coal about 550 ft. above top of Madison Formation, Daggett County, Utah, U.S.A.; Mississippian.

Diagnosis (emended from description in Schemel 1950, p. 242). Amb circular, subcircular, or rounded-triangular. Body triangular, angles rounded, sides straight to slightly concave. Laesurae simple, slightly shorter than body radius. Width of zona roughly constant, thickened at periphery to form a rim. In compressed specimens the zona lies over the distal surface of the body in the radial positions thereby appearing narrower than in the interradial areas. Body and zona laevigate. Folding of body infrequent.

Size in microns. (i) 28–35, body 17–24; maceration method not known (Schemel 1950). (ii) 24–40, fum. HNO_3 (Butterworth and Will. 1958).

Remarks. Schemel considered that the zona was narrower in the radial positions but his figure of the holotype (1950, pl. 40, fig. 8) clearly shows the peripheral rim of the zona crossing one of the angles of the spore body.

It has been established by the exchange of slides that *Rotaspora fracta* in Butterworth and Williams (1958) is this species and is not *Camarozonotriletes circumligus* Staplin as stated by Staplin (1960, p. 23).

Occurrence. Infrequent to frequent, Assemblages II and III; Viséan and Namurian A.

Rotaspora knoxi Butterworth and Williams 1958

Plate 15, figs. 15–17

1948 Knox, p. 157, text-fig. 5.
1958 *Rotaspora knoxi* Butterworth and Williams, p. 378, pl. 3, figs. 21–23.

Holotype. Plate 15, fig. 15. Preparation T56/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Lower Garscadden Ironstone Seam at 1,010 ft. 2 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 378). Amb triangular, angles broadly rounded, sides convex; body triangular, less rounded. Laesurae simple, straight, extending two-thirds to three-quarters body radius. Zona broadest in interradial areas, narrow at angles; cingulum with narrow peripheral rim. Exine smooth, body vitreous in appearance.

Size in microns. Holotype 40; 26(32)44, fum. HNO_3 (Butterworth and Will. 1958).

Description. Width of zona in the interradial area up to 5 μ. Thickened peripheral rim of zona, up to 3 μ wide, often linked to the body by thin, closely spaced radial thickenings. Exine relatively thick.

Comparison. Distinguished from *R. fracta* by its thicker exine, slightly larger size, and by the body outline, which is convex or only slightly concave with broadly rounded angles. In *R. knoxi* the zona is not generally folded over the body in the radial positions.

Occurrence. Infrequent to frequent, Assemblages II and III; Viséan and Namurian A.

Suprasubturma LAMINATITRILETES s.subturma nov.

Laminatitriletes includes trilete aperinate spores which possess a cavate exine, the layers of which are not widely separated.

Subturma AZONOLAMINATITRILETES subturma nov.

Azonolaminatitriletes includes trilete aperinate cavate spores in which the spore layers are not differentially thickened.

Infraturma TUBERCULORNATI infraturma nov.

Tuberculornati includes trilete aperinate cavate spores with simple or ridged laesurae and with an exoexine bearing sculptural elevations including grana, verrucae, spinae, bacula, etc. Elevations may be discrete or confluent at their bases.

Genus GRUMOSISPORITES gen. nov.

Type species. *G. verrucosus* (Butterworth and Williams) comb. nov.

Diagnosis. Trilete aperinate cavate spores with simple laesurae. Exoexine moderately thick, verrucate, rugulate-verrucate, or murinate-verrucate. Height of ornament low in proportion to width, in plan view shape variable depending on degree of confluence between bases of verrucae. The ornament may be a poorly defined reticulum. Intexine thin and often with narrow, pointed compression folds. Margin of intexine more or less corresponds with limits of laesurae.

Remarks. Species included in *Grumosisporites* were formerly assigned to genera such as *Dictyotriletes*, *Camptotriletes*, and *Verrucosisporites*. They have been excluded from these genera on the basis of the separation of the exine layers and the appearance of a more or less clearly defined intexine.

Affinity. Unknown.

Grumosisporites inaequalis (Butterworth and Williams) comb. nov. emend.

Plate 16, figs. 1–8

1948 39K Knox, text-fig. 47.
1958 *Verrucosisporites inaequalis* Butterworth and Williams, p. 362, pl. 1, figs. 46, 47.

Holotype. Plate 16, fig. 1 after Butterworth and Williams. Preparation T37/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 1,336 ft. 3 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (emended from diagnosis and description in Butterworth and Williams 1958, p. 362). Amb circular to oval; outline uneven. Laesurae straight, two-thirds of radius. Intexine thin and indistinct. Exoexine covered by irregularly shaped verrucae, 2–4 μ in diameter, 15 to 20 projecting at the margin. Exoexine moderately thick.

Size in microns. Holotype 40; 29(37)47, Schulze and 5% KOH (Butterworth and Will. 1958).

Description. Laesurae often obscured by ornament. Intexine usually folded and well separated from exoexine except in contact areas; only visible by careful focusing under oil. Verrucae of irregular shape and uneven disposition. In profile verrucae are broadly conical, up to 2·5 μ in height, and with pointed or well-rounded apices. In plan, shape of verrucae is difficult to determine since the verrucae are, in part, confluent at their bases.

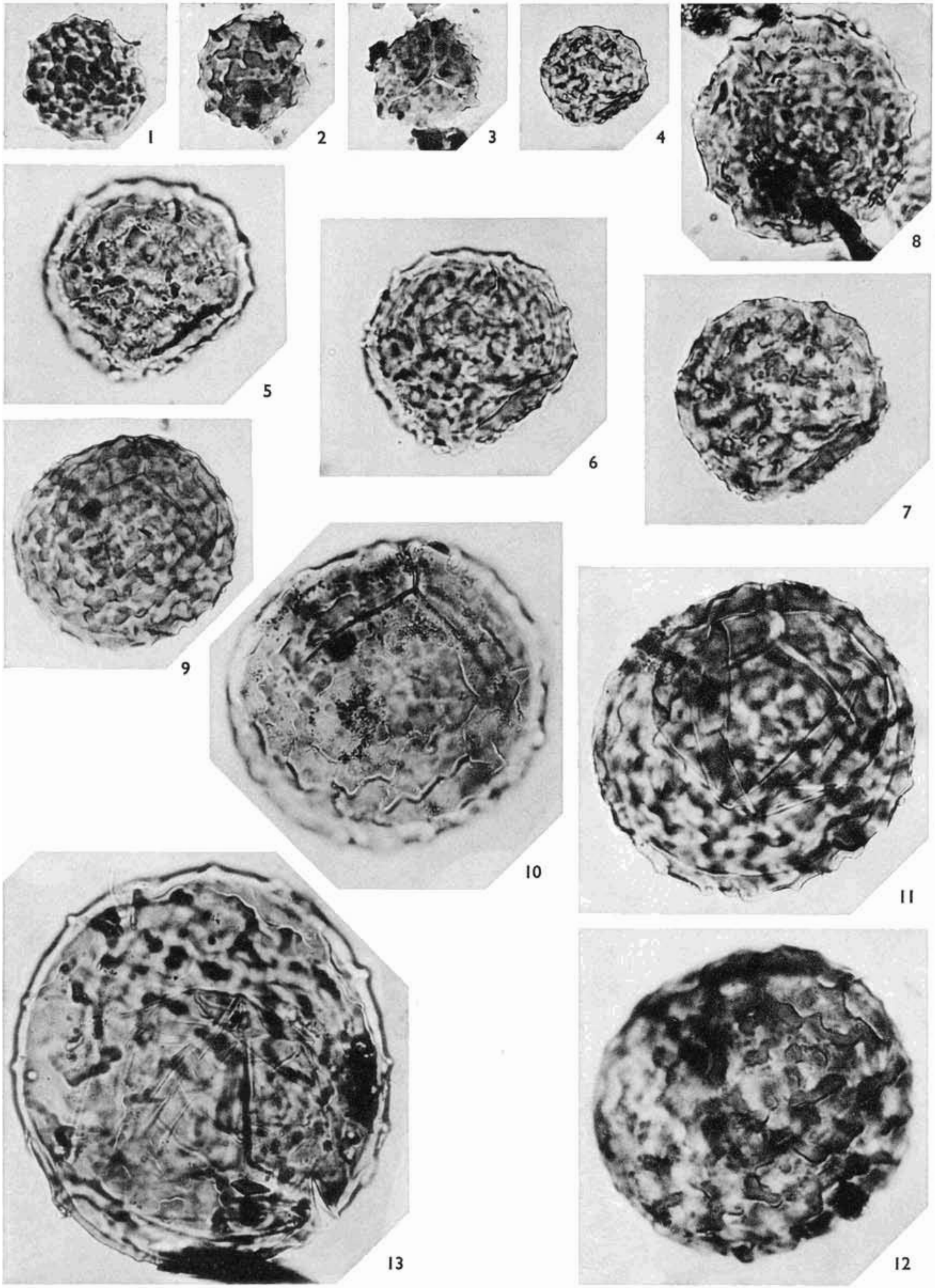
Remarks. The forms recorded by Horst under *Verrucosisporites microverrucosus* may in part include this species. Potonié and Kremp (1955, p. 68) note that the spore figured by Horst (1943, pl. 8, fig. 73 and presumably that figured in 1955, pl. 24, fig. 73) is unlike the holotype of *V. microverrucosus*. Horst's figured specimen resembles forms assigned to *Grumosisporites inaequalis*.

EXPLANATION OF PLATE 16

All figures $\times 500$, and of proximal surface, unless otherwise stated.

Figs. 1–8. *Grumosisporites inaequalis* (Butterworth and Williams) comb. nov. emend. 1, Holotype; slide T37/1, 50·0 111·5. 2, slide 167, 32·6 109·5. 3, slide 167, 50·5 118·5. 4–7, slide 168, 48·4 117·3. 4, distal surface. 5, proximal surface. 6, medium focus showing laesurae and intexine. 7, distal surface. 5–7, $\times 1{,}000$. 8, medium focus showing laesurae and intexine, $\times 1{,}000$; slide 167, 52·2 119·7.

Figs. 9–13. *G. papillosus* (Ibrahim) comb. nov. emend. 9–12, slide 169, 51·9 108·2. 10, proximal surface. 11, medium focus showing intexine. 12, distal surface. 10–12, $\times 750$. 13, $\times 750$; slide 170, 12·6 108·7.



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Comparison. The ornament of this species appears somewhat coarser and more variable than that of *V. difficilis* Potonié and Kremp 1955. There is a resemblance between *G. inaequalis* and *Filicitriletes densus* Luber 1955 (pl. 3, fig. 56).

Occurrence. Infrequent, Assemblages III and IV; Namurian.

Grumosisporites papillosus (Ibrahim) comb. nov. emend.

Plate 16, figs. 9–13

1933 *Verrucosi-sporites papillosus* Ibrahim, p. 25, pl. 5, fig. 44.
1944 *Punctati-sporites papillosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 31.
1950 *Verrucoso-sporites papillosus* (Ibrahim); Knox, p. 318, pl. 17, fig. 229.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 206 after Ibrahim. Preparation C28, h4 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from Ibrahim 1933, p. 25). Amb circular. Laesurae simple, two-thirds to three-quarters of radius. Exine layers clearly separated except in contact areas; intexine thin. Exoexine covered by verrucae mostly with well-rounded apices, 4–12 μ in breadth, but less than 5 μ in height; 20 to 30 verrucae project at margin. Exoexine about 3·0 μ thick.

Size in microns. (i) Holotype 77 × 74; 77–98, Schulze and KOH (Ibrahim 1933). (ii) 68–86 (6 specimens) fum. HNO_3; various localities, Yorkshire and Leicestershire Coalfields, England; Westphalian A and Lower Westphalian B.

Description. Intexine thin and folded as in many species of *Calamospora* and does not fill the entire cavity within the exoexine. Verrucae broad, but height low in proportion. In profile apices mostly rounded or flattened; more or less conical verrucae occur in some specimens. In plan view verrucae very irregular in shape; the bases may be confluent to a varying degree.

Remarks. The brief diagnosis given by Ibrahim has been expanded and emended to include reference to the separation of the exine layers. This feature, well seen in all British specimens, was, however, not clearly apparent in photographs of the holotype taken at high magnification under oil (Smith *et al.* 1964, pl. 2, fig. 12). The spores are stated by Ibrahim to be triangular to circular, but the holotype and all British specimens are circular in polar compression. Ibrahim also stated that the laesurae are short, although a length of two-thirds of radius is quoted.

Comparison. The relatively large size of the verrucae and the small number projecting at the margin are features which distinguish this species from the others belonging to the genus.

Occurrence. Infrequent, Assemblages VI to VIII; Upper Westphalian A and Westphalian B.

Grumosisporites rufus (Butterworth and Williams) comb. nov. emend.

Plate 17, figs. 1–7

1948 Knox, fig. 20.
1958 *Verrucosisporites rufus* Butterworth and Williams, p. 363, pl. 1, figs. 44, 45.

Holotype. Plate 17, figs. 1–4. Preparation T36/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Cadell's Parrot Seam at 1,110 ft. 9 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (emended from Butterworth and Williams 1958, p. 363). Outline circular, subcircular, or broadly rounded-triangular. Laesurae simple, straight, equal in length to radius or nearly so. Separation of exine layers indistinct. Exoexine thick, ornamented with irregular low ridges and verrucae; margin uneven.

Size in microns. Holotype 54; 48(56)68, Schulze and 5% KOH (Butterworth and Will. 1958).

Description. There is no wide separation of the exine layers since the contact areas correspond to almost the entire proximal surface. Intexine only visible by careful focusing under oil. Ornament over entire spore essentially verrucate; elements may be discrete, or confluent to a varying extent, giving rise to projections which in plan view are very irregular in shape but seldom result from the confluence of more than 2 or 3 verrucae; the projections do not form continuous ridges, or give rise to a reticulate pattern. Height of ornament up to 4 μ; width of discrete verrucae up to 4 μ. Intervening spaces irregular, of the order of size of the smaller verrucae. At margin about 20 broadly conical projections with rounded apices, irregularly spaced and varying in size. Exoexine thickness, including ornament, 4–6 μ.

Remarks. The ornament of this species is less regular than in most species of *Verrucosisporites* but examination under oil shows that the individual elements are more or less discrete and not predominantly elongated as in *Camptotriletes*.

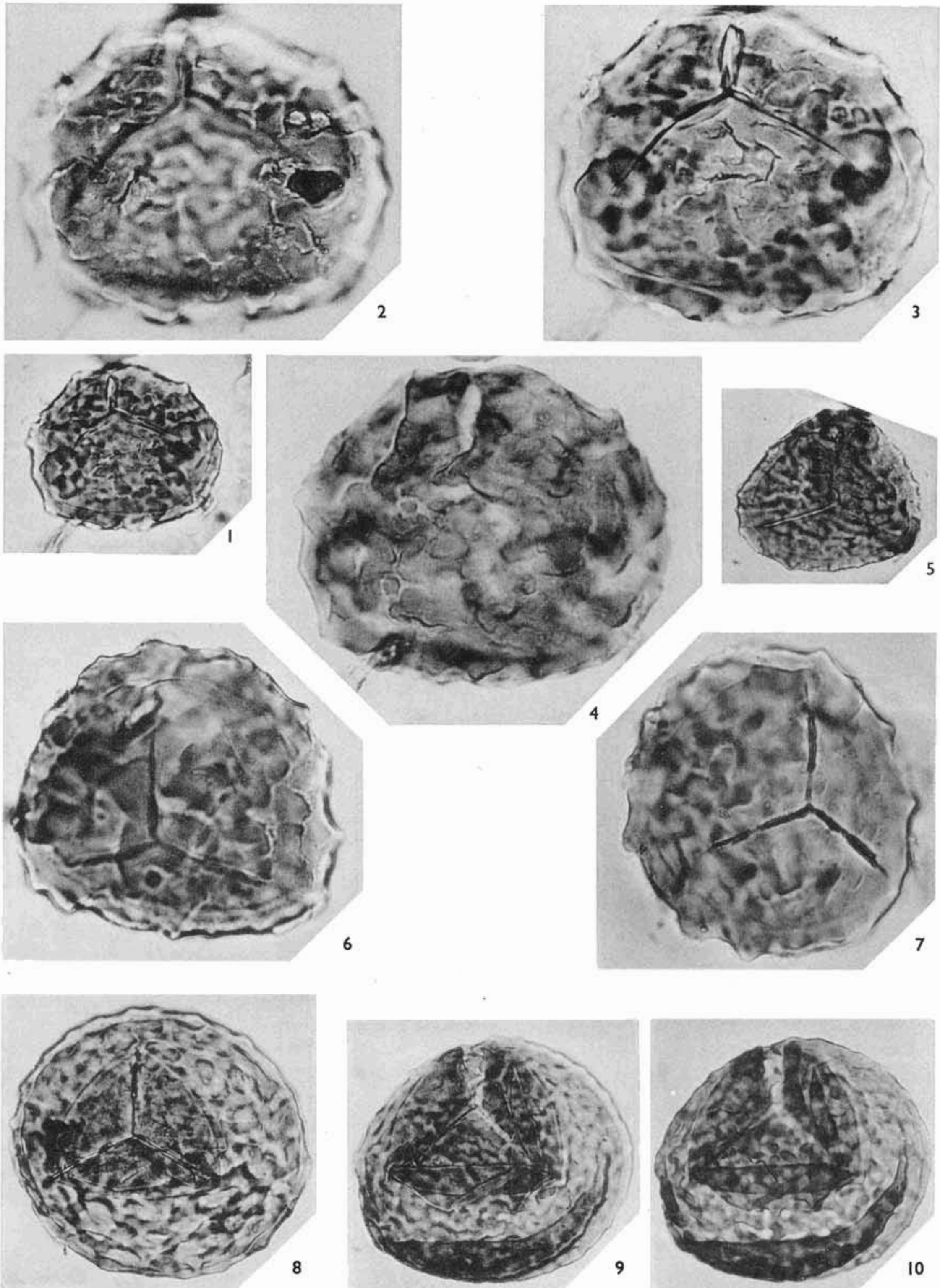
Occurrence. Infrequent, or occasionally frequent, Assemblages I to IV; Viséan and Namurian. Recorded from Viséan of Scotland in rocks other than coal by Love (1960).

EXPLANATION OF PLATE 17

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1–7. *Grumosisporites rufus* (Butterworth and Williams) comb. nov. emend. 1–4, Holotype, slide T36/1, 44·5 107·6. 2, proximal surface. 3, medium focus showing laesurae and intexine. 4, distal surface. 2–4, ×1,000. 5, slide T36/1, 43·0 111·5. 6, medium focus showing folded intexine, ×1,000; slide 171, 24·4 114·2. 7, medium focus, ×1,000; slide 171, 24·5 101·7.

Figs. 8–10. *G. varioreticulatus* (Neves) comb. nov. emend. 8, medium focus showing intexine, ×750; slide 172, 20·7 113·1. 9–10, slide 173, 44·5 106·9. 9, medium focus showing intexine. 10, distal surface, ×750.



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Grumosisporites varioreticulatus (Neves) comb. nov. emend.

Plate 17, figs. 8–10

1958 *Dictyotriletes varioreticulatus* Neves, p. 8, pl. 2, figs. 1*a*, *b*.

Holotype. Neves 1958, pl. 2, fig. 1. Preparation F 7Sl, reference 056550 in collection of Geological Department, Sheffield University.

Type locality. Roof shales of Six Inch Seam, Quarnford, North Staffordshire Coalfields, England; Namurian C.

Diagnosis (emended from Neves 1958, p. 8). Outline circular to oval. Laesurae straight, simple, two-thirds to three-quarters of radius. Exine layers well separated except in contact areas. Intexine thin. Ornament a slightly irregular and weakly defined reticulum; muri low. Approximately 25 small conical projections at margin.

Size in microns. (i) Holotype 106; 70–110, Schulze and 10% KOH (Neves 1958). (ii) 67(78)89 (16 specimens) fum. HNO_3; various localities; Westphalian A and B.

Description. Margin undulate. Laesurae straight, occasionally longer than three-quarters of spore radius (range 20–35 μ). In most compressed specimens intexine approximately triangular, thin, and folded, with radius equal to the length of the laesurae. Reticulate pattern not always well defined; sometimes only clearly visible in high focus; usually better developed on distal surface. Where well developed, muri project at margin and appear in profile as low, broad-based coni with rounded apices. Muri do not exceed 2 μ in height. Lumina vary in size; exceptionally as much as 15 μ in diameter. Exoexine 2–3·5 μ in thickness.

Remarks. The holotype of *Grumosisporites varioreticulatus* has not been examined but photographs of it (Neves 1958, pl. 2, figs. 1*a*, *b*) suggest the presence of an inner membrane. *G. varioreticulatus* and *Dictyotriletes maculatus* (Ibrahim) Potonié and Kremp 1955 (p. 110, pl. 16, fig. 305) may be conspecific although Neves mentions that *D. maculatus* (in the Upper Westphalian B) is somewhat smaller (53–70 μ) with apparently stronger muri. The size difference may not be important. Ibrahim probably examined few specimens. The known range of *G. varioreticulatus* now includes the Westphalian B. Unfortunately the holotype of *D. maculatus* is poorly preserved and the species has not been recorded from the Ruhr Coalfield by Potonié and Kremp.

Comparison. Differs from other species of *Grumosisporites* in possessing a poorly defined reticulate ornament.

Occurrence. Infrequent, Assemblages IV to VIII; fairly regularly recorded in seams in Assemblage IV; Namurian B to Westphalian B. Recorded in coals and other rocks of Namurian B and C age from the southern Pennines by Neves (1961).

Grumosisporites verrucosus (Butterworth and Williams) comb. nov. emend.

Plate 18, figs. 1–6

1958 *Camptotriletes verrucosus* Butterworth and Williams, p. 368, pl. 2, figs. 2, 3.

Holotype. Plate 18, figs. 1–3. Preparation T46/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Calpatie (Upper Blackbird) Seam at 2,851 ft. 3 in., Monkton House borehole, Lothians Coalfield, Scotland; Namurian A.

Diagnosis (emended from diagnosis and description in Butterworth and Williams 1958, p. 368). Amb circular to rounded-triangular; margin irregular to undulating. Laesurae simple, straight, two-thirds radius, or longer. Exine layers separated except in region of contact areas. Intexine thin. Ornament of irregular low ridges connecting poorly defined verrucae which are separated by shallow meandering channels; ridges approximately 3 μ wide with a general disposition parallel to amb. Approximately 30 projections at the amb.

Size in microns. Holotype 64; 42(53)64, Schulze and 10% KOH (Butterworth and Will. 1958).

Description. Intexine folded and well separated from exoexine except in contact areas. Verrucae fairly regular in their disposition giving a definite reticulate pattern in high focus; apices well rounded. The more prominent elements of ornament seldom project more than about 2·5 μ. Exoexine thickness, including ornament, 1·5–4 μ.

Comparison. Differs from *G. rufus* in possessing more regular sculptural pattern and a thinner exoexine. Ornament in *G. verrucosus* somewhat finer with a greater number of projecting elements than that of *Camptotriletes corrugatus* (Ibrahim) Potonié and Kremp 1955 (p. 104, pl. 16, figs. 289, 290).

Occurrence. Infrequent, Assemblages I–III; Viséan and Namurian A.

Subturma ZONOLAMINATITRILETES subturma nov.

Zonolaminatitriletes includes trilete aperinate cavate spores in which the exine layers are not widely separated and in which the outer layer of the exine (exoexine) is equatorially thickened and/or extended; the equatorial thickenings and/or extensions may encroach on to the proximal and/or distal surfaces.

Infraturma CRASSITI (Bharadwaj and Venkatachala) emend.

The infraturma Crassiti is emended to include trilete cavate miospores with a crassitudinous margin not distinctly demarcated from the rest of the spore. This follows the demonstration of an intexine in *Crassispora* by Sullivan (1964).

Genus CRASSISPORA (Bharadwaj) Sullivan 1964

Type species. C. kosankei (syn. *C. ovalis*) (Potonié and Kremp) Bharadwaj 1957.

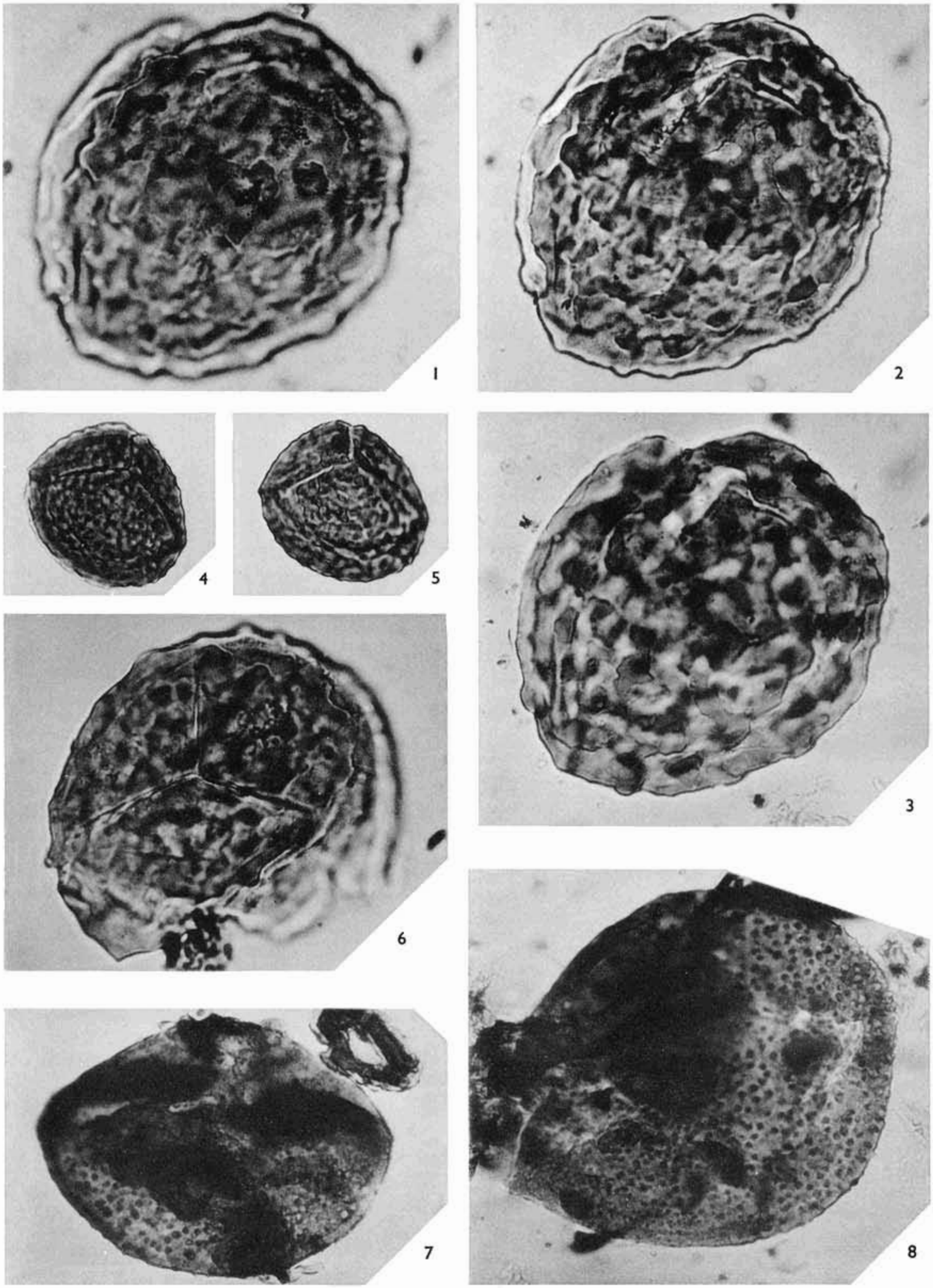
Diagnosis (generic description in Sullivan 1964, p. 375). 'Radial trilete miospores. Amb circular to oval, or roundly triangular. Exoexine finely to coarsely infrapunctate;

EXPLANATION OF PLATE 18

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1–6. *Grumosisporites verrucosus* (Butterworth and Williams) comb. nov. emend. 1–3, Holotype × 1,000; slide T46/1, 33·0 103·8. 1, proximal surface. 2, medium focus showing intexine. 3, distal surface. 4, 5, proximal and distal surfaces respectively; slide T46/2. 6, medium focus showing folded intexine, × 1,000; slide 174, 35·8 110·1.

Figs. 7, 8. *Crassispora maculosa* (Knox) Sullivan 1964. 7, equatorial view showing laevigate proximal surface; slide 180, 36·9 109·0. 8, Lectotype, oblique compression; slide T83/1, 50·8 115·7.



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crassitudinous thickening present at the equator. Distal surface ornamented with cones and, occasionally, spines; proximal surface without ornamentation. Intexine thin and translucent, outline rarely seen; margin conformable to equator of the spore. Apical papillae visible in intertectal areas. These are particularly well seen in over-macerated specimens [Wilson and Venkatachala (in press)]. Trilete rays usually indistinct, sometimes accompanied by folds.'

Remarks. The above generic description given by Sullivan is considered by the authors to constitute an emendation of Bharadwaj's diagnosis (1957*b*, p. 125) in which it is stated that the ornament covers the entire exine. Sullivan also mentions other features not referred to in the original diagnosis.

Affinity. Rettschlag and Remy (1954, pl. 4, fig. 1) isolated spores from *Sigillariostrobus ciliatus* which resemble *Crassispora*.

Crassispora kosankei (Potonié and Kremp) Bharadwaj 1957 emend.

Plate 19, figs. 2–4

1955 *Planisporites kosankei* Potonié and Kremp, p. 71, pl. 13, figs. 208–13.
1957 *Planisporites ovalis* Bharadwaj, p. 86, pl. 23, figs. 9, 10.
1957*b* *Crassispora ovalis* Bharadwaj, p. 126, pl. 25, figs. 73–76.
1957*b* *Crassispora kosankei* (Potonié and Kremp); Bharadwaj, p. 127.
1957*a* *Apiculatisporites apiculatus* (Ibrahim); Dybová and Jachowicz (*non sensu* Ibrahim), p. 87, pl. 15, figs. 1–4.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 208. Preparation 565/V, KT 20·9 126·1.

Type locality. Seam R_1, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany; Westphalian B.

Diagnosis (emended from Potonié and Kremp 1955, p. 71). Amb circular to subcircular or oval; in equatorial view shape more or less lenticular, somewhat distorted by crassitudinous thickening at the equator. Laesurae simple, extending nearly to amb; not usually apparent, or split wide open to give a triangular-shaped tear in polar region. Exine with finely granulate or punctate infrasculpture. Distal surface covered by small coni rarely exceeding 2 μ in height or breadth, irregularly distributed, bases not touching; up to 5 μ between coni which project at margin. Proximally, ornament is lacking or greatly reduced. Exine in region of crassitudinous thickening darker in colour than in polar region.

Size in microns. (i) Holotype 79·8; 68–85, Schulze (Potonié and Kr. 1955). (ii) 46–55, Schulze (Bharadwaj 1957*a* for *C. ovalis*); Constanze Seam, Göttelborn Colliery, Saar Coalfield; Stephanian. (iii) 40(56)69, fum. HNO_3; Mynyddislwyn Seam, Tirpentwys Colliery, South Wales Coalfield; Westphalian D. (iv) 50(61)74, fum. HNO_3; No. 4 Seam, Nantgarw Colliery, South Wales Coalfield; Westphalian C. (v) 47(62)79;* Winter Seam at 1,455 ft. 8 in., Cross Hill borehole. (vi) 47(63)84;* High Hazel Seam at 2,181 ft. 5 in., Gate Farm borehole. (vii) 72(90)105, Schulze and 10% KOH; High Hazel Seam as above. (viii) 47(60)79;* Swallow Wood Seam at 2,552 ft. 2 in., Gate Farm borehole. (ix) 47(58·5)77;* Top Haigh Moor Seam at 1,532 ft. 3 in., Kellingley borehole. (x) 47(58)69;* Lidgett Seam at 2,715 ft. 3 in., Gate Farm borehole. (xi) (4757)69, fum. HNO_3; Alton Seam at 533 ft. 8 in., Denby (Drury Lowe) borehole, Nottinghamshire Coalfield, England; Westphalian A. [*Macerated with fum. HNO_3; seams (in stratigraphic sequence) of Yorkshire Coalfield, England; Westphalian B.

Description. Amb often distorted into somewhat irregular outline. Majority of specimens appear alete, or with a triangular tear in polar region which may be result of rupture of exine along triradiate lines of weakness (Bharadwaj 1957*b*, p. 125). Coni vary in size and shape. Equatorial thickening of exine extends towards the poles for a distance of 5–10 μ; inner margin of thickening ill defined; exine in polar area often appears almost colourless. Exine within crassitudinous thickening often plicated and folded.

Remarks. This spore possesses a type of ornament which characterizes *Planisporites* (Knox) Potonié but it was given separate generic status by Bharadwaj on account of the slight equatorial thickening. The diagnosis of Potonié and Kremp has been emended to include reference to the crassitudinous thickening and the restriction of ornament to the distal surface referred to by Sullivan.

The distinction between *C. kosankei* and *C. ovalis* is only one of size. The effect of different maceration treatments on the dimensions of spores from the same coal indicates that the exines of *Crassispora* are particularly liable to swell when certain alkalis are used following Schulze reagent. The difference between mean sizes of specimens from the High Hazel Seam macerated by different methods is statistically highly significant ($P < 0{\cdot}001$). This fact and the progressive change in size of assemblages from seams closely spaced in the vertical sequence (differences between means not statistically significant, $P > 0{\cdot}05$) make it unwise to use size alone for speciation in this genus until further experimental work has been carried out. The original species name has therefore been retained for all forms resembling *C. kosankei* and with overlapping size ranges.

Occurrence. Frequent to very common, Assemblages IV to VII; mostly abundant, Assemblages VIII to X, frequent Assemblage XI; Namurian to Westphalian D. Neves (1961) has also recorded *C. kosankei* from sediments of Namurian B (R_1) age in the Southern Pennine Basin, and subsequently (pers. comm.) in the Bowland Shales, Namurian A.

Crassispora maculosa (Knox) Sullivan 1964

Plate 18, figs. 7, 8; Plate 19, fig. 1

1948 23K Knox, p. 158, fig. 26.
1950 *Verrucoso-sporites maculosus* Knox, p. 318.
1955 *Apiculatisporis maculosus* (Knox); Potonié and Kremp, p. 78.
1964 *Crassispora maculosa* (Knox); Sullivan, p. 376.

Lectotype. Plate 18, fig. 8. Knox did not select a holotype in 1950. A specimen identified by Knox on a slide in the authors' possession is therefore designated as lectotype. Knox preparation 360A (T83/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Dunfermline Splint Seam, Lumphinnans No. 1 Colliery, West Fife Coalfield, Scotland; Namurian A.

Diagnosis. Amb circular. Laesurae ridged; ridges narrow and flexuose, one-half to three-quarters of spore radius. Equatorial crassitude narrow and weakly developed. Exine with fine and dense granulate infrasculpture and distally covered at fairly regular intervals with grana and coni not exceeding 2 μ in height. Proximal surface laevigate.

Size in microns. (i) Lectotype 121 × 113; 100–20, Schulze (Knox 1950). (ii) 76(94)111, fum. HNO_3; Knightswood Gas Seam at 715 ft. 4 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Description. Although in well-preserved specimens the amb is circular, most specimens are folded and distorted by compression. In equatorial view, proximal and distal surfaces are pointed and convex respectively. Ridges of laesurae seldom exceed 4 μ in width or height; ridged condition not apparent when commissures are open; rays sometimes accompanied by folds. Crassitudinous thickening is best seen in specimens preserved in off-centre compression, when it appears as a narrow, darker zone, sometimes accompanied or concealed by arcuate folds. The pointed apices of coni scarcely project more than 1 μ from margin and number about 60 or 70. Exine 2·5–3 μ thick.

Comparison. Differs from *Apiculatisporis latigranifer* in the dimorphic character of the ornament and in possessing infrasculpture.

Occurrence. Infrequent to frequent, Assemblages II to IV; Viséan and Namurian.

Infraturma CINGULICAVATI infraturma nov.

Cingulicavati includes trilete cavate spores with simple or ridged laesurae and a comprehensive equatorial thickening (cingulum) or extension (zona) of the outer exine layer.

Genus SIMOZONOTRILETES (Naumova) Potonié and Kremp 1954

Type species. *S. intortus* (Waltz) Potonié and Kremp 1954.

Diagnosis (Sullivan 1958, p. 126). 'Trilete isospores or microspores; triangular in equatorial plane with convex to markedly concave sides and rounded apices; central area triangular, margin well defined and runs approximately parallel to the equator of the spore; exine laevigate to infrapunctate or infragranulate; trilete rays exceed two-thirds radius of central area; cingulum may be of uniform width and thickness but is frequently wider and thicker at the apices; it can also be differentiated into an outer dark zone and

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EXPLANATION OF PLATE 19

All figures $\times$ 500, and of proximal surface, unless otherwise stated.

Fig. 1. *Crassispora maculosa* (Knox) Sullivan 1964. Slide 181, 40·5 110·2.

Figs. 2–4. *C. kosankei* (Potonié and Kremp) Bharadwaj 1957 emend. 2, equatorial view showing reduction of sculpture proximally; slide 178, 41·7 106·5. 3, slide 179, 32·4 106·9. 4, faint trilete mark; slide 46, 26·9 114·7.

Figs. 5, 6. *Densosporites anulatus* (Loose) comb. nov. 5, slide 182, 21·6 113·8. 6, slide 182, 56·1 108·7.

Figs. 7, 8. *D. gracilis* sp. nov. 7, Holotype; slide T90/1, 35·9 106·0. 8, Isotype; slide T90/2, 52·7 107·2.

Figs. 9, 10. *D. intermedius* Butterworth and Williams 1958. 9, slide 183, 38·5 115·7. 10, Holotype; slide T61/1, 37·0 109·7.

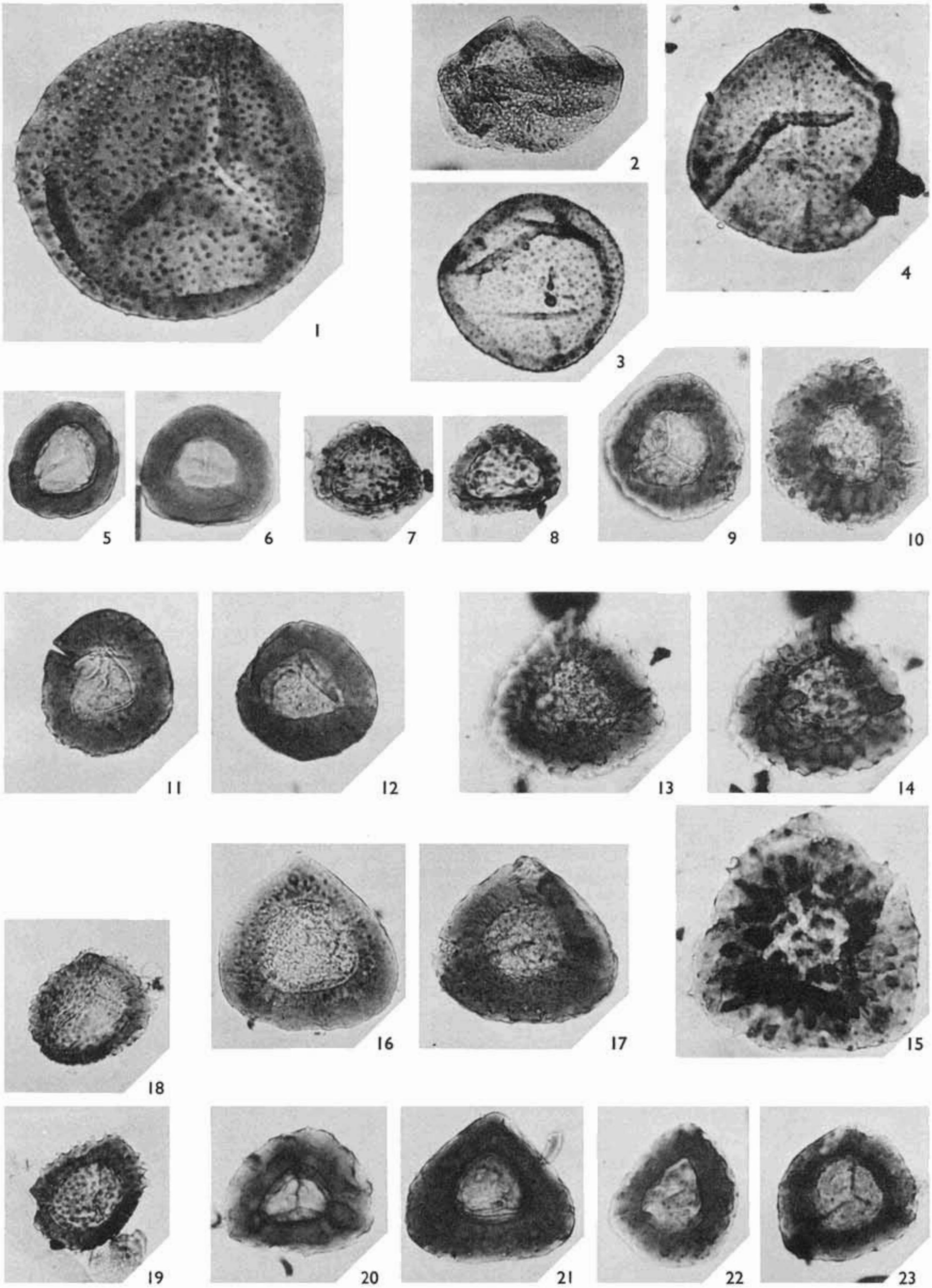
Figs. 11, 12. *D. pseudoannulatus* Butterworth and Williams 1958. 11, Holotype; slide T59/1, 40·1 110·8. 12, distal surface; slide 183, 33·5 112·3.

Figs. 13–15. *D. regalis* (Bharadwaj and Venkatachala) comb. nov. 13, 14, proximal and distal surfaces respectively; slide 184, 49·5 111·3. 15, medium focus; slide 184, 57·3 105·9.

Figs. 16, 17. *D. triangularis* Kosanke 1950. 16, medium focus; slide 188, 39·3 113·4. 17, medium focus; slide 188, 37·5 114·1.

Figs. 18, 19. *D. spinifer* Hoffmeister, Staplin, and Malloy 1955. 18, slide 187, 50·0 102·8. 19, slide 187, 51·7 109·3.

Figs. 20–23. *D. sphaerotriangularis* Kosanke 1950. 20, slide 185, 38·0 114·8. 21, slide 185, 29·5 108·5. 22, slide 186, 37·9 111·8. 23, slide 186, 25·5 108·7.



SMITH and BUTTERWORTH, British Carboniferous miospores

inner light zone; dark zone often expanded and thickened into smooth, pad-like valvae at the apices, and may be absent or discontinuous along the sides; in some forms thickened areas are also present in interradial regions; secondary folds absent due to good proximo-distal orientation; extrema lineamenta smooth to sinuous, sometimes incised.'

Comparison. Differs from *Tripartites* in not possessing plicated radial crassitudes and from *Triquitrites* by the presence of a continuous equatorial structure.

Remarks. There is a superficial resemblance between *Simozonotriletes*, *Murospora* Somers 1952, and *Westphalensisporites* Alpern 1958. Hacquebard and Barss (1957) consider *Murospora* and *Simozonotriletes* to be congeneric, the former having priority over *Simozonotriletes*, which was only validated by Potonié and Kremp in 1954. Playford (1962) accepts this synonymy and further suggests that there is no basis for recognizing *Westphalensisporites* as distinct from *Murospora*. Bharadwaj and Venkatachala (1961) prefer to retain *Simozonotriletes* and *Murospora* as separate genera while accepting that *Murospora* and *Westphalensisporites* are probably congeneric. The authors are in accord with Bharadwaj and Venkatachala and have retained *Simozonotriletes* for forms referred to this genus by Horst, Potonié and Kremp, and Sullivan. The principal reason for this is the uncertainty in the literature concerning the structure of spores of this type. Hacquebard and Barss (1957, p. 34) interpret the equatorial structure as a centrifugal extension and not a true cingulum. Sullivan (1958, p. 128, fig. 1) and Playford (1962, p. 615, text-fig. 8) show a similar construction but refer to a cingulum. Staplin (1960, p. 28) refers only to a single genus, *Murospora*, to include patellate and capsulate forms 'composed of a separate spore body and a tightly attached but separate outer structure, not a centrifugal extension of the spore body'. He does not, however, emend the diagnosis of Somers. According to Staplin (1960) the forms originally assigned to *Murospora* are capsulate. It is not known whether the type of *Simozonotriletes intortus* has a cingulum, a patella, or a capsula (Pocock 1961, p. 1233). Due to inadequate material it has not been possible to confirm any of these statements.

Affinity. Unknown.

Simozonotriletes intortus (Waltz) Potonié and Kremp 1954

Plate 15, figs. 18–23

1938 *Zonotriletes intortus* Waltz in Luber and Waltz, pl. 2, fig. 24.
1954 *Simozonotriletes intortus* (Waltz) Potonié and Kremp, p. 159.
1962 *Murospora intorta* (Waltz) Playford, p. 609, pl. 86, figs. 12, 13.

Lectotype. Luber and Waltz 1938, pl. 2, fig. 24 (designated by Horst 1955).

Type locality. Moscow Brown Coal; Tournaisian or Viséan. Neotype, Horst (1955, pl. 22, fig. 52), Upper Silesia; Westphalian A. Holotype, designated by Hacquebard and Barss (1957, pl. 5, fig. 1), Canada; Lower Carboniferous.

Diagnosis (Sullivan 1958, p. 127). 'Trilete rays extend almost to margin of the central area; lips thin, intratectum narrow, remainder as for genus.'

Size in microns. (i) Lectotype approximately 60, Schulze. (ii) 35–110, Schulze and 10% KOH (Sullivan 1958). (iii) 49–68, fum. HNO_3: (Horst 1955). (iv) 65–75, hypotype 66·5 × 60·9, Schulze (Hacquebard and Barss 1957). (v) 50(65)82, body 33(44)57, Schulze and NH_4OH (Playford 1962); Spitsbergen; Lower Carboniferous. (vi) 52(64)76, body 34(43)50, fum. HNO_3; Greenses Seam at 147 ft. 8 in., Stamford borehole, Northumberland Coalfield, England; Viséan.

Remarks. The considerable variation in the structure of the equatorial region and the shape of these spores has been described by Sullivan (1958) and made the basis for the erection of nine varieties of this species.

Comparison. *Murospora conduplicata* (Andrejeva) Playford 1962 (p. 613, pl. 86, figs. 14, 15) and *M. sublobata* (Waltz) Playford, 1962 (p. 613, pl. 86, figs. 17–19) are smaller. In *M. aurita* (Waltz) Playford 1962 (p. 609, pl. 87, figs. 1–6, text-figs. 6*a*–*q*, 7), *M. circumscutata* Staplin 1960 (p. 30, pl. 7, fig. 5), and *M. friendii* Playford 1962 (p. 617, pl. 87, figs. 10–12) the body sides are more convex than in *S. intortus* and except in *M. circumscutata* the laesurae are markedly ridged. In *M. strigata* (Waltz) Playford 1962 (p. 615, pl. 86, figs. 20, 21, text-fig. 8*b*) and *M. dupla* (Ishchenko) Playford 1962 (p. 614, pl. 86, fig. 22, text-fig. 8*a*) the cingulum is conspicuously subdivided into bands parallel to the equator. In *M. tripulvinata* Staplin 1960 (p. 29, pl. 6, figs. 13–15) the angles are conspicuously expanded and *M. paenulata* Staplin 1960 (p. 30, pl. 7, figs. 1–4) is much larger and has convex sides.

Occurrence. Infrequent, Assemblages II to VIII; Viséan to Westphalian B.

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

Type species. *D. covensis* Berry 1937.

Diagnosis (Butterworth, Jansonius, Smith, and Staplin in Staplin and Jansonius 1964, p. 101). 'Spores trilete; outline convexly triangular to subcircular; two-layered; intexine (central body) thin, psilate or faintly roughened, laesurae indistinct, apical papillae sometimes present; proximal surface of outer layer evenly arched or with zona slightly raised above the central proximal area; sutural ridges weak to strong; sometimes connected at their extremities to the zonal region; proximal sculpture generally absent or minor except for scalloping of the zona in some species, faint roughening or granulosity of the central proximal area, and granules, spines or apiculae on the zona; sculpture of central distal area usually differentiated from distal zonal surface, usually granulose; zona psilate, granulose, spinose, apiculose, verrucose etc.; internal vacuoles ("rods") rare or absent.'

Note. In this diagnosis 'zona' applies to the structural feature referred to by the authors of the present work as a cingulum.

Comparison. *Cingulizonates* emend. is distinguished by its bizonate cingulum, which is differentiated into a sharply raised inner part and a thin outer part. *Cristatisporites* emend. has mammoid or setose ornament, and may have a ring of processes encircling the easily detached central proximal area of the exoexine.

Remarks. The emendation of *Densosporites* by Schopf, Wilson, and Bentall (1944, p. 39) included forms now assigned to *Cristatisporites* and *Cingulizonates* and, in fact, could include most spores with the exoexine thickened in the equatorial area. The emendation by Potonié and Kremp (1954, p. 160) is not practicable because it excludes the type *Densosporites covensis* (mistakenly believed to be similar to *Radiizonates faunus*), and other unornamented species, which these authors would place in the genus

Anulatisporites (Loose) Potonié and Kremp 1954. With the emendation of *Densosporites* mentioned above, which is based on the characteristics of the type species, the genus *Anulatisporites* becomes superfluous.

Affinity. Lycopsida (Bharadwaj 1958).

Densosporites anulatus (Loose) comb. nov.

Plate 19, figs. 5, 6

1932 *Sporonites anulatus* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 18, fig. 44.
1934 *Zonales-sporites (Anulati-sporites) anulatus* Loose, p. 151.
1944 *Densosporites annulatus* (Loose); Schopf, Wilson, and Bentall, p. 40.
1956 *Anulatisporites anulatus* (Loose); Potonié and Kremp, p. 112, pl. 17, figs. 365–72.
1950 *Denso-sporites reynoldsburgensis* Kosanke, p. 33, pl. 6, figs. 9–11.

Holotype. Potonié and Kremp 1956, pl. 17, fig. 365 after Loose. Preparation III31, b_5 (m/or).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 112; translation). 'Cingulum relatively uniform and smooth, having scaly structure. Amb smooth. Central area relatively much lighter than cingulum. Infragranulation obscure. Tetrad mark scarcely discernible.'

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 37·5; 35–60		Schulze (Potonié and Kr. 1956).
32(48)56	4(7)11	Fum. HNO_3; Lower Little Flint Seam at 1,196 ft. 2 in., Madeley Wood No. 4 borehole, Coalbrookdale Coalfield, England; Upper Westphalian A.
33(40)43	6(8)12	Fum. HNO_3; Upper Bed of Marshall Green Seam at 325 ft. 6 in., Callerton No. 23 borehole, Northumberland Coalfield, England; Lower Westphalian A.
26(34)42	4(7)9	Fum. HNO_3; Extra Seam at 2,589 ft. 8 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian B/C.
28(37)42	5(8)11	Fum. HNO_3; Upper Bed of Kittlepurse Seam at 4,108 ft. 11 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A.

Description. Amb subtriangular. Laesurae simple, faint, extending to the inner margin of the cingulum. Central body or intexine thin, laevigate. Apical papillae sometimes discernible. Central area of exoexine thin, laevigate. Cingulum narrow, tapering very slightly towards the equator, laevigate; about 40% of total diameter. Margin smooth.

Remarks. *D. anulatus* has been reassigned to the genus *Densosporites* because of its similarity to the type species of that genus. Examination of the holotype of *D. reynoldsburgensis* Kosanke has convinced the authors that it is conspecific with this species.

Comparison. *D. anulatus* is distinguished from most other species of the genus by its complete lack of ornament. *D. covensis* Berry 1937 (p. 157, text-fig. 11), *D. simplex* Staplin 1960 (p. 24, pl. 5, fig. 6), and *D. tripapillatus* Staplin 1960 (p. 24, pl. 5, figs. 4, 5) have relatively wider cinguli and the latter has prominent apical papillae.

Occurrence. Infrequent to abundant, Assemblages I to IX; Viséan to Lower Westphalian C.

Densosporites gracilis sp. nov.

Plate 19, figs. 7, 8

Holotype. Plate 19, fig. 7. Preparation T90/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Dicky Gobbler Seam at 625 ft. 0 in., Caldwell Ashley House borehole, South Derbyshire Coalfield, England; Westphalian B.

Diagnosis. Amb round to subtriangular or oval. Laesurae flexuose, extending almost to equator of spore. Cingulum (about 37% of total spore diameter) laevigate, granulate, vermiculate, or having small spinae; also often lobate and sometimes with dissections. Outline irregular. Central area granulate with dissections, or vermiculate.

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 35		Fum. HNO_3; type locality.
27(35)42	4(6)10	Fum. HNO_3; type locality.
28(34)38	5(6)8	Fum. HNO_3; Barncraig Seam, Michael Colliery, East Fife Coalfield, Scotland; Westphalian B.

Description. The laesurae are not always visible. The ornamentation of this species is very variable and may be due, in part, to the effects of weathering or maceration.

Comparison. *D. gracilis* is distinguished from *D. sphaerotriangularis* by its much narrower cingulum and from *D. anulatus* by its ornament and irregular outline. *D. lobatus* Kosanke 1950 (p. 32, pl. 6, figs. 4, 5) has a relatively wider cingulum (42% of the total diameter), a consistently vermiculate ornament, and a more tapering, lobate cingulum. *D. lori* Bharadwaj 1957*a* (p. 104, pl. 27, figs. 19, 20) is slightly smaller (27–33 μ) and has a bizonate cingulum, approximately one-half the total diameter of the spore.

Occurrence. Infrequent to abundant, Assemblages VIII and IX; Westphalian B.

Densosporites intermedius Butterworth and Williams 1958

Plate 19, figs. 9, 10

1958 *Densosporites intermedius* Butterworth and Williams, p. 379, pl. 3, figs. 38, 39.
1955 *Densosporites tenuis* Hoffmeister, Staplin, and Malloy, p. 387, pl. 36, figs. 18, 19, and 23.

Holotype. Plate 19, fig. 10. Preparation T61/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 2,082 ft. 2 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 379). Outline round to rounded-triangular. Central area thin, unornamented, or slightly granular. Tetrad mark not always seen; rays narrow, extending to the edge of the central area. Cingulum broad, roughly one-half spore radius; differentiated into a darker, thicker, inner zone and a lighter equatorial zone. Margin smooth or slightly notched.

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 56 35–36		Schulze and 5% KOH (Butterworth and Will. 1958).
37(43)51	8(11)15	Fum. HNO_3; upper bed of Marshall Green Seam at 325 ft. 6 in., Callerton No. 23 borehole, Northumberland Coalfield, England; Lower Westphalian A.

Description. Laesurae faint, length slightly greater than radius of central area. Intexine thin, laevigate, frequently folded. Proximal central area of exoexine slightly granulate. Thickened part of cingulum irregular in outline, slightly lobate. Cingulum about 50% of total diameter.

Remarks. It has been established by the exchange of material that *D. intermedius* is conspecific with *Densosporites tenuis* Hoffmeister, Staplin, and Malloy, but since the latter name is invalid [because of the existence of *D. tenuis* (Loose) Potonié and Kremp] the later name is used. Since *D. tenuis* (Loose) Potonié and Kremp was transferred to the genus *Radiizonates* by Butterworth *et al.* in 1964 the species *Densosporites tenuis* Hoffmeister, Staplin, and Malloy is no longer invalid and should be used in preference to *D. intermedius.*

Occurrence. Infrequent to abundant, Assemblages I to VI; Viséan to Westphalian A.

Densosporites pseudoannulatus Butterworth and Williams 1958

Plate 19, figs. 11, 12

Holotype. Plate 19, fig. 11. Preparation T59/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 2,082 ft. 2 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 379). Amb round to subtriangular. Laesurae not always seen; rays simple, extending to edge of central area. Margin smooth or finely serrated. Central area thin, finely granulate, frequently showing arcuate folding at the margin. Cingulum massive, breadth roughly equal to radius of central area; uniform in thickness; smooth to slightly spinose and often with characteristic radial fractures on the interradial margin.

Size in microns. Holotype 45; 35(44)51, Schulze and 5% KOH (Butterworth and Will. 1958).

Comparison. Distinguished from other species by its uniform, broad, thick cingulum and lack of prominent ornament. *Densosporites granulosus* Kosanke 1950 (p. 32, pl. 6, fig. 8) is larger, with a relatively wider cingulum, more ornament, and longer laesurae. *Densosporites covensis* Berry 1937, (p. 157, text-fig. 11) may be conspecific with *D. pseudoannulatus* but the synonymy cannot be determined until more details of the former species are available.

Occurrence. Infrequent to abundant, Assemblages I to IV; Viséan and Namurian.

Densosporites regalis (Bharadwaj and Venkatachala) comb. nov.

Plate 19, figs. 13–15

1961 *Cristatisporites regalis* Bharadwaj and Venkatachala, p. 33, pl. 6, figs. 101–4.
1963 *Densosporites spitsbergensis* Playford, p. 627, pl. 89, figs. 1–5.

Holotype. Bharadwaj and Venkatachala 1961, pl. 6, fig. 101. Preparation at Birbal Sahni Institute of Palaeobotany, Lucknow, India.

Type locality. Shale, Pyramidenburg, Spitsbergen; Lower Carboniferous.

Diagnosis (Bharadwaj and Venkatachala 1961, p. 33). 'Radial, subtriangular, angles blunt and conical, central body hyaline girdled by a dark brown cingulum, 18–26 μ wide between the angles, proximal exine granulose and distal spinose. Extrema lineamenta granulose, Y-mark prominent and extending into the cingulum.'

Size in microns. (i) Holotype 95; 62–100, cingulum 18–26 between the angles, up to 35 at the angles, commercial HNO_3 and 5% KOH (Bharadwaj and Ven. 1961). (ii) 55(66)80, body 23(31)39, Schulze and NH_4OH (Playford 1963); Spitsbergen; Lower Carboniferous (for *D. spitsbergensis*). (iii) 40(55)80, cingulum 10(17)21, fum. HNO_3; Oakshaw Ford Seam, Oakshaw Ford Colliery, Cumberland, England; Viséan.

Description. Laesurae rarely distinct, frequently extending for a short distance into the cingulum. Cingulum occasionally with small circular dissections. Ornament variable; distal spinae more prominent towards the inner margin of the cingulum than at the equator. Cingulum about 50% of total diameter.

Remarks. Certain specimens could be regarded as belonging to the genus *Cristatisporites*, but as they are in a minority, and as in most of the specimens there is a clear differentiation between cingulum and central area, the species has been referred to the genus *Densosporites*. The range of ornament found in the present assemblage is comparable to that in the *D. sphaerotriangularis–D. duriti–C. connexus* complex of the Westphalian A and B; it is also similar to that found by Alpern (1959) in *Densosporites* assemblages from the Stephanian of France.

Bharadwaj and Venkatachala (1961) compare these spores to those found by Bharadwaj (1958) from *Porostrobus zeilleri* Nathorst. *Densosporites spitsbergensis* Playford, which appears to be similar in all respects to *D. regalis*, is also said to be closely comparable to the spores of this cone.

Comparison. The specimens from the Oakshaw Ford Seam are smaller than those described by Bharadwaj and Venkatachala and by Playford but this may in part be due to the use of differing macerating agents.

Occurrence. Abundant, Oakshaw Ford Seam, Cumberland, Assemblage I; Viséan.

Densosporites sphaerotriangularis Kosanke 1950

Plate 19, figs. 20–23

Holotype. Kosanke 1950, pl. 6, fig. 7. Preparation 520–A, slide 2.

Type locality. Bald Hill Coal, Williamson County, Illinois, U.S.A.; Tradewater Group.

Diagnosis (from description in Kosanke 1950, p. 33). Outline rounded triangular. Proximal and distal central areas ornamented with widely spaced papillae. Tetrad mark distinct, 16–18 μ long, extending into equatorial portion. Equatorial portion varying from 12·5 to 14·7 μ wide; thickest at inner margin, translucent at equator—the two portions sharply contrasted, but the junction is irregular due to a construction of small plicating sheets. Folding lacking except at inner margin of thick wall.

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 50·4×48·3 46–59		Schulze and 10% KOH (Kosanke 1950).
39(47)60	7·5(11)17	Fum. HNO_3; Great Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, Westphalian D or Stephanian A.
26(50)59	5(12)18	Fum. HNO_3; Barncraig Seam, Michael Colliery, East Fife Coalfield, Scotland; Upper Westphalian B.
40(47)61	8(12)17	Fum. HNO_3; upper bed of Low Main Seam at 234 ft. 0 in., South Pelaw borehole, Durham Coalfield, England; Lower Westphalian B.
43(50)60	8(13)18	Fum. HNO_3; seam at 1,758 ft. 2 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Lower Westphalian B.
38(47)59	8(12)16	Fum. HNO_3; Yard of Tamworth Seam at 1,074 ft. 3 in., Bolehall borehole, Warwickshire Coalfield, England; Upper Westphalian A.

Description. Central body, or intexine, thin, laevigate. Proximal central area finely granulate, distal central area verrucate. Cingulum may have occasional well-spaced verrucae, or coni. Margin irregular, undulating, with protruding spinae or verrucae. Cingulum about 50% of total diameter.

Remarks. In its most verrucate form *D. sphaerotriangularis* is very similar to *D. duriti* Potonié and Kremp 1956 (p. 117, pl. 18, figs. 383, 384) which is more heavily ornamented. In the densospore-rich durains of the Westphalian A and B the densospores present show all gradations between these two species and it has been decided for the present to use only the earlier name.

Comparison. This is one of the more ornate species of the genus but does not have so many verrucae or spinae that it could be confused with species of the genus *Cristatisporites*.

Occurrence. Infrequent to abundant, Assemblages VI to IX; infrequent, Assemblage X; infrequent to abundant, Assemblage XI; Westphalian A to D.

Densosporites spinifer Hoffmeister, Staplin, and Malloy 1955

Plate 19, figs. 18, 19

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 17, TCO–82. Preparation 3, ser. 19,066.

Type locality. Shale at 2,075 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 386). Outline convexly triangular. Trilete rays not always distinct, extending into thickened equatorial region. Thickened equatorial region almost opaque, thinning only slightly at outer margin. Body coarsely granulate. Equatorial region with dense or scattered spinae, 2–6 μ long, sometimes bifurcated; extremely variable in shape and disposition; spinae project at margin.

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 46×42 32–48		HF (Hoffmeister, Stap., and Mall. 1955).
31(36)46	5(8)11	Fum. HNO_3; South Seam at 4,455 ft. 6 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A.
33(40)53	6(9)15	Fum. HNO_3; Seam at 39 ft. 10 in., Cheswick borehole No. 110, Northumberland Coalfield, England; Namurian A.

Description. Cingulum about 44% of total diameter.

Comparison. *D. spinifer* is less spinose than species of *Cristatisporites* and has a more clearly defined cingulum. *D. pannosus* Knox 1950 (1948, text-fig. 1) has longer, more closely packed spinae and well-marked laesurae with spinose ridges.

Occurrence. Infrequent to frequent, Assemblages I to IV; Viséan and Namurian.

Densosporites triangularis Kosanke 1950

Plate 19, figs. 16, 17

1950 *Denso-sporites triangularis* Kosanke, p. 34, pl. 7, fig. 1.
1958 *Densosporites spongeosus* Butterworth and Williams, p. 380, pl. 3, figs. 40, 41.

Holotype. Kosanke 1950, pl. 7, fig. 1. Preparation 144, slide 3.

Type locality. 'Sub-Babylon' Coal, Fulton County, Illinois, U.S.A.; Tradewater Group.

Diagnosis (from description in Kosanke 1950, p. 34). Outline subtriangular. Tetrad mark indistinct. Proximal and distal central areas granulose to vermiculate. Equatorial portion, measuring about 55% of spore diameter, tapers slightly and is variously spinose or punctate.

Size in microns.

Spore diameter	*Cingulum width*	
Holotype 58·8×58·8 52–65	12–19	Schulze and 10% KOH (Kosanke 1950).
40(51)50	8(12)17	Schulze and 5% KOH (Butterworth and Will. 1958 for *D. spongeosus*). Diamond Seam at 1,966 ft. 8 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.
41(47)54	9(11·5)16	Fum. HNO_3; Shilbottle Seam at 589 ft. 1 in., Hazon Ford borehole, Northumberland Coalfield, England; Viséan.

Description. Amb subtriangular, one apex frequently more prominent than the remainder. Laesurae of exoexine, where discernible, simple, extending to inner margin of cingulum. Central body, or intexine, thin, ? laevigate. Central area granulate or vermiculate to minutely foveolate. Cingulum with foveolate dissections and conate. Margin smooth to finely serrate.

Comparison. *D. spongeosus* is rather smaller than *D. triangularis*, perhaps on account of the use of different macerating agents. Examination of the holotype of each species has convinced the authors that they are conspecific; both have typically vermiculate-foveolate central areas. Distinguished from other species of the genus by its vermiculate-foveolate sculpture.

Remarks. In Butterworth and Williams (1958) the type locality of *D. spongeosus* was given in error as the Seam at 2,082 ft. 2 in., Righead borehole; it should have read Seam at 1,966 ft. 8 in., Righead borehole.

Occurrence. Infrequent to abundant, Assemblages I to V; Viséan and Namurian.

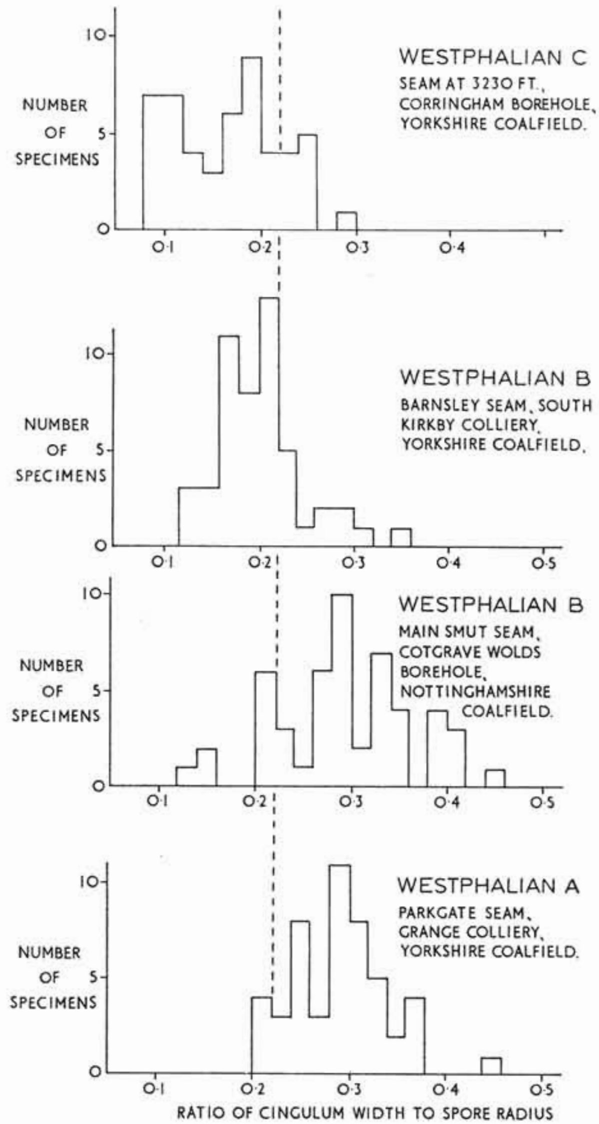
Genus LYCOSPORA (Schopf, Wilson, and Bentall) Potonié and Kremp 1954

This genus is tentatively included within the Cingulicavati because of its close morphological similarity to *Densosporites* and *Cingulizonates* and because the apical papillae recognizable in some specimens suggest the presence of an intexine.

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

Diagnosis (Potonié and Kremp 1954, p. 156; translation). 'Trilete isospores and microspores having a cingulum, approximately cuneiform in cross-section around the equator. The height of the wedge in section may be more than double its width at the base. The cingulum tapers down to its periphery, thus giving the spore a lenticular appearance. The relative sharpness of the outline at the equator, due to the cingulum, is also evident in polished sections of the spore exine made in the meridional plane. These exine cross-sections also show the thick base of the cuneiform cingulum characteristic of *Lycospora*. The equatorial margin of the cingulum is sometimes smooth, but generally rough to finely undulate. The body is granulate, or infragranulate, sometimes distinctly so. Granulation or infragranulation of the cingulum is also more or less plainly visible. Trilete rays distinct and fairly straight and, without tapering (or tapering only slightly), extend at least as far as the equator of the body, or often into the cingulum itself. The trilete rays may likewise show granulate ornamentation, or be more or less gnarled.'

Remarks. The structure of *Lycospora* is discussed by Bharadwaj (1957*a*, p. 101) and comparison is made with genera of somewhat similar construction. The appearance of the cingulum in *Lycospora* in polar sections of uncompressed spores from sections of a dolomitized *Lepidostrobus* cone is illustrated by Potonié and Kremp (1956, pl. 17, figs. 333–5). Some 50 morphographic species are described in the literature. Although some of these names may be synonyms, and others probably should be excluded from the genus, there remains a considerable number of species which are sufficiently alike to cause uncertainty in their identification. With such a ubiquitous genus it is particularly difficult to recognize the limits of a morphographic species in an assemblage comprising a number of natural species many of which undoubtedly overlap in their characters. This difficulty is enhanced in a genus in which the size of the spore may vary according to its position in the cone (Chaloner 1953*b*). Among the criteria used to separate species are size, type of ornament, and extent of development of the cingulum. The latter character, expressed as a proportion of the spore radius, has been extensively quoted as being diagnostic and for this reason an examination was made to see how far distinct forms could be recognized on this criterion alone. The width of the cingulum (including any flange-like extension) was calculated as the difference between the total diameter



TEXT-FIG. 71. Ratios of cingulum width to spore radius of *Lycospora spp.* from various seams and localities

of the spore and the diameter of the spore body within the cingulum. Both measurements were made along the axis corresponding to the maximum dimension of the compressed spore. The measurements were recorded for several assemblages of *Lycospora* having finely granulate ornament from different seams. The data suggest that only two forms can clearly be distinguished on this basis. Histograms showing the variations in this character are given in text-fig. 71. These two forms have been named after the first described species which most closely resemble the modal types, *L. pusilla* and *L. pellucida*. In describing these species the limits of cingulum breadth quoted by Potonié and Kremp (1956) have been extended and as a result it is probable that the present 'species' include several of those of other authors.

Comparison. Structurally the genus *Lycospora* is similar to other genera of the Cingulicavati but comprises relatively small forms in which the cingulum is not of massive proportions. In *Cirratriradites* the flange does not possess a crassitudinous base. Bharadwaj (1957*a*, p. 102, text-fig. 6*c*) figures a type of *Lycospora* structure in which there is only a flange at the equator and cites as an example *L. pseudoannulata* Kosanke; this species, however, possesses a cingulum like *L. punctata* Kosanke or *L. pellucida* Wicher. Small forms in which the flange lacks a crassitudinous base can only be differentiated from *Cirratriradites* by their size.

Affinity. Lycopsida. Arborescent Lepidodendra (Chaloner 1953*b*, Felix 1954, Abbott 1963); Lepidocarpon (Andrews and Pannell 1942).

Lycospora ? *granulata* Kosanke 1950

Plate 20, figs. 1–3

Holotype. Kosanke 1950, pl. 10, fig. 6. Preparation 519–A, slide 14.

Type locality. Dekoven Coal, Williamson County, Illinois, U.S.A.; Tradewater Group.

Diagnosis (from Kosanke 1950, p. 45). Amb circular to subtriangular. Laesurae with elevated lips, distinct, extending to margin. Equatorial ridge (cingulum) small. Exine coarsely granulate and 2 μ or more thick.

Size in microns. (i) Holotype 35·5, 30–40, Schulze and 10% KOH (Kosanke 1950). (ii) 27(32)37, fum. HNO_3; Barnsley Seam, South Kirkby Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb rounded-triangular, angles pointed or rounded; outline crenulate. Laesurae (about 1 μ in breadth and height) ridged and may extend to flange margin. Cingulum 3–5 μ in width, or one-quarter to one-third radius of spore; width of inner, thickened zone generally equal to outer, flange-like portion; not always very distinct. Exine, including ridges of laesurae, covered by closely spaced grana. Ornament generally developed on proximal and distal surfaces; size of ornament variable, seldom exceeds 2·5 μ in height or breadth. Exine thin.

Comparison. *L.* ? *granulata* is distinguished from other forms of *Lycospora* described here by the relatively coarse ornament which covers the entire exine. Spores of this type are only tentatively assigned to *L. granulata* since the holotype is more finely granulate than most of the specimens referred to this species in British coals. Potonié and Kremp have assigned coarsely granulate spores to *L. torquifer* (Loose) Potonié and Kremp but Piérart (Report to the Commission Internationale de Microflore du Paléozoïque, 1961) considers that the holotype is without a cingulum and does not belong to *Lycospora*. This opinion is based on an examination of photographs of the type taken at high magnification and at several planes of focus. *L. rotunda* Bharadwaj 1957*a* (p. 103, pl. 27, figs. 10–12) is identical in size and ornament but its circular shape is emphasized by Bharadwaj as a distinguishing character from similarly ornamented forms.

Occurrence. Common to abundant, Assemblages V to VII; infrequent to very common, Assemblages VIII and IX; infrequent, Assemblage X and infrequent to common, Assemblage XI. Upper Namurian to Westphalian D.

Lycospora noctuina Butterworth and Williams 1958

Plate 20, figs. 4–6

Holotype. Plate 20, fig. 4. Preparation T54/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. 9 in. coal at 256 ft. 11 in., Darnley No. 3 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (expanded from diagnosis in Butterworth and Williams 1958, p. 376). Amb rounded-triangular; outline smooth or minutely indented, sometimes undulate. Laesurae ridged, straight or flexuose, up to 2 μ in width and height, extending to inner, thickened zone of cingulum and sometimes beyond. Cingulum (including flange) relatively broad, 4–8 μ in width. Exine of central area and inner zone of cingulum finely granulate. A small number of large grana, or verrucae, or rugulae 1–3 μ broad and variable in length, occur distally in the central area within the cingulum; flange of

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EXPLANATION OF PLATE 20

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1–3. *Lycospora ?granulata* Kosanke 1950. 1, distal surface; slide 189, 17·8 107·5. 2, slide 189, 13·8 113·9. 3, equatorial view; slide 189, 15·3 113·3.

Figs. 4–6. *L. noctuina* Butterworth and Williams 1958. 4, Holotype; slide T54/1. 5, Isotype; slide T54/2. 6, Westphalian specimen; slide 190, 43·8 105·6.

Figs. 7–9. *L. pellucida* (Wicher) Schopf, Wilson, and Bentall 1944. 7, slide 194, 39·6 110·0. 8, slide 195, 52·5 107·1. 9, equatorial view; slide 195, 47·7 117·5.

Figs. 10–12. *L. pusilla* (Ibrahim) Schopf, Wilson, and Bentall 1944. 10, slide 196, 60·7 112·6. 11, distal surface; slide 196, 41·3 115·6. 12, equatorial view; slide 196, 51·2 115·2.

Figs. 13–15. *L. ?rugosa* Schemel 1951. 13, slide 38, 22·0 106·4. 14, slide 113, 46·5 100·9. 15, slide 197, 28·8 110·0.

Figs. 16–19. *L. orbicula* (Potonié and Kremp) comb. nov. emend. 16, slide 191, 35·1 105·6. 17, oblique compression showing portion of laevigate proximal surface; slide 191, 53·1 105·8. 18, oblique compression showing portion of laevigate proximal surface, ×1,000; slide 192, 15·8 119·0. 19, ×1,000; slide 193, 42·5 105·5.

Figs. 20, 21. *Cristatisporites connexus* Potonié and Kremp 1955. 20, slide 198, 46·4 116·9. 21, distal surface; slide 198, 37·0 108·3.

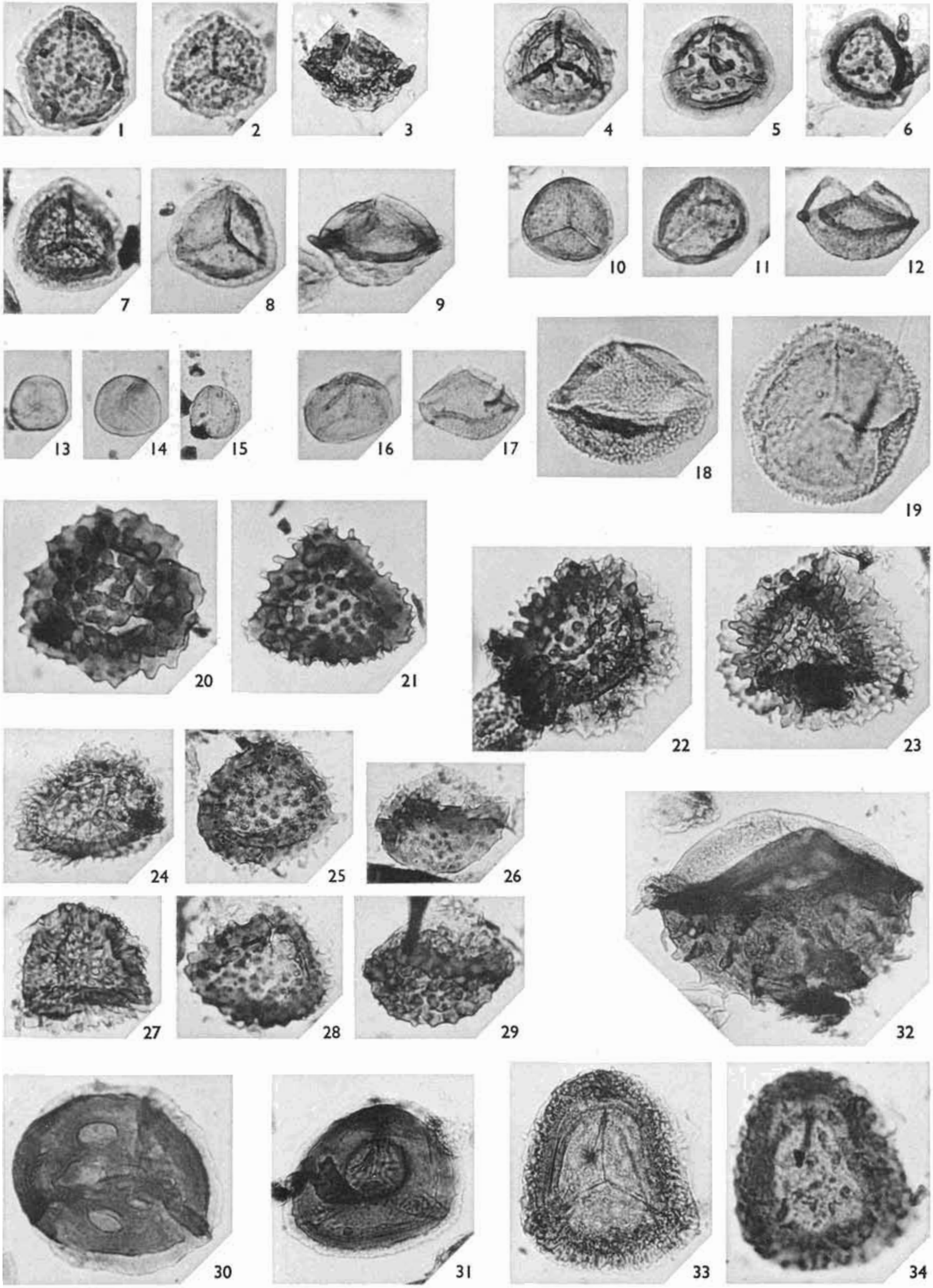
Figs. 22, 23. *C. indignabundus* (Loose) Staplin and Jansonius 1964. 22, slide 199, 47·7 103·2. 23, distal surface; slide 199, 30·2 106·6.

Figs. 24–29. *C. solaris* (Balme) Butterworth and Smith (in Butterworth *et al.* 1964). 24, Lectotype; slide T69/1, 41·3 105·7. 25, distal surface; slide T69/2, 53·5 112·0. 26, equatorial view; slide T69/3, 48·0 107·6. 27, distal surface; slide 200, 51·9 120·3. 28, slide 201, 20·0 107·1. 29, equatorial view; slide 201, 31·1 114·4.

Fig. 30. *Cirratriradites annulatus* Kosanke and Brokaw (in Kosanke 1950). Distal surface; slide 242, 25·9 114·9.

Fig. 31. *C. annuliformis* Kosanke and Brokaw (in Kosanke 1950). Slide 202, 18·7 107·3.

Figs. 32–34. *C. megaspinosus* (Ibrahim) comb. nov. emend. 32, equatorial view; slide 203, 45·0 117·8. 33, 34, proximal and distal surfaces respectively; slide 203, 30·1 115·7.



SMITH and BUTTERWORTH, British Carboniferous miospores

cingulum laevigate, finely granulate, or with small circular, or radially elongate, dissections. Exine of central area thin.

Size in microns. (i) Holotype 36; 30–45, Schulze and 5% KOH (Butterworth and Will. 1958). (ii) 31(35)38, fum. HNO_3; seam at 419 ft. 6 in., Houghton Colliery borehole, Durham Coalfield, England; Westphalian A. (iii) 27(36)47, fum. HNO_3; seam at 31 ft. 4 in., Culross No. 2 borehole, West Fife Coalfield, Scotland; Namurian A.

Description. The relative widths of the inner thickened zone and the outer flange-like extension of the cingulum vary, but generally the width of the flange is greater than that of the inner zone.

Remarks. Forms from the Westphalian A appear to lack rugulae and possess only verrucate ornament.

Occurrence. Infrequent to common, Assemblages I to VI; occasionally abundant in Assemblage III; Viséan to Westphalian A.

Lycospora orbicula (Potonié and Kremp) comb. nov. emend.

Plate 20, figs. 16–19

1955 *Cyclogranisporites orbiculus* Potonié and Kremp, p. 63, pl. 13, figs. 179–83.

Holotype. Potonié and Kremp 1955, pl. 13, fig. 179. Preparation 607/2, KT 18·6 110·0.

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

Diagnosis (emended from Potonié and Kremp 1955, p. 63). Amb more or less circular to oval; outline denticulate. Laesurae simple, reaching to, or nearly to, equator, sometimes indistinct. Exine finely granulate; ornament reduced or lacking on proximal surface. Cingulum indistinct, very narrow; does not extend polewards; less than 1 μ in width, or less than one-tenth of spore radius. Exine thin, often with narrow folds.

Size in microns. (i) Holotype 27; 25–35, Schulze (Potonié and Kr. 1955). (ii) 20(25)30, fum. HNO_3; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England; Westphalian A. (iii) 22(27)30, fum. HNO_3; top bed of Wheatley Lime(?) Seam at 2,189 ft. 9 in., Little Smeaton borehole, Yorkshire Coalfield, England; Westphalian A.

Description. Cingulum often only apparent in slightly oblique compression. In such specimens narrow, arcuate folds, or ridges, may connect the end of a laesura to the equator (?'curvatura imperfecta'). Narrow folds commonly occur.

Remarks. Cyclogranisporites pressoides Potonié and Kremp 1955 was transferred to *Lycospora* by Bharadwaj (1957*b*, p. 127) on account of the length of the laesurae. This was stated to be the sole criterion for the change although in his emended diagnosis Bharadwaj refers to a cingulum. The authors have examined the holotypes and other specimens of *L. pressoides* and *Lycospora* (*Cyclogranisporites*) *orbicula* figured by Potonié and Kremp (1955, pl. 13, figs. 187–90 and 179–83) and conclude that the British species is closer to *orbicula* than to *pressoides*. In fact, the latter species does not appear to possess characters that justify its retention in *Lycospora*. *L. orbicula* is not typical of the genus in that the cingulum is weakly developed but Chaloner has isolated spores of this type with a size range of 19(26)34 μ from the cone of *Lepidostrobus olryi* Zeiller (Chaloner 1953*b*, text-figs. 23A–D), which justifies the inclusion of the species in *Lycospora*.

Comparison. *Anaplanisporites baccatus* (Hoffmeister, Staplin, and Malloy) comb. nov. is of similar size and has a superficial similarity to *L. orbicula* in structure but differs in possessing a more prominent distal ornament and in the absence of a cingulum. *Cyclogranisporites leopoldi* (Kremp) Potonié and Kremp 1955 (p. 62, pl. 13, figs. 174–8) is in part larger and the laesurae, when seen, are only about one-half the length of the spore radius. The grana are rather more distinct than in *L. orbicula*.

Occurrence. Infrequent to common, Assemblages V to XI; not recorded from the Kent Coalfield and only one record from Assemblages VI to VIII from the South Wales Coalfield; Westphalian A to D.

Lycospora pellucida (Wicher) Schopf, Wilson, and Bentall 1944

Plate 20, figs. 7–9

1934 *Sporites pellucidus* Wicher, p. 186, pl. 8, fig. 29.
1944 *Lycospora pellucidus* (Wicher); Schopf, Wilson, and Bentall, p. 54.

Holotype. Potonié and Kremp 1955, pl. 17, fig. 341 after Wicher. Preparation III B5, d1 (o/r).

Type locality. Seam R_1, Wehofen Colliery, Ruhr Coalfield, Germany; Westphalian C. (Seam R_1 in Wicher 1934 is a thin coal between the Seams Kobold and Loki and is not the authentic R_1 of the Ruhr Coalfield).

Diagnosis (expanded from Potonié and Kremp 1956, p. 102). Amb rounded-triangular; outline smooth to minutely indented. In equatorial view proximal profile pointed, distal profile convex. Laesurae ridged, straight or flexuose, narrow and seldom more than 1 μ in height; they extend to the outer margin of the inner zone of cingulum and sometimes beyond. Cingulum comprises a darker inner zone and a lighter, flange-like, outer zone. Total width of cingulum 4–8 μ, or one-fifth to nearly one-half radius. Exine including cingulum and ridged portion of laesurae, granulate.

Size in microns. (i) Holotype 46, Schulze and KOH. (ii) 35–50, Schulze (Potonié and Kr. 1956). (iii) 30(38) 44, fum. HNO_3; Beamshaw Seam, South Kirkby Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 32(39)49, fum. HNO_3; Main Smut Seam at 1,152 ft. 7 in., Cotgrave Wolds borehole, Nottinghamshire Coalfield, England; Lower Westphalian B. (v) 30(35)42, fum. HNO_3; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England; Westphalian A.

Description. There is a tendency for one angle to be pointed and others to be well rounded. The outer zone of the cingulum may be equal to, or twice, the width of the darker inner portion (zone where cingulum overlaps spore body). Folds are uncommon, but are generally narrow and located along the inner margin of the cingulum.

Comparison. The only distinction between *L. punctata* Kosanke 1950 (p. 45, pl. 10, fig. 3) on the one hand, and *L. pellucida* and *L. pseudoannulata* Kosanke 1950 (p. 45, pl. 10, fig. 7) on the other, appears to be in the body ornament, which is described by Kosanke as punctate in the former species and granulose in *L. pseudoannulata*. This is not considered a reliable basis upon which to separate species which otherwise appear to be similar. Bharadwaj (1957*a*, p. 101) apparently interprets the cingulum in *L.*

pseudoannulata as a membranous flange lacking the crassitudinous base (that is the inner thickened zone of the cingulum) but Kosanke's description does not support this.

Histograms of the ratio of cingulum breadth to spore radius were plotted (text-fig. 71) for several assemblages of *Lycospora* excluding those readily recognizable forms already described. The histograms showed that the cingulum breadth varied from one-fifth to one-half with a modal value lying within the range one-quarter to one-third of spore radius. The published values (Potonié and Kremp 1956) for *L. pellucida*, *L. pseudoannulata*, and *L. punctata* fall within the latter range. The spread of values about the mode is uniform but the range is much greater than has been recognized for any of these species. The British material has accordingly been referred to *L. pellucida*, the first-named species, the remaining species being regarded as synonyms. Staplin (1960, p. 20) also suggests that *L. uber* (Hoffmeister, Staplin, and Malloy 1955, p. 383, pl. 36, fig. 24) Staplin and *L. pseudoannulata* Kosanke may be synonymous. *L. microgranulata* Bharadwaj 1957*a* (p. 104, pl. 27, fig. 18) does not appear to differ significantly from certain forms included in *L. pellucida*. *L. pellucida* differs from *L. noctuina* Butterworth and Williams in the absence of any coarse ornament on the proximal and distal faces.

Occurrence. Abundant, Assemblages I to XI. In the Upper Carboniferous may constitute 80% of the microfloras in Assemblage V, falling to less than 30% of those in Assemblage XI. Viséan to Westphalian D.

Lycospora pusilla (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 20, figs. 10–12

1932 *Sporonites pusillus* Ibrahim in Potonié, 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. 3, fig. 33 and pl. 8, fig. 105.
1944 *Lycospora pusillus* (Ibrahim); Schopf, Wilson, and Bentall, p. 54.

Holotype. Potonié and Kremp 1956, pl. 17, fig. 351 after Ibrahim. Preparation B27, a1 (o).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 103; translation). 'Tecta straight, fine, ornamented with small grana. Cingulum about one-ninth of radius. Amb slightly and fairly regularly indented ('korrodiert'). Exine finely granulate.'

Size in microns. (i) Holotype 38, Schulze and KOH. (ii) (25) 30–40, Schulze (Potonié and Kr. 1956). (iii) 20(27)32, fum. HNO_3; Barnsley Seam, South Kirkby Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 22(27)35, fum. HNO_3; Top Silkstone Seam, Elsecar Main Colliery, Yorkshire Coalfield, England; Westphalian A.

Description. Amb circular or very slightly triangular; outline smooth or minutely indented; in equatorial view proximal profile pointed, distal profile convex. Laesurae simple, or slightly ridged, extending approximately to amb; precise limit often not clear. Exine often ruptured along laesurae. Cingulum with, or without, flange-like extension. In polar compression inner darkened zone of cingulum narrow, about $1{\cdot}5\,\mu$ in width. Flange at maximum development scarcely exceeds width of inner zone; part of cingulum only may show flange development; in some instances an apparent flange may be formed by an arc of the distal exine projecting beyond the cingulum, due to manner of compression. Total width of cingulum up to $3\,\mu$ or one-ninth to one-fifth of spore radius.

Folds of very narrow, taper-pointed type; when present usually located parallel to inner margin of cingulum. Exine, including cingulum, finely granulate and thin.

Comparison. Compared to species of comparable size *L. pusilla* is more rounded, and has a narrower cingulum, less prominent laesurae, and finer granulate ornament. *L. brevijuga* Kosanke 1950 (p. 44, pl. 10, fig. 5), with a size range of 30–40 μ and a small equatorial ridge (one-sixth to one-fifth of spore radius according to Potonié and Kremp 1956), appears very like *L. pusilla* but possesses apical papillae. Experience suggests that the latter feature is not, in general, a reliable character upon which to separate species. Papillae can sometimes just be detected in British material. *L. micropapillata* (Wilson and Coe) Schopf, Wilson, and Bentall, with a size range of 25–30 μ (Wilson 1958, p. 100, pl. 1, fig. 6) and a cingulum without a flange, also resembles *L. pusilla*. *L. parva* Kosanke 1950 (p. 44, pl. 16, fig. 5), with a size range of 25–32 μ, is stated by Kosanke to be smaller than *L. pusilla* and to have a narrower flange. No distinction between *L. parva* and *L. pusilla* can be made on these bases in British material. It is considered that these forms are not sufficiently different from *L. pusilla* to justify the status of species.

Occurrence. Abundant, Assemblages I to XI; Viséan to Westphalian D.

Lycospora ? *rugosa* Schemel 1951

Plate 20, figs. 13–15

Lectotype. Schemel did not publish details of a holotype, but the specimen figured by Schemel (1951, p. 748, text-fig. 4) is stated to be in the author's collection at the West Virginia Geological Survey and this specimen has been chosen as a lectotype.

Type locality. Mystic Coal of southern Iowa, U.S.A.; Des Moines Series.

Diagnosis (from description in Schemel 1951, p. 747). Amb circular. Laesurae extend to equatorial ridge (cingulum), lips slightly thickened. Equatorial ridge 2–2·5 μ in width, opaque. Exine thin and translucent, minutely granulate to rugulate.

Size in microns. (i) 20(24)26, maceration method not known (Schemel 1951). (ii) 17(22)30, fum. HNO_3; Swinton Pottery Seam at 772 ft. 9 in., Kellingley borehole, Yorkshire Coalfield, England; Upper Westphalian B.

Description. Amb circular to rounded-triangular; outline smooth to minutely indented. Laesurae straight, simple, sometimes indistinct. Cingulum, narrow without any flange, about 1 μ in width and one-fifth, or less, of radius. Exine finely granulate; grana closely spaced, may be distinct or scarcely recognizable. Generally without folds.

Remarks. A number of small species of *Lycospora* have been described but none of the descriptions exactly fit the above form. Tentatively this is assigned to Schemel's species which, apart from the slightly broader cingulum, the width of which is quoted as 2–2·5 μ, closely resembles the British form.

Comparison. *L.* ? *rugosa* is a more robust species than *L. orbicula*, lacks folds, and has a more obvious cingulum. *L.* ? *rugosa* is in general smaller than *L. pusilla* and has no flange to the cingulum. *L. brevis* Bharadwaj 1957*a* (p. 103, pl. 27, figs. 6–8), with a size range of

18–22 μ, is in part smaller than *L.* ?*rugosa* and appears to possess more prominent laesurae.

Occurrence. Infrequent, Assemblage III; infrequent to frequent, Assemblages VI to X; Namurian to Westphalian C.

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

Type species. C. indignabundus (Loose) Potonié and Kremp 1954.

Diagnosis (Butterworth, Jansonius, Smith, and Staplin in Staplin and Jansonius 1964, p. 108). 'Spores trilete; outline subcircular to subtriangular; two-layered; intexine often indistinct, when preserved almost fills the exoexinal cavity, sculpture absent-minor; central proximal area of exoexine minutely sculptured, usually surrounded by a loose ring of setae, apiculae, granules or small pits; sutural ridges or grooves often indistinct, terminated by the setose ring; zona beyond the setae psilate or with scattered granules or small apiculae; spore margin irregular with small scattered processes, or strongly incised if the distal sculpture carries to the equatorial margin; distal sculpture prominent, often mammoid or with warts that in part bear setose tips; inner surface of exoexine may be minutely foveolate and vacuolate.'

Comparison. Distinguished from other genera by its prominent distal sculpture.

Remarks. The basis for the emendation is the distinction between proximal and distal sculpture, as well as the two-layered exine.

Affinity. Lycopsida, Chaloner 1962.

Cristatisporites connexus Potonié and Kremp 1955

Plate 20, figs. 20, 21

Holotype. Potonié and Kremp 1955, pl. 16, fig. 291. Preparation 77*e*.

Type locality. Gas Boring KM 1, Ascheburg, Germany; Lower Westphalian B.

Diagnosis (Potonié and Kremp 1955, p. 106; translation). 'About 30 projections at the equator. Ornamental elements more or less interconnected to form ridges.'

Size in microns.

Spore diameter	*No. of equatorial projections*	
56 Holotype		Schulze (Potonié and Kr. 1955).
45–70	*ca.* 30	
41(54)66	26(32)42	Fum. HNO_3; seam at 1,758 ft. 2 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Lower Westphalian B.
51(58)67	24(34)49	Schulze and 5% KOH; Lower Furnace Seam, Bradford Colliery, Lancashire Coalfield, England; Lower Westphalian B.
37(47)59	22(27)36	Fum. HNO_3; Yard of Tamworth Seam at 1,074 ft. 3 in., Bolehall borehole, Warwickshire Coalfield, England; Upper Westphalian A.

Description. Amb subcircular. Laesurae not always apparent; may extend into the cingulum. Central body or intexine thin, ? laevigate; central proximal area of exoexine granulate. Cingulum and central distal area verrucate; verrucae closely packed and arranged in ridges or cristae on the cingulum, more widely spaced in the central area. Margin modified by projecting verrucae, some with setose tips; 22 to 50 verrucae have been counted on the equator.

Comparison. *C. connexus* is distinguished from other species of *Cristatisporites* by ornament consisting only of verrucae and by its greater size.

Occurrence. Infrequent to common, Assemblages VI to IX; Upper Westphalian A and Westphalian B.

Cristatisporites indignabundus (Loose) Staplin and Jansonius 1964

Plate 20, figs. 22, 23

1932 *Sporonites indignabundus* Loose in Potonié, Ibrahim, and Loose, p. 451, pl. 19, fig. 51.
1934 *Apiculati-sporites indignabundus* Loose, p. 153.
1944 *Densosporites indignabundus* (Loose); Schopf, Wilson, and Bentall, p. 40.
1954 *Cristatisporites indignabundus* (Loose); Potonié and Kremp, p. 142.

Holotype. Potonié and Kremp 1955, pl. 16, fig. 294 after Loose. Preparation IV24, d_4 (ol).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Staplin and Jansonius 1964, p. 108). 'Spores trilete; subcircular to subtriangular; two-layered; intexine lines cavity of exoexine, but seldom seen; central proximal area of exoexine roughened to finely granulose, bounded by an irregular ring of hooked setose spines up to 2·5 microns long and 1·2 microns wide at their bases; sutural ridges flush with or slightly raised above the central proximal surface, narrow, often indistinct, terminated at the row of setae; zona beyond the setae almost psilate or bears scattered small granules or conical apiculae; spore margin irregular with scattered small coni that often have minute setose tips; on specimens where the distal sculpture carries to the equator, the margin is strongly irregular; distal surface sculptured with prominent warts that in part connect at their bases, individual warts up to 6 microns high and 4 microns wide, some warts have setose tips; warts become smaller and well separated towards the equatorial margin and are interspersed with small coni, the warts also may become smaller in the central distal area; inner wall of exoexine minutely foveolate distally; zona not clearly marked, width (measured from equator to outside of ring of setose spines) generally less than half spore radius.'

Size in microns.

Spore diameter	*No. of equatorial projections*	
52·5 Holotype		Schulze (Potonié and Kr. 1955).
50–80		Schulze (Potonié and Kr. 1955).
42(53)64	36(43)51	Fum. HNO_3; Brooch Seam at 2,350 ft. 5 in., Sandon Bank borehole, Cannock Chase Coalfield, England; Upper Westphalian B.
41(51)58	33(42)58	Fum. HNO_3; seam at 13 ft. 11 in., No. 6 Underground borehole, Madeley Wood Colliery, Coalbrookdale Coalfield, England; Upper Westphalian B.
44(52)61	35(44)56	Fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B.

Remarks. An assemblage from the High Hazel Seam was examined by Staplin and Jansonius and provided the basis for their emended diagnosis.

Occurrence. Infrequent to common, Assemblages VIII and IX; Westphalian B.

Cristatisporites solaris (Balme) Butterworth and Smith (in Butterworth *et al.* 1964)

Plate 20, figs. 24–29

1952 *Densosporites solaris* Balme, text-figs. 1*a*, *b*.
non 1956 *Densosporites solaris* Balme; Potonié and Kremp, p. 119, pl. 18, figs. 380, 381.

Lectotype. Plate 20, fig. 24. Balme did not designate a holotype. A lectotype (T69/1) has been chosen from material deposited by him in the collection of the Coal Survey Laboratory, Sheffield.

Type locality. Houghton Thin Seam at 766 ft. 5 in., Wentbridge No. 2 borehole, Yorkshire Coalfield, England; Lower Westphalian C.

Diagnosis (from diagnosis in Balme 1952, p. 175). Amb oval to subtriangular in equatorial view; proximal surface tetrahedral, distal surface hemispherical. Trilete sutures extend to inner margin of flange (cingulum). Exine of central polar region thin, finely punctate, and ornamented with small tubercles. The outer periphery of the flange indented and prolonged into flattened spinose projections, about 4 μ in length. Similar projections also occur on the proximal and distal surfaces of the flange.

Size in microns. (i) Lectotype 49·5; diameter 39(49)65, cingulum 7–10, Schulze and 5% KOH (Balme 1952). (ii) Diameter 36(45)53, cingulum 4(7)11, Schulze and 5% KOH; seam at 652 ft. 7 in., Hawksyard borehole, Cannock Chase Coalfield, England; Lower Westphalian C. (iii) 33(42)56, cingulum 4(7)11, Schulze and 5% KOH; Bradford Yard Seam, Bradford Colliery, Lancashire Coalfield, England; Westphalian C.

Description. Laesurae weakly ridged, not always seen. Intexine not discernible. Central proximal area of exoexine coarsely granulate or conate. Cingulum relatively narrow, averaging 30% of total spore diameter; proximal inner margin with a ring of spinae or verrucae. Cingulum and distal central areas with spinae or verrucae, those on the cingulum joined at their bases to form concentric zones of cristae. Little differentiation distally between cingulum and central area. Lateral compressions frequent. Margin modified by projecting spinae and verrucae; approximately 20 to 35 elements project at the equator.

Comparison. Distinguished from *C. indignabundus* by its smaller size and relatively narrower cingulum. Distinguished from *C. saarensis* Bharadwaj (1957*a*, pl. 27, figs. 24–6) by its slightly larger size and coarser ornament.

Remarks. The spores figured by Potonié and Kremp (1956) have a wider cingulum and are less densely ornamented than the spores from the type locality.

Occurrence. Infrequent to abundant, Assemblage IX and X; Upper Westphalian B and Westphalian C.

Genus CIRRATRIRADITES Wilson and Coe 1940

Type species. C. saturni (Ibrahim) Schopf, Wilson, and Bentall 1944.

Diagnosis (from Schopf, Wilson, and Bentall 1944, p. 43). Spores radial, trilete with strongly projecting equatorial flange (zona). Amb subtriangular to triangular; margin minutely to coarsely serrate. Laesurae simple or tectate, extending to the spore body margin, often continued by a line of thickening to edge of the zona. Spore body round to triangular, smooth, granulate, or finely punctate, or with radial ridges anastomosing to give reticulation. Distal surface may have one or more foveae with pronounced margins. Zona relatively broad; sometimes comprising more than half the total spore diameter, radially striate with one or more bands of concentric irregular thickening; zona often broader opposite rays than in interradial areas. Size 40 to over 100 μ in diameter.

Comparison. Spores of the genera *Lycospora*, *Densosporites*, *Cingulizonates*, and *Cristatisporites* are distinguished by their cuneiform cingulum, which overlaps the spore body proximally and distally.

Remarks. Microtome sections of *Cirratriradites elegans* (Waltz) Potonié and Kremp described by Hughes, Dettmann, and Playford (1962) show an intexine and a surprisingly thick distal exoexine; the lips of the laesurae are seen to be 'upturned extensions of the exoexine, as opposed to thickenings'. It appears likely, from a comparison of the photograph of *C. elegans* with other species, that these characteristics are common to the genus as a whole.

Affinity. Lycopsida. Chaloner (1954, p. 85, text-figs. 4, 5) isolated spores comparable with *Cirratriradites annulatus* Kosanke and Brokaw (in Kosanke 1950) from the herbaceous lycopod *Selaginellites suissei* Zeiller. Similar spores have also been recorded from *S. crassicinctus* Hoskins and Abbott (1956, p. 38, figs. 8, 10).

Cirratriradites annulatus Kosanke and Brokaw 1950 (in Kosanke 1950)

Plate 20, fig. 30

Holotype. Kosanke 1950, pl. 7, fig. 4. Preparation 540–C, slide 6.

Type locality. No. 6 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 35). Amb rounded-triangular; laesurae distinct, extending to the margin of zona. Exine of body sharply punctate with four or more foveae on the distal surface; zona minutely radially striate. Body exine over 2 μ thick. Folding rare.

Size in microns. (i) Holotype 98·6×89·2, body 67·2×65·1; 84–102, Schulze and 10% KOH (Kosanke 1950). (ii) 68(85)104, body 56(69)84, zona 5(8)12, Schulze and KOH; seam at 511 ft. 0 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England; Westphalian D.

Description. The zona is sometimes wider at the angles, but more often of equal width all round; in addition to radial striations it may have irregular, concentric bands of thickening. The distal foveae (numbering 4 to 12 in the Westphalian D assemblage) are enclosed by thickened ridges; where there are only four of these they are generally joined on the distal pole and are irregular in shape, but when there are more than four they tend to be smaller, separated from each other, and circular in outline. Body moderately thick, zona thin.

Comparison. Distinguished from other species by the larger number of foveae on the distal surface of the body.

Occurrence. Infrequent or frequent, Assemblage XI; Westphalian D.

Cirratriradites annuliformis Kosanke and Brokaw (in Kosanke 1950)

Plate 20, fig. 31

Holotype. Kosanke 1950, pl. 7, fig. 6. Preparation 596–A, slide 8.

Type locality. Grape Creek No. 6 Coal, Vermilion County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 35). Amb round to rounded-triangular, margin irregular and minutely toothed. Laesurae extending to margin of zona. Exine minutely punctate. Zona narrow, not striate, appears to originate proximally and distally of the equator of the spore body. Distal foveae may not be present. Body exine 2–3 μ thick, zona 1–1·25 μ thick.

Size of microns. (i) Holotype 84×82; 76–90, Schulze and 10% KOH (Kosanke 1950). (ii) 58(78)95; body 46(64)81; zona 4(7)11, Schulze; seam at 729 ft. 3 in., Pie Rough (Keele No. 1) borehole, North Staffordshire Coalfield, England; Westphalian D.

Description. Laesurae ridged, flexuose. Zona punctate, of equal width all round, not much thinner than the spore body. Distal foveae (not always present) are often difficult to distinguish; up to three have been observed. Body and zona moderately thick.

Comparison. Distinguished from other species by its relatively narrow, non-striate zona and minutely punctate exine.

Occurrence. Infrequent or frequent, Assemblage XI; Westphalian D.

Cirratriradites megaspinosus (Ibrahim) comb. nov. emend.

Plate 20, figs. 32–34

1933 *Apiculati-sporites megaspinosus* Ibrahim, p. 24, pl. 8, fig. 69.
1955 *Cristatisporites megaspinosus* (Ibrahim); Potonié and Kremp, p. 105.

Holotype. Ibrahim 1933, pl. 8, fig. 69. Preparation B27, b4 (ol).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (emended from Ibrahim 1933, p. 24). Amb circular to rounded-triangular; in equatorial view proximal surface slightly, distal surface strongly, convex; margin of zona irregularly crenulate. Laesurae simple, extending to inner edge of zona. Zona relatively narrow; width beyond equator 2·5–6 μ; outer zone more translucent than the inner zone, which may slightly overlap the equator. Zona pitted with circular and lenticular dissections. Proximal surface laevigate, distal surface covered with dispersed falcate spinae having a height of 4–9 μ and breadth of 2·5–7 μ. Exine infragranulate. Thickness of proximal exine about 2·5 μ; distal exine thickness about 3·5 μ.

Size in microns. (i) Holotype 88·5 × 84·5, Schulze and KOH. (ii) 52(67)92 (15 specimens) fum. HNO_3; seam at 1,433 ft. 0 in., Hartswell Farm borehole, Nottinghamshire Coalfield, England; Westphalian C.

Description. The laesurae are sometimes accompanied by folds. The distal spinae taper abruptly from their relatively broad bases and are sharply pointed. The longer spinae are usually curved or bent. In compression about 12 spinae project from the margin of the distal hemisphere. In polar compression they scarcely project beyond the margin of the zona. No foveae are present.

Remarks. Ibrahim did not recognize that the spinae are confined to the distal surface.

Comparison. C. megaspinosus is morphologically similar to *C. ornatus* Neves 1961 (p. 269, pl. 33, fig. 3) but is smaller and has a relatively narrower zona and larger spinae.

Occurrence. Infrequent, Assemblages X and XI; Westphalian C and D.

Cirratriradites saturni (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 21, figs. 1, 2

1932 *Sporonites saturni* Ibrahim in Potonié, Ibrahim, and Loose, p. 448, pl. 15, fig. 14.
1933 *Zonales-sporites saturni* Ibrahim, p. 30, pl. 2, fig. 14.
? 1938 *Zonotriletes saturni* (Ibrahim); Luber in Luber and Waltz, pl. 8, fig. 102.
1944 *Cirratriradites saturni* (Ibrahim); Schopf, Wilson, and Bentall, p. 44.

Holotype. Ibrahim 1932, pl. 15, fig. 14, Potonié and Kremp 1956, pl. 18, fig. 412 after Ibrahim. Preparation B26, d2 (ul).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 128; translation). 'Amb rounded-triangular. Trilete rays distinct, extending to the equator. Only one, circular, polar fovea, which through constriction may give the appearance of two.'

Size in microns. (i) Holotype 69·5, Schulze and KOH. (ii) 70–100, Schulze (Potonié and Kr. 1956). (iii) 68(79)91; body 50(58)68; zona 8(11)16, Schulze and 10% KOH; Bottom Robins Seam at 2,396 ft. 11 in., Springslade Pool borehole, Cannock Chase Coalfield, England; Westphalian C. (iv) 59(73)81; body 45(55)59; flange 7(9)14, fum. HNO_3; Virgin Seam, Cadzow Colliery, Central Coalfield, Scotland; Westphalian B. (v) 67(76)84; body 53(58)64; flange 7(9)12, fum. HNO_3; Yard seam at 285 ft. 4 in., Link House borehole, Northumberland Coalfield, England; Westphalian B. (vi) 68(77)92; body 54(62)79; zona 6(7·5)9, fum. HNO_3; Bowhouse Seam, Frances Colliery, East Fife Coalfield, Scotland; Westphalian A. (vii) 46(57)68; body 34(48)58; flange 4(6)9, fum. HNO_3; seam at 117 ft. 0 in., No. 2 Drift, St. Helen's No. 3 Colliery, Cumberland Coalfield, England; Westphalian A.

Description. Amb convexly triangular. Body subtriangular; outline irregular and serrulate. Laesurae ridged, flexuose; the ridges extend to the equator. Exine of body coarsely granulate, or verrucate. Zona with radial striations and concentric thickenings, wider at angles. Body moderately thick, zona thin.

Remarks. All the Westphalian A and B assemblages recorded above contain some specimens with three distal foveae. Potonié and Kremp (1956) place such forms in

Cirratriradites flabelliformis Wilson and Kosanke 1944 (p. 330, pl. 1, fig. 6), which is also distinguished by its broader zona (10–15 μ); this according to Potonié and Kremp (1956, p. 127) measures at least one-third of the total spore radius. However, the specimens with three foveae do not appear to be differentiated in any other way from those with only one or two and are therefore included under *C. saturni*. At most horizons the zona is slightly less wide than in the specimens measured from the Westphalian C. The spores from the Westphalian A horizon in Cumberland are much smaller, but in other respects similar to the specimens in the other assemblages. The smaller forms have not been seen elsewhere in the Westphalian A and for the present, therefore, they have not been accorded specific status.

Comparison. Distinguished from other species by its relatively broad, striate zona and the presence of one to three distal foveae. Potonié and Kremp (1956, p. 128) consider *Cirratriradites maculatus* Wilson and Coe 1940 (p. 183, pl. 1, fig. 7) to be a synonym of *C. saturni*. The zona of the former species is stated, however, to be without rods (radial striations).

Occurrence. Infrequent or frequent, Assemblages V to X; Upper Namurian to Westphalian C.

Genus CINGULIZONATES (Dybová and Jachowicz) Butterworth, Jansonius, Smith, and Staplin 1964

Type species. *C. bialatus* (Waltz) comb. nov.

Diagnosis (Butterworth, Jansonius, Smith, and Staplin in Staplin and Jansonius 1964, p. 105). 'Spores trilete; outline convexly triangular to subcircular; two-layered; central

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EXPLANATION OF PLATE 21

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Cirratriradites saturni* (Ibrahim) Schopf, Wilson, and Bentall 1944. 1, slide 204, 50·4 111·6. 2, equatorial view; slide 162, 31·9 105·7.

Figs. 3, 4. *Cingulizonates bialatus* (Waltz) comb. nov. 3, slide 205, 40·7 109·1. 4, slide 206, 39·2 108·3.

Figs. 5, 6. *C.* cf. *capistratus* (Hoffmeister, Staplin, and Malloy) Staplin and Jansonius 1964. 5, slide 183, 40·0 117·5. 6, slide 183, 38·4 119·5.

Figs. 7, 8. *C. loricatus* (Loose) Butterworth and Smith (in Butterworth *et al.* 1964). 7, slide 207, 44·2 113·1. 8, slide 207, 42·3 116·3.

Figs. 9–11. *Radiizonates aligerens* (Knox) Staplin and Jansonius 1964. 9, 10, Neotype, proximal and distal surfaces respectively; slide T80/1, 36·6 112·2. 11, slide 208, 16·9 108·5.

Figs. 12, 13. *R. faunus* (Ibrahim) comb. nov. 12, slide 210, 35·0 106·4. 13, slide 210, 47·5 109·1.

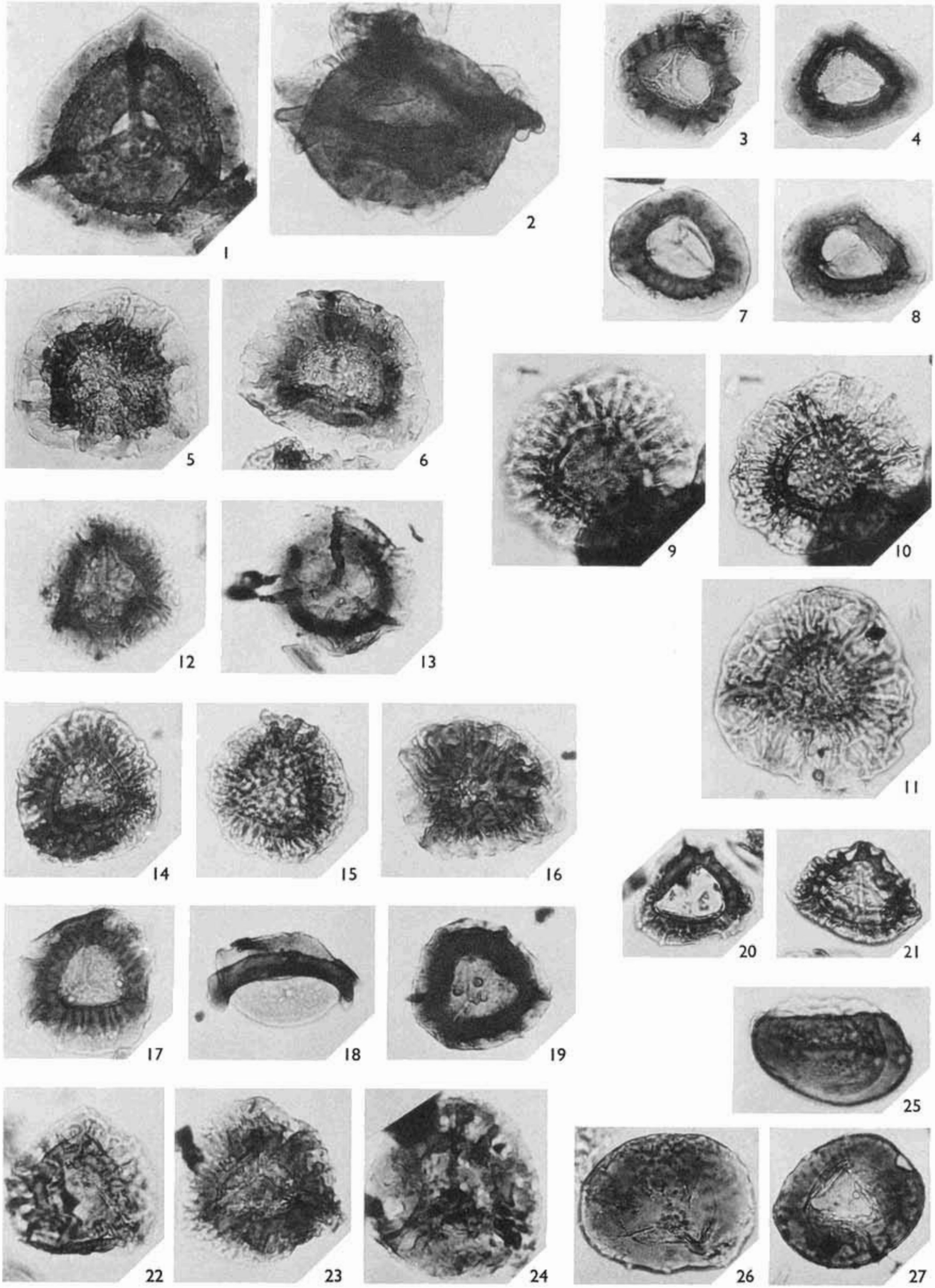
Figs. 14–16. *R.* cf. *difformis* (Kosanke) Staplin and Jansonius 1964. 14, distal surface; slide 209, 36·7 102·8. 15, slide 209, 38·9 102·2. 16, distal surface; slide 209, 44·9 112·1.

Figs. 17–19. *R. striatus* (Knox) Staplin and Jansonius 1964. 17, slide 211, 33·2 115·7. 18, equatorial view; slide 211, 23·9 107·3. 19, distal surface; slide 211, 47·5 116·1.

Figs. 20, 21. *R.* cf. *striatus* (Knox) Staplin and Jansonius 1964. 20, slide 212, 53·5 106·1. 21, slide 212, 42·9 112·6.

Figs. 22–24. *R. tenuis* (Loose) Butterworth and Smith (in Butterworth *et al.* 1964). 22, slide 104, 39·5 109·3. 23, slide 213, 25·2 111·4. 24, slide 213, 46·7 106·5.

Figs. 25–27. *Tholisporites scoticus* Butterworth and Williams 1958. 25, Holotype, equatorial view; slide T63/1, 35·8 107·2. 26, slide 183, 41·3 112·7. 27, slide 214, 38·5 105·1.



SMITH and BUTTERWORTH, British Carboniferous miospores

body (intexine) thin, psilate; outer layer complex, central proximal area thin, minutely sculptured to psilate, sutural ridges or grooves distinct but fine, reaching to the cuesta; cuesta distinctly raised, sometimes internally vacuolate; outer portion of zona much lower than the cuesta, sometimes sculptured; in section, outer portion of zona tapered and relatively thin; distal surface of outer layer generally differentiated into two zones, the central distal area (usually granulose or verrucose) and the zona.'

Comparison. This genus is distinguished by the presence of a cuesta.

Remarks. The basis of the emendation is the exclusion of species with radially costate cinguli and the placing of emphasis on the cuesta.

Affinity. Lycopsida (Chaloner 1958*b*).

Cingulizonates bialatus (Waltz) comb. nov.

Plate 21, figs. 3, 4

1938 *Zonotriletes bialatus* Waltz in Luber and Waltz, p. 22, pl. 4, fig. 51.
1941 *Zonotriletes bialatus* var. *undulatus* Waltz in Luber and Waltz, p. 28, pl. 5, figs. 71*a*, *b*.
1941 *Zonotriletes bialatus* var. *costatus* Waltz in Luber and Waltz, p. 29, pl. 5, fig. 72.
1956 *Densosporites bialatus* (Waltz); Potonié and Kremp, p. 114.
1956 *Hymenozonotriletes bialatus* var. *undulatus* (Waltz); Ishchenko, pp. 63, 64; pl. 12, figs. 135–7.
1957 *Cingulizonates tuberosus* Dybová and Jachowicz, p. 171, pl. 53, figs. 1–4.
1958 *Densosporites striatus* (Knox); Butterworth and Williams, p. 380, pl. 3, fig. 36.

Holotype. Not designated.

Type locality. Bed 6, Verkhni-Goubakhin Colliery, Kalinin Shaft, Kizel region, U.S.S.R.; Lower Carboniferous.

Diagnosis (from Waltz, in Luber and Waltz 1941). Body rounded-triangular or ovate. Rays seldom seen but somewhat shorter than radius of spore body. Flange thin, broad, with undulating surface and irregular margin; inner edge thickened, smooth or striated, sometimes with large tubercles projecting into the thinner outer flange.

Size in microns. (i) 70–80, Schulze (Luber and Waltz 1938). (ii) 25–60; body 20–35; flange 10–25 (Luber and Waltz 1941). (iii) 46(60)77; body 21(27)34, Schulze and NH_4OH (Playford 1963); Spitsbergen; Lower Carboniferous. (iv) 27(37)45; thickened part of cingulum 2(5)9, thin part 1(4)8, fum. HNO_3; Extra Seam at 2,589 ft. 8 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian B or C. (v) 36(41)48; thickened area of cingulum 2(6)9, thin part 2(5)8, fum. HNO_3; seam at 32 ft. 6 in., Cheswick borehole No. 108, Northumberland Coalfield, England; Namurian A.

Remarks. This species is transferred to the genus *Cingulizonates* because of the presence of a cuesta on the inner margin of the cingulum.

Comparison. Playford (1963, p. 621) describes similar spores from the Lower Carboniferous of Spitsbergen. The present authors agree with him that the two varieties described by Waltz are difficult to distinguish and should be regarded as a single taxon. Playford (loc. cit.) refers to the synonymy between *Cingulizonates tuberosus* Dybová and Jachowicz and the present species.

The spore figured by Butterworth and Williams (1958, pl. 3, fig. 36) as *Densosporites striatus* (Knox) is now considered to be *C. bialatus*. In *Radiizonates striatus* (Knox) Staplin and Jansonius 1964 the delineation of the inner, thickened part of the cingulum (cuesta) is sharper than in *C. bialatus* and the cuesta is plicate rather than lobate.

Occurrence. Infrequent to abundant, Assemblages I to V; Viséan and Namurian.

Cingulizonates capistratus (Hoffmeister, Staplin, and Malloy) Staplin and Jansonius 1964

1955 *Densosporites capistratus* Hoffmeister, Staplin, and Malloy, p. 386, pl. 36, figs. 14, 15.
1964 *Cingulizonates capistratus* (Hoffmeister, Staplin, and Malloy); Staplin and Jansonius, p. 105.

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 36, fig. 15. Preparation 8, ser. 18,650.

Type locality. Shale at 2,072 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 386). Outline convexly subtriangular. Rays with narrow ridges, extending to inner edge of equatorial region. 'Thickened equatorial region divided into three zones, inner zone thick, middle zone variable in thickness, composed of radiating, crowded variable rods or cylindrical processes, outer zone thin and translucent, tapering to an even outer margin.' Central area granulate; small coni sometimes present on outer zone.

Size in microns. Holotype 46×41, inner zone 2·5, middle zone 2·5–3; 41–61, HF (Hoffmeister, Stap., and Mall. 1955).

Cingulizonates cf. *capistratus* (Hoffmeister, Staplin, and Malloy) Staplin and Jansonius 1964

Plate 21, figs. 5, 6

1958 *Densosporites capistratus* Hoffmeister, Staplin, and Malloy; Butterworth and Williams, pl. 3, figs. 44, 45.
1958 *Densosporites variabilis* (Waltz) Potonié and Kremp; Butterworth and Williams, pl. 3, figs. 32–34.

Size in microns.

Spore diameter	*Cingulum width*	
41(52)60	11(15)20	Fum. HNO_3; middle bed of Great Seam at 3,921 ft. 8 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A.
41(50)60	8(13)18	Fum. HNO_3; Oakwood Seam at 29 ft. 6 in., Cheswick borehole No. 108, Northumberland Coalfield, England; Namurian A.

Description. In these specimens the central area is foveolate compared with the granulate ornament of *C. capistratus sensu stricto*. The cingulum is somewhat greater than 50% of total diameter. The spores described and figured by Butterworth and Williams (1958) as *Densosporites variabilis* (Waltz) Potonié and Kremp and *Densosporites capistratus* differed only in the extent of the radiating processes of the cingulum; in specimens assigned to the former these processes exceptionally extended almost to the equator of the spore to form arches enclosing irregularly shaped alveolae, whereas in those assigned to the latter these were confined to the middle zone.

Comparison. Radiizonates tenuis (Loose) Butterworth and Smith 1964 is a smaller spore, with a thinner exine and longer, more marked laesurae. In *Radiizonates aligerens* (Knox) Staplin and Jansonius 1964 the laesurae are longer and the cingulum broader. In both of these species the outer zone of the cingulum is less solid and the radiating struts form a more positive element in the ornamentation.

Occurrence. Infrequent to abundant, Assemblages III and IV; Viséan and Namurian.

Cingulizonates loricatus (Loose) Butterworth and Smith (in Butterworth *et al.* 1964)

Plate 21, figs. 7, 8

1932 *Sporonites loricatus* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 42.
1934 *Zonales-sporites loricatus* Loose, p. 151.
1944 *Densosporites loricatus* (Loose); Schopf, Wilson, and Bentall, p. 40.
1964 *Cingulizonates loricatus* (Loose) Butterworth and Smith; Butterworth *et al.*, p. 1053, pl. 2, fig. 4.

Holotype. Potonié and Kremp 1956, pl. 18, fig. 400 after Loose. Preparation III2, a_3 (ur).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 119; translation). Small indented ('korrodiert') form. Dark zone of cingulum broader than the light zone, which is clearly in contrast to it. Strong tetrad mark.

Size in microns.

Spore diameter	*Cingulum cuesta*	*outer zone*	
Holotype 41·5			Schulze.
35–50			Schulze (Potonié and Kr. 1956).
32(41)48	3(4·5)6	1(4·2)6	Fum. HNO_3; Upper Flint Seam at 1,069 ft. 2 in., Madeley Wood No. 4 borehole, Coalbrookdale Coalfield, England; Lower Westphalian B.
24(34)40	2(3·5)4	1(3·5)5	Fum. HNO_3; Bottom Robins Seam at 843 ft. 0 in., Plantation borehole, Cannock Chase Coalfield, England; Lower Westphalian C.

Description. Amb rounded-triangular. Laesurae prominent, simple, flexuose, extending to inner margin of cingulum. Cingulum approximately 40% of total spore diameter. Central body or intexine thin, laevigate. Central proximal area of exoexine slightly rugose; central distal area granulate, or with small verrucae. Outer margin of cuesta minutely crenulate; outer thin part of cingulum minutely granulate, sometimes slightly plicated. Margin of spore slightly modified by grana and plications.

Occurrence. Infrequent to abundant, Assemblages VI to IX, infrequent Assemblage X; Westphalian A to C.

Remarks. Forms indistinguishable from this species have been found in populations of *C. bialatus* (pl. 21, fig. 4). However, specimens with tubercles projecting into the outer area of the cingulum do not occur in populations of *C. loricatus*.

Genus RADIIZONATES Staplin and Jansonius 1964

Type species. R. aligerens (Knox) Staplin and Jansonius 1964.

Diagnosis (Staplin and Jansonius 1964, p. 106). 'Spores trilete; subtriangular to subcircular; two-layered; inner part of zona slightly raised above level of central proximal area, outer part of zona much thinner except for distinct radial ribs or costae; distal surface of zona characterized by radial striae or ribs that invade the central distal area, central distal area often bears granules or verrucae.'

Comparison. The strong radial ribs of the outer part of the cingulum and the indistinct intexine distinguish *Radiizonates* from *Cingulizonates*. *Cirratriradites* differs in having a zona, and in the distal part of the exoexine being thicker than the remainder of the exoexine (Hughes, Dettmann, and Playford 1962, p. 251).

Affinity. Unknown.

Radiizonates aligerens (Knox) Staplin and Jansonius 1964

Plate 21, figs. 9–11

1950 *Cirratriradites aligerens* Knox, p. 329, pl. 19, fig. 288.
1964 *Radiizonates aligerens* (Knox); Staplin and Jansonius, p. 106, pl. 18, figs. 23–28, text-fig. 2*r*.

Neotype. Plate 21, figs. 9, 10. Knox did not designate a holotype. A neotype has been selected by Staplin from Scottish material (T80/1 in collection of Coal Survey Laboratory, Sheffield).

Type locality. Glass Seam at 819 ft. 8 in., Monkton House borehole, Lothians Coalfield, Scotland; Westphalian A.

Diagnosis (Staplin and Jansonius 1964, p. 106). 'Spores trilete; subtriangular to subcircular; two-layered; intexine not usually visible; central proximal area of exoexine frequently lost, but when preserved, sutural features fine and extending to inner edge of zona, surface finely granulose; margin of central proximal area slightly raised, finely striate, sometimes with minute pits, sometimes overhangs the zona; zona extremely variable with irregular radial rib and gouge structure that extends to the equatorial margin on both the proximal and distal surfaces; central distal surface of exoexine commonly bears a few distinct warts or granules and is to a smaller or larger extent involved in the rib and gouge structure of the zona; specimens with thick zonae often have internal vacuoles; internally the exoexinal wall is finely pitted; zona width about the spore diameter; diameter 55–80 microns and perhaps slightly larger.'

Size in microns.

Spore diameter	*Cingulum inner thickness*	*Cingulum outer thin area*	
70–90			Schulze and 10% KOH (Knox 1950).
Neotype 59 47(59)76	4(5)7	10(13)16	Schulze and 5% KOH; type locality.
48(60)76	4(5)8	10(14)19	Fum. HNO_3; Brockwell Seam at 696 ft. 8 in., Spanish Battery borehole, Durham Coalfield, England; Westphalian A.

Occurrence. Infrequent to common, Assemblage VI; Upper Westphalian A.

Radiizonates difformis (Kosanke) Staplin and Jansonius 1964

1950 *Cirratriradites difformis* Kosanke, p. 35, pl. 7, fig. 3.
1964 *Radiizonates difformis* (Kosanke); Staplin and Jansonius, p. 106.

Holotype. Kosanke 1950, pl. 7, fig. 3. Preparation 625–B, slide 7.

Type locality. Willis Coal, Gallatin County, Illinois, U.S.A.; Tradewater Group.

Diagnosis (from description in Kosanke 1950, p. 35). Outline circular to subtriangular. Laesurae simple, distinct, generally extending into the flange. Large equatorial flange occasionally folded or slightly twisted. Exine of spore body reticulate with anastomosing ridges at periphery extending into the flange.

Size in microns. Holotype 63×53·5, body 31·5; 52–68, Schulze and 10% KOH (Kosanke 1950).

Remarks. This species is transferred to the genus *Radiizonates* because of the prominent radial striations present on the cingulum.

Radiizonates cf. *difformis* (Kosanke) Staplin and Jansonius 1964

Plate 21, figs. 14–16

Size in microns. 42(47)54, thickened inner area of cingulum 3(6)8, thin outer area of cingulum 7(9)12, fum. HNO_3; ?Glass Seam at 2,071 ft. 4 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Westphalian A.

Description. Amb circular to subtriangular. Laesurae generally indistinct, extending into the flange. Equatorial flange divided into two parts, an inner, thicker part composed of ridges radiating from the edges of the spore body and extending into the outer, membranous part. Flange averages about 60% of total diameter. Spore body occasionally with verrucate ornament.

Comparison. The size difference between the present forms and *R. difformis* (Kosanke) Staplin and Jansonius may be due, in part, to the method of maceration. The main difference lies in the relatively wider cingulum in *R.* cf. *difformis*. The inner, thickened area of cingulum, if present, is much narrower in Kosanke's species. *R. aligerens* is larger with a less prominent inner and a broader outer portion of the cingulum.

Occurrence. Infrequent to frequent, Assemblage VI; Westphalian A.

Radiizonates faunus (Ibrahim) comb. nov.

Plate 21, figs. 12, 13

1932 *Sporonites faunus* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 4.
1933 *Zonales-sporites faunus* Ibrahim, p. 28, pl. 1, fig. 4.
1944 *Cirratriradites faunus* (Ibrahim); Schopf, Wilson, and Bentall, p. 44.
1956 *Densosporites faunus* (Ibrahim); Potonié and Kremp, p. 117, pl. 18, figs. 385–92.

Holotype. Ibrahim 1932, pl. 14, fig. 4, Potonié and Kremp 1956, pl. 18, fig. 385 after Ibrahim. Preparation B39, a5 (m).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 117; translation). 'Relatively large, broad, indented ('korrodiert') cingulum within which there are clearly differentiated light and dark zones, each of the same width. Central area markedly infragranulate. Tetrad mark long, prominent, and nodular, in some instances extending into the cingulum.'

Size in microns.

Spore diameter	*Cingulum width*	
50–70		Schulze (Potonié and Kr. 1956).
34(44)53	7(11)14	Fum. HNO_3; No. 15 Seam, Nantgarw Colliery, South Wales Coalfield; Lower Westphalian C.
34(42)56	8(11)15	Schulze and 10% KOH; Wyrley Yard Seam, Springslade Pool borehole, Cannock Chase Coalfield, England; Lower Westphalian C.

Description. Amb subcircular to triangular. Laesurae tectate, flexuose, extending almost to equator of spore. Body or intexine not discernible; central areas of exoexine granulate to rugulate. Cingulum averages 50% of total diameter; projects slightly at the angles; divided into inner thick and outer thin areas of about equal width; outer cingulum with radiating costae which anastomose and bifurcate to form irregular alveolae. Outline of spore ragged.

Remarks. This species has been assigned to the genus *Radiizonates* because of the radiating costae prominent on the cingulum.

Occurrence. Infrequent to common, Assemblage IX; Westphalian B and C.

Radiizonates striatus (Knox) Staplin and Jansonius 1964

Plate 21, figs. 17–19

1950 *Cirratriradites striatus* Knox, p. 330, pl. 19, fig. 289.
1957 *Densosporites marginata* Artüz, p. 252, pl. 6, fig. 42.
non 1958 *Densosporites striatus* (Knox); Butterworth and Williams, p. 380, pl. 3, fig. 36.
1964 *Radiizonates striatus* (Knox); Staplin and Jansonius, p. 106.

Neotype. Butterworth and Williams 1954, pl. 18, fig. 1. Specimen number PF 3009 (formerly 76486), Geological Museum, London. This specimen was one of two designated as hypotypes by Butterworth and Williams.

Type locality. Ruabon Yard Seam, 388's Drift, Llay Main Colliery, North Wales Coalfield; Upper Westphalian A.

Diagnosis (from description in Butterworth and Williams 1954, p. 757). Amb round to subtriangular. Cingulum divided into inner thickened, and outer thin zones; the former is plicated in well-preserved specimens, the plications extending into the thinner zone. Exine in polar areas thin, laevigate or granulate.

Size in microns.

Spore diameter	*Cingulum inner zone*	*outer zone*		
35(41)53	3(7)10	2(4)6·5	Fum. HNO_3	Type locality (Butterworth and Will. 1954).
36(46)58	5(8)11	2·5(5)9	Schulze and 5% KOH	

43–58, maceration method not known; Büyük Seam, Turkey; Westphalian A (Artüz 1957, for *Densosporites marginata*).

Description. Laesurae indistinct, confined to the central area. Distal polar area laevigate or granulate; often has small number of scattered verrucae.

Comparison. *Cingulizonates radiatus* Dybová and Jachowicz 1956 (pl. 4, fig. 6) is probably conspecific with this species, as is *Densosporites marginata* Artüz 1957 (pl. 6, fig. 42). *Densosporites striatus* (Knox) Butterworth and Williams 1958 (pl. 3, fig. 36) is now considered to be *Cingulizonates bialatus* (Waltz) comb. nov. *Cingulizonates loricatus* (Loose) and *Cingulizonates bialatus* (Waltz) comb. nov. both have comparable inner thickened areas of the cingulum, narrower and less prominent in the former species, but without the radial plications which characterize *R. striatus*.

Occurrence. Infrequent to abundant, Assemblages V and VI; Westphalian A.

Radiizonates cf. *striatus* (Knox) Staplin and Jansonius 1964

Plate 20, figs. 20, 21

Size in microns. Diameter 30(37·5)45, inner zone of cingulum 1·5(5·5)8·5, outer zone of cingulum 1·5(4)8·5. Fum. HNO_3; Bush Seam, Michael Colliery, East Fife Coalfield, Scotland; Lower Westphalian B.

Comparison. These spores differ from *Radiizonates striatus* only in their smaller size and narrower inner thickened zone of the cingulum. They have the radial plications or striations of the cingulum and the granulate, or verrucate, distal central area characteristic of the genus but are otherwise very similar to *Cingulizonates loricatus*.

Occurrence. Infrequent to very common, Assemblages VI to VIII; Westphalian A and B.

Radiizonates tenuis (Loose) Butterworth and Smith (in Butterworth *et al.* 1964)

Plate 21, figs. 22–24

1932 *Sporonites tenuis* Loose in Potonié, Ibrahim, and Loose, p. 450, pl. 18, fig. 34.
1934 *Zonales-sporites tenuis* Loose, p. 149.
1944 *Cirratriradites tenuis* (Loose); Schopf, Wilson, and Bentall, p. 44.
1956 *Densosporites tenuis* (Loose); Potonié and Kremp, p. 120, pl. 18, figs. 404–7.
1964 *Radiizonates tenuis* (Loose); Butterworth *et al.*, p. 1054, pl. 2, fig. 13.

Holotype. Potonié and Kremp 1956, pl. 18, fig. 404 after Loose. Preparation IV78, d_6 (m).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 120; translation). 'Large indented ('korrodiert') form. Broad cingulum, light zone of which is broader than dark zone, each clearly separated from the other. Tetrad mark long and prominent.'

Size in microns.

Spore diameter	*Mean cingulum width*		
Holotype 61		Schulze.	
50–70		Schulze (Potonié and Kr. 1956).	
32(42)54	9·5	Fum. HNO_3	Crank Seam, Gresford Colliery, North Wales Coalfield; Westphalian B (Butterworth and Will. 1954).
40(50)58	12	Schulze and 5% KOH	

Description. Amb rounded-triangular. Laesurae slightly flexuose, extending to the inner margin of the cingulum and sometimes beyond. Central body or intexine thin, laevigate. Central areas of exoexine membranous, irregularly reticulate. Inner thickened area of cingulum less than one-half its total width. Costae bifurcating and, in well-preserved specimens, anastomosing to form a compact equatorial outline. Equatorial margin usually ragged. Cingulum generally less than one-half radius of spore in width.

Comparison. *R. tenuis* is very similar to *R. faunus* but the latter tends to be more triangular because of the radial projection of the laesurae. The thickened area of the cingulum in *R. faunus* is almost equal in width to the thinner area. *R. tenuis* and *R. faunus* are distinguished from *R. aligerens* (Knox) Staplin and Jansonius and *R. difformis* (Kosanke) Staplin and Jansonius by their smaller size and relatively narrower cinguli; they are also distinguished from *R. aligerens* by their bifurcating and anastomosing radial thickenings.

Occurrence. Infrequent to common, Assemblages VIII and IX; Westphalian B and C.

Infraturma PATINATI (Butterworth and Williams) emend.

The infraturma Patinati is emended to include trilete cavate spores in which one whole hemisphere is enclosed in a prominent thickening of the outer layer of the exine.

Genus THOLISPORITES Butterworth and Williams 1958

Type species. *T. scoticus* Butterworth and Williams 1958.

Diagnosis (Butterworth and Williams 1958, p. 381). 'Trilete isospores or microspores possessing a central body enclosed on the distal side by a thick distal patina. (A patina is here defined as an exinal thickening which extends over the entire area of one hemisphere. It may extend over an area greater than one hemisphere so long as one or other pole remains free). The patina in this genus extends for a short distance beyond the equator proximally enclosing the body both distally and equatorially so that the body is exposed only over a relatively small area surrounding the proximal pole. Patina thickest in the equatorial region, thinning slightly towards the distal pole. Body circular. Equatorial outline of spore circular. In lateral view the distal outline is semicircular, the proximal convex or pyramidal.'

Comparison. *Tholisporites* is distinguished from *Densosporites* (Berry) Butterworth *et al.* by the presence of a distal crassitude. Although no limits for its thickness are given in the diagnosis it is defined as a thickening and can be assumed to be at least 3 or 4 μ thick. In *Densosporites* and allied genera the exine is markedly thinner over the distal central area than in the equatorial area. The distal exine in *Tholisporites foveolatus* Hughes and Playford 1961 (p. 38, pl. 4, figs. 1–7) does not appear to be markedly thickened, and for this reason the species should be excluded from the genus.

Affinity. Unknown.

Tholisporites scoticus Butterworth and Williams 1958

Plate 21, figs. 25–27

Holotype. Butterworth and Williams 1958, pl. 3, fig. 48. Preparation T63/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 1,872 ft. 7 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (restated by Staplin and Jansonius 1964, p. 105). 'Spores trilete; outline subcircular to convexly subtriangular; two-layered; central body thin, psilate, sometimes folded; outer layer thin over the central body at the central proximal area; sutural ridges distinct, attached to and ending at the inner margin of the zona; proximal surface of outer layer psilate to faintly chagrinate, equatorial margin with a few small granulations; distal hemisphere strongly inflated, usually with scattered small setose apiculae; distal sculpture not differentiated into central distal and zonal areas as in *Densosporites* and *Cingulizonates*; outer layer very thick equatorially and distally (patellate, or patinate) and commonly scabrate internally; spores commonly compressed in a lateral orientation; zona width generally a little less than one-half spore radius; central distal thickness of outer layer 4–9 microns, usually less than the zonal thickness. . . .'

Size in microns. Holotype 52; 35(43)52, Schulze and 5% KOH (Butterworth and Will. 1958).

Comparison. *Tholisporites densus* McGregor 1960 (p. 37, pl. 13, figs. 6, 7), *T. punctatus* McGregor 1960 (p. 38, pl. 13, fig. 10), and *T. tenuis* McGregor 1960 (p. 38, pl. 13, fig. 9), all from the Devonian of Melville Island, Canada, are larger than *T. scoticus* and have longer laesurae and relatively thinner distal crassitudes.

Occurrence. Occasionally abundant, Assemblage I (Fourlaws Coal, Northumberland Coalfield); infrequent to common, Assemblages II to IV; Viséan and Namurian A.

Suprasubturma PSEUDOSACCITRILETES Richardson 1965
Infraturma MONOPSEUDOSACCITI infraturma nov.

Monopseudosacciti includes trilete aperinate cavate spores with simple or ridged laesurae and a comprehensive inflated extension of the exoexine at least at the equator. Separation of exine layers may extend over part or all of the proximal or distal hemisphere.

Genus SPENCERISPORITES Chaloner 1951

Type species. *S. radiatus* (Ibrahim) Felix and Parks 1959.

Diagnosis. (Chaloner 1951, p. 861). 'Spores with a spheroidal body and an inflated marginal wing. Body 100–200 μ wide, circular in the plane of the equator, but somewhat flattened perpendicular to this plane. Wall of body fairly thin (*c*. 2 μ) bearing a triradiate ridge. Equator of body encircled by an inflated wing, broader opposite the triradiate ridges than elsewhere, so as to give the spore as a whole a triangular shape. The edge of the wing is continued by a single thin layer of cuticle, forming a marginal flange.'

Remarks. Chaloner (1951) proposed the name *Spencerisporites karczewskii* for spores which appear identical with those from the cone of *Spencerites insignis* Scott and which occur in British coal seams. He states that there is little doubt that the spores *S. karczewskii* are, in fact, the same species as *Triletes karczewskii* Zerndt 1934 and *Microsporites karczewskii* (Zerndt) Dijkstra and van Vierssen Trip 1946. In his discussion of the generic name *Spencerisporites*, Chaloner gives his reasons for rejecting for these spores *Triletes* and *Microsporites* [also *Endosporites*, which was employed by Schopf, Wilson, and Bentall (1944) and Dijkstra (1955)]. *Microsporites* has not been diagnosed as a genus and was only used as a provisional name by Dijkstra.

In 1954 and 1956 Potonié and Kremp considered *Microsporites* to have priority over *Spencerisporites* on the grounds of an earlier date of publication. They state (1956, p. 156), in error, that Chaloner had given no diagnosis for *Spencerisporites*. This view is not upheld by Felix and Parks (1959), who state (p. 360) that 'the authenticity of *Spencerisporites* over *Microsporites* is valid'. Chaloner (1951) designated *S. karczewskii* (Zerndt) Chaloner as the type but Felix and Parks (1959) consider the species conspecific with *S. radiatus* Ibrahim 1932.

Comparison. Differs from *Endosporites* in shape, mode of attachment of pseudosaccus (wing) to body, and the presence of a marginal flange extending beyond the wing.

Affinity. Lycopsida; *Spencerites* Scott (Chaloner 1951).

Spencerisporites radiatus (Ibrahim) Felix and Parks 1959

Plate 22, figs. 5–8

1932 *Sporonites radiatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 449, pl. 16, fig. 25.
1933 *Zonales-sporites radiatus* Ibrahim, p. 28, pl. 3, fig. 25.
1934 *Triletes karczewskii* Zerndt, p. 27, pl. 31, fig. 3.
1944 *Triletes radiatus* (Ibrahim); Schopf, Wilson, and Bentall, p. 24.
1944 *Endosporites? karczewskii* (Zerndt); Schopf, Wilson, and Bentall, p. 45.
1946 *Microsporites karczewskii* (Zerndt); Dijkstra and van Vierssen Trip, p. 64, pl. 4, fig. 40.
1951 *Spencerisporites karczewskii* (Zerndt); Chaloner, p. 862, text-figs. 1, 2 and 6, 7.
1955 *Endosporites*(?) *radiatus* (Ibrahim); Dijkstra, p. 342, pl. 45, fig. 54.
1956 *Microsporites radiatus* (Ibrahim) Dijkstra; Potonié and Kremp, p. 156, pl. 20, figs. 449, 450.
1959 *Spencerisporites radiatus* (Ibrahim) Chaloner; Felix and Parks p. 362, pl. 1, figs. 1–4 and pl. 2, figs. 1–4.

Holotype. Potonié and Kremp 1955, pl. 20, fig. 400, after Ibrahim 1932. Preparation B43, c6 (ul).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (abbreviated from Chaloner 1951 for *S. karczewskii*). Spore body circular in equatorial plane. Triradiate ridges prominent, normally folded sideways by compression. Proximal body wall ornamented by fine, broken lines which radiate from three points placed symmetrically, one on each of the three contact faces. Distal surface probably smooth. The wing as a whole is subtriangular in equatorial plane. Cuticle of wing thinner than that of body and both surfaces show a pattern of rather indefinite intersecting lines. Marginal rim of uniform width.

Size in microns. (i) Holotype 330, Schulze and KOH. (ii) 270–440, Schulze (Potonié and Kr. 1956). (iii) Overall 252(288)343; spore body 127(153)178, Schulze and NaOH (Chaloner 1951); Arley Seam, Burnley, Lancashire Coalfield, England; Westphalian A. (iv) Overall 240–60; spore body 120–210 (10 specimens) Schulze or fum. HNO_3 (the smaller specimens were macerated with fum. HNO_3); various localities, Great Britain; Westphalian A and B.

Description. Amb subtriangular, with rounded angles and convex or straight sides; margin (of flange) more or less crenulate. Laesurae ridged, thin, and flexuose (60–120 μ); extend to margin of body or a short distance beyond; height above proximal surface 15–20 μ; no indication of commissure. Pseudosaccus has an uneven surface due to a loose pattern of low, narrow, intersecting ridges with a tendency to radial alignment through which can be seen an irregular pattern of ? infrasculptural elements. The network of ridges is more pronounced towards the pseudosaccus margin, where it passes on to the flange. The radiating system of lines which characterizes the contact area appears also to be developed distally. Plate 22, figs. 7, 8, show the pattern at two levels of focus and it can be seen that there are two distinct systems radiating from different points on the body. There is often a narrow, dark zone, 5–6 μ wide, at the equator of the pseudosaccus possibly due to overlap of the flange resulting from compression. The pseudosaccus overlaps the body to some extent as a result of compression. Compression folds are peripheral on the body and tend to be radial on the pseudosaccus.

Remarks. Chaloner (1951) did not discuss the position of *Sporonites radiatus* Ibrahim. Dijkstra (1955), however, considered this species to be identical with *Triletes karczewskii* Zerndt and other workers have reached the same conclusion (Horst 1955; Potonié and Kremp 1956; Felix and Parks 1959; Winslow 1959).

Occurrence. Infrequent, Assemblages II to XI; Viséan to Westphalian D.

Genus ENDOSPORITES Wilson and Coe 1940

Type species. *E. ornatus* Wilson and Coe 1940.

Diagnosis (extension of Wilson and Coe 1940). Trilete pseudosaccate microspores in which the intexine and exoexine are separated distally. In polar compression the intexine (central body) is surrounded by the pseudosaccus, both of them being round, or rounded-triangular. Laesurae do not extend beyond the equator of the body. The pseudosaccus usually possesses a limbus.

Remarks. The original diagnosis of the genus by Wilson and Coe, which has not so far been emended, is clearly an unsatisfactory basis for separating the several somewhat similar pseudosaccate genera in the literature. For instance, Wilson and Coe make no reference to the limbus which occurs in many, but not all, of the published species of the genus and yet has been considered diagnostic of the genus by some authors (Potonié and Kremp 1954, Bharadwaj 1957*a*) and has been used (Richardson 1960) to distinguish

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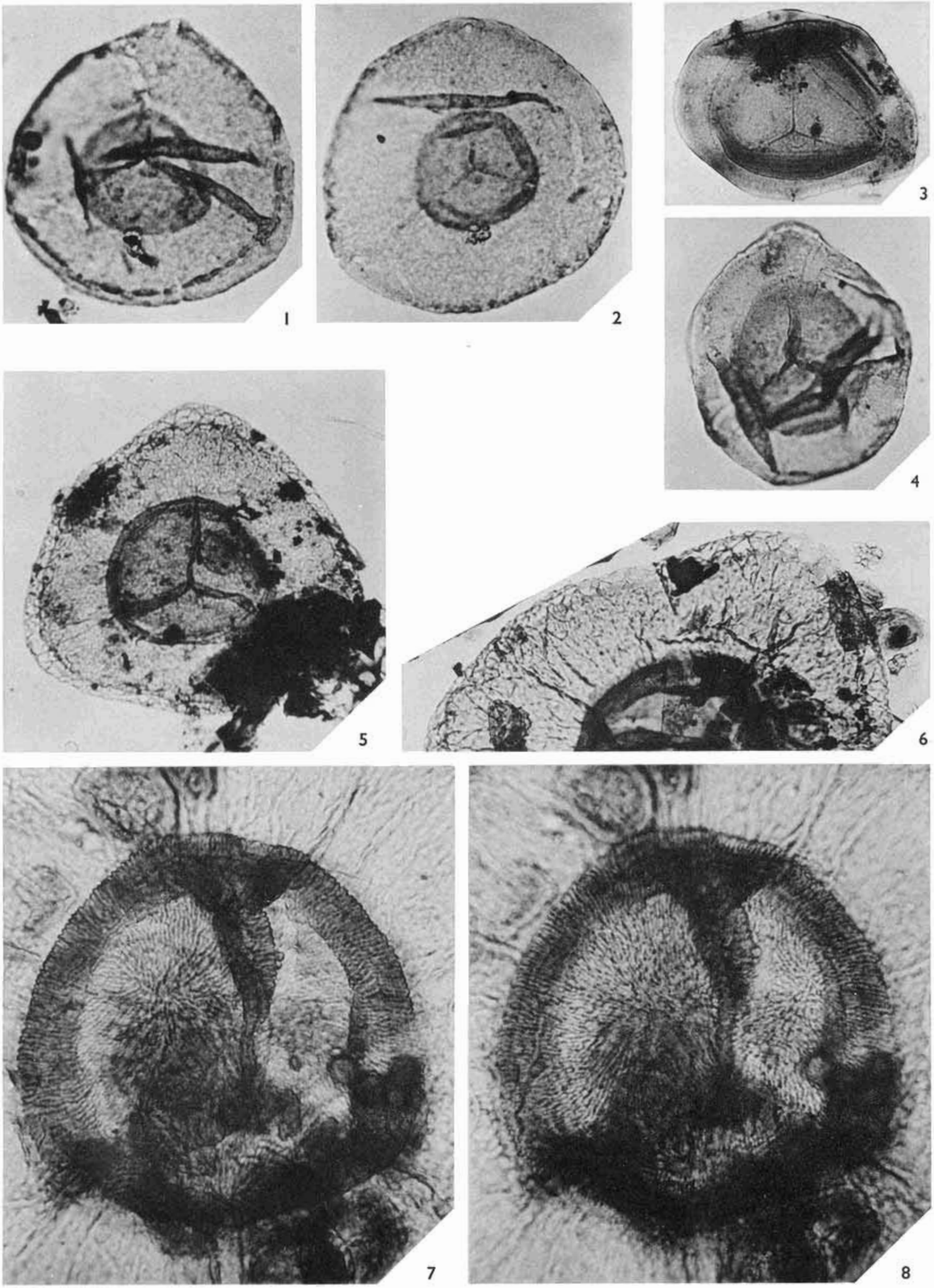
EXPLANATION OF PLATE 22

All figures × 500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Endosporites globiformis* (Ibrahim) Schopf, Wilson, and Bentall 1944. 1, slide 217, 40·4 107·7. 2, slide 217, 50·3 110·3.

Figs. 3, 4. *E. zonalis* (Loose) Knox 1950. 3, slide 218, 25·4 111·0. 4, slide 219, 23·8 102·6.

Figs. 5–8. *Spencerisporites radiatus* (Ibrahim) Felix and Parks 1959. 5, × 125; slide 215, 58·1 113·1. 6–8, slide 216, 58·7 110·9. 6, portion of pseudosaccus showing sculpture, × 250. 7, 8, central area, proximal and distal surfaces respectively, showing two distinct sets of fine radiating ridges.



SMITH and BUTTERWORTH, British Carboniferous miospores

genera such as *Auroraspora* Hoffmeister, Staplin, and Malloy from *Endosporites*. Since a reappraisal of the cavate genera is at present being undertaken by the Commission Internationale de Microflore du Paléozoïque the authors have not attempted to emend the diagnosis.

It is difficult to determine whether the pseudosaccus possesses infrasculpture and/or external ornament. Many of the specimens examined by the authors show a granulate ornament at their margin but this has been interpreted by Potonié and Kremp (1956, p. 162) as an impression of the infrasculpture on the outer surface. Kosanke (1950, p. 36), however, in his description of the genus, states that 'the bladder may be ornamented externally by being laevigate to granular to punctate or internally by coarse punctations or by being reticulate'. Also Wilson (1960, p. 31) states, from the examination of a section of *Endosporites ornatus* from a coal ball peel, that the bladder wall is 1–2 μ thick and finely reticulate on both surfaces.

The central body according to Chaloner (1953*a*, p. 104), who examined the spores isolated from the cone *Polysporia mirabilis* Newberry (syn. *Lepidostrobus zea* Chaloner), lacks any features but interradial papillae and triradiate sutures. Wilson (loc. cit.), on the other hand, states that the body wall is 2 μ thick and finely reticulate on the outer surface. The proximal attachment of the body to the exoexine is clearly shown in the polar section figured by Wilson (1960, pl. 1, figs. 5, 6).

The spores of this genus have been found to be susceptible to swelling after maceration with Schulze reagent and treatment with potassium hydroxide (see under *E. globiformis*). Size is not, therefore, a reliable criterion to distinguish species, unless a standard maceration treatment is employed. For this reason some of the forms which have been named in the literature are probably synonyms.

Comparison. *Endosporites* differs from *Florinites* in the proximal attachment of the central body to the pseudosaccus and in having a granulate, or infragranulate, rather than an infrareticulate, exoexine. According to Hoffmeister, Staplin, and Malloy (1955, p. 381) *Auroraspora* differs from *Endosporites* in possessing a thick-walled central body enclosed by a transparent and very thin bladder.

Affinity. Lycopsida, Chaloner 1953*a*, 1958*a*.

Endosporites globiformis (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 22, figs. 1, 2

1932 *Sporonites globiformis* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 5.
1933 *Zonales-sporites globiformis* Ibrahim, p. 28, pl. 1, fig. 5.
1938 *Zonotriletes globiformis* (Ibrahim); Luber in Luber and Waltz, pl. 8, fig. 103 and pl. B, fig. 30.
1944 *Endosporites globiformis* (Ibrahim); Schopf, Wilson, and Bentall, p. 45.

Holotype. Potonié and Kremp 1956, pl. 20, fig. 459 after Ibrahim. Preparation B33, d1 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 161; translation). 'Width of pseudosaccus at the equator greater than body radius.'

Size in microns. Holotype 131, Schulze and KOH. 110–60, Schulze (Potonié and Kr. 1956).

Pseudosaccus (maximum)	*Body (along same axis)*	*Ratio body to pseudo-saccus, %*	
62(87)109	30(40)54	39(46)53	Fum. HNO_3; Two Foot Seam at 1,410 ft. 4 in., Cross Hill borehole, Yorkshire Coalfield, England; Westphalian B.
72(86)112	29(38)73	38(45)53	Fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.
104(131)161	37(56)78	34(42)51	Schulze and 5% KOH; High Hazel Seam at 2,181 ft. 5 in., Gate Farm borehole, Yorkshire Coalfield, England; Westphalian B.
74(92)112	34(41)57	39(45)52	Fum. HNO_3; High Hazel Seam (as above).

Description. Amb of pseudosaccus and body round to rounded-triangular. Laesurae weakly ridged, straight or flexuose, extending from one-half to entire radius of body, although folds or other marks on the exoexine may appear to give an extension to the pseudosaccus margin. Apical (interradial) papillae sometimes faintly visible. Pseudosaccus thin, appears granulate, or even finely microreticulate (granules visible at margin). Limbus 4–6 μ in width. Pseudosaccus often folded. Body laevigate, slightly thicker than the pseudosaccus membrane, through which it shows distinctly. Body sometimes shows peripheral compression folds and may show a more or less distinctly darker peripheral zone, due to the separation of the exine layers for a short distance proximally from the equator of the body (cf. Wilson 1960; pl. 1, fig. 6).

The laevigate appearance of the body is inferred from an examination of isolated bodies of the microspores of *Polysporia mirabilis* Newberry (syn. *Lepidostrobus zea* Chaloner) on slide 4838i, Kidston Collection, Geological Survey and Museum, London. The spores of *P. mirabilis* are indistinguishable from dispersed spores referred to *E. globiformis*.

Comparison. There are a number of species, among them *E. ornatus* Wilson and Coe 1940 (pl. 1, fig. 2), *E. formosus* Kosanke 1950 (pl. 7, fig. 9), and *E. vesicatus* Kosanke 1950 (pl. 7, fig. 8), which closely resemble *E. globiformis*. Comparison of these species must await the examination of assemblages from the type localities and isolated by the same maceration method.

Occurrence. Infrequent, Assemblages VI and VII; infrequent to common, Assemblage VIII; frequent to very common, Assemblage IX; infrequent to abundant, Assemblages X and XI; not recorded from seams of Radstock Group of Bristol and Somerset Coalfield; Upper Westphalian A to Westphalian D.

Endosporites zonalis (Loose) Knox 1950

Plate 22, figs. 3, 4

1934 *Zonales-sporites zonalis* Loose, p. 148, pl. 7, fig. 5.
1944 *Cirratriradites zonalis* (Loose); Schopf, Wilson, and Bentall, p. 44.
1950 *Endosporites zonalis* (Loose); Knox, p. 332.

Holotype. Potonié and Kremp 1956, pl. 20, fig. 455 after Loose. Preparation IV27, f_5 (m/o!).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. (Potonié and Kremp 1956, p. 163; translation). 'Width of pseudosaccus at the equator less than body radius.'

Size in microns. Holotype 95, Schulze and KOH. 90–100, Schulze (Potonié and Kr. 1956).

Pseudosaccus (maximum)	*Body (along same axis)*	*Ratio body to pseudo-saccus, %*	
69(83)104	38(48)60	46(57)72	Fum. HNO_3; Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B.
61(78)100	33(50)61	48(65)77	Fum. HNO_3; Silkstone Seam, various localities, Yorkshire Coalfield, England (Smith and Will. 1957); Westphalian A.

Description. Similar to *E. globiformis* except that the ratio of body to pseudosaccus is different and the pseudosaccus in most individuals appears slightly thicker and darker in colour so that the body is less distinct.

Remarks. The species *E. globiformis* and *E. zonalis* overlap slightly in the ratio of their body to pseudosaccus dimensions. Histograms of ratios from seams containing both species in British coals are bimodal and provide very little support for the existence of a third species, *E. ornatus* Wilson and Coe 1940, having a mean ratio of body to pseudosaccus of about 50% (Smith and Williams 1957). An arbitrary ratio of 50% is used to distinguish between the two forms described here in assemblages in which both are present.

Comparison. The following species appear similar to, and may be synonyms of, *E. zonalis*: *Zonotriletes punctulosus* Luber in Luber and Waltz 1938 (pl. 6, fig. 79 and pl. B, fig. 26), *E. rotundus* (Ibrahim 1933, p. 31, pl. 8, fig. 73) Schopf, Wilson, and Bentall 1944, *E. plicatus* Kosanke 1950 (p. 37, pl. 7, fig. 7), *Wilsonia granulata* Dybová and Jachowicz 1957*a* (p. 217, pl. 76, figs. 2–4), and *Wilsonia punctata* Dybová and Jachowicz 1957*a* (p. 215, pl. 75, figs. 1–3). The specimen recorded as *E.* cf. *zonalis* in Butterworth and Williams 1958 (pl. 4, fig. 10) does not possess a limbus and is considered to be *E. pallidus* Schemel 1950 (p. 239, pl. 40, fig. 3).

Occurrence. Infrequent to frequent, Assemblages VI to XI; not recorded from seams of Radstock Group of Bristol and Somerset Coalfields; Upper Westphalian A to Westphalian D. Recorded from rocks other than coal in Viséan of Scotland (Love 1960).

Genus SCHULZOSPORA Kosanke 1950

Type species. *S. rara* Kosanke 1950.

Diagnosis (expanded from Kosanke 1950, p. 53). Radial, trilete spores with a bilateral appearance due to the presence of an elliptical pseudosaccus. Body spherical, equatorial limit marked by a darker annular zone about 3–5 μ wide. Laesurae straight, simple, never exceeding body radius in length. Ornament of body and pseudosaccus uniformly punctate, granulate, or minutely reticulate. Exine thin, not exceeding 2μ. Folding of the pseudosaccus common.

Comparison. *Schulzospora* is distinguished from *Endosporites* by the elliptical shape of its pseudosaccus, and from *Florinites* and *Wilsonites* by its clearly defined body and laesurae.

Affinity. Remy and Remy (1955*b*) have isolated a species of *Schulzospora* from the pteridosperm fructification *Simplotheca silesiaca* Remy and Remy from the Namurian of Lower Silesia.

Schulzospora campyloptera (Waltz) Hoffmeister, Staplin, and Malloy 1955

Plate 23, fig. 1

1884 No. 619, Reinsch, p. 60, pl. 22, fig. 231 D.
1938 *Zonotriletes campylopterus* Waltz in Luber and Waltz, p. 16, pl. 3, fig. 39, and pl. A, fig. 15.
1955 *Schulzospora campyloptera* (Waltz); Hoffmeister, Staplin, and Malloy, p. 396.
1958 *Dilobozonotriletes campylopterus* (Waltz); Ishchenko, p. 94, pl. 12, figs. 160, 161.

Holotype. Not known.

Type locality. Seam 46, Skakulin Colliery, Selizharovo, Moscow Basin.

Diagnosis (from Luber and Waltz 1938, C.E.D.P. French translation No. 1443). Outline approximately oval; pseudosaccus thin, of variable width, three or four times wider at equator than at poles, giving the spore an oval rather than a round shape; pseudosaccus margin crenulate. Laesurae indistinct, rays one-third to two-thirds spore radius, not all of equal length. Exine microreticulate, more distinct on the pseudosaccus than on the body.

Size in microns. (i) 90–114 × 65–75, body 60–70, Schulze (Luber and Waltz 1938). (ii) 76(87)100 × 44(55)62, body 46(54)66 × 40(48)60, fum. HNO_3; Greenses Seam at 147 ft. 8 in., Stamford borehole, Northumberland Coalfield, England; Viséan.

Remarks. Luber and Waltz (loc. cit.) state that two rays of the laesurae are generally orientated more or less parallel to the equatorial diameter of the spore. It is deduced from their illustrations that the third ray is at right angles to the longest diameter of the spore. This arrangement is usual in elongate species of *Schulzospora*.

EXPLANATION OF PLATE 23

All figures × 500, and of proximal surface, unless otherwise stated.

Fig. 1. *Schulzospora campyloptera* (Waltz) Hoffmeister, Staplin, and Malloy 1955. Slide 220, 32·3 115·2.

Figs. 2, 3. *S. rara* Kosanke 1950. 2, slide 223, 33·3 102·3. 3, slide 224, 42·4 105·4.

Figs. 4, 5. *S. plicata* Butterworth and Williams 1958. 4, Holotype; slide T67/1, 31·8 106·0. 5, slide 221, 38·2 112·2.

Fig. 6. *S. ocellata* (Horst) Potonié and Kremp 1955. Slide 222, 36·4 111·1.

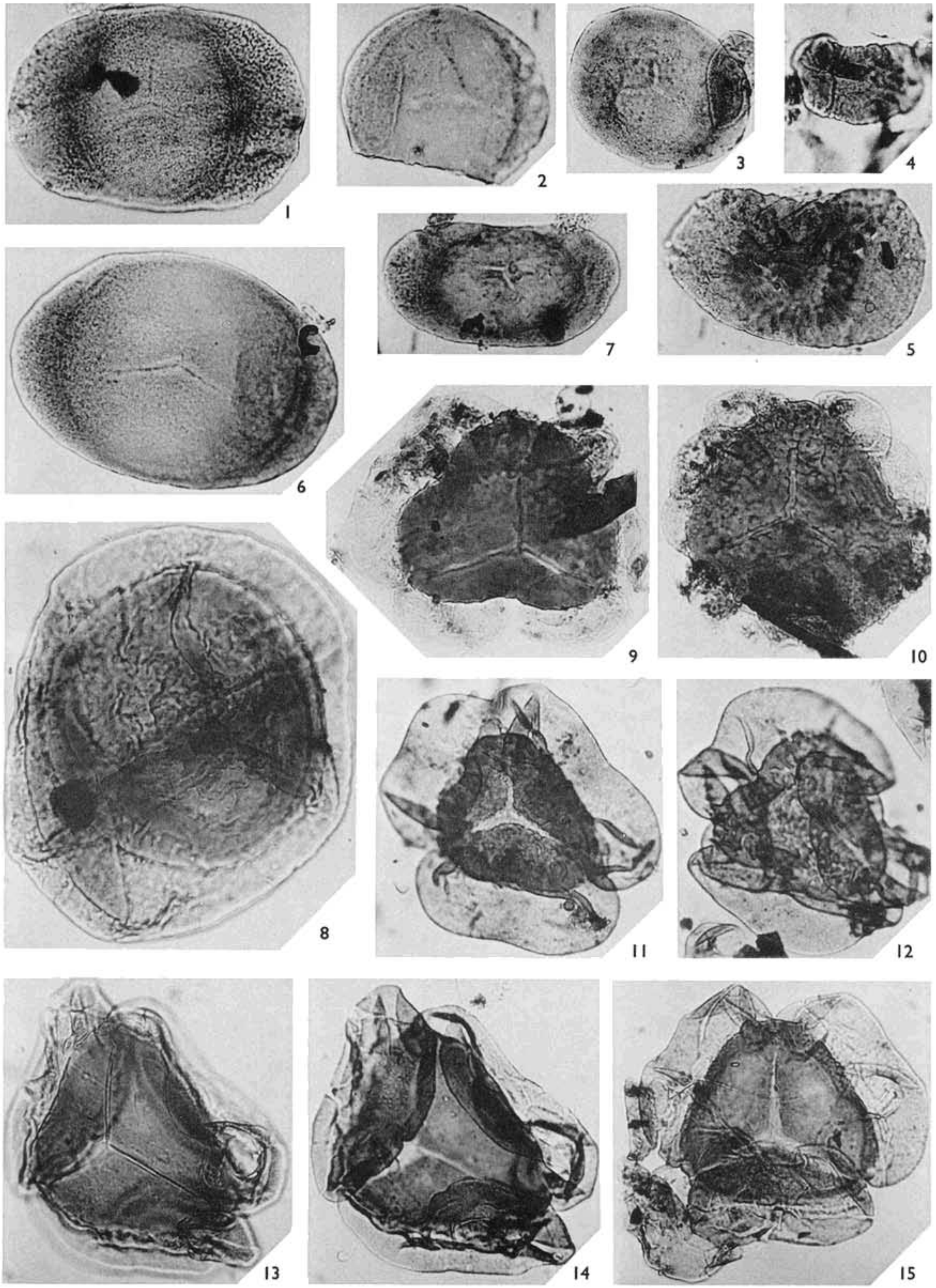
Fig. 7. *S. elongata* Hoffmeister, Staplin, and Malloy 1955. Slide 187, 43·5 106·0.

Fig. 8. *Remysporites magnificus* (Horst) Butterworth and Williams 1958. Slide 225, 39·4 112·6.

Figs. 9, 10. *Alatisporites hoffmeisterii* Morgan 1955. 9, slide 226, 39·5 106·3. 10, slide 227, 39·0 108·3.

Figs. 11, 12. *A. pustulatus* Ibrahim 1932. 11, slide 228, 21·2 110·7. 12, distal surface; slide 229, 42·3 116·0.

Figs. 13–15. *A. trialatus* Kosanke 1950. 13, 14, proximal and distal surfaces respectively; slide 230, 35·5 109·5. 15, slide 231, 37·6 111·5.



SMITH and BUTTERWORTH, British Carboniferous miospores

Comparison. The length of *Schulzospora campyloptera* is comparable to that of *Schulzospora rara* Kosanke but it is distinguished by its more elongate shape, the overall width being barely greater than the body width.

Occurrence. Infrequent to common, Assemblages I to V; Viséan and Namurian.

Schulzospora elongata Hoffmeister, Staplin, and Malloy 1955

Plate 23, fig. 7

Holotype. Hoffmeister, Staplin, and Malloy 1955, pl. 39, fig. 2; Preparation 1, ser. 15,800.

Type locality. 2,072 ft., Carter No. 3 borehole (TCO–82), Webster County, Kentucky, U.S.A.; Hardinsburg Formation, Chester Series.

Diagnosis (from description in Hoffmeister, Staplin, and Malloy 1955, p. 396). Equatorial outline elongate-oval. Trilete rays distinct, approximately three-quarters of body radius. Body thick, translucent, smooth to slightly granulate. Pseudosaccus very thin, occasionally folded, granulate to finely reticulate.

Size in microns. (i) Holotype 60·8 × 30·5, body 35 × 25·7, HF (Hoffmeister, Stap., and Mall. 1955). (ii) 52(63)76 × 34(40)52, body 30(39)48 × 24(33)42, fum. HNO_3; South Seam at 4,455 ft. 6 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Namurian A. (iii) 50(66)76 × 30(39)44, body 28(37)46 × 26(34)40, fum. HNO_3; Little Limestone Seam, Whinnetly Colliery, Northumberland Coalfield, England; Namurian A.

Remarks. The alignment of the laesurae is similar to that quoted by Luber and Waltz (1938) for *Schulzospora campyloptera*—one ray is at right angles to the longer diameter of the spore and the other two tend to be in alignment with the longer diameter.

Comparison. The present size ranges are larger than those given for the type but as there is an overlap in the two size ranges, and as these spores correspond in other respects exactly to the diagnosis of *S. elongata*, they have been assigned to that species. *S. elongata* is narrower than other species and is smaller than *S. campyloptera*—the two size ranges appear to fall into well-defined groups above and below 76 μ; the smaller forms are predominant in the Namurian A and the larger forms in the Viséan.

Occurrence. Infrequent to common, Assemblages I to IV; Viséan and Namurian.

Schulzospora ocellata (Horst) Potonié and Kremp 1956

Plate 23, fig. 6

1943 *Triletes* (*Zonales*) *ocellatus* Horst, (thesis) figs. 40, 41.
1955 *Schulzospora ocellata* (Horst) Potonié and Kremp in Horst, p. 195, pl. 21, figs. 40*a*, *b*.
1956 *Schulzospora ocellata* (Horst); Potonié and Kremp, p. 166.
non 1958 *Schulzospora ocellata* (Horst) Potonié and Kremp; Butterworth and Williams, pl. 4, fig. 15.

Holotype. Horst 1955, pl. 21, figs. 40*a*, *b*. Preparation IV68, 20·5 75·8.

Type locality. Osmana Seam, Michael Colliery, Moravska-Ostrava; Namurian A.

Diagnosis (from Horst 1955, p. 195). Microspores with fine infragranulation. Amb oval to round. Body thin-walled. Pseudosaccus circular to oval, darkest at the boundary of the grey body. The rays sometimes reach to this boundary; generally, however, they are shorter. Spores with a ruptured tetrad mark, in which the exine is generally torn outwards, are rare. The body, the size of which varies from 25 to 59 μ, almost always lies obliquely to the length of the spore.

Size in microns. (i) Holotype 90; 61–130 (80–100), body 25–59, fum. HNO_3 (Horst 1955). (ii) 76(92)110 × 60(69)88, body 56(66)77 × 52(61)74, fum. HNO_3; seam at 127 ft. 2 in., Ouston Airfield borehole, Northumberland Coalfield, England; Namurian A.

Description. Longest diameter of the body is occasionally at right angles to that of the pseudosaccus; the obliqueness of the body is not general. Laesurae indistinct, rays 8–18 μ in length. Exine moderately thick, folding infrequent.

Comparison. This is the largest species of *Schulzospora* found during the present investigation and the orientation of the body differs from that in the other species. It is more rounded than *S. campyloptera* and has a thicker exine than *S. rara.*

Occurrence. Infrequent to common, Assemblages II to IV; Viséan and Namurian.

Schulzospora plicata Butterworth and Williams 1958

Plate 23, figs. 4, 5

Holotype. Plate 23, fig. 4. Preparation T67/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Seam at 1,555 ft. 4 in., Righead borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 388). Outline elongate-elliptical, constricted in the region of the body. Body circular, distinct. Trilete rays indistinct, extending about one-half the radius of the body. Body and pseudosaccus granulate. Body with a peripheral, thickened zone, plicate. Pseudosaccus with median constriction, radiating folds and pleats.

Size in microns. Holotype 43 × 26; 44–64 × 25–40 at type locality, 40–100 (10 specimens) various horizons, Schulze and 5% KOH (Butterworth and Will. 1958).

Remarks. The median restriction of the pseudosaccus often gives the appearance of a bipseudosaccate spore. One laesura is invariably at right angles to the longer spore diameter.

Comparison. Distinguished from other species by its smaller size and by its constricted, pleated pseudosaccus.

Occurrence. Infrequent, Assemblages II to VI; Viséan to Westphalian A.

Schulzospora rara Kosanke 1950

Plate 23, figs. 2, 3

1950 *Schulzospora rara* Kosanke, p. 53, pl. 13, figs. 5–8.
non 1950 *Planisporites ovatus* Knox, p. 316, pl. 17, fig. 222.
1952 *Endosporites ovatus* (Knox); Balme, p. 180, text-fig. 1*e*.
1958 *Schulzospora ocellata* (Horst) Potonié and Kremp; Butterworth and Williams, pl. 4, fig. 15.

Holotype. Kosanke 1950, pl. 13, fig. 8. Preparation 587, slide 8.

Type locality. Battery Rock Coal, Hardin County, Illinois, U.S.A.; Caseyville Group.

Diagnosis (from description in Kosanke 1950, p. 53). Outline elliptical, body spherical. Trilete rays at least 20 μ in length, distinct, lips poorly developed. Pseudosaccus and body finely punctate. Exine thin, not exceeding 2 μ.

Size in microns. (i) Holotype 109·2×81·9, body 73·5×73·5, Schulze and 10% KOH (Kosanke 1950). (ii) 70(81)105×55(65)75, body 48(60)75, Schulze (Balme 1952); Seam at 3385 ft. 5 in. (3,387 ft. in Balme 1952), Blacklake borehole, North Staffordshire Coalfield, England; Upper Westphalian A. (iii) 54(67)83 ×38(50)60, body 40(51)62×32(42)56, fum. HNO_3; Rushy Park Seam, Sutton Manor Colliery, Lancashire Coalfield, England; Upper Westphalian A. (iv) 56(63)78×44(49)62, body 40(45)60×40(43)52, fum. HNO_3; seam at 436 ft. 4 in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England; Upper Westphalian A. (v) 62(77)102×44(57)72, body 44(59)80×36(47)58, fum. HNO_3; seam at 2,803 ft., Colston Bassett (British Petroleum Co. Ltd.) borehole, Nottinghamshire Coalfield, England; Lower Westphalian A.

Description. Amb oval or ovate with one end blunter than the other. Body circular to oval, the longer axis parallel to that of pseudosaccus. Laesurae not always evident; rays generally 8–15 μ long. Exine moderately thick, occasionally folded.

Remarks. The spores from the Nottinghamshire Coalfield sources resemble the type material most closely, in that they are bilaterally symmetrical with one laesura invariably lying at right angles to the longest axis of the spore. In other miospore floras examined the amb tends to be egg-shaped and it is more usual for one laesura to be consistently in alignment with the longest axis. In none of the spores examined was the body quite circular, as in the type material, or the rays of the laesurae more than 20 μ long.

Planisporites ovatus Knox (6K of Knox 1942, text-fig. 4) described from the Namurian A is a much larger species, possibly *Schulzospora campyloptera*. Balme (1952) applied the name to a smaller Westphalian spore and queried its synonymy with *S. rara* Kosanke.

Comparison. Distinguished from most other species in being less elongate. In *Schulzospora ocellata* the longer axis of the body sometimes lies at right angles to that of the pseudosaccus.

Occurrence. Infrequent, Assemblages I to IV; infrequent to frequent, Assemblages V to VII; Viséan to Westphalian A.

Genus REMYSPORITES Butterworth and Williams 1958

Type species. *R. magnificus* (Horst) Butterworth and Williams 1958.

Diagnosis (restated from diagnosis in Butterworth and Williams 1958, p. 386). Spores radial, trilete, pseudosaccate. Amb circular to oval. Laesurae distinct. Body circular, thin, relatively large. Pseudosaccus enveloping body on distal and proximal surfaces, externally laevigate to microreticulate. Folding concentrated mainly in the polar areas.

Remarks. The diagnosis is restated to accommodate Playford's indication (1963, p. 652) that the pseudosaccus totally envelops the body.

Comparison. Distinguished from *Endosporites* by the character of the external ornament of the pseudosaccus and the absence of a limbus. *Vestispora* has a distinctive ornament of the exoexine and an operculum. *Remysporites* is also distinguished from *Endosporites* and *Vestispora* by folding in the polar areas. In *Velosporites* Hughes and Playford the intexine is relatively thick and has a characteristic apiculate ornament.

Affinity. Cycadofilicales. Remy (1953, 1954) has shown that these spores were borne by *Paracalathiops stachei* Remy (the fructification of *Rhodea* in part).

Remysporites magnificus (Horst) Butterworth and Williams 1958

Plate 23, fig. 8

1943 *Triletes (Zonales) magnificus* Horst (thesis), fig. 37.
1955 *Endosporites magnificus* (Horst) Potonié and Kremp; Horst, p. 194, pl. 21, fig. 37.
1956 *Endosporites magnificus* (Horst); Potonié and Kremp, p. 161.
1958 *Remysporites magnificus* (Horst); Butterworth and Williams, p. 386, pl. 4, figs. 7–9, text-fig. 6.

Holotype. Horst 1955, pl. 21, fig. 37. Preparation II29, 21·9 76·0.

Type locality. Seam C, Gleiwitzer Mine, Gleiwitz Coalfield, Upper Silesia; Namurian A.

Diagnosis (from diagnosis in Butterworth and Williams 1958, p. 387). Outline circular to oval, no preferred orientation, margin smooth. Laesurae ridged, straight, distinct, extending one-third to full body radius. Body circular, distinct. Pseudosaccus laevigate to distinctly microreticulate; contact area sometimes distinguished by vermiculate ornament. Body moderately thick; pseudosaccus thin. Folding in central area, and along rays, frequent.

Size in microns. (i) Holotype 106; 84–249 (140–220), fum. HNO_3 (Horst 1955). (ii) 195–255, Remy (1954) for spores of *Paracalathiops stachei* (see, however, comment on these limits by Potonié 1962, p. 147). (iii) 169–225 (12 specimens) for spores ascribed to *P. stachei* obtained by Chaloner from the Namurian A of Northern Ireland (in Butterworth and Williams 1958). (iv) 137–238 (12 specimens) Schulze, 138–84 (11 specimens) fum. HNO_3 (Butterworth and Will. 1958); Namurian A.

Remarks. In their diagnosis Butterworth and Williams (loc. cit.) erroneously state that the margins of the laesurae are simple. These authors have indicated that the variation in size range quoted by various authors is probably due to the use of different macerating agents.

Comparison. Staplin (1960, p. 35) has stated that more than one species may be represented by *R. magnificus*; more than one form species could probably be made but, considering the range of variation shown by Remy's and Chaloner's material, the comparative rarity of the spore among sporae dispersae, and the lack of stratigraphical significance of the forms concerned, such a procedure would not seem to be advisable. *R. albertensis* Staplin 1960 (p. 35, pl. 8, figs. 8, 10) is said to be distinguished by its smaller size (141–60 μ) and by the prominent verrucate to vermiculate sculpture of the contact area. The size range of this species has, however, been considerably extended by Playford [1963, p. 653; 146(178)205 μ] so that the difference in size becomes negligible, particularly in view of the expected variation in spores of this dimension. Also, the contact areas in *R. magnificus* are occasionally vermiculate. These two forms may be conspecific.

Occurrence. Infrequent, Assemblages ?I to IV; Viséan and Namurian.

Infraturma POLYPSEUDOSACCITI infraturma nov.

Polypseudosacciti includes trilete aperinate cavate spores in which separation and inflation of exine layers at the equator is restricted radially to give three or more pseudosacci.

Genus ALATISPORITES (Ibrahim) emend.

Type species. A. pustulatus Ibrahim 1932.

Diagnosis (emended from diagnosis in Potonié and Kremp 1956, p. 154). Trilete microspores in which the exoexine is separated, and expanded, from the intexine both proximally between the laesurae and distally (except in polar region), to form pseudosacci. Sometimes the three pseudosacci thus formed are further constricted so as to give the impression of six or more pseudosacci.

Remarks. The diagnosis of Potonié and Kremp 1956 has been emended with respect to the number of pseudosacci and the statement that they extend to the laesurae on the proximal surface. Sometimes the proximal separation of the exine layers only takes place for a short distance polewards from the equator.

Affinity. Unknown.

Alatisporites hoffmeisterii Morgan 1955

Plate 23, figs. 9, 10

Holotype. Morgan 1955, pl. 2, fig. 1. Preparation D–54a. Leitz stage readings V–112·2, H–149·5.

Type locality. Rowe Coal, Wagoner County, Oklahoma, U.S.A.; Des Moines Series.

Diagnosis (from Morgan 1955, p. 37). Body subtriangular; interradial margins commonly slightly concave to convex; angles well rounded. Laesurae simple, extending to, or nearly to, margin of body. Body verrucate. Exine about 3 μ in thickness. Pseudosacci vary in number, ovate to elongate in outline; laevigate to finely granulate; about 1 μ thick and overlapping body by as much as 16 μ.

Size in microns. (i) Holotype, overall 98, body 69×66; body, mean diameter 45–75, Schulze (Morgan 1955). (ii) Overall 54(76)104, body 41(56)68, (13 specimens) fum. HNO_3; seam at 670 ft. 2 in., Garth Place borehole, South Wales Coalfield; Westphalian C.

Remarks. The number of pseudosacci appears to be variable. Morgan quotes 7 to 11. British specimens with 6 or fewer pseudosacci, which otherwise closely resemble *A. hoffmeisterii*, have been included in this species.

Occurrence. Infrequent, Assemblages IX to XI. Only recorded from the coalfields of the Southern Province. Westphalian C and D.

Alatisporites pustulatus Ibrahim 1932

Plate 23, figs. 11, 12

1932 *Sporonites pustulatus* Ibrahim in Potonié, Ibrahim, and Loose, p. 448, pl. 14, fig. 12.
1933 *Alati-sporites pustulatus* Ibrahim, p. 32, pl. 1, fig. 12.

Holotype. Potonié and Kremp 1956, pl. 19, fig. 445 after Ibrahim. Preparation B36, b4 (u).

Type locality. Ägir Seam, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Potonié and Kremp 1956, p. 155). Tripseudosaccate. Amb of body with well-rounded angles; body margin smooth to slightly crenulate. Outline of pseudosacci smooth. Laesurae reach to equator. Pseudosacci envelop entire proximal side, meeting along the line of the laesurae; distally, only the polar region (about one-half the diameter of the body) is free from the pseudosacci. Pseudosacci with fine, dense, granulate infrasculpture. Body ornamented by numerous small, sinuose folds of the pseudosaccus.

Size in microns. (i) Holotype 73; 70–90, Schulze and KOH (Potonié and Kr. 1956). (ii) Overall maximum 74(81)89, maximum body 47(52)57, (8 specimens) fum. HNO_3; various localities; Westphalian A to C.

Description. Body triangular with rounded angles and straight, slightly convex, or concave sides. Laesurae simple and straight. Body ornament finely and densely rugulate-verrucate, appearing superficially microreticulate, and becoming coarser towards equator where a zone of radial pleating may occur. In most British specimens amb of body is distinctly crenulate. Pseudosaccus outline in proximal-distal view phaseolate, when not distorted by secondary compression folds; under oil, pseudosaccus margin rough, external surface finely granulate. Pseudosaccus thin, body moderately thick.

Remarks. Potonié and Kremp (1956, p. 155) state that the separation of the exoexine from intexine takes place proximally over the whole surface up to the laesurae. The evidence for this is the occurrence of pseudosaccus folds extending to the laesurae. This has not been verified in British specimens.

Comparison. *A. punctatus* Kosanke 1950 (p. 24, pl. 4, fig. 4) appears morphologically similar but is larger with body dimensions 70–79 μ. In *A. hoffmeisterii* Morgan the body is verrucate and never appears superficially microreticulate, the angles of the body are broader, and there are generally more than three pseudosacci.

Occurrence. Infrequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Alatisporites trialatus Kosanke 1950

Plate 23, figs. 13–15

Holotype. Kosanke 1950, pl. 4, fig. 3. Preparation 543–B, slide 20.

Type locality. No. 5 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 25). Tripseudosaccate. Body subtriangular; interradial margins concave; angles broadly rounded. Body laevigate; pseudosacci punctate. Body exine 2–4 μ, or more, in thickness; pseudosacci up to 2 μ thick.

Size in microns. (i) Holotype, overall $98{\cdot}2 \times 90{\cdot}3$, body $64{\cdot}8 \times 55{\cdot}2$, length of pseudosacci $67{\cdot}0 \times 65{\cdot}8$; mean diameter of body 50–65; Schulze and 10% KOH (Kosanke 1950). (ii) Overall 61(75)92, body 44(55)63, fum. HNO_3; Trenchard Seam, Princess Royal Colliery, Forest of Dean Coalfield, England; Upper Westphalian C.

Description. Interradial margins may be straight, slightly convex, or concave; body margin smooth. Laesurae simple, straight, extending to margin of body, often open.

Pseudosacci overlap the body proximally by not more than 5 μ; distally the zone of overlap is greater, up to 20 μ; overlapping may appear greater due to compression folding. Proximal body surface laevigate; distal surface laevigate, or sometimes weakly granulate. Pseudosacci appear finely granulate at margin, possibly due to impression of infrasculpture on outer surface.

Remarks. Kosanke states that the pseudosacci of *A. trialatus* are not usually folded, whereas the pseudosacci of British spores assigned to this species exhibit varying degrees of folding and constriction.

Comparison. *A. pottsvillensis* Guennel 1958 (p. 86, pl. 6, figs. 10, 11) is probably a synonym of *A. trialatus*. *A. pottsvillensis* is smaller (overall size 60–75 μ) than *A. trialatus* but falls within the range of the British specimens. The slightly larger size of *A. trialatus* may be due to the method of maceration. The morphology of the American and British species appears similar although the pseudosacci of *A. pottsvillensis* may be laevigate. Included under *A. trialatus* are forms morphologically similar to but smaller than *A. inflatus* Kosanke 1950 (p. 24, pl. 4, fig. 2), overall size 123–50 μ, and *A. varius* Kosanke 1950 (p. 25, pl. 4, fig. 1), overall size of holotype 129 μ. Occasionally forms resembling *A. hexalatus* Kosanke 1950 (p. 23, pl. 4, fig. 5), apparently with 5 or 6 or even more pseudosacci, have been recorded from British coals but the numbers of pseudosacci may only be due to partial constriction and the effects of compression on the three pseudosacci of *A. trialatus*. It differs from *A. pustulatus* in that proximal body surface is laevigate and largely free from pseudosacci.

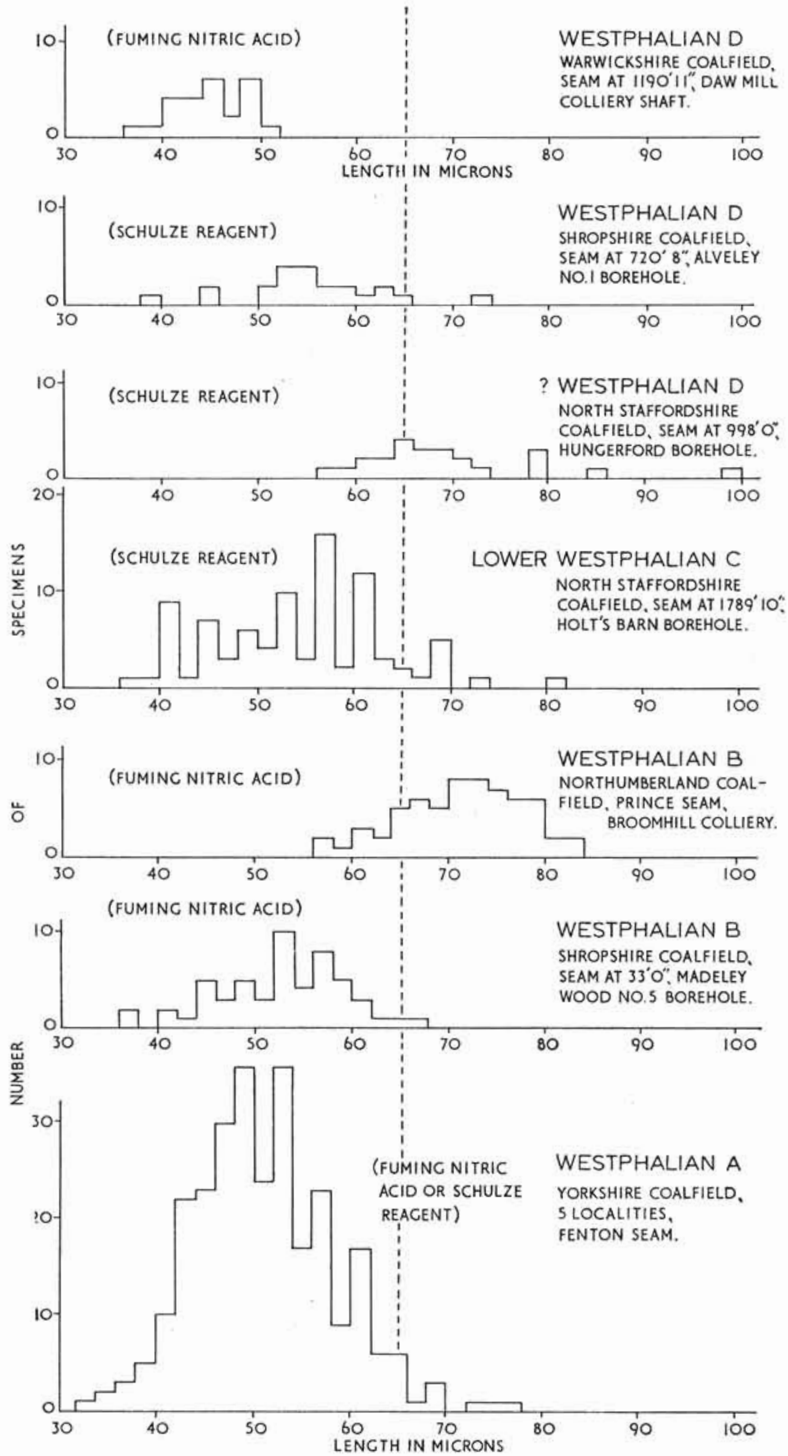
Occurrence. Infrequent, Assemblage XI; South Wales, Bristol and Somerset, and Forest of Dean Coalfields; Upper Westphalian C and Westphalian D.

Turma MONOLETES Ibrahim 1933
Suprasubturma ACAVATOMONOLETES Dettmann 1963
Subturma AZONOMONOLETES Luber 1935
Infraturma LAEVIGATOMONOLETES Dybová and Jachowicz 1957
Genus LAEVIGATOSPORITES Ibrahim 1933

Type species. *L. vulgaris* Ibrahim 1933.

Diagnosis (Potonié and Kremp 1954, p. 165; translation). 'Monolete spores. Outline smooth. Laevigate to infrapunctate. Amb more or less oval; shape in meridian plane, phaseolate. Distal margin slightly, and not, as in *Latosporites*, markedly convex; polar axis therefore relatively shorter than in *Latosporites*. Exine always sculptureless. Monolete mark straight.'

Remarks. The spores of this genus are all laevigate by definition and do not show much variation in haptotypic features, or in thickness of exine. Any subdivisions have, therefore, to be made on overall size or on small variations in shape. Twenty or more specimens have been measured from coals at 16 horizons distributed throughout the Westphalian and from six localities at one of the horizons, from which it appears that there is no significant variation in the length/breadth ratio of the approximately 700



TEXT-FIG. 72. Maximum dimensions of *Laevigatosporites spp.* from various seams and localities spores measured. In most of these spores the breadth was between five-eighths and three-quarters of the length. There were, however, occasional specimens in which the breadth was more than seven-eighths of the length and a few with a breadth of less than one-half of the length.

When histograms of spore lengths were prepared, very few well-defined frequency peaks occurred. Some Westphalian D coals yielded assemblages of a very small species 16–33 μ, and a consistently large species 60–85 μ was present in certain Westphalian B Coals. The majority of the spores measured fell into the range 33–70 μ. From what is known of the affinities of *Laevigatosporites*-type spores there is no doubt that these assemblages comprise spores from several taxa of parent plants. Because of the practical difficulty of using size as the sole criterion for speciation, and because species thus defined have no apparent stratigraphic value, the authors recognize only three species in spores having a maximum length less than 100 μ. Spores with a length less than 35 μ are referred to *Laevigatosporites minimus* (Wilson and Coe) Schopf, Wilson, and Bentall. The larger spores are arbitrarily assigned to one of two species separated at 65 μ on the basis of the data shown in text-fig. 72. The larger specimens are referred to *L. vulgaris* Ibrahim, originally given a size range of 56–77 μ. Loose subsequently subdivided this species into two forms at a limiting value of 70 μ; the smaller form *L. vulgaris minor* is here given species status and applied to spores with a size range of 35–65 μ. This treatment, which is purely for systematic convenience in stratigraphic work, does not diminish the value of the statistical treatment of size characteristics of assemblages in the solution of problems of seam correlation.

Affinity. Sphenopsida and Filicales. The larger forms of *Laevigatosporites* (those exceeding about 35 μ in length) have so far only been obtained from the Sphenopsida. Reed (1938) described spores with a length of 50 μ from a calamitean type fructification. Andrews and Mamay (1951) recovered spores ranging from 20 to 40 μ in length from a species of *Bowmanites* and Remy (1960 and 1961) isolated spores with size ranges from 35 to 50 μ and 55 to 70 μ from two other species of *Bowmanites*. The smaller forms of *Laevigatosporites* have been recovered from the Sphenopsida by Baxter (1950) and from the Filicales by Mamay (1950).

Laevigatosporites minimus (Wilson and Coe) Schopf, Wilson, and Bentall 1944

Plate 24, figs. 1, 2

1940 *Phaseolites minimus* Wilson and Coe, p. 183, pl. 1, text-fig. 5.
1944 *Laevigato-sporites minimus* (Wilson and Coe); Schopf, Wilson, and Bentall, p. 37.

Holotype. Wilson 1958, pl. 1, fig. 5 after Wilson and Coe (1940). Preparation 121P.

Type locality. What Cheer Clay Products Company Mine, What Cheer, Keokuk County, Iowa, U.S.A.; Des Moines Series.

Diagnosis. Amb oval, shape in equatorial view phaseolate. Laesura simple, greater than one-half of spore diameter in length. Exine very thin, folding infrequent.

Size in microns. (i) Holotype 25; length 20–30, width in equatorial view 16–20, Schulze and 25% NH_4OH (Wilson 1958). (ii) 20–35, Schulze (Potonié and Kr. 1956). (iii) 16(22)33, fum. HNO_3; Slyving Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Comparison. Distinguished from other species by its smaller size.

Occurrence. Infrequent to frequent, Assemblage XI; Westphalian D.

Laevigatosporites minor Loose 1934

Plate 24, fig. 3

1932 *Sporonites vulgaris* Ibrahim in Potonié, Ibrahim, and Loose, in part.
1933 *Laevigato-sporites vulgaris* Ibrahim, in part.
1934 *Laevigatosporites vulgaris minor* Loose, p. 158, pl. 7, fig. 12.
1957*a* *Laevigatosporites minor* (Loose) Potonié and Kremp; Bharadwaj, p. 109, pl. 29, figs. 8, 9.

Holotype. Loose 1934, pl. 7, fig. 12. Preparation V29, a.

Type Locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. As for *L. vulgaris*.

Size in microns. (i) Holotype 58·5, 40–70, Schulze and KOH (Loose 1934). (ii) 45–65, Schulze (Bharadwaj 1957*a*). (iii) 37(44)50, fum. HNO_3; seam at 1,190 ft. 11 in., Daw Mill Colliery shaft, Warwickshire Coalfield, England; Westphalian D. (iv) 44(55)64, Schulze; seam at 720 ft. 8 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England; Westphalian D. (v) 34(50)68, Schulze; seam at 1,521 ft. 0 in., Holt's Barn borehole, North Staffordshire Coalfield, England; Westphalian C. (vi) 40(56)71, fum. HNO_3; seam at 1,758 ft. 2 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; West-

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EXPLANATION OF PLATE 24

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Laevigatosporites minimus* (Wilson and Coe) Schopf, Wilson, and Bentall 1944. 1, slide 232, 42·8 106·1. 2, equatorial view; slide 232, 26·2 106·6.

Fig. 3. *L. minor* Loose 1934. Slide 233, 48·3 112·7.

Fig. 4. *L. vulgaris* Ibrahim 1932. Equatorial view; slide 234, 54·1 117·0.

Figs. 5, 6. *Latosporites globosus* (Schemel) Potonié and Kremp 1956. 5, slide 235, 32·1 114·6. 6, slide 235, 39·1 115·1.

Fig. 7. *L. minutus* Bharadwaj 1957. Slide 235, 30·5 103·6.

Figs. 8, 9. *Punctatosporites minutus* Ibrahim 1933. 8, slide 21, 44·0 106·3. 9, equatorial view; slide 239, 37·5 115·8.

Figs. 10, 11. *P. granifer* Potonié and Kremp 1956. 10, slide 236, 53·6 107·7. 11, slide 236, 29·6 109·8.

Figs. 12–15. *P. oculus* sp. nov. 12, Holotype; slide T20/1. 13, slide 237, 22·9 108·8. 14, slide 237, 23·7 106·2. 15, Isotype; slide T20/2.

Figs. 16–18. *P. rotundus* Bharadwaj 1957. 16, slide 238, 19·2 106·7. 17, slide 238, 26·6 103·4. 18, slide 238, 39·5 104·8.

Figs. 19–23. *Thymospora obscura* (Kosanke) Wilson and Venkatachala 1963. 19, slide 241, 19·9 111·8. 20, slide 241, 25·8 116·4. 21–23, slide 240, 45·2 115·6. 22, 23, proximal and distal surfaces respectively; ×1,000.

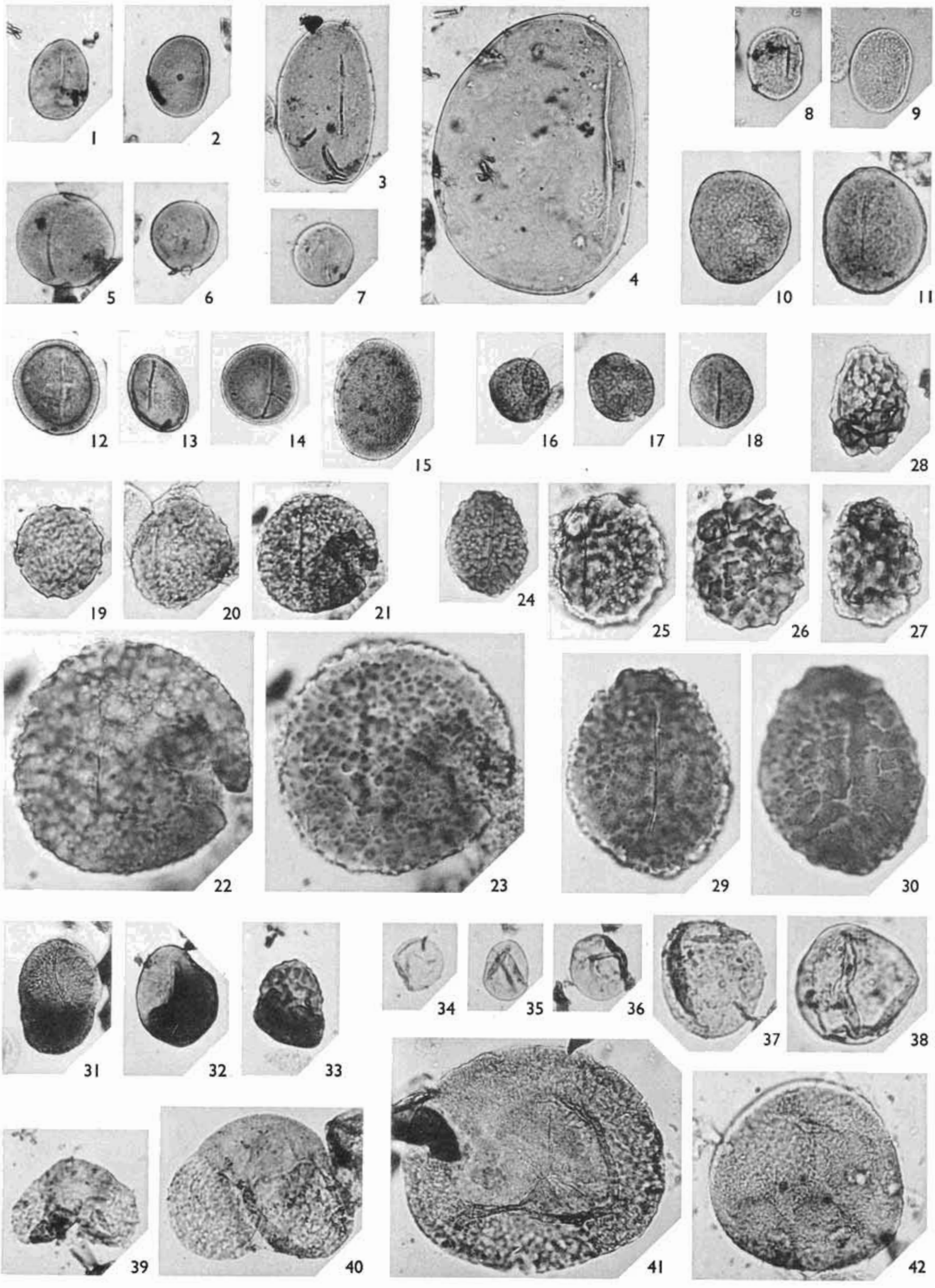
Figs. 24–30. *T. pseudothiessenii* (Kosanke) Wilson and Venkatachala 1963. 24, 29, 30, slide 238, 21·0 102·3. 29, 30, proximal and distal surfaces respectively; ×1,000. 25, 26, proximal and distal surfaces respectively; slide 239, 32·3 111·6. 27, slide 239, 42·2 113·4. 28, slide 241, 50·1 105·6.

Figs. 31–33. *Torispora securis* Balme 1952. 31, Lectotype; slide T68/1, 49·2 108·5. 32, slide 242, 33·4 116·3. 33, slide 243, 52·8 115·0.

Figs. 34–38. *Fabasporites pallidus* Sullivan 1964. 34, slide 244, 38·7 110·6. 35, slide 244, 25·1 107·3. 36, slide 244, 46·7 111·4. 37, ×1,000; slide 208, 38·6 105·7. 38, ×1,000; slide 245, 54·2 104·3.

Figs. 39, 40. *Pityosporites westphalensis* Williams 1955. 39, slide 233, 48·9 116·3. 40, large size probably due to use of alkali following Schulze reagent; slide 258, 28·9 106·3.

Figs. 41, 42. *Wilsonites* cf. *delicatus* Kosanke 1950. 41, slide 259, 30·3 117·7. 42, slide 260, 35·4 116·8.



SMITH and BUTTERWORTH, British Carboniferous miospores

phalian B. (vii) 36(52)67, fum. HNO_3; New Mine Seam at 33 ft. 0 in., Madeley Wood No. 5 Underground borehole, Coalbrookdale Coalfield, England; Westphalian B. (viii) 41(52)68, Schulze; Fenton Seam, Wentworth Silkstone Colliery, Yorkshire Coalfield, England; Westphalian A. (ix) 33(48)63, Schulze; Fenton Seam, Houghton Main Colliery, Yorkshire Coalfield, England; Westphalian A. (x) 41(57)71, fum. HNO_3; Musselband Seam at 3,256 ft. 11 in., Slatehole Farm borehole, Ayrshire Coalfield, Scotland; Westphalian A.

Description. Laesura simple, one-half to three-quarters of spore diameter in length. Exine thin to moderately thick, laevigate; seldom folded.

Remarks. Bharadwaj (1957*a*) evidently attributed *Laevigatosporites minor* (Loose) to Potonié and Kremp in error.

Comparison. In practice *L. minor* is given an arbitrary size range of 35–64 μ to separate it from the smaller *L. minimus* and the larger *L. vulgaris*.

Occurrence. Infrequent, Assemblage IV, common to abundant, Assemblages VI to XI; Namurian to Westphalian D.

Laevigatosporites vulgaris Ibrahim 1933

Plate 24, fig. 4

1932 *Sporonites vulgaris* Ibrahim in Potonié, Ibrahim, and Loose, p. 448, pl. 15, fig. 16.
1933 *Laevigato-sporites vulgaris* Ibrahim, p. 39, pl. 2, fig. 16.
1940 *Phaseolites desmoinesensis* Wilson and Coe, p. 182, pl. 1, fig. 4.
1944 *Laevigatosporites desmoinensis* (Wilson and Coe); Schopf, Wilson, and Bentall, p. 37.

Holotype. Potonié and Kremp 1956, pl. 19, fig. 429 after Ibrahim. Preparation B31, c6 (or).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Ibrahim 1933, p. 39). Amb oval, shape in equatorial view, phaseolate; margin smooth. Laesura about two-thirds of length of spore. Exine laevigate to faintly punctate (? infrasculpture), about 1 μ thick.

Size in microns. (i) Holotype 69·5; 56–77, Schulze and KOH (Ibrahim 1933). (ii) 56(72)83, fum. HNO_3; Prince Seam, Broomhill Colliery, Northumberland Coalfield, England; Westphalian B.

Description. Laesura simple, rather longer than one-half the spore diameter [27(38)55 μ in length]. Exine laevigate; occasionally slightly scabrate.

Remarks. In practice forms of *Laevigatosporites* between 65 and 100 μ are attributed to *L. vulgaris*. The size of *L. desmoinesensis* was given by Wilson and Coe as 60–75 μ, which is almost identical to that of *L. vulgaris*.

Occurrence. Infrequent to common, Assemblages VIII and IX; Westphalian B.

Genus LATOSPORITES Potonié and Kremp 1954

Type species. *L. latus* (Kosanke) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 165; translation). 'Monolete isospores or microspores with a more or less smooth margin. Structure laevigate to infrareticulate. Amb broadly oval to approximately circular. In lateral view the distal surface is more strongly convex, and as a result may even be roundly pointed. In lateral view the margin of the distal portion is more strongly arched than in *Laevigatosporites*, which has a more circular curvature. In typical forms of this genus the polar axis is half as long as, to as long as, the longest equatorial axis.'

Remarks. Of the many spores measured in connexion with the investigations of the genus *Laevigatosporites* a few had the characteristic outline of *Latosporites*, but they never occurred in significant numbers at any part of the size range.

The two species described here do not have the deltoid shape of *L. latus* Kosanke but are almost circular; they have been ascribed to the genus by Potonié and Kremp (1956).

Affinity. Filicales. Bharadwaj and Singh (1956, pl. 2, figs. 12, 21) obtained finely granulate spores of this type from the pecopterid fern *Asterotheca meriani* (Brongniart) Stur from the Trias of Austria (in Potonié 1962, p. 93).

Latosporites globosus (Schemel) Potonié and Kremp 1956

Plate 24, figs. 5, 6

1951 *Laevigato-sporites globosus* Schemel, p. 748, text-fig. 2.
1956 *Latosporites globosus* (Schemel); Potonié and Kremp, p. 140.

Holotype. Type specimen in collection of West Virginia Geological Survey.

Type locality. Mystic Coal of Appanoose and Madison Counties, Iowa, U.S.A.; Des Moines Series.

Diagnosis (description in Schemel 1951, p. 746). 'Spores monolete, bilateral; circular to subcircular in transverse plane; . . . surface of spore densely and minutely punctate; exine slightly thickened and opaque; suture extends from one-half to two-thirds the diameter of the spore, lips not prominent.'

Size in microns. (i) Mean diameter 19(24)30, maceration method not known (Schemel 1951). (ii) 15(22)30, fum. HNO_3; Yorkley Seam, Cannop Colliery, Forest of Dean Coalfield, England; Westphalian D. (iii) 17(21)26, fum. HNO_3; Great Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. Under oil the exine appears finely granulate. The minute grana are clearly apparent at the margin but are less than $0{\cdot}5\ \mu$ in diameter with no intervening spaces. Exine $1{\cdot}5$–$2\ \mu$ thick.

Remarks. In some specimens, there is an incipient third ray to the laesura.

Comparison. Schemel (1951) states that *L. globosus* has a similar shape and ornament to *Punctatisporites obliquus* Kosanke 1950 (p. 16, pl. 2, fig. 5) and that it is difficult to distinguish between these species when the tetrad mark is not seen. No specimens were found which fell into the size range of *P. obliquus* (31–46 μ). *L. globosus* is distinguished from the small species of *Laevigatosporites* by its rounder shape and by its thicker exine. It is distinguished from species of *Punctatosporites* by its very finely granulate surface, which under dry objectives appears almost laevigate.

Occurrence. Infrequent to frequent, Assemblages X and XI; Upper Westphalian C and Westphalian D.

Latosporites minutus Bharadwaj 1957

Plate 24, fig. 7

Holotype. Bharadwaj 1957*a*, pl. 29, fig. 12. Preparation 10705/1c.

Type locality. Grenzkohlen Seam, Labach Colliery, Saar-Pfalz Coalfield, Germany; Stephanian.

Diagnosis (Bharadwaj 1957*a*, p. 110). '. . . circular, monolete suture more or less one-half the diameter. Exine thin, smooth, intrapunctate–intragranulate.'

Size in microns. (i) 12–18, Schulze (Bharadwaj 1957*a*). (ii) 12(16)20, fum. HNO_3; Yorkley Seam, Cannop Colliery, Forest of Dean Coalfield, England; Westphalian D. (iii) 11(14)20, fum. HNO_3; Great Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. Amb circular. Laesura simple, short, less than one-half diameter of spore. Exine almost laevigate, very thin, folding infrequent.

Comparison. It was not possible to distinguish between this species and *Laevigatosporites perminutus* Alpern 1959 (p. 152, pl. 10, figs. 249–55), size 12–16 μ, shape oval to round, in British coals. *Latosporites minutus* is distinguished from *Laevigatosporites minimus* by its rounder shape and smaller size and from species of *Punctatosporites* by its smaller size and almost complete lack of ornament. It is smaller and has a much thinner exine than *Latosporites globosus*.

Occurrence. Infrequent to frequent, Assemblages X and XI; Upper Westphalian C and Westphalian D.

Infraturma SCULPTATOMONOLETES Dybová and Jachowicz 1957
Genus PUNCTATOSPORITES Ibrahim 1933

Type species. *P. minutus* Ibrahim 1933.

Diagnosis (Potonie and Kremp 1954, p. 165; translation). 'Monolete isospores or microspores. Amb roughly oval; in equatorial longitudinal view shape oval to phaseolate. Monolete laesura generally straight, without, or barely rising to, an apex. Outline rough due to more or less fine granulation of the entire exine.'

Comparison. Distinguished from other monolete genera such as *Laevigatosporites* Ibrahim 1933 and *Latosporites* Potonié and Kremp 1954 by its ornament of fine grana. *Speciososporites* Potonié and Kremp 1954 differs in possessing an equatorial cingulum.

Remarks. The generic name is not apt and does not describe the type of ornament which characterizes the members of the genus. No doubt this led Dybová and Jachowicz (1957*a*) to adopt the name *Granulatosporites* (already used by Imgrund in his thesis 1952) for monolete spores with an ornamentation of grana. Potonié (1960), however, rejects this name on the grounds that the species designated as the nomenclatural type of the new genus was already the type of *Punctatosporites*.

Affinity. The spores of certain species of the Mesozoic eusporangiate fern *Marattiopsis* resemble *Punctatosporites* (in Potonié 1962, pp. 96, 97).

Punctatosporites granifer Potonié and Kremp 1956

Plate 24, figs. 10, 11

Holotype. Potonié and Kremp 1956, pl. 19, fig. 442. Preparation 671/4.

Type locality. Glücksburg Seam, Ibbenbüren, Germany; Westphalian C.

Diagnosis (from Potonié and Kremp 1956, p. 142). Amb oval with a tendency toward circular. Laesura ridged, extends almost to equator. Margin rough due to grana, which cover entire exine; about 50 grana project at the periphery.

Size in microns. (i) Holotype 30; 25–35, Schulze (Potonié and Kr. 1956). (ii) 21(28)37, fum. HNO_3; Yorkley Seam, Northern United Colliery, Forest of Dean Coalfield, England; Westphalian D.

Description. Shape in polar view, oval to near circular; in equatorial longitudinal view, proximal profile is more or less flat to convex; distal profile convex. Laesura simple, straight, curved, or flexed, and distinct, but quite often not seen in equatorial view, or when spore is viewed from distal surface; length greater than one-half of longest dimension, often reaching nearly to equator. In one assemblage about 10% showed incipient trilete condition. Grana about $\frac{1}{2}\mu$ in diameter, apices under oil immersion appear somewhat pointed; granulate ornament varies in degree of prominence; in some forms the exine appears almost laevigate at low powers of magnification. Exine relatively thick. Folds rare.

Remarks. Imgrund (1960, p. 175) considers *P. granifer* as a synonym of *P. scabellus* Imgrund 1952 (in thesis). This is not accepted in view of the doubt whether a name used in a thesis, not widely distributed, can be regarded as validly published (Article 29, International Code of Botanical Nomenclature, 1961). Potonié (1958) has created a genus *Leschikisporis* for spores in which the laesurae are asymmetrically developed with one laesura greatly reduced in length. In the present work, forms possessing this feature, which in other respects resemble *P. granifer*, have not been accorded a separate status.

Occurrence. Infrequent, Assemblage X; infrequent to frequent, Assemblage XI; Westphalian C and D.

Punctatosporites minutus Ibrahim 1933

Plate 24, figs. 8, 9

1933 *Punctato-sporites minutus* Ibrahim, p. 40, pl. 5, fig. 33.
1938 *Azonomonoletes minutus* (Loose); Luber in Luber and Waltz, pl. 8, fig. 112.
1957 *Granulatosporites minutus* (Ibrahim); Dybová and Jachowicz, p. 191.

Holotype. Ibrahim 1933, pl. 19, fig. 439. Preparation A45, a1 (o).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Potonié and Kremp 1956, p. 143). Amb oval; shape in longitudinal equatorial view phaseolate. Laesura about two-thirds of longest dimension. Outline granulate.

Size in microns. (i) Holotype 25·5, Schulze and KOH. (ii) 21–28, Schulze (Potonié and Kr. 1956). (iii) 21(29)40, Schulze and KOH; seam at 511 ft. 0 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England; Westphalian D. (iv) 18(22)27, Schulze and KOH; seam at 772 ft. 9 in., Bowsey Wood borehole, North Staffordshire Coalfield, England; Westphalian D. (v) 21(25)30, Schulze and KOH; seam at 3,025 ft. 5 in., A3/9 borehole, Lancashire Coalfield, England; Westphalian B.

Description. Some forms included in this species have a nearly rounded shape in polar view. Laesura not always distinct and may vary from approximately one-half to two-thirds of longest dimension; sometimes open. Secondary folds occasionally occur. Exine thin, covered by very small grana which are closely spaced and are just visible at the margin of the spore.

Comparison. *P. pygmaeus* Imgrund 1960 (p. 175, pl. 16, figs. 110–13) is comparable in size to *P. minutus* but possesses a more distinctly granulate ornament.

Occurrence. Infrequent to common, Assemblages VI to XI; Westphalian A to D.

Punctatosporites oculus sp. nov.

Plate 24, figs. 12–15

1956 (unpublished) *Laevigatosporites oculus* Williams, (thesis) vol. 2, p. 20, pl. 3, fig. 16–18.

Holotype. Plate 24, fig. 12. Preparation T20/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Bull Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Diagnosis. Amb circular to oval; outline smooth to minutely denticulate. Monolete mark simple, two-thirds to nearly full length of spore, often flexed at mid-point where sometimes joined by a short indistinct ray. Exine scabrate, 2–4μ thick, sometimes folded.

Size in microns. Holotype 31; 17(24)32, fum. HNO_3; Bull Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. The monolete mark is quite often oblique, or even at right angles to the long axis of the compressed spore. The exine ornament can only be detected at high powers of magnification and is most easily seen at the margin, which appears minutely indented.

Remarks. There is a superficial resemblance to *Speciososporites minor* Alpern 1958 but *P. oculus* is not cingulate and the marginal 'rim' is due to the thickness of the exine. In equatorial view the shape may approach that of *Latosporites* Potonié and Kremp 1954; Bharadwaj (1957*a*) has already referred a relatively thick-walled, finely granulate species, *L. saarensis*, to the genus. The majority of specimens are not, however, of this type. The tendency to trilete condition is apparent in about one-third of specimens. The origin of the distinctive tetrad mark is described by Danzé and Laveine (1960).

Comparison. *P. oculus* differs from *Latosporites globosus* and *L. minutus* in possessing a thicker and more obviously granulate exine and from *L. saarensis* by its longer laesura. *P. granifer* is similar in size and shape, but has a thinner exine and a more distinctly granulate ornament.

Occurrence. Infrequent to abundant, Assemblages X (only in Tillery Seam of the South Wales Coalfield) and XI; Westphalian C (top) and Westphalian D.

Punctatosporites rotundus Bharadwaj 1957

Plate 24, figs. 16–18

Holotype. Bharadwaj 1957*a*, pl. 29, fig. 16. Preparation 7321/2.

Type locality. Kallenburg Seam, Kohlwald Colliery, Saar Coalfield, Germany; Westphalian D.

Diagnosis (Bharadwaj 1957*a*, p. 111). '. . . spherical to subspherical; slit more than one-half the diameter but not reaching the equator; approximately 40 grana along the equator.'

Size in microns. (i) Holotype 23; 20–24, Schulze (Bharadwaj 1957*a*). (ii) 15(20)22, fum. HNO_3; Mynydd-islwyn Seam, Tirpentwys Colliery, South Wales Coalfield; Westphalian D.

Description. Shape in polar or equatorial longitudinal view very similar. Laesura when visible usually distinct, sometimes curved or flexed; may pass out of sight over margin of spore when compression is not normal to equatorial plane. Exine relatively thick and covered with grana.

Comparison. The small size, relatively thick exine, and approximately circular shape distinguish this species from others of the genus. Occasional specimens with similar ornament, but more oval or elliptical in shape, could be referred to *P. granulatus* Bharadwaj 1957*a* (p. 111, pl 29, fig. 20). *Granulatosporites altus* Dybová and Jachowicz 1957*a* (p. 192; pl. 64, figs. 1–4) is probably synonymous with *P. rotundus*.

Occurrence. Infrequent to frequent, Assemblage XI; Westphalian D.

Genus THYMOSPORA Wilson and Venkatachala 1963

Type species. *T. thiessenii* (Kosanke) Wilson and Venkatachala 1963*a*.

Diagnosis (from diagnosis in Wilson and Venkatachala 1963*a*, p. 76). Monolete miospores, oval to phaseolate. Laesura simple, ranging to three-quarters of long diameter of spore, in many cases obscured by ornamentation. Ornamentation verrucate, verrucae often overlapping to form obervermiculate, rugose pattern. Exine approximately 1–2 μ thick in optical section.

Remarks. *Thymospora* replaces *Verrucososporites*. The genus *Verrucososporites* was established by Knox for trilete forms of varying shape, but she did not name a type species. Among the species listed by Knox as belonging to the genus was one species *V*. (*Tuberculatisporites*) *tuberculatus* (Berry) Knox which was considered as possibly monolete by Schopf, Wilson, and Bentall (1944, p. 37). On the basis of this species Potonié and Kremp (1954) retained the generic name for monolete verrucate spores. *V. tuberculatus*, however, was too poorly defined to serve as the type of the genus and they selected *Laevigatosporites obscurus* Kosanke 1950 for this purpose. Wilson and Venkatachala (1963*a*, p. 75) consider *V. tuberculatus* to be a nomen ambiguum and they contend, therefore, that the use of *Verrucososporites* by Potonié and Kremp for monolete verrucate spores is illegitimate. They accordingly propose *Thymospora* as a new name for spores of this kind and designate *Laevigatosporites thiessenii* Kosanke 1943 as the type. This species was the first monolete spore with verrucate ornament to be adequately described.

Affinity. Filicales. Spores figured from *Scolecopteris oliveri* Scott 1932 (in Potonié 1962) and *Asterotheca oveopteridia* Schlotheim (Moore 1946, in Potonié 1962) probably belong to *Thymospora*.

Thymospora obscura (Kosanke) Wilson and Venkatachala 1963

Plate 24, figs. 19–23

1950 *Laevigato-sporites obscurus* Kosanke, p. 29, pl. 16, fig. 6.
1954 *Verrucososporites obscurus* (Kosanke); Potonié and Kremp, p. 166.
1963*a* *Thymospora obscura* (Kosanke); Wilson and Venkatachala, p. 76, pl. 1, fig. 6.

Holotype. Kosanke 1950, pl. 16, fig. 6. Preparation 576, slide 14.

Type locality. New Haven Coal, Gallatin County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 29). Shape broadly oval. Outline irregular due to ornament. Laesurae two-thirds to three-quarters body length, somewhat distorted by ornament; lips slightly elevated and suture well defined. Exine 2–2·25 μ in thickness, punctate, folds rare.

Size in microns. (i) Holotype 32×29; 28–34, Schulze and KOH (Kosanke 1950). (ii) 20(25)33, fum. HNO_3; Slyving Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England; Westphalian D.

Description. Ornament comprises verrucae with rounded apices and more or less confluent bases. Size of verrucae variable in profile; basal diameter up to 2·5 μ; height up to 2 μ, mostly smaller.

Remarks. Although Kosanke describes the exine as punctate the ornament is sufficiently coarse to modify the outline of the spore.

Comparison. According to Bharadwaj (1957*a*, p. 112) the chief difference between *T. obscura* and *T. pseudogranulata* Bharadwaj 1957*a* (p. 112, pl. 29, figs. 21–23), size 23–28 μ, lies in the presence of confluent verrucae with distinct tips in the latter species. This is a subtle distinction, and one which is difficult to make in practice. Some of the smaller forms considered to belong to *T. obscura* lie within the size range (14–24 μ) of *T. thiessenii* (Kosanke) Wilson and Venkatachala. The authors have examined specimens of the latter species supplied by Kosanke and it is apparent that the two species may be separated by their ornament. In *T. thiessenii* the ornament is distinctly rugulate, whereas in *T. obscura* it is verrucate with little tendency to produce elongated sculptural elements.

Occurrence. Infrequent, Assemblage XI; Westphalian D.

Thymospora pseudothiessenii (Kosanke) Wilson and Venkatachala 1963

Plate 24, figs. 24–30

1950 *Laevigato-sporites pseudothiessenii* Kosanke, p. 30, pl. 5, fig. 10.
1956 *Verrucososporites pseudothiessenii* (Kosanke); Potonié and Kremp, p. 144.
1963*a* *Thymospora pseudothiessenii* (Kosanke); Wilson and Venkatachala, p. 78, pl. 1, fig. 7.

Holotype. Kosanke 1950, pl. 5, fig. 10. Preparation 543–D, slide 4.

Type locality. No. 5 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 30). Elongate to oval in plane of longitudinal symmetry, round or oval in transverse plane. Outline in both longitudinal and transverse planes broken by sculpturing of exine. Monolete laesura well over one-half spore length. Exine verrucate to obervermiculate and sometimes appearing reticulate. Exine 1·5–3·5 μ thick.

Size in microns. (i) Holotype 38 × 29; 26–46, Schulze and 10% KOH (Kosanke 1950). (ii) 26(32)35, fum. HNO_3, 33(42)48, Schulze and KOH, 6 in. coal at 720 ft. 8 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England; Westphalian D.

Description. Ornament reduced on proximal face. On distal profile verrucae may be up to 7·5 μ in breadth and 2·5 μ in height; bases of verrucae often confluent. Ornament sometimes almost convolute; small grana occasionally apparent among the verrucae; under oil these appear to be distributed on both surfaces and sometimes arranged in such a way as to give a polygonal pattern.

Comparison. T. pseudothiessenii is generally larger and possesses a coarser form of ornament than *T. obscura* (Kosanke) Wilson and Venkatachala. The present authors include within *T. pseudothiessenii* forms such as *T. verrucosa* (Alpern 1959, p. 154, pl. 11, figs. 291, 292) Wilson and Venkatachala, size 25–35 μ, and *T. perverrucosa* (Alpern 1959, p. 154, pl. 11, figs. 294–8) Wilson and Venkatachala, size 30–40 μ. Wilson and Venkatachala (1963*b*, p. 125, pls. 1, 2) also consider that these forms are morphological variants of *T. pseudothiessenii* and should not be given separate taxonomic status. They consider the possibility that the variations are due to the positions occupied by the spore tetrads in the sporangium.

Occurrence. Infrequent or frequent, Assemblage XI; Westphalian D.

Genus TORISPORA (Balme) Doubinger and Horst 1961

Type species. T. securis Balme 1952.

Diagnosis (Doubinger and Horst 1961, Report to Commission Internationale de Microflore du Paléozoïque; translation). 'Round to oval body of average microspore size with more or less distinctly darker crassitude and lighter thinner portion. Can be alete, monolete, or triletoid and possess various types of structural configuration.'

Remarks. Since Balme described *Torispora*, several authors (Horst 1957, Guennel and Neavel 1961, Artüz 1962) have investigated its structure and origin. Additional species, distinguished by the ornament, have also been published. As a result Doubinger and Horst have found it necessary to emend Balme's diagnosis of the spore.

Examination of certain isolated sporangia from coals has shown that the outer cells of the sporangial mass are of *Torispora* type. The function of these cells remains obscure but it may have been protective. It is apparent, however, from the examination of the contents of individual sporangia that considerable variation exists in the extent and location of the thickening and that spores from the interior lack thickening. The ornament of these inner spores resembles that occurring on the unthickened portions of the outer cells.

It is possible to suggest the following relationships between certain monolete species in British coals and forms with similar exine ornament (species of *Torispora*) in which the exine has, in part, become modified.

Punctatosporites granifer	{ *Torispora granulata* { *Torispora securis*
Thymospora obscura	*Torispora verrucosa*
T. pseudothiessenii	*Torispora perverrucosa*

If these relationships are established there would be justification for no longer recognizing *Torispora* as a separate taxon, although the type species *T. securis* was established before its related species *P. granifer*.

Affinity. Probably ferns or fern-like plants (Doubinger and Horst 1961).

Torispora securis Balme 1952

Plate 24, figs. 31–33

1957*a* *T. recta* Dybová and Jachowicz, p. 197, pl. 66, figs. 1–4.
1957*a* *T. speciosa* Dybová and Jachowicz, p. 198, pl. 68, figs. 1–4.
1957*a* *T. undulata* Dybová and Jachowicz, p. 197, pl. 67, figs. 1–4.

Lectotype. Balme did not establish a holotype in 1952 but he subsequently designated as lectotype a specimen selected by the authors from the type locality (preparation T68/1 in the collection of the Coal Survey Laboratory, Sheffield).

Type locality. Big Vein Seam, Norton Hill Colliery, Bristol and Somerset Coalfields, England; Westphalian D.

Diagnosis (from Balme 1952, p. 183). The spore is elliptical when viewed in full proximo-distal orientation, but its tendency to preservation in other planes of compression leads to distortion in many specimens. Margin finely notched. Laesura distinct with well-marked straight, or curved, suture line parallel to the major axis of the spore. The exine is considerably thickened at one extremity of the spore and expanded into a crescentic or rectangular projection darker in colour than the remainder of the spore coat (crassitude). Exine of thinner areas punctate, crassitude smooth or indeterminately marked.

Size in microns. (i) Lectotype, total length 36, Schulze. (ii) Total length 26(34)44; maximum breadth of unthickened part of body 15(21)28; thickened projection, length 5(10)18, breadth 16(24)35, Schulze (Balme 1952).

Description. The location and extent of the thickening (crassitude) is variable; it is often equatorial and transverse to the long axis, but may vary in position from a symmetrically disposed transverse cap to a position parallel to the long axis; it may also vary in extent from a scarcely perceptible darkening of the exine to a covering of almost the entire body. The variety of form is illustrated in Plate 24, figs. 31–33. Although the boundary between the thickened and thinner portions of the exine is usually distinct, the spore margin is uninterrupted at this point since the thickening tends to take place gradually. The thickened portion of the exine is sometimes found without the remainder of the spore body.

Remarks. Although *Torispora securis* is referred to above as a spore it is uncertain whether it functioned as such in view of the special position which cells of this type have been shown to occupy in the sporangium. While working on British coals the authors did not differentiate between the forms of *Torispora* on a basis of exine ornament. Forms referable to the following species have, however, been encountered: *T. granulata* Alpern 1959 (p. 155, pl. 12, figs. 319–23), *T. laevigata* Bharadwaj 1957*a* (p. 112, pl. 30, fig. 5), *T. securis* Balme 1952 (p. 183, text-fig. 3), *T. verrucosa* Alpern 1958 (p. 80, pl. 2, figs. 36–40). The species created by Dybová and Jachowicz are unsatisfactory since their recognition is based on the configuration as determined by the extent of development of the crassitude, which is known to be very variable.

Occurrence. Infrequent to very common, occasionally abundant, Assemblages X and XI; Westphalian C and D (*T. verrucosa* probably only Westphalian D).

Turma HILATES Dettmann 1963
Suprasubturma CAVATIHILATES s.subturma nov.

Cavatihilates includes hilate spores which possess a cavate exine.

Subturma AZONOCAVATIHILATES subturma nov.

Azonocavatihilates includes hilate cavate spores in which the exine layers are of more or less uniform thickness.

Infraturma EPITYGMATI (Spode, in press)

Epitygmati includes 'miospores possessing a disc-like operculum at the proximal pole. The operculum is delimited by a ring suture along which it separates from the remainder of the exoexine. Thus the operculum may be observed "in situ" partly discarded or discrete' (Spode, in press).

Genus VESTISPORA (Wilson and Hoffmeister) Wilson and Venkatachala 1963

Type species. *V. profunda* Wilson and Hoffmeister 1956.

Diagnosis (Wilson and Venkatachala 1963, p. 96). 'Spores radially symmetrical; trilete dehiscence; shape spherical or subspherical, generally flattened and discoid or oval; spore consisting of an outer wall and an inner trilete-bearing body which is detached except at and near the edge of the opercular area on the proximal hemisphere; operculum approximately one-third of the total spore diameter; ornamentation of the outer wall variable; laevigate, scabrate, reticulate, foveolate, or possibly of other types; inner wall normally smooth but may exhibit compression folds which simulate muri of various patterns; observed size ranges of spores in the genus 45–80 microns; relative size of the inner body normally 8–20 microns less than the total diameter of spore in compressed state.'

Remarks. Spode (in press) has extended the size range from 45–80 μ to 40–140 μ.

Potonié (1960) transferred *Cancellatisporites* Dybová and Jachowicz 1957, and *Glomospora* Butterworth and Williams 1958, to *Vestispora*, and Wilson and Venkatachala (1963) also included within it *Foveolatisporites* Bharadwaj 1955 and *Novisporites* Bharadwaj 1957*b*.

Comparison. Vestispora is distinguished from other genera by the presence of an operculum on the proximal surface.

Affinity. Noeggerathiopsida ?, Levittan and Barghoorn (1948); Sphenopsida, Mamay (1954*a*), Remy (1955), Remy (1959), Brush and Barghoorn (1964).

Vestispora costata (Balme) Spode (in press)

Plate 25, figs. 1, 2

1952 *Endosporites costatus* Balme, p. 178, text-fig. 1*f*.
1957*b Vestispora costata* (Balme); Bharadwaj, p. 118, pl. 24, figs. 36–40.
1958 *Glomospora costata* (Balme); Butterworth and Williams, p. 385.

Lectotype. Balme did not designate a holotype but a lectotype (T71/1) has been chosen by Spode from the material deposited by Balme in the collection of the Coal Survey Laboratory, Sheffield.

Type locality. Seam at 719 ft. 3 in., Manton Colliery, No. 4 Shaft Sinking, Yorkshire Coalfield, England; Westphalian C.

Diagnosis (Spode, in press). 'Circular (spherical) miospores having a costate exoexine. The muri are arranged circumcentrically around the spore and are rarely branched. They intersect to enclose large polygonal lumina.'

Size in microns. (i) Lectotype 74×64; 60(79)104; body 46(60)85, Schulze (Balme 1952). (ii) 55–100, body 40–70, operculum 25–35, fum. HNO_3 and 5% KOH (Piérart 1958); Belgium; Westphalian C. (iii) 52–88, Schulze and 5% KOH (Spode, in press). (iv) 48(68)82, Schulze and 10% KOH; Winghay Seam at 2,034 ft. 6 in., Bowsey Wood borehole, North Staffordshire Coalfields, England; Westphalian C.

Remarks. Outline of body seldom seen in specimens macerated by fuming nitric acid but its presence is inferred from the occurrence of frequent minor folds not modifying the exoexine ornament. Costae generally 10–20 μ apart but may appear closer because of folding. The operculum is frequently detached, when it may be identified with the less elaborately costate form of *Reticulatasporites facetus* (Ibrahim) Potonié and Kremp 1955 (pl. 11, fig. 104) and *R. taciturnus* (Ibrahim) Potonié and Kremp 1955 (pl. 11, figs. 105*a*, *b*). It is not proposed to continue recognizing the operculum as a separate taxon.

EXPLANATION OF PLATE 25

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Vestispora costata* (Balme) Spode (in press). 1, Lectotype; slide T71/1, 35·5 109·0. 2, slide T71/1, 31·8 113·2.

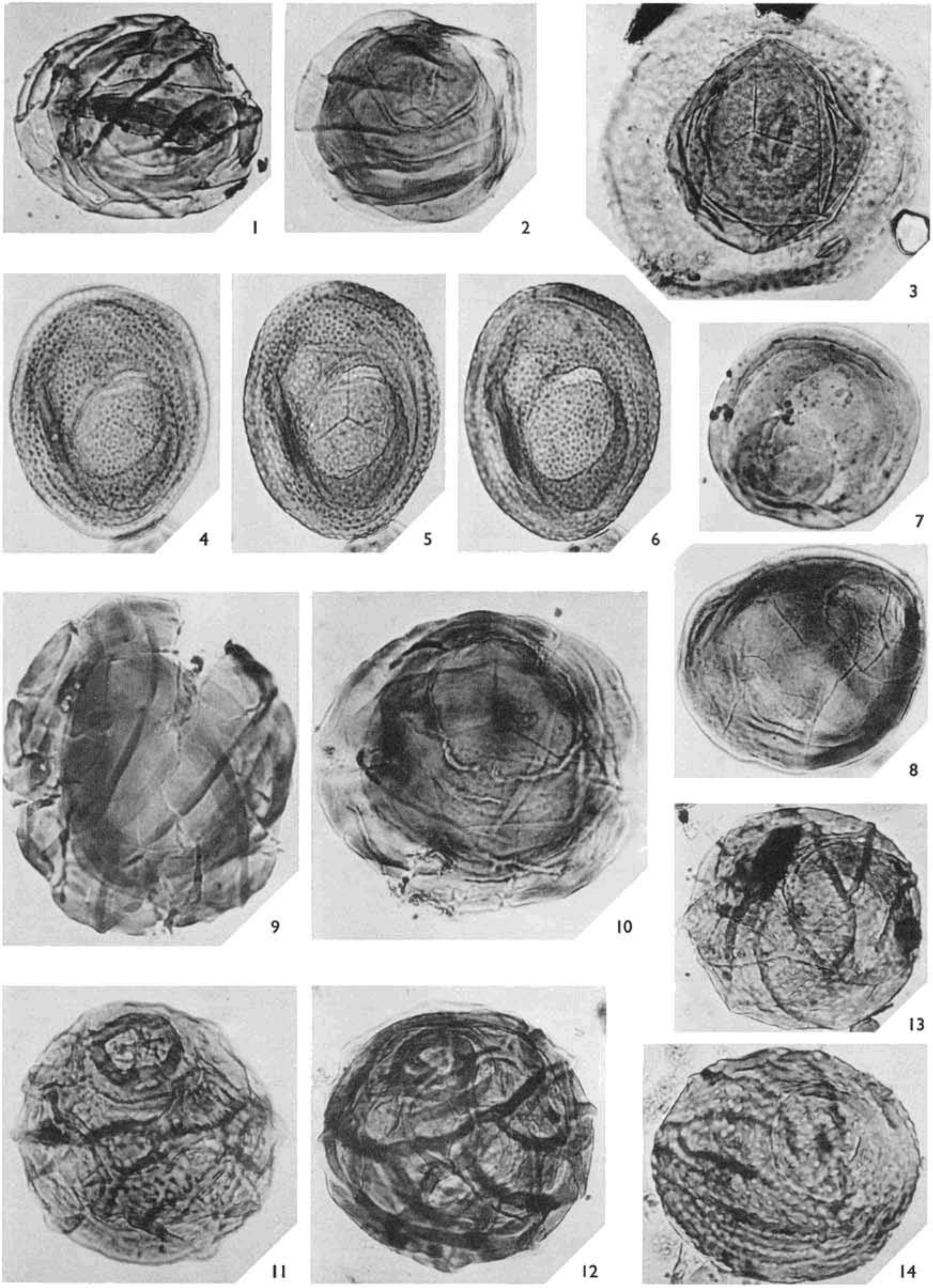
Figs. 3–6. *V. fenestrata* (Kosanke and Brokaw) Spode (in press). 3, medium focus, ? over-macerated using Schulze reagent and alkali; slide 239, 37·8 108·8. 4–6, upper, medium, and lower focus; slide 242, 42·8 103·2.

Figs. 7, 8. *V. laevigata* Wilson and Venkatachala 1963. 7, slide 246, 38·5 109·2. 8, slide 247, 36·6 109·1.

Figs. 9, 10. *V. lucida* (Butterworth and Williams) Potonié 1960. 9, Holotype; slide T65/1. 10, Isotype; slide T65/6.

Figs. 11, 12. *V. magna* (Butterworth and Williams) Spode (in press). 11, Holotype. 12, slide 248, 19·8 118·1.

Figs. 13, 14. *V. pseudoreticulata* Spode (in press). 13, slide 249, 45·1 110·3. 14, slide 9, 28·7 112·7.



SMITH and BUTTERWORTH, British Carboniferous miospores

Comparison. Distinguished from other Westphalian species by its unmodified costae which are seldom branched.

Occurrence. Infrequent, Assemblage VIII; infrequent to frequent, Assemblages IX and X; Westphalian B and C.

Vestispora fenestrata (Kosanke and Brokaw) Spode (in press)

Plate 25, figs. 3–6

1950 *Punctati-sporites fenestratus* Kosanke and Brokaw in Kosanke 1950, p. 15, pl. 2, fig. 10.
1954 *Microreticulatisporites fenestratus* (Kosanke and Brokaw); Butterworth and Williams, p. 755, pl. 17, figs. 1–3, text-fig. 1, fig. 2.
1955 *Foveolatisporites fenestratus* (Kosanke and Brokaw); Bharadwaj, p. 126, pl. 1, fig. 4.
1963 *Vestispora fenestrata* (Kosanke and Brokaw); Wilson and Venkatachala, p. 99, pl. 1 figs. 13, 14.

Holotype. Kosanke 1950, pl. 2, fig. 10. Preparation 474–A, slide 3.

Type locality. No. 6 Coal, Franklin County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (Spode, in press). 'Miospores having a thick exoexine which is perforated by numerous foveolae less than 3 microns in diameter and less than 3 microns apart. A foveolate operculum is present at the proximal pole.'

Size in microns. (i) Holotype 79·8 × 77·7; 68–85, Schulze and 10% KOH (Kosanke 1950). (ii) 68–90, Schulze (Bharadwaj 1955). (iii) 54(66)80, operculum 27(31)36, fum. HNO_3; 61(77)92, operculum 29(39)45, Schulze and 10% KOH (Butterworth and Will. 1954); seam at 729 ft. 3 in., Pie Rough (Keele No. 1) borehole, North Staffordshire Coalfield, England; Westphalian ?D. (iv) 50–88, Schulze and 5% KOH; various localities (Spode, in press). (v) 52(62)76, operculum 24–36, fum. HNO_3; seam at 997 ft. 6 in., Dudleston borehole, North Wales Coalfields; Westphalian D. (vi) 62(75)94; operculum 30–42, Schulze and 10% KOH; seam at 575 ft. 3 in., Plas Thomas borehole, North Wales Coalfield, Westphalian D.

Description. Amb circular or oval, margin crenulate. Laesurae simple, clearly seen only when proximal operculum is detached. Ornament of exoexine and operculum foveolate; muri 1·5 μ high, 1·5 μ wide, triangular in section with broad bases; foveolae oval or polygonal, 2–3 μ in diameter. Body laevigate, thin. Exoexine thick, arcuate folds occasionally present.

Remarks. The operculum has been described under the names *Punctatisporites quaesitus* Kosanke 1950, *Microreticulatisporites quaesitus* (Kosanke) Butterworth and Williams 1954, and *Foveolatisporites quaesitus* (Kosanke) Bharadwaj 1955; it is not proposed to continue naming this as a separate taxon.

Comparison. Distinguished from other species of the genus by the complete absence of primary muri or costae.

Occurrence. Infrequent to frequent, Assemblages X and XI; Westphalian C and D.

Vestispora laevigata Wilson and Venkatachala 1963

Plate 25, figs. 7, 8

1956 (unpublished) *Ovaspora vitra* Williams, (thesis) vol. 2, p. 62, pl. 13, figs. 8–13.
1963 *Vestispora laevigata* Wilson and Venkatachala, pl. 1, figs. 8–11.

Holotype. Wilson and Venkatachala 1963, pl. 1, fig. 8, Oklahoma Geological Survey specimen number WH 7–5.

Type locality. Croweburg Coal, Rogers County, Oklahoma, U.S.A.; Des Moines Series.

Diagnosis (Wilson and Venkatachala 1963). 'Spores radial, trilete, spherical; . . . operculum . . . opening to expose the inner body which bears the trilete mark; inner body as well as exoexine laevigate; in some specimens the inner body folded to appear like outer ornamentation. Several specimens with faint scabrate ornamentation on the distal side have been observed.'

Size in microns. (i) Holotype 65·2 × 63·8; 60–75, operculum 25–32, maceration method not known (Wilson and Ven. 1963). (ii) Maximum overall diameter 58(72)88, minimum overall diameter 46(62)73, maximum body diameter 40(56)75, minimum body diameter 34(48)58, (20 specimens) fum. HNO_3 (Williams, thesis); Coleford High Delf Seam, Northern United Colliery, Forest of Dean Coalfield, England; boundary Westphalian C/D. (iii) Maximum overall diameter 62–90, Schulze and 5% KOH, various localities (Spode, in press).

Description. Amb circular to oval. Laesurae (seldom seen) simple, about one-quarter of spore radius.

Comparison. Distinguished from other species by its thick, unornamented, or only faintly ornamented, exoexine.

Occurrence. Infrequent, Assemblages X (highest seams) and XI; Upper Westphalian C and Westphalian D.

Vestispora lucida (Butterworth and Williams) Potonié 1960

Plate 25, figs. 9, 10

1958 *Glomospora lucida* Butterworth and Williams, p. 384, pl. 4, figs. 4–6.
1960 *Vestispora lucida* (Butterworth and Williams); Potonié, p. 52.

Holotype. Plate 25, fig. 9. Preparation T65/1 in collection of Coal Survey Laboratory, Sheffield.

Type locality. Garibaldi Ironstone Seam at 1,058 ft. 3 in., Cawder Cuilt borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis (from Butterworth and Williams 1958, p. 385). Amb circular or oval, outline of body circular to oval. Laesurae simple, rays straight, one-half body radius or less in length (not always seen). Body laevigate, exoexine with widely spaced, spiral costae. Body moderately thick, exoexine very thin, membranous. Folding frequent.

Size in microns. Holotype 104 × 88; 70–150, body 50–110, fum. HNO_3 (Butterworth and Will. 1958).

Description. Muri 3 μ wide, about 10–20 μ or more apart, not sufficiently continuous to form lumina. Occasional specimens are without costae, when the laevigate body and membranous exoexine, much folded, are sufficient to identify the spore. Operculum not always visible.

Comparison. Distinguished from *Vestispora costata* by its greater size and less frequent costae.

Occurrence. Infrequent, Assemblages III and IV; Namurian.

Vestispora magna (Butterworth and Williams) Spode (in press)

Plate 25, figs. 11, 12

1954 *Reticulatisporites magnus* Butterworth and Williams, p. 756, pl. 17, figs. 5, 6, text-fig. 1, fig. 5.
1957*b* *Novisporites magnus* (Butterworth and Williams); Bharadwaj, p. 121.
1963 *Vestispora magna* (Butterworth and Williams); Wilson and Venkatachala, p. 99.

Holotype. Plate 25, fig. 11. Specimen no. PF 3007 (formerly 76484), Geological Survey Museum, London.

Type locality. Bottom Robins Seam, Pilot borehole, Lea Hall Colliery, Cannock Chase Coalfield, England; Westphalian C.

Diagnosis (Spode, in press). 'Miospores having a characteristically strong, irregular, reticulate ornament. The primary muri may, or may not, be present whilst the secondary reticulum is strongly developed enclosing irregular, often elongate lumina. Operculum, similarly ornamented, at the proximal pole.'

Size in microns. (i) Holotype 84 × 78, fum. HNO_3. 67(92)127, Schulze and 10% KOH; 73(86)103, fum. HNO_3; (Butterworth and Will. 1954). (ii) 58–92, Schulze and 5% KOH; various localities (Spode, in press). (iii) 84(95)120, Schulze and 10% KOH; Smith Seam, Hafod Colliery, North Wales Coalfields; Upper Westphalian B. (iv) 74(84)100, fum. HNO_3; Smith Seam at 1,885 ft. 1 in., Plas Thomas borehole, North Wales Coalfield; Upper Westphalian B.

Description. Amb circular or oval. Margin crenulate, often irregular. Laesurae not always evident, rays 12–16 μ long, sometimes enclosed in a triangular lacuna formed by the intersection of three prominent muri. Primary muri thick, up to 8 μ wide, forming a coarse reticulation; these muri sometimes coalesce and frequently project at the equator. Secondary reticulum strong, enclosing circular, or elongate, lumina 4 μ, or more, in diameter. Body laevigate, thinner than exoexine, frequently folded.

Comparison. The primary muri in *Vestispora magna* are coarser than those of other species, and the lumina formed by their intersection are more irregular in shape, being often rounded or triangular. The secondary reticulum is also more strongly developed and the lumina more irregular in shape than in other species.

Occurrence. Infrequent to common, Assemblages IX and X; Upper Westphalian B and Westphalian C.

Vestispora pseudoreticulata Spode (in press)

Plate 25, figs. 13, 14

1952 *Reticulatisporites tortuosus* Balme (in part), p. 179.

Holotype. Plate 1, fig. 3, Spode (in press).

Type locality. Barnsley Seam, Yorkshire Coalfield, England; Westphalian B.

Diagnosis (Spode, in press). 'Circular miospores, outline uneven due to presence of muri at the equator. The exoexine has an irregular extrareticulum composed of weak primary muri and a well-developed secondary reticulum between them. The lumina are 2–8 μ in maximum diameter and separated by muri 1–3 μ wide.'

Size in microns. (i) Holotype 122·6×101; 50–80, various localities, Yorkshire Coalfield, England; Schulze and 5% KOH (Spode, in press). (ii) 64(72)80, fum. HNO_3; Clayknowes Seam at 1,196 ft. 10 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Lower Westphalian B. (iii) 58(73)90, fum. HNO_3; Bottom Droughy Seam at 1,818 ft. 6 in., Plas Thomas borehole, North Wales Coalfield; Lower Westphalian B.

Description. Amb circular to elliptical, margin crenulate. Laesurae simple, rays short, about one-third of spore radius. Exoexine murinate, primary muri carinate, small reticulum developed between primary muri. Body rarely discernible. Proximal operculum with similar ornament to exoexine, frequently detached; diameter for six specimens 32(38)42 μ. The operculum may be identified with the more elaborately ornamented forms of *Reticulatasporites facetus* (Ibrahim) Potonié and Kremp 1955 (pl. 11, fig. 104) and *R. taciturnus* (Ibrahim) Potonié and Kremp 1955 (pl. 11, figs. 105*a*, *b*). It is not proposed to continue recognizing the operculum as a separate taxon.

Comparison. Vestispora costata has no secondary reticulum between the primary muri. In *V. magna* the primary muri are much coarser and the areas between are more irregularly reticulate.

Occurrence. Infrequent to common, Assemblages VIII and IX; single record from Assemblage V, Yorkshire Coalfield; Westphalian A to C.

Vestispora tortuosa (Balme) Spode (in press)

Plate 26, figs. 1, 2

1952 *Reticulatisporites tortuosus* Balme (in part), text-fig. 1*d*.
1957*b* *Vestispora tortuosa* (Balme); Bharadwaj, p. 119.
1957*a* *Cancellatisporites cancellatus* Dybová and Jachowicz, p. 111, pl. 24, figs. 1–4.

Lectotype. No holotype was designated by Balme but a lectotype (T 72/1) has been chosen from material deposited by him in the collection of the Coal Survey Laboratory, Sheffield.

Type locality. Wheatworth Seam at 907 ft. 11 in., Wentbridge No. 2 borehole, Yorkshire Coalfield, England; Upper Westphalian B.

Diagnosis (Spode, in press). 'Miospores, circular in shape, outline slightly uneven due to presence of primary muri 1–2 μ wide and 1–1·5 μ high. The muri are often branched and intersect to enclose polygonal lumina; they are sometimes carinate and may even show the development of a weak, secondary reticulum. Operculum, similarly ornamented, at proximal pole, covers the position of the trilete mark.'

Size in microns. (i) Lectotype 77; 65(86)100, Schulze (Balme 1952). (ii) 65–80, fum. HNO_3 and 30% NH_4OH (Dybová and Jach. 1957); Westphalian B. (iii) 53–80, Schulze and 5% KOH; various localities (Spode, in press). (iv) 56(67)78, fum. HNO_3; seam at 1,777 ft. 3 in., Musselburgh No. 1 borehole, Lothians Coalfield, Scotland; Lower Westphalian A. (v) 64(73)86, fum. HNO_3; seam at 491 ft. 10 in., Seafield No. 2 borehole, East Fife Coalfield, Scotland; Westphalian B.

Comparison. Distinguished from *Vestispora costata* by the branching and incipient carination of the muri. *V. pseudoreticulata* has a well-developed secondary reticulum.

Occurrence. Infrequent to frequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Turma ALETES Ibrahim 1933

Corsin, Carette, Danzé, and Laveine (1962) have restricted the Turma Aletes to spores without a dehiscence mark as originally intended by Ibrahim, and have included Aletes in the Anteturma Sporites.

Subturma AZONALETES (Luber) Potonié and Kremp 1954
Genus FABASPORITES Sullivan 1964

Type species. *F. pallidus* Sullivan 1964.

Diagnosis (Sullivan 1964, p. 378). 'Amb oval, sometimes circular. Exine thin, laevigate, or may bear dispersed grana. No monolete mark visible. Exine folded; usually there is a single fold located along the major axis of the spore.'

Comparison. This genus is distinguished from *Aletes* Somers 1953 and *Inaperturopollenites* (Thomson and Pflug) Potonié 1958 by the presence of the single longitudinal fold.

Remarks. The diagnostic feature of the genus is the longitudinal fold which gives the spores a pseudobilateral symmetry. Spores possessing this feature, but with a very finely granulate ornament, are referred to this genus in the present work although it provides only for essentially laevigate spores.

Affinity. Unknown.

Fabasporites pallidus Sullivan 1964

Plate 24, figs. 34–38

Holotype. Sullivan 1964, pl. 61, fig. 11.

Type locality. Edgehills Coal, Forest of Dean Coalfield, England; ? Westphalian A.

EXPLANATION OF PLATE 26

All figures ×500, and of proximal surface, unless otherwise stated.

Figs. 1, 2. *Vestispora tortuosa* (Balme) Spode (in press). 1, Holotype; slide T72/1, 36·5 109·6. 2, slide 123, 29·6 113·8.

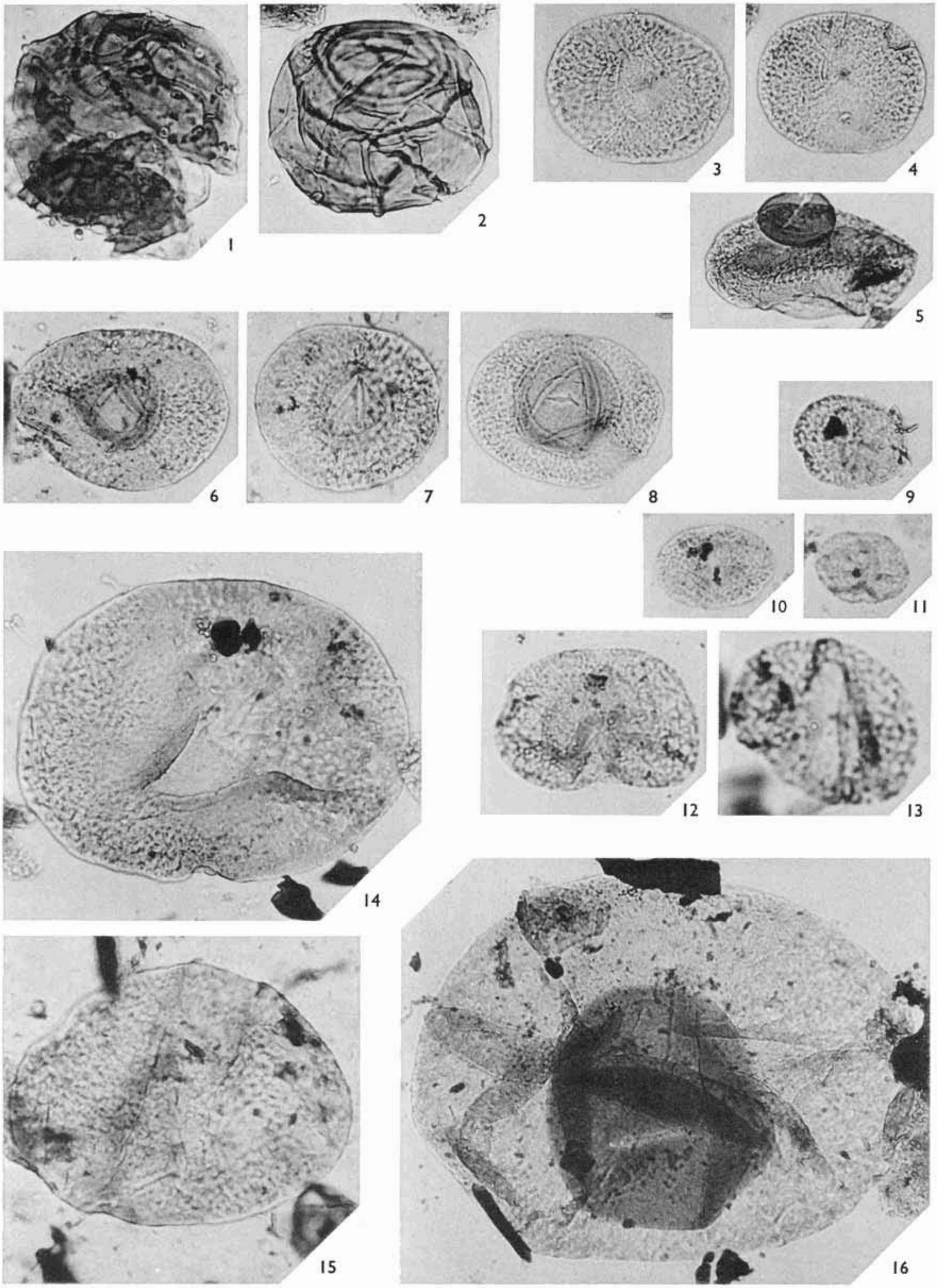
Figs. 3–5. *Florinites* cf. *florini* Imgrund. 3, ? distal surface; slide 250, 22·8 103·4. 4, slide 250, 47·5 112·9. 5, equatorial view; slide 251, 40·6 114·8.

Figs. 6–8. *F. mediapudens* (Loose) Potonié and Kremp 1956. 6, slide 252, 32·4 102·6. 7, slide 252, 48·5 103·7. 8, slide 17, 26·2 103·2.

Figs. 9–13. *F. millotti* Butterworth and Williams 1954. 9, Holotype. 10, slide 253, 51·2 112·2. 11, slide 253, 35·8 112·3. 12, ×1,000; slide 254, 49·3 106·6. 13, ×1,000; slide 254, 23·5 119·6.

Figs. 14, 15. *F. pumicosus* (Ibrahim) Schopf, Wilson, and Bentall 1944. 14, slide 256, 34·8 117·1. 15 slide 255, 43·0 110·9.

Fig. 16. *F. similis* Kosanke 1950. Slide T69/2, 42·8 108·1.



SMITH and BUTTERWORTH, British Carboniferous miospores

Diagnosis (Sullivan 1964, p. 379). '. . . amb usually oval, sometimes circular; exine thin, less than 0·5 μ; in their most frequent preservation the spores have a single longitudinal fold.'

Size in microns. (i) 13(17)23, HF and 2% KOH (Sullivan 1964). (ii) 16(20)24, fum. HNO_3; Yorkley Seam, Northern United Colliery, Forest of Dean Coalfield, England; Westphalian D. (iii) 14(20)29, fum. HNO_3; Kent's Thin Seam, Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B. (iv) 16(21)27, fum. HNO_3; Tilley Seam, Fishburn Colliery, Durham Coalfield, England; Westphalian A.

Description. Shape oval to circular. Exine laevigate to finely granulate; grana closely spaced and may be visible at margin, not exceeding 0·3 μ in height. Exine usually folded; major fold usually along major axis of spore simulating appearance of monolete mark.

Comparison. *F. pallidus* superficially resembles *Latosporites minutus* and small specimens of *Punctatosporites minutus* but does not possess a recognizable monolete mark. It is generally more rounded in shape than *P. minutus*.

Occurrence. Infrequent to common, Assemblages VI to XI; Westphalian A to D.

Anteturma POLLENITES Potonié 1931
Turma SACCITES Erdtman 1947
Subturma MONOSACCITES (Chitaley) Potonié and Kremp 1954
Infraturma ARADIATES Bharadwaj 1957*a*
Genus FLORINITES Schopf, Wilson, and Bentall 1944

Type species. *F. pellucidus* (Wilson and Coe 1940) Wilson 1958 [?synonym of *F. mediapudens* (Loose) Potonié and Kremp].

Diagnosis (abbreviated from Schopf, Wilson, and Bentall 1944, p. 56). Bilateral pollen grains, broadly elliptical in outline. Body somewhat more spherical and nearly entirely enclosed by bladder; greatest diameter of body corresponds to major diameter of bladder; body generally marked by numerous peripheral folds. Bladder smooth, finely granulose or rugose on exterior surface, reticulate on inner surface, tends to be obsolescent in central proximal area. Bladder and body walls are joined distally, and centrally from this junction there is no evidence of reticulation. Trilete imprint (where discernible) is vestigial.

Remarks. A longitudinal-polar section of the *Florinites*-type pollen grain of *Cordaianthus schuleri* figured by Wilson (1960, pl. 1, figs. 3, 4) clearly shows a single distal wall where the body and bladder are attached, whereas no attachment of the central body occurs on the proximal side. Brush and Barghoorn (1964), however, state that in pollen grains isolated from cordaitean cones the body is proximal.

Originally the shape of the body in *Florinites* was probably more or less spherical in polar section whereas the saccus was probably more elliptical, since in compressed grains the body is more intensely folded than the saccus. In polar view the major axes of the body and saccus in compressed grains lie in the same plane but they do not always lie in the same direction as implied in the above diagnosis. The maximum and minimum lengths of the saccus and body have, therefore, been recorded without regard to the directions of their long axes. Ratios of body to saccus dimensions, however, are based on measurements taken along the major axis of the saccus.

Comparison. Florinites superficially resembles *Guthörlisporites*, which differs in that the saccus covers the entire distal face of the body and not the proximal face, which bears a distinct trilete mark. This structural distinction is not always easy to determine in practice.

Affinity. Cycadofilicales, Cordaitales, Coniferales (in Potonié 1962).

Florinites florini Imgrund 1960

Holotype. Imgrund 1960, pl. 16, fig. 94. Preparation A 33.

Type locality. Seam 4, Kaiping Basin, China; Lower Permian.

Diagnosis (from Imgrund 1960, p. 179). Amb circular to moderately oval. Outline somewhat rough. Tetrad mark mostly not recognizable. Internal reticulum on the central body with a distinctly finer meshwork. Outline of central body frequently scarcely recognizable.

Size in microns. Holotype 46; 50–70, Schulze and KOH (Imgrund 1960).

Florinites cf. *florini* Imgrund

Plate 26, figs. 3–5

Description. Amb of saccus oval, amb of body circular to oval; in equatorial view, saccus oval. Distal furrow not distinct in polar view, but saccus often shows (distally?) a small aperture, roughly triangular or polygonal in shape and usually less than one-third of the least diameter of the saccus. Sometimes there is a bigger portion of exine missing centrally from the saccus and a tetrad mark has been seen on the proximal surface through the tear. Saccus laevigate and thin, with reticulate infrasculpture. Proximally, infrasculpture is less distinct centrally, but distally it is developed to the margin of the aperture. Lumina, which are less than 3 μ in maximum dimension, tend to be elongated radially. Muri less than 1 μ. Saccus sometimes appears slightly darker at equator. Where compression folds occur they are usually of minor proportions and developed diagonally across saccus, but often to one side of central area. Almost colourless.

Size in microns.

	Saccus dimensions		*Average body dimensions*		*Number of specimens*	
	Maximum	*Minimum*	*Maximum*	*Minimum*	*Total measured*	*With measurable body*
(*a*)	42(51)60	34(41)52	27	26	25	3
(*b*)	47(56)77	37(45)77	30	27	38	5
(*c*)	47(62)77	32(45)60	25	24	23	3
(*d*)	52(67)76	40(52)63	30	26	28	4
(*e*)	50(66)79	37(51)65	32	30	36	6

(*a*) Fum. HNO_3; Slyving Vein Seam, Camerton Colliery, Bristol and Somerset Coalfield, England, Westphalian D.

(*b*) Fum. HNO_3; Tillery Rider Seam, outcrop above Hafodyrynys Colliery, South Wales Coalfield; Westphalian D.

(*c*) Fum. HNO_3; seam at 294 ft. 2 in., Margam No. 4 borehole, South Wales Coalfield; Westphalian C.

(*d*) H_2O_2; lower bed of Chislet No. 2 Seam at 58 ft. 9 in., No. 30 up-borehole, Chislet Colliery, Kent Coalfield, England; Westphalian B.

(*e*) Fum. HNO_3; Beamshaw Seam, South Kirkby Colliery, Yorkshire Coalfield, England; Westphalian B.

Remarks. Bharadwaj (1957*a*, p. 116) tentatively assigned spores of this type to *F.* cf. *pumicosus*. There is, however, a greater resemblance between the forms described here and *F. florini*. For this reason, these forms have provisionally been assigned to *F.* cf. *florini* until comparison has been made with populations of the Permian species.

Comparison. It is possible that *F.* cf. *florini* is the saccus of *F. mediapudens*. Schopf, Wilson, and Bentall state (1944, p. 58) that it is fairly common to find examples of *F.* (syn. *antiquus*) *pellucidus* (Wilson and Coe) Wilson 1958 lacking a body. He suggests that this feature may result from the maceration process. However, until this possibility is explored such forms are given separate status. The species is similar in size and shape to *F. mediapudens*, but lacks a distinct body. Approximately 70% of the individuals recorded in the above assemblages were apparently without bodies. A few forms with bodies sufficiently well defined for measurement are difficult to assign to one or other of these species.

Occurrence. Generally infrequent, Assemblages VI to XI, but occasionally frequent, or common, in the upper part of Assemblage VIII and Assemblage IX; Upper Westphalian A to Westphalian D.

Florinites mediapudens (Loose) Potonié and Kremp 1956

Plate 26, figs. 6–8

1934 *Reticulata-sporites mediapudens* Loose, p. 158, pl. 7, fig. 8.
1956 *Florinites mediapudens* (Loose); Potonié and Kremp, p. 169, pl. 21, figs. 468–71.
1957*a* *Endosporites mediapudens* (Loose); Dybová and Jachowicz, p. 207, pl. 71, fig. 4.

Holotype. Potonié and Kremp 1956, pl. 21, fig. 468 after Loose. Preparation III4, b_4 (o).

Type locality. Bismarck Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis (from Potonié and Kremp 1956, p. 169). Central body often distinct. Breadth of saccus surrounding central body as great as, or less than, radius of central body.

Size in microns. (i) Holotype 60, Schulze and KOH. (ii) 50–65, Schulze (Potonié and Kr. 1956).

	Saccus dimensions		*Body dimensions*	
	Maximum	*Minimum*	*Maximum*	*Minimum*
(*a*)	51(63)78	41(49)60	21(30)36	20(26)32
(*b*)	50(58)72	33(43)52	22(33)42	22(27)34
(*c*)	42(55)77	31(40)57	26(31)46	20(26)40

(*a*) Fum. HNO_3; seam at approximately 3,230 ft., Corringham borehole, Nottinghamshire Coalfield, England; Westphalian C.
(*b*) Fum. HNO_3; Top Haigh Moor Seam at 1,532 ft. 3 in., Kellingley borehole, Yorkshire Coalfield, England; Westphalian B.
(*c*) Fum. HNO_3; seam at 819 ft. 0 in., Harry Stoke 'A' borehole, Bristol and Somerset Coalfield, England; Westphalian A.

Description. Amb roughly oval, shape in equatorial view oval; polar axis shorter than equatorial axes. Margin smooth, or minutely indented. Body usually distinct, oval to circular in polar view, often distorted by folding. When elongated, long axis may be variously orientated in equatorial plane with respect to that of saccus. Ratio body to saccus along long axis of saccus approximately 50%. Trilete mark generally not apparent. Distal furrow more or less oval, generally orientated transverse to long axis of saccus. Boundary of area faint and often masked by folds. Saccus laevigate and thin, but with reticulate infrasculpture. Lumina tend to be elongated radially; maximum dimension of lumina less than 2 μ, muri less than 1 μ. Infrasculpture less marked in region of body, both proximally and distally, and is absent from distal furrow. In some specimens there appears to be a slight thickening of saccus at equator. Body laevigate, thin, and folded, mainly in peripheral region. Saccus with minor random folds. Body usually slightly darker than saccus, which is often colourless.

Remarks. Certain differences are apparent between the three populations recorded. The increase in mean saccus size is accompanied by an increase in proportion of forms with a more rounded amb. 25% of the bodies were circular in the Westphalian C assemblage, although generally oval in other assemblages. The percentage of individuals in which the body was elongated transverse to the long axis of the saccus was approximately 80, 65, and 30 in assemblages from the Westphalian A, B, and C respectively. The ratio body to saccus remains more or less constant. Further data are required to establish whether these differences are consistent in assemblages of similar age and whether the trends which these data suggest can be substantiated. Balme (1952) records spores from the Westphalian B of Yorkshire with greater mean dimensions than those given. He designated these as *F. antiquus* Schopf, Wilson, and Bentall and stated that this species is widely distributed in British coals. The difference in size may be attributed to the method of maceration (Balme used Schulze and alkali). *F. antiquus* is now known to be a synonym of *F. pellucidus* (Wilson and Coe) Wilson 1958 with the dimensions 51–92 μ. There is considerable overlap in the size ranges of *F. pellucidus* and *F. mediapudens* and as there is no morphological basis for separating these species in practice, the authors consider that there is no reason for recognizing *F. pellucidus* as a distinct species.

Comparison. F. junior Potonié and Kremp 1956 (p. 168, pl. 21, figs. 466, 467) is larger (70–90 μ) but the diameter of the body is smaller in proportion to the diameter of the saccus than in *F. mediapudens*. Two species, the somewhat smaller *F. parvus* Wilson and Hoffmeister 1956 (p. 16, pl. 4, figs. 11, 12; size 50–58 μ) and *F. ovalis* Bharadwaj 1957*a* (p. 116, pl. 31, figs. 1–3; size 48–65 μ) with a distinct oval body, have been recognized in British coals but they are very similar to *F. mediapudens* and for this reason no attempt has been made to separate them from *F. mediapudens* in quantitative analyses. Forms similar to *F. mediapudens* in size, but with a distinct tetrad mark, are referred to *F. triletus* by Kosanke (1950, p. 50, pl. 12, figs. 3, 4). This very variable character seems a questionable basis for speciation.

Occurrence. Infrequent to frequent, Assemblages VI and VII; frequent to common, Assemblages VIII, X, and XI; common to very common, Assemblage IX; Upper Westphalian A to Westphalian D.

Florinites millotti Butterworth and Williams 1954

Plate 26, figs. 9–13

Holotype. Plate 26, fig. 9. Specimen no. PF 3013 (formerly 76490), Geological Survey Museum, London.

Type locality. Bottom 1 ft. 4 in. coal at 3,388 ft. 2 in., Upton borehole, Oxfordshire, England; Westphalian D.

Diagnosis (abbreviated from Butterworth and Williams 1954, p. 760). Amb broadly elliptical. Apparently alete. Body oval to elliptical, or almost circular, with main axis at right angles to length of grain. Saccus and body very thin; saccus appears micro-reticulate.

Size in microns. Holotype, saccus 37×29, body 19×19, maceration method not known; saccus, max. 30(39)49, min. 23(30)37, Schulze; max. 32(37)48, min. 24(29)43 (22 specimens), fum. HNO_3; body, length 13–35, breadth 16–32, maceration not specified; (Butterworth and Will. 1954).

Description. Features of grain tend to be indistinct owing to extreme thinness of exine. Distal furrow is oval, but very indistinct, greatest dimension transverse to principal axis of the grain. The body is sometimes not apparent. Generally appears almost colourless.

Comparison. F. millotti is similar in size to *F. minutus* Bharadwaj 1957*a* (p. 117, pl. 31, figs. 6, 7; size 35–45 μ) but lacks the distinctive brown body. *F. minutus* has been recognized in assemblages from the Westphalian D in Britain but no quantitative data are available. In assemblages in which *F. millotti* and *F.* cf. *florini* occur it is difficult to classify some individuals since the populations overlap in their sizes. The presence of a body is not a valid criterion on which to separate *F. millotti* since some individuals appear to lack a body. In these instances an arbitrary limit of 50 μ has been used to separate the species. *F. parvus* Dybová and Jachowicz 1957*a* (p. 214, pl. 74, figs. 1–4), *non sensu* Wilson and Hoffmeister, may be conspecific with *F. millotti.*

Occurrence. Infrequent, Assemblage VIII; sometimes frequent, Assemblages IX to XI; Westphalian B to D.

Florinites pumicosus (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 26, figs. 14, 15

1932 *Sporonites pumicosus* Ibrahim in Potonié, Ibrahim, and Loose, p. 447, pl. 14, fig. 6.
1933 *Reticulata-sporites pumicosus* Ibrahim, p. 38, pl. 1, fig. 6.
1938 *Zonaletes pumicosus* (Ibrahim); Luber in Luber and Waltz, pl. 8, fig. 110.
1944 *Florinites*? *pumicosus* (Ibrahim); Schopf, Wilson, and Bentall, p. 59.

Holotype. Potonié and Kremp 1955, pl. 21, fig. 472 after Ibrahim. Preparation B34, d4 (u).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from Potonié and Kremp 1956, p. 169). Outline of central body very indistinct to unrecognizable. Saccus surrounding body where visible has breadth less than radius of central body.

Size in microns. (i) Holotype 92·5, Schulze and KOH. (ii) Saccus, 80–100, Schulze (Potonié and Ki. 1956). (iii) Saccus, max. 77(93)117, min. 52(78)99, fum. HNO_3; Swallow Wood Seam, Denaby Marn Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Amb oval to nearly circular; outline smooth. Central body approximately circular in polar view, but rarely seen. According to Potonié and Kremp (1956, p. 169) the body occupies about one-half the diameter of the entire spore. Tetrad mark has not been seen. Distal furrow is not well defined. Saccus is laevigate and thin. Infrareticulation is less well developed in central area; lumina less than 3 μ; muri less than 1 μ. Folds usually occur in the saccus across, or to one side of, the central area. Generally colourless.

Comparison. Larger than *F.* cf. *florini*, which it otherwise resembles.

Occurrence. Infrequent, or sometimes frequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Florinites similis Kosanke 1950

Plate 26, fig. 16

Holotype. Kosanke 1950, pl. 12, fig. 2. Preparation 524–C, slide 2.

Type locality. No. 8 Coal, Peoria County, Illinois, U.S.A.; McLeansboro Group.

Diagnosis (from description in Kosanke 1950, p. 49). Amb elongate-elliptical; body originally spherical, but due to compression is sharply folded. Apparently alete. Body minutely granulate. Saccus laevigate with reticulate infrasculpture. Lumina less than 3 μ.

Size in microns. (i) Holotype 133 × 92; saccus, max. 124–42, min. 88–97; Schulze and 10% KOH (Kosanke 1950). (ii) Saccus, max. 112–61, min. 99–127; body, max. 65–92, min. 55–72, fum. HNO_3; (7 specimens); seam at 1,387 ft. 4 in., Gate Farm borehole, Yorkshire Coalfield, England; Lower Westphalian C.

Description. Amb more or less broadly oval; outline smooth to weakly crenulate. Body irregular in shape due to folding on compression. Distally?, saccus overlaps the body to some extent. No well-defined furrow has been seen. Body occupies 40 to 60% of saccus along major axis of grain. Granulate sculpture is often visible on that part of body not covered by saccus. Compression folds occur in the peripheral region of body and to some extent in the saccus. Body generally brown, saccus pale yellow.

Comparison. *F. similis* is considerably larger than *F. mediapudens*, but smaller than *F. elegans* Wilson and Kosanke 1944 (p. 330, pl. 1, fig. 3; size 180–210 μ). *F. volans* (Loose) Potonié and Kremp is stated to possess a short tetrad mark but in other respects the species resembles *F. similis*. In spores of this type the distinctness of the tetrad mark probably varies and may not, therefore, be a reliable basis for speciation. Examination of specimens from the type localities may show that *F. similis* is a synonym of *F. volans*.

Occurrence. Infrequent, or sometimes frequent, Assemblages V to XI; Westphalian A to D.

Florinites visendus (Ibrahim) Schopf, Wilson, and Bentall 1944

Plate 27, fig. 1

1933 *Reticulata-sporites visendus* Ibrahim, p. 39, pl. 8, fig. 66.
1944 *Florinites*? *visendus* (Ibrahim); Schopf, Wilson, and Bentall, p. 60.

Holotype. Potonié and Kremp 1956, pl. 21, fig. 477 after Ibrahim. Preparation E29, c6 (ur).

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (from description and diagnosis in Potonié and Kremp 1956, p. 170). Amb circular to oval; shape in equatorial view somewhat phaseolate; margin more or less smooth. Central body indistinct.

Size in microns. (i) Holotype 165, Schulze and KOH. (ii) Saccus, 150–75, Schulze (Potonié and Kr. 1956). (iii) Saccus, max. 122(151)186, min. 79(112)146, fum. HNO_3; seam at 1,387 ft. 4 in., Gate Farm borehole, Yorkshire Coalfield, England; Westphalian C.

Description. Central body generally not apparent but may be just visible. Tetrad mark has not been seen. Saccus laevigate and infrareticulate; reticulations irregular in size and shape. Lumina less than 5μ, muri less than 2μ. Proximally and distally the infrareticulate pattern is less pronounced in the region of the body, where an infragranulate sculpture may sometimes be seen. In some instances the equatorial margin of the saccus is darker. Usually one or more compression folds traverse the saccus around, or across, the central portion.

Comparison. Resembles *F. pumicosus*, but is distinctly larger.

Occurrence. Infrequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Infraturma TRIRADITES (Pant) Bharadwaj 1955
Genus WILSONITES Kosanke 1959

1950 *Wilsonia* Kosanke, p. 54.

Type species. *W. vesicatus* Kosanke 1950.

Diagnosis (Kosanke 1950, p. 54). 'Grains are radial, trilete, and body and bladder are round in transverse plane. They are usually flattened in good proximal-distal orientation. Folding of the bladder is common and folding of the body occasionally occurs. . . . The bladder covers all of the distal portion of the body. The proximal portion of the body is either completely covered by the bladder or largely covered by it. . . . There appears to be a slight peripheral bladder thickening in *Wilsonia delicata* sp. nov. which may or may not be due to the internal bladder ornamentation. The rays extend at least three-fourths the distance to the body margin, the lips are elevated, and the commissure is usually thin. . . .'

Comparison. In *Endosporites* Wilson and Coe the body is more distinct. As regards the species dealt with in the present paper, *Wilsonites* has a coarser ornament, reticulate rather than granulate as in *Endosporites spp*., and it is never subtriangular. *Wilsonites* differs from *Florinites* in being consistently trilete and often, but not invariably, circular in outline.

Affinity. Unknown.

Wilsonites delicatus Kosanke 1950

Holotype. Kosanke 1950, pl. 14, fig. 4. Preparation 540–C, slide 8.

Type locality. No. 6 Coal, Fulton County, Illinois, U.S.A.; Carbondale Group.

Diagnosis (from description in Kosanke 1950, p. 54). Outline of body and saccus circular. Trilete rays distinct, almost equal to body radius in length, lips greatly elevated, suture very thin. Saccus covers distal surface and large part of proximal surface of body.

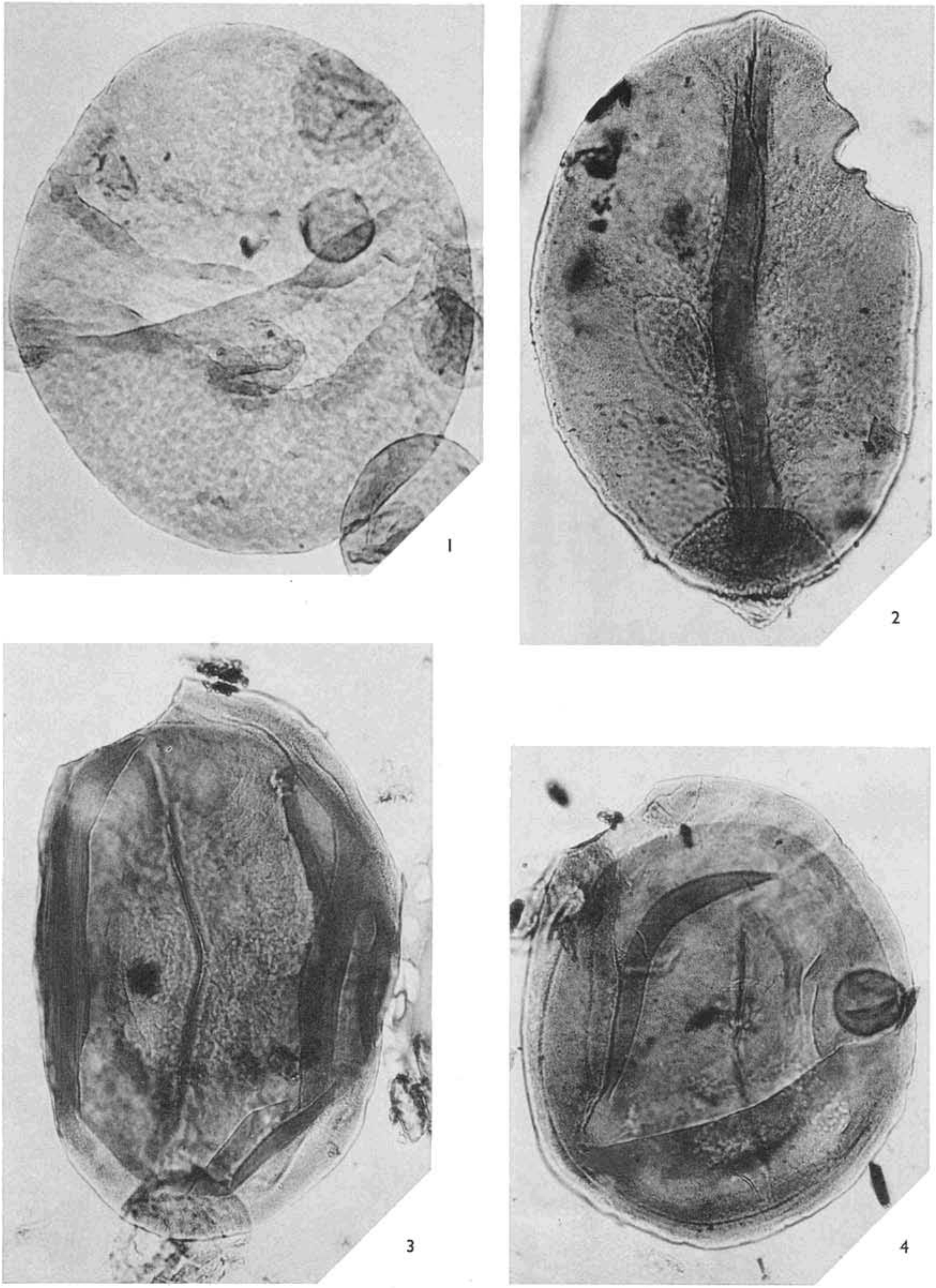
EXPLANATION OF PLATE 27

All figures × 500, and of proximal surface, unless otherwise stated.

Fig. 1. *Florinites visendus* (Ibrahim) Schopf, Wilson, and Bentall 1944. Slide 257, 50·0 114·6.

Fig. 2. *Schopfipollenites ellipsoides* (Ibrahim) Potonié and Kremp 1954. Slide 261, 16·4 120·2.

Figs. 3, 4. *S. ellipsoides* var. *corporeus* Neves 1961. 3, slide 262, 34·3 112·4. 4, slide 263, 52·8 112·1.



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Saccus laevigate externally, reticulate internally, slightly thickened at periphery. Body laevigate to minutely granulate. Saccus 1·5–2·25 μ thick; body 2–3 μ thick; folding of saccus and body common.

Size in microns. Holotype 92·4 × 86·1, body 56·7 × 52·5; overall diameter 81–98, body 52–61; Schulze and 10% KOH (Kosanke 1950).

Wilsonites cf. *delicatus* Kosanke 1950

Plate 24, figs. 41, 42

Size in microns. 68(90)124; body (maximum diameter) 26(43)65, fum. HNO_3; Three Quarter Seam at 1,873 ft. 2 in., No. 1 Off-shore borehole, Durham Coalfield, England; Westphalian A.

Description. Amb circular to oval. Laesurae distinct, slightly ridged, extending almost to margin of body. Saccus infrareticulate, continuous over distal surface of body, discontinuous over proximal surface, slightly thickened at the periphery. Body laevigate, or faintly granulate. Saccus and body thin, or very thin, folding frequent.

Comparison. Differs from *W. delicatus* in its much wider size range (only 11 of 25 specimens measured fell within the range quoted by Kosanke), in its not consistently circular amb, and in its less prominent laesurae.

Remarks. Specimens approximating to the above description and varying in overall diameter from 54 to 138 μ have been found at various horizons in the Westphalian.

Occurrence. Infrequent, Assemblages VI to IX; Upper Westphalian A to Lower Westphalian C.

Subturma DISACCITES Cookson 1947
Genus PITYOSPORITES (Seward) Manum 1960

Type species. P. antarcticus Seward 1914.

Diagnosis (Manum 1960, p. 14). 'Grains with two bladders. Bladders attached to the ventral side of the body and distinctly set off from it, greatly diverging, and narrowing towards their roots; dorsally the roots reach the equator of the body or slightly beyond it, ventrally they are separated by a more or less narrow furrow. Bladders reticulate. Body wall smooth, or only finely sculptured, its thickness moderate and not conspicuously increasing towards the roots of the bladders.'

Remarks. The genus was emended by Potonié and Klaus in 1954 and by Manum in 1960. Manum examined the type and concluded that some of the characters attributed to the genus by Potonié and Klaus were erroneous and that the diagnosis given by these authors excluded the type species.

Comparison. Differs from other Carboniferous bisaccate forms in that the bladders are distinctly offset from the body and are entirely separate.

Affinity. A pteridospermous affinity is suggested by Cranwell (1959, p. 1785) and Potonié (1962, p. 150) from resemblance to grains of *Pteruchus* Thomas, but this is not accepted by Manum (1960).

Pityosporites westphalensis Williams 1955

Plate 24, figs. 39, 40

Holotype. Williams 1955, pl. 6, fig. 1. Preparation No. V31900 in collection of British Museum (Natural History), London.

Type locality. No. 12 Seam, Nantgarw Colliery, South Wales Coalfield; Westphalian C.

Diagnosis (from diagnosis in Williams 1955, p. 467). In proximal view body of grain circular, or slightly elongated in direction of principal axis. Length of body less than full length of grain owing to lateral displacement of sacci; breadth almost full breadth of grain. The axes of the sacci diverge distally. Lines of junction of sacci with body proximally coincide with the equatorial axis of the grain. The sacci are quite separate, there being no continuation of the bladder membrane between them in the central subequatorial region. In this region a single long and poorly defined furrow extends over entire width of body. Body wall in this region thin. Proximal caps of grain laevigate to finely granulate; distal side largely occupied by sacci, whose external surfaces are smooth, or minutely granulate; internally the sacci are strongly reticulate, the reticulation ending abruptly at the bases.

Size in microns. Holotype: dimensions have no significance due to oblique compression; body partly concealed by sacci. Length of grain 39(47)51 (13 specimens); breadth of grain 33(37)44 (6 specimens); depth of grain 29(39)44 (15 specimens), measured along the proximo-distal axis; depth of sacci 11(15)21 (13 specimens), measured from distal furrow to the furthest extent of the sacci projected on to the proximo-distal axis; fum. HNO_3 (Williams 1955).

Description. No trace of a triradiate mark has been observed. Sometimes a narrow slit traverses the length of the furrow.

Occurrence. Infrequent, Assemblages VI to XI; Upper Westphalian A to Westphalian D.

Turma PLICATES (PLICATA Naumova 1937, 1939) Potonié 1960
Subturma PRAECOLPATES Potonié and Kremp 1954
Genus SCHOPFIPOLLENITES Potonié and Kremp 1954

Type species. *S. ellipsoides* (Ibrahim) Potonié and Kremp 1954.

Diagnosis (Potonié and Kremp 1954, p. 180; translation). 'Relatively large microspores (pollen grains), over 100 μ, with more or less oval equatorial and meridional outline. Running parallel to the long axis is a weak fold (furrow) whose ends may expand delta-wise as the equator is approached. On the opposite side and immediately over the furrow is a longitudinal and more or less well-defined umbo (a convexity). This also runs parallel to the long axis and is bordered on either side by a fold having a wide overlap.'

Remarks. The name *Monoletes* was proposed by Ibrahim in 1933 and subsequently adopted by Schopf (1938) as the generic name for spores of the above type. The genus was not, however, satisfactorily validated (see Potonié 1960, p. 67). In 1944 Schopf, Wilson, and Bentall recognized two species, *Monoletes ellipsoides* (Ibrahim) Schopf, Wilson, and Bentall and *Monoletes ovatus* Schopf, but Winslow (1959) has pointed out that the basis for the distinction between these species now seems uncertain. *Monoletes aureolus* Schopf 1938 was referred to *Zonalo-sporites* Ibrahim in Schopf, Wilson, and Bentall 1944, but is now recognized as a species of *Schopfipollenites* by Potonié and Kremp 1955.

Affinity. Medullosan pteridosperms (Florin 1937; Schopf 1938; Schopf, Wilson, and Bentall 1944).

Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954

Plate 27, fig. 2

1932 *Sporonites ellipsoides* Ibrahim in Potonié, Ibrahim, and Loose, p. 449, pl. 17, fig. 29.
1933 *Laevigato-sporites ellipsoides* Ibrahim, p. 40, pl. 4, fig. 29.
1934 *Punctato-sporites ellipsoides* (Ibrahim); Loose, p. 158, pl. 7, fig. 35.
1934 *Sporites ellipsoides* (Ibrahim); Wicher, p. 185.
1938 *Monoletes ellipsoides* (Ibrahim); Schopf, p. 45, pl. 1, fig. 14 and pl. 6, figs. 5, 6.
1954 *Schopfipollenites ellipsoides* (Ibrahim); Potonié and Kremp, p. 180.

Holotype. Potonié and Kremp 1956, pl. 22, fig. 478 after Ibrahim. Preparation E55, a.

Type locality. Ägir Seam, Ruhr Coalfield, Germany; top of Westphalian B.

Diagnosis (Potonié and Kremp 1956, p. 184; translation). 'Outline elliptical. On one surface the umbo extends lengthwise and on each side is bordered by a sharply creased pleat with a substantial overlap. These pleats taper to a point and almost reach the margin. On the opposite surface there is only a very small fold, also running lengthwise, which appears as a furrow. The margin is more or less smooth. The surface is stippled ('paillettiert').'

Size in microns. Holotype 350; 200–500, Schulze (Potonié and Kremp 1956).

Description. In polar compression the shape varies from circular to oval. The proximal suture is normally bent (not sharply) near the middle; the prominence and length of the suture varies. The folds associated with the distal grooves (and other more or less longitudinally aligned compression folds) also vary in the extent of their development.

Remarks. Winslow (1959, pl. 14, fig. 9) figures a specimen with a short third ray joining the proximal suture at its point of flexion.

Comparison. All specimens in which an inner spore membrane can be recognized are assigned to *S. ellipsoides* var. *corporeus* Neves.

Occurrence. Insufficient data to give limits; probably corresponds to the range of *S. ellipsoides* var. *corporeus*, which occurs more often in British coals.

Schopfipollenites ellipsoides var. *corporeus* Neves 1961

Plate 27, figs. 3, 4

Holotype. Neves 1961, pl. 34, fig. 5. Preparation 4.236800.

Type locality. Pot Clay Coal, Consall, North Staffordshire Coalfield, England; Namurian C.

Diagnosis (Neves 1961, p. 274). '. . . equatorial outline oval; proximal surface with a narrow suture, characteristically bent about its middle point; distal surface bears two major longitudinal folds of the exoexine; the inner spore membrane is preserved as a circular to ovate "spore body".'

Size in microns. (i) Holotype 168; 145–210, Schulze and KOH (Neves 1961). (ii) 124(167)223, maximum body size 99(141)183, (13 specimens) fum. HNO_3; Barnsley Seam, Yorkshire Main Colliery, Yorkshire Coalfield, England; Westphalian B.

Description. Shape of inner body often conformable with that of exoexine; varies from circular to oval. Suture variable in length, may extend full length of body; greater part often flanked on either side by a margin about 2 μ in width and usually darker in colour than remainder of exine. In polar compression the 'body' sometimes almost fills the cavity within the exoexine, except for a marginal border 4–8 μ in width; where 'body' is appreciably smaller than exoexine this border appears somewhat darker than remainder of exoexine outside the body; ratio body size to overall size 0·75 to 0·9. Exoexine externally laevigate, internally finely granulate. Folding of spore body variable and usually confined to peripheral region; folds of exoexine usually aligned with long axis. Exoexine and inner membrane thin.

Remarks. Schopf (1938) under *Monoletes ovatus* refers to the fact that the thin, inner membrane which ordinarily fits closely within the outer membrane sometimes diverges from it. Most of the British specimens here referred to *S. ellipsoides* var. *corporeus* show a distinct separation of the two membranes. Spores of this type are figured by Winslow (1959, pl. 14, figs. 1, 3, and 4) but they are not given specific identity.

Occurrence. Infrequent and not recorded from every seam, Assemblages V to XI; Namurian B to Westphalian D. Recorded in coals and other rocks of Namurian C and Westphalian A age from the southern Pennines by Neves (1961).

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APPENDIX

Sources of figured specimens (excepting types)

Slide numbers	*Coal seams (depths below boring datum)*	*Collieries or boreholes*	*Coalfields*
1, 59, 107, 148	Possil Main (600′ 2″)	Cawder Cuilt Borehole	Central, Scotland
2, 140, 181	Kilsyth Coking (1,097′ 0″)	Cawder Cuilt Borehole	Central, Scotland
3, 12, 36, 73, 76	Shilbottle (201′ 1″)	New Moor Hall Borehole	Northumberland
4, 115, 135, 137	Sharlston Top (1,168′ 8″)	Cross Hill Borehole	Yorkshire
5	Rock	Deakin's Slope Colliery	South Wales
6	Beamshaw	Frickley Colliery	Yorkshire
7, 87, 96, 104, 126, 151, 152, 153, 199	High Hazel of Hatfield	Thorne Colliery	Yorkshire
8, 64, 97, 122, 162, 213, 217, 219, 255	Swallow Wood	Denaby Main Colliery	Yorkshire
9	Wheatworth (1,820′ 3″)	Gate Farm Borehole	Yorkshire
10, 77, 81, 143, 176	Shale (663′ 6″)	Cawder Cuilt Borehole	Central, Scotland
11	Oakley Upper (1,796′ 4″)	Blairmains Borehole No. 2	West Fife, Scotland
13	Newhill (845′ 4″)	Kellingley Borehole	Yorkshire
14	No. 8 Seam	Nantgarw Colliery	South Wales
15, 231, 250	Tillery Rider	Hafodyrynys outcrop	South Wales
16, 17	Swallow Wood (1,475′ 0″)	Kellingley Borehole	Yorkshire
18	Upper Lount	Bagworth Colliery	Leicestershire
19	Garibaldi Ironstone (1,058′ 3″)	Cawder Cuilt Borehole	Central, Scotland
20, 52, 53, 54, 118, 119	Trenchard	Princess Royal Colliery	Forest of Dean
21, 253, 254	Tillery Rider	Tirpentwys Colliery	South Wales
22, 260	592′	Linton Colliery (Drift)	Northumberland
23	Top Soft (1,606′ 11″)	Cotgrave Wolds Borehole	Nottinghamshire
24	673′ 0″	Darnley Borehole No. 3	Central, Scotland
25	Possil Wee (1,606′ 10″)	Queenslie Bridge Borehole	Central, Scotland
26	2nd Piper (1,781′ 11″)	Cotgrave Wolds Borehole	Nottinghamshire
27	Blocking (2,155′ 7″)	Kellingley Borehole	Yorkshire
28, 169	Cannel	Bagworth Colliery	Leicestershire
29, 99	Flockton Thick	West Riding Colliery	Yorkshire
30	1,088′ 8″	Cotgrave Wolds Borehole	Nottinghamshire
31	Thorncliffe (2,414′ 2″)	Cross Hill Borehole	Yorkshire
32	Brass Thill	Silksworth Colliery	Durham
33	56′ 4″	Murton Colliery Borehole (21 NW. 3)	Durham
34	Kilnhurst	Cadeby Main Colliery	Yorkshire
35	Chemiss	Michael Colliery	East Fife, Scotland
37	253′ 10″	Broadlaw Deep Borehole No. 36	Northumberland
38	1,647′ 4″	Musselburgh No. 1 Borehole	Lothians, Scotland
39	4,316′ 6″	,, ,,	Lothians, Scotland
40	3,926′ 7″	,, ,,	Lothians, Scotland
41	Unnamed seam	Bickershaw Colliery	Lancashire
42	1,119′ 2″	Cotgrave Wolds Borehole	Nottinghamshire

Slide numbers	Coal seams (depths below boring datum)	Collieries or boreholes	Coalfields
43, 56, 58, 85, 90, 192, 195	Parkgate	Grange Colliery	Yorkshire
44	223′ 1″	Metal Bridge Borehole (35 NW. 34)	Durham
45	1,108′ 6″	Moat Farm Borehole	Cannock Chase
46	1,540′	Wyck Beacon Borehole	Oxfordshire
47, 100, 101	3,199′	Upton Borehole	Oxfordshire
48	Wheatley Lime (2,136′ 11″)	Stubbs Lane Borehole	Yorkshire
49, 68, 111, 184	Oakshaw Ford	Oakshaw Ford Colliery	Cumberland
50, 51, 114, 146, 147, 206	Chapelgreen (314′ 2″)	Cawder Cuilt Borehole	Central, Scotland
55	299′ 5″	Acresford Borehole	South Derbyshire
57	1,333′ 7″	No. 4 Off-shore Borehole (8A SW. 1)	Durham
60, 136	58′ 9″	Chislet Colliery No. 30 Upbore	Kent
61	Deep Soft (1,798′ 5″)	Manns Bridge Borehole	Nottinghamshire
62	739′ 10″	Alveley Borehole No. 1	Forest of Wyre
63	635′ 3″	Sharpness Point Borehole (87 SW. 102)	Durham
65	1,754′ 11″	Sandon Bank Borehole	South Staffordshire
66	Barncraig	Michael Colliery	East Fife, Scotland
67	1,321′ 11″	Acklington Borehole	Northumberland
69	1,758′ 2″	Musselburgh No. 1 Borehole	Lothians, Scotland
70	4,219′ 1″	Musselburgh No. 1 Borehole	Lothians, Scotland
71	998′ 0″	Hungerford Borehole	North Staffordshire
72	Seam at base of Newcastle Series	Penkhull outcrop	North Staffordshire
74, 154, 155, 156, 177, 220	Greenses (147′ 8″)	Stamford Borehole	Northumberland
75	Houston Coal	Coalheughhead Mine	Central, Scotland
78	Threequarters	Creswell Colliery	North Derbyshire
79	1,019′ 3″	Cotgrave Wolds Borehole	Nottinghamshire
80	256′ 11″	Darnley Borehole No. 3	Central, Scotland
82	1,973′ 7″	Margam Borehole No. 4	South Wales
83	Swallow Wood (1,878′ 2″)	Cross Hill Borehole	Yorkshire
84	Flockton Thick (2,205′ 8″)	Cross Hill Borehole	Yorkshire
86	Chislet No. 5	Chislet Colliery	Kent
87, 178	High Hazel of Hatfield (2181′ 5″)	Gate Farm Borehole	Yorkshire
88	Shafton	Dearne Valley Colliery	Yorkshire
89	1,926′ 0″	Cotgrave Wolds Borehole	Nottinghamshire
90	Parkgate (3063′ 7″)	Gate Farm Borehole	Yorkshire
91, 207	Dunsil	Frickley Colliery	Yorkshire
92, 93	455′ 2″	Denby (Drury Lowe) Borehole	North Derbyshire
94, 103, 161	Clown	Shireoaks Colliery	Yorkshire
95	Swannington Yard	Bagworth Colliery	Leicestershire
98	Parkgate	Barnburgh Main Colliery	Yorkshire
102, 159, 223	436′ 4″	Mapperley Colliery Borehole	North Derbyshire

Slide numbers	*Coal seams (depth below boring datum)*	*Collieries or boreholes*	*Coalfields*
105, 180	Knightswood Gas (715′ 4″)	Cawder Cuilt Borehole	Central, Scotland
106, 110, 117, 144	Shale (1,801′ 5″)	Queenslie Bridge Borehole	Central, Scotland
108, 145	Cloven (1,764′ 2″)	Queenslie Bridge Borehole	Central, Scotland
109, 142	191′ 3″	Darnley Borehole No. 3	Central, Scotland
112, 157, 158, 164	Meiklehill Main (1,623′ 4″)	Queenslie Bridge Borehole	Central, Scotland
113	31′ 4″	Culross Borehole No. 2	West Fife, Scotland
116	Sharlston Low (1,639′ 0″)	Gate Farm Borehole	Yorkshire
120	High Hazel of Hatfield	Askern Main Colliery	Yorkshire
121	903′ 4″	Harry Stoke 'B' Borehole	Bristol & Somerset
123	1,064′ 0″	No. 4 Off-shore Borehole (8A SW. 1)	Durham
124	36′ 6″	Chislet Colliery No. 29 Upbore	Kent
125	Deep Soft (3,194′ 4″)	Torworth Jubilee Farm Borehole	Nottinghamshire
127	Beamshaw	South Kirkby Colliery	Yorkshire
128	2015′ 4″	Cotgrave Wolds Borehole	Nottinghamshire
129, 193	Swinton Pottery (772′ 9″)	Kellingley Borehole	Yorkshire
130	Two Foot (2,345′ 1″)	Torworth Jubilee Farm Borehole	Nottinghamshire
131	Top Silkstone	Brookhouse Colliery Underground Borehole No. 1	Yorkshire
132	2,776′ 0″	Colston Bassett Borehole	Nottinghamshire
133	1,252′ 1″	Apley Barn Borehole	Oxfordshire
134	79′ 4″	Ferrers Opencast Borehole	Leicestershire
138, 139, 246, 247	Coleford High Delf	Northern United Colliery	Forest of Dean
141	Ashfield Coking (1,717′ 5″)	Queenslie Bridge Borehole	Central, Scotland
149	Lethemwell	Frances Colliery	East Fife, Scotland
150	Over Main (1,226′ 8″)	Caldwell Ashley House Borehole	South Derbyshire
160	48′ 9″	Whitworth Park Borehole (34 SE. 22)	Durham
163, 205	Lyoncross (558′ 10″)	Darnley Borehole No. 4	Central, Scotland
165, 166, 222	Lower Garscadden Ironstone (1010′ 2″)	Cawder Cuilt Borehole	Central, Scotland
167	1,872′ 7″	Righead Borehole	West Fife, Scotland
168	658′ 0″	Darnley Borehole No. 3	Central, Scotland
170, 172	Clod (424′ 0″)	Lindridge Hall Farm Borehole	Leicestershire
171	Cadell's Parrot (1,110′ 9″)	Righead Borehole	West Fife, Scotland
173	Barnsley Rider (2,666′ 0″)	Torworth Jubilee Farm Borehole	Nottinghamshire
174	Calpatie (2,851′ 3″)	Monkton House Borehole	Lothians, Scotland
175	New Main	Bagworth Colliery	Leicestershire
179	Alton (533′ 8″)	Denby (Drury Lowe) Borehole	North Derbyshire
182	Ganister Clay (214′ 10″)	Keverstone Borehole (47 NE. 17)	Durham
183	2,082′ 2″	Righead Borehole	West Fife, Scotland
185, 189	Barnsley	South Kirkby Colliery	Yorkshire
186, 202, 230	Great Vein	Camerton Colliery	Bristol & Somerset
187	4,455′ 6″	Musselburgh No. 1 Borehole	Lothians, Scotland
188	Diamond (1,966′ 8″)	Righead Borehole	West Fife, Scotland

Slide numbers	*Coal seams (depth below boring datum)*	*Collieries or boreholes*	*Coalfields*
190	419′ 6″	Houghton Colliery Borehole (14 SW. 3)	Durham
191	Top bed of Wheatley Lime (?) (2,189′ 9″)	Little Smeaton Borehole	Yorkshire
194	Lower Four Feet	Llanharan Colliery	South Wales
196, 211	Top Silkstone	Elsecar Main Colliery	Yorkshire
197	Kilnhurst	Wharncliffe Woodmoor Nos. 4 and 5	Yorkshire
198	Swallow Wood	Barrow Colliery	Yorkshire
200	Bradford Yard	Bradford Colliery	Lancashire
201, 218, 252	*ca.* 3,230′ 0″	Corringham Borehole	Nottinghamshire (Lincolnshire)
203	1,374′ 2″	Hartswell Farm Borehole	Nottinghamshire
204	819′ 0″	Harry Stoke 'A' Borehole	Bristol & Somerset
208	Tilley (324′ 2″)	Fishburn Colliery	Durham
209	2,071′ 4″	Musselburgh No. 1 Borehole	Lothians, Scotland
210	No. 15 Seam	Nantgarw Colliery	South Wales
212	Dunsil (1,248′ 3″)	Cotgrave Wolds Borehole	Nottinghamshire
214	1,854′ 9″	Righead Borehole	West Fife, Scotland
215	Dunsil (1,406′ 7″)	Kellingley Borehole	Yorkshire
216	2,117′ 11″	Cotgrave Wolds Borehole	Nottinghamshire
221	1,555′ 4″	Righead Borehole	West Fife, Scotland
224	Rushy Park	Sutton Manor Colliery	Lancashire
225	Upper Hirst (2,310′ 4″)	Brucefield Borehole	West Fife, Scotland
226	670′ 2″	Garth Place (Rudry) Borehole	South Wales
227	Bodwr Fawr	Wernddu Clay Pit	South Wales
228	Parkgate	Manvers Main Colliery	Yorkshire
229	2nd Waterloo (1,313′ 9″)	Cotgrave Wolds Borehole	Nottinghamshire
232, 243, 251	Slyving Vein	Camerton Colliery	Bristol & Somerset
233	Kent's Thick	Wath Main Colliery	Yorkshire
234	Prince	Broomhill Colliery	Northumberland
235	Yorkley	Cannop Colliery	Forest of Dean
236	Yorkley	Northern United Colliery	Forest of Dean
237	Bull Vein	Camerton Colliery	Bristol & Somerset
238	Mynyddislwyn	Tirpentwys Opencast Site	South Wales
239, 241	720′ 8″	Alveley Borehole No. 1	Forest of Wyre
240	802′ 3″	Ruabon A5/6 Borehole	North Wales
242	Big Vein	Norton Hill Colliery	Bristol & Somerset
244	Kent's Thick (1,627′ 4″)	Cross Hill Borehole	Yorkshire
245	Kent's Thin	Denaby Main Colliery	Yorkshire
248	Shafton (1,405′ 3″)	Gate Farm Borehole	Yorkshire
249	1,358′ 1″	No. 4 Off-shore Borehole (8A SW. 1)	Durham
256	Lidgett (1,633′ 1″)	Kellingley Borehole	Yorkshire
257	2,060′ 11″	Kellingley Borehole	Yorkshire
258	Barnsley (1,459′ 6″)	Fenwick Borehole	Yorkshire
259	1,369′ 0″	Seafield No. 2 Borehole	East Fife, Scotland
261	Abdy	Carr Bank Borehole	Nottinghamshire
262	Lidgett (2,715′ 3″)	Gate Farm Borehole	Yorkshire
263	919′ 5″	No. 4 Off-shore Borehole (8A SW. 1)	Durham