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THE PALYNOLOGY OF CARBONIFEROUS STRATA IN NORTHUMBERLAND OFF-SHORE BOREHOLES

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Thesis submitted for degree of Doctor of Philosophy at the University of Aston in Birmingham, Department of Geological Sciences.

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UNIVERSITY OF ASTON IN BIRMINGHAM

1982

SUMMARY

The work described represents a palynological study of Carboniferous coal seams of Upper Westphalian A and Westphalian B age from eight off-shore boreholes sunk by the National Coal Board in Northumberland. When treated chemically the majority of the coal samples yielded well-preserved miospores which were studied by means of the optical and scanning electron microscopes. Systematic descriptions of 151 miospore species belonging to 57 genera, and including 18 new types, are given. One miospore assemblage is recognised from the coals of Upper Westphalian A age and two further assemblages from those of Westphalian B age. These compare with assemblages described by earlier workers from strata of similar age elsewhere, but there are differences in the distributions of some of the more abundant taxa, and some of the stratigraphically significant species are not present.

Correlations based on miospore distributions between the coal seams encountered in the eight off-shore boreholes agree fairly closely with those established by the National Coal Board on lithological criteria. Relations are discussed between palynology and palaeoecology and detailed comparisons made with the work of Smith and Butterworth 1967 from the adjacent on-shore area. It is concluded that the miospore assemblages described are restricted in that they contain very low representation of Smith's (1962) Densospore phase. This restriction, due to the relatively rapid subsidence of the depositional area, is reflected in the distributions of some of the less common spores as well as in the abundances of species such as Densosporites sphaerotriangularis, Lycospora pusilla and Apiculatisporis irregularis.

Key Words:- PALYNOLOGY CARBONIFEROUS

COALS NORTHUMBERLAND

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Dedication

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*Submitted separately (in back folder)

INTRODUCTION

The present study represents a description of the palynology of Westphalian A and B coal seams recovered from eight off-shore boreholes in Northumberland (fig. 1.1) Details of the geology and structure of the adjacent on-shore area are described in chapter 1. The boreholes form part of a big exploration project currently being carried out by the National Coal Board. The samples which are all of coal were treated physically and chemically to extract good miospore assemblages. The techniques used in the present work are described in detail in chapter 3.

The principal aims of this work were as follows:-

1. To study the previous work done by other authors dealing with Silesian (Upper Carboniferous) palynology both in Britain and in the rest of the world. A summary of most of these publications is presented in chapter 2.
2. To study the miospore genera and species in the Westphalian A and B strata. The systematic descriptions of 151 species belonging to 57 genera are given in chapter 4.

Also described are 18 new types, with detailed SEM photographs.

3. To study the distributions of the miospore taxa in the coal seams of the eight off-shore boreholes and compare their distributions with those from other areas in Britain and elsewhere. Details of these are represented in chapter 5 and shown in tables No. 1 and 2.

4. To confirm or otherwise the N.C.B. correlations between the eight boreholes. This was carried out by comparing the frequencies of selected species; histograms were drawn for seams represented in more than one borehole. Details are shown in chapter 5.

5. To study the palaeoecology of the miospore distributions and their significance. Details are represented in chapter 6.

CHAPTER 1

The Coalfield of Durham and Northumberland:-

1.1 Introduction

The present area of study lies in the northern part of the Northumberland Coalfield; off-shore from Druridge Bay to the North of Ellington (fig. 1.1). The geology of the present area was studied in detail by A. Fowler (1936), in the Geology of the Country around Rothbury, Amble and Ashington Memoir of the Geological Survey of Great Britain. Later Hopkins (in Trueman 1954) outlined the stratigraphy and structure of the coalfields. Recent work on these fields and on the Carboniferous System was described by Taylor et. al. 1971 in British Regional Geology (Northern England). Specific work at Westoe Colliery, County Durham was carried out by D. Magraw 1963 which involved the structure and stratigraphy of the area.

In general coal-bearing strata of both Lower and Upper Carboniferous age occur in Northumberland and Durham. The two counties are built-up almost entirely of Carboniferous rocks, except for the Cheviot igneous massif of Devonian age in Northumberland, and Permian strata in southeast Durham. In the Northumberland trough deposition was continuous and the sequence of beds is more complete than in Durham. George et. al. 1976 state that the oldest sediments, the Cementstone Group, are of Courceyan age. These are succeeded by the Fell sandstone Group, deltaic

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Fig·1·1 Geological map of the studied area showing borehole locations based on Inst. of Geol. Sciences map and Robson 1980, fig·6

sediments brought in by a large river flowing from the northeast. In Asbian times the whole area subsided and cyclic marine deposition, responsible for the Yoredale facies of the Lower and Middle Limestone Groups, persisted throughout the rest of the Dinantian.

Similar conditions persisted throughout the deposition of the Upper Limestone Group representing the Pendleian and Arnsbergian stages of the Namurian (Ramsbottom et. al, 1978). The later stages of the Namurian are represented by a near-shore facies consisting of coarse-grained, cross bedded sandstone together with siltstones and with occasional thin coals and limestone; these are thin compared with equivalent strata further south where the more typical Millstone Grit developed. According to Calver 1969 there were only slight changes in the conditions of deposition in early Westphalian time. Cyclic deposition continued, but in the Westphalian cyclothems marine limestones are absent, marine shales and coarser sandstone are less common than in the Namurian cyclothems and non-marine shales, sandstone and coals predominate. The coal seams as described in the special publication of the Natural History Society of Northumbria (editor, Robson, 1980) are of bituminous rank and vary in thickness from a maximum of 3 metres, in places of seam junction, to thin coal traces; an average thickness is around 0.5 metres. The coals are bright with vitrinite dominant, especially toward the base of most seams. Cleat is usually strong, becoming very close

in the higher rank coals of west Durham, which results in the seams becoming soft. Pyrite and ankerite are the most commonly associated mineral matter forming films on the cleat surfaces. The thickness to which a coal seam is developed and its liability to splitting is dependent upon the rate of subsidence of the growing peat surface. Too slow a rate of subsidence, due to the presence of a thick underlying sandstone which, unlike shale, is not subject to compaction, can result in impoverishment of the coal (Hopkins, 1933). Too rapid subsidence, arising from an excessive shale proportion in the underlying strata or from penecontemporaneous faulting, can lead to splitting of coal seams.

1.2 Structure

The known structure of the coalfield is comparatively simple. The rocks lie in the form of an irregular basin, the major axis of which has a north-east trend. The deepest part of the basin is near the mouth of the River Wear and the eastern limb is mainly under the North sea. Dips are generally small, about 2 to 5 degrees, but locally and near large faults the beds may be steeply inclined. The general direction of dip varies from east to north-east. The southeastern part of the Durham coalfield is overlain by Permian strata. In south Northumberland the basin is traversed by the 90 Fathom fault, and its major axis appears to be displaced to the east. The general direction of dip is still easterly and this is maintained for a distance of

1½ miles in the undersea workings near Blyth, when the beds begin to show a slight rise.

The coal field is traversed by a number of important faults. The largest faults running E.N.E. to W.S.W. include the Hauxely, Stakeford and Ninety Fathom in Northumberland and the St. Hilda, Seaham and Butterknowle in Durham. They are of variable throw.

CHAPTER 2

PREVIOUS WORKS ON SILESIAN PALYNOLOGY

This review of published work on Upper Carboniferous miospore assemblages is presented according to the geographical origin of such assemblages. The microfloras, especially in coals, of Westphalian age are now known in considerable detail. Their useful application to problems of coal seam correlation and in the elucidation of general stratigraphical problems is well established.

2.1 Silesian Palynology in Britain

2.1.1 Early Investigations

Raistrick and Simpson (1933) and Raistrick (1934 and 1937) examined coal from Northumberland and Durham and discussed the usefulness of their miospore content for correlation of the seams. For this purpose, 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 histograms for the general spores. The accessory spore histograms could generally be used for correlation when different seams gave similar general spore histograms. They observed that many of these accessory spores had restricted vertical ranges. Later Raistrick (1938) described the miospores present in some seams in the Namurian and Lower Carboniferous of Northumberland, figuring different spore types not previously observed in the Westphalian of this region. Millott (1939, 1945) studied the vertical distribution of miospore assemblages in seams of

Namurian and Westphalian age in the Cheadle and main North Staffordshire Coalfields. Coal seams in the Scottish Upper Carboniferous were examined by Knox (1942, 1945). She indicated that the occurrence of certain accessory spore assemblages within a seam are of value in correlation, and she observed a vertical variation in these assemblages which thus had value as zone fossils. In her (1948) paper on the Namurian Limestone Coal Group in Scotland, she noted that the miospores from this group were relatively greater in number and most of them different from those in the Productive Coal Measures.

2.1.2. Zonations

An important work by Balme and Butterworth (1952) used the ranges and distributions of certain spore fossils to zone the Coal Measures of the Central Group of British Coalfields. These zones were characterised by three main spore assemblages, the boundaries of these zones were recognised by the presence or absence of certain species. This line of enquiry was continued by Butterworth and Millott (1954) to include Upper Carboniferous strata in the North Staffordshire, Cannock Chase and North Wales Coalfields. The detailed examination of the vertical distribution of certain species enabled the authors to add another two main spore assemblages to those already defined by Balme and Butterworth (1952), and these assemblages were designated as S0 to S4, and the work continued in this direction by the same authors when in 1960

they added another four assemblages to give a total of nine which covered a sequence from Upper Viséan to Westphalian D based on the evidence available from coal seams. In 1967 Smith and Butterworth, in a special paper, carried out the most comprehensive and elaborate study of British Carboniferous palynology. They demonstrated the use of miospores isolated from coal seams in the problems of seam correlation and refined the zonation scheme of 1960. They were able to distinguish eleven stratigraphically distinctive miospore assemblages with reference to their occurrence in different coalfields. These miospore assemblages have been numbered from I to XI in ascending order and embraced horizons from Lower Viséan to Westphalian D.

Neves (1961) has published the first range charts for selected miospores in the clastic sediments and coals of Namurian age in the Southern Pennine Region of Central England and related them to the standard sequence of goniatite stages. He didn't erect an independent zonal scheme until 1968 when he studied the vertical distributions of miospore assemblages from twenty five horizons in the Woodland Borehole Co. Durham, and subdivided the sequence into eight stratigraphical zones ranging from Upper Viséan to Westphalian A in age. Owens, in Owens and Burgess (1965) examined the microfloral distributions in the Upper Carboniferous sediments of the Stainmore outlier , Westmorland, and he correlated these with similar work done by Neves (1961)

in the Southern Pennines. He found a close agreement between the composition and distribution of the microfloral assemblages in both areas, but the succession could not be positively correlated at all horizons with that in the Southern Pennine area due to the inadequate nature of the goniatite record at Stainmore. He also utilised the assemblages to support the established goniatite stages and non-marine lamllibranch zones.

Later Owens et. al. (1977) erected a broad palynological zonal scheme for the Namurian Series in Britain. They prepared five assemblages zones for Namurian deposits in North England and Scotland based on data obtained from coal seams and clastics. These assemblages substitute the three assemblages of Smith and Butterworth (1967), while the six Westphalian assemblages of the later authors were still recognised as standard for the British Westphalian.

Clayton et. al. (1977) proposed a composite zonal scheme which extends from the uppermost Devonian to lowermost Permian, and which appears to be applicable over much of Western Europe because it is a result of intensive co-operation between the authors and palynological colleagues in both Western and Central Europe and the U.S.S.R.

2.1.3. Correlations

Butterworth and Williams (1958) had shown that there was a possibility of regional correlation using the extracted miospores from Limestone Coal Group and Upper Limestone

Group (Namurian A) in Scotland and they found a similarity of spore assemblages in North America, Russia and elsewhere.

Sullivan (1964) proposed an Upper Viséan and Westphalian A age respectively for two horizons in the Drybrook Sandstone of the Forest of Dean Coalfield.

Marshall and Williams (1970) studied spore assemblages from 23 horizons of coals and shales in the Yoredale Series of the Roman Wall area in Western Northumberland. They found no significant changes in miospore assemblages at the Viséan-Namurian boundary.

Neves et. al. (1965) in a short paper examined miospore assemblages from the Passage Group in Scotland and showed evidence for the presence of Upper Namurian stages according to the spores and goniatite content. Love and Neves (1964) examined the miospore assemblages of a Carboniferous succession of a coal lenticle in sandstone, an underclay, and the Main Coal at Inninmore Bay in Scotland and indicated a Westphalian B age for the coal lenticle and underclay and Westphalian B-C boundary age for the Main Coal.

Sabry and Neves (1970) described the miospore distributions in the sediments of the Sanquhar Coalfield, Dumfriesshire, Scotland, ranging from Upper Viséan to Westphalian C in age.

Whitaker and Butterworth (1978) examined miospore assemblages from Viséan and Namurian strata in the Ballycastle area, Co. Antrim, Northern Ireland and suggested that the miospore

assemblages of the Upper Coal Group are more consistent with a Pendleian age than with the hitherto postulated Arnsbergian age. In 1979 the same authors examined miospore assemblages from the type section of the Arnsbergian stage of the Namurian Series in County Leitrim, Southern Ireland.

Butterworth and Smith (1976) suggest a broad comparison between the miospore assemblages of Upper Coal Measures age in Britain and those in Europe, Russia and the U.S.A. Wagner and Spinner (1972) suggested an Upper Westphalian D age for Upper Coal Measures in the Forest of Dean; this was based on a study of the megaspore and microspore assemblages in the succession. They also compared their assemblages with those of the Carbondale and Modesto Formations of Illinois, and with assemblages from Upper Westphalian D - Lower Stephanian deposits in northwest Spain.

2.1.4. Palaeoecology

Neves (1958) studied in detail the miospore assemblages of a thin sequence of coal, marine and non-marine shale from the basal Westphalian of North Staffordshire. He observed significant differences in both the type of spores present and their relative numerical proportions. He found a striking number of the saccate genus Florinites in the marine shale in contrast to the associated coal and non-marine shale, and he considered that this was due to the surrounding of the basin of deposition with plants which yielded this pollen. Chaloner (1958) in his

comment on the Neves paper suggested that these Florinites, which are derived from plants with Cordaitalean (Florin 1933) and Coniferalean (Potonié and Kremp, 1955) affinities, were derived from an upland flora outside the area of the swamp, and remained undisturbed during the transgression of the sea, in contrast to the Lycopods, Calamites and Pteridosperms of the swamp itself. Sullivan (1962) examined the miospores in coals and shales at 45 horizons exposed in Wernddu Claypit, Caerphilly, South Wales. The assemblages ranged in age from Upper Westphalian A to Upper Westphalian C. He demonstrated the continuity of range of the stratigraphically important spores through both coal and shales. He also suggested that shale assemblages could be used in areas previously neglected because of the high rank of coals, and where well-preserved spores had been obtained from shales. The most comprehensive and elaborate studies of miospore successions in certain coal seams of Lower and Middle Coal Measures in the Yorkshire Coalfield are those of Smith (1957, 1962). He described a series of miospore "phases" which tend to occur in a particular order in the British coal seams. These he called "Lycospore", "Transition", "Denspospore" and "Incursion". The Lycospore and Densospore Phases were named after their respective dominant miospore genera, the Transition Phase because of its position in the phase sequence and the Incursion Phase is probably associated with a period of flooding of the swamp by fresh water. He observed that the Lycospore

Phase always occurs at the base of the coal seams and that Lycospore and Densospore Phases never occur vertically adjacent to one another; the Transition Phase always intervenes. The Incursion Phase is an irregular component which might be found anywhere within a seam excepting within the Densospore Phase. The Lycospore - Transition - Densospore - Transition - Lycospore sequence might be repeated any number of times with two or more Lycospore or Densospore Phases repeated around a Transition and with Incursion Phases randomly present. Petrographically the Lycospore Phase is associated with bright coal (Vitrain), the Transition Phase is associated with coal intermediate between the bright and dull coal (clarain), the Densospore Phase with black dull coal (crassidurain), and the Incursion Phase with gray dull coal (tenuidurain). After that Marshall and Smith (1965) investigated the miospore assemblages in the coal, seat-earth and roof measures of certain Yorkshire seams. They indicated that the spore content of the seat-earth are of value for the solution of correlation problems when the associated coal is lacking.

2.2 Silesian Palynology outside Britain

2.2.1. North America

Schopf (1938) conducted the first detailed investigation of Megaspores from the Carbondale Herrin (No.6) Coal (Upper Westphalian) from Illinois. Brokaw (1942) described spores from the Harrisburg (No.5) Coal Member and after comparing them with those of No.6 Coal, concluded that the

two coals could be distinguished on the basis of their spore content. Schopf, Wilson and Bentall's (1944) synopsis of Palaeozoic spores and definitions of generic groups outlines certain principles in many of the problems in spore nomenclature. Kosanke (1950) carried out a comprehensive study in which he established correlation of the important coals of Pennsylvanian age in Illinois by using spore genera and species including 100 new species described in the report. Guennel (1952, 1958) investigated the miospore content of the Pennsylvanian coals of Indiana. Hoffmeister, Staplin and Malloy (1955) studied Upper Mississippian plant spores from coal and carbonaceous shale of the Hardinsburg Formation of Illinois and Kentucky. They discovered considerable variation in relative distributions of spore genera and species within a short vertical interval, but generally the same genera and species were found through-out the Hardinsburg Formation.

Wilson and Hoffmeister (1956) studied spores and leaf cuticles of the Croweburg coal of Pennsylvanian age from nine localities in northeastern Oklahoma.

Peppers (1964) examined the vertical variation in relative abundance and variety of miospore assemblages in various marine and non-marine units of cyclothems in the McLeansboro Group, late Pennsylvanian of Illinois and in equivalent strata of western Kentucky. Later Peppers (1970) examined miospore assemblages from the Carbondale and Spoon Formations, Pennsylvanian. The data obtained clarified the geologic ranges of the plant microfossils in the strata of the Kewanee Group.

Habib (1966) examined the vertical and geographical distribution of miospores in the Lower Kittanning Coal Seam of Western Pennsylvania (Lower Westphalian D). He recognised five assemblages starting with Lycospora assemblages at the bottom where a fresh water facies inundated the swamp and terminating upwards with Densosporites assemblages with a change to a brackish-water facies in the coal swamp.

Felix and Burbridge (1967) studied the miospore assemblages of the Springer Formation of South Oklahoma to establish its correct age. The three formations ranged from Tournaisian to Westphalian B.

Ettensohn and Peppers (1979) studied miospore assemblages from shales and thin coals from the Pennington Formation (Chesterian) and Breathitt and Lee Formations (Morrowan) in northeastern Kentucky, to establish their correct age. They concluded that the samples from the Pennington Formation range from late Visēan to Namurian A in age and samples from the Breathitt and Lee Formations are Namurian B - Westphalian A in age.

Ravn (1979) made a detailed examination of the vertical variability of miospore assemblages in a thick coal designated CP-19-4 from the Cherokee Group of Iowa of Pennsylvanian age (Westphalian B). CP-19-4 yielded a diverse miospore population with marked vertical variation which enabled the author to recognise three major miospore associations, termed "Intervals". The first occurring at the bottom of the seam, is the Florinites interval dominated

by gymnosperm saccate taxa, Florinites, Potonieisporites, and Wilsonites. The middle portion of the seam is the Densosporites - Crassispora interval dominated by spores produced by herbaceous plants. The upper part of the seam is the Lycospora interval dominated by spores produced by arborescent lycopods.

In Canada Barss (1967) illustrated thirteen Carboniferous and Permian miospore assemblages from the Yukon Territory, the Northwest Territories and the Maritime Provinces. Neves and Belt (1970) examined assemblages from late Viséan and Namurian A and B ages from the Antigonish and South West Mabon Basin, Nova Scotia, Canada, and compared them with assemblages of similar ages from Britain and Spain.

Hacquebard and Donaldson (1969) and Hacquebard and Barss (1970) studied spore populations in order to interpret the environments of deposition of coal measures in different areas of Canada.

2.2.2 Western Europe

In Germany Potonié (1932), Ibrahim (1933) and Loose (1932, 1934) studied the spore assemblages of the Westphalian Äigr and Bismark seams of the Ruhr Coalfield and described many common species. Bharadwaj (1957a,b) studied the miospore distributions in coal seams of the Saar and Ruhr Coalfields, which range from Westphalian C to late Stephanian and Lower Westphalian D respectively. Grebe (1962,1972) studied the stratigraphical distribution of the miospores in the Ruhr Coalfield from deposits ranging

in age from Upper Westphalian A to Upper Westphalian C. She compared the spore associations of the Ruhr with their equivalents in Britain, north France and Belgium. She also concluded that the spore associations of the Ruhr agree to a great extent with the spore associations of Britain described by Smith and Butterworth 1967.

Pierart (1958) examined the miospores and megaspores of the Upper Westphalian C Neeroeteren zone of the Belgium Campine. In (1962) he described the miospores and megaspores of the Westphalian B and C of the Western part of the Borinage Massif, south-western part of Belgium. Laveine (1965) described the miospores and megaspores content of the groups at Auchel-Braugand Bethusse Noeux (North France). The age of his recorded microflora was Westphalian C. He discussed some of the ecological aspects of these assemblages.

Alpern et. al. (1966, 1967 and 1969) studied the spore assemblages from small basins of the Central Massif and in the Saar-Lorraine basins in France. He tried to correlate various basins inside, and with areas outside France.

Loboziak (1971) examined the miospores and megaspores of coal seams in the western part of the Nord-Pas-de-Calais Coalfields of Upper Namurian to Upper Westphalian C age and he proposed six zones subdivided into eighteen subzones. Loboziak (1974) and Coquel et. al. (1976) examined a great number of coal samples from different basins of Western Europe and proposed a broad palynological zonation scheme

for Westphalian and Stephanian deposits. The work continued in this direction when Loboziak et. al. (1976) suggested a new palynological subdivision for the Westphalian Series of Western Europe and Poland. They divided it into four zones:-

Zone 4	Thymospora obscura-thiessenii	Westphalian D
Zone 3	Torispora securis-laevigata	Westphalian C
Zone 2	Florinites junior	Westphalian B
Zone 1	Radiizonates aligerens	Westphalian A

Van Wijhe and Bless (1974) studied the miospores isolated from coal seams and clastic material of the Westphalian in the Netherlands. They divided it into six miospore zones and compared their zonation with that of Great Britain by Smith and Butterworth 1967 and with that of the Ruhr area according to Grebe 1972, and they found a great similarity between these zonations.

Neves (1964) examined miospores from 45 coal seams exposed in La Camocha coal mine, Gijon, Northern Spain. He suggested an Upper Namurian A to Lower Westphalian B age for the succession since it compares favourably with other Namurian-Westphalian sequences in Europe and elsewhere depending on the appearance of spores with restricted ranges. He also divided the succession into five zones based on distinctive associations of spores in the seams.

Moore et. al. (1971) studied the vertical distribution of miospore assemblages in the Villamnin area of Northern Leon, northwestern Spain, ranging in age from Namurian B to Westphalian C. They recognised four miospore zones.

These are:-

Zone 4	Triquitrites additus	Lower Westphalian C
Zone 3	Vestispora pseudoreticulatus	Westphalian B
Zone 2	Dictyotriletes bireticulatus	Lower Westphalian A
Zone 1	Raistrickia fulva	Namurian B-C

They also attempted long range correlations with successions in the U.S.A. and Russia based on the distributions of miospores, plant impressions, cephalopods and foraminifera.

2.2.3. Eastern Europe

Horst (1955) examined miospore assemblages of Namurian A and Westphalian A age from Western Upper Silesia and Mahrisch-Ostrau in Poland. Later, in 1957 Dybova and Jachowicz studied miospores in 156 seams from Silesia ranging in age from Namurian A to Westphalian D. This line of inquiry was continued by Dybova and Jachowicz who in 1970 recognised three miospore phases and eleven subphases in a detailed study of subsections of Upper Silesian Coals ranging in age from Namurian A to Westphalian D. Jachowicz (1971) examined spore assemblages of Namurian and Westphalian A age in North Poland and recognised ten zones in the Namurian and three in the Westphalian A. He compared them with those in Britain and Western Europe. Jachowicz (1974) published further details of miospore distributions in Upper Silesian coal seams of Namurian and Westphalian A age.

Kalibova (1970) studied miospores and megaspores in coal seams from the Lower grey Formation (Westphalian D) to

Upper Red Formation (Upper Stephanian) in the Bohemian Massif, Czechoslovakia. She also examined megaspores from seams belonging to Westphalian A and B to Lower Westphalian C and correlated the lower ones with assemblages of Westphalian A age from Poland. She continued her investigations in 1970 when she recognised eight megaspore assemblages in the Plzen Basin, Western Bohemia, ranging from the Westphalian B-C boundary to Stephanian C in age. Beju (1970) studied miospore assemblages from the Moesian Platform of Romania, and suggested three zones ranging from Viséan to lowermost Westphalian in age.

2.2.4. Asia

In Turkey, Artüz (1957, 1959) investigated the miospore content of Namurian and Lower Westphalian A coals of the Zonguldak Coalfield and described important new taxa. Agrali and Konyali (1969) examined miospore distribution from Viséan to Westphalian D age in the Amasra Basin. They recognised ten new genera and listed the stratigraphical ranges of 699 spore species belonging to 109 genera.
In Russia Inosova et. al. (1975) proposed a comprehensive zonal scheme based on miospores and pollen grains in the Donets Basin for strata of Westphalian, Stephanian and Lower Permian age.
Teteriuk (1976) expanded the initial work of Ishchenko (1956 and 1958) in the Donets Basin and examined miospores from strata of Tournaisian to Westphalian D age. He

divided the Dinantian strata into three zones and the Namurian and Westphalian strata into five zones each. He also linked the various zonations in Europe and Russia.

2.3 Nomenclature and Classification of Miospores

The classification of spores is based purely on morphological features, due to the lack of knowledge regarding natural or phylogenetic relationships of the majority of Palaeozoic miospores. The nomenclature of the spore taxa is subject to the rules of priority and typification laid down in the International Code of Botanical Nomenclature 1961. At suprageneric level there is no universally accepted classification and different authors have used different criteria for their classification.

The first classification in Britain was introduced by Raistrick and Simpson 1933. They divided the miospores into seven groups, based on morphological features, indicated by the letters A to G. Each group was further sub-divided into sub-groups indicated by a suffix A_1 , A_2 , A_3 , A_4 , B_1 , B_2 ....etc. Raistrick called the rare spores "accessory", most of them having a short stratigraphical range with a potential for correlation purposes.

Naumova 1939 proposed a classification in Russia in which she divided the spores into Triletes and Monoletes, and then further subdivided these into Zonotriletes and Azonotriletes. One of the important features in her classification is that she used only one morphological feature at any taxonomic level. Her classification became

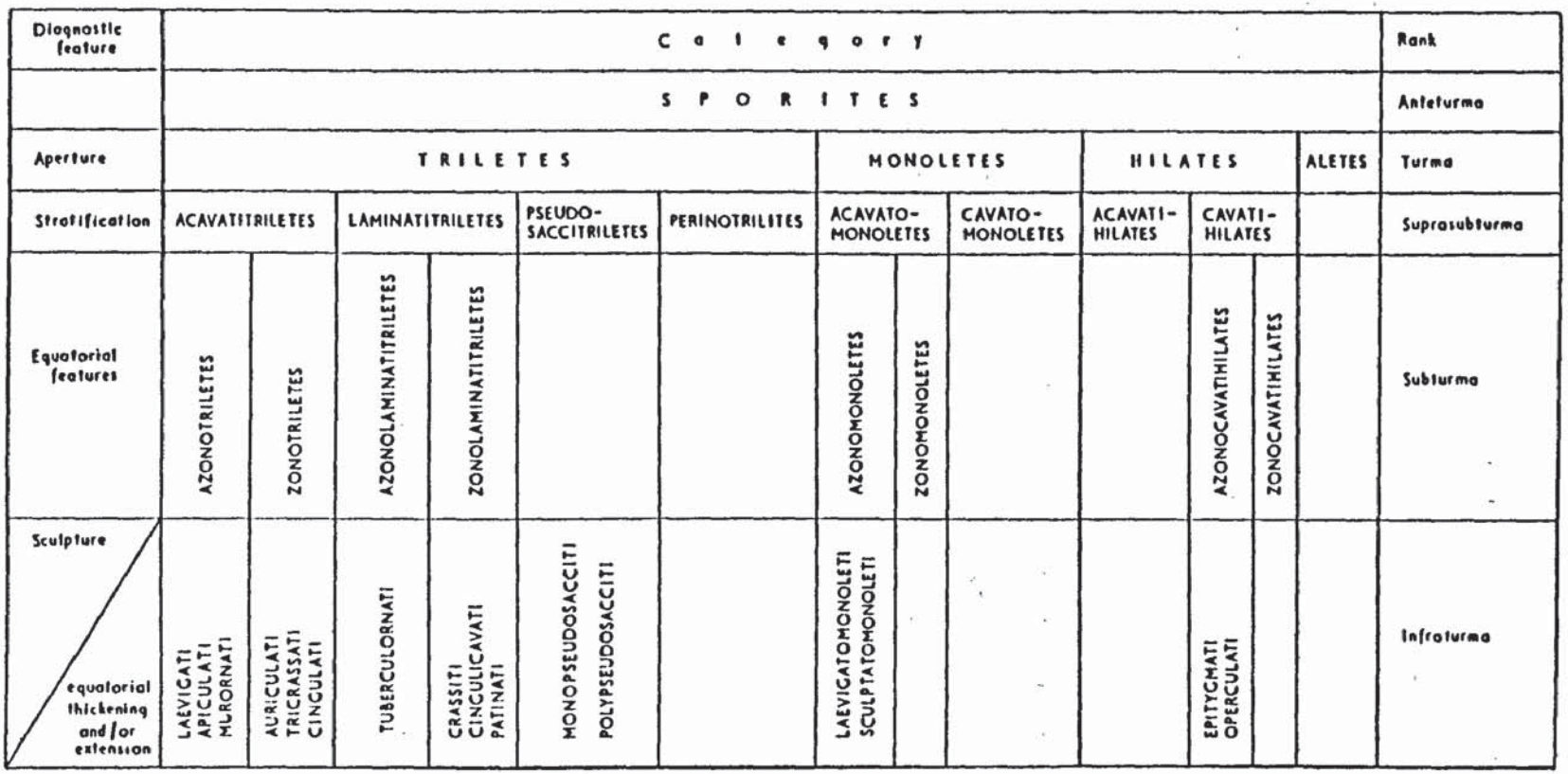
unwieldy in subsequent years because it is very broad. Potonié and Kremp (1955, 1956) were the first to recognise the value of wall stratification in the classification of spores. They divided their anteturma Sporites into the ranks of turma, subturma and infraturma depending on aperture, wall stratification, sculpture and equatorial features. This scheme was later amplified by other authors and became the most widely used outside Russia. Dettmann 1963 revised the above system and suggested the use of one diagnostic feature only at any particular rank. Previously spores of identical morphology could be placed into more than one suprageneric category because of the use of more than one feature.

Neves and Owens' 1966 system of classification is essentially a modification of that proposed by Dettmann based on the same principles but using different terminology. They introduced the term camerate to replace cavate, sensu Dettmann. They reject PERINOTRILITES by Dettmann and retained the original sense (Erdtmann 1947). Their subdivision of suprasubturma CAMERATITRILITES is based on the degree of attachment of the intexine and exoexine. The system as proposed by Neves and Owens,is not used without certain reservations, as they state that the subdivision of CAMERATITRILITES is based on the nature of the attachment of the two exine layers. The determination of the nature and degree of membrane attachment is in practice somewhat difficult and subjective as Neves and

Owens state (p.340) "in certain genera, e.g. Geminospora the degree of cameration may vary".

Smith and Butterworth 1967 (fig. 2.1) in their revision of Dettmann's classification agree with Richardson that the root "Perino" in combination with triletes, monoletes or hilates is unsatisfactory and that it should be retained only for spores in which there is a perispore or a perispore-like membrane. They divided the miospores at suprasubturma level on the basis of exine separation and introduced two new suprasubturmae, Laminatitriletes for trilete, cavate spores in which the exine layers are separated but remain in close contact and Pseudos-accitriletes (proposed as a subturma by Richardson 1965) for spores in which the exine layers are well separated. At subturma level they use the presence or absence of an equatorial feature as the only factor for this subdivision. They introduce a new infraturma Tuberculornati for a zonate, cavate spores. The emphasis in the subdivision of trilete camerate/cavate spore is thus placed on different features in the two systems. Neves and Owens emphasise the nature of the attachment of the exine layers, whereas Smith and Butterworth emphasise the degree of separation of the exine layers, both of which are subjective in their interpretation.

Potonié 1970 used anteturma Proximegerminates to replace his anteturma Sporites and in 1975 he revealed the detail of his new classification. He divided his anteturma Proximegerminates into four turma, and then subdivided each turma



F.2.1 The scheme for the classification of Anteturma Sporites as proposed by Smith and Butterworth 1967, text-fig.66.

into lower ranks. In his infraturma Cingulati, which related to the subturma Zonotriletes and turma Triletes, he did not distinguish between cavate and non-cavate genera; thus he put the genera Densosporites, Lycospora, Knoxisporites, Cingulizonates, Callisporites and Kraeuselisporites in this infraturma.

Since the classification of Smith and Butterworth 1967 accommodates all the Westphalian genera, which were not recorded by Neves and Owens 1966 in their Namurian sequences, the classification of Smith and Butterworth is used in this work. The assignment of genera to suprageneric taxa in this work is indicated in the table of contents.

CHAPTER 3

PRACTICAL TECHNIQUES

3.1 Sample Preparation.

No field work is involved in this study as all the samples of the present investigation were kindly provided by the N.C.B. They are of coal as detailed in Tables 1 and 2. The samples represent 8 off-shore boreholes from Northumberland; the seams in each borehole are represented either by core samples or by many subsections which together constitute the whole thickness of the seam and which may include small gaps indicating the omission of certain inferior subsections.

After the samples were checked and arranged they were ready for laboratory treatment which is of two kinds.

3.1.1. Physical treatment

The samples were reduced in bulk to 30gm by a manual splitter and then crushed by pestle and mortar to pass a 36 B.S. (0.42mm) mesh sieve. After each sample was crushed the mortar and the pestle were cleaned thoroughly with a brush and hot water and then dried; compressed air was also used to clean the sieve and the splitter. These precautions were taken in order to reduce the chance of contamination. Composite samples were then made from successive subsections of the same lithology, the contribution of each subsection to the whole sample depending upon its thickness. Any subsection which was separated by a gap or had different lithology was kept as a separate sample.

3.1.2. Chemical treatment

The maceration techniques used during the present investigation followed the method of Zetzsche and Kälin (1932), only preliminary treatment with bromine appeared unnecessary. 25-30 ml. of fuming nitric acid are added to 0.75-1gm of coal in a 75ml. beaker at room temperature for at least 16 hours. After the appropriate time filtration was carried out in a pyrex Buchner funnel containing a sintered glass disc (porosity grade 3). The residue is washed first with fuming nitric acid until the filtrate is colorless, then with concentrated nitric acid followed by dilute nitric acid and finally distilled water. This gradation in washing the samples will prevent any flocculation of the particles and will accelerate the filtration process. The method using fuming nitric acid can be easily controlled, is simple, and does not require the use of alkali with its possible damaging effect on the spore exines.

3.1.3. Use of Ultrasonic vibrations

Some spore residues, especially those of inferior coal, are improved by treatment with ultrasonic vibrations; this treatment disrupts aggregates and removes particles of adhering matter from the exine. The time of treatment is usually between 10-20 secs; after 4 hours all the spores settle at the bottom of the jar and the suspended material is decanted. This process is repeated two or three times until the sample is cleaned. The equipment used is an Ultrasonic Cleaning Kit, Type UL-100, manufactured

by Burndept Ltd. with tank unit.

3.1.4. Mounting of organic residue

During the present investigation cellosize and canada balsam were used as mounting media. This method is applied following the procedure of Jeffords and Jones (1959) in which cellosize (hydroxyethyl cellulose) is used as an excellent dispersing agent and as a thin film-former which is mixed with the organic residue. The method adopted in this work differs from that of Jeffords and Jones in that canada balsam is used to mount the cover slip onto the glass slide instead of a thermosetting plastic.

I. A few drops of the organic residue are drawn off by means of a slender pipette and with a few drops of 2% cellosize solution are placed in a small jar and thoroughly mixed using a pipette.

II. One or two drops of the mixture is then spread evenly over the entire surface of the cover slip. The moisture is allowed to dry off slowly on a low-temperature hot plate and the cellosize dries as a hard thin film.

III. The temperature of the hot plate is raised up to 110°C and the canada balsam spread thinly over the entire cover slip.

IV. The cover slip is removed carefully, inverted and replaced on the cleaned glass slide on the 110°C hot plate. A needle aids in moving the cover slip to the proper position.

V. The slide is removed from the hot plate and left until

cooled and the canada balsam set hard. Any excess balsam may be cleaned from around the cover slip with methylated spirits. After labelling the slide is ready for use.

The advantages of this method over other mounting media are firstly, cellosize is a dispersal agent so that flocculation does not occur on the slide and secondly, since cellosize dries as a thin film the spores are all in the same plane of focus. In addition such slides appear to be permanent as they are not liable to dry up in the way that slides made up with glycerine jelly do.

3.2 Microscopy

Routine logging of the assemblages was carried out at a magnification of 400 times using VICKERS MICROSCOPE. Fine details of morphology were observed at higher magnification; all photographs taken were with the ZEISS PHOTOMICROSCOPE II and the stage coordinates for photographed specimens relate to that microscope.

3.3 Use of Scanning Electron Microscope

3.3.1. Introduction

The use of SEM (scanning electron microscope) in palynological investigations has increased considerably since its introduction. This instrument has proven to be useful not so much because of its greater magnification capability but because its greater depth of focus produces better illustration for publication.

One of the basic problems, however, is the picking and mounting of the spores on SEM stubs. This often is time-

consuming and involves special care and techniques.

3.3.2. Picking and Coating Technique

I. A drop of a suspension containing clean well preserved material is spread over a glass slide and a search for a good specimen is carried out using a binocular microscope at a magnification of x100.

II. Another glass slide is cut into three pieces each with a diameter approximately equal to the diameter of the SEM,stub. One of these small glass slides, with a drop of distilled water on it which serves as a cushion for the transferred spores, is placed on the stage of a stereoscopic microscope using a magnification of x40.

III. A thin painting brush with not more than 6 hairs, and fuse wire mounted to a wooden holder, are used to pick up the spores.

IV. Cleaning around the spore which is chosen to be picked, is carried out with the fuse wire. Then the spore is picked up with the brush and transferred to the small glass slide where the drop of water will prevent the spore from breaking when it is released from the brush.

V. Five or six spores in every attempt are transferred to the small glass slide before the drop of water dries, after which the spores are marked by an ink circle which can be easily detected in the SEM because of its higher relief.

VII. Since palynomorphs are nonconductors, it is necessary to coat them with a heavy metal in order to obtain a satisfactory emission of secondary electrons and consequently

good detail. Proper coating is absolutely necessary for satisfactory results with the SEM. Experimentation has shown that gold gives the best reproducible results. Specimens to be coated are placed 2cm under the anode (gold disc) for exactly three minutes; time here is a critical factor. It is advisable to switch-off the current of the coating machine in the course of the 3 minutes to allow the specimen to cool down.

VII. The glass slide is then mounted on the SEM stub and because glass is a nonconductor, silver metal is used to connect the thin film of gold with the SEM stub. 2 to 3 minutes is allowed for the silver to dry and the specimen is ready for SEM study.

Satisfactory results have been obtained using this technique and scanning election photographs are presented in this work.

CHAPTER 4

SYSTEMATIC DESCRIPTION OF SPORES

All the spores described in this chapter and figured in plates 1-24 were recovered from the Westphalian A and B of eight off-shore boreholes in Northumberland. The description terminology and classification of ornament etc. are those suggested by Grebe 1971.

The suprageneric arrangement of spore genera is according to that of Smith and Butterworth 1967.

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

Diagonis. (Smith and Butterworth 1967, p.121, translation from Potonié and Kremp 1954, p.120).

Remarks

Deltoidospora Miner 1935 is the post-Palaeozoic

equivalent of Leiotriletes, and following Smith and Butterworth 1967 in retaining the generally accepted nomenclature for Palaeozoic dispersed-spora genera since the problem is not confined to Leiotriletes, it is considered appropriate in this study to keep the genus Leiotriletes.

Leiotriletes adnatus (Kosanke) Potonié and Kremp 1955.

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

1955 Leiotriletes adnatus (Kosanke) Potonié and Kremp.

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

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

Diagnosis. (See the description in Kosanke 1950, p.20).

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

Leiotriletes cf. adnatus (Kosanke) Potonié and Kremp 1955.

Plate 1 figures 1-5 & 7

Size in micrometres (i) 24(26)33 (22 specimens), fum. HNO_3. Top and Bottom Yard (Top leaf) (G1./G2.1 at 217 ft. 1 in. Northumberland off-shore borehole No.6, England, Westphalian B.

Description. Amb triangular, angleS rounded, sides straight to slightly convex. Laesurae simple straight, 1/2-2/3 of spore radius, commonly opened. Exine laevigate distally and proximally, 1-2.0 µm, thick sharp contact area present. No folds.

Remarks. L. cf adnatus differs from the type in its smaller size, its straight to slightly convex interradial margins, and the specimens observed in the Bottom Main and Bottom Brass Thill seams display no ornamentation in the area adjacent to the tetrad mark, even under high power oil immersion objective.

Comparison. L. sp.1 (Ravn 1979, Pl.1, fig.5) resembles L. cf adnatus but the former has concave sides.

Occurrence. Infrequent in Top and Bottom Yard seam and rare in Bottom Brass Thill seam of Northumberland offshore boreholes, Westphalian B.

Leiotriletes guennelii Ravn 1979

Plate 1 figures 8 & 11

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

non 1953 Leiotriletes parvus Naumova, p.44, Pl.5, fig.10.

non 1958 Leiotriletes parvus Nilsson, p.30, Pl.1, fig.1

1967 Leiotriletes parvus Guennel in Smith and Butterworth, p.122 Pl.1, figs. 3,4.

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

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

Type locality. Outcrop coal, Upper Block b Zone, Owen County, Indiana, USA, Pottsville Series.

Diagnosis. See Smith and Butterworth 1967, p.122, from description in Guennel 1958, p.57.

Size in micrometres. (i) Holotype 22; 16(20)28, Schulze (Guennel 1958). (ii) 27-29 (4 specimens), fum. HNO_3, Top Yard and Bottom Yard (Top leaf) (Gl./G.2.1) at 217 ft. 1 in., Northumberland off-shore borehole No.6, England, Westphalian B. (iii) 23(27)29 (8 specimens), fum. HNO_3, Bottom Brass Thill (K2) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb triangular, angles rounded, inter-radial margins concave. Laesurae simple, sometimes slightly flexuose, ¾ of spore radius. Exine thin, laevigate. Gulaferus type of compression present.

Remarks. As noted by Ravn 1979 the employment of L. parvus by Nilsson 1958 for a Mesozoic taxon required the adoption of a new name for the species. L. parvus Naumova 1953 is a homonym of L. parvus Guennel 1958 but Naumova's name was not erected in accordance with the provisions of the International Code of Botanical Nomenclature and is considered invalid.

Comparison. L. subadnatoides Bhardwaj 1957a is comparable in size with L. guennelii but differs in possessing "intrapunctate" ornamentation and straight sides. Deltoidospora implumis Staplin 1960 (p.14, pl.3, fig.5) is also similar

in size but the exine is thicker in the contact area.

Occurrence. Infrequent in Top and Bottom Yard and Bottom Brass Thill seams of Northumberland off-shore boreholes Westphalian B. Smith and Butterworth 1967, Westphalian A-D., Coals of Great Britain; Ravn 1979. Cherokee Group CP-19-4 Coals of Iowa.

Leiotrilete levis (Kosanke) Potonié and Kremp 1955.

Plate 1, figures 14-16.

1950 Granulati-sporites levis Kosanke, p.21, Pl3, fig.5.

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

1966 Ahrensisporites vagus Habib, p.640, Pl.106, fig.5.

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

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

Diagnosis. See description in Kosanke 1950, p.21.

Size in micrometres. (i) Holotype 48x50, Schulze and 10% KOH (Kosanke 1950) (ii) 35(36)41 (14 specimens), fum. HNO_3, Top Yard and Bottom Yard (Top leaf) (Gl./G2.1) at 217 ft. lin., Northumberland off-shore borehole No.6, England, Westphalian B.

Description. Amb triangular, angles rounded, sides

straight to slightly convex, occasionally concave. Laesurae simple, straight ½-¾ of spore radius, sometimes reaching the amb. Exine moderately thick 2-3 µm , laevigate, or sometimes infrapunctate; conspicuous thickening of the exine around the contact area, occasionally extends round the spore apices to produce pseudokyrtomes. No folds.

Comparison. Ahrensisporites vagus Habib 1966, p.640, pl. 106, fig. 5 is very similar to L. levis and is considered in this study to be synonymous with it.

Occurrence. Rare in Top and Bottom Yard, Bottom Brass Thill and Bottom Main (Top leaf) seams of Northumberland off-shore boreholes, Westphalian B. Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois Basin; Ravn 1979 Cherokee Group CP-19-4 Coals of Iowa, USA.

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, USA, Upper Mississipian.

Diagnosis. (Smith and Butterworth 1967; p.122, from Berry 1937, p.156).

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

Leiotriletes cf. priddyi (Berry) Potonie and Kremp 1955

Plate 1 figures 6,9 & 10

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

Size in micrometres. (i) 27(32)36, fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England; Westphalian B (Smith and Butterworth 1967). (ii) 20(27)35, conc. HNO_3 and 2% KOH (Sullivan 1964); Edgehills Coal, Forest of Dean Coalfield, England, Westphalian A. (iii) 24(29)32 (21 specimens), fum. HNO_3, Bottom Brass Thill (K2) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb triangular, angles well rounded, sides straight to slightly convex. Laesurae simple, straight, usually opened, 1/2 - 2/3 of spore radius. Exine thin, laevigate. Compression folds exist, commonly gulaferus type compression.

Remarks. As noted by Sullivan 1964 and Smith and Butterworth 1967, the inadequate description and

illustration of L. priddyi make comparison impossible.

Comparison. L. cf. priddyi differs from L. guennelii in having straight to slightly convex sides and from L. cf. adnatus in the absence of a distinct contact area.

Occurrence. Rare in Bottom Brass Thill, Bottom Main (Top leaf) seams of Northumberland off-shore boreholes, Westphalian B. Sullivan 1964, Edgehills coal, Westphalian A, Forest of Dean, Smith and Butterworth, 1967, Namurian to Westphalia B, Coals of Great Britain.

Leiotriletes sphaerotriangulus (Loose) Potonié and Kremp 1954

Plate 1, figures 12,13, & 17

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 sphaerotriangulus (Loose); Schopf, Wilson, and Bentall, p.31.

1950 Plani-sporites sphaerotriangulus (Loose); Knox, p.316, pl.17, fig.214.

1954 Leiotriletes sphaerotriangulus (Loose); Potonié Kremp, p.120.

1955 Leiotriletes sphaerotriangulus (Loose); Potonié and Kremp, p.41, pl.11, figs. 107-109.

Holotype. Potonié and Kremp 1955, pl.11, fig.107 after Loose. Preparation IV 21, f_2 (m/ol).

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

Diagnosis. (See Smith and Butterworth 1967, p.123, from Potonié and Kremp 1955, p.41; translation).

Size in micrometres. (i) Holotype 43.5, Schulze. (ii) 40-60 Schulze (Potonié and Kremp 1955). (iii) 30-66, fum. HNO_3 (Horst 1955). (iv) 38(46)55, fum. HNO_3; Swallow Woodseam Denaby Main Colliery, Yorkshire Coalfield, England, Westphalian B (Smith and Butterworth 1967). (v) 32(37)45 (18 specimens), fum. HNO_3, Top Yard and Bottom Yard (Top leaf) (G.1/G2.1) at 217 ft. 1 in., Northumberland off-shore borehole No.6, England, Westphalian B.

Description. Amb triangular, angles rounded, interradial margins straight to slightly convex, occasionally one or two sides tend to be concave. Laesurae simple, straight, ½ - ¾ of spore radius (average 13 µm). Exine 1-1·5 µm in thickness, laevigate. Compression folds usually absent.

Comparison. The absence of a contact area distinguishes this species from L. levis which is comparable in size. L. sphaerotriangulus is larger than L. cf. priddyi. In the present work unornamented forms of Leiotriletes having straight to slightly convex sides, no contact area and a diameter of 33-45 µm are assigned to L. sphaerotriangulus. L. ficilis Ishchenko 1952 (pl.1, fig. 5) and L. falsus Ishchenko 1952 (pl.1, fig.6) are considered by Dybova and Jachowicz 1957, p.123 to be in part synonymous with L. sphaerotriangulus.

Occurrence. Infrequent in Top and Bottom Yard (Top leaf)

and High Main seams of Northumberland off-shore boreholes Westphalian B. Artüz 1959, Zonguldak Basin, Namurian and Westphalian A; Love 1960, Lower Oil Shale Group of Scotland; Smith and Butterworth 1967, Westphalian A to Lower Westphalian C, Coals of Great Britain; Grebe 1972, Upper Westphalian A to Upper Westphalian C, Ruhr Coal-field, Germany; Ravn 1979 Cherokee Group CP-19-4 Coals of Iowa, USA.

Genus PUNCTATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. P. punctatus

Diagnosis. (Smith and Butterworth 1967, p.124, translation from Potonié and Kremp 1954, p.120).

Punctatisporites edgarensis Peppers 1970

1970 Punctatisporites edgarensis Peppers, p.82-83, pl.1, figs. 16,17.

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

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

Size in micrometres. (i) Holotype 121.9 x 113.8; 90 (130.7) 152.8 (21 specimens), Schulze and KOH (Peppers 1970).

Punctatisporites cf. edgarensis Peppers 1970, in Ravn 1979

Plate 1, figures 18-23.

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

Size in micrometres. (i) 132.1, Schulze and KOH (Ravn 1979)

(ii) 74(84)96, (13 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded-triangular with undulating margin. Laesurae simple straight, ½-¾ of spore radius, sometimes open. The distal surface bears conspicuous, sharply bounded, low, vermiform to convolute ridges, situated all over the surface, but mainly around the spore margin, while on the proximal surface the number of those structures is reduced and they sometimes tend to merge with the rest of the spore coat. Exine laevigate, 4-8 µm thick.

Remarks. The specimens are smaller than those described by Ravn 1979.

Comparison. Differs from the type in possessing distinct and well-defined structures on the distal surface. P sinuatus (Artüz) Neves 1961 has a more rounded shape and is not so strongly folded as P cf. edgarensis, especially on the distal surface.

Occurrence. Rare in Bottom Brass Thill, Bottom Main and Harvey seams of Northumberland off-shore boreholes, Westphalian A and B. Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Puntatisporites punctatus Ibrahim 1932

Plate 2, figues 1-4

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(U1).

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

Diagnosis. (See Smith and Butterworth 1967, p.189, from Ibrahim 1933, p.21).

Size in micrometres. (i) Holotype 77, Schulze and KOH. (ii) 50-80 Schulze (Potonie and Kremp 1955). (iii) 59 (74)89 (14 specimens) fum HNO_3, Swallow Wood Seam at 1,475 ft. 0 in., Kellingly borehole Yorkshire Coalfield, England, Westphalian B, (Smith and Butterworth 1967). (iv) 49(64)75 (9 specimens), fum HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb circular to subcircular. Laesurae simple, straight ½-2/3 of spore radius, (range 13 to 24 µm), sometimes open and occasionally with narrow lips about 1 µm wide. Exine 1-2.5 µm thick, punctate or scabrate but the margin smooth, sometimes faint contact area present, usually single narrow fold present.

Comparison. P aerarius Butterworth and Williams 1958 differs in having a finely granulate and slightly thicker exine. According to Smith and Butterworth 1967 P irrasus Hacquebard 1957 has a major arcuate compression fold.

Occurrence. Rare throughout Westphalian A and B sequences. Northumberland off-shore boreholes. Guennel 1958, Pottsville Coals, Indiana. Sullivan 1964, Edgehills Coal, Forest of Dean, Westphalian A, England. Smith and Butterworth 1967, Upper Westphalian A to Lower Westphalian C, British Coalfields. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany.

Punctatisporites obesus (Loose) Potonié and Kremp, 1955

Plate 2, figures 5,6.

1932 Sporonites obesus Loose in Potonié, Ibrahim, and Loose, p.451, pl.9, 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. Bismark Seam, Ruhr Coalfield, Germany, Upper Westphalian B.

Diagnosis. (see Smith and Butterworth 1967, p.127, from description in Loose 1934, p.145).

Size in micrometres. (i) Holotype 117, Schulze. (ii) 100-130, Schulze (Potonié and Kremp, 1955). (iii) 94(106)125 (8 specimens) fum. HNO_3 various horizons, Great Britain; Westphalian B to D, (Smith and Butterworth 1967). (iv) 72

(93)107 (8 specimens), fum HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb subcircular to rounded triangular. Laesurae simple, straight, ½-2/3 of spore radius (range 22.5 to 32 µm) sometimes open, Exine 5-6.5 µm thick, laevigate, conspicuous contact area present. No folds.

Remarks. Specimens recorded in this study are smaller than those described by other authors.

Comparison. The size and the thickness of the exine differentiate this species from other species of Punctatisporites. According to Smith and Butterworth P. flavus (Kosanke) Potonie and Kremp is similar in size and appearance to P obesus.

Occurrence. Rare throughout Westphalian A and B sequences. Northumberland off-shore boreholes. Guennel 1958, Pottsville Coals, Indiana, Smith and Butterworth 1967, Upper Westphalian A-D, British Coalfields. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany.

Punctatisporites sp.A

Plate 2, figures 7-9

Size in micrometres. (i) 54.5 (58.6) 64 (5 specimens) fum HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded-subtriangular with one apex longer and narrower than the others, margin smooth. Laesurae

simple, straight, ¾-4/5 of spore radius, rays form two equal obtuse angles and the other one acute. Exine 2-3 µm thick, laevigate. Compression folds infrequent.

Comparison. Differs from other species of Punctatisporites in its shape and the angles between the laesurae.

Occurrence. Rare in Bottom Main, Bottom Brass Thill and seam 'D_2' at 146.07m, borehole EL_2, Northumberland offshore boreholes Westphalian B.

Genus RETUSOTRILETES Naumova 1953

1955 Phyllothecotriletes Luber 1935, p.37.

Type species R.simplex Naumova 1953

Diagnosis. (Streel 1964, pp 6-7 emended from Naumova 1953, p.18).

Comparison. Distinguished by its curvaturae and smooth exine.

Retusotriletes sp.A

Plate2, figures 10-13

Size in micrometres. (i) 32(33)35 (5 specimens) fum HNo_3, Bottom Main, at 123 ft. 6 in. Northumberland offshore borehole No.3, Westphalian B.

Description. Amb rounded triangular, margin smooth. Laesurae simple, straight, extending to the margin; the ends of the laesurae are connected by curvaturae. Exine 3.5 to 5 µm thick (measured at the equatorial margin), surface laevigate. Compression folds infrequent.

Occurrence. Rare in Bottom Main seam, Northumberland off-shore borehole No. 3, Westphalian B.

Genus CALAMOSPORA Schopf, Wilson, and Bentall, 1944

Type species. C. hartungiana Schopf in Schopf, Wilson and Bentall 1944.

Diagnosis. (Smith and Butterworth 1967, p.130, translation from Potonié and Kremp 1955, p.46).

Comparison. Differs from Punctatisporites (Ibrahim) Potonie and Kremp in possessing secondary folding due to a relatively thin exine.

Calamospora breviradiata Kosanke 1950

Plate2, figures 14-18.

1950 Calamospora breviradiata Kosanke pl.9, fig. 4

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

Type locality. No.2 Coal, Bureau County, Illinois, USA. Carbondale Group.

Diagnosis. (Smith and Butterworth 1967, p.131, from Kosanke 1950, p.41).

Size in micrometres. (i) Holotype 65.1 x 57.7; 52-71, Schulze and 10% KOH (Kosanke 1950). (ii) 64(67)74 (46 specimens), fum. HNO_3, Bottom Brass Thill at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B. (iii) 64(67)72 (31 specimens), fum. HNO_3,

Ashington seam at 45 ft. 1½ in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb circular or oval, shape irregular due to the compression folds. Laesurae raised, flexuose, commonly with lips, 1/3 of spore radius. Exine thin, pronounced thicker contact area present. Compression folds commonly well-developed.

Comparison. C. breviradiata can easily be distinguished by its ridged, short laesurae and darkened contact area.

Occurrence. Infrequent to frequent in Ashington, Bottom Brass Thill and Harvey seams, Northumberland off-shore boreholes. Smith and Butterwoth 1967; Namurian A to Westphalian C, British Coalfields. Owens and Burgess 1965, Namurian A to Westphalian A of Stainmore outlier, Britain; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, USA, Westphalian B.

Calamospora cf. breviradiata Kosanke 1950 in Smith and Butterworth 1967

Plate 3, figures 1-4

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

Diagnosis. (Description in Smith and Butterworth 1967, p.132).

Size in micrometres. (i) 42(49)57, fum. HNO_3 (Smith and Butterworth 1967) South Wales Coalfield, Lower Westphalian D.

(ii) 48(57.5)63 (40 specimens), fum. HNO_3, Bottom Brass Thill seam at 377 ft. 9 in., (iii) 51(57.5)61 (39 specimens) fum. HNO_3 Ashington seam at 45 ft. 1½ in., (ii) and (iii), Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb circular or oval, shape distorted by folding. Laesurae raised, slightly flexuose, with lips, 1/3 of spore radius. Exine thin, laevigate, contact area well developed. Numerous compression folds tend to follow the margin of the spore.

Remarks. C. cf. breviradiata is a smaller form of the type.

Comparison. C. minuta Bhardwaj 1957a is similar to C. cf. breviradiata and may actually be conspecific with it, the only difference mentioned by Bhardwaj 1957a, p.80 is that C. minuta has a thicker exine. However one of the specimens he illustrated (1957a, pl.2, fig.9) possesses numerous folds.

Occurrence. Infrequent in Ashington, Top and Bottom Yard, Bottom Brass Thill and Harvey seams, Northumberland off-shore boreholes, Westphalian A and B and rare throughout the sequence. Smith and Butterworth 1967, Upper Westphalian A to Westphalian D, British Coalfields.

Calamospora hartungiana Schopf, in Schopf, Wilson and Bentall 1944

Plate 3, figures 5-9

1944 Calamospora hartungiana Schopf, in Schopf, Wilson and Bentall pp. 51-52, text. fig. 1.

1965a Calamisporites hartungianus (Schopf) Laveine, p.131.

1966 Calamospora elliptica Habib, p.632-633, pl.104 figs. 9, 10.

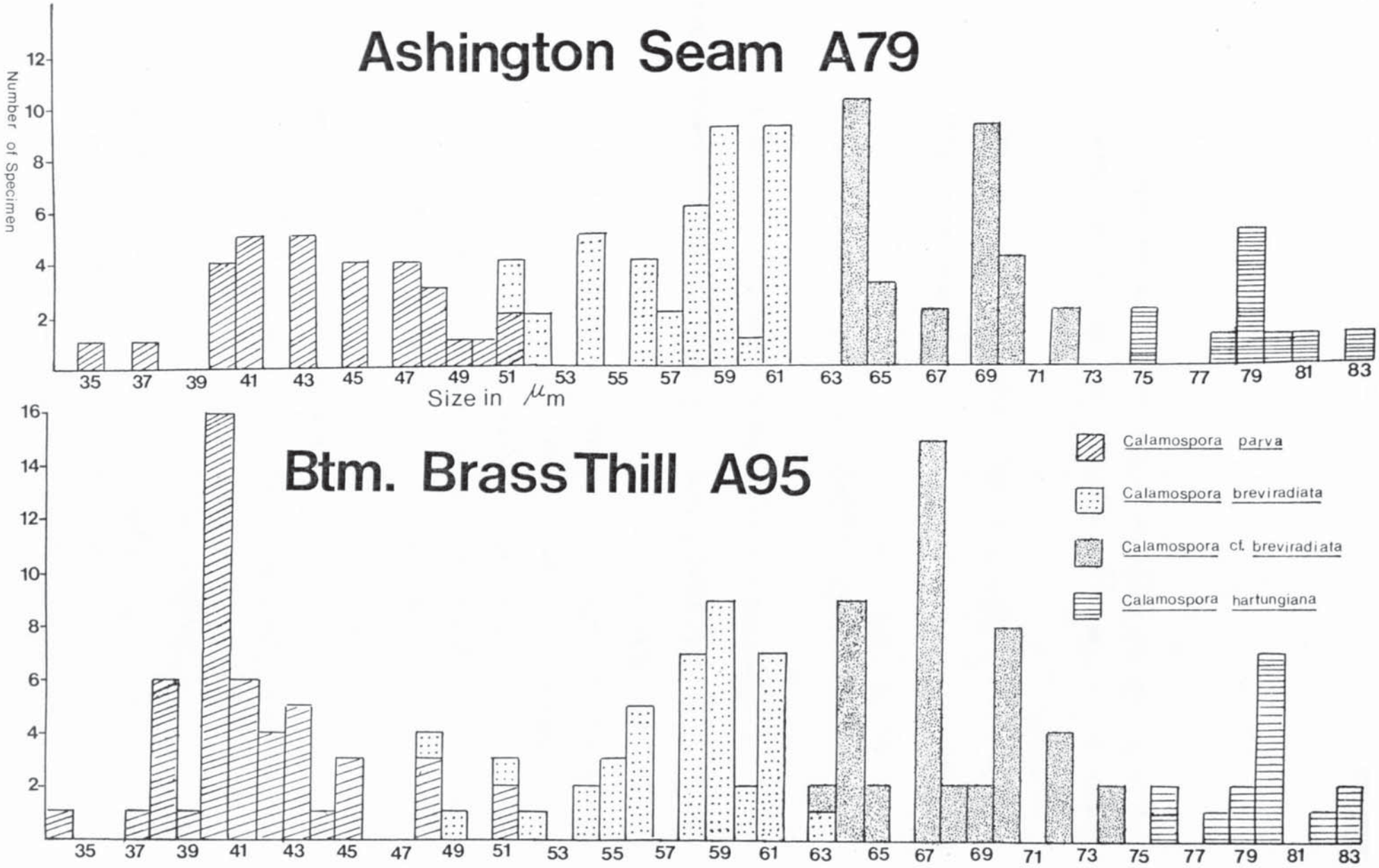
Holotype. Schopf 1944, slide Y of maceration 90, deposited in the Illinois Geological Survey collections, Urbana.

Type locality. 8-10 in. coal of the Macoupin cyclothem exposed along Salt Fork of Vermilion River north west of Fairmount, Vermilion County, Illinois, USA.

Diagnosis. (see description in Schopf, Wilson and Bentall 1944, p.51).

Size in micrometres. (i) 80-100 (Schopf 1944) (ii) 76(81)90 (18 specimens) fum. HNO_3, Bottom Brass Thill (K.2) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B. (iii) 74(81)103 (10 specimens) fum. HNO_3, Ashington seam (D/E) at 45 ft. 4 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb circular, sometimes oval. Laesurae short, slightly flexuose with narrow lips, ¼ of spore radius in length. Exine thin, laevigate, thicker in the area around the proximal pole, i.e. the contact area. Compression folds well-developed, often parallel to the margin of the spore.



Fig·4·1 Histograms showing the size distributions of four species of Calamospora

Comparison. In this study a size boundary is employed to differentiate between C. hartungiana and the smaller C. breviradiata, C. cf. breviradiata and C. parva. As shown in the histogram in Figure 4.1 , specimens larger than 75 µm are C. hartungiana, those between 63-75 µm are C. breviradiata, those between 50-61 µm are C. cf. breviradiata, and those less than 50 µm are C. parva. Ravn 1979 considered C. elliptica Habib to be synonymous with this species.

Occurrence. Rare but widely distributed in Bottom Brass Thill, Ashington, Main and Harvey seams, Northumberland off-shore boreholes, Westphalian A and B. Peppers 1970 Carbondale and Spoon Formation, Illinois, USA, Pennsylvanian. Ravn 1979 Cherokee Group CP 19-4 Coal of Iowa, Westphalian B.

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. (In Smith and Butterworth 1967, p.132, from diagnosis and description in Potonié and Kremp 1955, p.48.)

Size in micrometres. (i) Holotype 490, Schulze and KOH. (ii) 500, Schulze (Potonié and Kremp 1955).

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

Plate 3 figures 10-12

Size in Micrometres. (i) 150-260, fum. HNO_3, various localities, Great Britain, Westphalian A and B (Smith and Butterworth 1967). (ii) 154(168)183 (6 specimens), fum. HNO_3. Bottom Brass Thill at 377 ft. 9 in. borehole No. 3. (iii) 121(136.5)168 (4 specimens), fum. HNO_3, unnamed seam at 325 ft. 1 in., borehole No.5. (ii) and (iii) from Northumberland off-shore boreholes, England, Westphalian B.

Description. Amb elliptical, shape distorted by compression folding. Laesurae raised, straight, 1/3 of spore radius, surrounded by lips, width of lips 2-3.5 µm, and sometimes concealed by folding. Exine laevigate, 2 µm thick and darker in colour than any other species of Calamospora. A darkened contact area is present, although it is sometimes faint and the exine appears mottled. Broad major compression folds present.

Remarks. The presence of the contact area, the smaller size and the raised laesurae distinguish this form from the type.

Comparison. No other forms of Calamospora look like C. cf. laevigata; it can easily be distinguished by its size and the brown colour of the exine.

Occurrence. Rare in the Top Maudlin, Bottom Low Main, Bottom Brass Thill, and unknown at 225 ft., 1 in., borehole No. 5 seams in Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A to Lower Westphalian C, British Coalfields.

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

Plate 4 figures 1-3

1932 Sporonites microrugosus Ibrahim in Potonié, Ibrahim 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 microrugosa (Ibrahim) Schopf, Wilson, and Bentall, p.52.

1950 Calamospora liquida Kosanke p.41, pl.9, fig.1.

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 (1).

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

Diagnosis. (See Smith and Butterworth 1967, p.133 from description and diagnosis in Potonié and Kremp 1955, p.490.)

Size in micrometres. (i) Holotype 77, Schulze and KOH; 70-100, Schulze (Potonié and Kremp 1955). (ii) 62(82)104 Schulze and NH_4OH (Playford 1962); Spitsbergen, Lower Carboniferous. (iii) British specimens have been recorded up to 110, (Smith and Butterworth 1967). (iv) 74(79.5)95 (11 specimens), fum. HNO_3, Bottom Brass Thill at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B. (v) 74(79.5)89 (13 specimens) fum. HNO_3. Ashington seam (D/E) at 45 ft. 1½ in.; Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb rounded to oval, Laesurae simple, straight, 1/3-1/2 of spore radius. Exine thin, laevigate, markedly folded. Compression folds tend to follow the margin of the spore.

Comparison. C. microrugosa is distinguished from other forms of Calamospora in having longer laesurae and no contact area. C. liquida Kosanke 1950 differs only in possessing longer laesurae; this cannot be considered a sufficient basis for recognising a separate species, and in this study C. liquida is considered as a synonym of C. microrugosa (See Smith and Butterworth 1967, p.134).

Occurrence. Rare to frequent throughout the sequence; Artüz 1957, Namurian A to Westphalian B, Zonguldak, Turkey. Bharadwaj 1957, Westphalian C, Saar Coalfield, Germany. Dybova and Jachowicz 1957, Namurian A to Westphalian B, Upper Silesia. Smith and Butterworth 1967,

Viséan to Westphalian C, British Coalfields; Loboziak 1971, Viséan to Stephanian of Nord-Pas-de Calais Coalfield, France; Grebe 1972, Westphalian B and C, Ruhr Coalfield, Germany.

Calamospora nebulosa Ravn 1979

Plate 4 figures 4-9

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

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

Type locality. Cherokee Group CP 19-4 Coals of Iowa, USA.

Diagnosis. (See diagnosis in Ravn 1979, p.24).

Size in micrometres. (i) Holotype 85.2, 63-94 Schulze and 10% KOH. (Ravn 1979) (ii) 56(77)89.5 (15 specimens) fum. HNO_3, Ashington seam, at 45 ft., 1½ in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb circular or oval due to folding. Laesurae simple straight or slightly flexuose, often accompanied by distinct lips, 1/3-1/2 of spore radius. Distal surface shows irregular thickening usually in the polar region, often superimposed, due to compression, upon the laesurae giving the appearance of a contact area. Compression folds tend to follow the margin. Exine moderately thick.

Comparison. Distinguished from other species of the same size in posessing the distal thickening.

Occurrence. Rare to infrequent in the seam D_2 at 146.07m,

borehole EL_2, Ashington and Harvey seams, of Northumberland off-shore borehole, Westphalian A and B. Ravn 1979, Cherokee Grup CP19.4 Coals of Iowa, Westphalian B.

Calamospora pallida (Loose), Schopf, Wilson and Bentall 1944

Plate 4 Figures 10,11

1932 Sporonites pallidus Loose in Potonié, Ibrahim, and Loose, p.449, pl.18, fig.31.

1934 Punctatisporites pallidus Loose, p.146.

1944 Calamospora pallida (Loose); Schopf, Wilson and Bentall,p.52.

Holotype. Loose 1932, pl.18, fig.31 preparation Iv 26, d_4(U1).

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

Diagnosis. (Smith and Butterworth 1967 p.135, from description and diagnosis in Potonié and Kremp 1955, p.50).

Size in micrometres. (i) Holotype 58.5, Schulze. (ii) 55-70, Schulze (Potonié and Kremp 1955). (iii) 49(65)79 fum. HNO_3, Cannel seam, Bagworth Colliery, Leicestershire Coalfield, England, Lower Westphalian B (Smith and Butterworth 1967). (iv) 61(67.5)73 (18 specimens) fum. HNO_3, Bottom Brass Thill (K.2) at 377 ft. 9in. Northumberland off-shore borehole No.3 England, Westphalian B.

Description. Amb. circular, shape often distorted by folding. Laesurae simple, straight, 1/3-1/2 of spore radius, sometimes with lips. Exine, thin, laevigate,

numerous compression folds tend to follow the margin of the spore.

Comparison. A maximum size limit of 75 µm is used in this study to differentiate C. pallida from the larger C. microrugosa; most specimens of C. pallida were smaller than 70 µm, whereas most specimens of C. microrugosa were larger than 75 µm. C. flexilis Kosanke is very similar to C. pallida except that the former has folds running parallel with the laesurae. C. membrana Bhardwaj 1957a possesses a dark contact area and a characteristic thinning of the exine towards the equator. C. saariana Bhardwaj 1957a has a darkened contact area.

Occurrence. Rare in the Bottom Brass Thill and throughout the Westphalian B sequence of Northumberland off-shore boreholes. Bhardwaj 1957, Westphalian C, Saar Coalfield, Germany; Guennel 1958, Namurian C to Westphalian B, Pottsville Series, Indiana, USA; Smith and Butterworth 1967, Visean to Westphalian D, British Coalfields; Neves 1968, Visean to Lower Westphalian A, Woodland Borehole, Co. Durham; Sabry and Neves 1971, Namurian to Westphalian C, Sanquhar Coalfield, Scotland; Grebe 1972 Westphalian B to C, Ruhr Coalfield, Germany.

Calamospora parva Guennel 1958

Plate 4 figures 12, 13

1958 Calamospora parva Guennel Fig.16

Holotype. Guennel 1958, fig.16, p.71. Sample 66 slide 4104

Type locality. Outcrop Coal, Upper Block b Zone, Daviess County, Indiana, USA., Pottsville Series.

Diagnosis. (Smith and Butterworth 1967 p.136 from description in Guennel 1958, p.70).

Size in micrometres. (i) 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. (ii and iii Smith and Butterworth 1967). (iv) 34(41.5)51 (49 specimens) fum. HNO_3, Bottom Brass Thill (K.2), at 377 ft. 9in. Northumberland off-shore borehole No.3, England, Westphalian B. (v) 35(44)51 (34 specimens) fum. HNO_3, Ashington Seam (D/E), Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb commonly circular, but sometimes tends to be elliptical or irregular due to compression folds. Laesurae simple, slightly flexuose, sometimes concealed by folds, 1/3 of spore radius. Exine thin, laevigate, slightly darkened contact area. Compression folds short and narrow.

Comparison. C. parva can easily be distinguished from other forms of Calamospora by its smaller size and shorter laesurae. (See Fig. (4·1) for histograms). C. exigua staplin 1960 is identical to C. parva

in all respects except in the unequal length of its laesurae.

Occurrence. Frequent to common throughout the sequence in Northumberland off-shore boreholes. It is the most common species of Calamospora observed in this study. Guennel 1958, Pottsville Coals of Indiana, USA; Owen and Burgess 1965, Stainmore, Britain, Namurian A to Lower Westphalian B; Smith and Butterworth 1967, Visean to Westphalian B, British Coalfields; Sabry and Neves 1971, Sanquhar Coalfield, Scotland; Whitaker 1978, Ballycastle, Ireland.

Calamospora pedata Kosanke 1950

Plate 4 figures 14-16

1950 Calamospora pedata Kosanke pl.9, Fig.3

Holotype. Kosanke 1950, pl.9, fig.3. Maceration 542-C, slide 3.

Type locality. No. 8 Coal, Peoria County, Illinois, USA, McLeansboro Group.

Diagnosis. (Smith and Butterworth 1967 p.136 from description in Kosanke 1950, p.42).

Size in micrometres. (i) Holotype 70.3 X44.1; 41-75 Schulze and 10% KOH (Kosanke 1950). (ii) 38(49.0)72 (14 specimens), fum. HNO_3 Bottom Brass Thill (K.2) at 377 ft.9in., Northumberland off-shore borehole No.3, England, Wesphalian B.

Description. Amb elliptical as a result of compression.

Laesurae simple, straight, sometimes unequal in length. Exine, thin, laevigate. One major broad compression fold is present, others if present are narrow and short.

Comparison. C. pedata is characterised by the presence of a single major broad fold which easily distinguishes this species from other forms of Calamospora.

Occurrence. Absent to rare throughout the sequence. Infrequent in Ashington and Bottom Brass Thill seams, Northumberland off-shore boreholes. Grebe 1962, Westphalian B to C, Ruhr Coalfield, Germany; Owens and Burgess 1965, Upper Namurian A to Lower Westphalian B, Stainmore, Britain; Smith and Butterworth 1967, Namurian and Westphalian British Coalfields.

Calamospora cf. pedata Kosanke 1950 in Ravn 1979

Plate 4 figures 17-20

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

Description. Amb more or less circular, sometimes sharply lenticular due to compression. Laesurae, ridged, raised with distinct lips, sometimes unequal in length, ½ of spore radius. Exine yellowish brown, laevigate, moderately thick, a faint contact area is present and single major, broad, well-developed compression fold.

Size in micrometers. (i) 61.0 x 92.3 µm, (Schulze, KOH, HF) (Ravn 1979). (ii) 32(55.5)80 (28 specimens), fum. HNO_3 Bottom Brass Thill at 377 ft. 9 in., Northumberland off-

shore borehole No.3, England, Westphalian B.

Comparison. Differs from the type in possessing, short raised laesurae with distinct lips. A faint contact area is often present in C. cf. pedata and the colour of the species is darker than the type.

Occurrence. Rare in the Bottom Brass Thill, and Bottom Main (Top leaf). in Northumberland off-shore boreholes. Ravn 1979 Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Calamospora straminea Wilson and Kosanke 1944

Plate 4 figures 21-24

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. 276P, circle 2.

Type locality. Coal from Angus Coal Company Mine, Iowa, USA, Des Moines Series.

Diagnosis. (See Smith and Butterworth 1967, p.137, from description in Wilson and Kosanke 1944, p.329).

Size in micrometres. (i) 30-45, maceration method not known (Wilson and Kosanke 1944). (ii) 31(39)47, fum. HNO_3; seam at 56 ft. 4 in., Murton Colliery borehole, Durham Coalfield, England, Upper Westphalian B. (Smith and Butterworth 1967.).

(iii) 33(39)43 (25 specimens) fum. HNO_3 Bottom Brass Thill (K.2) at 377 ft.9in, Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb circular. Laesurae distinct, simple, slightly flexuous, 1/3 of spore radius sometimes with lips. Exine laevigate 1-1.5 µm thick, part of the contact area is faintly darker in colour. Compression folds few, commonly only one fold present, and sometimes the spore is preserved without folding.

Remarks. The spores examined in this study have a thinner exine than those recorded by Wilson and Kosanke 1944.

Comparison. The presence of a narrow single fold, and the slightly thicker exine distinguish this species from C. parva which is of similar size.

Occurrence. Frequent to common throughout the Westphalian B seams of the Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian B-D, British Coalfields; Loboziak 1971, Westphalian B, Nord-Pas-de-Calais Coalfield, France.

Calamospora sp.A

Plate 5 figures 1-5

Size in micrometres. 32(37.3)42 (15 specimens) fum. HNO_3, Bottom Brass Thill, at 377 ft. 9 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb circular, sometimes slightly oval, margin

smooth. Laesurae short, 1/3 of spore radius or less, accompanied by narrow folds which diverge at the end of the rays. Only part of the contact area is darker in colour, usually extending to half the laesurae. Exine thick, laevigate, with several shallow partially superimposed depressions separated from each other and from non-depressed areas by arcuate ribs; the radius of their curvature never exceeds the maximum observed spore radius. Single narrow peripheral fold occasionally present.

Comparison. C. straminea Wilson and Kosanke 1944 lacks the arcuate boundaries.

Remarks. According to Clayton 1972, p.124 this style of exine deformation is due to preservation of spores in clusters within the sporangia. If the exine is thick relative to the spore diameter, indentations from surrounding spores result rather than folding, during compression. He states that a laevigate exine allows contact with adjacent spores over a large surface area, unimpeded by ornament; but this is not necessarily true because this style of exine deformation also occurs in ornamented spores like Apiculatasporites sp.A.

Occurrence. Rare in Bottom Brass Thill borehole No.3 and Top and Bottom Yard borehole No.6, Northumberland off-shore boreholes, Westphalian B.

Genus ADELISPORITES Ravn 1979

Type species A. multiplicatus Ravn 1979

Diagnosis. (Ravn 1979, p.25).

Comparison. Distinguished from Calamospora by its more or less hexagonal shape and raised ridged laesurae.

Adelisporites multiplicatus Ravn 1979

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

Type locality. Cherokee Group CP.19.4 Coals of Iowa, Pennsylvanian.

Diagnosis. (See diagnosis in Ravn 1979, p.25).

Size in micrometres. (i) Holotype 26.8, 21-34, Schulze and 10% KOH (Ravn 1979).

Adelisporites cf. multiplicatus

Plate 5 figures 6-10

Size in micrometres. (i) 24(28.1)30.5 (10 specimens) fum. HNO_3. Bottom Main at 123 ft.6in., Northumberland off-shore borehole No.3, Westphalian B. (ii) 22.5(32.0)41.5 (8 specimens) fum. HNO_3, various localities, Northumberland off-shore boreholes, Westphalian A and B.

Description. Shape polygonal, often more or less hexagonal. Laesurae raised slightly flexuose, ¾ of spore radius to full extent of the radius. Exine moderately thick, 1-2 µm thick, laevigate, heavily folded, folds with no specific orientation.

Comparison. Differs from the type in maintaining a less definite pseudohexagonal shape; some specimens slightly larger. C. macer Williams lacks the pseudohexangonal shape and the ridged elevated laesurae.

Occurrence. Rare to infrequent in Seam D_2 at 146.07m borehole EL_2, Top and Bottom Yards borehole 6 and Bottom Main borehole No.3, Northumberland off-shore boreholes, Westphalian B.

Infraturma APICULATI (Bennie and Kidston) Potonié 1956

Subinfraturma GRANULATI Dybova and Jackowicz 1957

Genus GRANULATISPORITES (Ibrahim) Potonié and Kremp 1954

Type species. G. granulatus

Diagnosis. (Smith and Butterworth 1967, p.138, translation from Potonié and Kremp 1954, p.126).

Comparison. Distinguished from other genera by its triangular outline and regular, granulate nature of the ornament.

Granulatisporites adnatoides (Potonié and Kremp) Smith and Butterworth 1967

Plate 5 figures 11-13

1955 Leiotriletes adnatoides Potonié and Kremp, p.38, pl.11 figs 112-115

1960 Granulatisporites parvigranulatus Staplin, p.15, pl.3, figs 8, 9.

1964 Granulatisporites tenuis Peppers, p.20, pl.12, figs.11,12

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1965a Deltoidisporites adnatoides (Potonié and Kremp) Laveine, p.131.

1967 Granulatisporites adnatoides (Potonié and Kremp) Smith and Butterworth, p.139, pl.3, figs. 12,14.

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. (See Smith and Butterworth 1967, p.139, emended from diagnosis in Potonié and Kremp 1955, p.38).

Size in micrometres. (i) Holotype 36; 30-40, Schulze (Potonie and Kremp 1955). (ii) 27(31)35 (18 specimens) fum. HNO_3, Sharlson Top Seam, Cross Hill borehole, Yorkshire Coalfield, England, Westphalian C. (iii) 27(31)38, fum. HNO_3, Yorkshire Coalfield, England, Westphalian B (ii and iii Smith and Butterworth 1967. (iv) 26(29.5)36 (18 specimens) fum. HNO_3 Top and Bottom Yard (G1./G2.1) at 217 ft. lin., Northumberland off-shore borehole No.6, England, Westphalian B.

Description. Amb triangular, angles broadly rounded, interradial margins straight to slightly convex. Laesurae simple, straight, sometimes open, 2/3 of spore radius occasionally reaching the equator. Exine thin, very finely granulate, a narrow thickened contact area is present along the sutures and extends almost to the ends of the rays. Folding sometimes occurs.

Remarks. As noted by Smith and Butterworth 1967, examination under oil immersion reveals the outer surface of the spore to be granulose and not an infrasculpture as stated by Potonié and Kremp 1955. Leiotriletes adnatus (Kosanke 1950, p.20, pl.3, fig. 9). Potonié and Kremp is a very similar species and is described as finely granulose in the area adjacent to the tetrad scar. In practice it is very difficult to distinguish between the two species. In this work all forms with very fine grana which are visible under low power are assigned as G. adnatoides.

Comparison. G. adnatoides can easily be distinguished by its very fine ornament, straight to slightly convex sides and the presence of a narrow contact area. Leiotriletes subadnatoides Bhardwaj 1957a is infra-punctate. G. cf. parvus (Ibrahim). Potonié and Kremp illustrated in Peppers 1970 appears very similar to G. adnatoides.

Occurrence. Frequent in Top and Bottom Yard (Top leaf) Seam, infrequent in Ashington seams, and rare throughout the sequence of Westphalian A and B of Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A - Upper Westphalian C. Ravn 1979, Cherokee Group CP.19.4 Coal of Iowa, USA.

Granulatisporites granlatus Ibrahim 1933

Plate 5 figures 14,15

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

1967 Granulatisporites granulatus Ibrahim; Smith and Butterworth, p.140, pl.3, figs. 15-17.

Holotype. Ibrahim 1933, pl.6, fig.51, preparation D57, 67(U1).

Type locality. Bismark Seam, Ruhr Coalfield, Germany, Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.140, from Potonié and Kremp 1955, p.58, translation).

Size in micrometres. (i) Holotype 31, Schulze and KOH. (ii) 25-35, Schulze (Potonié and Kremp 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 Low deep No.36 borehole, Northumberland Coalfield, England, Namurian B/C. (v) 22(27)35, fum. HNO_3, Northumberland Coalfield, England, Viséan. (iii - V. Smith and Butterworth 1967). (vi)24(26)29 (14 specimens), fum. HNO_3, Top and Bottom Yard (G1./G2.1) at 217 ft. lin., Northumberland off-shore borehole No.6, England, Westphalian B. (vii) 26, fum. HNO_3, Bottom Brass Thill (K.2.) at 377 ft. 9 ins., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb triangular, angles rounded, sides concave. Laesurae simple straight, sometimes opened, ½ - ¾ of spore radius. Exine, thin, granulate, the grana are

about 0.75-1.5 μm and are evenly distributed but their bases are not touching, 25-40 project at the equator. Folding commonly absent.

Remarks. All the specimens encountered in this study have concave inter-radial sides rather than convex ones which is different from the type. This was also noted by Smith and Butterworth 1967.

Occurrence. Rare to infrequent throughout the sequence of Westphalian A and B of Northumberland off-shore boreholes. Horst 1943, Ostrau, Oberschlesien, Westphalian A; Smith and Butterworth, 1967, Viséan to Lower Westphalian C, Coals of Great Britain; Ravn 1979 Cherokee Group CP-19-4 Coals of Iowa, USA.

Granulatisporites minutus Potonié and Kremp 1955

Plate 5 figures 16-19

1955 Granulatisporites minutus Potonié and Kremp p.59, pl.12, fig.147.

1967 Granulatisporites minutus (Potonié and Kremp) Smith and Butterworth, p.141, pl.3, fig. 20.

Holotype. Potonié and Kremp 1955, pl.12, fig. 147. Preparation 607/5, KT14.4.123,9.

Type locality. Baldur Seam, Brassert Colliery, Ruhr Coalfield, Germany, Lower Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.141, expanded from Potonié and Kremp 1956, p.59).

Size in micrometres. (i) Holotype 23, approximately 20-25

Schulze (Potonie and Kremp 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. 8in., 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. (ii - v Smith and Butterworth 1967). (vi) 19(22.5)27 (29 specimens), fum HNO_3, Top and Bottom Yard (G1./G2.1) at 217 ft. 1 in., Northumberland off-shore borehole No. 6, England, Westphalian B.

Description. Amb triangular, angles rounded, sides concave. Laesurae simple, straight, sometimes opened, ½-¾ of spore radius, occasionally reach the amb. Ornament of grana about ½ µm, space between grana irregular and more than their diameter. Exine thin, rarely very faint contact area present. Folding commonly absent.

Comparison. Distinguished from G. granulatus by its slightly smaller size and smaller grana. It differs from G. microgranifer by its coarser ornamentation. G. piroformis has more dense ornament than G. minutus.

Occurrence. Infrequent to frequent in Top and Bottom Yard (Top leaf) Seam borehole No.6, and rare throughout the sequence of Westphalian A and B of Northumberland off-shore

boreholes; Smith and Butterworth 1967, Lower Westphalian A to Upper Westphalian C, British Coalfields; Loboziak 1969, Westphalian B-C in the Basin of Northern France; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany.

Granulatisporites microgranifer Ibrahim 1933

Plate 5 figures 20-22

1933 Granulatisporites 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.55, pl.12, figs. 149-151.

1956 Lophotriletes microgranifer (Ibrahim) Ishchenko, p.38, pl.5, figs. 70-71.

1957a Granitriletes microgranifer (Ibrahim) Dybová and Jachowicz, p.127-128, pl.31, fig.4.

1967 Granulatisporites microgranifer (Ibrahim) Smith and Butterworth, p.140, pl.3, figs.18,19.

Holotype. Ibrahim 1933, pl.5, fig.32, Potonié and Kremp 1955, pl.12, fig.149 after Ibrahim. Preparation B29, a2(0/1).

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

Diagnosis. (See Smith and Butterworth 1967, p.140, from Potonié and Kremp, p.58, translation).

Size in micrometres. (i) Holotype 32.5, Schulze and KOH. (ii) (25,) 30-40 Schulze (Potonié and Kremp 1955). (iii) 18(23)28, fum. HNO_3, Chemiss Seam, Michael Colliery, East Fife Coalfield, Scotland; Westphalian B. (Smith and Butterworth 1967). (iv) 21(25.5)32 (36 specimens) fum. HNO_3. Top and Bottom Yard (Gl./G2.1) at 217 ft. 1 in., Northumberland off-shore borehole No. 6, England, Westphalian B. (v) 22(25.5)30 (18 specimens) fum. HNO_3, Bottom Brass Thill (K2.) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb triangular, angles broadly rounded, interradial sides concave. Laesurae, simple, straight, slightly opened, ½-¾ of spore radius. The surface of the spore coat is covered by minute grana, evenly distributed. Exine, thin, faint contact area commonly present.

Comparison. G. microgranifer can be easily distinguished by its fine grana and concave sides.

Occurrence. Frequent in Top and Bottom Yard (Top leaf), Top Brass Thill and common in Bottom Brass Thill seams of Northumberland off-shore boreholes, Westphalian B; Horst 1955, West-Oberschlesien, Mährisch-Ostrau, Upper Silesia, Namurian A; Dybova and Jachowicz 1957, Westphalian B to Middle Westphalian C; Smith and Butterworth 1967, Upper Westphalian A to Upper Westphalian C in British Coal Fields; Grebe 1972, Ruhr, Germany, Upper Westphalian A-C; Ravn 1979, Westphalian B Cherokee Group CP-19-4 Coals of Iowa, USA,

Granulatisporites pallidus Kosanke 1950

Plate 5 figures 23-26

1950 Granulatisporites pallidus, Kosanke, p.21, pl.3, fig.3.

1958 Granulatisporites pallidus, Kosanke, in Guennel, pl.3, fig.6.

1970 Granulatisporites pallidus, Kosanke, in Peppers, pl.3, fig.10.

Holotype. Kosanke (1950), pl.3, fig.3, Maceration 587 slide 1.

Type locality. Battery Rock Coal, Hardin County, Illinois, USA.

Diagnosis. (see description in Kosanke 1950).

Size in micrometres. (i) 35(38)42 Schulze and 10% KOH (Kosanke 1950). (ii) 37(39.6)46.5 (9 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, England, Westphalian A-B.

Description. Amb triangular, angles broadly rounded, in some instances flattened, inter-radial margins concave. Laesurae simple, straight, ½-¾ of spore radius. Exine, thin and very finely granulate (oil), grana less than 0.5 µm in height, bases touching, Exine sometimes darker in the area around the sutures. No folds.

Comparison. G. granulatus Ibrahim differs from G. pallidus in being smaller in size and haS larger grana.

Occurrence. Rare throughout the sequence of Westphalian A and B, of Northumberland off-shore boreholes. Guennel 1958, Coals of the Pottsville Series, Indiana; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois.

Granulatisporites parvus (Ibrahim) Potonié and Kremp 1955.

Plate 5 figures 27-31

1932 Sporonites parvus Ibrahim in Potonié, Ibrahim and Loose, pl.15, fig.21.

1933 Punctati-sporites parvus Ibrahim, pl.2, fig.21.

1934 Reticulati-sporites parvus (Ibrahim) Loose, p.154, ok,7, fig.18.

1944 Granulati-sporites parvus (Ibrahim) Schopf, Wilson and Bentall, p.33.

1950 Microreticulati-sporites parvus (Ibrahim) Knox, p.321, pl.18, fig. 247.

1955 Granulatisporites parvus (Ibrahim) Potonié and Kremp, p.59, pl.12, figs. 161-171.

1957b Granitriletes parvus (Ibrahim) Dybova and Jachowicz, p.181, pl.2, fig.17.

Holotype. Ibrahim in Potonié, Ibrahim and Loose (1932), pl.15, fig.21.

Type locality. Ägir seam, Rhur Coalfield, Germany.

Diagnosis. See Potonié and Kremp 1955, p.59.

Size in micrometres. (i) Holotype 38.5, 35-50, Schulze (Potonié and Kremp 1955). (ii) 40(44.6)48 (11 specimens) fum. HNO_3. Bottom Brass Thill (K2.1) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B. (iii) 40, 42 (2 specimens) fum. HNO_3. Bottom Main (F2.1) at 123 ft. 6 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb. triangular, angles broadly rounded, sides straight to slightly convex. Laesurae simple, straight, ½-¾ of spore radius. Ormanent of fine, closed spaced grana about 0.5 µm in diameter. Exine thin, commonly darker in the area around the sutures. Folding frequent.

Comparison. Potonié and Kremp (1955, p.59) made G. pallidus synonymous with G. parvus, but the photographs shown by Potonié and Kremp (1955, pl.12, figs.161-171) tend to give a different appearance of the species than does Kosanke's photo (Kosanke, 1950, pl.3, fig.3). The concave sides mentioned by Kosanke as a definite feature of G. pallidus seem to be lacking in the specimens photographed by Potonié and Kremp. Depending on this difference the two species are herein considered distinct.

Occurrence. Rare in Bottom/Main and Bottom Brass Thill seams of Northumberland off-shore boreholes, Westphalian B; Sullivan 1964, , Westphalian A, Forest of Dean Coalfield, England; Peppers 1970, Carbondale and Spoon Formations,

Pennsylvanian, Illinois; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa.

Genus CYCLOGRANISPORITES Potonié and Kremp 1954

Type species. C. leopoldi (Kremp 1952) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.142, translation from Potonié and Kremp 1955, p.60).

Comparison. Differs from Granulatisporites (Ibrahim) Potonié and Kremp in possessing more or less circular amb.

Cyclogranisporites aureus (Loose) Potonié and Kremp 1955

Plate 5 figures 32-37

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,

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

Diagnosis. (See Smith and Butterworth 1967, p.142, from Potonié and Kremp 1955, p.61, translation).

Size in micrometres; (i) Holotype 55.5, Schulze and KOH. (ii) 50-80 Schulze (Potonié and Kremp 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 µm were recorded ((iii)-(v) Smith and Butterworth 1967). (v) 55(64.5)80, (20 specimens), fum. HNO_3, unnamed seam at 225 ft. lin., Northumberland off-shore borehole No.5, England, Westphalian B.

Description. Amb circular or oval. Laesurae simple, straight, unequal length. Exine, yellowish brown, thin, sometimes thickened in the area bordering the sutures. Ornament of minute, evenly distributed, grana 0.5 - 1 µm in diameter and height with their bases not touching, and is modifying the margin. Compression folds few and narrow, occasionally single broad fold present.

Comparison. C. microgranus Bhardwaj 1957a (p.84, pl.22, figs.29-32) is very similar to C. aureus and comparable in size but it has a thicker exine, 2 µm.

Occurrence. Rare, but widely distributed in the unnamed seam, at 255 ft. lin., of Northumberland off-shore borehole No. 5, and Top and Bottom Yard (T.ℓ) seam, Northumberland off-shore boreholes, Westphalian B; Owens and Burgess 1965, Namurian A to Lower Westphalian B of Stainmore Outlier; Smith and Butterworth 1967, Westphalian A-D, British Coals; Peppers 1970, Lowell Coal, Pennsylvian,

Illinois; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, USA.

Cyclogranisporites leopoldi (Kremp) Potonié and Kremp 1955

Plate 5 figures 38-40

1952 Granulatisporites leopoldi Kremp, p.348, pl.15b, figs. 15,16.

1954 Cyclogranisporites leopoldi (Kremp) Potonié and Kremp, p.126, pl.2a, fig.103.

Holotype. Potonié and Kremp 1955, pl. 13, fig.174, Preparation 472/1.

Type locality. Bismark Seam, Ruhr Coalfield, Germany, Lower Westphalian B.

Size in micrometres. (i) Holotype 33, 25-35 Schulze and KOH (Potonié and Kremp 1955). (ii) 33(35)37 (10 specimens) fum. HNO_3, Bottom Brass Thill at 377 ft. 9in., Northumberland off-shore borehole No.3,Westphalian B.

Description. Amb circular, margin denticulate due to the projection of the grana. Laesurae simple, short, about ½ of spore radius, sometimes accompanied by narrow lips less than 1 µm. Ornament consists of well separated grana of uniform size and shape 0.7 - 1 µm in diameter. Number of elements projecting at the margin 40-60. Exine thin, compression folds not common.

Comparison. C. leopoldi is distinguished from the similar-

sized C. minutus Bharadwaj 1957 by possession of coarser, well spaced grana.

Occurrence. Rare in Bottom Main and Bottom Brass Thill, Northumberland off-shore borehole No.3; Grebe 1972, Upper Westphalian A to Upper Westphalian C, Ruhr, Germany. Ravn 1979, Cherokee Group CP19-4 Coal of Iowa, USA, Westphalian B.

Cyclogranisporites minutus Bharadwaj 1957

Plate 6 figures 1-4

1957a Cyclogranisporites minutus Bharadwaj, p.83, pl.22, fig. 22-23.

Holotype. Bharadwaj 1957a, pl.22, fig.22. Preparation 7314/2.

Type locality. Warlschied Seam, Gottelborn Colliery, Saar Coalfield, Germany; Stephanian A.

Diagnosis. (Bharadwaj 1957a, p.83, in Smith and Butterworth 1967).

Size in micrometres. (i) Holotype 40; 34-43, Schulze (Bharadwaj 1957a). (ii) 30(34.5)39 (7 specimens) fum. HNO_3, unnamed seam at 225 ft. 1 in., Northumberland off-shore borehole No.5, England, Westphalian B. (iii) (39,37,30) fum. HNO_3, the first one from Ashington seam, the other two from Bottom Brass Thill, Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb circular. Laesurae simple, sometimes

curved and not always distinct, one ray is shorter than the other two, 1/2 - 2/3 of spore radius. Ornament of very fine grana about 0.5 μm in diameter cover the surface of the spore evenly and slightly modify its margin. Exine thin, compression folds narrow and few.

Comparison. C. leopoldi (Kremp) Potonié and Kremp (p.62, pl.13, figs 174-178) is comparable in size with C. minutus but the latter has finer and more closely spaced grana. C. parvus Bharadwaj 1957 (pl.23, figs. 7,8) is similar in the character of its ornament, but is somewhat larger and has distinct darkened contact areas.

Occurrence. Rare in unnamed seam at 225 ft. 1 in., borehole No.5, Bottom Brass Thill, and Ashington seams of Northumberland off-shore borehole No.3, Westphalian B; Bhardwaj 1957, WestphalianC -Stephanian, Saar Coalfield, Germany; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Cyclogranisporites cf. minutus Bhardwaj 1957 in Smith and Butterworth 1967

Plate 6 figures 5-7

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

Size in micrometres. (i) 39(42)45 (5 specimens) fum. HNO_3; Low Hutton Seam at 223 ft. 1 in., Metal Bridge borehole (35NW34), 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, Westphalina B.
(iii) 41-52 (6 specimens) fum. HNO_3, various localities, Yorkshire and Durham Coalfields, England, Westphalian A and B, ((i) to (iii) Smith and Butterworth 1967).
(iv) 42(48)54 (15 specimens), fum. HNO_3. Unnamed seam at 225 ft. 1in., Northumberland off-shore borehole No.5, England, Westphalian B.

Description. Amb circular to oval. Laesurae simple, straight, 2/3 of spore radius, with narrow lips. Exine thin, yellowish brown, covered by evenly distributed grana 0.5 - 1 µm in diameter. Compression folds tend to follow the margin.

Comparison. In this study size limits of 40 µm and 55µm are employed to differentiate between C. minutus, C. cf. minutus and C. aureus. Specimens of C. minutus are smaller than 40 µm, those of C. aureus are larger than 55 µm, while those of C. cf. minutus are within the range (40-55)µm. C. aureus also differs from C. cf. minutus in possessing coarser and more regular grana.

Occurrence. Rare in the unnamed seam at 225 ft. 1 in., borehole No.5 and Top and Bottom Yard (T.1) seam, of Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Namurian A to Westphalinan D, British Coals.

Cyclogranisporites multigranus Smith and Butterworth 1967

Plate 6 figures 8-12

1967 Cyclogranisporites multigranus Smith and Butterworth, p.144, pl.4, Figs. 10-13

Holotype. Plate 4, fig.12. Preparation T91/1 in collection of N.C.B. Laboratory, Wath Upon Dearne, Yorkshire.

Type locality. Seam at 491 ft. 10in. , Seafield No.2 borehole, East Fife Coalfield, Scotland, Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.144).

Size in micrometres. (i) Holotype 53, 38(47)55, fum. HNO_3, type locality, (Smith and Butterworth 1967). (ii) 39(44)48 (8 specimens), fum. HNO_3 unnamed seam at 225 ft. 1 in., Northumberland off-shore borehole No.5, England, Westphalian B. (iii) 43(46)49 (10 specimens) fum. HNO_3, Ryhope Marine Band Coal at 29.06m, Northumberland off-shore borehole E12, England, Upper Westphalian B.

Description. Amb circular. Laesurae simple, straight, 1/2 - 2/3 of spore radius, unequal in length sometimes the laesurae are faint and opened, or even torn. Exine covered by very minute, closely packed grana less than 0.5 µm in diameter and height, very slightly modifying the margin. Exine is about 1.5 - 2.0 µm thick, spore commonly preserved without folds but occasionally a single narrow fold may be present.

Comparison. Distinguished from C. aureus (Loose) Potonié and Kremp 1955 by its finer grade of ornament and smaller size. C. parvus Bhardwaj 1957a (p85, pl.23, figs.7,8) is very similar but has a thickening of the exine around the laesurae. C. densus Bhardwaj (pl.23, figs. 1,2) is comparable in size and ornament with C. multigranus but the former has a thicker exine and one or two crescentic folds.

Occurrence. Frequent in unnamed seams at 58.8 m and 91.7 m borehole El_2, Upper Westphalian B, Northumberland off-shore borehole and rare in Ryhope Marine Band Coal at 29.06m, borehole El_2 and unnamed at 225 ft. 1 in., borehole No.5, Northumberland off-shore borehole. Smith and Butterworth 1967, Westphalian B, British Coals.

Genus APICULIRETUSISPORA Streel 1964

Type species. A. brandtii Streel 1964

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

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

Apiculiretusispora sp.A

Plate 6 figures 13-19

Size in micrometres. (i) 29.5(32.5)39, (25 specimens)

fum. HNO_3, unnamed seam at 225 ft. 1 in., Northumberland off-shore borehole No.5, Westphalian B.

Description. Amb circular or subcircular, margin indented. Laesurae distinct, straight, extending to the amb sometimes accompanied by very narrow lips 0.5 µm or less in width; ends of laesurae are connected by curvaturae; margin of contact faces identified clearly by the abrupt change in the exine thickness. Contact faces laevigate. Distal surface covered by evenly distributed small coni of approximately the same size and shape, 0.5 - 0.8 µm in height and basal diameter. The sculptural elements are well separated, 0.5 - 1 µm apart, with pointed apices; number of elements projecting at the margin between 30-51 (average 40). Thickness of the exine at the equator 1.5 - 2.5 µm, secondary folds infrequent.

Occurrence. Rare to infrequent in Bottom Main seam borehole 3 and unnamed seam at 225 ft. 1 in., borehole 5, Northumberland off-shore boreholes Westphalian B.

Apiculiretusispora sp.B

Plate 6 Figures 20-25

Size in micrometres. (i) 45(53.2)67.5 (25 specimens) fum. HNO_3, Bottom Main at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb circular to subcircular, margin denticulate due to projection of ornament. Laesurae simple, straight, sometimes accompanied by narrow lips

0.5 - 1 μm in diameter, often open, extending 4/5 spore radius. Ends of laesurae are connected by curvaturae, contact faces laevigate. Distal surface covered by relatively closely packed, evenly distributed grana, nearly of the same size and shape 0.5 μm in diameter, spaces between the elements are equal to their diameter, grana with rounded apices clearly modifying the margin. Number of elements projecting from the margin between 75-108 (average 93). Exine 4-6.5 μm thick at the equator. Compression folds infrequent.

Comparison. Differs from A. sp.A in its larger size, thicker exine and ornament of grana rather than coni.

Occurrence. Infrequent only in a thin subsection of inferior coal of Bottom Main seam at 123 ft. 6 in., of Northumberland off-shore borehole No.3,Westphalian B.

Subinfraturma VERRUCATI Dybova and Jachowicz 1957

Genus CONVERRUCOSISPORITES Potonié and Kremp 1954

Type species C. triquetrus (Ibrahim) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.146, translation from Potonié and Kremp 1954, p.137).

Comparison. Differs from Verrucosisporites (Ibrahim) Smith and Butterworth 1967 in having a triangular outline.

Converrucosisporites armatus (Dybova and Jachowicz) Smith and Butterworth 1967

Plate 6 figures 26-31

1957a Converrucitriletes armatus Dybova and Jachowicz, p.128, pl. 32, fig.1.

1967 Converrucosisporites armatus (Dybova and Jachowicz) Smith and Butterworth, p.146, pl.4, figs. 19-21.

Holotype. Dybova and Jachowicz 1957a, pl.32, fig.1. Preparation CV1/25.

Type locality. Seam 12, Vaclav Colliery, Czechoslavakia; Namurian A.

Diagnosis. (See Smith and Butterworth 1967, p.146, from Dybova and Jachowicz 1957b, p.182).

Size in micrometres. (i) Holotype not specified. (ii) Average 30, fum. HNO_3 and 30% NH_4OH (Dybova and Jachowicz 1957a); 45 (Dybova and Jachowicz 1957b). (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. (iii and iv Smith and Butterworth 1967). (v) 32(34.4)37 (10 specimens) fum. HNO_3, Bottom Busty, at 186.25m, Northumberland off-shore borehole P_2, Westphalian A.

Description. Am triangular, inter-radial margins straight

to slightly concave. Laesurae simple, straight, ¾ of spore radius, sometimes reaching the equator. Ornament on the distal surface composed of verrucae of different size and shape, size varies in any individual from 2 µm up to 8 µm in basal width and 1-3.5 µm in height bases of the verrucae not touching and with round apices. On the proximal surface verrucae reduced in number and size. Number of verrucae projecting from margin between 13-19. Exine 2.5 - 3 µm thick, sometimes shows a membrane like structure which welds the projecting verrucae.

Comparison. According to Smith and Butterworth 1967 C. triquetrus (Ibrahim) Potonié and Kremp 1955 is larger with convex sides. C. mosaicoides Potonié and Kremp 1955 is smaller with finer ornament.

Occurrence. Rare in Bottom Busty, borehole P_2, Northumberland off-shore borehole, Westphalian A. Smith and Butterworth 1967, Westphalian A, British Coalfields. Grebe 1972, Upper Westphalian A, Ruhr, Germany.

Genus VERRUCOSISPORITES (Ibrahim) Smith and Butterworth 1967

Type species. V. verrucosus (Ibrahim) Ibrahim 1933.

Diagnosis. Smith and Butterworth 1967, p.147.

Comparison. Differs from Camptotriletes Naumova in possessing more or less discrete elements, which may sometimes fuse at the bases, but never form narrow rugulate ridges. Convolutispora Hoffmeister, Staplin and Malloy distinguished by its anastomosing ornament.

Verrucosisporites donarii Potonié and Kremp 1955

Plate 7 figures 1, 2

1955 Verrucosisporites donarii Potonié and Kremp, p.67, pl.13, fig.193.

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. (See Smith and Butterworth 1967, p.149, from diagnosis in Potonié and Kremp 1955, p.67).

Size in micrometres. (i) Holotype 71; about 70, Schulze (Potonié and Kremp 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. (Smith and Butterworth 1967). (iv) 35(54.8)72, (6 specimens), fum. HNO_3, Bottom Main (Top leaf), at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B, England. (v) 56(59.1)64 (3 specimens), fum. HNO_3, Harvey Seam, at 144.83m, Northumberland off-shore borehole P_2, Westphalian A, England.

Description. Amb circular, sometimes oval, margin crenulate. Laesurae simple, ½-¾ spore radius (average 17 µm), sometimes obscured. Ornament consists of closely spaced verrucae associated with rugulae; in surface view, verrucae circular or irregular in shape, maximum width of

verrucae and rugulae 1-3 µm (mostly 2 µm), length of rugulae up to 5 µm. In profile apices well-rounded, spaces between sculptural elements usually uniform in width. Folds generally absent but occasionally a single fold present. Exine 2 µm thick.

Comparison. Verrucosisporites cerosus (Hoffmeister, Staplin and Malloy) Butterworth and Williams 1958 is smaller and has coarser ornament. V. grandiverrucosus (Kosanke) Smith et al 1964 possess slightly larger and more rounded verrucae, but it is difficult in practice to distinguish large specimens of V. donarii from V. grandiverrucosus.

Occurrence. Rare in Bottom Main and Harvey seams, of Northumberland off-shore boreholes, Westphalian A-B, England. Piérart 1958, Upper Westphalian C, Campine, Belgium; Venkatachala and Bhardwaj 1964, Lorrain, Westphalian D, France; Owens and Burgess 1965, Westmoreland, Westphalian B, Great Britain; Smith and Butterworth 1967, Westphalian B-D, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennysylvanian, Illinois, USA; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Verrucosisporites microtuberosus (Loose) Smith and Butterworth 1967

Plate 7 figures 3-6

1932 Sporonites microtuberosus Loose in Potonié, Ibrahim, and Loose, p.450, pl.18, fig.22.

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, pl.100, pl.15, figs. 273-277.

1955 Microreticulatisporites verus Potonié and Kremp, p.102-103, pl.15, fig.286.

1957a Planisporites microtuberosus (Loose) Knox in Bhardwaj, p.87, pl.23, figs.13,14.

1964 Verrucosisporites verus (Potonié and Kremp) Smith et al., p.1075, pl.3, fig.8.

1967 Verrucosisporites microtuberosus (Loose) Smith and Butterworth, p.149, pl.5, figs.9-11.

Holotype. Potonié and Kremp 1955, pl.15, fig.273 after Loose. Preparation II50, C_6(or).

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

Diagnosis. (See Smith and Butterworth 1967, p.150, emended from diagnosis in Potonié and Kremp 1955, p.100).

Size in micrometres. (i) Holotype 67.5, Schulze.
(ii) 55-85, Schulze (Potonié and Kremp 1955).
(iii) 55(72)84 (20 specimens), H_2O_2; Lower bed of

Chislet No.2 Seam at 58 ft. 9 in., No.30 borehole, Chislet Colliery, Kent Coalfield, England; Westphalian B. (iv) 55(68)79, fum. HNO_3; Parkgate Seam, Grange Colliery, Yorkshire Coalfield, England, Westphalian A. ((iii) and (iv) Smith and Butterworth 1967).(v) 64(75.9)100, (10 specimens) fum. HNO_3, Harvey Seam, at 144.83m, Northumberland off-shore borehole P_2, Westphalian A, England. (vii) 56(71.1)86.5 (7 specimens), fum. HNO_3. Bottom Main (Top leaf), at 123 ft. 6 in., Northumberlnad off-shore borehole No.3, Westphalian B, England.

Description. Amb subcircular to oval, margin crenulate. Laesurae, simple, ¾ spore radius, often obscured. Ornament consists of small closely space verrucae, rugulae very rare. In plan view verrucae usually rounded, polygonal, or irregular, maximum basal width 1-3 µm . In profile verrucae with slightly tapering sides. Channels between verrucae narrow. Exine thin with compression folds similar to those developed in Calamospora.

Remarks. V. (Microreticulatisporites) verus Potonié and Kremp 1955, p.102, pl.15, fig.286 is very similar and could not be distinguished from V. microtuberosus in practice, therefore in this work it is considered to be synonymous with V. microtuberosus.

Comparison. V. microtuberosus differs from V. donarii and V. verrucosus in its smaller and more closely packed verrucae with correspondingly larger number of projecting

elements at margin and by the absence of rugulae. According to Peppers 1970, V. sinensis Imgrund 1960 (Cyclobaculisporites sinensis (Imgrund) Bhardwaj 1955) is closely similar to V. microtuberosus excepting for the presence of verrucae from 3.5 µm in width, but Bhardwaj 1957a reported that the verrucae in the type material did not exceed 2µm in width.

Occurrence. Rare in Bottom Main and Harvey seams, of Northumberland off-shore boreholes, Westphalian A-B, England. Artüz 1957, Zonguldak, Namurian A. Westphalian A, Turkey; Smith and Butterworth, 1967, Westphalian A-D, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Verrucosisporites sifati (Ibrahim) Smith and Butterworth 1967

Plate 7 figures 10,11

1933 Reticulati-sporites sifati Ibrahim, p.35, pl.8, fig.67.

1955 Microreticulatisporites sifati (Ibrahim); Potonié and Kremp, p.102, pl.15, figs.282-285.

1967 Verrucosisporites sifati (Ibrahim) Smith and Butterworth, p.152, pl.6, fig.1.

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. (See Smith and Butterworth 1967, p.152, emended from diagnosis in Potonié and Kremp 1955, p.102.

Size in micrometres. (i) Holotype 100, Schulze and KOH. (ii) 80-140 (Potonié and Kremp 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. (Smith and Butterworth 1967). (iv) 62.5(81)96.0, (5 specimens), fum. HNO_3, Bottom Main, (Top leaf) at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B, England.

Description. Amb oval to subcircular, outline gently undulating. Laesurae, simple, ½ spore radius, usually obscured by ornament. Exine covered by broad, low verrucae, sometimes with rugulae, relatively widely separated. In plan view verrucae polygonal, elongate or irregular, maximum length 2-4 µm. In profile verrucae mostly broader than high and well rounded. Exine thin, with compression folds.

Comparison. The broad, low, well rounded, and relatively loosely packed verrucae distinguish this species from V. donarii and V. verrucosus.

Occurrence. Rare in Bottom Main seam of Northumberland off-shore boreholes, Westphalian B, England. Smith and Butterworth 1967, Westphalian A-D, British Coalfields.

Artüz 1957, Namurian A to Westphalian A, Zonguldak basin, Turkey. Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA. Ravn 1979 Cherokee Group CP19-4 Coal of Iowa, Westphalian B.

Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933

Plate 7 figures 7-9

1932 Sporonites verrucosus Ibrahim in Potonié, Ibrahim and Loose, p.488, 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, dI(O).

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

Diagnosis. (See Smith and Butterworth 1967, p.154, from diagnosis and description, Potonié and Kremp 1955, p.69).

Size in micrometres. (i) Holotype 77, Schulze and KOH. (ii) 70-100, Schulze (Potonié and Kremp 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. (Smith and Butterworth 1967). (iv) 58(68.9)77, (7 specimens), fum. HNO_3, Harvey Seam, at 144.83m, Northumberland off-shore borehole P_2, Westphalian A, England. (v) 51(68)99 (11 specimens) fum. HNO_3 Bottom Main (Top leaf), at 123 ft. 6 in., Northumberland off-shore boerehole No.3, Westphalian B, England.

Description. Ambsubcircular to oval, margin crenulate, spacing between crenulation distinct. Laesurae, 1/2 to 2/3 of spore radius, usually obscured. Ornamentation consists of fairly closed spaced verrucae, sometimes associated with rugulae, maximum diameter 1.4 µm (mostly 2 µm); variation occurs in the size and shape of the verrucae within and between specimens of the same population. In profile verrucae with tapering sides and obliquely truncated apices or well rounded or flat, height mostly 1 µm. Exine 1.5 - 2µm in thickness with one major fold or more compression folds.

Comparison. V. donarii can be distinguished from V. verrucosus by its closely spaced and rounded verrucae, and the number of elements projecting from the margin is greater in the former species.

Occurrence. Rare in Bottom Main and Harvey seams, of Northumberland off-shore boreholes, Westphalian A-B,

England. Smith and Butterworth 1967, Westphalian A-D, British Coalfiels; Ravn 1979, Cherokee Group CP19-4 Coal of Iowa, Westphalian B.

Verrucosisporites sp.A.

Plate 7 figures 12-17

Size in micrometres. 79(94)105.5 (15 specimens fum. HNO_3, Bottom Main, at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb usually rounded-triangular, occasionally rounded or oval, margin undulate. Laesurae simple, straight, often one ray is longer than the other two, 1/2 - 2/3 of spore radius. Exine ornamented with closely packed, low and well rounded discrete verrucae, associated with rugulae, the elements have approximately the same size 2-3 µm in width, 1-2µm in height, channels between verrucae give the appearance of a negative reticulum to the spore. Number of verrucae projecting from margin 65-80. Exine is darker in colour in the contact area, 3-5 µm thick, rarely folded.

Comparison. V. sifati (Ibrahim) Smith and Butterworth has more or less discrete verrucae. V. microtuberosus is distinguished by its frequent compression folds, thinner exine and shape of verrucae which tend to be irregular and more densely packed.

Remarks. Specimens assigned to this species in the present work are characterised by their large size and variation in shape and size of verrucae. The shape of verrucae vary

from circular to irregular and from rounded to flat.

Occurrence. Rare in Bottom Main seam, borehole No.3 and Harvey seam, borehole P_2, Northumberland off-shore boreholes, Westphalian A and B.

Subinfraturma NODATI Dybová and Jachowicz 1957a

Genus LOPHOTRILETES (Naumova) Potonié and Kremp 1954

Type species. L. gibbosus (Ibrahim) Potonié and Kremp.

Diagnosis. (Smith and Butterworth 1967, p.155, translation from Potonié and Kremp 1954, p.129).

Comparison. Lophotriletes is distinguished from Apiculatisporis Potonié 1956 which has similar ornament by its triangular outline.

Lophotriletes commissuralis (Kosanke) Potonié and Kremp,1955

Plate 8 figures 1,2

1950 Granulatisporites commissuralis Kosanke, p.20, pl.3, fig.1

1955 Lophotriletes commissuralis (Kosanke); Potonié and Kremp, p.73, pl.14, figs. 222, 293.

non 1960 Lophotriletes commissuralis; (Kosanke) Potonié and Kremp, Imgrund, p.164, pl.15, figs. 66-68.

1965a Lophisporites commissuralis (Kosanke) Laveine, p.133.

Holotype. Kosanke 1950, pl.3, fig.1. Preparation 486-B, slide 22.

Type locality. Friendsville Coal, Wabash County, Illinois, USA; McLeansboro Group.

Diagnosis. (See Smith and Butterworth 1967, p.156, from description in Kosanke 1950, p.20).

Size in micrometres. (i) Holotype 29.5 x 26; 25-34, Schulze and 10% KOH (Kosanke 1950). (ii) 24(29)35 (18 specimens), Schulze and 5% KOH, seam at 737 ft. 10 in., Alveley No. 1 borehole, Forest of Wyre Coalfield, England, Westphalian D. (Smith and Butterworth 1967). (iii) 21(24.3)27 (19 specimens), fum. HNO_3. Top and Bottom yard (T.ℓ) (G1./G2.1) at 217 ft. 1 in., Northumberland off-shore boreholes No.6, England, Westphalian B.

Description. Amb triangular, angles rounded, sides concave. Laesurae distinct, simple, straight, ¾ of spore radius, sometimes reaching the equator. Ornament consists of small coni, varying on single specimen, up to 1 - 1.5 µm in height and basal width, rounded and modifying the outline of the spore. Exine thin.

Comparison. The possession of apiculate ornament differentiates this species from species of Granulatisporites which are covered by grana; it can be easily distinguished from other species of Lophotriletes by its finer grade of ornament.

Occurrence. Rare in Top and Bottom Yard (Top leaf) (G1./G2.1) and throughout the sequence of Westphalian A and B seams of Northumberland off-shore boreholes.

Smith and Butterworth 1967, Namurian to Westphalian D; British Coals. Peppers 1970, Coals in Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA; Grebe 1972, Ruhr, Germany, Upper Westphalian A-C; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Lophotriletes gibbosus (Ibrahim) Potonié and Kremp 1954

1933 Verrucosi-sporites gibbosus Ibrahaim, 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.

1955 Lophotriletes gibbosus (Ibrahim); Potonié and Kremp, p.74, pl.14, figs. 220, 221.

non 1958 Lophotriletes gibbosus (Ibrahim); Potonié and Kremp, Guennel, p.62, pl.3, fig.9.

1965a Lophitriletes gibbosus (Ibrahim); Laveine, p.133.

Holotype. Potonié and Kremp 1955, pl.14, fig.220 after Ibrahim. Preparation B61, e5(U1).

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

Diagnosis. (See Smith and Butterworth 1967, p.156, from description and diagnosis in Potonié and Kremp 1955, p.74.

Size in micrometres. Holotype 46, Schulze and KOH (Potonié and Kremp 1955).

Lophotriletes cf. gibbosus (Ibrahim) Potonié and Kremp,1954
in Smith and Butterworth 1967
Plate 8 figures 3,4

Size in micrometres. (i) 29(34)41, fum. HNO_3, lower bed of Brockwell Seam at 635 ft. 3 in., Sharpness Point borehole, Durham Coalfield, England, Westphalian A. (Smith and Butterworth 1967). (ii) 30(32.7)35.5, (11 specimens), fum. HNO_3, Top Ashington Seam (D/E.1) at 192 ft. 9 in., Northumberland off-shore borehole No.5, England, Westphalian B.

Description. Amb triangular, sides concave, angles rounded. Laesurae distinct, simple, 1/2 - 2/3 spore radius. Ornament of varying size, widely spaced coni, 2-4 µm in basal width, and 2-3 µm in height, mainly rounded, occasionally pointed. Exine thin, rarely folded.

Comparison. Differs from the type in having a smaller size; L. mosaicus Potonié and Kremp 1955 has a more dense sculpture and the angles are not so broad as in L. cf. gibbosus.

Occurrence. Rare throughout the Westphalian A and B sequence of Northumberland off-shore boreholes. Smith

and Butterworth 1967, Westphalian A, British Coalfields.

Lophotriletes granoornatus Artüz 1957

Plate 8 figures 5-9 & 23

1957 Lophotriletes granoornatus Artüz, p.244, pl.2, fig.13.

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

Holotype. Artüz 1957, pl.2, fig.12. Preparation II14, 2e.

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

Diagnosis. (See Smith and Butterworth 1967, p.157, from Artüz 1957, p.244; translation).

Size in micrometres. (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. (Smith and Butterworth 1967). (iii) 35(39.1)45, (17 specimens), fum. HNO_3, Bottom Brass Thill (K2.) at 377 ft. 9 in., Northumberland off-shore borehole No3, England, Westphalian B.

Description. Amb triangular, angles broadly rounded, sides straight to slightly convex. Laesurae, simple sometimes flexuose, 1/2-2/3 spore radius. Exine thickened in region of proximal pole. Ornament consists of small coni, 0.5 - 2 µm in diameter (mostly 1 µm), spaces between coni one to two times their diameter, apices pointed or slightly rounded. 30-55 coni project from

margin. Exine 15-20 µm thick. Compression folds commonly present, sometimes of gulaferus type.

Remarks. In this study all the specimens examined are closely similar to those illustrated by Peppers (1970, pl.5, figs. 18,23). Artüz did not mention the darkened contact area, but her photograph appears to show such a feature, and she described the ornament as consisting of grana.

Comparison. The finer ornament of L. granoornatus distinguishes it from other species of similar size.

Occurrence. Rare in Bottom Brass Thill (K2) and Bottom Main (Top leaf) seams, of Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Upper Westphalian A and Westphalian B, British Coalfields; Peppers 1970, Coals in Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA; Ravn 1970, Cherokee Group, CP-19-4 Coal of Iowa, Westphalian B.

Lophotriletes microsaetosus (Loose) Potonié and Kremp 1955

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.229-230.

1958 Lophotriletes gibbosus (Ibrahim) Potonié and Kremp 1954; Guennel, p.62, pl.3, fig.9.

1965a Lophisporites microsaetosus (Loose) Laveine, p.133.

Holotype. Potonié and Kremp, 1955, pl.14, fig.229 after Loose. Preparation IV6 f_2(U1).

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

Diagnosis. (See Smith and Butterworth 1967, p.158, from diagnosis and description in Potonié and Kremp 1955, p.74).

Size in micrometres. (i) Holotype 39, Schulze. (ii) 25-40, Schulze (Potonié and Kremp 1955).

Lophotriletes cf. microsaetasus (Loose) Potonié and Kremp in Smith and Butterworth 1967

'Plate 8 figures 10-12

Size in micrometres. (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 Collierty, 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. (i-iv Smith and Butterworth 1967). (v) 22.5(25.2)27, (13 specimens) fum. HNO_3, Bottom Main Seam at 123 ft. 6 in., Northumberland off-shore borehole No.3, England, Westphalian B. (vi) 22.5,24, fum. HNO_3, Bottom Brass Thill (K2.) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb triangular, angles rounded, inter-radial margins concave, very rarely straight. Laesurae, simple, straight, 2/3 of spore radius, sometimes partly concealed by ornament. Ornament consists of coni equal in height and basal width 1.5 - 2.5 µm, generally pointed, and unevenly distributed. Exine thin, no folding.

Comparison. Differs from the type in its smaller size. L. cf. microsaetosus has coarser ornament than L. commissuralis (Kosanke) Potonié and Kremp, and the coni are more pointed and denser than those of L. cf. gibbosus which is slightly larger in size.

Occurrence. Rare in Bottom Main, Bottom Brass Thill, and Top and Bottom Yard seams of Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Upper Westphalian B to Westphalian D. British Coalfields.

Genus WALTZISPORA Staplin 1960

Type species. W. lobophora (Waltz) Staplin 1960.

Diagnosis. (Smith and Butterworth 1967, p.159, from Staplin 1960, p.18).

Remarks. Sullivan 1964 transferred this genus to the Infraturma Apiculati on the basis that the type species possess a prominent ornament, although some species assigned to this genus are laevigate or granulate.

Comparison. Distinguished from Leiotriletes (Loose) Potonié and Kremp by its angular junctions between radial and inter-radial areas of the amb.

Waltzispora prisca (Kosanke) Sullivan 1964

Plate 8 figures 13-15

1950 Triquitrites prisca Kosanke, p.39, pl.8, fig.4.

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

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

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

Diagnosis. (See description in Kosanke 1950, p.39-40).

Size in micrometres. (i) Holotype 40.4; (36-45), Schulze and 10% KOH (Kosanke 1950). (ii) 35.3(37.5)41.5 (8 specimens), fum. HNO_3, Bottom Brass Thill (top leaf) at 377 ft. 9 in., borehole No.3, Westphalian B. (iii) 36 (2 specimens) fum. HNO_3, Plessey at 122.24m borehole P_2, Westphalian B. (ii and iii from Northumberland off-shore boreholes, England).

Description. Amb triangular, inter-radial margins concave,

angles blunted to slightly rounded. The junction between the apices and the concave inter-radial margins are angular. Laesurae simple, straight, ¾ of spore radius, occasionally reaching the amb, sometimes open. Ornament consists of very fine grana, widely spaced, about 0.5 µm in diameter, which scarcely modify the margin. Exine thin, faint contact area present, usually without folds.

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

Occurrence. Rare in Bottom Brass Thill and Plessey, Northumberland off-shore boreholes, Westphalian A and B. Sullivan 1964, Drybrook Sandstone, Forest of Dean, Lower Westphalian A.

Genus ANAPICULATISPORITES (Potonié and Kremp) Smith and Butterworth 1967

Type species. A. isslburgensis Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.160 emended from Potonié and Kremp 1954, p.133).

Anapiculatisporites minor (Butterworth and Williams) Smith and Butterworth 1967

Plate 8 figures 16-19

1967 Anapiculatisporites minor (Butterworth and Williams) Smith and Butterworth, p.161, pl.6, figs.21-24.

Holotype. pl.6, fig.21. Preparation T40/1 in collection of N.C.B. Laboratory, Wath-Upon-Dearne, Rotherham, Yorkshire.

Type locality. Lyoncross Seam at 558 ft. 10 in., Darnely No.4 borehole, Central Coalfield, Scotland; Namurian A.

Diagnosis. (Smith and Butterworth 1967, p.161).

Size in micrometres. (i) Holotype 23; 14(22)28, fum. HNO_3 (Butterworth and Williams1958). (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 3833 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. (ii - vi Smith and Butterworth 1967). (vii) 16.5(23)26.5 (16 specimens), fum. HNO_3, Bottom Brass Thill (Top leaf) at 377 ft. 9 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Shape triangular, inter-radial margins straight to slightly concave angles rounded and narrow. Laesurae simple, straight 2/3 - 3/4 of spore radius,

sometimes open. Ornament consists of uniform spinae 1-3 μm in height (average 2 μm) and about 1.5 μm in breadth, with a sharp end, almost galeate, restricted to the distal surface only, about 36-74 spinae arranged randomly or in areas mostly parallel to the laesurae. Exine thin, occasionally folded.

Comparison. A. spinosus (Kosanke) Potonié and Kremp 1955 has longer and more spinae on the distal surface. A. hispidus Butterworth and Williams 1958 is larger and has fewer spinae.

Occurrence. Common in Bottom Brass Thill (Top leaf) and Bottom Main (Top leaf) seams, borehole No.2, infrequent in Top and Bottom Yard (Top leaf) seam, borehole No.6, Northumberland off-shore boreholes, England, Westphalian B. Smith and Butterworth 1967, Viséan to Upper Westphalian C, British Coalfields; Marshall and Williams 1970, Namurian, Northumberland.

Genus ANAPLANISPORITES Jansonius 1962

Type species. A. telephorus Klaus 1960

Diagnosis. (Smith and Butterworth 1967, p.165, from Jansonius 1962).

Comparison. Differs from Anapiculatisporites Potonié and Kremp in having the ornament projecting regularly and uniformly beyond the margin and lack of spinae.

Anaplanisporites baccatus (Hoffmeister Staplin and Malloy); Smith and Butterworth 1967

Plate 8 figures 20-23

1955 Punctatisporites ? baccatus Hoffmeister, Staplin and Malloy, p.392, pl.36, fig.2.

1958 Apiculatisporites baccatus (Hoffmeister, Staplin, and Malloy) Butterworth and Williams, p.363, pl.1, fig.25.

1967 Anaplanisporites baccatus (Hoffmeister, Staplin, and Malloy) Smith and Butterworth, p.166, pl.7, figs.1-5.

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, USA, Hardinsburg Formation, Chester Series.

Diagnosis. (See Smith and Butterworth 1967, p.166, emended from Hoffmeister, Staplin and Malloy 1955, p.392).

Size in micrometres. (i) Holotype 29; 26-46, HF (Hoffmeister, Staplin and Malloy 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 (ii and iii Smith and Butterworth 1967). (iv) 21.5(27.2)27 (11 specimens), fum. HNO_3, Plessey

at 122.24m,borehole P_2. (v) 19.2(22.5)25 (10 specimens) fum. HNO_3, Bottom Brass Thill, at 377 ft. 9 in., borehole No.3. ((iv) & (v) from Northumberland off-shore boreholes).

Description. Amb circular to subcircular, occasionally rounded triangular, sometimes distorted due to folding. Laesurae, raised, flexuose, equal in length to spore radius, sometimes obscured by ornament. Ornament consists of uniform coni, sometimes sharply pointed, 0.6 - 2.2 µm in height and basal diameter. Number of elements projecting from the margin between 31-61 (average 45). Exine thin, compression folds present.

Occurrence. Common to very common and sometimes abundant throughout the Westphalian A and B sequence. Northumberland off-shore boreholes. Smith and Butterworth 1967, British Coalfields, Viséan to Lower Westphalian C; Staplin 1960, Golata Formation, Alberta, Canada, Upper Mississippian; Owens 1963, Stainmore, Namurian A to Lower Westphalian B; Sullivan and Marshall 1966, Western part of Midland Valley, Scotland, Upper Viséan; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany. Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Anaplanisporites sp.A.

Plate 8 Figures 24-31

Size in micrometres. (i) 24(27.4)31 (40 specimens) fum. HNO_3, Bottom Main at 123 ft. 6 in., Northumberland off-

shore borehole No.3, Westphalian B.

Description. Amb usually rounded-triangular, sometimes rounded or oval. Laesurae usually accompanied by narrow lips and about 0.5 µm wide, slightly flexuose, ¾ of spore radius, sometimes nearly reaching the amb. Distal surface covered by well separated galea, up to 5 µm apart, of approximately same size and shape, 2.3 µm in height and basal diameter, sometimes the spinae of the galea only distinct at the margin; exine between galea laevigate to very finely granulate, grana less than 0.5 µm in diameter. Number of galea projecting at the margin 6-15 (average 8), number of galea on the distal surface (including those on the margin) 18-34 (average 22). Proximal surface laevigate or very finely granulate. Exine 1 µm thick. Compression folds infrequent.

Comparison. The drawing of Lopotriletes fulvus Ischenko 1958 (pl.IV, fig. 5a) looks similar, but in the description Ischenko did not mention any lack of ornament on the proximal surface, and Lophotriletes fulvus is larger with a size range of 50-65 µm.

Occurrence. Frequent in Bottom Main seam, Northumberland off-shore borehole No.3, Westphalian B.

Genus PUSTULATISPORITES Potonié and Kremp 1954

Type species. P. pustulatus Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.168, translation

from Potonié and Kremp 1954, p.134).

Pustulatisporites papillosus (Knox) Potonié and Kremp 1955

Plate 8 figures 32-35

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.

Holotype. Smith and Butterworth 1967, pl.7, fig.9., from Knox preparation 360A (T84/1 in collection of National Coal Board, Wath-Upon-Dearne, Rotherham, Yorkshire).

Type locality. Dunfermline Splint Seam, Lumphinnans No. 1 borehole, West Fife Coalfield, Scotland; Namurian A.

Diagnosis. (See Smith and Butterworth 1967, p.168, from Butterworth and Williams 1958, p.365).

Size in micrometres. (i) Lectotype 45, Schulze. (ii) 37(50)65, Schulze (Butterworth and Williams 1958); Namurian A. (ii) 40(46.3)51 (10 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb triangular, angles well rounded, sides straight or slightly convex. Laesurae simple, straight, 4/5 of spore radius, often reaching the equator. Distally exine covered with verrucae or short baculae,

varying in size from 3.- 7 µm in height and up to 7 µm in basal width; the elements are well separated, with truncated or rounded apices, sometimes mainly concentrated on the polar region leaving much of the margin of the spore smooth. Number of elements projecting from margin between 8-29. Proximal surface laevigate. Exine 1.5 - 2.0 µm thick, rarely folded.

Occurrence. Rare in the Three Quarter and Bottom Busty seams, borehole P_2 and Bottom Brass Thill seam, borehole No.2, Northumberland off-shore boreholes, Westphalian A and B. Butterworth and Williams 1958, Coals in Limestone Coal Group and Upper Limestone Group, Scotland, Upper Carboniferous; Sullivan 1964, Drybrook Sandstone Westphalian A, Forestof Dean, England; Smith and Butterworth 1967, Coals of Great Britain, Namurian A.

Pustulatisporites pustulatus Potonié and Kremp 1954

Plate 8 figures 36-39

1954 Pustulatisporites pustulatus Potonié and Kremp, pl.14, fig. 256.

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. (See Smith and Butterworth 1967, p.168, from Potonié and Kremp 1954, p.134).

Size in micrometres. (i) Holotype 66; approximately 70, Schulze (Potonié and Kremp 1955). (ii) 50-70 (6 specimens) fum. HNO_3; various localities, British Coalfields (Smith and Butterworth 1967). (iii) 47(50)51 (5 specimens) fum. HNO_3; various seams, Northumberland off-shore boreholes Westphalian B.

Description. Amb rounded to rounded-triangular. Laesurae simple, straight, 2/3 - 3/4 of spore radius. Distal surface covered by well spaced coni or verrucae, with rounded or truncated and sometimes pointed apices, 2.4 µm in height, 1.5 - 3.5 µm in basal diameter and 2- 5 µm apart. On the proximal surface the sculptural elements are reduced sharply and the exine appears to be laevigate. Number of elements projecting from margin between 14-18. Exine 2.5 - 3 µm thick. Compression folds infrequent.

Comparison. Differs from P. papillosus in having a more rounded outline and smaller ornament.

Occurrence. Rare in Bottom Main seam, borehole No.3 and Seam "D_1" borehole EL_2, Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, British Coalfields, Upper Westphalian A to Westphalian D. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany.

Pustulatisporites sp.A.

Plate 8 figures 40-46

Size in micrometres. (i) 40.5(42.5)53 (15 specimens) fum. HNO_3, Bottom Brass Thill, at 377 ft. 9 in., Northumberland

off-shore borehole, Westphalian B.

Description. Amb triangular, angles well rounded, sides convex. Laesurae sometimes accompanied by narrow lips about 0.5 µm wide, straight, 2/3 - 3/4 of spore radius. Distal surface ornamented with well separated verrucae and coni of different sizes 1.5 - 4 µm in height, 1.5 - 6 µm in basal diameter and up to 9 µm apart. Elements mostly with rounded apices, sometimes truncated or pointed. Proximal surface laevigate. Number of elements projecting from margin between 9-18. Well pronounced darker contact area present. Exine 1.5 - 2 µm thick. Compression folds infrequent.

Comparison. Differs from P. papillosus and P. pustulatus in possessing a prominent contact area; the ornament tends to be verrucate and apiculate rather than baculate, compared with P. papillosus.

Occurrence. Infrequent in the Bottom Brass Thill seam, Northumberland off-shore borehole No.3, Westphalian B.

Genus APICULATISPORIS Potonié and Kremp 1956

Type species. A. aculeatus Ibrahim 1933

Diagnosis. (Smith and Butterworth 1967, p.169, translation from Potonié and Kremp 1954, p.130).

Comparison. Lophotriletes (Naumova) Potonié and Kremp, is distinguished by its triangular shape. Planisporites (Knox) Potonié 1960, is distinguished by its uniform ornamentation.

Apiculatisporis abditus (Loose) Potonié and Kremp,1955

Plate 9 figures 1-6

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 Verrucosi-sporites abditus (Loose); Knox, p.317.

1955 Apiculatisporis abditus (Loose), Potonié and Kremp, p.78, pl.14, figs. 237-239.

1962 Apiculatisporis abditus (Loose) Pierart, tabl.2.

Holotype. Potonié and Kremp 1955, pl.14, fig.237 after Loose. Preparation IV29, e_4 (m/or).

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

Diagnosis. (See Smith and Butterworth 1967, p.17).

Size in micrometres. (i) Holotype 78 x 55.5, Schulze. (ii) 50-70, fum. HNO_3, British Coals of varying age. (Smith and Butterworth 1967). (iii) 48(52.5)59 (6 specimens), fum. HNO_3, Bottom Brass Thill (Top leaf), at 377 ft., 9 in., Northumberland off-shore borehole No.3, Westphalian B, England. (iv) 45(55.1)67 (5 specimens), fum. HNO_3, various seams, Westphalian A and B, Northumberland off-shore boreholes, England.

Description. Shape rounded, rounded-triangular, or oval. Laesurae simple, straight, 1/2 - 2/3 of spore radius.

Ornament of coni with variable shape and size and rounded or flat apices, 3-10 µm in height, 5-13 µm in basal width, bases sometimes fused; these cover the distal face mainly, while on the proximal surface the coni are reduced sharply in number and size and sometimes totally absent. 14-26 elements project from margin. Exine 1.5 - 3 µm thick, very rarely folded.

Comparison. A. irregularis (Kosanke) Potonié and Kremp 1955 differs from A. abditus in possessing ornament longer than they are broad and the ornament of A. abditus sometimes fuse at their bases. A. puncatus Hoffmeister, Staplin and Malloy 1955 is very similar and can be considered synonymous with A. abditus.

Occurrence. Rare throughout the sequence of Westphalian A and B of Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A to D, British Coalfields; Artuz 1957, Westphalian A, Zonguldak Coalfield, Turkey; Peppers 1970 Carbondale and Spoon Formations, Pennsylvanian, Illinois, USA; Grebe 1972, Ruhr, Upper Westphalian A-C; Ravn 1979 Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Apiculatisporis aculeatus (Ibrahim) Smith and Butterworth 1967

Plate 9 figures 7-12

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.

1956 Apiculatisporis aculeatus (Ibrahim); Potonié and Kremp, p.94.

1967 Apiculatisporis aculeatus (Ibrahim), Smith and Butterowrth, p.170, pl.7, figs.12,13.

Holotype. Potonié and Kremp 1955, pl.14, fig.235 after Ibrahim, Preparation A27, d_6(or).

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

Size in micrometres. (i) Holotype 53, Schulze and KOH. (ii) 50-60, Schulze (Potonié and Kremp, 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. ((iii) and (iv) Smith and Butterworth 1967). (v) 37(41.2)48 (8 specimens), fum. HNO_3; various seams of Northumberland off-shore boreholes, England, Westphalian A-B.

Description. Amb circular to rounded-triangular. Laesurae simple, straight, about 1/3, rarely 1/2, of spore radius (average 8 µm), sometimes partly or completely obscured by ornament. Ornament consists almost entirely of narrow,

sharply pointed coni, about (1-3) µm in height and (1-2) µm in basal width, generally the spaces between coni more than basal diameter. Number of coni projecting from the margin between 22-28. Exine 1-2 µm thick, single narrow compression fold generally present.

Comparison. The shorter laesurae distinguish this form from A. punctaornatus Artüz 1957 which is oval in shape. Filicitriletes curvispinus Luber 1955 is smaller than A. aculeatus but otherwise similar. Some rounded-triangular forms resemble Lophotriletes pseudoaculeatus Potonié and Kremp 1955, but the latter is more distinctly triangular.

Occurrence. Absent to rare throughout the sequence of Westphalian A and B. Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A to D. British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B; Neves 1961, Upper Namurian B to Westphalian A of Southern Pennines, England; Grebe 1972, Westphalian A to C, Ruhr, Germany.

Apiculatisporis irregularis (Alpern) Smith and Butterworth, 1967

Plate 9 figures 13-20

1959 Granasporites irregularis Alpern, p.139, pl.1, fig.7-9.

1967 Apiculatisporis irregularis (Alpern) Smith and Butterworth, p.171, pl.7, figs.18,19.

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 Mörsbach, Lorraine Coalfield, France; Lower Stephanian.

Diagnosis. (See Smith and Butterworth 1967, p.171, from description in Alpern 1959, p.139).

Size in micrometres. (i) Holotype 52 x 44; 50-75 (Alpern 1959), 45-65 (Alpern, in Smith and Butterworth 1967), 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, Woolley Colliery, Yorkshire Coalfield, England; Westphalian B. ((ii) and (iii) Smith and Butterworth 1967). (iv) 45(49)56 (20 specimens), fum. HNO_3, Ryhope Marine Band Coal at Northumberland off-shore borehole EL_2, Westphalian B.

Description. Amb rounded or oval. Laesurae simple, straight, about ½ of spore radius. Usually not visible, but frequently a triangular-shape tear can be observed. Exine bears small coni, 0.5 - 1 µm in height and breadth which occur in localized patches leaving areas of the exine without any ornament. Exine very thin, folding common.

Remarks. In this work some specimens show clearly the

trilete suture and most specimens show a triangular-shaped tear. Two specimens (pl.9, figs. 13,19) show prominent thickened patches in the inter-radial areas.

Comparison. Cappasporites distortus Urban 1966 displays an ornament similar to that of A. irregularis but it is more evenly distributed and confined to the distal surface.

Occurrence. Very common to abundant and sometimes dominant throughout the sequence of Westphalian A and B of Northumberland off-shore boreholes; Smith and Butterworth 1967, Westphalian A to D, British Coalfields.

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 Apiculatisporis 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(U1).

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

Diagnosis. (See Smith and Butterworth 1967, p.172, from

Potonié and Kremp 1955, p.79; translation).

Size in micrometres. (i) Holotype 78, Schulze. (ii) 55-90, Schulze (Potonié and Kremp 1955).

Apiculatisporis cf. latigranifer (Loose)
Potonié and Kremp 1955
Plate 9 Figures 21-26

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

Size in micrometres. British specimens fall within the limits given by Potonié and Kremp for A. latigranifer (Smith and Butterworth 1967). (ii) 54.5(60.7)69 (8 specimens), fum. HNO_3. Bottom Brass Thill (Top leaf) at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B. (iii) 54.6(56.7)59 (4 specimens), fum. HNO_3, Three-quarter, Northumberland off-shore borehole No. P_2, England, Westphalian A.

Description. Amb circular to oval. Laesurae simple, straight 2/2 - 3/4 of spore radius, sometimes reaching the margin, occasionally unequal in length, and obscured by ornament. Exine covered by variable size, well separated, pointed, coni, (1-3) µm in height and (1-2) µm basal width. Coni are generally evenly distributed. Number of element projecting from margin 10 - 32. Exine (2.3) µm thick dark contact area sometimes present, occasionally single, broad compression fold present.

Remarks. Differs from the type in possessing coarser ornament.

Comparison. According to Smith and Butterworth sculptural elements in A cf. setulosus (Kosanke) Potonié and Kremp 1955 are more closely packed and evenly distributed; they number 40 to 50 at the margin. A. aculeatus has a smaller size, shorter laesurae and is more triangular in shape.

Occurrence. Rare in Bottom Brass Thill, Bottom Main and Three-quarter seams, Northumberland off-shore boreholes, Westphalian A-B. Smith and Butterworth 1967, Westphalian A-D, British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Apiculatisporis spinososaetosus (Loose) Smith and Butterworth 1967

Plate 10 Figures 1 - 5

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.

1967 Apiculatisporis spinososaetosus (Loose); Smith and Butterworth, pl.7, figs.22,23.

Holotype. Potonié and Kremp 1955, pl.14, fig.249, after Loose. Preparation I2,h.

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

Diagnosis. (see Smith and Butterworth 1967 , p.173, emended from diagnosis in Potonié and Kremp 1955, p.80).

Size in micrometres. (i) Holotype 74, Schulze. (ii) 50-80, Schulze (Potonie and Kremp 1955). (iii) 38(50)60, fum. HNO_3, Dunsil Seam, Frickley Colliery, Yorkshire, Coalfield, England, Westphalian B, (Smith and Butterworth 1967). (iv) 35.5(43)51 (14 specimens), fum.HNO_3, Bottom Brass Thill (Top leaf), at 377 ft. 9 in., Northumberland off-shore borehole No.3, England, Westphalian B.

Description. Amb rounded-triangular. Laesurae, simple, straight, 1/2 - 3/4 of spore radius, occasionally one ray is shorter than the other two, sometimes partly obscured by ornament. Exine covered by widely separated coni and bacula, height and basal width generally between 1.5-4.5 µm, coni are pointed, while the bacula show truncated apices which are generally partate, the proportion of coni to bacula varied in different specimens but usually the coni constitute more than 50% of the ornament. Between 12-28 elements project from margin. In plan view the sculptural elements are irregular in shape and well separated from each other. Exine 1.5 - 2.5 µm thick, rarely folded.

Comparison. A. spinososaetosus can be distinguished from other forms of Apiculatisporis described in this study

in possessing sculptural element of coni and bacula. Raistrickia fulva resembles A. spinososaetosus but the former possesses coarser ornament.

Occurrence. Rare but widely distributed in Bottom Brass Thill seam and recorded throughout Westphalian A & B sequence of Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A-C, British Coalfields; Pierart 1962, Upper Westphalian B to C, Borinage Massif, Belgium; Loboziak 1971, Westphalian, Nord-Pas-de-Calais, North France.

Apiculatisporis variocorneus Sullivan 1964

Plate 10 figures 6-9

1964 Apiculatisporis variocorneus Sullivan, p.363, pl.58, fig.4.

Holotype. Sullivan 1964, pl.58, fig.4. Preparation SMUD/1.

Type locality. Edgehills Coal, Drybrook Sandstone, Forest of Dean Coalfield, England, ? Westphalian A.

Diagnosis. (See Smith and Butterworth 1967,p.173 from Sullivan 1964, p.363).

Size in micrometres. (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, frum. HNO_3; seam at 445 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 (47NE.17), Durham Coalfield, England; Westphalian A. ((ii) - (iv) Smith and Butterworth 1967).
(v) 44(49.7)61 (10 specimens), fum. HNO_3, Bottom Brass Thill (top leaf), at 377 ft. 9 in., Northumberland offshore borehole No.3, England, Westphalian B.

Description. Amb circular, rounded triangular, or oval. Laesurae, simple, 1/2 - 2/3 of spore radius sometimes obscured. Sculptural elements consist of coni and spinae, varying in proportion in different specimens, the ornament reduced in size and number on the proximal surface; mostly 1-2 µm in height, sometimes totally absent, while the distal ornament attains a height of (3-5) µm and is more closely packed, some coni are rounded, others are pointed. Number of elements projecting from margin between 14 to 29. Exine 1.5 - 2.5 µm thick, compression folds usually exist.

Comparison. The uneven distribution of sculptural elements distinguish this species from A. cf. latigranifer (Loose) Potonié and Kremp, A. cf setulosus (Kosanke) Potonié and Kremp, and Apiculatasporites spinulistratus (Loose) Ibrahim 1933. A. subspinosus Artüz 1957 has a thinner exine.

Occurrence. Absent to rare throughout the sequence, infrequent in Bottom Brass Thill and Three quarter seams,

Northumberland off-shore boreholes, Westphalian A-B. Smith and Butterworth 1967, Namurian C to Lower Westphalian B, British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B; Marshall and Williams 1970, Namurian A, Northumberland; Neves, Read, and Wilson 1965, Lower Westphalian A, Scotland; Neves 1968, Namurian C to Lower Westphalian A, Woodland Borehole, Co. Durham; Owens et. al 1977, Namurian A to Westphalian A, Northern England and Scotland; Clayton et. al 1977, Namurian A to Westphalian A, Western Europe.

Genus APICULATASPORITES (Ibrahim)
Smith and Butterworth 1967

Type species. A. spinulistratus (Loose) Ibrahim 1933

Diagnosis. (Smith and Butterworth 1967, p.176).

Comparison. Differs from Apiculatisporis Potonié and Kremp in possessing a uniform ornament and from Planisporites (Knox) Potonié 1960 by its rounded amb.

Apiculatasporites spinulistratus (Loose)
Ibrahim 1933
Plate 10 figures 10-14

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. 214-219.

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. Bismark Seam, Ruhr Coalfield, Germany, Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.176, from Potonié and Kremp 1955, p.71; translation).

Size in micrometres. (i) Holotype 53, Schulze. (ii) 45-75, Schulze (Potonie and Kremp 1955). (iii) 32(70-90)160, fum. HNO_3 (Horst 1955). (iv) 38(57)87, fum. HNO_3 (Smith and Butterworth 1967); Swallow Wood Seam, Denaby Main Colliery, Yorkshire Coalfield, England, Westphalina B. (v) 49.5(59)73.5 (11 specimens), fum. HNO_3, Bottom Brass Thill (top leaf), Northumberland off-shore borehole No.3, at 377 ft. 9 in., Westphalian B. (vi) 54.5(66.5)73.5 (5 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb usually rounded, sometimes oval. Laesurae simple, straight, 1/2 - 2/3 of spore radius, 16-25.5 µm (average 19 µm), sometimes open, occasionally unequal and one laesura curved. Exine covered by uniform, evenly distributed coni which varied in size in different specimens, but usually maintain the same size in one specimen. The coni 1-2 µm in height, 1-3 µm breadth, 1.5-2 µm apart, number of elements projecting from margin 47-60. Exine 1-2 µm thick, usually faint to dark contact area present. Single narrow compression fold usually present.

Remarks. Most specimens recorded in this study have a contact area.

Comparison. The uniform size of the ornament differentiates this species from Apiculatisporis cf. latigranifer and as noted by Ravn 1979 it is desirable to transfer A spinulistratus to Apiculatisporis and eliminate the confusion between the similar generic names.

Occurrence. Infrequent in Bottom Brass Thill seam and rare but widely distributed in Bottom Main seam, Northumberland off-shore boreholes, Westphalian B. Grebe 1972, Upper Westphalian A to C, Ruhr, Germany; Smith and Butterworth 1967, Westphalian A-D, British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B. Bhardwaj 1957, Westphalian D to Stephanian, Saar Coalfield; Dybova and Jachowicz 1957

Namurian to Westphalian B, Upper Silesia.

Apiculatasporites SP.A

Plate 10 figures 15-18

Size in micrometres. 48(52.3)57.5 (30 specimens) fum. HNO_3, Three-quarter seam at 203.48m, Northumberland off-shore borehole P_2, Westphalian A.

Description. Amb. circular or slightly oval. Laesurae simple, straight 1/2 - 3/4 of spore radius, sometimes one or more laesura curved. Exine covered with evenly distributed coni of approximately the same size and height 1-1.5 µm apart. Exine 2-2.5 µm thick, affected by several shallow, depressions, which are separated from each other and from non-depressed area by "muri-like structures". Single peripheral fold usually present.

Comparison. Differs from A. spinulistratus (Loose) Ibrahim 1933 in having a thicker exine and in the possession of muri-like structures. Clayton 1972 transferred Dictyotriletes admirabilis Playford 1963 to Punctatisporites admirabilis (Playford) Clayton 1972, after the examination of the holotype, on the basis that the muri and reticulation of Dictyotriletes admirabilis is formed by partially superimposed depressions in the spore exine, which is otherwise laevigate. A. SP.A differs from Punctatisporites admirabilis in its ornament; the latter is finely

scabrate but otherwise it resembles A. SP.A.

A. pseudomuricatus Butterworth and Mahdi (in press) differs in its closely packed and occasionally coarser ornament but is otherwise very similar.

Occurrence. Infrequent in Three quarter seam and rare in Busty seam, Northumberland off-shore borehole P_2, Westphalian A.

Genus ACANTHOTRILETES (Naumova) Potonié and Kremp 1954

Type species. A. ciliatus (Knox) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.177, translation from Potonié and Kremp 1954).

Comparison. Differs from Lophotriletes and Apiculatisporis by its ornament which consists of long and strongly pointed spinae, the ratio of length to width is more than 2:1.

Acanthotriletes echinatus (Knox) Potonié and Kremp 1955

Plate 10 figures 19-21

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

1955 Acanthotriletes echinatus (Knox), Potonié and Kremp, p.84.

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

Neotype. Smith and Butterwoth 1967. T86/1 in collection of N.C.B. Laboratory, Wath-Upon-Dearne, Rotherham, Yorks.

Type locality. Splint Seam, Cadzow Colliery, Central Coalfield, Scotland; Westphalian B.

Diagnosis. (See Smith and Butterwoth 1967, p.178, from Knox 1950, p.313).

Size in micrometres.(i) Neotype 26, fum. HNO_3 (Smith and Butterwoth 1967). (ii) 25, Schulze (Knox 1950). (iii) 12(20)28, fum. HNO_3 type locality, (Smith and Butterworth 1967, (iv) 16(28)35, (4 specimens), fum. HNO_3, Top and Bottom Yard (top Leaf) at 217 ft. 1 in., Northumberland off-shore borehole No.6, Westphalian B. (v) 20,27 (2 specimens) fum. HNO_3, Bottom Main, at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb. rounded, rounded-triangular or oval. Laesurae simple, usually not visible, extending up to 2/3 of spore radius. Exine bears fine, sharp spinae, 0.5-1 µm in breadth, 2-4 µm long, 1-2 µm apart, 19 to 36 project from margin. Exine thin, rarely folded.

Remarks. Some of the specimens recorded in this work are slightly bigger than those described by Smith and Butterworth 1967.

Occurrence. Rare in Bottom Main and Top and Bottom Yard (top leaf) seams of Northumberland off-shore boreholes

No.6 and 3, Westphalian B. Smith and Butterworth 1967, Namurian to Westphalian C, British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B; Sabry and Neves 1971, Viséan to Namurian A, Sanquhar Coalfield., Scotland.

Acanthotriletes triquetrus Smith and Butterworth 1967

Plate10 figures 22, 23

1967 Acanthotriletes triquetrus Smith and Butterworth, p. 179, pl.8, figs. 13,14.

Holotype. Plate 8, fig.13. Preparation T92/1 in collection of N.C.B. laboratory, Wath-Upon-Dearne, Rotherham, Yorks.

Type locality. Seam at 1,413 ft. 6 in., Darkslade borehole, Cannock Chase Coalfield, England; Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.179).

Size in micrometres. (i) Holotype 37; 19(26)37, Schulze, type locality, (Smith and Butterworth 1967). (ii) (27)30.5 (10 specimens), fum. HNO_3, Top and Bottom Yard (top leaf) at 217 ft. 1 in., Northumberland off-shore borehole No.6, Westphalian B.

Description. Amb triangular, angles well rounded, interradial margins concave. Laesurae, simple, straight, 2/3 of spore radius. Ornament of fine spinae with tapering ends, 1-2.5 µm long, less than 1 µm in diameter, 2-3 µm apart. Number of elements projecting from margin 13 to

26. Exine very thin, no folds.

Comparison. According to Smith and Butterworth 1967 A. microspinosus (Ibrahim) Potonié and Kremp 1955 is larger and has longer and numerous spinae. According to Ravn 1979 Granulatisporites spinosus Kosanke in Felix and Burbridge 1967, p.364, pl.54, fig.10 is very similar and can be considered synonymous with A. triquetrus.

Occurrence. Rare in Top and Bottom Yard (top leaf) seam, Northumberland off-shore borehole No.6, Westphalian B. Smith and Butterworth, 1967, Upper Westphalian B-C, British Coalfields; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Subinfraturma BACULATI Dybova and Jachowicz 1957

Genus RAISTRICKIA (Schopf, Wilson and Bentall) Potonié and Kremp 1954

Type species. R. grovensis Schopf in Schopf, Wilson and Bentall 1944.

Diagnosis. (Smith and Butterworth 1967, p.179, translation from Potonié and Kremp 1955, p.85).

Comparison. Distinguished by its parallel sided baculae and occasionally truncated cones. Neoraistrickia Potonié 1956 differs in having a triangular amb.

Raistrickia firma (Loose) Smith 1971

Plate 10 figures 24,25

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

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

1955 Verrucosisporites firmus (Loose) Potonié and Kremp, p.67, pl.13, figs. 203-204.

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

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

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

Diagnosis. (See diagnosis and description in Potonié and Kremp 1955, p.67).

Size in micrometres. (i) Holotype 60; 60-70, Schulze (Potonié and Kremp 1955). (ii) 33(40.6)45 (10 specimens) fum. HNO_3, various localities, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded to slightly oval. Laesurae, often obscured by ornament, simple, straight, $\frac{3}{4}$ of spore radius, occasionally reaching the margin. The distal and proximal surfaces are covered with relatively low, broad and irregular shaped verrucae, up to 6 µm in width, 2 µm in height, and bacula which constitute the majority of the elements; each baculum consists

of a rod-like stem with spherical head or mushroom cap-shaped structure. The bacula are so closely packed that the apices touch each other or sometimes fuse; length of the baculae 2-4 µm, width of the cap 2-7 µm. Number of elements projecting from the margin between 30-35. Exine thin, rarely folded.

Remarks. Smith 1971 after re-examination of spores from the Bismarck Seam near the type locality suggested that the sculptural elements are mainly bacula and for this reason transferred this species to Raistrickia. Speciments observed in this study are smaller than those of Potonié and Kremp 1955.

Comparison. Differs from other species of Raistrickia in possessing bacula with verrucae, peculiar shaped bacula, and also in the number of elements projecting from the margin.

Occurrence. Absent to rare throughout the sequence, Northumerland off-shore boreholes, Westphalian A and B. Grebe 1972, Lower Westphalian B to Upper Westphalian C, Ruhr, Germany.

Raistrickia fulva Artüz 1957

Plate 10 figures 26-30

1957 Raistrickia fulva, Artüz, p.246, pl.3, fig.19

Holotype. Artüz 1957, pl.3, fig.19, Preparation 1I15,6d.

Type locality. Sülü Seam, Zonguldak Coalfield, Turkey;

Westphalian A.

Diagnosis. (See Smith and Butterworth 1967, p.180, from description in Artüz 1957, p.246).

Size in micrometres. (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, 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. ((ii) -(iv) Smith and Butterworth 1967). (v) 40.3(48.3)59 (12 specimens), fum. HNO_3, various seams, Westphalian A and Lower B, Northumberland off-shore boreholes.

Description. Amb rounded-triangular. Laesurae simple, straight, 2/3 - 3/4 of spore radius, occasionally reach the margin, sometimes open. Lips when present are about 2 µm wide. The spore coat is ornamented with two kinds of elements: the majority consist of bacula, 3.5 - 9 µm in width, 3-7 µm in height, apices rounded, truncated, or often apiculate; the remainder are loosley scattered coni, 2.3-5 µm in height and 2-5 µm in basal width. Number of elements projecting from margin between 11 and 20. Exine between the sculptural elements laevigate.

Remarks. Some of the specimens observed in this study show coarser ornament than those described by Smith and Butterworth 1967. This species has been used by Clayton et al 1977 as a Zonal index for the highest Namurian.

Occurrence. Infrequent in Bottom Brass Thill, and Harvey seams. Rare in Plessy and Bottom Busty seams, Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A-C, British Coalfields. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany. Clayton et al 1977, Upper Namurian C- Westphalian A. Western Europe.

Raistrickia lacerata Peppers 1970

Plate 11 fig.1

1970 Raistrickia lacerata, Peppers 1970, p.104, pl.7, figs. 12-13.

Holotype. Peppers 1970, pl.7, fig.12, maceration 1246, slide 20.

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

Diagnosis. (See Peppers 1970, p.104).

Size in micrometres. (i) Holotype 65.0 x 62.4, 45.8 - 74.8, Schulze and 5% KOH (Peppers 1970). (ii) 46.6,48.0, fum. HNO_3, Harvey seam, Northumberland off-shore borehole P_2, Westphalian A.

Description. Amb rounded-triangular. Laesurae simple, straight 1/2 of spore radius. Ornament consists of

three types, the most conspicuous are large bacula up to 12 µm in height and up to 16 µm in basal diameter and some may be subdivided at the top, apices serrated. The second set consists of smaller bacula 2-4 µm wide and up to 6 µm long and the third set are of loosely scattered verrucae up to 4 µm in height and basal diameter. Exine about 2 µm thick.

Comparison. The possession of three types of ornament one of which is a very wide bacula differentiate this species from R fulva which has two types of ornament.

Occurrence. Only two specimens were found in the Harvey seam, Northumberland off-shore borehole P_2. Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.

Raistrickia pilosa Kosanke 1950

Plate 11 figures 2-5

1950 Raistrickia pilosa Kosanke, p.48, pl.11, fig.4.

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

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

Diagnosis. (See description in Kosanke 1950, p.48).

Size in micrometres. (i) Holotype 39.9 x 40.3, 37-43, Schulze and 10% KOH (Kosanke 1950). (ii) 3[illegible]5(35.7)40.2 (5 specimens) fum. HNO_3, various seams, Westphalian A

and B, Northumberland off-shore boreholes.

Description. Amb rounded or oval. Laesurae simple, straight, 2/3 - 3/4 of spore radius, usually concealed by the bacula. Ornament covers the distal and the proximal surfaces and consists of bacula, 6-10 µm in height, occasionally reaching up to 15 µm, 2-3.5 µm in width, apices flat or fimbriate, a majority of the bacula show widening at the top, but a few bacula widen at the base, and sometimes bacula branch into two subdivisions. Number of elements projecting from margin 9-15. Exine 1-1.5 µm thick, sometimes folded.

Comparison. Differentiated from other species of Raistrickia in its smaller size and longer bacula.

Occurrence. Rare in Bottom Brass Thill, Bottom Main, and Harvey seams, Northumberland off-shore boreholes, Westphalian A and B. Peppers 1970, Carbondale and Spoon Formation, Illinois, Pennsylvanian; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Raistrickia saetosa (Loose) Schopf, Wilson, and Bentall 1944

Plate 11 figures 6-9

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 Ill,c.

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

Diagnosis. (See Smith and Butterworth 1967, p.181, from Potonié and Kremp 1955, p.87; translation).

Size in micrometres. (i) Holotype 78, Schulze. (ii) 60-90, Schulze (Potonié and Kremp 1955). (iii) 41(50)62 (20 specimens) fum. HNO_3; High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England, Westphalian B, (Smith and Butterworth 1967). (iv) 47.2(53.6)60.8 (11 specimens), fum. HNO_3, various seams, Westphalian A and B, Northumberland off-shore boreholes.

Description. Amb rounded to oval. Laesurae simple, 1/2 - 2/3 of spore radius, usually obscured by ornament. Ornament consists of bacula, majority of the same size and shape on any one specimen; the size of bacula depends on the size of the individual and it may attain up to 16.3 µm in height (average 10), and up to 6 µm in width (average 4), sometimes a few bacula show widening bases or apices, apices usually flat or serrated. The distance between bacula is variable and it may reach up to 12 µm. Number of elements projecting from margin 12-26, surface of the bacula and the exine laevigate. Exine 2-3 µm thick, usually with compression folds.

Comparison. The similarity in shape and size of bacula

any one individual and the proportion of the length to the width of the bacula differentiate this species from other species of Raistrickia. According to Smith and Butterworth 1967, R crocea Kosanke is probably a synonym of R saetosa.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence of Northumberland off-shore boreholes; Bharadwaj 1957, Westphalian C-D, Saar Coals, Germany; Neves 1961, Southern Pennines, Namurian A to Lower Westphalian B; Owens 1963, Stainmore, Namurian B to Lower Westphalian B; Smith and Butterworth 1967 Westphalian A-D, British Coalfields; Grebe 1972 Upper Westphalian A-C, Ruhr, Germany.

Raistrickia solaria Wilson and Hoffmeister 1956

Plate 11 figures 10,11

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

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

Type locality. Croweburg coal, Mc Nabb Mine, Catoosa, Rogers County, Oklahoma.

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

Size in micrometres. (i) Holotype 58, 51-63.5, Schulze and KOH (Wilson and Hoffmeister 1956). (iii) 40.3(47.5)54.2, (3 specimens), fum. HNO_3. various seams,

Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded. Laesurae simple, ¾ of spore radius, often obscured by the sculptural elements. Ornament consists of crowded club-shaped bacula with flat to slightly rounded apices or fimbriate, 6-11 µm in height, 3-7 µm in width, a few bacula branch into two subdivisions near the middle or at the apex. Transverse striation can be observed on some bacula. Number of elements projecting from the margin 24-28. Exine 2-3 µm thick.

Comparison. Differs from R saetosa in having crowded sometimes branching bacula.

Occurrence. Rare in Ashington, Plessy and Harvey seams, Northumberland off-shore boreholes, Westphalian A-B; Peppers 1970, Carbondale and Spoon Formations, Illinois, Pennysylvanian.

Raistrickia sp.A.

Plate 11 figure 12-14

Size in micrometres. (i) 41(473)61 (8 specimens), fum. HNO_3, Ashington seam at 8 ft. 1½ in., Northumberland off-shore borehole No.3, Westphalian B. (ii) 48,51.0,50.0, fum. HNO_3, the first one from Top Maudlin seam at 66.59m, the other two from Plessy seam at 122.24m, Northumberland off-shore borehole P_2.

Description. Amb generally rounded, occasionally oval. Laesurae simple, straight 2/3-3/4 of spore radius, sometimes with lips about 1 µm wide. The distal surface

is covered with moderately closely spaced bacula, generally of the same size and shape on any one individual, 5-8 µm in height, 2.5-3.5 µm in basal diameter, distinctly fan-shaped, tips fimbriate. On the proximal surface the sculptural elements are reduced in number and size, with some flat topped bacula. Number of elements projecting from margin between 14-23. Excluding ornament, exine about 1-2 µm thick, generally without compression folds.

Comparison. R lowellensis Peppers 1970 has few bacula which branch into major subdivisions and the bacula cover the proximal and distal surfaces. R superba lacks fan-shaped projections and also has the same ornament on the distal and proximal surfaces.

Occurrence. Rare in Ashington seam, borehole No.3 and Plessy seam, borehole P_2, Northumberland off-shore boreholes, Westphalian A and B.

Genus SPACKMANITES Habib 1966

Type species. S. ellipticus Habib 1966

Diagnosis. Habib 1966, p.638.

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

Spackmanites facierugosus (Loose) Habib 1966

Plate 11, figures 15,16

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

1958 Verrucososporites facierugosus (Loose) Butterworth and Williams p.754, pl.18, fig.6.

1966 Spackmanites facierugosus (Loose) Habib, p.638, pl.105, fig.19.

Holotype. Loose 1934, pl.7, fig.26, Preparation III 41 e_s (o/or), in the collection of the Staatl, Geological Commission, Berlin.

Type locality. Fritz Mine, Ruhr-area, Germany; Middle Westphalian B.

Diagnosis. (See description in Butterworth and Williams 1954, p.754, for V. facierugosus.)

Size in micrometres. (i) Holotype 48.5, Schulze and KOH (Loose 1934. (ii) 39(47)61, Schulze, 32(41)51, fum. HNO_3 (Butterworth and Williams 1954). (iii) 38.5(45.8)54.5 (10 specimens) fum. HNO_3, various localities, Northumberland off-shore boreholes, Westphalian B.

Description. Amb circular, occasionally subcircular. Laesurae usually obscured by ornament, short, 1/3 of spore radius, simple. Exine ornamented with numerous radially arranged, rod-like baculae with rounded or flat apices, 2-6 µm long and up to 3 µm wide. Elements

are so closely packed that they are fused at the bases and sometimes it is difficult to distinguish individual elements along the margin. Compression folds absent.

Remarks. Peppers (1970, p.109) in his description of this species mentioned that the exine is differentiated into exoexine and intexine, but the generic diagnosis given by Habib indicates that species belong to this genus are acavate. No evidence of an intexine was seen in the present study.

Comparison. S. ellipticus Habib 1966 possesses slightly fimbrate baculae and an elliptical to oval shape.

Occurrence. Rare in the Top and Bottom Brass Thill seams of Northumberland off-shore borehole No.3, Westphalian B; Habib 1966, Lower Kittanning coal seam, Western Pennsylvania, Lower Westphalian D; Peppers 1970, Carbondale and Spoon Formations, Illinois, Pennsylvanian. Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B.

Infraturma MURORNATI Potonié and Kremp 1954

Genus CONVOLUTISPORA Hoffmeister, Staplin and Malloy 1955

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

Diagnosis. In Smith and Butterworth 1967, p.183 (from description in Hoffmeister, Staplin and Malloy 1955, p.384).

Convolutispora sp.A

Plate 11 figures 17-20

Size in micrometres. (i) 41.5(43.8)46.5 (10 specimens) fum. HNO_3, Bottom Main at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb rounded to oval, margin undulate due to the projection of the muri. Laesurae simple, straight, 2/3 - 3/4 of spore radius, occasionally reaching the margin. Exine foveolate with broad, low anastomosing muri, 2-3 µm in width, lumina circular to oval in shape, regular, 0.5- 2 µm in diameter, usually coarser towards the margin. Exine 1-2 µm thick, compression folds infrequent.

Comparison. C. cerebra Butterworth and Williams 1958 is bigger and has a thicker exine.

Occurrence. Rare in the Bottom Main seam of Northumberland off-shore borehole No. 3, Westphalian B.

Genus MICRORETICULATISPORITES (Knox) Potonié and Kremp 1954

Type species. M. lacunosus (Ibrahim) Knox 1950

Diagnosis. (Smith and Butterworth 1967, p.189, translation from Potonié and Kremp 1954, p.143).

Comparison. Distinguished by its extrareticulate exine with small lumina.

Microreticulatisporites harrisonii Peppers 1970

Plate 11 figures 21-23

1970 Microreticulatisporites harrisonii, Peppers, pl.9, fig.1.

Holotype. Peppers 1970. pl. 9., fig. 1., megative 7931, maceration 1160 (RR), slide 16, co-ordinates, 135.5 x 34.3.

Type locality. Murphysboro Coal, Spoon Formation, Illinois, USA.

Diagnosis. (See Peppers 1970, p.110).

Size in micrometres. (i) Holotype, 30.9 x 33.8 (28.3-33.8), Schulze and 5% KOH, (Peppers 1970). (ii) 27.7(32.0)37 (7 specimens), fum. HNO_3, unnamed seam at 225 ft. 1 in., borehole No.5. (iii) 30.2(32.5)35.3 (4 specimens) fum. HNO_3, Top Ashington at 192 ft. 9 in., borehole No.5. (iv) 27.7(30.7)34.0 (3 specimens), Top and Bottom Yard (top leaf) at 217 ft. 1 in., borehole No.6, ((ii), (iii) and (iv), Northumberland off-shore boreholes, Westphalian B.

Description. Amb triangular, angles well rounded, sides concave. Laesurae straight, usually open, 2/3-3/4 of spore radius. The proximal and the distal surfaces are finely reticulate. Lumina 0.5 - 1 µm in diameter of uniform size and shape, muri 0.6-1.5 µm in width, notching the margin regularly, occasionally irregular. Number of muri projecting from the margin 35-59 (average

43). Exine thin, generally without folds.

Comparison. The finer reticulation and the slightly smaller size differentiate this species from M concavus Butterworth and Williams 1958.

Occurrence. Rare in Top Ashington, Top and Bottom Yard, Bottom Main seams and unnamed seam at 225 ft. 1 in., borehole No.5, Northumberland off-shore boreholes, Westphalian B. Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Microreticulatisporites nobilis (Wicher) Knox 1950

Plate 11 figures 24-26

1934 Sporites nobilis Wicher, p.186, pl.8, fig.30.

1944 Punctati-sporites 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 IVX5, 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. (See Smith and Butterworth 1967, p.192, translation from Potonié and Kremp 1955, p.101).

Size in micrometres. (i) Holotype 36, Schulze and KOH.

(ii) 30-45, Schulze (Potonié and Kremp 1955). (iii) 32(37)43, fum. HNO_3; Sharlston Top Seam at 1168 ft. 8 in., Cross Hill borehole, Yorkshire Coalfield, England; Westphalian C, (Smith and Butterworth 1967). (iv) 27(29.8)37.1, (15 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian B.

Description. Amb triangular, angles rounded, sides straight to slightly convex. Laesurae simple, straight, ¾ to a full length of spore radius, sometimes open. Exine distally and proximally reticulate, lumina 0.5 - 1 µm in diameter and of uniform shape and size, muri 1 µm in width. Number of sculptural elements projecting from the margin between 36-64 (average 48). Exine 1-1.5 µm thick, occasionally faint contact area present, generally without compression folds.

Comparison. M nObilis differs from M harrisonii in having straight to slightly convex interradial margin.

Remarks. This species has been used by Clayton et al. 1977 as a zonal index for Upper Westphalian B.

Occurrence. Rare in Bottom Main, Top Ashington and Top and Bottom Yard, Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Westphalian B and C, British Coalfields. Peppers 1970, Pennsylvanian Carbondale and Spoon Formations, Illinois, U.S.A. Grebe 1972, Ruhr, Germany, Westphalian B-C. Clayton

et al. 1977, ~~Upper Namurian C~~ - Westphalian B, Western Europe;Ravn 1979 Cherokee Group CP-19-4 Coal of Iowa, Westphalian B; Sullivan 1962, Westphalian B, Wernddu Claypit, Caerphilly, South Wales; Van Wijhe and Bless 1974, Upper Westphalian C, Netherlands.

Genus SECARISPORITES Neves 1961

Type species. S. lobatus Neves 1961.

Diagnosis. Neves 1961, p.260.

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

Secarisporites remotus Neves 1961

Plate 11 figures 27-31

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

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

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

Diagnosis. (See diagnosis in Neves 1961, p.262).

Size in micrometres. (i) Holotype 46; 35-50, Schulze and KOH (Neves 1961). (ii) 35(39.6)51 (10 specimens)

fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded-triangular, margin lobate. Laesurae usually obscured by ornament, simple, straight, ¾ of spore radius, sometimes with narrow lips. Distal surface covered by relatively loose, narrow ridges and small verrucae, with flat tops, generally 2-8 µm in height and up to 15 µm in basal width; sometimes the vermicular structures enclose irregular shaped lumina 3-4 µm in diameter. Number of elements projecting from the margin between 9-14 (average 11). On the proximal surface the ornament is reduced sharply, often absent. Exine 2-2.5 µm thick. Compression folds infrequent.

Comparison. This species is very similar to Convolutispora florida Hoffmeister, Staplin and Malloy 1955; it has a comparable size range, but differs in possessing pronounced lobation of the margin and a laevigate proximal surface.

Occurrence. Absent to rare throughout the sequence. Neves 1961, Namurian, Southern Pennines, England; Felix and Burbridge 1967, Mississippian/Pennsylvanian, Springer Formation, Oklahoma; Owens and Burgess 1965, Namurian B to Lower Westphalian A, Stainmore Outlier, Westmorland; Marshall and Williams 1970, Upper Viséan to Namurian A, Roman Wall District, West Northumberland; Sabry and Neves 1970, Namurian A to Westphalian C, Sanquhar Coalfield, Scotland; Owens et. al. 1977

Namurian A to Westphalian A, Northern England and Scotland.

Genus DICTYOTRILETES(Naumova) Smith and Butterworth 1967

Type species. D. ~~bi~~*media* (Ibrahim) ~~Potonié and Kremp 1954~~ *Smith and Butterworth 1967*.

Diagnosis. (Smith and Butterworth 1967, p.194, emended from Potonié and Kremp 1954, p.144).

Comparison. Reticulatisporites (Ibrahim) Neves 1964 is distinguished by its differentiated cingulum.

Dictyotriletes bireticulatus (Ibrahim) Smith and Butterworth 1967

Plate 11 figures 32-38

1932 Sporonites bireticulatus Ibrahim in Potonié, Ibrahim, and Loose, p.447, pl.14, fig.1.

1953 Reticulati-sporites bireticulatus Ibrahim, p.35, pl.1, fig.1.

1934 Reticulati-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.1c.

1952 Reticulati-sporites cf. mediareticulatus Ibrahim, Balme and Butterworth, pl.48, figs. 4a,b.

1954 Dictyotriletes bireticulatus (Ibrahim), Potonié and Kremp 1954, p.108.

1954 Reticulati-sporites cf. mediareticulatus Ibrahim; Butterworth and Millott, pl.21, fig. 8b.

1956 Reticulatisporites mediareticulatus Ibrahim, Butterworth and Millott, text - fig.3(8).

1964 Dictyisporites bireticulatus (Ibrahim) Levet-Carette, p.271, pl.10, fig.17.

1967 Dictyotriletes bireticulatus (Ibrahim); Smith and Butterworth p.194-195, pl.11, figs.14-15.

Holotype. Potonié and Kremp 1955, pl.16, fig.296 after Ibrahim. Preparation B_{33}, a4(r).

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

Diagnosis. (See Smith and Butterworth 1967, p.194, emended from diagnosis in Potonié and Kremp 1955, p.108).

Size in micrometres. (i) Holotype 57.5, Schulze and KOH. (ii) 40-60 Schulze (Potonié and Kremp 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 Seam at 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 of 100 ft. 2 in., Common Gate borehole No.1, Northumberland Coalfield, England, Lower Westphalian A. ((iv)-(vi) Smith and Butterworth 1967); (vii)28.5(34)40, 20 specimens), fum. HNO_3, Bottom Brass Thill, at 377 ft.

9 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb rounded-triangular, sides convex; in equatorial view the distal profile is strongly convex compared with the proximal profile. Outline smooth to gently undulate, usually modified by the projection of the muri 1-2 μm from the margin. Laesurae simple, straight, extending ¾ to almost entire spore radius, sometimes open, frequently obscured by the ornament. Reticulation covers the distal surface only, polygonal shaped lumina, 3.5-9.4 μm in diameter, number between 16-24, usually the lumina are regular in size and shape except in the equatorial region, muri 0.5-1.5 μm in width, sometimes sinuous. Exine thin, laevigate. Compression folds infrequent.

Occurrence. Frequent to common in Bottom Brass Thill, Bottom Yard, Main, and Top Main seams, Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Westphalian A-Lower Westphalian C, British Coalfields; Grebe 1972, Upper Westphalian A-C, Ruhr Germany; Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Clayton et al 1977, Westphalian A-C, Western Europe; Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B.

Dictyotriletes castaneaeformis (Horst) Sullivan 1964

Plate 11, figures 39,40

1943 Aletes castaneaeformis Horst, p.124, fig.82.

1955 Reticulatisporites castaneaeformis (Horst) Potonié and Kremp, 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. (See Smith and Butterworth 1967, p.195, from Horst 1955, p.169).

Size in micrometres. (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 (Smith and Butterworth 1967). (iii) 24(25.3)27 (4 specimens), fum. HNO_3, unknown seam at 225 ft. 1 in., Northumberland off-shore borehole No.5, Westphalian B.

Description. Amb oval, margin undulate. Trilete suture not visible, apparently alete. Reticulation on both proximal and distal surfaces. Lumina vary in size, up to 7 µm in diameter, muri sinuate, 0.5 - 1 µm in width. Number of muri projecting from margin between 8 and 11.

Comparison. D. castaneaeformis is smaller than D. clatriformis (Artüz 1957, p.248, pl.4, fig.26) Sullivan 1964 and D. crassireticulatus (Artüz 1957) Smith and Butterworth 1967. D. cf. clatriformis (Artüz 1957) Sullivan 1964 is similar to D. castaneaeformis and can be considered a synonym. According to Smith and Butterworth 1967 Microreticulatisporites fundatus Hoffmeister, Staplin and Malloy 1955 differs only in possessing smaller lumina.

Occurrence. Rare in unknown seam at 225 ft. 1 in., borehole No.5, and Bottom Main seam, Northumberland off-shore borehole Westphalian B; Sullivan 1964, Dry Brook sandstone of the Forest of Dean, Upper Viséan and Westphalian A. Smith and Butterworth 1967, Namurian A - Westphalian B, British Coalfields; Grebe 1972, Upper Westphalian A, Ruhr, Germany. Ravn 1979 Cherokee Group CP 19-4 Coals of Iowa, Westphalian B. Neves 1968, Namurian C to Westphalian A, Woodland Borehole, Co. Durham; Owens and Burgess 1965, Namurian A, Stainmore Outlier, Westmorland.

Dictyotriletes falsus Potonié and Kremp 1955

Plate 11 figures 41-43

1955 Dictyotriletes falsus Potonié and Kremp, pl.16, fig. 303.

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. (See Smith and Butterworth, 1967, p.196, translation from Potonié and Kremp 1955, p.109).

Size in micrometres. (i) Holotype 48; 45-55, Schulze (Potonié and Kremp 1955). (ii) 40(46)52 (6 specimens) fum. HNO_3; various localities, Yorkshire and Nottinghamshire Coalfields, England; Westphalian A and B. (Smith and Butterworth 1967). (iii) 36.5(40.5)46.5 (6 specimens), fum.. HNO_3, Bottom Brass Thill at 377 ft. 9 in., Northumberland off-shore borehole No.3, Westphalian B. (iv) 41.5, 38.5 (2 specimens) fum. HNO_3, Bottom Main at 123 ft. 6 in., Northumberland off-shore borehole No.2, Westphalian B.

Description. Amb rounded, margin undulate. Laesurae usually obscured by ornament, ¾ of spore radius. Both distal and proximal surfaces are reticulate, lumina vary in size and shape in any one individual, 2-11 µm in diameter, muri relatively broad, frequently distorted, 2·5-3·5 µm in width, project 2-2.5 µm from margin, between 8 to 12 marginal projecting muri. Exine laevigate, thin, compression folds infrequent.

Occurrence. Rare in Bottom Brass Thill and Bottom Main seams, Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth 1967, Westphalian A to Lower Westphalian C, British Coalfields; Grebe 1972, Lower

Westphalian B to Upper Westphalian C, Ruhr, Germany, Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Loboziak 1971, Westphalian A to C, Houiller Basin, North France.

Dictyotriletes muricatus (Kosanke) Smith and Butterworth 1967

Plate 12 figures 1-5

1950 Reticulati-sporites muricatus Kosanke, p.27, pl.4, fig.7.

1967 Dictyotriletes muricatus (Kosanke) Smith and Butterworth, p.197, pl.11, figs.

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. (See Smith and Butterworth 1967, p.197, from description in Kosanke 1950, p.27).

Size in micrometres. (i) Holotype 91 x 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. (Smith and Butterworth 1967). (iii) 56(62.7)72 (15 specimens), fum. HNO_3, Bottom Hutton, Northumberland off-shore borehole P_2 at 122.24m Westphalian B, England.

Description. Amb circular, margin undulate. Laesurae

frequently obscured by ornament, simple, straight 2/3 - 3/4 of spore radius, sometimes slightly open, occasionally with narrow lips. Both proximal and distal Surfaces reticulate with large lumina and thin twisted, but high, muri, up to 6 μm in height, 1-1.5 μm in width and extending up to 10 μm beyond the margin. The high muri usually reduced in height in the contact area, and in compression it gives the spore the appearance of having a membranous flange around the body. The body often shows a darker equatorial zone due to the overlapping of the body by the high muri. Exine laevigate, or scabrate, usually preserved without compression folds.

Occurrence. Infrequent to frequent in Bottom Hutton seam and rare in Bottom Brass Thill and Bottom Main, Northumberland off-shore boreholes, Westphalian B. Smith and Butterworth 1967, Upper Westphalian A- Lower Westphalian C. British Coalfields. Van Wijhe and Bless 1974 Westphalian A-D, Netherlands.

Dictyotriletes reticulocingulum (Loose)
Smith and Butterworth 1967
Plate 12 figures 6-12

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.

1967 Dictyotriletes reticulocingulum (Loose) Smith and Butterworth, p.198, pl.11, figs. 27-29.

Holotype. Potonié and Kremp 1955, pl.16, fig.306 after Loose. Preparation IV44, a_2 (ul).

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

Diagnosis. (See Smith and Butterworth 1967, p.198, from diagnosis in Potonié and Kremp 1955, p.113).

Size in micrometres. (i) Holotype 45, Schulze. (ii) 40-60 Schulze (Potonié and Kremp 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. ((iii) and (iv) Smith and Butterworth 1967). (v) 33(38)51 (13 specimens) fum. HNO_3, Top and Bottom Yard at 217 ft. 1 in., Northumberland off-shore borehole No.6 Westphalian B.

Description. Amb circular, occasionally rounded-triangular, margin modified by the projecting muri. Laesurae simple, straight, extending $\frac{3}{4}$ to full length of spore radius, sometimes with narrow lips. Reticulation on the distal surface is prominent and well defined compared with that on the proximal surface. Lumina more or less polygonal,

sometimes circular, 3-13 μm in diameter.

Comparison. Differs from D. mediareticulatus (Ibrahim) Smith and Butterworth 1967 in being smaller and less reticulate on the proximal surface. D. areolatus (Guennel 1958) Smith and Butterworth 1967 is smaller and the lumina are less variable.

Occurrence. Infrequent in Top and Bottom Yard, Bottom Main, Bottom Brass Thill and Harvey seams, Northumberland off-shore boreholes, Westphalian A-B. Smith and Butterworth 1967, Upper Westphalian A to Lower Westphalian C, British Coalfields. Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Ravn 1979 Cherokee Group CP 19-4 Coals of Iowa, Westphalian B.

Genus CAMPTOTRILETES (Naumova) Potonié and Kremp 1954

Type species. C. corrugatus (Ibrahim) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.199 translation from Potonié and Kremp 1954, p.142).

Camptotriletes bucculentus (Loose) Potonié and Kremp 1955

Plate 12 figures 13-17

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 1934. Preparation III94, d_2 (m/or).

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

Diagnosis. (See Smith and Butterworth 1967, p.199, from diagnosis and description in Potonié and Kremp 1955, p.104).

Size in micrometres. (i) Holotype 47.5, Schulze and KOH. (ii) 45-75, Schulze (Potonié and Kremp 1955). (iii) 50(56)67, fum. HNO_3, various localities; Westphalian A and B. (Smith and Butterworth 1967). (iv) 40(47)59 (12 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded to rounded-triangular, margin modified by ornament. Laesurae simple, straight, 1/2 - 2/3 of spore radius. Ornament consists of low ridges or vermiculae and loosely scattered verrucae 1-2.5 µm in height and up to 8 µm in basal width; apices of the ridges and the vermiculae pointed, rounded, truncate or even fimbriate; these are clearly shown when the elements project at the margin. Number of projections at the margin between 15-23; ornament is well developed on the

distal surface rather than on the proximal surface which sometimes appears more or less laevigate. Exine 2-2.5 µm thick. Compression folds rare.

Comparison. Distinguished by its irregular discontinuous ridges which result from the lateral fusion of verrucae.

Occurrence. Absent to rare throughout the sequence Smith and Butterworth 1967, British Coalfields, Upper Westphalian A and Westphalian B; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B; Neves 1964, Namurian B to C, La Camocha Mine, Gijǻn, North Spain; Owens and Burgess 1965, Westphalian A, Stainmore Outlier, Westmorland; Sabry and Neves 1970, Namurian B and C, Sanquhar Coalfield, Scotland; Owens et. al 1977, Namurian A to Westphalian A, Northern England and Scotland; Clayton et. al. 1977 Namurian A to Westphalian A, Western Europe.

Camptotriletes corrugatus (Ibrahim) Potonié and Kremp 1954

Plate 12 figures 18-21

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

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

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

1954 Camptotriletes corrugatus (Ibrahim) Potonié and Kremp, p.104, pl.16, figs.289, 290.

Holotype. Potonié and Kremp 1955, pl.16, fig.289, after Ibrahim 1933, pl.5, fig.41, Preparation B31, b_5 (or).

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

Diagnosis. (See diagnosis in Potonié and Kremp 1955, p.104).

Size in micrometres. (i) Holotype 46, Schulze and KOH; (ii) 40-50, Schulze (Potonié and Kremp 1955). (iii) 40(46.3)52 (10 specimens) fum. HNO_3, various localities, Northumberland off-shore boreholes, Westphlian A and B.

Description. Amb triangular to rounded triangular, angles well rounded, sides convex. Laesurae distinct, simple, straight, 2/3-3/4 of spore radius. Exine covered with well spaced low anastomosing vermiculae, ridges and sometimes verrucae, 1-2 µm in height; these elements intersect with each other to enclose lumina of different size and shape and give the spore the appearance of reticulate ornament; incomplete lumina may also be formed by sinuate single ridges. Sculptural elements are coarser and more well defined on the distal surface, number of elements projecting from the margin between 16-24 (average 18). Exine 2-3 µm thick, rarely folded.

Comparison. Differs from C. bucculentus in the way that the sculptural elements tend to form a reticulate pattern.

Occurrence. Absent to rare throughout the sequence,

Grebe 1972, Lower Westphalian B - Upper Westphalian C, Ruhr, Germany. Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B.

Camptotriletes sp.A

Plate 12 figures 22-25

Size in micrometres. (i) 38.5(40.7)45 (8 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb triangular, sides straight or slightly convex, angles well rounded. Laesurae distinct, simple, straight, 1/2-2/3 of spore radius, sometimes open. Exine covered by long, low ridges 1 µm in height and up to 16 µm in ~~width~~ length, with scattered small coni and verrucae in between, the elements are relatively closely packed 1-3 µm apart. Number of elements projecting from the margin between 22-36 (average 26). Exine 2-3 µm thick. Faint contact areas are sometimes recognizable. Compression folds rare.

Comparison. Differs from both C. bucculentus and C. corrugatus in possessing narrow low and long ridges with coni and verrucae, and the greater number of elements projecting from the margin. It is very similar to Lophotriletes granoornatus Artüz but it is easily distinguished by the presence of the ridges.

Occurrence. Absent to rare throughout the Westphalian A and B sequences.

Subturma ZONOTRILETES WALTZ 1935

Spores assigned to this subturma are acavate with an equatorial thickening and/or extension.

Infraturma AURICULATI (Schopf) Dettmann 1963

Genus AHRENSISPORITES Potonié and Kremp 1954

Type species. A. querickei (Horst) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.200, translation from Potonié and Kremp 1954, p.155.)

Ahrensisporites querickei (Horst) Potonié and Kremp 1954

Plat 12 figures 26-30

1943 Triletes querickei Horst , (thesis) pl.7, figs. 58, 61-64.

1954 Ahrensisporites querickei (Horst), Potonié and Kremp, p.155.

Holotype. Horst 1955, pl.23, fig.63. Preparation I6, 28.7 71.4.

Type locality. Seam VI, Karsten Colliery, Beuthen, Upper Silesia; Westphalian A.

Diagnosis. (See Smith and Butterworth 1967, p.201, expanded from Horst 1955, p.178).

Size in micrometres. (i) Holotype 67; 50-84(50-68), fum. HNO_3 (Horst 1955). (ii) 42(51)61, fum. HNO_3; seam at about 2776 ft., Colston Bassett (British Petroleum Co.

Ltd.) borehole, Nottinghamshire Coalfield, England, Westphalian A. (Smith and Butterworth 1967). (iii) 35(41.8)50 (15 specimens), fum. HNO_3, Top and Bottom Yard at 217 ft. 1 in., Northumberland off-shore borehole No.6, Westphalian B.

Description. Amb triangular, sides straight to slightly convex, angles rounded. Laesurae simple, straight or slightly flexuose, extending almost entirely to the spore margin, sometimes slightly open. Kyrtomes are very prominent, continuous ridges, 5-9 µm in width and height, (measured when projected beyond the amb in the radial region); margin smooth or undulate, occasionally the undulation is narrow and up to 3 µm in height especially in the radial region. Kyrtomes usually truncated in the radial region, 16-23 (average 18.5 µm) in width. Exine 1·5-2.0 µm thick, granulate, grana loosely scattered and usually associated with verrucae 1-1.5 µm in diameter.

Comparison. According to Smith and Butterworth 1967 A. angulatus (Kosanke) Potonié and Kremp is morphologically similar to A. guerickei and the size difference is due to the method of maceration although Kosanke mentioned that the arcuate thickening is connected proximally by a thickened line. A. guerickei var. ornatus Neves 1961 is larger (65 - 80 µm) and possesses a wart-like thickening on the distal surface. A. irroratus Felix and Burbridge 1967 is very similar and can be

considered a synonym.

Occurrence. Absent to rare throughout the sequence; Smith and Butterworth Upper Namurian B to Westphalian A, British Coalfields. Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A. Grebe, 1972 Upper Westphalian A - Middle Westphalian B, Ruhr, Germany. Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Clayton et. al. 1977, Westphalian A (Radiizonates aligerens Zone), Western Europe. Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, Westphalian B.

Genus TRIQUITRITES (Wilson and Coe) Potonié and Kremp 1954

Type species. T. arculatus Wilson and Coe 1940.

Diagnosis. (Smith and Butterworth 1967, p.201, translation from Potonié and Kremp 1954, p.153).

Comparison. Ahrensisporites guerickei (Horst) Potonié and Kremp 1954 is distinguished by the presence of a kyrtome and lack of valvae or auriculae which are restricted to radial margin in the genus Triquitrites.

Triquitrites protensus Kosanke 1950

Plate 13 figures 1-5

1950 Triquitrites protensus Kosanke, p.40, pl.8, fig.2

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. (See Smith and Butterworth 1967, p.203, from description in Kosanke 1950, p.40).

Size in micrometres. (i) Holotype 38 x 36.5; 33.5-39, Schulze and 10% KOH (Kosanke 1950). (ii) 32(39.1)48 (12 specimens) fum. HNO_3, Bottom Brass Thill, at 377 ft. 9 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb triangular, sides straight to slightly convex sometimes undulate, angles rounded, truncate or undulate. Laesurae usually distinct, simple, straight or slightly flexuose, nearly touching the spore margin, sometimes open. Development of radial crassitude variable in length and width in any one individual, radial length between 2-10 µm, width between 9.5 -16 µm. Arcuate thickening extending from the crassitudes on the distal surface, usually not continuous and variable in prominence, diminishing polewards often forming a loop-like structure and occasionally forming a faint kyrtome. Exine 1-2 µm thick, laevigate or scabrate, sometimes with few loosely scattered verrucae. Compression folds absent.

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

Occurrence. Absent to rare throughout the sequence. Infrequent in the Bottom Brass Thill, Northumberland off-shore borehole No. 3, Westphalian B. Smith and Butterworth 1967, British Coalfields, Lower Westphalian A; Ravn 1979, Cherokee Group Cp-19-4 Coals of Iowa, Westphalian B.

Triquitrites tribullatus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 13 figures 6-10

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, 63(U1).

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

Diagnosis. (See Smith and Butterworth 1967, p.205, from Potonié and Kremp 1956, p.90, translation).

Size in micrometres. (i) Holotype 62, Schulze and KOH.

(ii) 40-70, Schulze (Potonié and Kremp 1956).
(iii) 37(43)52, fum. HNO_3, seam at 436 ft. 4 in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England, Westphalian A. (Smith and Butterworth 1967).
(iv) 35.5(43.3)48 (10 specimens) fum. HNO_3, Bottom Main seam, at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb triangular, angles rounded or truncated, sides straight, slightly convex or concave. Laesurae simple, straight, extending more or less to the inner margin of the radial crassitudes. Radial crassitudes vary in their development from a slight thickening which does not modify the margin to well developed rounded or truncated thickenings which project beyond the margin; the crassitudes also vary in any one specimen; radial length up to 15 µm, width up to 24 µm. Exine laevigate or scabrate, 1.5 - 2 µm thick. Compression folds infrequent.

Comparison. Differs from T. protensus Kosanke in lacking the distal thickening which extends polewards from the crassitude. T. bransonii Wilson and Hoffmeister 1956 is similar but smaller and it is difficult to differentiate between them if they exist in one assemblage.

Occurrence. Absent to rare throughout the sequence, Artüz 1957, Westphalian A, Zonguldak Coalfields, Turkey; Dybova and Jachowicz 1957, Westphalian D, Silesia;

Smith and Butterworth 1967, British Coalfields, Namurian A to Westphalian C ; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Lower Westphalian C, Netherlands. Loboziak 1971, Namurian to Stephanian, Nord-Pas-de-Calais, France.

Triquitrites sp.A

Plate 13 figures 11-15

Size in micrometres. (i) 27(32.8)38.5 (15 specimens) fum. HNO_3, Top and Bottom Yard, at 217 ft. 1 in., Northumberland off-shore borehole No.6, Westphalian B.

Description. Amb.triangular, sides straight to slightly convex, angles rounded or flat, sometimes lobed due to the projection of verrucae. Laesurae raised, extending ¾ of spore radius, occasionally to the inner margin of the radial crassitude. Distal surface ornamented with loosely scattered, broad verrucae, often concentrated towards the distal pole to give the appearance of darker coloured contact areas proximally, 2-7 µm wide, 1-3 µm in height. Ornament reduced sharply on the proximal surface or even absent. Radial crassitudes vary in their development in any one individual, sometimes almost absent, they scarcely project from the margin except when they are ornamented, radial length 1.5 - 6 µm, width 5-11 µm. Exine 1-1.5 µm thick. Compression folds rare.

Comparison. T. sculptilis (Balme) Smith and Butterworth has an undulating or wavy ornament of the exine which

gives the spore the appearance of being reticulate. T. crassus Kosanke 1950 is bigger than T. sp.A. T. bucculentus Guennel 1958 has concave sides and the verrucae greatly modify the sides and radial crassitudes. T. coesfeldens Bhardwaj 1957b has a smooth exine and cushion-like radial crassitudes.

Occurrence. Rare in the Top and Bottom Yard seam, Northumberland off-shore borehole No.6, Westphalian B.

Genus TANTILLUS Felix and Burbridge 1967

Type species. T. triquetrus Felix and Burbridge 1967.

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

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

Tantillus triquetrus Felix and Burbridge 1967
Plate 13, figures 16,17

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

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

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

Diagnosis. (See diagnosis in Felix and Burbridge 1967, p.383).

Size in micrometres. (i) Holotype 18 x 18, 16.5 -25, Schulze and KOH (Felix and Burbridge 1967). (ii) 26.5(27)32 (4 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalina A and B.

Description. Amb triangular, sides slightly concave, angles rounded. Laesurae simple, slightly flexuose, extending ¾ of spore radius usually obscured by the distal thickening. Distal thickening consists of triangular bands parallel to the interradial margin 2.5-5.5 µm wide, and having the same length as the laesurae, bands expand at apices forming a T shape structure, the expansion is equal to the width of the body. Exine finely granulate or minutely spinose, 1-1.5 µm thick.

Occurrence. Absent to rare throughout Westphalian A and Lower Westphalian B sequences; Urban 1971, Upper Mississippian of the Independence shale of Iowa, U.S.A. Ravn 1979, Cherokee Group Cp-19-4 Coals of Iowa, Westphalian B.

Infraturma TRICRASSATI Dettmann 1963

Genus REINSCHOSPORA Schopf, Wilson, and Bentall 1944

Type species. R. speciosa (Loose) Schopf, Wilson, and Bentall 1944.

Diagnosis. (Smith and Butterworth 1967, p.211, translation from Potonié and Kremp 1956, p.131).

Comparison. Differs from Diatomozonotriletes (Naumova) Playford in possessing a corona of relatively finer setae.

Reinschospora speciosa (Loose) Schopf, Wilson and Bentall 1944

Plate 13 figures 18-21

1934 Alati-sporites speciosus Loose, p.151, pl.7, fig.1

1944 Reinschospora belliatus Bentall in Schopf, Wilson and Bentall, p.53, fig.2.

1944 Reinschospora speciosa (Loose) Schopf, Wilson and Bentall, p.53.

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. (See Smith and Butterworth 1967, p.212, from Potonié and Kremp 1956, p.132).

Size in micrometres. (i) Holotype 81, Schulze and KOH. (ii) Spore body 56(58)60 (8 specimens) fum. HNO_3, High Hazel Seam, Thorne Colliery, Yorkshire Coalfield, England, Westphalian B. (Smith and Butterworth 1967). (iii) Body dimensions 48(53)57.5 (10 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian B.

Description. Amb of corona rounded-triangular to circular, shape of the spore body triangular, interradial margins

concave, angles well rounded. Laesurae simple, straight, extending almost to the body equator, sometimes open. The setae which form the corona radiate only from the proximal surface and are embedded up to 7 µm into the spore wall. Individual seta about 1 µm in width and more or less in lateral contact throughout their length, truncate at the apex. Corona reduced in width in the radial regions, maximum width including the part inside the spore coat 16-22 µm. Occasionally in lateral compression the inner margin of the spore may lie interradially up to 5 µm from the amb. Exine moderately thick, very finely granulate (oil immersion). Compression folds infrequent.

Comparison. R. magnifica posses shorter and more discrete setae. R punctata Kosanke 1950 is distinguished by its punctate exine.

Occurrence. Rare in Top and Bottom Yard and Bottom Main seams of Northumberland off-shore boreholes, Westphalian B. Felix and Burbridge 1967, Springer Formation, Missippian-Pennsylvanian. Smith and Butterworth 1967, Westphalian A-C, British Coalfields. Grebe 1972, Upper Westphalian A-Lower Westphalian C, Ruhr, Germany. Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, Westphalian B.

Reinschospora triangularis Kosanke 1950

Plate 13 figures 22-24

1950 Reinschospora triangularis Kosanke, p.43, pl.9, Fig. 6,7.

1965a Reinschisporites triangularis (Kosanke) Laveine, p.134, pl.10, fig.40.

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. (See Smith and Butterwoth 1967, p.212, from Kosanke 1950, p.43).

Size in micrometres. (i) Holotype (including corona) 74 x 74; 79 x 78 to 66 x 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. (Smith and Butterworth 1967). (iii) Body dimensions, 48(53.3)62.5 (8 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian A-B.

Description. Amb triangular exclusive of the corona, sides straight to slightly convex, angles narrowly rounded, rarely folded. Laesurae straight, simple, frequently open, extending almost to the equator, each laesura is accompanied by two parallel bands of thickening 2-3 µm in width. Corona composed of separated setae, reduced in width by half or sometimes absent in the radial regions, setae extend 2-5 µm beyond the spore margin, maximum width (including overlap) 10-16 µm. Individual seta 0.5 -2 µm in width, the majority branching

in the middle or at the top into 2-4 spines. Similar corona but with shorter setae occur opposite the laesurae on the distal surface. Exine laevigate, moderately thick, rarely folded.

Comparison. R triangularis differs from R speciosa (Loose) Schopf, Wilson and Bentall in having straight interradial margins, separate and branched setae on both proximal and distal surfaces.

Occurrence. Rare in the Top and Bottom Yard, Bottom Main, and Bottom Brass Thill seams, Northumberland off-shore boreholes Westphalian B. Smith and Butterworth 1967, Westphalian B, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Clayton et. al. 1977, Namurian B (Grumosisporites varioreticulatus - Crassispora Kosankei Zone) Western Europe; Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, Westphalian B; Artüz 1957, Westphalian A, Zonguldak Coalfield, Turkey; Neves 1964, Namurian B to Westphalian A, Gijon, North Spain.

Infraturma CINGULATI (Potonié and Klaus) Dettmann 1963

Genus KNOXISPORITES (Potonié and Kremp) Neves and Playford 1961

Type species. K. hageni Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.218, from Neves and Playford 1961).

Comparison. This genus is characterised by a cingulum of more or less uniform thickness throughout its width. Reticulatisporites (Ibrahim) Neves 1964 is distinguished by its differentiated cingulum.

Knoxisporites triradiatus Hoffmeister,Staplin and Malloy 1955

Plate 13 figures 25-30

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

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

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

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

Size in micrometres. (i) Holotype 80 x 86, HF (Hoffmeister, Staplin and Malloy 1955). (ii) 48(55.6)64 (10 specimens) fum. HNO_3, Bottom Main, at 123 ft. 6 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb circular to rounded-triangular, occasionally rectangular, margin smooth. Laesurae straight, extending to the inner margin of the cingulum, usually accompanied by narrow lips, and bifurcating into two short branches (?curvaturae imperfectae). Equatorial

thickening (cingulum) is regular on individual specimens, between 5-8.5 (average 6.5) µm wide. Distal surface shows three bands of thickening or muri 8-11.5 µm in width, radiating from the pole and joining the cingulum in the interradial areas, making an angle of about 60° with the laesurae. Exine laevigate and rarely folded.

Comparison. K. hageni Potonié and Kremp 1954 possesses three distal bands of thickening arranged along the sides of a triangle and enclosing a circular unthickened area at the distal pole.

Occurrence. Absent to rare throughout the sequence. Love 1960, Lower Oil shale Group of Scotland, Upper Viséan; Felix and Burbridge 1967, Springer Formation, Tournaisan to Westphalian B, Oklahoma, U.S.A.; Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, U.S.A., Westphalian B. Loboziak 1971, Namurian to Westphalian, Nord-Pas-de-Calais, North France; Urban 1971, Upper Mississippian of the Independence Shale of Iowa, U.S.A.

Genus RETICULATISPORITES (Ibrahim) Neves 1964

Type species. R. reticulatus Ibrahim 1932

Diagnosis. (Smith and Butterworth 1967, p.22a, from Neves 1964, p.1066).

Comparison. Differs from Knoxisporites (Potonié and Kremp) Neves and Playford 1961 in possessing a differentiated cingulum.

Reticulatisporites polygonalis (Ibrahim)

Smith and Butterworth 1967

Plate 14 figures 1-4

1932 Sporonites polygonalis Ibrahim in Potonie, 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.

1967 Reticulatisporites polygonalis (Ibrahim), Smith and Butterworth, pl.14, fig.13.

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. (See Smith and Butterworth 1967, p.221, emended from Potonié and Kremp 1955, p.117).

Size in micrometres. (i) Holotype 108, Schulze and KOH. (ii) 80-110, Schulze (Potonié and Kremp 1955). (iii) 79(91)1)2 (11 specimens) fum. HNO_3 seam at 2,015 ft. 4 in., Cotgrave Wolds borehole, Nottinghamshire Coalfield, England, Westphalian A. (Smith and Butterworth

1967). (iv) 64(81.7)97 (10 specimens), fum. HNO_3, Bottom Brass Thill, at 377 ft. 9 in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb usually polygonal, due to the projections of the interradial muri, sometimes shape varies due to oblique compression, outline undulate. Laesurae simple, occasionally slightly raised, straight or slightly flexuose, usually touching the inner margin of the cingulum, sometimes open. In polar compression the cingulum is differentiated into three zones, inner broad zone 6-9.5 µm in width, peripheral zone 3-6 µm in width and the thinner zone in between 2-5 µm in width. Ornament well-defined distally, but reduced proximally; on the distal surface it usually consists of a single central triangle or polygonal structure formed by bands 3-8 µm in width which is connected interradially to the cingulum by three prominent muri. Proximally three less defined muri arise in the radial positions from the cingulum and head polewards to meet the laesurae. Muri from other positions on the cingulum pass for short distances towards the proximal pole. Exine laevigate. Compression folds infrequent.

Comparison. R carnosus (Knox)Neves 1964 differs from R polygonalis in having less defined distal thickenings.

Occurrence. Rare in Harvey, Bottom Brass Thill and Bottom Main seams of Northumberland off-shore boreholes, Westphalian A-B; Smith and Butterworth 1967, Westphalian

A, B and Lowest part of C, British Coalfields; Neves 1961, Namurian A to Westphalian A, Southern Pennines; Owens and Burgess 1965, Namurian A to Westphalian A, Stainmore Outlier; Neves 1968 Namurian B to Westphalian A, Woodland Borehole, Co. Durham; Marshall and Williams 1970, Namurian A, Roman Wall District, Western Northumberland, England; Loboziak 1971 Namurian to Westphalian, North France; Van Wijhe and Bless 1974, Westphalian C, Netherlands.

Reticulatisporites reticulatus (Ibrahim) Ibrahim 1933

Plate 14 figures 5,6

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 B_5, b_2 (or).

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

Diagnosis. (See Smith and Butterworth 1967, p.222, expanded from Potonié and Kremp 1955, p.112).

Size in micrometres. (i) Holotype 81, Schulze and KOH. (ii) 75-90 Schulze (Potonié and Kremp 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. (Smith and Butterworth 1967). (iv) 64(70.6)78.5 (8 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes Westphalian A-B.

Description. Shape variable from subcircular to more or less polygonal, margin smooth or slightly undulate due to the projection of the muri. Laesurae simple, straight or slightly curved ¾ of spore radius, sometimes touching the inner margin of the cingulum. Cingulum is clearly differentiated into three zones, inner broader zone 3-5 µm in width, marginal zone 2-3 µm in width and the thinner zone in between 1.5-2.5 µm in width. Reticulation on the distal surface usually consists of central polygonal area surrounded by 6-8 marginal areas, lumina 10-27 µm in diameter, muri 3-6 µm in width. Number of muri reaching the equator 6-9. Exine laevigate, rarely folded.

Occurrence. Rare in Bottom Brass Thill and Bottom Main Seams of Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth 1967, Westphalian A-D, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Grebe 1972, Ruhr, Germany, Lower Westphalian B- Lower Westphalian C.; Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, Westphalian B; Clayton et. al. 1977, Namurian C to

Westphalian D, Western Europe.

Genus SAVITRISPORITES Bharadwaj 1955

1958 Callisporites Butterworth and Williams, p376

Type species. S triangulus Bharadwaj 1955.

Diagnosis. (Smith and Butterworth 1967, p223, from Bharadwaj 1955, p127).

Remarks. Sullivan (1964, p.373) considered Callisporites to be congeneric with Savitrisporites following his re-examination of the type species of C. nux. Butterworth and Williams 1958.

Savitrisporites nux (Butterworth and Williams) Sullivan 1964

Plate 14 figures 7-15

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.

1967 Savitrisporites nux (Butterworth and Williams) Sullivan in Smith and Butterworth, p.233-225, pl.15, figs. 1-3.

Lectotype. Plate 15, figs. 1,2. Preparation T55/1 in collection of National Coal Board Laboratory, Wath-Upon Dearne, Rotherham, Yorkshire, designated by Smith and Butterworth 1967.

Type locality. Upper Hirst Seam at 2310 ft 4in., Brucefield bolehole, West Fife Coalfield, Scotland, Namurian A.

Diagnosis. (See Smith and Butterworth 1967, p.224, emended from Butterworth and Williams 1958, p.377).

Size in micrometres. (i) Lectotype 58; 45(56)64, Schulze and 5% KOH (Butterworth and Williams 1958). (ii) 30 (47) 60,

fum. HNO_3 (Sullivan 1964); Edgehills Coal, Forest of Dean Coalfield, England; Westphalian A. (iii) 30.5 (42.4) 64 (15 specimens) fum. HNO_3, various seams, Northumberland offshore boleholes Westphalian A-B.

Description. Amb triangular, sides straight to slightly convex or slightly concave, angles well rounded, margin crenulate. Laesurae simple, straight extending to the inner margin of the cingulum.

Cingulum 2-6.5 (average 4) μm wide. Ornamentation varied in form and development, distal surface covered with verrucae or ridges, varying in height and basal width, up to 4μm in height and 10μm in basal width; sculptural elements may be oriented randomly or arranged in concentric zones parallel to the spore margins. On the proximal surface the ridges, low and broad, are usually associated with the laesurae to give the sutures the appearance of having lips. Compression folds absent.

Comparison. According to Smith and Butterworth 1967 S. triangulus Bharadwaj 1955 (p.128, pl.1, fig.5) is similar to S. nux except that the cingulum in the former is slightly more developed at the angles and the laesurae lack the accompanied bands of thickening. S. asperatus Sullivan 1964 is very similar to S. nux and is considered by Sullivan as possibly an immature form of S. nux. S. concavus Marshall and Smith 1965 (pl.99, figs. 9-12) differs in possessing concave sides and less ornament on the distal surface.

Occurrence. Absent, rare to infrequent throughout the sequence; Sullivan 1964, Edgehills Coal, Forest of Dean Coalfield England, Westphalian A.; Smith and Butterworth 1967

Namurian A to Westphalian B, British Coalfields; Felix and Burbridge 1967, Springer Formation, Tournaisian to Westphalian B, Oklahoma, U.S.A.; Grebe 1972, Upper Westphalian A, Ruhr, Germany. Van Wijhe and Bless 1974, Westphalian A-C, Netherlands; Ravn 1979 Cherokee Group CP 19-4 of Iowa, U.S.A., Westphalian B.

Suprasubturma LAMINATITRILETES Smith and Butterworth 1967

This includes all trilete, cavate spores in which the intexine is not widely separated from the exoexine.

Subturma AZONOLAMINATITRILETES Smith and Butterworth 1967

This includes trilete, cavate spores in which the intexine and exoexine are not differentially thickened.

Infraturma TUBERCULORNATI Smith and Butterworth 1967

This includes trilete, cavate spore in which the exoexine is ornamented with grana, verrucae, spinae, bacula .... etc.

Genus GRUMOSISPORITES Smith and Butterworth 1967

Type species. G. verrucosus (Butterworth and Williams) Smith and Butterworth 1967.

Diagnosis. (Smith and Butterworth 1967, p.228)

Remarks. According to Smith and Butterworth 1967 this genus was erected to accomodate spores which show a well defined exine separation and were formerly assigned to genera such as Dictyotriletes, Camptotriletes, and Verrucosispories.

Grumosisporites papillosus (Ibrahim) Smith and Butterworth 1967

Plate 15 figures 1-4

1933 Verrucosi-sporites papillosus Ibrahim, p.25, pl.5, fig.44.

1944 Punctati-sporites papillosus (Ibrahim), Schopf, Wilson and Bentall, p.31.

1950 Verrucoso-spories papillosus (Ibrahim); Knox, p.318, pl.17, fig. 229.

1967 Grumosisporites papillosus (Ibrahim) Smith and Butterworth, pl.16, figs. 9-13.

Holotype. Potonie 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. (See Smith and Butterworth 1967, p.230, emended from Ibrahim 1933, p.25).

Size in micrometres. (i) Holotype 77 x 74; 77-98. Schulze and KOH (Ibrahim 1933). (ii) 68-86, fum HNO_3, various localities, Yorkshire and Leicestershire Coalfields, England, Westphalian A and Lower Westphalian B. (Smith and Butterworth 1967), (iii) 61 (66.2) 72 (8 specimens) fum HNO_3, various seams, Northumberland off-shore boleholes, Westphalian A and B.

Description. Amb rounded or rounded-triangular. Laesurae simple, straight or slightly flexuose, $\frac{2}{3}$ - $\frac{3}{4}$ of spore radius. Intexine thin, folded with a radius equal to the length of the

laesurae. Exoexine is relatively thick 3.5/μm, covered with irregularly shaped verrucae up to 6/μm in height (mostly 3-4/μm) and 3.15/μm in basal width. Number of verrucae projecting from the margin between 14-27. Exoexine rarely folded.

Occurrence. Rare in Top Maudlin and Bottom Brass Thill Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth 1967, Upper Westphalian A and Westphalian B, British Coalfields.

Grumosisporites varioreticulatus (Neves) Smith and Butterworth 1967

Plate 14 figures 16-20

1958 Dictyotrilotes varioreticulatus Neves, p.8, pl.2, fig. 1a,b.

1967 Grumosisporites varioreticulatus (Neves) Smith and Butterworth, o.232, pl.17, figs. 8-10.

Holotype. Neves 1958, pl.2, fig. 1. Preparation F_7SI, reference 056550 in collection of Geological Department, Sheffield University.

Type locality. Roof shale of Six Inch Seam, Quarnford, North Staffordshire Coalfield , England; Namurian C.

Diagnosis. (See Smith and Butterworth 1967, p.232, emended from Neves 1958, p.8).

Size in micrometres. (i) Holotype 106; 70-110, Schulze and 10% KOH (Neves 1958). (ii) 67 (78) 89 fum. HNO_3, various localities; Westphalian A and B (Smith and Butterworth 1967). (iii) 61 (69.4) 79 (10 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A-B.

Description. Amb circular or slightly oval, margin undulate due to the projection of the muri. Laesurae simple, straight, $\frac{3}{4}$ of spore radius. Exine is clearly separated into two layers except in the contact area. Intexine triangular in shape, thin, folded,and with its radius equal to the length of the laesurae. Exoexine is irregularly reticulate, lumina incomplete and varying in size, muri sinuate and up to 2-4μm in width, reticulation pattern is well defined on the distal surface, whereas the proximal surface scarcely shows the pattern; muri project at the margin as low, broad based coni with rounded apices and up to 2μm in height, number of muri projecting at the margin 21-32. Exine 2-4 μm thick.

Comparison. Differs from G. papillosus in possessing weakly reticulate ornament.

Remarks. The photograph given by Owens et al 1977 (pl.18, fig. 12) for Camptotriletes superbus Neves shows exine separation and is very similar to G. varioreticulatus.

Occurrence. Rare in the Harvey and Top Brass Thill seams Northumberland off-shore boreholes, Westphalian A and B. Neves 1961, Upper Namurian B, Westphalian A (for Dictyotriletes varioreticulatus), Southern pennines, England; Owen and Burgess 1965, Namurian B to Westphalian A, Stainmore Outlier, Westmorland; Smith and Butterworth 1967, Namurian B to Westphalian B, British Coalfields; Owens et al. 1977, Namurian B to Westphalian A, Northern England and Scotland; Clayton et al 1977, used it as a zonal fossil for Namurian B, Western Europe.

Genus DIAPHANOSPORA (Balme and Hassell) Evans 1970.

Type species. D. riciniata Balme and Hassell 1962.

Diagnosis. (Evans 1970, p.68 emended from Balme and Hassell 1962).

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

Diaphanospora parvigracila (Peppers) Ravn 1979

Plate 15 figures 1-4

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

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

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

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

Diagnosis. (See diagnosis in Peppers 1970, p.128-129.)

Size in micrometres. (i) Holotype 45.8 x 40.6, 42.5-52.3, Schulze and 5% KOH (Peppers 1970); (ii) Over all dimension 39(42.1) 48, Body 29 (35.2) 43 (8 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded or oval. Exine differentiated into two layers. Intexine 1-2μm thick. Laesurae distinct, simple sometimes with narrow lips about 0.5μm, short, ½ the intexine radius, usually one ray is shorter than the other two, straight or slightly flexuose. Exoexine thin, translucent, less than

0.5μm thick, it extends 1.3μm, but in a few specimens up to 6μm, beyond the margin of the intexine, very finely punctate, with numerous small folds. Ornament of the intexine can not be determined because it is obscured by the exoexine.

Remarks. Evans 1970 in his emendation of the genus describes more precisely the nature of the exoexine and omits reference to a perispore. On this basis Ravn 1979 transferred the species from Perotrilites to Diaphanospora but Ravn still considered the exoexine as a perispore in his description of Diaphanospora sp.1 (Ravn, p.48, pl.18, fig.12)

Occurrence. Rare in the Harvey, Top Busty and Top and Bottom Yard seams, Northumberland off-shore boreholes Westphalian A and B; Peppers 1970, Carbondale and Spoon Formations, Illinois, U.S.A., Pennsylvanian; Ravn 1979, Cherokee Group CP19.4 Coals of Iowa, Westphalian B.

Diaphanospora sp.A

Plate 15 figures 10-14

Size in micrometres. (i) 37 (45.4) 58 (10 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb mainly rounded, sometimes oval or rounded-triangular. Exine is separated into two layers. Intexine 1.5 - 2μm thick, fill almost the whole cavity of the exoexine. Laesurae usually indistinct and obscured by the exoexine covering, simple, sometimes with narrow lips, straight, $\frac{3}{4}$ of the body radius. Exoexine thin, enclosing the distal and the proximal surfaces, usually pulled toward the polar region to form numerous small folds and rarely projecting at the margin as a continuous membrane; the only indication of its existance

is the occasional projection at some parts of the margin. Ornament of the body cannot be determined due to the exoexine covering which is finely punctate.

Comparison. Differs from D. parvigracila (Peppers) Ravn in that the exoexine does not project beyond the intexine margin, and in its longer and equal laesurae, which are also usually obscured.

Occurrence. Rare in Top and Bottom Yard and Bottom Brass Thill seams, Northumberland off-shore boreholes, Westphalian B.

Diaphanospora sp.B

Plate 15 figures 15-21

Size in micrometres. (i) 35 (41.0) 48 (10 specimens) fum. HNO_3 Bottom Brass Thill at 377ft 9in. Northumberland off-shore borehole No. 3, Westphalian B.

Description. Amb rounded-triangular, occasionally circular or oval. Laesurae raised 1-2μm wide, straight, one ray is shorter than the other two extending almost to the equatorial margin; one of the angles between the laesurae measured approximately 150-170°. Exine differentiated into relatively thick intexine 1.5-2μm, and thin highly folded exoexine, enclosing both proximal and distal surfaces of the intexine. Exoexine only occasionally projects at certain parts beyond the margin. Ornament of the intexine cannot be determined with certainty because it is concealed by the exoexine which is very finely punctate.

Comparison. Differs from D. sp.A in possessing distinct laesurae and a thicker intexine.

Occurrence. Rare in the Bottom Brass Thill and Main seams, Northumberland off-shore boreholes, Westphalian B.

Genus HYMENOSPORA Neves 1961

Type species. H. palliolata Neves 1961.

Diagnosis. (Neves 1961, p.270)

Hymenospora multirugosa Peppers 1970

Plate 15 figures 22-24

1970 Hymenospora multirugosa Peppers, p.129, pl.13, figs.8,9.

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

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

Diagnosis. (See diagnosis in Peppers 1970, p.129).

Size in micrometres. (i) Holotype 39 x 35.1, body 32.5 x 29.3, over-all size range 35.8 - 45.8, body 29.3 - 39, Schulze and 5% KOH (Peppers 1970), (ii) Over-all dimension 25.5 (29.1) 36, body 21 (25) 30.5, (20 specimens), fum. HNO_3, Bottom Busty, at 186.25m, Northumberland off-shore borehole P2, Westphalian A.

Description. Amb rounded to rounded triangular, margin undulating. Exine closely differentiated into inner intexine and outer exoexine. Intexine is slightly darker in colour. $^5/_6$ the radius of the exoexine, bearing distinct laesurae extending between ¾ to nearly full radius of the intexine, simple, sometimes with very narrow lips, straight. Ornament of the intexine cannot be determined with certainty because it is concealed by the exoexine; distal surface almost laevigate. Exoexine finely punctate and deeply furrowed, connected to the intexine in the region of the laesurae and in the troughs of the furrows. Compression folds very rare to absent.

Remarks. Peppers 1970 in his diagnosis of H. multirugosa considers the exoexine as a perispore, but the diagnosis given by Neves 1961 for the genus Hymenospora mentions nothing about a perispore and regards the outer layer as an exoexine.

Occurrence. Absent to rare throughout the Westphalian A and B sequence, Northumberland off-shore boreholes. Peppers 1970, Carbondale and Spoon Formations, Illinois, U.S.A. Pennsylvanian; Ravn 1979. Cherokee Group CP19.4 Coals of Iowa, Westphalian B.

Subturma ZONOLAMINATITRILETES Smith and Butterworth 1967

All spore assigned to this subturma are trilete, cavate in which the exoexine shows equatoral thickening and/or extensions.

Infraturma CRASSITI (Bharadwaj and Venkatachala) Smith and Butterworth 1967

Genus CRASSISPORA (Bharadwaj) Sullivan 1964

Type species. C. kosankei (Potanie and Kremp) Bharadwaj 1964.

Diagnosis. (Smith and Butterworth 1967, p.233, from Sullivan 1964 p.375).

Remarks. Potonié and Kremp (1955) placed this genus in the infraturma Apiculati (Bennie and Kidston) Potonié 1956. Sullivan (1964) indicated the presence of an intexine in Crassispora which frequently shows apical papillae. Smith and Butterworth (1967) following Sullivan's suggestion of the presence of an intexine, emended the infraturma Crassiti (Bharadwaj and Venkatachala 1961) to accommodate trilete, cavate miospores with a crassitudinous margin.

Crassispora annulata Ravn 1979

Plate 15 figures 25-27

1964 Crassispora plicata Peppers (in part), p.17, pl.2, fig. 2.

non 1964 Crassispora plicata Peppers (in part) p.17, pl.1, fig.18, pl.2, fig.1.

1964 Crassispora kosankei (Potonié and Kremp) Bharadwaj in Sullivan, pl.60, fig.14.

1979 Crassispora annulata Ravn, p.39, pl.12, figs. 11-15.

Holotype. Ravn 1979, pl.12, fig.11, slide 6 3, coordinates 131.5 x 48.5.

Type locality. Cherokee Group CP19.4 Coals of Iowa, Pennsylvanian.

Diagnosis. (See diagnosis in Ravn 1979, p.39).

Size in micrometres. (i) Holotype 49.6, 36-55, Schulze and 5% KOH (Ravn 1979). (ii) 35 (46.0) 54.5 (10 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded-triangular. Laesurae usually not visible, raised, extending to the angles. Intexine is clearly separated in the equatorial region to form a uniform subequatorial annular structure; the zone of exine separation varies between 3-6.5μm in diameter. Sometimes the body show a more or less distinctive darker peripheral zone. Apical papillae present. Exine 1.5-2μm thick. Compression folds are usually concentrated in the polar region and sometimes obscure the laesurae.

Occurrence. Rare in Top and Bottom Yard, Harvey and Bottom Brass Thill, Northumberland off-shore boreholes, Westphalian A and B. Peppers 1964, pl.2, Modesto and Bond Formations, Illinois and Henshaw Formation, Kentucky, U.S.A., late Pennsylvanian; Sullivan 1964, pl.60, fig.14. Drybrook Sandstone

of the Forest of Dean, Upper Viséan and Westphalian A, England; Ravn 1979 Cherokee Group Coal CP19-4 Coals of Iowa, Westphalian B.

Crassispora kosankei (Potonié and Kremp) Smith and Butterworth 1967.

Plate 15 figures 28-35

1955 Planisporites kosankei Potonié and Kremp, p.71, pl.13, figs. 208-213.

1957a Planisporites ovalis Bharadwaj, p.86, pl.23, figs. 9,10.

1957b Crassispora ovalis Bharadwaj, p.126, pl.25, figs.73-76.

1957b Crassispora kosankei (Potonié and Kremp) Bharadwaj, p.127.

1957 Apiculatisporites apiculatus (Ibrahim) Dybova and Jachowics (non sensu Ibrahim). R87, pl.15, figs.1-4.

1964 Crassispora plicata Peppers (in part), p.17, pl.1, fig.18, pl.2, fig.1.

non 1964 Crassispora plicata Peppers (in part) p.17, pl.2, fig.2.

1967 Crassispora kosankei (Potonié and Kremp) Smith and Butterworth, p.234, pl.19, figs.2-4.

Holotype. Potonié and Kremp 1955, pl.13, fig.208. Preparation 565/V, KT20.9.126.1.

Type locality. Seam R, Friedrich Thyssen 2/5 (Wehofen) Colliery, Ruhr Coalfield, Germany, Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.234, emended from Potonié and Kremp 1955, p.71).

Size in micrometres. (i) Holotype 79.8, 68-85 Schulze (Potonié and Kremp 1955). (ii) 46-55. Schulze, Saar Coalfield; Stephanian (Bharadwaj 1957a) (iii) 40 (56) 69, fum. HNO_3,

Westphalian B. (vi) 47 (63) 84 fum. HNO_3, Westphalian B. (vii) 72 (90) 105 Schulze and 10% KOH, Westphalian B. (ix) 47 (58.5) 77, fum. HNO_3, Westphalian B. (x) 47 (58) 69, fum. HNO_3 Westphalian B. (xi) 47 (57) 69, fum. HNO_3, Westphalian A. (iii - (xi) Smith and Butterworth 1967). (xii) 49.5 (59) 73.5 (20 specimens), fum. HNO_3, Ashington Seam at 45ft 1½in. Northumberland off-shore borehole No. 3, Westphalian B.

Description. Shape varies from circular to elliptical and sometimes irregular. Laesurae usually indistinct and very rarely intact, often split open to form trianguar opening in the polar region. Distal surface covered with loosely spaced cone, varying in size and shape in any individual specimen, with rounded or pointed apices 0.6 - 1.5μm in diameter, distance between cone up to 4μm; this ornament is greatly reduced on the proximal surface. Equatorial thickening or crassitude gradually diminishes polewards with no sharp inner margin; it usually extends polewards for a distance of 3 to 9.5μm. Exine occasionally folded. Apical papillae frequently present.

Remarks. Some specimens show a clear separation of the intexine.

Comparison. According to Smith and Butterworth 1967 the exine of Crassispora has the ability to swell when KOH is used, so it is unwise to use size alone for specification in this genus. According to Ravn, C annulata Ravn 1979 lacks the presence of a crassitude, shows very clearly the exine separation, and the folds are mostly in the polar region and not around the equator as in C kosankei.

Occurrence. Rare, common to abundant throughout the

sequence of Northumberland off-shore boreholes; Neves (1961), NamurianB - Westphalian A, Southern Pennine Basin, England; Sullivan 1964, pl,60, fig.13,15, Drybrook Sandstone of the Forest of Dean, Upper Visean and Westphalian A, England. Felix and Burbridge 1967, Mississippian - Pennsylvanian, Springer Formation, Oklahoma, U.S.A.; Smith and Butterworth 1967, Namurian-Westphalian D, British Coalfields; Grebe 1972, Upper Westphalian A - Upper Westphalian C, Ruhr, Germany. Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Clayton et. al. 1977, Namurian B (Zonal spore with Grumosisporites varioreticulatus) Western Europe; Ravn 1979, Cherokee Group, CP19-4 Coals of Iowa, Westphalian B.

Infraturma CINGULICAVATI Smith and Butterworth 1967

This includes, trilete, cavate spores with equatorial thickening (cingulum) or extension (zona) of the exoexine.

Genus SIMOZONOTRILETES (Naumova) Potonié and Kremp 1954.

Type species. S. intortus (Waltz) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.236, from Sullivan 1958, p.126).

Simozonotriletes intortus (Waltz) Potonié and Kremp 1954

Plate 16 figures 1-8

1938 Zonotriletes intortus Waltz in Luber and Waltz, pl.2, fig. 24.

1954 Simozonotriletes intortus (Waltz) Potonié and Kremp,

p.159.

1957a Simozonotriletes priscus Dybova and Jachowicz, p.152, pl.41, figs.1,2.

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 Visean. Neotype, Horst (1955, pl.22, fig.52), Upper Silesia; Westphalian A. Hypotype designated by Hacquebard and Brass (1957, pl.5, fig.1), Canada, Lower Carboniferous.

Diagnosis. (See Smith and Butterworth 1967, p.237, from Sullivan 1958, p.127).

Size in micrometres. (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 x 60.9, Schulze (Hacquebard and Brass 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 147ft.8in.; Stamford borehole, Northumberland Coalfield, England; Visean (Smith and Butterworth 1967). (vii) 47 (53.5) 64 (10 specimens) fum. HNO_3, Bottom Main, at 123ft.6in. (vii) 47 (49) 53 (6 specimens) fum. HNO_3, Bottom Brass Thill, at 377ft.9in. (vii) and (viii) from Northumberland off-shore borehole No,3, Westphalian B.

Description. Amb triangular, sides straight to concave, angles well rounded. Laesurae distinct, simple, straight

extending to the inner margin of the cingulum, sometimes open. Cingulum may be homogeneous or differentiated into dark and light zones, thickened at the apices, thin zone 1-3μm wide, usually separating the outer broad zone from the inner narrow one; sometimes the cingulum tends to be thin in the interradial region, expanded and thickened into valvae at the apices. Exine laevigate, darker in the contact areas. Compression folds absent.

Remarks. Sullivan (1958) erected nine different varieties of the species on the basis of modifcations in sculpture which are not enough to erect new species. Among the most common is S. intortus var. polymorphosus which includes a very wide variation in sculpture. In this work the following varieties have been observed, S. intortus var. intortus, S. intortus var. concavus and S. intortus var. polymorphosus.

Occurrence. Absent to rare throughout the sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, British Coalfields, Viséan to Westphalian B; Felix and Burbridge 1967, Springer Formation, Mississippian Pennsylvanian; Grebe 1972, Ruhr, Germany, Upper Westphalian A to Lower Westphalian C; Van Wijhe and Bless 1974, Westphalian A-C, Netherlands; Ravn 1979 Cherokee Group CP.19-4 Coals of Iowa, Westphalian B.

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

Type species D. covensis Berry 1937

Diagnosis. (Smith and Butterworth 1967, p.238, from Butter-

worth, Jansonius, Smith and Staplin in Staplin and Jansonius 1964, p.101).

Comparison. Cingulizonates (Dybova and Jachowicz) Butterworth et al 1964 is distinguished by possession of a cuesta. Radiizonates Staplin and Jansonius 1964 is distinguished by the presence of radial plications on the outer part of the cingulum. Cristatisporitis (Potonié and Kremp) Butterworth et. al. 1964 is distinguished by its prominent distal sculpture and the arrangement of its ornament in cristae.

Densosporites anulatus (Loose) Smith and Butterworth 1967

Plate 16 figures 9-11

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.

1950 Denso-sporites reynoldsburgensis Kosanke, p.33, pl.6, figs. 9-11.

1956 Anulatisporites anulatus (Loose) Potonié and Kremp, p.112, pl.17, figs.365-372.

1967 Densosporites anulatus (Loose) Smith and Butterworth, p.239, pl.19, figs.5,6.

Holotype. Potonié and Kremp 1956, pl.17, fig. 365 after Loose.

Preparation III31, b_5(m/or).

Type locality. Bismark Seam, Ruhr Coalfield, Germany. Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.239, from Potonié and Kremp 1956, p.112).

Size in micrometres. (i) Holotype 37.5, 35-60, Schulze (Potonié and Kremp 1956). (ii) 32 (48) 56 Coalbrookdale Coalfield, Upper Westphalian A. (iii) 33 (40) 43 Northumberland Coalfield, Lower WestphalianA(iv) 26 (34) 42. Lothians Coalfield, Scotland, Namurian B/C. (v) 28 (37) 42 Lothians Coalfield, Scotland, Namurian A. (from ii - v all fum. HNO_3, Smith and Butterworth 1967.) (vi) 31 (35.3) 41.0 (15 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft.9in Northumberland off-shore borehole No. 3, Westphalian B.

Description. Amb rounded-triangular, margin smooth. Laesurae slightly raised, flexuose, extending to the inner margin of the cingulum. Cingulum relatively uniform and smooth with very faint striations and minute flutings, 4 to 11μm (average 7.2μm) in width. Intexine thin laevigate, sometimes marked with three apical papillae. Central distal and proximal surfaces of exoexine thin and laevigate.

Comparison. Differs from other species of the genus by its laevigate exine and uniform cingulum.

Occurrence. Rare to common throughout the Westphalian A and B sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, British Coalfields, Visean to Lower Westphalian C; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian A-C, Netherlands; Ravn 1979, Cherokee Group CP.19-4 Coals of Iowa,

Westphalian B.

Densosporites sphaerotriangularis Kosanke 1950

Plate 16 figures 12-17

1950 Densosporites sphaerotriangularis Kosanke, p.33-34, pl.6, fig.7.

1964 Densisporites sphaerotriangularis (Kosanke) Levet-Carette p.273.

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. (See Smith and Butterworth 1967, p.242, from description in Kosanke 1950, p.33).

Size in micrometres. (i) Holotype 50.4 x 48.3, 46-59, Schulze and 10% KOH (Kosanke1950). (ii) 39 (47) 60, Westphalian D or Stephanian A. (iii) 26 (47) 59, Upper Westphalian B. (iii) 40 (47) 61, Lower Westphalian B. (iv) 43 (50) 60, Lower Westphalian B, (v) 38 (47) 59, Upper Westphalian A. (ii-v all fum. HNO_3, Smith and Butterworth 1967, British Coalfields) (vi) 41.5 (50.0) 62.5 (20 specimens) fum. HNO_3, Bottom Brass Thill at 377ft.9in, Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb rounded-triangular. Laesurae raised, flexuose, extending to the inner margin of the cingulum. Exine two layered, intexine thin, laevigate and rarely seen. Central proximal area of exoexine finely granulate, distal central area ornamented by widely spaced verrucae. Cingulum

9.5-21.5 wide (average 14μm), about 56% of total spore diameter, laevigate, verrucate or having spinae which clearly modify the margin, sometimes differentiated into an inner thick zone and an outer thin zone, but the differentiation is gradational.

Remarks. Some specimens of this species are heavily ornamented and are very similar to D. duriti Potonié and Kremp 1956; others have a more or less smooth cingulum and there are specimens in between indicating that there is a gradation between the two species and it is difficult to separate them. Following Smith and Butterworth 1967, it is considered more practical in this work to use the earlier name.

Occurrence. Absent, rare to common throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Smith and Butterworth 1967, British Coalfields, Westphalian A-D; Grebe 1972, Upper Westphalian A-C, Ruhr Germany; Van Wijhe and Bless 1974, Westphalian A-C, Netherlands; Ravn 1979, Cherokee Group CP.19.4 Coals of Iowa, Westphalian B.

Genus LYCOSPORA (Schopf, Wilson, and Bentall) Somers 1972

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

Diagnosis. Emended in Somers 1972, p.55

Remarks. Somers 1972 tried to reduce the number of species belonging to this genus. She re-examined a large

number of types and other specimens. She grouped many published species into four species using type of ornament and development of cingulum as basic criteria, these species are:-

1. Lycospora orbicula (Potonié and Kremp) Smith and Butterworth 1967 with a very narrow cingulum.
2. Lycospora pusilla (Ibrahim) Somers 1972 with a well defined cingulum. Somers divided this species into two tendencies, tendency A with the zona reduced or faint, (cingulum + zona)/radius weak, tendency B with the zona clear to well developed (cingulum + zona)/ radius high. She further sub-divided tendency B into tendency B_1 with ornament of the central area and cingulum punctate to smooth and tendency B_2 with ornament of central area and cingulum clearly granulate.
3. Lycospora rotunda (Bharadwaj) Somers 1972, ornamented with verrucae and with a clearly lobed margin.
4. Lycospora noctuina var. noctuina Butterworth and Williams 1958, with verrucate and rugulate ornament arranged irregularly, zona smooth; and L. noctuina var. reticulata Kruszewska 1963 with rugulae arranged in a pseudoreticulum.

In this study some species confirmed with Somer's diagnosis, while others can be distinguished easily and there is no need to group them together. These are Lycospora rugosa and L. pellucida the first of which Somers grouped with L. orbicula and the second with L. pusilla.

Lycospora orbicula (Potonié and Kremp)
Smith and Butterworth 1967

Plate 16 figures 18-22

1955 Cyclogranisporites orbiculus Potonié and Kremp, p.63, pl.13, figs.179-183.

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

1972 Lycospora orbicula (Potonié and Kremp) Smith and Butterworth; in Somers, p.71, pl.I, fig.4; pl.11, fig.2; pl.XIV.

Holotype. Potonié and Kremp 1955, pl.13, fig.179, Preparation 607/2, KT18.6 110.0.

Type locality. Baldur Seam, Brassert Colliery, Ruhr, Coalfield, Germany, Lower Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.249, emended from Potonié and Kremp 1955, p.63).

Size in micrometres. (i) Holotype 27; 25-35, Schulze (Potonié and Kremp 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 2,189ft 9in. Little Smeaton borehole, Yorkshire Coalfield, England, Westphalian A. (ii and iii Smith and Butterworth 1967). (iv) 20 (24) 30 (30 specimens) fum. HNO_3 Bottom Main, at 123ft. 6in., Northumberland off-shore borehole No, 3, Westphalian B.

Description. Amb rounded, margin indented. Laesurae flexuose, faint, extending to the equator. Cingulum very narrow, sometimes indistinct. Exine thin, very finely granulate, grana 0.5 μm or less in diameter, often reduced on the proximal side. Compression folds if present narrow and usually around the margin.

Remarks. In oblique compression the laesurae in some specimens branch into two before reaching the equator forming curvaturae imperfecta; this phenomena has been observed by Smith and Butterworth 1967.

Comparison. Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967, has a similar size and shape, but differs in its coarser, more prominent distal ornament and lack of zona.

Occurrence. Frequent, common to abundant throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Owens and Burgess 1965, Namurian A to Lower Westphalian A, Stainmore Outlier, Westmorland; Smith and Butterworth 1967, Westphalian A to D, British Coalfields; Loboziak 1971, Namurian to Westphalian, Coal Basin of North France; Somers 1972, Westphalian C, Ruhr Coalfield; Germany.

Lycospora pellucida (Wicher) Schopf, Wilson and Bentall 1944

Plate 16 figures 23-27

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

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

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

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

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

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

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

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

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

1964 Lycosisporites pellucidus (Wicher) Levet-Carette, p,272, pl.10, fig.24.

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

1972 Lycospora pusilla "tendence B_2" (Ibrahim) Somers p.66 pl.1, figs. 5-33, pl.II, figs. 3-20; pl.IX and IIX.

Holotype. Potonié and Kremp 1955, pl.17 fig.341 after Wicher.

Preparation III B5, di (O/r).

Type locality. Seam R, Wehofen Colliery, Ruhr Coalfield, Germany. Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.250 expanded from Potonié and Kremp 1956, p.102).

Size in micrometres. (i) Holotype 46, Schulze and KOH . (ii) 35-50 Schulze (Potonié and Kremp 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 1,152ft. 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 (iii - v Smith and Butterworth 1967), (vi) CIMP type 35 (Somers 1972), (vii) 32 (37.4 43.0 (30 specimens) fum. HNO_3, unamed seam at 225ft. 1in. Northumberland off-shore borehole No. 5, Westphalian B.

Description. Amb triangular to rounded-triangular, sides convex, outline smooth or slightly indented. Laesurae with elevated lips 1-1.5 μm wide, extending to the outer margin of the inner zone of the cingulum, sometimes to the amb. Cingulum, 5-8 μm wide is clearly differentiated into an inner darker zone and a lighter outer zone which is equal to or more than the width of the inner zone. Exine covered by grana less that 1 μm in diameter. Compression folds are uncommon, if present, usually a narrow single fold along the inner margin of the cingulum.

Occurrence. Frequent, common to abundant throughout the sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, Visean to Westphalian D, British Coalfields; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Ravn 1979, Cherokee Group CP 19-4 Coals of Iowa, Westphalian B.

Lycospora pusilla (Ibrahim) Somers 1972

Plate 16 figures 28-31

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.

1972 Lycospora pusilla "tendency B" (Ibrahim), Somers p.66, pl.I, fig.5-33;, pl.II, fig.30-20; Pl. ix and vii.

Holotype. Potonié and Kremp 1956, pl.17, fig.351 after Ibrahim.

Preparation B27,a1(O)

Type CIMP. Somers 1972; pl.XII, fig.17. Preparation EDS5 $(i)_2$; Iniex, Liege.

Type locality. Ägir Seam, Ruhr,Coalfield, Germany, Upper Westphalian B.

Type locality CIMP. Reynoldsburg coal bed, Johnson County, Illinois, U.S.A. Abbott Formation, McCormick Group, Pennsylvanian.

Diagnosis. In Somers 1972, p.67.

Size in micrometres. (i) Holotype 38, Schulze and KOH. (ii) (25) 30-40 Schulze (Potonié and Kremp 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. ((iii) & (iv) Smith and Butterworth 1967) (v) CIMP type28 (Somers 1972). (vi) 23 (27.6) 32 (30 specimens) fum. HNO_3. Top and Bottom Yard, at 217ft. 1in., Northumerbland off-shore borehole No.6, Westphalian B.

Description. Amb rounded to rounded-triangular, margin smooth. Laesurae distinct, simple, straight extending to the amb. Cingulum differentiated into an outer thin flange and an inner thickened zone, sometimes the flange-like extension is absent ; total width of the cingulum up to $3\mu m$. Exine finely granulate, compression folds, infrequent if present very narrow with tapering ends.

Comparison. According to Smith and Butterworth there is a great similarity between L. pusilla, L. brevijuga Kosanke

1950, and L. micropapillata (Wilson and Coe) Schopf, Wilson and Bentall, 1944 with a size range of 25-30 μ_m (Wilson 1958), and L. parva Kosanke 1950, and there are insufficient differences to distinguish between them.

Occurrence. Abundant to dominant throughout the sequence of Northumberland off-shore boreholes; Sullivan 1964, Drybrook Sandstone of the Forest of Dean, Upper Viséan and Westphalian A, England. Smith and Butterworth 1967, Viséan-Westphalian D, British Coalfields; Grebe 1972, Upper Westphalian A - C, Ruhr, Germany. Clayton et al 1977, Zonal fossil for Viséan V1-2, Western Europe.

Lycospora rotunda (Bharadwaj) Somers 1972

Plate 16 figures 32-34

1956 Lycospora granulata Kosanke in Potonié and Kremp, p.102, pl.17, figs.339-340.

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

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

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

Holotype. Bharadwaj 1957a, pl.27, fig.10; Preparation S1. No. 7325. 11 Geologisches Landesamt für Nordrhein Westfalen, Krefeld, and the same holotype in Somers, pl.1, fig.36.

CIMP type. Somers 1972, pl.xv, fig.4, Preparation 125(3)2; Iniex, Liege.

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

CIMP locality. Couche 16, siege de Houthalen, bassin de Campine,

Belgium.; Zone de Genk, Westphalian A.

Diagnosis. Emendation in Somers 1972, p.73.

Size in micrometres. (i) Holotype ? ; 29-37 (Bharadwaj 1957a). (ii) CIMP type 33; 24-37 (Somers 1972). (iii) 27-37 fum. HNO_3 Yorkshire Coalfield, Westphalian B (Smith and Butterworth 1967). (iv) 29 (33.2) 38.5 (20 specimens) fum. HNO_3 Top and Bottom Yard, at 217ft 1in, Northumberland off-shore borehole No. 6, Westphalian B.

Description. Amb rounded-triangular, margin crenulate. Laesurae with lips 1-1.5μm in width and height, extending to the amb. Cingulum 3.5-7.5μm in width, differentiated into an inner thick zone and an outer thin flange which is usually equal to the inner thick zone, occasionally the flange is not very distinct. Exine is covered by relatively closely spaced grana and verrucae 1.5-2.5μm in width and height. Exine thin and rarely folded.

Remarks. Smith and Butterworth 1967 included this species tentatively with L. granulata Kosanke 1950 and they mentioned that the ornament is coarser than that given by Kosanke. The photograph shown by Ravn 1979 (pl.13, figs.19,20) of L. rotunda Bharadwaj 1957a is of a rounded-triangular spore which is contrary to what Bharadwaj emphasised, i.e. that the rounded shape is the distinguishing character of L. rotunda. The diagnosis of Bharadwaj 1957 has been emended by Somers to include all verrucate forms with circular and triangular outlines. She did not use L. torquifer (Loose) Potonié and Kremp 1956 because the holotype is very badly preserved.

Occurrence. Rare, frequent to common throughout the sequence of Northumberland off-shore boreholes. This species is recorded by many workers and reported by Somers to have a wide range from (Viséan), Namurian A to Stephanian B (?C).

Lycospora rugosa Schemel 1951 in Smith and Butterworth 1967.

Plate 16 figures 35,36

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

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

1972 Lycospora orbicula (Schemel); Somers, p.71, pl.I, fig.4; pl.11, fig.2, and pl.XIV.

Lectotype. Schemel (1951, p.748, text fig.4) in the West Virginia Geological Survey Collection.

Type locality. Mystic Coal of Southern Iowa, U.S.A., Des Moines Series.

Diagnosis. (See Smith and Butterworth 1967, p.252, from description in Schemel 1951, p.747).

Size in micrometres. (i) 20 (24) 26, maceration method not known (Schemel 1951). (ii) 17 (22) 30, fum. HNO_3; Swinton Pottery.Seam at 772ft 9in., Kellingley borehole, Yorkshire Coalfield, England; Upper Westphalian B (Smith and Butterworth 1967). (iii) 16 (17.8) 22.5 (30 specimens) fum. HNO_3, Top and Bottom Yard, at 217ft. 1in., Northumberland off-shore borehole No.6 Westphalian B.

Description. Amb mostly rounded, sometimes rounded-triangular, margin smooth or slightly indented. Laesurae distinct, simple, straight extending to the cingulum. Cingulum without outer

flange 1-1.5 μm wide. Exine ornamented with very fine, closely spaced grana. Compression folds absent.

Comparison. L. rugosa is smaller than L. pusilla (Ibrahim) Schopf, Wilson and Bentall 1944 and has no flange-like extension. L. brevis Bharadwaj 1957a has raised laesurae as shown by his photographs (pl.27, figs.6-8).

Occurrence. Rare to frequent throughout the sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, Namurian - Westphalian C, British Coalfields.

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

Type species. C. indignabundus (Loose) Potonié and Kremp 1954.

Diagnosis. (Smith and Butterworth 1967, p.253, from Butterworth, Jansonius, Smith and Staplin in Staplin and Jansonius 1964, p.108)

Comparison. Differs from Densosporites by its prominent distal ornament.

Cristatisporites connexus Potonié and Kremp 1955

Plate 16 figures 37-39

1955 Cristatisporites connexus Potonié and Kremp, p.106, pl.16, figs.291-293.

Holotype. Potonié and Kremp 1955, pl.16, fig.291, Preparation 77e.

Type locality. Gas Boring KM1, Ascheburg, Germany, Lower Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.253 from Potonié and Kremp 1955, p.106).

Size in micrometres. (i) Holotype 56, 45-70, Schulze (Potonié and Kremp 1955). (ii) 41 (54) 66 fum. HNO_3, Scotland, Lower Westphalian B. (iii) 51 (58) 67 Schulze and 5% KOH, England, Lower Westphalian B. (iv) 37 (47) 59, fum. HNO_3, England, Upper Westphalian A. (ii-iv Smith and Butterworth 1967). (v) 45 (52.5) 55 (15 specimens) fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian A-B.

Description. Amb subcircular to rounded-triangular, margin modified by ornament. Laesurae usually obscured by ornament, extending to the thickened inner margin of the cingulum. Intexine not discernible. Central proximal area punctuate or finely granulate. Cingulum 8-13 (average 10 μm) wide; cingulum and the distal polar area covered by verrucae, arranged in ridges on the cingulum, up to 5 μm in height, and 4 μm in basal diameter, verrucae more widely spaced in the central area 2-2.5 μm in height and basal width, coni may also be present at the equator. Number of elements projecting at the margin between 23-39 (average 29). Compression folds infrequent or absent.

Occurrence. Frequent in Harvey seam and rare throughout the sequence of Northumberland off-shore boreholes. Smith and Butterworth 1967, British Coalfield, Upper Westphalian A-B. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany. Van Wighe and Bless 1974, Upper Westphalian A to Lower Westphalian C, Netherlands.

Cristatisporites indignabundus (Loose) Staplin and Jansonius 1964

Plate 16 figures 40-42

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.

1964 Cristatisporites indignabundus (Loose) Staplin and Jansonius, p.108-109, text fig.2C, pl.19, figs.7-9, 12, 14, 20.

1965b Densisporites indignabundus (Loose) Laveine, p.133

Holotype. Potonié and Kremp, 1955, pl.16, fig.294 after Loose. Preparation IV24, d4 (01)

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

Diagnosis. (See Smith and Butterworth 1967, p.254, from Staplin and Jansonius 1964, p.108).

Size in micrometres. (i) Holotype 52.5, 50-80, Schulze (Potonié and Kremp 1955). (ii) 42 (53) 64, fum. HNO_3. England, Upper Westphalian B. (iii) 41 (51) 58 fum. HNO_3, England, Upper Westphalian B. (iv) 44 (52) 61 fum. HNO_3, England, Westphalian B. (ii - iv Smith and Butterworth 1967). (v) 45 (49.5) 56 (22 specimens) fum. HNO_3, Top and Bottom Yard, at 217ft. 1in., Northumberland off-shore

borehole No.6, Westphalian B.

Description. Amb rounded-triangular, occasionally circular. Laesurae usually obscured by ornament, raised, extending to the inner margin of the cingulum. Exine is separated into two layers. Intexine rarely seen. Proximal polar surface of exoexine finely punctate or granulate. Distal polar surface covered with well separated coni or verrucae 1.5-2.5 μm in height and basal diameter and about 1 μm apart.

Cingulum 8-16 (average 12) μm wide, differentiated into inner thickened zone or cuesta, which is distinctly raised, and an outer portion relatively thin. Distal surface ornament of the cingulum consists of closely packed cristae and isolated verrucae up to 6 μm in height, 5 μm in basal width, usually arranged in concentric zones, elements become slightly smaller toward the equator. Number of elements projecting from the margin 32-53 (average 44). Compression folds infrequent or absent.

Comparison. Ornament of C. connexus is coarser and more verrucate and the number of elements projecting less than that of C. indignabundus.

Occurrence. Common in Bottom Yard seam and absent to rare throughout the sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, British Coalfields, Westphalian B; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Upper Westphalian A to Lower Westphalian C; Ravn 1979, Cherokee Group, CP19-4

Coals of Iowa, Westphalian B.

Genus CIRRATRIRADITES Wilson and Coe 1940

Type species. C. saturni (Ibrahim) Schopf, Wilson and Bentall 1944.

Diagnosis. (Smith and Butterworth 1967, p.256, from Schopf, Wilson and Bentall 1944, p.43).

Cirratriradites saturni (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 17 figures 1-6

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, p.8 fig.102.

1944 Cirratriradites saturni (Ibrahim) Schopf, Wilson and Bentall, p.44.

1965a Cirratrisporites saturni (Ibrahim) Laveine, p.134.

Holotype, Ibrahim 1932, pl.15, fig.14, Potonié and Kremp 1956, pl.18, fig.412 after Ibrahim. Preparation B26, d2 (ui).

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

Diagnosis. (See Smith and Butterworth 1967, p.258, from Potonié and Kremp 1956, p.128).

Size in micrometres. (i) Holotype 69.5, Schulze and KOH. (ii) 70-100 Schulze (Potonié and Kremp 1956). (iii) 68 (79) 91; body 50 (58) 68; zona 8 (11) 16, Schulze and 10% KOH, Westphalian C. (iv) 59 (73) 81, body 45 (55) 59;

flange 7 (9) 14, Westphalian B. (v) 67 (76) 84, body 53 (58) 64; flange 7 (9) 12, Westphalian B. (vi) 68 (77) 92; body 54 (62) 79, zona 6 (7.5) 9, fum. HNO_3, Westphalian A. (vii) 46 (57) 68; body 34 (48) 58; flange 4 (6) 9, Westphalian A. ((iv) to (vii) fum. HNO_3; (iii) to (vii) all British Coalfield in Smith and Butterworth 1967). (viii) body 64 (70.1) 75, zona 6 (8.1) 12 (20 specimens), fum. HNO_3, Top and Bottom Yard, at 217ft. 1in., Northumberland off-shore borehole No,6, Westphalian B.

Description. Outline triangular, sides convex, margin irregular or serrate. Body rounded-triangular. Laesurae ridged, slightly sinuose, crossing the zona to margin at angles. Three central distal foveolae usually present, sometimes only one. Body ornamented with grana, 1-1.5 μm in diameter. Zona thickened in a concentric band towards the middle with radial striations, usually wider at the angles. Exine rather thick.

Comparison. Differs from C. maculatus in possessing radial striations in the zona.

Occurrence. Frequent in the Plessey and Bottom Yard seams and rare throughout the sequence of Northumberland off-shore boreholes; Guennel 1958, Brazil Formation, Indiana, Pottsville Series; Sullivan 1964, Edgehills Coal, Forest of Dean, Westphalian A. Smith and Butterworth 1967, British Coalfields, Upper Namurian to Westphalian C; Felix and Burbridge 1967, Springer Formation, Oklahoma, Mississippian/ Pennsylvania; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany

Van Wijhe and Bless 1974, Westphalian A to Upper Westphalian C, Netherlands; Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B.

Genus CINGULIZONATES (Dybova and Jachowicz) Butterworth, Jansonius, Smith and Staplin 1964

Type species. C. bialatus (Waltz) Smith and Butterworth 1967

Diagnosis. (Smith and Butterworth 1967, p.259, from Butterworth, Jansonius, Smith and Staplin in Staplin and Jansonius 1964, p.105).

Comparison. Distinguished by the presence of a cuesta.

Cingulizonates loricatus (Loose) Butterworth and Smith (in Butterworth et al. 1964)

Plate 17 figures 7-9

1932 Sporonites loricatus Loose in Potonié, Ibrahim and Loose, p.450, pl.18, fig.42.

1934 Zonales-sporites loricatus Loose, p.151.

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. Bismark Seam, Ruhr Coalfield, Germany; Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.262, from Potonié and Kremp 1956, p.119)

Size in micrometres. (i) Holotype 41.5, 35-50, Schulze (Potonié and Kremp 1956). (ii) 32 (41) 48, fum. HNO_3;

Upper Flint Seam at 1,069ft. 2in., Coalbrookdale Coalfield, England; Lower Westphalian B. (iii) 24 (34) 40 fum. HNO_3 Bottom Robins Seam at 843ft., Cannock Chase Coalfield, England; Lower Westphalian C. (ii and iii Smith and Butterworth 1967). (iv) Spore diameter 32 (37.7) 43, Cingulum (a) Cuesta 3 (4.6) 7, (b) outer zone 1.5 (3) 6.5 (15 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft. 9in., Northumberland off-shore borehole No,3, Westphalian B.

Description. Amb convexly rounded-triangular, margin denticulate due to the projection of fine grana. Laesurae simple, sometimes accompanied by raised lips, often open, extending to the inner margin of the cingulum. Cingulum consists of inner thick zone or cuesta, which is distinctly raised with a crenulate outer margin, and an outer zone which is usually thinner, narrower, and lower than the cuesta, ornamented with very fine grana. Central body (intexine) laevigate, sometimes faint apical papillae present, proximal polar area laevigate and distal polar area granulate or with small verrucae.

Occurrence. Frequent in the Top Plessey and Bottom Main seams, common in the Bottom Hutton seam and rare throughout the sequence of Northumberland off-shore boreholes; Smith and Butterworth 1967, Westphalian A-C, British Coalfields; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian B and C, Netherlands; Ravn 1979, Cherokee Group CP19.4 Coals of Iowa, Westphalian B.

Genus RADIIZONATES Staplin and Jansonius 1964

Type species. R. aligerens (Knox) Staplin and Jansonius 1964.

Diagnosis. (Smith and Butterworth 1967, p.263, from Staplin and Jansonius 1964, p.106).

Comparison. Differs from Cingulizonates, Densosporites and Cirratriradiates by the presence of radial ribs of the outer part of the cingulum.

Radiizonates striatus (Knox) Staplin and Jansonius 1964

Plate 17 figures 10-14

1950 Cirratriradites striatus Knox, p.330, pl.19, fig.229.

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 PF3009 (formerly 76486), Geological Museum, London.

Type locality. Ruabon Yard Seam, 388's Drift Llay Main Colliery, North Wales Coalfield; Upper Westphalian A.

Diagnosis. (See Smith and Butterworth 1967, p.265, from description in Butterworth and Williams 1954, p.757).

Size in micrometres. (i) 35 (41) 53 fum. HNO_3, 36 (46) 58 Schulze and 5% KOH both from type locality (Butterworth and Williams 1958) (ii) 43-58, maceration method not known;

Büyük Seam, Turkey, Westphalian A (Artüz 1957, for Densosporites marginata) (iii) 32 (39.9) 45, outer zone 2 (3.5) 5, inner zone 4.5 (6.5) 9.5 (30 specimens), fum. HNO_3, Three-quarter at 203.48m, Northumberland off-shore borehole P2, Westphalian A.

Description. Amb rounded triangular. Laesurae usually indistinct, slightly raised, extending to the inner margin of the cingulum. Cingulum is divided into inner thickened zone and outer thin part, the thickened cingulum has striations which usually extend to the outer thin zone. Central part of the exoexine laevigate or with loosely scattered verrucae on the distal surface. In well-preserved specimens the radial striae are connected equatorially by a narrow concentric thickening.

Comparison. The presence of the radial plications differentiates this species from Cingulizonates loricatus (Loose) Smith and Butterworth (in Butterworth et. al. 1964) and Cingulizonates bialatus (Waltz) Smith and Butterworth 1967.

Occurrence. Abundant in Three-quarter seam, Northumberland off-shore borehole P2. Westphalian A; Smith and Butterworth 1967, Westphalian A, British Coalfields. Grebe 1972, Upper Westphalian A to Lower Westphalian B, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Sullivan 1962, Westphalian A, South Wales; Artüz 1957, Westphalian A. Zonguldak Coalfield, Turkey.

Radiizonates tenuis (Loose) Butterworth and Smith (in Butterworth et. al. 1964)

Plate 17 figures 15-19

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. Bismark Seam, Ruhr Coalfield, Germany, Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.266, from Potonié and Kremp 1956, p.120).

Size in micrometres. (i) Holotype 60, 50-70 Schulze (Potonié and Kremp 1956). (ii) 32 (42) 54 fum. HNO_3, 40 (50) 58 Schulze and 5% KOH, Crank Seam, Gresford Colliery, North Wales Coalfield; Westphalian B (Butterworth and Williams 1954). (iii) 31 (40.3) 50, cingulum 7 (10) 12 (20 specimens) fum. HNO_3, Top and Bottom Yard at 217ft. 1in., Northumberland off-shore borehole No.6, Westphalian B.

Description. Amb rounded to rounded-triangular. Laesurae raised, flexuose with lips 1-2 μm wide, extending to the inner margin of the cingulum or slightly more, occasionally to the equator. Exine separated into two layers, intexine usually not visible and the exoexine which is ornamented in the polar region with minute grana,or is sometimes scabrate.

Cingulum is differentiated into an outer thin zone and an inner darker zone which is usually narrower than the former. Costae or ribs radiate from the inner cingulum and extend to the outer flange, usually bifurcating and enclosing open areas between them filled with flange matrix; occasionally the branches of the ribs may connect laterally. Compression folds rare.

Comparison. In practice it is difficult to distinguish between R. faunus (Ibrahim) Smith and Butterworth and R. tenuis but according to Smith and Butterworth (1967) R. faunus tends to be more triangular in shape.

Occurrence. Frequent in Bottom Main seam and rare to infrequent throughout the Westphalian B sequence, Northumberland off-shore boreholes; Smith and Butterworth 1967, Westphalian B and C, British Coalfields; Grebe 1972, Upper Westphalian A - Upper Westphalian C, Ruhr, Germany; Clayton et. al. 1977, Westphalian B - Lower C (Microreticulatisporites nobilis - Florinites junior zone), Western Europe.

Suprasubturma PSEUDOSACCITRILETES Richardson 1965

Infraturma MONOPSEUDOSACCITI Smith and Butterworth 1967

This includes trilete, cavate spores with inflated extension of the exoexine. Intexine may be separated from the exoexine over part or all of the proximal or distal surface.

Genus SPENCERISPORITES Chaloner 1951

Type species. S. radiatus (Ibrahim) Felix and Parks 1959.

Diagnosis. (Smith and Butterworth 1967, p.268, from Chaloner 1951, p.861).

Spencerisporites radiatus (Ibrahim) Felix and Parks 1959

Plate 17 figures 20-23

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 snd 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(u1).

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

Diagnosis. (See Smith and Butterworth 1967, p.269, abbrev-

iated from Chaloner 1951 for S. Karczewskii)

Size in micrometres. (i) Holotype 330, Schulze and KOH. (ii) 270-440, Schulze (Potonié and Kremp 1956) (iii) Overall 252 (288) 343; spore body 127 (153) 178, Schulze and NaOH (Chaloner 1951); England, Westphalian A (iv) overall 240-260; spore body 120-210, Schulze or fum. HNO_3 (the smaller specimens were macerated with fum. HNO_3); various localities, Great Britain, Westphalian A and B. (Smith and Butterworth 1967). (v) Overall diameter 256 (278.6) 300, body 136 (149.2) 157 fum. HNO_3, (10 specimens) fum. HNO_3, Bottom Brass Thill, at 377ft. 9in., Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb triangular to subtriangular, angles well rounded, sides straight or convex. Laesurae raised, 11-30 (average 17.5) μm long, flexuose extending to the margin of the spore body, sometimes extending for a short distance into the pseudosaccus, occasionally accompanied by folds in the pseudosaccus to give the appearance of extending to the equator of the pseudosaccus. Intexine circular to subcircular. Both distal and proximal surfaces ornamented by radiating fine broken lines, three foci of radiation placed symmetrically on the contact areas. Pseudosaccus ornamented internally by a pattern of thin intersecting lines, these lines become more pronounced near the marginal flange. An equatorial darker zone, 4-7 μm wide, of the pseudosaccus located at the base of the flange is possibly due to overlap of the flange resulting

from compression. Flange is almost uniform in width around the pseudosaccus, up to 16 μm wide. Compression folds are peripheral on the body, while there is no definite orientation for the folds on the pseudosaccus.

Occurrence. Absent to rare throughout the sequence, Northumberland off-shore boreholes, Westphalian A and B. Smith and Butterworth 1967, Viséan to Westphalian D, British Coalfields; Marshall and Williams 1970, Namurian A, Roman Wall, Northumberland, England.

Genus ENDOSPORITES Wilson and Coe 1940

Type species. E. ornatus Wilson and Coe 1940.

Diagnosis. (Smith and Butterworth 1967, p.270, expanded from Wilson and Coe 1940).

Comparison. Endosporites differs from Florinites in having granulate to infragranulate sculpture, rather than an infrareticulate exoexine, and in the possession of a limbus.

Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 18 figures 1-6

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.

1965 Endopollenites globiformis (Ibrahim) Laveine, p.136.

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. (See Smith and Butterworth 1967, p.271, from Potonié and Kremp 1956, p.161; translation).

Size in micrometres (i) Holotype 131, Schulze and KOH 110-60, Schulze (Potonié and Kremp 1956).

	Pseudosaccus (max.)	Body (along same axis)	Ratio of body to pseudosaccus,%	
(ii)	62 (87) 109	30 (40) 54	39 (46) 53	Fum.HNO_3 Westphalian B.
(iii)	72 (86) 112	29 (38) 73	38 (45) 53	Fum. HNO_3 Westphalian B.
(iv)	104(131) 161	37 (56) 78	34 (42) 51	Schulze and 5% KOH, Westphalian B.
(v)	74 (92) 112	34 (41) 57	39 (45) 52	Fum. HNO_3, Westphalian B.

(ii - v Smith and Butterworth 1967)

(vi) 67 (81.7) 94.5 29 (35.9) 41.5 43.2 (43.9) 44.0 (20 specimens) fum. HNO_3 Bottom Brass Thill, at 439ft. 6in. Northumberland off-shore borehole No.6 Westphalian B.

Description. Amb of pseudosaccus and the body rounded to rounded triangular, sometimes irregular due to folding. Laesurae raised, straight or flexuose extending from ½ to the whole radius of the body, sometimes folds on the exoexine attached to the laesurae may give the appearance that the laesurae extend to the margin of the pseudosaccus. Pseudosaccus thin, frequently folded, very finely micro-reticulate

or granulate. Limbus varies in any one individual, 2.5-5 μm wide. Body laevigate to very finely punctate, darker than the pseudosaccus membrane, sometimes displays darker zonate structure around the margin; according to Smith and Butterworth this may be due to some exine separation. Peripheral compression folds occasionally present on the body.

Occurrence. Frequent to common in High Main, Top and Bottom Main, Top Brass Thill and Bottom Brass Thill seams. Rare to infrequent throughout the rest of Westphalian B sequence, Northumberland off-shore boreholes. Smith and Butterworth 1967, Upper Westphalian A-D, British Coalfields. Peppers 1970 Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian A-D, Netherlands. Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Endosporites staplinii Gupta and Boozer 1969

Plate 18 figures 7-10

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

1969 Endosporites staplini Gupta and Boozer, p.78.

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

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

Holotype. Staplin 1960, pl.7, fig.12, sample 1707,

49.4 x 116.5.

Type locality. Golata Formation, West-central Alberta, Canada.

Size in micrometres. (i) Holotype 33, body 17, overall size 24.35, body 16.20 (Staplin 1960) (ii) 32 (36.5) 39.0, body 22 (23.7) 25.5 (15 specimens), fum. HNO_3, Bottom Brass Thill at 377ft. 9in., Northumberland off-shore boreholes, Westphalian B.

Description. Amb of pseudosaccus rounded-triangular, intexine rounded. Laesurae raised, flexuose, extending to the margin of the body, commonly involved in folds that may appear to give an extension to the pseudosaccus margin. Pseudosaccus thin, finely intragranulose to almost smooth, strongly folded which gives the surface a corrugated appearance. Limbus 0.5-1 μm, often absent. Body darker than the pseudosaccus with a thick peripheral zone, average 1 μm wide, finely granulate or scabrate and very rarely folded. Occasionally the body is indistinct.

Comparison. According to Ravn 1979 E. egemeni (Agrali) Loboziak 1971 resembles E. staplinii but the inadequacy of the description of E. egemeni makes comparison difficult.

Occurrence. Rare in the Bottom Brass Thill seam, borehole No.3, Northumberland off-shore borehole, Westphalian B; Ravn 1979, Cherokee Group CP19-4 Coal of Iowa, U.S.A., Westphalian B.

Endosporites zonalis (Loose) Knox 1950

Plate 18 figures 11-14

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.

1965a Endopollenites zonalis (Loose) Laveine, p.136.

Holotype. Potonié and Kremp, 1956, pl.20, fig.455 after Loose. Preparation IV27, f_5(m/o1).

Type locality. Bismark Seam, Ruhr Coalfield, Germany, Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.273, from Potonié and Kremp 1956, p.163; translation).

Size in micrometres. (i) Holotype 95, Schulze and KOH 90-100, Schulze (Potonié and Kremp 1956).

	Pseudosaccus (max)	Body (along same axis)	Ratio body to pseudosaccus %	
(ii)	69 (83) 104	38 (48) 60	46 (57) 72	Fum. HNO_3, Westphalian B.
(iii)	61 (78) 100	33 (50) 61	48 (65) 77	Fum. HNO_3, Westphalian A.

(ii and iii Smith and Butterworth 1967)

(iv) 77 (82.3) 95 46 (50.2) 55 59.7 (61) 68

(20 specimens), fum. HNO_3, Bottom Brass Thill at 439ft. 6in., Northumberland off-shore borehole No.6, Westphalian B.

Description. Similar to E. globiformis, excepting that the pseudosaccus is darker in colour which makes the body less distinct.

Comparison. Distinction between E. globiformis (Ibrahim) Schopf, Wilson and Bentall and E. zonalis is made on the basis of the ratio of the body to pseudosaccus dimension.

In this study specimens which have a ratio less than 50% are considered E. globiformis and those greater than 50% are E. zonalis. According to Smith and Butterworth, Zonotriletes punctulosus Luber in Luber and Waltz 1938, E. rotundus (Ibrahim 1933) Schopf, Wilson and Bentall 1944 and E. plicatus Kosanke 1950 are very similar to, and may be synonyms of E. zonalis.

Occurrence. Frequent in the Bottom Brass Thill seam. Rare to infrequent throughout the Westphalian A and B sequence. Smith and Butterworth 1967, Upper Westphalian A - D, British Coalfields; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Genus SCHULZOSPORA Kosanke 1950

Type species. S. rara Kosanke 1950.

Diagnosis. (Smith and Butterworth 1967, p.273, expanded from Kosanke 1950, p.53).

Schulzospora rara Kosanke 1950

Plate 18 figures 15-18

1950 Schulzospora rara Kosanke, p.53, pl.13, figs.5-8.

1950 Planisporites ovatus Knox, p.316, pl.17, fig.222.

1952 Endosporites ovatus (Knox); Balme, p.180, text-fig.1e.

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. (See Smith and Butterworth 1967, p.277 from description in Kosanke 1950, p.53).

Size in micrometres. (i) Holotype, 109.2 x 81.9 body 73.5 x 73.5, Schulze and 10% KOH (Kosanke 1950). (ii) 70 (81) 105 x 55 (65) 75, body 48 (60) 75, Schulze (Balme 1952); Seam at 3385ft. 5in., Blacklake borehole, North Staffordshire Coalfield, England; Upper Westphalian A. (iii) 54 (67) 83 x 38 (50) 60, body 40 (51) 62 x 32 (42) 56, fum. HNO_3; Rushy Park Seam, Sutton Manor Colliery, Lancashire Coalfield, England, Upper Westphalian A. (iv) 56 (63) 78 x 44 (49) 62, body 40 (45) 60 x 40 (43) 52, fum. HNO_3 seam at 436ft. 4in., Mapperley Colliery borehole, Nottinghamshire Coalfield, England, Upper Westphalian A. (v) 62 (77) 102 x 44 (57) 72, body 44 (59) 80 x 36 (47) 58, fum. HNO_3, seam at 2,803ft., Colston Bassett borehole, Nottinghamshire Coalfield, England; Lower West.A(iii - v Smith and Butterworth 1967), (vi) max. saccus dimension 56 (65.5) 77, mini 38.5 (48.8) 56; max.body dimension 40 (50.3) 57.5, mini 31.5 (42.1) 51, (10 specimens), fum. HNO_3, various horizons, Northumberland off-shore borehole P_2, Westphalian A.

Description. Amb of the pseudosaccus elliptical, margin smooth, intexine circular to oval, with the longer axis usually parallel to that of the saccus. Laesurae simple, straight, $^1/_2$-$^2/_3$ of body radius, sometimes not visible. Pseudosaccus and the body finely punctate. Exine moderately thick, occasionally folded.

Occurrence. Rare in the Three-quarter up to Harvey seams Northumberland off-shore borehole P_2, Westphalian A; Felix and Burbridge 1967, Mississippian-Pennsylvanian, Springer Formation, Oklahoma, U.S.A.; Smith and Butterworth 1967, Viséan to Westphalian A, British Coalfields; Grebe 1972 Upper Westphalian A, Ruhr, Germany; Clayton et. al. 1977, Namurian to Westphalian A, Western Europe.

Schulzospora cf. rara Kosanke 1950

Plate 18 figures 19,20

Size in micrometres. Saccus 56 (60.6) 69, body 40 (46.9) 52.5 (10 specimens) fum. HNO_3, various seams, Northumberland off-shore borehole P_2, Westphalian A.

Comparison. Differs from the type in being circular (both the pseudosaccus and the body) and the laesurae are more prominent.

Occurrence. Same range as S. rara

Infraturma POLYPSEUDOSACCITI Smith and Butterworth 1967

This includes trilete, cavate spores in which the exoexine is separated and expanded from the intexine to form three or more pseudosacci.

Genus ALATISPORITES (Ibrahim) Smith and Butterworth 1967

Type species. A. pustulatus Ibrahim 1932.

Diagnosis. (Smith and Butterworth 1967, p.279, emended from Potonié and Kremp 1956, p.154.

Alatisporites hoffmeisterii Morgan 1955

Plate 19 figures 1-4

1955 Alatisporites hoffmeisterii Morgan, p.37-38, pl.2, figs. 1-8.

Holotype. Morgan 2955, 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. (See Smith and Butterworth 1967, p.279, from Morgan 1955, p.37.)

Size in micrometres. (i) Holotype, overall 98, body 69 x 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 670ft. 2in., Garth Place borehole, South Wales Coalfield, Westphalian C (Smith and Butterworth 1967) (iii) overall 57.5 (65.8) 77, body 45 (53.6) 57.5 (10 specimens), fum. HNO_3 Bottom Brass Thill at 377ft. 9in. Northumberland off-shore borehole No,3, Westphalian B.

Description. Amb of the body triangular, angles well-rounded, margin distinctly crenulate due to projection of the verrucae, interradial margin straight or slightly convex. Laesurae simple, straight, extending almost to the margin of the spore, sometimes accompanied with narrow lips 0.5 - 1 μm in width. Exine ornamented by verrucae of different size and shape and rugulae. Pseudosacci cover the proximal and the distal surfaces, only a small area in the polar region is free from the sacci; thin, very finely

granulate (oil immersion), number of pseudosacci 6-8. Body moderately thick.

Occurrence. Rare to infrequent in Bottom Main and Bottom Brass Thill seams, Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth 1967, Westphalian C and D, British Coalfields. Ravn 1979 Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Alatisporites pustulatus (Ibrahim) Ibrahim 1933

Plate 19 figures 5-9

1932 Sporonites pustulatus Ibrahim in Potonié, Ibrahim and Loose, p.448, pl.14, fig.12.

1933 Alati-sporites pustulatus (Ibrahim) Ibrahim, p.32, pl.1, fig.12.

1965 Alatipollenites pustulatus (Ibrahim) Laveine, p.136.

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. (See Smith and Butterworth 1967, from Potonié and Kremp 1956, p.155).

Size in micrometres. (i) Holotype 73, 70-90, Schulze and KOH (Potonié and Kremp 1956). (ii) overall maximum 74 (81) 89, max. body 47 (52) 57, (8 specimens) fum. HNO_3; various localities in British Coalfields, Westphalian A to C (Smith and Butterworth 1967) (iii) overall max. 53 (64) 80, body 38.5 (42.7) 49.5 (11 specimens), fum. HNO_3, various horizons, Northumberland off-shore boreholes, Westphalian B.

Description. Amb of body triangular, sides straight to slightly concave, margin crenulate due to the projection of the rugulae, angles well rounded. Laesurae simple, straight, $^{1}/_{2}$ - $^{3}/_{4}$ of spore radius, sometimes open, occasionally with narrow lips. Ornamentation of the body composed of fine dense rugulae in the contact region, becoming coarser towards the margin, usually rugulae cross each other to enclose irregular shaped lumina and to give the spore the appearance of superficial microreticulation. Body moderately thick . Pseudosacii, usually three, enclose the entire proximal surface up to the laesurae, and on the distal surface about half of the spore radius in the polar region is free from the sacci. Pseudosacci thin, folded, usually phaseolate if they are not distorted by folding, surface finely granulate, margin slightly modified by the grana.

Comparison. differ from A. hoffmeisterii Morgan 1955 in having a superficially microreticulate exine, the number of the sacci is usually three and the sacci enclose less area on the proximal and distal surfaces than that of A. hoffmeisterii. A. trialatus Kosanke 1950 has a laevigate proximal surface; A. punctatus Kosanke 1950 is very similar to A. pustulatus but it is larger which could be due to the KOH used in the maceration method.

Occurrence. Infrequent in Top and Bottom Yard and Bottom Main seams of Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth1967, Upper Westphalian A to Lower

Westphalian C,British Coalfields; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian A-D, Netherlands; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa Westphalian B.

Turma MONOLETES Ibrahim 1933

Suprasubturma ACAVATOMONOLETES Dettmannn. 1963

Subturma AZONOMONOLETES Luber 1935

Infraturma LAEVIGATOMONOLETES Dybova and Jachowicz 1957

Genus LAEVIGATOSPORITES Ibrahim 1933

Type species. L. vulgaris Ibrahim 1933

Diagnosis. (Smith and Butterworth 1967, p.281, translation from Potonié and Kremp 1954, p.165).

Laevigatosporites dunkardensis Clendening 1970

Plate 19 figures 10-13

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

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

1970 Laevigatosporites dunkardensis Clendening, p.788.

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

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

Diagnosis. (See description in Clendening 1969).

Size in micrometres. (i) Holotype 80.5 x 53.7, length 46-95, width 30-60, Schulze and 10% KOH (Clendening 1969).

(ii) 48 (68.3) 112 (20 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft. 9in, Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb oval, sometimes irregular due to folding, margin smooth. Laesurae simple, $^1/_2$ - $^3/_4$ of spore length, sometimes the monolete suture cannot be discerned. Exine laevigate, very thin, and heavily folded. Folds have no specific orientation relative to the long axis of the spore.

Comparison. Easily distinguished from other species by its folds.

Occurrence. Rare but widely distributed from Bottom Brass Thill seam up to Seam C of Northumberland off-shore boreholes Westphalian B; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B; Clendening 1969, Washington Formation, Pennsylvanian.

Laevigatosporites minor Loose 1934

Plate 19 figures 14-16

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.

1957a 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. Bismark Seam, Ruhr Coalfield, Germany;

Upper Westphalian B.

Size in micrometres. (i) Holotype 58.5, 40-70, Schulze and KOH (Loose 1934). (ii) 45-65, Schulze (Bharadwaj 1957a). (iii) 37 (44) 50, fum. HNO_3, Westphalian D. (iv) 44 (55) 64, Schulze, Westphalian D. (v) 34 (50) 68, Schulze, Westphalian C. (vi) 40 (56) 71, fum. HNO_3, Westphalian B. (vii) 36 (52) 67, fum. HNO_3, Westphalian B. (viii) 41 (52) 68, Schulze, Westphalian A. (ix) 33 (48) 63, Schulze, Westphalian A. (x) 41 (57) 71, fum. HNO_3, Westphalian A. (iii) to (x) British Coalfields Smith and Butterworth 1967). (xi) 33 (52) 64 (30 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft. 9in. Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb oval in equatorial view, reniform, margin smooth. Laesurae $^1/_2$ - $^3/_4$ of spore length, occasionally with narrow lips, sometimes open. Exine about 1μm thick, laevigate, single compression fold often present.

Remarks. Only very few specimens fall within the range of L. minimus (Wilson and Coe) Schopf, Wilson and Bentall 1944, in assemblages where Laevigatosporits spp. are abundant, so it is appropriate to include them with L. minor.

Comparison. As noted by Smith and Butterworth 1967, a size boundary of 35μm - 65μm is employed here to differentiate this species from L. minimus, which is smaller than 35μm and L. vulgaris, which is larger than 64μm.

Occurrence. Infrequent to abundant throughout the Westphalian A and B sequences, Northumberland off-shore boreholes;

Smith and Butterworth 1967, Namurian to Westphalian D. British Coalfields; Van Wijhe and Bless 1974, Westphalian A to D, Netherlands; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Laevigatosporites striatus Alpern 1959

Plate 19 figures 17-22

1959 Laevigatosporites striatus Alpern, p.153, pl.11 figs.267, 268.

Holotype. Alpern 1959, pl.11, fig.267. Slide 509, 36 x 123.4.

Type locality. Seam Morsbach, Lorraine Coalfield, France; Lower Stephanian.

Diagnosis. (See description in Alpern 1959, p.153).

Size in micrometres (i) Holotype, 57 x 40 Schulze and KOH (Alpern 1959). (ii) 40 (55.1) 64 (15 specimens) fum. HNO_3, Bottom Brass Thill, at 377ft. 9in, Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb oval, margin smooth. Laesurae simple $^1/_2$ - $^3/_4$ of spore length. Exine ornamented by randomly distributed arcuate striations, more or less 1μm wide. Exine laevigate, moderately thick, rarely folded.

Remarks. According to Ravn 1970 the striation of L. striatus was due to compression of a group of spores against each other which may possibly indicate that the deposition of this species in masses may be due to their production by a plant phylogenetically distinct from that which produces other forms of Laevigatosporites.

Occurrence. Infrequent in the Bottom Brass Thill Seam, Northumberland off-shore borehole, Westphalian B. Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Laevigatosporites vulgaris (Ibrahim) Ibrahim 1933

Plate 19 figures 23,24

1932 Sporonites vulgaris Ibrahim in Potonié, Ibrahim and Loose, p.448, pl.15, fig.16.

1933 Laevigato-sporites vulgaris (Ibrahim) Ibrahim, p.39, pl.2, figs.6,

1940 Phaseolites desmoinesensis Wilson and Coe, p.182, pl.1, fig.4.

1944 Laevigatosporites desmoinesensis (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. (See Smith and Butterworth 1967, p.285, from Ibrahim 1933, p.39.

Size in micrometres (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. (Smith and Butterworth 1967). (iii) 67 (74.6) 85 (20 specimens), fum. HNO_3 Bottom Brass Thill at 37.7ft. 9in. Northumberland off-shore borehole No,3, Westphalian B.

Description. Same as L. minor.

Remarks. A few isolated specimens of slightly more than 100μm are here included in L. vulgaris although they are within the range of L. maximus (Loose) Potonié and Kremp 1956.

Comparison. In practice forms of Laevigatosporites ranging from 65-100 are assigned to L. vulgaris, so L. desmoinesensis (Wilson and Coe), Schopf and Bentall is considered synonymous with L. vulgaris.

Occurrence. Infrequent to common throughout the Westphalian A and B sequences, Northumberland off-shore boreholes; Smith and Butterworth 1967, Westphalian B, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless 1974, Westphalian A to D, Netherlands; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Infraturma SCULPTATOMONOLETES Dybova and Jachowicz 1957

Genus PUNCTATOSPORITES Ibrahim 1933

Type species. P. minutus Ibrahim 1933.

Diagnosis. (Smith and Butterworth 1967, p.287, from Potonié and Kremp 1954, p.165).

Comparison. Distinguished from other monolete genera such as Laevigatosporites Ibrahim 1933 and Latosporites Potonié and Kremp 1954 by its ornament of fine grana.

Punctatosporites minutus Ibrahim 1933

Plate 20 figures 1-4

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, al(o).

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

Diagnosis. (See Smith and Butterworth 1967, p.288, from Potonié and Kremp 1956, p.143).

Size in micrometres. (i) Holotype 25.5, Schulze and KOH. (ii) 21-28 Schulze (Potonié and Kremp 1956). (iii) 21 (29) 40, Schulze and KOH, seam at 511ft., Alveley No.1 borehole, Forest of Wyre Coalfield, England, Westphalian D. (iv) 18 (22) 27, Schulze and KOH; seam at 772ft. 9in., Bowsey Wood borehole, North Staffordshire Coalfield. England, Westphalian D. (v) 21 (25) 30, Schulze and KOH seam at 3,025ft. 5in., A3/9 borehole, Lancashire Coalfield, England; Westphalian B, (iii - v Smith and Butterworth 1967) (vi) 16 (25.7 35 (41 specimens), fum. HNO_3, Ashington seam at 45ft. 1½in, Northumberland off-shore borehole No.3, Westphalian B.

Description. Amb varies from oval, subcircular to circular. Laesura distinct, sometimes invisible if the spore is viewed from the distal surface, simple or raised, slightly curved, ½ - ¾ of spore length, often nearly reaching the equator, in one assemblage about 20% show incipient trilete condition. Ornament consists of very fine, loosely spaced grana more or less 0.5μm in diameter, distance between the elements is equal to or slightly less than twice their diameter. Grana

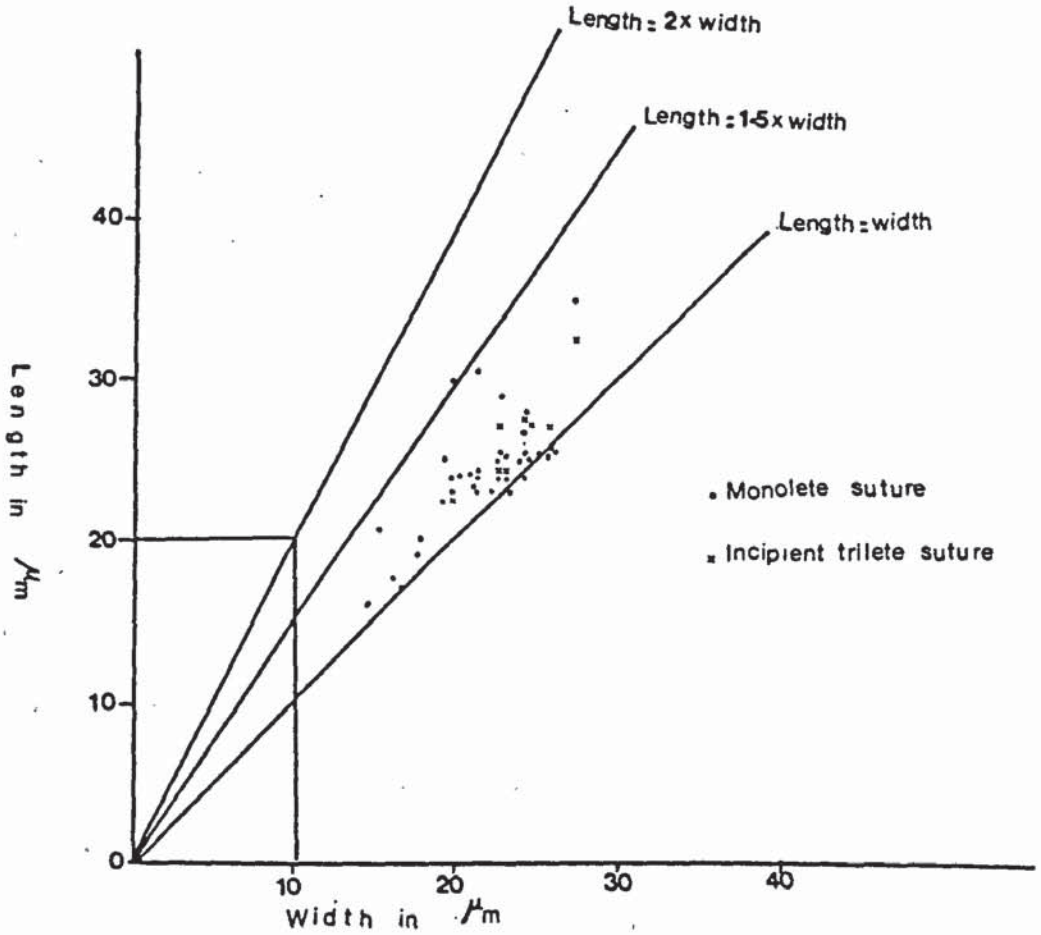


Fig. 4.2 Scatter diagram showing the distribution shape in Punctatosporites minutus

vary in degree of prominence, in some specimens the exine appears laevigate or nearly so under low power. Exine thin, secondary folds present.

Remarks. A scatter diagram of length against width fig(4·2) was drawn for this species from the Ashington seam; the diagram shows that it is not possible to recognise two species on the basis of shape, and also shows that the species is usually subcircular rather than oval. The specimens described in this work differ from those in Smith and Butterworth 1967 in being ornamented with loosely scattered grana and about 20% show an incipient trilete condition.

Occurrence. Infrequent to common throughout Westphalian A and B sequence, Northumberland off-shore boreholes. Smith and Butterworth 1967, Westphalian A-D, British Coalfields; Grebe 1972, Upper Westphalian A-C, Ruhr, Germany; Van Wijhe and Bless, Westphalian A-D, Netherlands.

Turma HILATES Dettmann 1963

Suprasubturma CAVATIHILATES Smith and Butterworth 1967

This includes hilate cavate cpores.

Subturma AZONOCAVATIHILATES Smith and Butterworth 1967

This includes hilate cavate spores in which the exine layers are of uniform thickness.

Infraturma EPITYGMATI (Spode in Smith and Butterworth 1967)

This includes spores which possess a rounded operculum at the proximal pole. The operculum may be observed "in situ" or detached.

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

Type species. V. profunda Wilson and Hoffmeister 1956.

Diagnosis. (Smith and Butterworth 1967, p.294, from Wilson and Venkatachala 1963, p.96).

Remarks. Potonié 1960 and Wilson and Venkatachala 1963 transferred Cancellatisporites Dybová and Jachowicz 1957 and Glomospora Butterworth and Williams 1958 (by the former author) and Foveolatisporites Bharadwaj 1955 and Novisporites Bharadwaj 1957 (by the latter authors) to Vestispora.

Comparison. Vestispora is distinguished from other genera by the presence of an operculum on the proximal surface.

Vestispora costata(Balme) Spode in
Smith and Butterworth 1967
Plate 20 figures 5-10

1952 Endosporites costatus Balme, p.178, text-fig 1f.

1957b Vestispora costata (Balme), Bharadwaj, p.118, pl.24, figs.36-40.

1958 Glomospora costata (Balme), Butterworth and Williams, p.385.

1967 Vestispora costata (Balme) Spode in Smith and Butterworth, p.295, pl.25, figs.1,2.

Lectotype. Balme did not designate a holotype but a lectotype (T71/1) has been chosen by Spode from the material deposited by Balme and now in the collection of the National Coal Board Laboratory, Wath Upon Dearne, Rotherham,Yorkshire.

Type locality. Seam at 719ft. 3in. Manton Colliery No.4 Shaft Sinking, Yorkshire Coalfield, England; Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.295 from Spode unpublished).

Size in micrometres. (i) Lectotype 74 x 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 (Pierart 1958); Belgium; Westphalian C. (iii) 52-88, Schulze and 5% KOH (Spode, in S.P.B. 1967 ~~unpublished~~). (vi) 48 (68) 82, Schulze and 10% KOH; Winghay Seam at 2.034ft. 6in., Bowsey Wood borehole, North Staffordshire Coalfield , England, Westphalian C (Smith and Butterworth 1967). (v) 51 (62.6) 70.5 (20 specimens) fum. HNO_3, Harvey seam, at 144.83m, Northumberland off-shore borehole P_2. Westphalian A.

Description. Amb circular to oval, margin usually smooth. Laesurae simple, straight, ½ of spore radius. Exoexine and operculum costate, muri 2-2.5 μm wide arranged circumcentrically around the spore, usually not branched, muri intersect to enclose large polygonal lumina. Some specimens tend to break along the muri. Operculum frequently detached and can easily be identified by the presence of less muri. Exoexine frequently folded.

Occurrence. Frequent in the Bottom Yard seam and rare to infrequent throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Smith and Butterworth 1967, Westphalian B and C, British Coalfields; Grebe 1972, Lower Westphalian B to Upper Westphalian C. Ruhr, Germany;

Van Wijhe and Bless 1974, Upper Westphalian A to Westphalian D, Netherlands; Clayton et al 1977, Westphalian A, Western Europe.

Vestispora laevigata Wilson and Venkatachala 1963

Plate 20 figures 11-15

1963b Vestispora laevigata Wilson and Venkatachala, p.98, pl.1, figs.8-11.

1965b Vestisporites laevigatus (Wilson and Venkatachala) Laveine, p.2556, pl.1, fig.10.

Holotype. Wilson and Venkatachala 1963, pl.1, fig.8,, Oklahoma Geological Survey specimen number WH7-5.

Type locality. Croweburg Coal, Rogers County, Oklahoma U.S.A.: Des Moines Series.

Diagnosis. (See Smith and Butterworth 1967, p.297, from Wilson and Venkatachala 1963).

Size in micrometres. (i) Holotype 65.2 x 63.8; 60-75, operculum 25-32, maceration method not known (Wilson and Vankatachala 1963). (ii) 58 (72) 88 fum. HNO_3, Coleford High Delf Seam, Northern United Colliery, Forest of Dean Coalfield, England, boundary Westphalian C/D (Williams 1956, thesis) (iii) 62-90, Schulze and 5% KOH, various localities (Spode, in press). (iv) 54.5 (60.3) 64, operculum 30 (32) 34 (18 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian B.

Description. Amb circular to slightly oval, margin smooth. Laesurae distinct only when the operculum detached, simple straight and short, about $^1/_3$ of spore radius sometimes open.

Exoexine and operculum are laevigate, some specimens show very faint short muri mostly around the operculum and sometimes the folding of the exoexine appears like an outer ornament. Exine thick, frequently folded.

Occurrence. Rare from Bottom Brass Thill seam up to Ryhope Marine band, Northumberland off-shore boreholes, Westphalian B; Smith and Butterworth 1967, Upper Westphalian C and Westphalian D, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa Westphalian B, U.S.A.

Vestispora luminata Ravn 1979

Plate 20 figures 16-19

1979 Vestispora luminata Ravn, p.46, pl.17, figs.4-10.

Holotype. Ravn 1979, pl.17, fig.4, slide 576 coordinates 123 x 51.5.

Type locality. Cherokee Group CP19-4 Coals of Iowa, Pennsylvanian.

Diagnosis. (See diagnosis in Ravn 1979, p.46).

Size in micrometres. (i) Holotype 96.6 78-111, Schulze and 5% KOH (Ravn 1979). (ii) 53 (62.5) 72 (10 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes, Westphalian B.

Description. Amb circular to oval margin undulate due to the projection of the muri. Laesurae simple, straight about ½ of spore radius. Exoexine and operculum are ornamented by numerous foveolae, rounded to oval or polygonal in shape, 2-6μm in diameter, muri 2-3μm wide. Exine thick and

occasionally folded.

Remarks. Specimens observed in this study are smaller than those described by Ravn 1979; this may be due to the difference in the maceration method used.

Comparison. V. fenestrata (Kosanke and Brokaw) Spode in Smith and Butterworth 1967 has smaller and more rounded lumina.

Occurrence. Absent to rare throughout the Westphalian B sequence of Northumberland off-shore boreholes, England; Ravn 1979, Cherokee Group CP19-4 Coals of Iowa Westphalian B, U.S.A.

Vestispora pseudoreticulata Spode in Smith and Butterworth 1967

Plate 20 figures 20-26

1952 Reticulatisporites tortuosus Balme (in part), p.179

1964b Vestispora pseudoreticulata Spode in Neves, p.1233, pl.3, figs.1,2.

1965b Vestisporites pseudoreticulatus (Spode) Laveine, p.2556, pl.1, figs.6,18.

1967 Vestispora pseudoreticulata Spode in Smith and Butterworth, p.298,299, pl.25, figs.13,14.

Holotype. Plate 1, fig.3, Spode (unpublished).

Type locality. Barnsley Seam, Yorkshire Coalfield, England, Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.299, from Spode unpublished).

Size in micrometres. (i) Holotype 122.6 x 101; 50-80, various localities, Yorkshire Coalfield, England; Schulze

and 5% KOH (Spode, unpublished). (ii) 64 (72) 80, fum. HNO_3; Clayknowes Seam at 1,196ft. 10in,, Musselburgh No,1 borehole, Lothians Coalfield, Scotland; Lower Westphalian B. (iii) 58 (73) 90, fum. HNO_3; Bottom Droughy Seam at 1,818ft. 6in., Plas Thomas borehole, North Wales Coalfield; Lower Westphalian B. (ii and iii Smith and Butterworth 1967). (iv) 45 (63.4) 80 (22 specimens), fum. HNO_3, Ashington seam at 45ft. 1½in., Northumberland off-shore borehole No,3, Westphalian B.

Description. Amb circular or oval, margin undulate due to the projection of the muri at the equator. Laesurae simple, straight $^1/_4$ - $^1/_3$ of spore radius, (average 13μm). Primary muri 2-3μm wide, carinate, the carinae fused together and forming secondary reticulum. Lumina usually regular and having the same size, approximately 1-2μm; the primary muri also intersect to enclose large polygonal lumina, up to 13μm in diameter. Operculum, 30-40 (average 33)μm similarly ornamented and frequently detached. Exoexine thick, occasionally folded.

Comparison. Differs from V. costata (Balme) Spode (in S&B 1967) in possessing secondary reticulum. V. luminata Ravn 1979 lacks the primary muri.

Occurrence. Rare, infrequent to frequent throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Smith and Butterworth 1967, Westphalian A-C, British Coalfields; Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A.; Grebe 1972, Middle Westphalian C. Ruhr, Germany; Van Wijhe and Bless 1974 Upper

Westphalian A - Lower Westphalian C, Netherlands; Ravn 1979 Cherokee Group CP-19-4 Coals of Iowa Westphalian B, U.S.A.

Vestispora tortuosa (Balme) Spode in Smith and Butterworth 1967

Plate 21 figures 1-7

1952 Reticulatisporites tortuosus Balme (in part), text-fig.1d.

1957b Vestispora tortuosa (Balme); Bharadwaj, p.119.

1957a Cancellatisporites cancellatus Dybova and Jachowicz p.111, pl.24, figs. 1-4.

1967 Vestispora tortuosa (Balme) Spode in Smith and Butterworth, p.299, pl.26, figs. 1,2.

Lectotype. No holotype was designated by Balme but a lectotype (T72/1)was chosen by S&B 1967 from material deposited by him and is now in the collection of the National Coal Board Laboratory, Wath upon Dearne, Rotherham, Yorkshire.

Type locality. Wheatworth Seam at 907ft. 11in., Wentbridge No.2 borehole, Yorkshire Coalfield, England; Upper Westphalian B.

Diagnosis. (See Smith and Butterworth 1967, p.299, from Spode, unpublished).

Size in micrometres. (i) Lectotype 77; 65 (86) 100, Schulze (Balme 1952). (ii) 65-80, fum. HNO_3 and 30% NH_4OH (Dybova and Jach. 1957), Westphalian B. (iii) 53-80, Schulze and 5% KOH; various localities (Spode unpublished) (iv) 56 (67) 78, fum. HNO_3; seam at 1,777ft.3in., Musselburgh No,1 borehole, Lothians Coalfield, Scotland, Lower Westphalian A.

(v) 64 (73) 86, fum. HNO_3; seam at 491ft. 10in, Seafield No,2 borehole, East Fife Coalfield, Scotland; Westphalian B. (iv and v Smith and Butterworth 1967). (vi) 64 (73.6) 88 (10 specimens) fum. HNO_3, Ashington Seam, at 45ft. 1½in. Northumberland off-shore borehole No,3, Westphalian B. (vii) 55 (61.5) 70.5 (15 specimens) fum. HNO_3, Harvey seam at 144.83m., Northumberland off-shore boreholes P_2, Westphalian A.

Description. Amb rounded to elliptical, margin uneven due to the projection of the muri. Laesurae simple, straight $^1/_3$ - $^1/_2$ of spore radius. Exoexine and operculum are murinate, muri, 1.5 - 2.5 μm wide, usually branched and carinate, the primary muri intersect to form polygonal or irregular large lumina, sometimes the carination may form a very faint secondary reticulum. In some specimens the spores break along one of the primary muri. Exoexine thick, occasionally with crescentic folds.

Comparison. Distinguished from V. costata by the branching and incipient carination of the muri. V. pseudoreticulata has a strongly-developed secondary reticulum.

Occurrence. Rare to frequent throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Smith and Butterworth 1967, Upper Westphalian A to Lower Westphalian C, British Coalfields; Van Wijhe and Bless 1974 Upper Westphalian A-C, Netherlands.

Subturma AZONALETES (Luber) Potonié and Kremp 1954

Genus FABASPORITES SULLIVAN 1964

Type species. F. pallidus Sullivan 1964

Diagnosis. (Smith and Butterworth 1967, p.300, from Sullivan 1964, p.378).

Comparison. Differs from Aletes Somers 1953 by the presence of the single longitudinal fold.

Fabasporites pallidus Sullivan 1964

Plate 21 figures 8-10

1964 Fabasporites pallidus, p.379, pl.61, figs.9-11

Holotype. Sullivan 1964, pl.61, fig.11.

Type locality. Edgehills Coal, Forest of Dean Coalfield, England; Westphalian A.

Diagnosis. (See Smith and Butterworth 1967, p.301, from Sullivan 1964, p.379).

Size in micrometres (i) 13 (17) 23, HF and 2% KOH (Sullivan 1964) (ii) 16 (20) 24 (fum. HNO_3, Westphalian D. (iii) 14 (20) 29, fum. HNO_3, Westphalian B. (iv) 16 (21) 27, fum. HNO_3, Westphalian A (ii - iv Smith and Butterworth 1967). (v) 16 (22.7) 33 (20 specimens) fum. HNO_3 Bottom Busty, at 186.25m, Northumberland off-shore borehole P_2. Westphalian A.

Description. Amb oval, monolete suture not visible. Exine thin leavigate or very finely granulate, single major compression fold usually parallel to the long axis of the spore.

Remarks. In this work all specimens displaying no monolete suture and with the characteristic compression fold are

assigned to this species. In Sullivan 1964, pl.61, fig.9 is very similar to Punctatosporites minutus Ibrahim 1933 because it shows clearly the monolete suture and lacks the fold.

Occurrence. Infrequent to common throughout the Westphalian A and B sequence, Northumberland off-shore boreholes. Sullivan 1964, Drybrook Sandstone of the Forest of Dean, England, Westphalian A. Smith and Butterworth 1967, Westphalian A to D, British Coalfields.

Anteturma POLLENITES Potonié 1931

Turma SACCITES Erdtman 1947

Subturma MONOSACCITES (Chitaley) Potonié and Kremp 1954

Infraturma ARADIATES Bharadwaj 1957a

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. (Schopf, Wilson and Bentall 1944, p.56).

Florinites florini Imgrund 1960

Holotype. Imgrund 1960, pl.16, fig.94. Preparation A 33.

Type locality. Seam 4, Kaiping Basin, China; Lower Permian.

Diagnosis. (See Smith and Butterworth 1967, p.302, from Imgrund 1960, p.179).

Size in micrometres. Holotype 46; 50-70, Schulze and KOH (Imgrund 1960).

Florinites cf. florini Imgrund 1960

Plate 21 figures 11-15

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

Size in micrometres.

	Saccus dimensions						Average body dimensions		Number of Specimens		
	Maximum			Minimum			Max.	Min.	Total measured	With measurable body	
a.	42	(51)	60	34	(41)	52	27	26	25	3	Westphalian D
b.	47	(56)	77	37	(45)	77	30	27	38	5	Westphalian D
c.	47	(62)	77	32	(45)	60	25	24	23	3	Westphalian C
d.	52	(67)	76	40	(52)	63	30	26	28	4	Westphalian B
e.	50	(66)	79	37	(51)	65	32	30	36	6	Westphalian B
f.	56	(65)	77	45	(51)	61	34.5	22.5	15	2	
g.	54.5	(66.7)	77	41.5	(50.5)	65	24	19.0	22	2	

(a-e Smith and Butterworth 1967)

(f) Seam 'D_2' at 146.07m, Northumberland off-shore borehole EL_2, Upper Westphalian B.

(g) Unnamed seam at 225ft. 1in., Northumberland off-shore borehole No.5, Westphalian B.

Description. Amb oval, central body elliptical, faint, occupies about half of spore diameter, usually not visible. Tetrad mark indistinct. Saccus laevigate and thin, but with reticulate infrasculpture which is less developed in the region of the body. Lumina 1.5-2μm, muri 0.5μm, sometimes saccus is slightly darker at the equator. Compression folds usually present.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence, Northumberland off-shore boreholes; Smith and Butterworth 1967, Upper Westphalian A to D, British Coal-

fields; Ravn (1979) includes F. cf. florini in F. mediapudens, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Florinites mediapudens (Loose) Potonié and Kremp 1956

Plate 21 figures 16-20

1934 Reticulata-sporites mediapudens Loose, p.158, pl.7, fig.8.

1956 Florinites mediapudens (Loose); Potonié and Kremp p.169, pl.21, figures 468-71.

1957a Endosporites mediapudens (Loose); Dybová and Jachowics, 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. (See Smith and Butterworth 1967, p.303, from Potonié and Kremp 1956, p.169).

Size in micrometres. (i) Holotype 60, Schulze and KOH (ii) 50-65 Schulze (Potonié and Kremp 1956).

	Saccus dimensions		Body dimensions		
	Maximum	Minimum	Maximum	Minimum	
a.	51(63)78	41(49)60	21(30)36	20(26)32	Westphalian C
b.	50(58)72	33(43)52	22(33)42	22(27)34	Westphalian B
c.	42(55)77	31(40)57	26(31)46	20(26)40	Westphalian A
d.	45(55.5)68.5	38.5(45.5)59	32(34.4)38.5	19(23.8)32	Upper West. B
e.	48(60.3)70.5	32(48.3)61	21(31.8)40	19(25.5)32	Westphalian B

(a - c Smith and Butterworth 1967). (d) (10 specimens), fum. HNO_3, Seam 'D_2' at 146.07m, Northumberland off-shore

borehole EL_2.

(e) (22 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft. 9in., Northumberland off-shore borehole No,3,

Description. Amb elliptical to almost circular in outline, margin smooth, body distinct, also elliptical, circular or sometimes irregular due to folding on compression. Ratio of body to saccus along long axis of saccus approximately 55%. Trilete mark usually not visible. Saccus is externally laevigate but infrareticulate. Lumina 1-1.5μm in diameter and are largest away from the body, muri less than 1μm, saccus usually folded. Body enclosed in the saccus, laevigate, thin, folded with the folds mostly tending to follow the equator; the body is usually darker in colour than the saccus.

Comparison. According to Smith and Butterworth 1967, F. parvus Wilson and Hoffmeister 1956 and F. ovalis Bharadwaj 1957a are very similar to F. mediapudens. Ravn 1979 stated that F. pellucidus (Wilson and Coe) Wilson 1958, F. antiquus Schopf, Wilson and Bentall (which is considered by Smith and Butterworth a synonym of F. pellucidus) and F. junior Potonié and Kremp 1956 are similar and can be considered as synonyms of F. mediapudens. In this study the name F. mediapudens is employed following the practice of Smith and Butterworth 1967 and Ravn 1979.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence, Northumberland off-shore boreholes. Smith and Butterworth 1967, Upper Westphalian A to D, British Coalfields; Grebe 1972, Upper Westphalian A to C, Ruhr,

Germany; Ravn 1979, Cherokee Group CP-19-4 Coal of Iowa, Westphalian B.

Florinites millotti Butterworth and Williams 1954

Plate 21 figures 21-25

1954 Florinites millotti Butterworth and Williams, p.760, text-fig.1,8, pl.18, figs.7,8.

1966 Florinipollenites millotti (Butterworth and Williams) Coquel, p.21, pl.2, fig.14,15.

Holotype. Plate 26, fig.9. Specimen No. PF3013 (formerly 76490), Geological Survey Museum, London.

Type locality. Bottom 1ft. 4in. Coal at 3,388ft. 2in., Upton borehole, Oxfordshire, England; Westphalian D.

Diagnosis. (See Smith and Butterworth 1967, p.305, abbreviated from Butterworth and Williams 1954, p.760).

Size in micrometres. (i) Holotype, saccus 37 x 29 body 19 x 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 Williams 1954). (ii) Saccus, max. 29 (42.5) 50, min. 27 (33.5) 46.5 (15 specimens), body max. 24-32, min. 19-22.5 (3 specimens only with central body), Seam 'D_2', at 146.07m, Northumberland off-shore borehole EL_2, Upper Westphalian B.

Description. Amb elliptical, amb of body oval or circular very rarely seen. Saccus is laevigate and thin, but with reticulate infrasculpture. Lumina less than 1μm, muri less than 0.5μm. Compression folds usually present.

Comparison. F. millotti is smaller than F. cf. florini but otherwise very similar and in assemblages where the two species occur it is difficult to differentiate between them. In this work, as in Smith and Butterworth 1967, a limit of 50μm, is employed to differentiate between the two species.

Occurrence. Rare to infrequent throughout Westphalian B sequence, Northumberland off-shore bores, England; Smith and Butterworth 1967, Westphalian B to D, British Coalfields; Peppers 1970, Pennsylvanian, Carbondale and Spoon Formations, Illinois, U.S.A.; Grebe 1972, Middle Westphalian B to Upper Wesptphalian C, Ruhr, Germany; Ravn 1979, Cherokee Group CP-19-4, Coal of Iowa, Westphalian B.

Florinites pumicosus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 22 figures 1-4

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 B_{34}, d_4(u).

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

Diagnosis. (See Smith and Butterworth 1967, p.305, from Potonié and Kremp 1956, p.169).

Size in micrometres. (i) Holotype 92.5, Schulze and KOH. (ii) Saccus, 80-100, Schulze (Potonié and Kremp 1956). (iii) Saccus, max. 77 (93) 117, min. 52 (78) 99, fum. HNO_3; Swallow Wood Seam Denaby Main Colliery, Yorkshire Coalfield, England; Westphalian B (Smith and Butterworth 1967). (iv) Saccus max. 80 (98.5) 118.5, min. 62 (73.6) 83 (15 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes.

Description. Amb broadly elliptical, margin smooth. Central body circular and occupies more than half the diameter of the entire spore, but rarely seen. Tetrad mark usually not visible. Saccus laevigate and thin with reticulate infrasculpture which is less well developed in the central area. Lumina 1-2.5μm, muri 0.5-1μm. Folds usually in the saccus parallel or across the long axis of the spore.

Remarks. Some specimens show a rounded-triangular shape

Comparison. F. pumicosus is larger than F cf. florini but otherwise similar.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence, Northumberland off-shore boreholes; Sullivan 1964. Westphalian A, Drybrook Sandstone, Forest of Dean; Smith and Butterworth 1967, Upper Westphalian A to D, British Coalfields; Grebe 1972, Lower Westphalian B to Upper Westphalian C, Ruhr, Germany; Sabry and Neves 1970, Namurian C to Westphalian B, Sanquhar Coalfield, Scotland.

Florinites similis Kosanke 1950

Plate 22 figures 5-7

1950 Florinites similis Kosanke, p.49, pl.12, fig.2.

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. (See Smith and Butterworth 1967, p.306, from description in Kosanke 1950, p.49).

Size in micrometres. (i) Holotype 133 x 92; saccus, max. 124-142, min. 88-97; Schulze and 10% KOH (Kosanke 1950). (ii) Saccus, max. 112-161, min. 99-127; body, max. 65-92, min. 55-72, fum. HNO_3; seam at 1,387ft. 4in., Gate Farm borehole, Yorkshire Coalfield, England; Lower Westphalian C. (Smith and Butterworth 1967). (iii) Saccus, max. 88 (111) 137.5, min. 61 (87) 105.5; body max. 48 (60) 73.5, min. 35 (50) 66, (12 specimens), fum. HNO_3, Harvey seam at 144.83m, Northumberland off-shore borehole P_2, Westphalian A; (iv) Saccus, max. 110.3 (120) 128, min. 73.5 (100) 115; body max. 61 (66) 77, min. 46.5 (54) 61, (6 specimens), various seams, Northumberland off-shore boreholes.

Description. Monosaccate, trilete, amb elliptical to almost circular in outline, margin smooth, body is sharply defined, elliptical, circular or irregular due to folding on compression. The laesurae are usually covered by folds but are distinct when the body is not strongly folded. Saccus encloses the body almost entirely. Body occupies

approximately 55% of saccus along major axis of grain. The surface of the body is very finely granulate or puncatate (oil immersion). Saccus laevigate externally, but infrareticulate, Lumina 1-2μm and are largest away from the body.

Remarks. Kosanke 1950 stated that F. similis is apparently alete but Peppers 1970, after examination of the holotype found no suture because the body is torn and folded. He remacerated the sample from which the holotype had been selected and found specimens with the same characteristics as the holotype and with a clear trilete mark.

Comparison. According to Peppers 1970 Guthoerlisporites magnificus Bharadwaj 1954 is morphologically similar to F. similis.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence, Northumberland off-shore boreholes; Smith and Butterworth 1967, Westphalian A to D, British Coalfields; Peppers 1970, Pennsylvanian, Carbondale and Spoon Formation, Illinois, U.S.A.; Sullivan 1962, Westphalian A-B, Wernddu Claypit, South Wales; Owens and Burgess 1965, Upper Namurian A to Lower Westphalian B, Stainmore Outlier, Westmorland.

Florinites triletus Kosanke 1950

Plate 22 figures 8,9

1950 Florinites triletus Kosanke, p.50, pl.12, figs.3-4

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

Type locality. Shoal Creek coal bed, Bond County, Illinois.

Diagnosis. (From description in Kosanke 1950, p.50).

Size in micrometres. (i) Holotype saccus 52.9 x 65.1, 49-69, body 33.6 x 27.3, 25-36, Schulze and 10% KOH (Kosanke 1950). (ii) Saccus, max 56 (64.5) 77, min. 35 (54.8) 72, body max 24 (35.6) 51, min. 24 (31) 41.5 (10 specimens), fum. HNO_3 various seams, Northumberland off-shore boreholes, Westphalian A-B.

Description. Amb elliptical, occasionally circular, margin smooth or minutely indented. Body sharply defined, oval, circular or irregular in shape due to folding. Laesurae distinct on the proximal surface of the body, average ($7^{\mu}m$) in length. Saccus laevigate externally but with infrareticulate sculpture, sometimes with slightly darker margin. Lumina $1-2^{\mu}m$, smaller in the region of the body, muri less than $1^{\mu}m$. Body partially enclosed by the saccus, laevigate or very finely punctate (oil immersion) with crescentic folds around the equator.

Comparison. Differs from F. mediapudens in having distinct trilete laesurae; F. volans (Loose) Potonié and Kremp 1956 is larger.

Occurrence. Absent to rare throughout Westphalian A and B sequence Northumberland off-shore boreholes. Clayton et al 1977, Silesian, Western Europe.

Florinites visendus (Ibrahim) Schopf, Wilson and Bentall 1944

Plate 22 figures 10-12

1933a Reticulata-sporites visendus Ibrahim, p.39, pl.8, fig.66.

1944 Florinites visendus (Ibrahim) Schopf, Wilson and Bentall, p.60.

1966 Florinipollenites visendus (Ibrahim) Coquel, p.28, pl.2, fig.16.

Holotype. Potonié and Kremp 1956, pl.21, fig.477 after Ibrahim. Preparation B29, c6(ur).

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

Diagnosis. (See Smith and Butterworth 1967, p.306, from description and diagnosis in Potonié and Kremp 1956, p.170).

Size in micrometres. (i) Holotype 165, Schulze and KOH. (ii) Saccus, 150-175, Schulze (Potonié and Kremp 1956). (iii) Saccus, max. 122 (151) 186, min. 79 (112) 146, fum. HNO_3; seam at 1,387ft. 4in., Gate Farm borehole, Yorkshire Coalfield, England; Westphalian C (Smith and Butterworth 1967). (iv) Saccus, max. 120 (128) 139, min. 80 (93) 109, (10 specimens), fum. HNO_3, various seams, Northumberland off-shore boreholes.

Description. Amb usually oval, central body not visible. Tetrad mark has not been seen. Saccus laevigate and infrareticulate, lumina vary in size and shape, reaching up to 4μm, muri 1-1.5μm, sometimes infrareticulation is less marked in the region of the body; occasionally the equatorial margin of the saccus is slightly darker. Compression folds are usually not oriented in one direction,

they may be parallel or transverse to the long axis of the spore and in some specimens they may be oblique.

Comparison. F. visendus is larger than F. pumicosus but otherwise similar.

Occurrence. Infrequent to rare throughout Westphalian A and B sequence, Northumberland off-shore boreholes; Felix and Burbridge 1967, Mississippian and Pennsylvanian, Springer Formation, Oklahoma, U.S.A.; Smith and Butterworth 1967, Upper Westphalian A to D, British Coalfields; Peppers 1970, Pennsylvanian, Carbondale and Spoon Formations, Illinois, U.S.A.; Grebe 1972, Upper Westphalian A to C, Ruhr, Germany.

Infraturma TRIRADITES (Pant) Bharadwaj 1955

Genus WILSONITES Kosanke 1959

1950 Wilsonia Kosanke, p.54

Type species. W. vesicatus Kosanke 1950.

Diagnosis. (Smith and Butterworth 1967, p.307, from Kosanke 1950, p.54).

Comparison. Differs from Endosporites Wilson and Coe in possessing infrareticulate ornament rather than granulate and the body is less distinct than in Endosporites. Wilsonites differ Florinites in being consistently trilete and circular in shape.

Wilsonites delicatus (Kosanke) 1959

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

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

1966 Guthoerlisporites delicatus (Kosanke) Habib, p.646, pl.107, fig.9.

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. (Smith and Butterworth 1967, p.307, from description in Kosanke 1950, p.54).

Size in micrometres. (i) Holotype 92.4 x 86.1, body 56.7 x 52.5; overall diameter 81-98, body 52-61; Schulze and 10% KOH (Kosanke 1950).

Wilsonites cf. delicatus

Plates 23 figures 1-5

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

Size in micrometres. (i) 68 (90) 124, body 26 (43) 65 fum. HNO_3, Three-quarter seam, No.1 off-shore borehole, Durham Coalfield, England, Westphalian A. (Smith and Butterworth 1967). (ii) 53 (61.5) 71, body 24 (32.3) 37 (10 specimens) fum. HNO_3, various seams, Northumberland off-shore boreholes Westphalian B. (iii) 122 body 64 (one specimen) fum. HNO_3 Top and Bottom Yard, Northumberland off-shore borehole No.6, Westphalian B.

Description. Amb of the saccus usually circular, occasionally slightly elongate. Laesurae well defined, simple, sometimes slightly raised, ¾ to almost entire body radius, sometimes open. Body circular, indistinct, laevigate to very finely granulate or punctuate. Saccus covers the distal surface and more than half the proximal surface of the body, laevigate with reticulate in-frasculp-

ture. Lumina 1-1.5μm in diameter muri less than 1μm in width, saccus slightly thickened at the equatorial margin, Compression folds usually present.

Comparison. Differs from the type in being smaller in size and not consistently circular amb.

Remarks. Only one specimen has the size of 122μm, the rest are smaller than those given by Kosanke but this may be due to the different maceration methods.

Occurrence. Rare to infrequent in Bottom Brass Thill, Top and Bottom Yard, Ryhope Marine Band Coal, and unnamed seam at 225ft. 1in. borehole No,5 Northumberland off-shore boreholes. Smith and Butterworth 1967, Upper Westphalian A - Lower Westphalian C, British Coalfields;, Peppers 1970, Carbondale and Spoon Formations, Pennsylvanian, Illinois, U.S.A. ; Grebe 1972, Middle to Upper Westphalian C, Ruhr, Germany; Ravn 1979 Cherokee Group CP19-4 Coals of Iowa, Westphalian B.

Infraturma VESICULOMONORADITI (Pant)

Bharadwaj 1956

Genus PALEOSPORA Habib 1966

Type species P. fragila Habib 1966

Diagnosis. (Habib 1966, p.647).

Remarks. This genus is characterised by an elliptical central body enveloped by saccus and wide equatorial flange.

Paleospora fragila Habib 1966

Plate 23 figures 6-11

1966 Paleospora fragila Habib, p.647, pl.108, figs.1,2.

Holotype. Habib 1966, pl. 108, fig.1, slide LKC-2 (21-22) 2,36.5 x 115.2.

Type locality. Lower Kittanning Coal Seam of Western Pennsylvania (Allegheny Series; Lower Westphalian D).

Diagnosis. (See diagnosis in Habib 1966, p.647-648).

Size in micrometres. (i) Holotype 161 x 93; Body 150-195, Saccus 105-140, HNO_3 or Schulze and 8% KOH (Habib 1966). (ii) Body 134 (147.5) 160, Saccus 109 (117.2) 128, Flange 13 (17.5) 22 (10 specimens), fum. HNO_3, Bottom Brass Thill, at 377ft. 9in., Northumberland off-shore borehole No 3, Westphalian B.

Description. Grain monosaccate, outline of saccus and body elliptical, saccus surrounded by a thin uniform flange. Both saccus and central body thin, always folded and very finely punctate. Flange ornamented with fine irregularly radiating corrugations which become clear toward the margin. Major fold running parallel to the long axis of the grain usually present and possibly covering the suture in the saccus.

Remarks. In this work none of the specimens observed show any clear suture. Habib 1966 mentions the presence of a longitudinal fissure extending to the entire length of the body.

Occurrence. Rare in the Three-quarter, Harvey, Bottom Brass Thill and Bottom Main seams, Northumberland off-shore boreholes, Westphalian A and B; Peppers 1970, Carbondale and Spoon Formations, Illinois, U.S.A., Pennsylvanian.

Genus POTONIEISPORITES Bharadwaj 1954

Type species. P. novicus Bharadwaj 1954

Diagnosis. (Bharadwaj 1954, p.520).

Comparison. Differs from species of Florinites in possessing a monolete suture.

Potonieisporites elegans (Wilson and Kosanke) Habib 1966

Plate 23 figures 12,13

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

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

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

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

Type locality. Angus Coal Company Mine, Iowa; Des Moines Series.

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

Size in micrometres. (i) 135-215, central body 85-110, Schulze and 8% KOH (Habib 1966). (ii) Overall size 100 x 137 to 145 x 200. Body 70-72 to 102 x 108, Schulze and KOH (Felix and Burbridge 1967). (iii) overall size 95 (117.6) 144, body 54.5 (70.1) 81.5 (9 specimens) fum. HNO_3, various localities, Northumberland off-shore boreholes, Westphalian A-B;

Description. Amb of saccus elliptical, body spherical, sometimes oval. Monolete laesura straight, curved or angularly bent. Body characterised by crescentic or lenticular folds which usually transect each other , laevigate or finely punctate. Saccus laevigate externally with

reticulate infrasculpture, saccus pale yellow, body brown.

Occurrence. Absent to rare throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Habib 1966, Lower Kittanning coal seam, Pennsylvania, Lower Westphalian D. Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B; Felix and Burbridge 1967, Lower Pennsylvania, Springer Formation, Southern Oklahoma, U.S.A.

Potonieisporites sp.A.

Plate 23 figures 14-16

Size in micrometres. (i) 45 (66.5) 86.5 (10 specimens) fum. HNO_3 Bottom Brass Thill at 377 ft. 9in., Northumberland off-shore borehole No.3, Westphalian B. (ii) 54.5 (61) 72 (7 specimens) fum. HNO_3 various localities, Northumberland off-shore boreholes Westphalian A and B.

Description. Amb of the saccus elliptical, occasionally nearly circular. Body circular or oval. Laesura straight, sinuous or angularly bent, extends up to $\frac{3}{4}$ of the body length, sometimes open. Body usually with two sets of lenticular folds, almost perpendicular to each other, laevigate or very finely punctate. Saccus laevigate externally, reticulate internally, lumina 1-2μm in diameter, tend to be coarser near the equatorial margin.

Comparison. Differs from P. elegans (Wilson and Kosanke) Habib in being smaller in size.

Occurrence. Absent to rare throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B.

Subturma DISACCITES Cookson 1947

Genus PITYOSPORITES (Seward) Manum 1960

Type species. P. antarcticus Seward 1914

Diagnosis. (Smith and Butterworth 1967, p.308, from Manum 1960, p.14).

Pityosporites westphalensis Williams 1955

Plate 24 figures 1-5

1955 Pityosporites westphalensis Williams, p.467, text-figs. 1,2, pl.6, figs.1-6

Holotype. Williams 1955, pl.6, fig.1. Preparation No. V_3 1900 in collection of British Museum (Natural History), London.

Type locality. No, 12 Seam Nantgarw Colliery, South Wales Coalfield; Westphalian C.

Diagnosis. (See Smith and Butterworth 1967, p.309, from diagnosis in Williams 1955, p.467).

Size in micrometres. (i) 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 the proximo-distal axis; fum. HNO_3 (Williams 1955). (ii) length of saccus 19.2 (21) 24, width of the body 31 (32) 34, fum. HNO_3, various seams of Northumberland off-shore boreholes, Westphalian A-B.

Description. Grain disaccate. Proximal view shows the body slightly elongated, sometimes circular with sacci of approximately the same width, laevigate to very finely granulate or punctate. Laesurae have not been seen. Sacci are well separated, their axes deflected distally, externally laevigate with infrareticulate sculpture coarsening away from the bases. Lumina 1-2μm in diameter, muri less than 1μm in width, usually preserved without compression folds.

Occurrence. Infrequent in Top and Bottom Yard and unamed seam at 225ft. 2½in. borehole No,5 Northumberland off-shore borehole, Westphalian B. Smith and Butterworth 1967, Upper Westphalian A-D British Coalfields. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany. Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B-

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. (Smith and Butterworth 1967, p.309, from Potonié and Kremp 1954, p.180).

Schopfipollenites ellipsoides (Ibrahim) Potonié and Kremp 1954

Plate 24 figures 6-8

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.

138 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. (Smith and Butterworth 1967, p.130, from Potonié and Kremp 1956, p.184).

Size in micrometres. (i) Holotype 350; 200-500, Schulze (Potonié and Kremp 1956). (ii) length 150.5 (166) 179, width 99 (117.8) 137.5 (8 specimens), fum. HNO_3, various seam, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb elliptical, margin smooth, suture flexed in the middle, varies in its length, sometimes associated with two parallel folds with tapering ends on the distal surface. Exine externally laevigate, finely punctate internally. The grain shows a narrow rim 2μm in width.

Occurrence. Absent to rare throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B;

Smith and Butterworth 1967, Namurian B to Westphalian D. Grebe 1972, Upper Westphalian A-C, Ruhr, Germany. Ravn 1979, Cherokee Group CP-19-4 Coals of Iowa, Westphalian B.

Schopfipollenites ellipsoides var. corporeus Neves 1961

1961 Schopfipollenites ellipsoides var. corporeus Neves pl.34, fig.5,

Holotype. Neves 1961, pl.34, fig. Preparation 4.236800.

Type locality. Pot Clay Coal, North Staffordshire Coalfield, England; Namurian C.

Diagnosis. (See Smith and Butterworth 1967, p.311, From Neves 1961, p.274).

Size in micrometres. (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. (Smith and Butterworth 1967. (iii) overall 150.5 (153.1) 155.5, body 128 (132.1) 137.5 (4 specimens) fum. HNO_3, Bottom Brass Thill at 377ft. 9in., Northumberland off-shore borehole No,3, Westphalian B.

Description. Amb of the grain and the body elliptical to subcircular, margin smooth. Suture often indistinct, varies in length and may reach the full length of the body. Body usually almost fills the cavity within the exoexine, separation between 4-10μm. Exoexine and the body laevigate externally, finely punctate internally. Major folds of exoexine usually parallel to the long axis of the grain.

Comparison. Differs from S. ellipsiodes in showing a clear

separation of the intexine from the exoexine.

Occurrence. Absent to rare throughout the sequence of Northumberland off-shore boreholes, Westphalian A and B; Neves 1961 Namurian C and Westphalian A, South Pennines, England; Smith and Butterworth 1967, Namurian B to Westphalian D. British Coalfields.

Spore type A

Plate 24 figures 11-13

Size in micrometres. (i) 29 (33) 35 (15 specimens) fum. HNO_3, Bottom Busty at 186.25m, Northumberland off-shore borehole P_2 Westphalian A. (ii) 23 (30) 35 (5 specimens), fum. HNO_3 various localities, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb circular to subtriangular. Laesurae simple or slightly raised, flexuose, $^1/_2$ - $^2/_3$ of spore radius. Apical papillae distinct. Ornament consists of very fine grana 0.5μm or less in diameter, distributed randomly, some specimens even show a laevigate exine. Separation of the intexine not always clear, but some specimens show a clear separation of the intexine in the equatorial region. Exine thin. Compression folds not common, if present usually around the margin.

Occurrence. Rare throughout the sequence, Northumberland off-shore boreholes, Westphalian A and B.

Spore type B.

Plate 24 figures 14-17

Size in micrometres. (i) 22.5 (24) 25.5 (15 specimens),

fum. HNO_3, Bottom Busty at 186.25m, Northumberland off-shore borehole P_2, Westphalian A. (ii) 24 (27.8) 30.5 (6 specimens), various localities, Northumberland off-shore boreholes, Westphalian A and B.

Description. Amb rounded-triangular, sides convex. Laesurae raised, flexuose, extending $^5/_6$ to the whole length of spore radius. Ornament consists of very fine grana less than 0.5μm in diameter randomly distributed, sometimes concentrated in small areas and occasionally the spore shows a laevigate exine. Apical papillae present, but faint and sometimes indistinct. Intexine indistinct and the separation is not clear. Exine about 1μm thick. Compression folds rare or absent.

Comparison. Differs from Spore type A in possessing more prominent and longer laesurae, and its outline is more triangular than Spore type A.

Occurrence. Rare throughout the sequence, Northumberland off-shore boreholes, Westphalian A and B, England.

CHAPTER 5

Miospore Distributions and Correlation.

5.1 Introduction

The Main purpose of this study is to try to use the miospores for biostratigraphic zonation and correlation of the Westphalian coal seams in the eight off-shore boreholes in Northumberland.

The miospore assemblages recovered from these seams are well preserved, and the majority of the spores found in them can be assigned to previously described Upper Carboniferous taxa. Eighteen new types were also found and the descriptions of all the species are given in detail in chapter 4.

Generally the miospore assemblages are dominated throughout the sequence by spores of the genera Lycospora and Apiculatisporis (particularly L. pusilla and A. irregularis), and also by high percentages of Crassispora, Laevigatosporites, Anaplanisporites and Punctatosporites minutus.

The distributions of all species recorded from Northumberland off-shore boreholes are shown in tables Nos. 1 and 2, and the ranges of selected miospores which are of stratigraphical importance are shown in fig. (5.1).

In the following section the assemblages are first described and then compared with the concurrent range zones defined by Clayton et. al. 1977, Smith and Butterworth 1967 and with assemblages from strata of comparable age described by other workers. The percentage occurrence of significant species in the assemblages recognised by Smith

and Butterworth 1967 are shown in fig. 5.2 and compared with Table 3 in Smith and Butterworth 1967.

5.2 Assemblages I

This includes miospores obtained from the Threequarter, Top and Bottom Busty, three unnamed (3 samples), and Harvey seams, Northumberland off-shore borehole P_2, fig. (5.3).

These samples are dominated by Lycospora pusilla but show relatively low percentages in the higher part of the Assemblage. Apiculatisporis irregularis fluctuates between common and abundant, and reaches its highest percentages in the lower part and highest part of the Assemblage . Crassispora kosankei has low percentages in the lower part of the Assemblage and becomes more common in the middle and upper parts. Punctatosporites minutus shows relatively high percentage only in the Top Busty seam, but otherwise its frequency is relatively low.

Anaplanisporites baccatus is common and locally abundant in the lower part of the Assemblage, but has low frequencies in the middle and upper part. Laevigatosporites minor has its highest percentages in the upper part of the Assemblage. Schulzospora rara is regularly present. Vestispora tortuosa appears in the higher part of the Assemblage and reaches percentages of 0.9% and 1% in the unnamed and Harvey seams respectively. Vestispora pseudoreticulata and V. costata occur rarely in the higher part of the Assemblage. Radiizonates striatus is present

Assemblages (S & B., 1967)	IX			VIII			VII			VI		
COALFIELDS *Present Work	Northumberland	Durham	Northumberland *	Northumberland	Durham	Northumberland *	Northumberland	Durham	Northumberland *	Northumberland	Durham	Northumberland *
Number of Samples	21	24	5	69	73	19	8	11	1	47	43	3
Miospore species	Percentage occurrence in total number of samples from each assemblage.											
Vestispora fenestrata		4										
Microreticulatisporites sulcatus												
Triquitrites sculptilis	14	42										
Cristatisporites solaris	38	17										
Vestispora magna	62	46										
Endosporites globiformis	95	100	80	91	96	95		9	0		7	0
Radiizonates faunus												
Radiizonates tenuis		4	0	25	23	52	87		0	2	2	0
Vestispora pseudoreticulata		75	100									
V. costata and V. tortuosa	100	92	100	90	70	92	87	73	100	11	12	0
Dictyotriletes reticulocingulum	5	8	0	10	10	16	50	9	0	2	5	33
Radiizonates aligerens										53	67	0
Florinites mediapudens	100	92	100	84	81	80	75	91	100	47	35	66
Pityosporites westphalensis	29	17	110	25	26	68	12	9	100	4	12	66
Dictotriletes bireticulatus		8	20	49	59	60	75	91	100	9	12	33
Densosporites sphaerotriangularis	14		40	65	59	80	87	91	100	75	63	100
Laevigatosporites spp.	100	100	100	100	100	100	100	100	100	92	93	100
Acanthotriletes echinatus				10	12	68	12		0	4	9	33
Reinschospora speciosa				3	3	12	25	9	0	4	9	33
Anapiculatisporites minor	38	33	40	49	52	88	37	64	100	36	53	100
Crassispora kosankei	100	92	100	100	99	100	100	100	100	100	100	100
Simozonotriletes intortus				16	5	16	12		0	2	2	0
Cristatisporites connexus and Cristatisporites indignabundus			20	46	36	56	75	55	100	36	33	33
Reticulatisporites reticulatus	5	38	0	19	22	56	25	45	0	17	21	33
R. polygonalis	24	4	0	26	12	32	50	36	100	26	16	66
Cingulizonates loricatus	43	29	60	69	77	84	25	73	100	21	35	66
Alatisporites pustulatus	10	12	0	9	22	16	12	18	100	13	7	33
Camptotriletes spp.			20	7	11	63	25	27	100	15	14	100
Ahrensisporites spp.			0	29	15	26		9	0	2	2	33
Savitrisporites nux	5		0	16	18	52		9	100	13	21	33
Densosporites anulatus	57	29	80	72	40	52	62	55	100	77	58	66
Radiizonates striatus					7	0	12	9	0	68	53	66
Spencerisporites radiatus		8	0	25	8	26	25	64	100	21	26	66
Schopfipollenites spp.		33	60	39	29	58	12	9	0	9	16	0
Schulzospora rara						0	62	55	100	66	60	66

FIG. 5.2 Percentage occurrence of miospore species in seams from Assemblages vi - ix of Smith and Butterworth 1967

Thickness in cms	Borehole No.	Sample No. / Miospores	Crassispora osankei	Apiculatisporis irregularis	Punctatosporites minutus	Anaplanisporites baccatus	Lycospora pusilla	Lycospora pellucida	Laevigatosporites minor
Harvey Seam									
10	P2	A129	1.6	30.8	2.4	3.6	19.8	8.3	9.7
87	P2	A128	12.2	12.6	1.6	1.4	32.0	0.4	11.4
Unknown seams at 134m, 139m and 145m									
28	P2	A130	8.9	6.1	3.9	0.4	57.0	2.4	6.3
16	P2	A131	13.2	13·0	3.3	1.2	50.9	4.1	3.9
43	P2	A132	8.4	23·0	3.0	3.6	35.5	1.1	9.0
Top Busty Q1									
32	P2	A133	8.5	27.1	7.3	0.6	34.3	2.0	6.5
Bottom Busty Q1									
2	P2	A135	1.0	43.6	1.0	6.9	23.0	2.4	8.9
37	P2	A134	3.3	8.0	1.1	8.0	52.5	2.2	3.0
Threequarter R									
41	P2	A137	2.7	20·0	1.2	1.0	35.0	1.8	4.5
12	P2	A136	-	7.1	1.8	24.5	50.8	9.3	0.4

FIG. 5.3 Selected miospore distributions in Assemblage I in Northumberland off-shore borehole P2

only in the Threequarter seam at a high percentage (19%). Relatively high percentages of Densosporites sphaerotriangularis and Dictyotriletes bireticulatus (12% and 1% respectively) occur in the Harvey seam.

The species recorded in this assemblage are comparable with the Radiizonates aligerens and Schulzospora rara assemblages described by Smith and Butterworth 1967 in the Northumberland and Durham Coalfields, extending from near the base of the C. communis chronozone to the middle of the A. modiolaris chronozone.

The significant species listed by Smith and Butterworth 1967 in the Radiizonates aligerens and Schulzospora rara assemblages are as follows: Laevigatosporites spp., the distribution of which is compared with that recorded in the present work in fig. (6.1); Densosporites anulatus which is very common in the Marshall Green and Bottom Busty seams, while in the present work it shows infrequent occurrences throughout the assemblage except in the uppermost part where it reaches a relatively high percentage (1.2%); Radiizonates striatus which is common or locally abundant in the Threequarter as in the present work and in the Top Busty seam; Radiizonates aligerens which is most prominent in the Busty and Tilley seams and not found above the Hodge seam.

The main difference between the present Assemblage I and those of Smith and Butterworth is that Radiizonates aligerens is absent, and it is therefore difficult to distinguish the base of the Schulzospora rara assemblage. Clayton et. al. 1977 define their Radiizonates aligerens (RA) zone by the constant occurrence of the characteristic species and the appearance of Punctatosporites minutus; the latter species is present in Assemblage I in the present study; but its first appearance can not be determined due to the shortness of the sequence. Clayton et. al. 1977 placed their RA zone in the middle and upper part of the Westphalian A, from near the base of the C. communis chronozone to the middle part of A. modiolaris chronozone. Mahdi 1981 divided the Westphalian A of Plenmeller and adjacent areas into three assemblages; he placed his Assemblage va in the middle to upper C. communis chronozone and Assemblages vb and vc near the base and lower part of the A. modiolaris chronozone respectively. He divided his Assemblage v into va, vb and vc based on variations in the characteristics of the miospore contents in the middle part of the assemblage from the lower part and upper part. The differences which distinguish Assemblage vb from va are changes in the frequencies of certain species; higher percentages of Densosporites sphaerotriangularis, Laevigatosporites minor and Punctatosporites minutus and lower percentages of Densosporites anulatus and Radiizonates striatus characterise his Assemblage vb.

The main difference between Assemblage vb and vc is the absence of Radiizonates aligerens and high percentage of Dictyotriletes bireticulatus in Assemblage vc. Most of the species present in Assemblage I of the present work correspond to the species present in the upper part of Assemblage va and Assemblages vb and vc of Mahdi; the absence of R. aligerens makes it difficult to distinguish the base of Mahdi's vc.

Van Wijhe and Bless 1974 in their study of the Westphalian of the Netherlands place their Radiizonates aligerens assemblage (Zone II) in the middle and upper Westphalian A. The base and the top of this zone is characterised by the first and last occurrence of Radiizonates aligerens, and the zone is also characterised by the regular occurrence of Raistrickia spp., Apiculatisporis spp. Florinites spp. and Laevigatosporites minor. The higher part of the zone shows the first occurrence of Endosporites globiformis, Vestispora costata and Vestispora tortuosa. The former species appears in the lower part of Assemblage IIa in the present work, while V. costata and V. tortuosa appear in the higher part of Assemblage I.

It is concluded therefore that the present Assemblage I, by comparison with other palynological studies, is most likely of Upper Westphalian A age, and it extends from the Upper C. communis chronozone to the Lower A. modiolaris chronozone. It is probably equivalent to the R. aligerens (RA) zone of Clayton et. al. 1977, and the upper part of the R. aligerens assemblage and the Schulzospora rara

assemblage of Smith and Butterworth 1967.

5.3 Assemblage II

This assemblage is dominated by Lycospora spp. (mainly Lycospora pusilla), Apiculatisporis spp. (particularly A. irregularis), Laevigatosporites minor, Anaplanisporites baccatus and Punctatosporites minutus. It has relatively high percentages of Calamospora spp. Anapiculatisporites minor and Dictyotriletes bireticulatus, and regularly occurring Cirratriradiates saturni, Cingulizonates loricatus, Vestispora spp. and Florinites mediapudens. However there are variations in the characteristics of the miospore contents in the lower part of this Assemblage and those of the upper part, so it is appropriate to subdivide this Assemblage into two Assemblages, IIa and IIb.

5.3.1 Assemblage IIa

This includes miospores obtained from the Plessey seam up to the Maudlin seam, fig. (5.4). Assemblage IIa differs from Assemblage I in the appearance of Endosporites globiformis and Laevigatosporites dunkardensis, and in the regular presence of Florinites millotti and Vestispora pseudoreticulata. Between the Bottom Brass Thill and Maudlin seams Radiizonates tenuis, Vestispora laevigata, Camptotriletes sp.A, Acanthotriletes triquetrus, Diaphanospora sp.A. and Diaphanospora sp.B. become significant components of this Assemblage.

The samples are all characterised by high percentages of Apiculatisporis irregularis which reaches its highest frequencies in the higher part of the assemblage. Crassispora

Thickness in cm	Borehole No.	Sample No. / Miospores	Crassispora kosankei	Apiculatisporis irregularis	Punctatosporites minutus	Anaplanisporites baccatus	Lycospora pusilla	Lycospora pellucida	Laevigatosporites minor
Top Maudlin H.1									
58.8	2	A68	6.8	27.2	1.4	6.0	42.1	1.2	4.6
52.5	3	A93	2.2	30.1	2.2	12.4	63.9	1.5	6.3
46.3	4	A26	5.5	19.2	2.3	6.3	40.0	2.5	3.6
145	P2	A116	6.5	13.9	3.6	4.0	38.6	0.4	8.5
Bottom Maudlin (Top leaf) H2.1									
55	4	A28	1.3	13.5	7.4	0.8	53.6	3.5	3.3
14	P2	A119	0.2	19.7	2.1	0.6	65.8	1.6	3.7
79	P2	A117	2.1	3.5	1.5	11.0	32.5	4.1	5.6
Bottom Maudlin (Btm.leaf) H2.2									
10	4	A30	0.6	2.8	7.1	1.8	28.6	11.6	14.2
20	4	A29	0.8	11.3	5.7	3.6	46.0	6.2	4.2
Top Brass Thill H.1									
62.5	2	A70	0.5	24.1	1.9	4.2	30.8	2.4	12.4
3.8	6	A20	1.3	23.1	2.0	4.7	26.9	1.1	10.7
149	P2	A122	2.3	16.9	1.1	9.3	35.4	1.7	11.6
Bottom Brass Thill (Top leaf) K2.1									
152.5	2	A74	3.5	18.0	1.7	9.2	27.2	1.9	12.1
92.5	3	A95	2.0	10.3	0.9	6.6	33.9	2.8	13.6
92.5	4	A31	2.1	15.5	1.3	5.6	34.5	1.8	11.6
71.3	5	A109	2.2	22.2	0.4	10.3	29.5	1.4	10.7
72.5	6	A23	2.7	17.6	0.6	3.8	38.9	0.8	9.9
23	P2	A123	5.7	29.4	-	5.5	44.6	3.3	2.0
Bottom Brass Thill (Btm. leaf) K2.2									
35	2	A77	2.6	18.4	1.1	-	55.3	4.4	2.1
14	P2	A124	5.8	6.3	0.6	1.3	69.6	1.9	3.5
Bottom Hutton L2									
38	P2	A125	5.4	14.4	4.5	0.4	47.3	0.6	6.9
Plessey M									
14	P2	A127	7.2	10.3	1.8	9.8	36.6	0.2	6.8
25	P2	A126	5.7	13.7	2.6	10.0	44.1	6.5	3.9

FIG. 5.4 Selected miospore distributions in Assemblage IIa of Northumberland off-shore boreholes.

kosankei has relatively higher percentages in the Plessey and Bottom Hutton seams in the lower part of the assemblage and in the Top Maudlin seam at the top. It also shows high percentages (11.8%, 10.9%) in two subsections of the Bottom Brass Thill (Top leaf) in borehole No.2, The percentages of Punctatosporites minutus are relatively higher in the Bottom Hutton and Maudlin seams. Anaplanisporites baccatus shows high percentages throughout the assemblage excepting in the Bottom Hutton and Bottom Brass Thill (Bottom leaf) seams, and in the Bottom Maudlin seam of borehole No.4, Laevigatosporites minor shows relatively high percentages in the middle part of the assemblage. Anapiculatisporites minor shows higher percentages in the same seams; this species occurs more commonly in the present samples than in those recorded by Smith and Butterworth 1967 (see fig. 5.2). Dictyotriletes bireticulatus reaches relatively high percentages in some samples of the Bottom Brass Thill.

5.3.2 Assemblage IIb

This includes miospores obtained from the Yard seam up to the Ryhope Marine Band Coal (fig.5.5). Assemblage IIb differs from Assemblage IIa in the appearance of Micro-reticulatisporites nobilis, M. harrisonii and Vestispora luminata and in decreases in the frequency of Dictyotriletes bireticulatus which disappears in the higher part of this Assemblage. Paleospora fragila also disappears above the Main seam.

The samples are characterised by high percentages of

Thickness in cms.	Borehole No.	Sample No. / Miospores	Crassispora kosankei	Apiculatisporis irregularis	Punctatosporites minutus	Anaplanisporites baccatus	Lycospora pusilla	Lycospora pellucida	Laevigatosporites minor
Ryhope Marine Band Coal									
26	EL2	A138	1.0	45.3	-	0.2	42.4	0.6	5.7
Unknown Seams at (60,92)m									
28	EL2	A139	1.1	7.0	1.3	13.3	41.4	2.9	3.8
37	EL2	A140	3.3	2.0	1.4	0.6	68.4	1.4	5.5
Seam C									
43	EL2	A141	3.7	16.7	2.6	18.6	30.1	5.1	4.3
60	7	A32	2.8	12.2	5.6	7.4	38.6	3.7	5.1
Unknown seam at 134m									
41	EL2	A142	1.2	16.5	2.0	0.6	61.2	3.6	2.4
Seam D1									
38	EL2	A143	4.9	15.4	8.4	5.5	40.7	6.3	5.1
Seam D2									
48	EL2	A144	3.0	21.5	1.8	4.7	37.3	9.1	5.7
Ashington D/E									
87.5	3	A80	12.0	19.4	4.3	7.0	38.7	2.1	3.2
76.3	5	A100	10.8	15.5	5.8	5.4	40.2	1.4	2.6
Bottom Ashington D/E.2									
37.5	5	A102	4.0	19.4	2.6	2.4	51.5	3.8	3.0
28.8	5	A103	4.9	4.2	3.1	0.2	55.1	6.2	11.9
High Main E									
80	2	A59	11.7	25.4	3.2	1.1	41.4	3.5	3.5
57.5	3	A83	11.2	10.0	8.6	5.3	41.3	3.1	6.2
45	5	A106	14.2	20.4	4.9	3.9	35·0	5.4	2.3
77.5	7	A33	16.1	22.3	5.2	2.1	29·0	2.4	4.7
7	EL2	A146	8.9	16.5	0.2	0.5	45.7	2.5	7.6
Top Main F1									
32.5	3	A86	7.7	6.7	5.9	6.1	42.1	12.3	1.2
18.8	3	A88	0.8	0.8	0.8	19·0	44.5	12.5	1.9
Main F									
20	6	A7	1.9	0.9	2.8	2.6	65·0	0.7	0.3
77.5	7	A39	14.3	13.9	5.1	1.3	49.4	3.0	3.2
53	P2	A112	2.9	11.2	1.6	0.2	48.1	8.8	7.6
Bottom Main F2.1									
65	3	A90	10.3	11.2	6.0	6.5	39.5	0.9	7.2
78.8	5	A108	10.1	15.2	2.9	1.8	41.9	4.5	5.3
Yard G									
71.3	2	A66	4.3	16	0.8	0.8	53.8	8.8	1.2

FIG.5.5 Selected miospore distributions in Assemblage IIb of Northumberland off-shore boreholes.

Apiculatisporis irregularis throughout; especially in the High Main seam, and the only low frequency recorded is in the unknown seam at 92m in borehole EL2. Crassispora kosankei shows relatively higher percentages up to the Ashington seam above which it is less common. Punctatosporites minutus fluctuates between frequent and common throughout the assemblage, and the same can be said about Laevigatosporites minor and Anplanisporites baccatus which however is locally abundant.

The Microreticulatisporites nobilis - Florinites junior (NJ) zone of Clayton et. al. 1977 compares closely with the present Assemblage II; their zone is characterised by almost the same miospores present in Assemblage II and by the appearance of Microreticulatisporites nobilis in the middle part of the zone. Clayton et. al. placed this zone between the middle of the A. modiolaris chronozone and the lower Similis-pulchra chronozone.

Assemblages II is also comparable with the Dictyotriletes bireticulatus zone (Assemblage VIII) of Smith and Butterworth 1967; the zone is characterised by the appearance of Endosporites globiformis, high frequencies of Crassispora kosankei, the regular occurrence of Cingulizonates loricatus and the absence of Dictyotriletes bireticulatus above the Main seam in Northumberland. Smith and Butterworth 1967 placed their zone between the middle part of the A. modiolaris chronozone and the higher part of the lower Similis pulchra chronozone. None of the species recorded by these authors in their Vestispora magna Assemblage ix with its base at

Seam C in the higher part of the lower Similis pulchra chronozone was seen in the present work.

Assemblage IIa compares closely with Assemblage VI of Mahdi 1981 from Hedley Park Site (Durham) and Low Close opencast site (West Cumbria), which is characterised by the presence of Endosporites globiformis, Dictyotriletes bireticulatus, Vestispora tortuosa and Florinites spp., and the absence of Microreticulatisporites nobilis and Radiizonates tenuis. Mahdi placed his zone in the upper part of the A. modiolaris chronozone.

It is therefore concluded that the present Assemblage II is of Westphalian B age and it extends from the middle of the A. modiolaris chronozone to the top of the Lower Similis-pulchra chronozone.

5.4 Correlation of Coals in the Northumberland off-shore boreholes

In the present study an attempt has been made to correlate coal seams in the eight off-shore borehole in Northumberland. Details of the correlations given by the National Coal Board are shown in (fig 5.6) and the miospore histograms drawn for selected seams in different borehole are shown in (fig 5.7). Where there is agreement to a great extent with the correlation given by the National Coal Board the correlation line in (fig 5.6) in solid, where the correlation by miospores is less positive the correlation line is broken.

All the seams correlated are those of Assemblage IIa and IIb; seam of Assemblage I are examined in one borehole only. Assemblage II is dominated by Lycospora (especially L. pusilla) which is not represented in the histograms (fig 5.7). The following observations are based on the quantitative evidence shown in the histograms and in table 1.

The Bottom Brass Thill (Btm. leaf) correlates poorly between borehole P2 and borehole No.2.; in the former borehole it has fewer Transition phase miospores and is dominated by the Lycospore phase (70% L. pusilla), while in borehole No, 2 it has a higher percentage of Apiculatisporis irregularis and fewer numbers of Lycospora pusilla (55%). The Bottom Brass Thill (Top leaf) shows a good correlation in five boreholes and is poorly correlated only in borehole P2 where its assemblage is

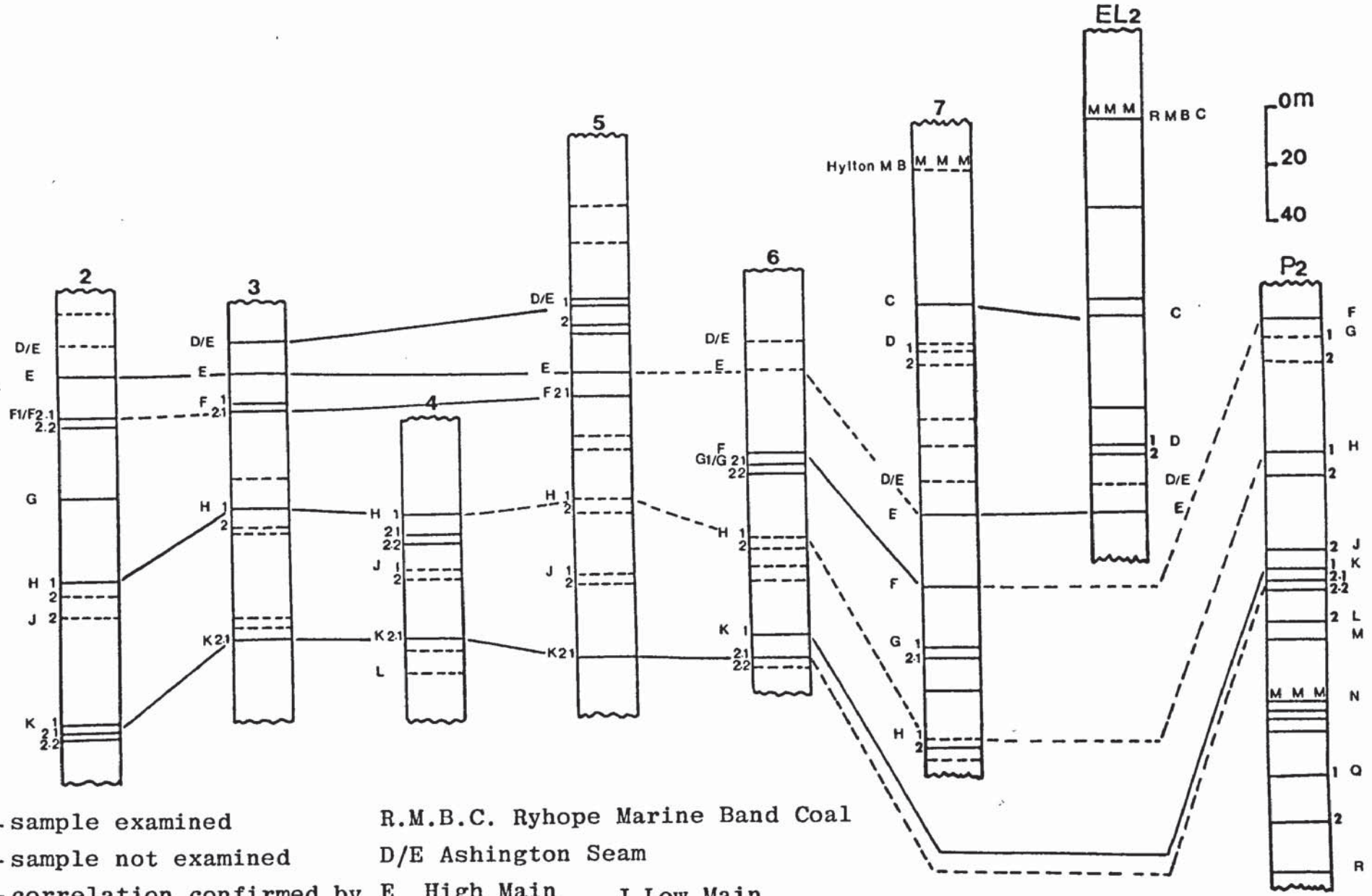


FIG.5.6 Correlation of Westphalian B coal seams in Northumberland off-shore boreholesafter N.C.B.

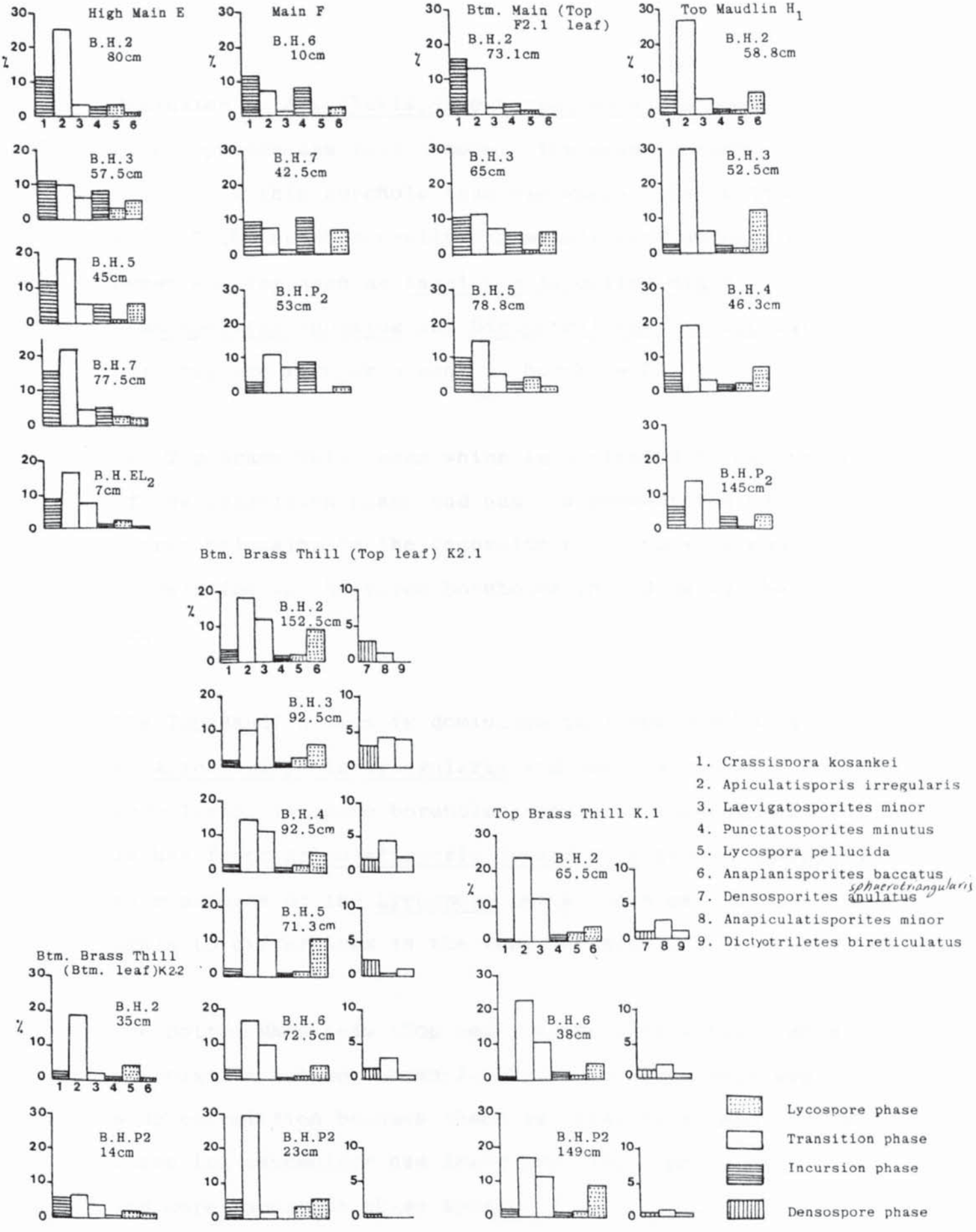


Fig. 5-7 Histograms for coal seams in assemblage II

dominated by Apiculatisporis irregularis and most other species are less common. The seam is much thinner in this borehole than elsewhere. The Bottom Brass Thill seam generally has significant numbers of other species such as Anapiculatisporites minor, Densosporites anulatus and Dictyotriletes bireticulatus, but they are rare or absent in borehole P2.

The Top Brass Thill seam which is dominated by miospores of the Transition phase and has low percentages of spores belonging to the Incursion phase shows a good correlation in the three boreholes including borehole P2.

The Top Maudlin seam is dominated in three boreholes by Apiculatisporis irregularis and shows a good correlation in those boreholes, while in borehole P2 it has fewer Apiculatisporis irregularis and is dominated by miospores of the Lycospore phase; this may be due again to differences in the seam thickness.

The Bottom Main seam (Top leaf) shows a relatively good correlation between borehole P2 and borehole No,3 and poor correlation between these and that in borehole No.2 where its assemblage has fewer Transition phase spores and more Incursion phase spores.

The opposite can be said about the Main seam which has

high percentages of Transition phase spores in borehole P2 while the Incursion phase spores are much higher in boreholes No. 7 and 6. The High Main seam shows a good correlation in four borehole and is poorly correlated in borehole No,3.

Chapter 6

Palynology and Palaeoecology

6.1 Introduction

In the interpretation of palaeo-ecology from pollen and spore distributions there are certain difficulties which have been recognised by many previous workers. These are:-

a. The uncertain affinities between miospore form taxa and their parent plants. This difficulty is clearly reflected in the classification of miospore taxa which is based on morphological features and is independent of any natural or phylogenetic relationship. Some genera (e.g. Punctatisporites, Granulatisporites, Cyclogranisporites) probably contain species of varied phylogenetic affiliation, but many important genera (e.g. Lycospora, Densosporites) are constantly associated with particular plant groups. According to Ravn 1979 certain distinct morphologies appear to be characteristic of major plant groups. Many rounded to rounded-triangular trilete spores with clear cinguli or similar equatorial structures (e.g. Lycospora, Densosporites, Cirratriradiates) are known to be of Lycopsid origin. Those small triangular shaped spores of various ornamentation have been associated consistently with ferns, suggesting that similar genera such as Anapiculatisporites which have never been reported in situ, are probably fern-related also. Most of the genera recovered from the successions in the Northumberland off-shore boreholes which are of quantitatively important value are of known affinities.

b. Differential preservation of certain miospora taxa. According to Sangster and Dale 1961 modern pollen grains are differentially affected by physical and chemical decomposition of organic detritus; this may probably suggest that ancient miospores suffer in a similar manner. Erdtman 1969 mentioned examples in modern pollen studies where certain grains for instance Populus are not preserved, or are destroyed during sample preparation. According to Ravn 1979 this phenomenon may occur with the Palaeozoic miospores as well. Some taxa with thinner exines are normally found in torn or folded condition, while thicker or more compact miospores are usually better preserved. Spores recovered from samples in Northumberland off-shore boreholes are well preserved, and most spores are positively identified.

c. Variation in abundance of miospores produced by different plants. According to Moore and Webb 1978 the distinction between a local and regional plant community from a pollen record is difficult and often speculative. This may be the same for the pre-Quaternery miospore taxa.

d. The distinction between the autochthonous and allochthonous elements in the microfloras. Usually Carboniferous coal-forming environments do not include great amounts of transport of spore by moving water although some has been suggested (Habib and Groth 1967; Smith 1962, Incursion phase). In general spores of allochthonous origin are subjected to oxidation and tend to be poorly preserved. Hacquebard and Donaldson 1969 suggested that the presence of

a significant amount of fusain indicates that the sediment is transported. Another means of transporting miospores into the peat seamp is by air but Faegri and Iverson 1975 suggested that observation of modern forests indicates that pollen from distant sources does not contribute greatly to the total pollen rain.

Our knowledge of the true palaeoecology of Carboniferous plants is very limited and according to Scott 1977 analogies drawn between fossil and recent plants based on similarity of structures or presumed habitat must be approached with caution. The reconstruction of the palaeoenvironment of the plant communities of coal seamps from miospore profiles varies. Disagreement exists between previous workers. Neves 1958 suggested that Cordaites plants, represented by high percentages of the saccate pollen genus Florinites in marine strata flourished in the area surrounding the basin of deposition. Chaloner 1958b on the other hand concluded that the pollen was possibly dispersed from the upland flora, which was relatively undisturbed during transgression by the sea. Later Chaloner 1968 suggested climatic control as a possible factor in Cordaites distribution as well. Cridland 1964 described Cordaites plants with stilt roots preserved in American coal-balls, which led him to suggest that the plant grew on the seaward margin of the coal seamp. Navale 1965 on the other hand found between 5% and 20% of Florinites throughout the Stephanian Lons Seam in the limnic Jura basin. These latter distributions are

consistent with Chaloner's 1958b idea of an upland origin for the genus Florinites. Scott 1977 suggested that the Cordaiteans could have inhabited widely different niches, from coastal plains to upland areas.

Another example is provided by Smith 1968 who attributed his Densospore phase to a culmination of peat deposition in a raised bog above water level i.e. accumulation under dry conditions. This was contrasted by Habib and Groth 1967 who believed that the cause for the domination of Densosporites in the higher parts of and in the roof measures of the Westphalian D Lower Kittanning Coal is due to a change of environment in the swamp from fresh to brackish-water during the transgression of the sea.

6.2 Northumberland off-shore borehole profiles.

These miospore profiles are shown in fig(6·1) in which the percentages of the quantitatively important taxa are given for each coal horizon. These percentages represent composites of the percentages recorded for the various subsections which constitute the coal seam. The present profiles are based on coal only, mainly in the form of whole seam samples; they can therefore be compared most closely with those given by Smith and Butterworth 1967 text-fig. 26.

The profile of Crassispora kosankei in the Coal Measures of Northumberland in Smith and Butterworth 1967 is shown as a dotted line on fig.(6·1) to make it possible to compare their results with the present profile from off-shore samples in the same area. The two profiles show a

good correspondence with Crassispora kosankei representing not more than 1% in the coal below the Ryhope Marine band (Westphalian B/C boundary) and becoming abundant in the Ashington seam with a mean percentage of 17%; it reaches up to 25% in some subsections of the Ashington seam in the Northumberland off-shore boreholes. At the horizon of the High Main seam there is a difference of 2% between the present profile and that of Smith and Butterworth, but Crassispora kosankei is still abundant with a mean percentage of 11%. A difference of 5% between the two profiles exists in the Top Main and Main seams with mean percentages of 5% and 8% respectively. In the Bottom Main seam the two profiles match very closely with a mean more or less of 5%. The frequencies of Crassispora kosankei dropped very sharply in the Top Yard seam to represent less than 1% of the total counted; this was not shown on the profile by Smith and Butterworth which showed the same percentages as in the overlying Bottom Main seam. From the Yard seam down to the Harvey seam the frequencies of Crassispora kosankei fluctuate between 1% and 7%, but in an unknown seam at 147.6m in borehole P_2 the percentage jumps up to 13% and Crassispora kosankei becomes abundant. The frequencies sharply fall from 9% in the Top Busty seam to reach its lowest 1% in the Threequarter seam in both profiles.

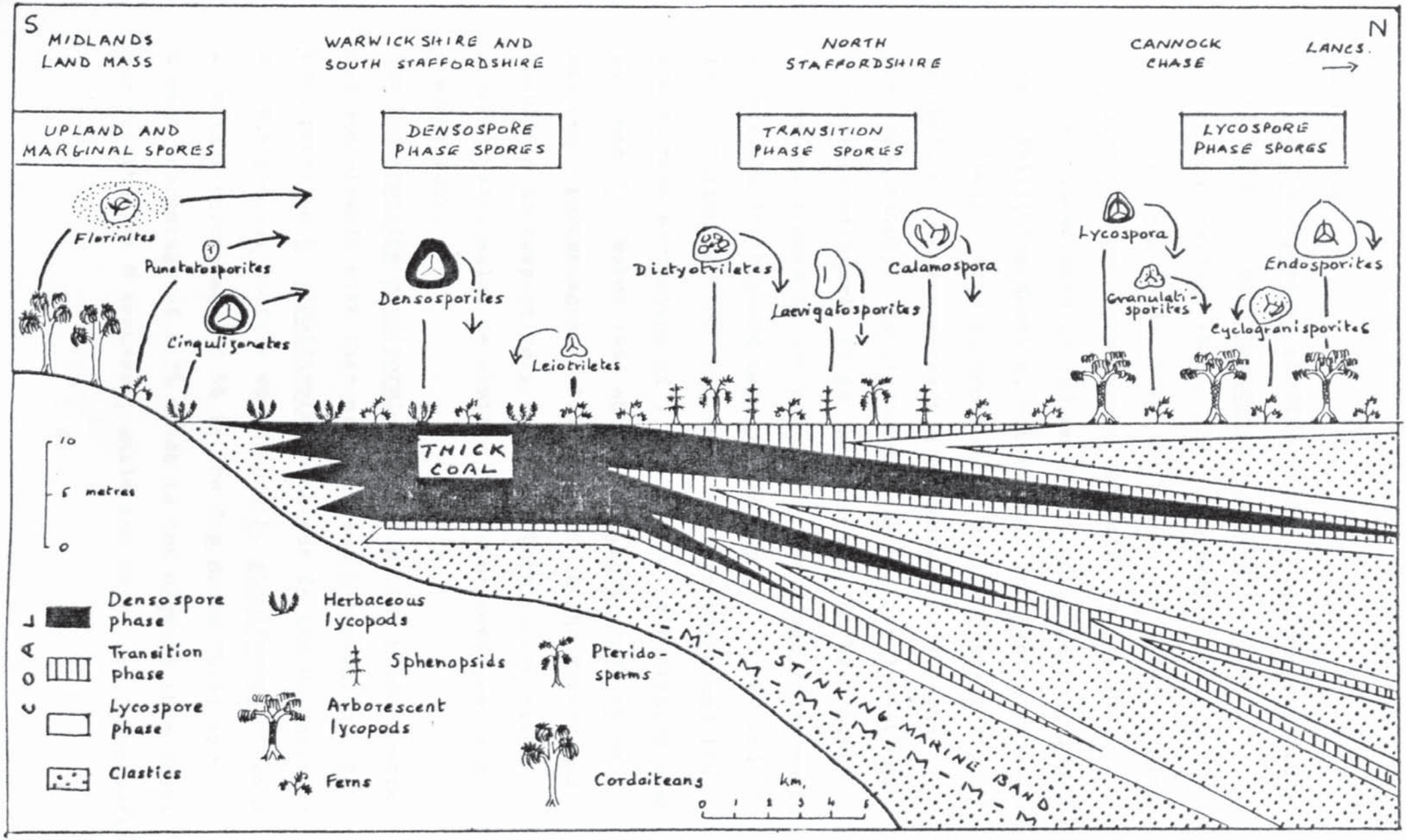
The miospore profile for Dictyotriletes bireticulatus is similar to that in Smith and Butterworth 1967, text-fig. 26. D. bireticulatus is very rare or absent in both

profiles from the Ryhope Marine Band down to the Ashington seam, and in both profiles it does not exceed a mean percentage of 1% from the Ashington seam down to the Plessey seam. Some subsections in the Bottom Yard and Bottom Brass Thill reach a percentage of 3% and 4% respectively. In the present profile D. bireticulatus exceeds a mean percentage of 1% in the unknown seam at 153.2m in borehole P_2, while in Smith and Butterworth it shows a mean percentage of 3.5% in the Top Harvey seam only. Below the Harvey seam both profiles show D. bireticulatus becoming infrequent.

The Densosporites profiles of the present work show considerable differences from those in Smith and Butterworth 1967, text-fig.26 (where D. sphaerotriangularis and D. anulatus are shown separately). Throughout the present Westphalian A and B sequence Densosporites does not exceed a mean percentage of 2%, except in the Harvey seam where it shows a mean percentage of 7.5% and a maximum of 12%. The profile shown by Smith and Butterworth 1967 displays higher percentages especially in the Threequarter, Top and Bottom Busty, Bottom Brass Thill, Low Main, Top Maudlin and Top Yard seams. In Northumberland the on-shore samples examined by Smith and Butterworth 1967 showed that the frequencies of D. sphaerotriangularis are greater in the Westphalian A than in the Westphalian B. Throughout the Westphalian B D. sphaerotriangularis and D. anulatus do not exceed a mean percentage of 8% and 5% respectively and maximum percentages of 16% and 9%, while in the Westphalian A

D. sphaerotriangularis has a mean percentage of 16% in the Threequarter, 40% in the Bottom Busty, 23% in the Top Busty and 18% in the Harvey seam, and the maximum percentages reach up to 50% in the Threequarter seam and 80% in the Top and Bottom Busty. In the present work the only samples representing Westphalian A are those from borehole P_2 (fig. 1.1 Location map), and the frequencies of D. sphaerotriangularis are low compared with Smith and Butterworth reaching their highest (12%) in the Harvey seam as previously stated.

The relatively low percentages of Densosporites in the Northumberland off-shore boreholes can be explained in terms of the concept of a dry environment suggested by Smith 1962 for the origin of his Densospore phase. This was substantiated by Butterworth 1964, when she studied the distribution of Smith's phases in the Midland - Pennine group of coalfields in Britain. She found that the genus Densosporites is abundant in the marginal thick coals and it is generally replaced by Laevigatosporites and then by Lycospora toward the centre of the basin as shown in fig (6·2). It is therefore possible that the low percentages of Densosporites in the Northumberland off-shore boreholes can be attributed to the position of the boreholes being nearer to the basin centre. This interpretation is supported by the diagram shown by Calver 1969 (fig.12, p.248) of the palaeogeography and faunal distributions in the Vanderbeckei and Aegiranum Marine Bands in which the Northumberland coalfield is not close to any of the postulated



Fig·6·2 Lower Westphalian B coal formation in the Midlands after Butterworth 1977

land masses.

The Laevigatosporites profile in Smith and Butterworth 1967, like that of Crassispora Kosankei is shown as a dotted line on fig. (6.2). The two profiles are not closely corresponding, with the present profile reaching its highest mean percentage of 9%, 11%, 9% 7%, 7% and 9% in the unknown seam at 153.2m borehole P_2, Harvey, Top Brass Thill, Top Maudlin, Bottom Main and Ashington seams respectively. Some subsections in Bottom Brass Thill and Bottom Main seams reach a percentage of 15% and 25% respectively. Laevigatosporites has its lowest mean percentage of nearly 1% in the Yard and Top Main seams. On the other hand in the profile by Smith and Butterworth it reaches its highest mean percentage of 19%, 8% and 7% in the Hutton, Bottom Yard and High Main seams and its lowest mean percentage of 1.5% - 2% in the Ashington seam and seam D_2. Mahdi 1981 shows that Laevigatosporites reaches percentages of 11% and 7.5% in the Harvey and Maudlin seam respectively at Hedley Park prospective opencast site which is similar to the percentages in the present work.

The Endosporites globiformis profile of the present work matches closely with that of Smith and Butterworth. In both profiles E. globiformis is absent in the Westphalian A. The present profile shows that E. globiformis reaches a maximum percentage of 5% in the Top Brass Thill and a mean percentage of 1.5% which is the highest throughout the Westphalian B sequence, while the Smith and Butterworth

profile shows a highest percentage of 3% in the High Main and Ashington seams, and is less than 1% in the rest of the Westphalian B sequence.

The same applies to the Florinites mediapudens profile which does not exceed 1% in the present work nor in that of Smith and Butterworth 1967 with the exception of the unknown seams at 307' 8" and 255' 11" below and above Kirkby's Marine Band at Weetslade colliery where it is 3% and 2% respectively. The Apiculatisporis irregularis profile which Smith and Butterworth 1967 did not compile constitutes a major part of the counted spores in the present work. Generally, this profile shows three peaks, the first in the Top and Bottom Busty with a mean percentage of 27% and a maximum percentage of 43%, the second peak in the Top Maudlin seam with a mean percentage of 26% and a maximum of 36% and the third is from seam D_2 to the Ryhope Marine Band Coal where A. irregularis reaches its maximum of 44%. Smith did not suggest to which of his phases this species belongs but in a personal communication 1982 with him he put A. irregularis in the Transition phase. Ravn 1979 in his study of the profile of his CP 19-4 Coal of Iowa recognised the species Cappasporites distortus Urban 1966 which is very similar to A. irregularis and he found that the occurrence of Cappasporites distortus is reduced in the Densosporites - Crassispora interval which may confirm that this species belongs to the Transition phase of Smith. It is therefore appropriate to compare this

profile with the profile of Laevigatosporites which is one of the main spores in the Transition phase. The two profiles show higher percentages in the Top Busty and unknown seam at 153.2m, borehole P_2. In the Harvey seam the highest mean percentage of Laevigatosporites is matched by a high mean percentage of 22% of A. irregularis and other peaks of Laevigatosporites in the Top Brass Thill and Top Maudlin seams are matched with high mean percentages of 17% and 26% of A. irregularis. Only in a seam below the Ryhope Marine Band where A. irregularis reaches its higher percentage of 44%, Laevigatosporites shows a percentage of 6% only.

A comparison can be made between the present A. irregularis profile and the percentages recorded by Mahdi 1981 from the St. Andrews and Hedley Park prospective opencast sites. A. irregularis reaches its highest percentages of 13% and 17% in the Top and Bottom Busty seams respectively at St. Andrews site which corresponds excellently with the present work. At Hedley Park A. irregularis reaches a percentage of 17% in the Bottom Busty and reaches its peak in the Maudlin seam with 23% which shows a close similarity with the present 25% of A. irregularis. Another profile which Smith and Butterworth 1967 did not compile and which constitutes a substantial part of the counted spores in the present work is that of Anaplanisporites baccatus. It reaches its highest mean percentages of 13%, 10%, 11%, 13%, 13%, 14% and 13% in the Threequarter, Plessey, Top Main and Ashington seams, Seam C and in an unknown seam at 59.8m, borehole EL_2 respectively. Some subsections

reach a maximum percentage of 24%, 19% and 18.5% in the Threequarter and Top Main seams and Seam C respectively. The lowest mean percentage is less than 1% in the Top Busty, Hutton, Bottom Yard, Yard, Top Yard and Main seams and in unknown seams at 146.5m borehole P_2, 130.54m and 91.77m borehole EL_2 and in a seam below the Ryhope Marine Band. Smith did not mention to which of his phases this species belongs and Ravn 1979 finds it rare in his profile CP19-4 coals of Iowa. In the present study the profile of this species did not match that of Crassispora or Laevigatosporites which are the main spores of Smith Incursion and Transition phases respectively, but higher percentages of this species correspond to higher percentages of Lycospora pusilla which may indicate affinites with the Lycospore phase. The Punctatosporites minutus profile is also not shown by Smith and Butterworth 1967, but in the present study this species displays three peaks of a mean percentage of 7.5%, 6% and 8.5% in the Top Busty, Top Ashington seam and seam D_1 respectively and in the rest of the Westphalian A and B sequence it reaches a mean percentage of between 1% and 4%. Smith did not mention to which of his phases this species belongs, but in a personal communication 1982 with him put P. minutus in the Incursion phase. A comparison between the profile of this species and that of Crassispora, which is the main spore in Smith's Incursion phase, shows that the three peaks of P. minutus correspond to higher percentages of Crassispora, and one

of the peaks of P. minutus in the Top Ashington seam matches with the highest percentage in the Crassispora kosankei profile. In the present work Cingulizonates loricatus and Cristatisporites spp. do not constitute a substantial part of the counted spores and their profile will be like that of Florinites mediapudens. In the Smith and Butterworth profile Cristatisporites spp. hardly exceeds a mean percentage of 1% except in a very few horizons, while Cingulizonates loricatus shows slightly higher percentages.

6.3 Conclusions

The Northumberland off-shore borehole profiles are dominated by Lycospora spp., particularly Lycospora pusilla which constitutes the Lycospore phase of Smith. The other quantitatively important taxa are Crassispora kosankei, Punctatosporites minutus, which are the main spores in Smith's Incursion phase, and Laevigatosporites spp. and Apiculatisporis irregularis, which constitute Smith's Transition phase. The percentages of Densosporites spp. are low which indicates that Smith's Densospore phase is barely reached throughout the profile and which indicates a wetter environment for the plant communities in this part of the coal swamp.

A comparison between some of the miospore profiles, particularly Crassispora and Laevigatosporites and those shown by Smith and Butterworth 1967, text-fig.26 shows a good degree of similarity. Comparison between the

frequencies of Apiculatisporis irregularis and Laevigatosporites of the present work and those of Mahdi 1981 from open-cast sites in the extreme western part of Northumberland. also show a high degree of similarity.

CHAPTER 7

CONCLUSIONS

151 species belonging to 57 genera are described in detail from Westphalian A and B coals encountered in eight off-shore boreholes from Northumberland; they include 18 new types. Scanning electron microscope photographs have been prepared for most of the species; they elaborate the nature of the sculpture and the structure of most of the species including those which have already been described. The method which is employed in this study is simple and produced excellent results. Comparison and discussion of individual species are given when needed.

Three miospore assemblages have been recognised in the present study. These are based mainly on the appearance of new taxa and the absence of others and, to some extent, on variations in frequencies of the more abundant taxa. Detailed comparisons with miospore assemblages previously described by several authors from similar stratigraphical horizons are discussed in detail in Chapter 5.

Assemblage I from the off-shore borehole P2 occurs in seams from the higher part of the Westphalian A stage and corresponds to the Radiizonates aligerens and Schulzospora rara assemblages of Smith and Butterworth 1967 and the Radiizonates aligerens concurrent range zone of Clayton et. al. 1977. It differs from the previously described assemblages in the absence of Radiizonates aligerens. It extends from the upper . .

C. communis chronozone to the lower A. modiolaris chronozone in the non-marine bivalve zonation of Ramsbottom et. al. 1978.

Assemblage IIa is characterised by the first appearance of Endosporites globiformis and Laevigatosporites dunkardensis and includes some of the new types including Camptotriletes sp.A., Diaphanospora sp.A. and D. sp.B.

Assemblage IIb differs from Assemblage IIa in the appearance of Microreticulatisporites nobilis, M. harrisonii and Vestispora luminata and a decrease in the frequency of Dictyotriletes bireticulatus.

Assemblage II is comparable with the Dictyotriletes bireticulatus zone (Assemblage VIII) of Smith and Butterworth 1967 and compares closely with the Microreticulatisporites nobilis - Florinites junior (NJ) concurrent range zone of Clayton et. al. 1977. It is of Westphalian B age and extends from the middle of the A. modiolaris chronozone to the top of the Lower Similis pulchra chronozone. Species characteristic of Smith and Butterworth's Vestispora magna (Assemblage IX) zone which those authors record from the higher part of the Lower Similis pulchra zone were not recognised in coals of this age in the present work. Correlation of selected Westphalian B seams in the eight Northumberland off-shore boreholes are considered in Chapter 5, and shown in (fig. 5.6) and (fig. 5.7). These correlations are based on the ones given by the National Coal Board and agree to a great extent with the N.C.B. correlations.

The palaeoecology of the coal seams, based on miospore profiles is discussed in detail in Chapter 6. The vertical distribution profiles of the quantitatively important species are compared with the work done by Smith and Butterworth 1967 in Northumberland, and Mahdi 1981 from opencast sites in the extreme western part of Northumberland. They show a high degree of similarity in respect of some of the abundant taxa including Crassispora kosankei, Apiculatisporis irregularis and Laevigatosporites minor. The present profiles differ from those established in the on-shore areas in the low numbers recorded of Densosporites sphaerotriangularis and other species of Smith's Densospore phase. It is concluded from this that the present borehole sequences are from an area which was in the more central and rapidly subsiding part of the coal swamp. Apiculatisporis irregularis is recorded in high numbers from certain seams; the seams in the Westphalian A stage and the lower part of the Westphalian B stage are at similar horizons to those from various parts of the north of England in which Mahdi 1981 recorded similar high percentages. This species was not included in the profiles published by Smith and Butterworth 1967. Smith (personal communication 1981) states that this spore occurs in his Transition phase; in the present work A. irregularis frequently but not always occurs in high numbers together with high numbers of Laevigatosporites minor which is the main constituent of the Transition phase.

Punctatosporites minutus similarly occurs in high numbers at horizons comparable to those at which Mahdi recorded it abundantly. This species was not included in Smith and Butterworth's profiles. Smith 1962 states that it occurs in his Incursion phase. There is a correlation between the distribution of this species and the main species of the phase which is Crassispora kosankei.

A third species recorded in high numbers by the present author and by Mahdi 1981 but not by Smith and Butterworth 1967 is Anaplanisporites baccatus. It is not known to which phase this belongs but in the present work it appears to occur most frequently with high numbers of Lycospora pusilla, representing the Lycospore phase.

It is concluded that in the present area of study the coal swamps were of the type, dominantly wet, represented by Smith's Lycospore, Transition and Incursion phases. This factor is responsible for the general rarity of Densosporites and perhaps also for the absence of some of the more stratigraphically useful spores.

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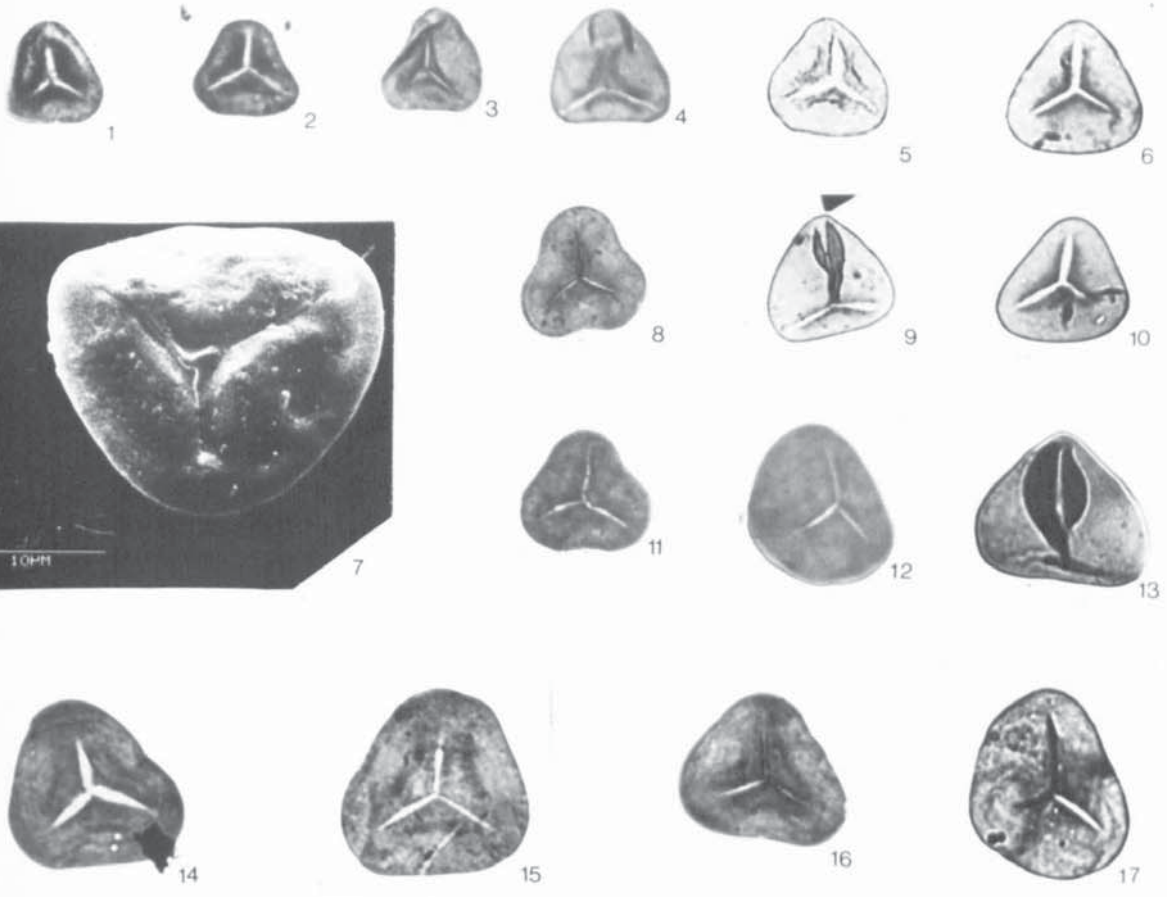
PLATES

All photographs are shown at x500 unless otherwise stated. Coordinates given are for the Zeiss photomicroscope II, with the slide label on the left unless the coordinates are prefixed by R when the slide label is on the right.

Plate 1

1. Leiotriletes cf. adnatus (Kosanke) Potonié and Kremp 1955 - $A11^{1}$ - 3.0/79.2
2. L. cf. adnatus - $A11^{7}$ - 23.1/73.2
3. L. cf. adnatus - $A11^{2}$ - 5.4/80.3
4. L. cf. adnatus - $A11^{6}$ - 10.1/69.5
5. L. cf. adnatus - $A11^{6}$ - 9.0/67.0
7. L. cf. adnatus - SEM proximal view, preparation A11
8. Leiotriletes guennelii Ravn 1979 - $A89^{7}$ - 19.2/73.7
11. L. guennelii - $A11^{2}$ - 22.6/69.8
14. Leiotriletes levis (Kosanke) Potonié and Kremp 1955 $A95^{5}$ - R0.4/72.8
15. L. levis - $A104^{8}$ - R2.7/72.7
16. L. levis - $A104^{1}$ - 13.9/71.2
6. Leiotriletes cf. priddyi (Berry) Potonié and Kremp 1955 $A95^{6}$ R1.7/77.9
9. L. cf. priddyi $A95^{5}$ 13.7/71.1
10. L. cf. priddyi $A95^{10}$ 5.5/72.3
12. Leiotriletes sphaerotriangulus (Loose) Potonié and Kremp 1954 $A104^{1}$ -7.6/77.1
13. L. sphaerotriangulus - $A95^{16}$ - 3.7/8.5
17. L. sphaerotriangulus - $A95^{5}$ - 28.6/68.7
18. Punctatisporites cf. edgarensis - Peppers 1970; in Ravn 1979 $A129^{2}$ -12.3/79.2 equatorial view
19. P. cf. edgarensis - $A128^{4}$ - 3.6/7.4
20. P. cf. edgarensis - SEM proximal view, preparation A95
21. P. cf. edgarensis - $A95^{13}$ - 29.1/72.4
22. P. cf. edgarensis - $A95^{17}$ - 11.8/80.4
23. P. cf. edgarensis SEM oblique view, prepration A95

PLATE 1



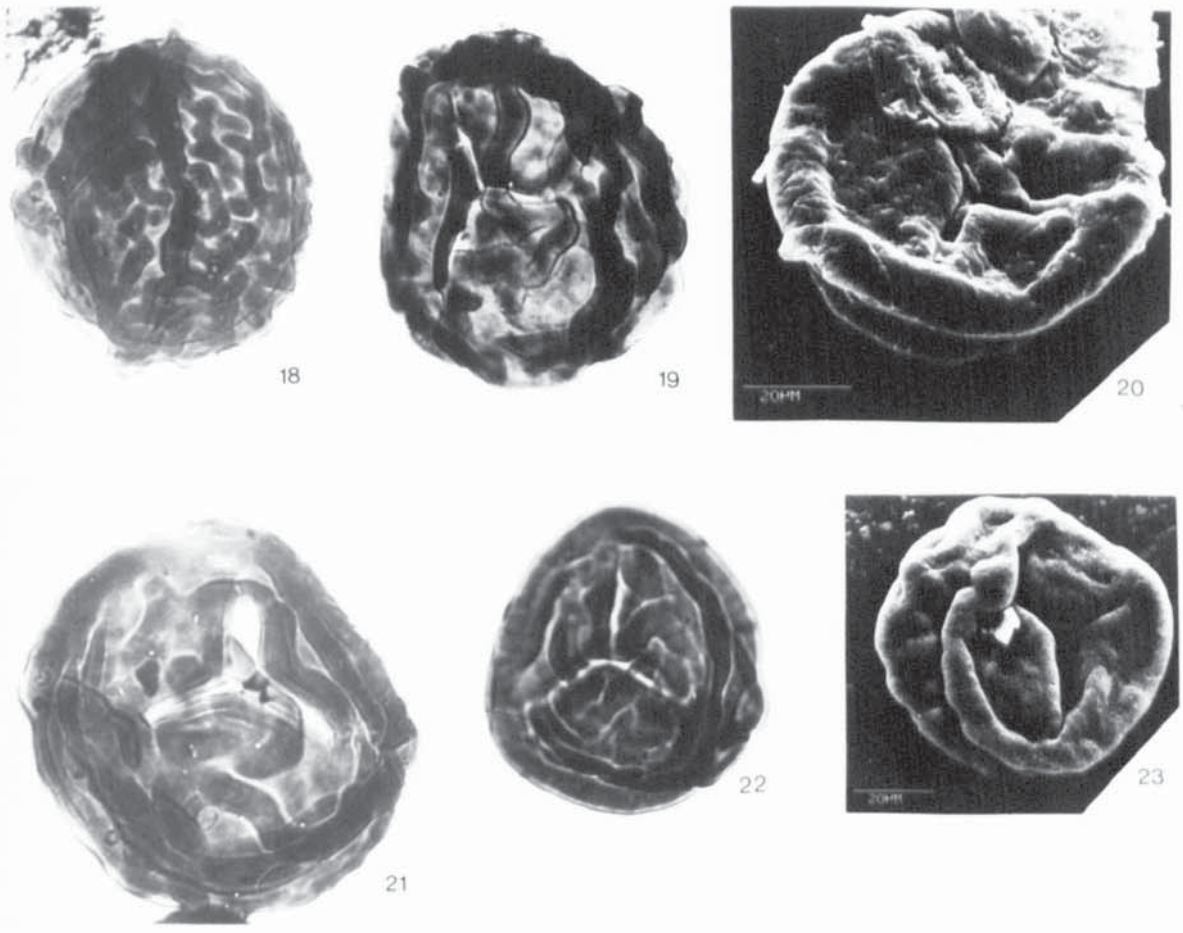
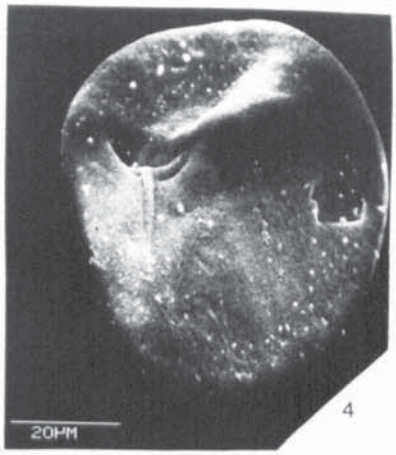


Plate 2

1. Punctatisporites punctatus Ibrahim 1932 A133[1] R7.5/67.3
2. P. punctatus - A95[25] - 26.5/67.4
3. P. punctatus - A113[2] - 2.7/68.6
4. P. punctatus SEM Preparation A113, proximal view
5. Punctatisporites obesus (Loose) Potonié and Kremp 1955 - A129[4] - 14.0/67.8
6. P. obesus - A131[1] - 25.6/71.1
7. Punctatisporites sp.A - A144[3] - 21.8/75.6
8. P. sp.A. - A123a - 7.0/63.2
9. P. sp.A. - A91[3] - 14.0/66.8
10. Retusotriletes sp.A.- A89[10] - R0.0/82.7
11. R. sp.A.- A89[8] - R8.3/75.0
12. R. sp.A.- A89[7] - 23.6/75.9
13. R. sp.A.- A89[4] - 14.1/72.1
14. Calamospora breviradiata Kosanke 1950 A95[22] - 13.0/75
15. C. breviradiata - A128a - 13.0/63.1
16. C. breviradiata - A95[8] - 30.3/66.0
17. C. breviradiata Tetrad - A95[15] - 18.0/69.2
18. C. breviradiata SEM - preparation A9, proximal view

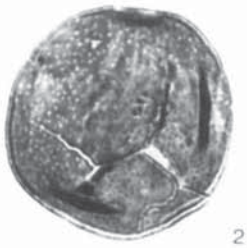
PLATE 2

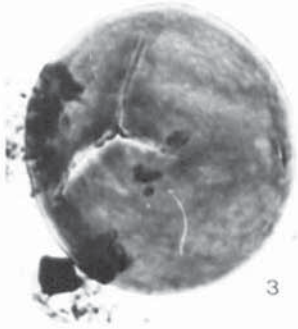

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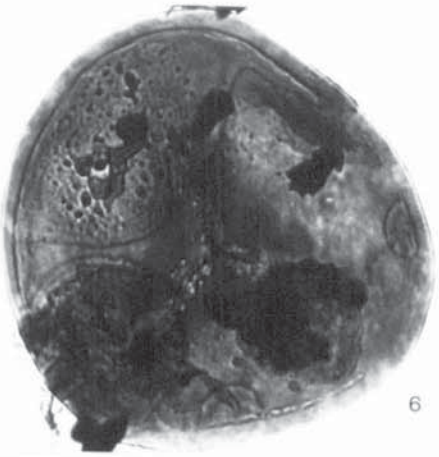


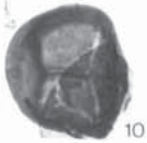
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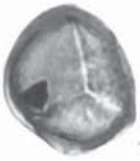

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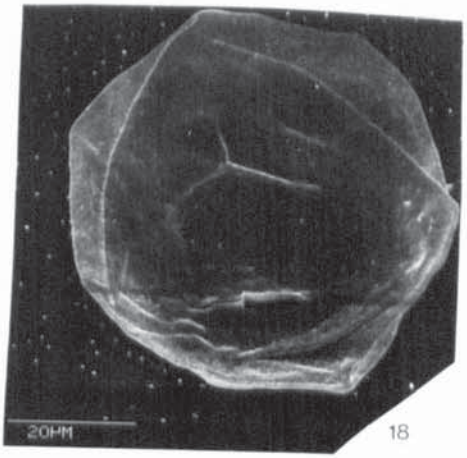

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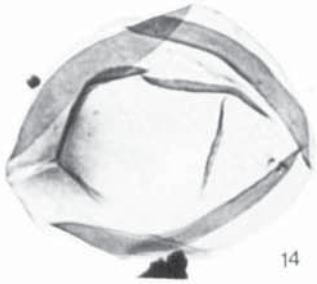

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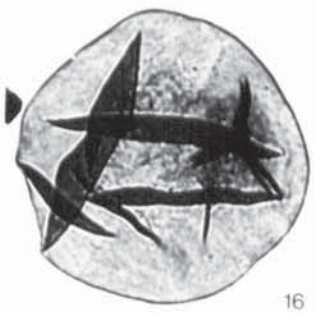


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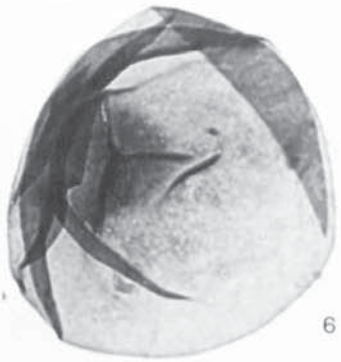

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Plate 3

1. Calamospora cf. breviradiata Kosanke 1950, Smith and Butterworth 1967 $A9^{4}$ -25.9/79.1.
2. C. cf. breviradiata - $A79^{4}$ 14.3/78.2
3. C. cf. breviradiata - $A129^{3}$ 27.4/79.2
4. C. cf. breviradiata - $A79^{2}$ 17.6/70.2
5. Calamospora hartungiana Schopf, in Schopf, Wilson and Bentall 1944 $A95^{23}$ - R5.4/78.5
6. C. hartungiana - $A138^{1}$ 10.5/74.6
7. C. hartungiana - $A112^{1}$ 27.8/68.1
8. C. hartungiana - $A129^{3}$ R7.0/75.4
9. C. hartungiana - $A95^{12}$ 4.1/70.5
10. Calamospora cf. laevigata (Ibrahim) Schopf, Wilson and Bentall 1944 $A120^{1}$ - 24/64.9
11. C. cf. laevigata - $A116^{1}$ 22.3/68.2
12. C. cf. laevigata SEM. Preparation A95, proximal view

PLATE 3

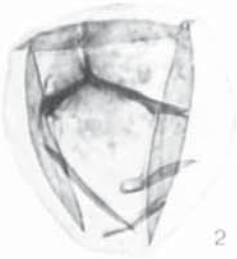

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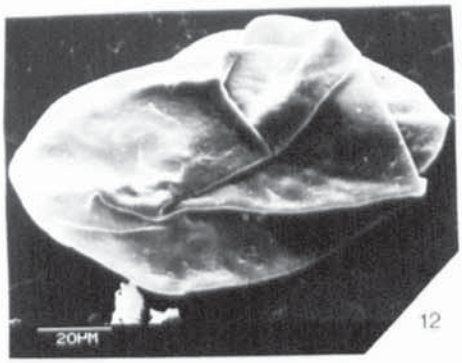

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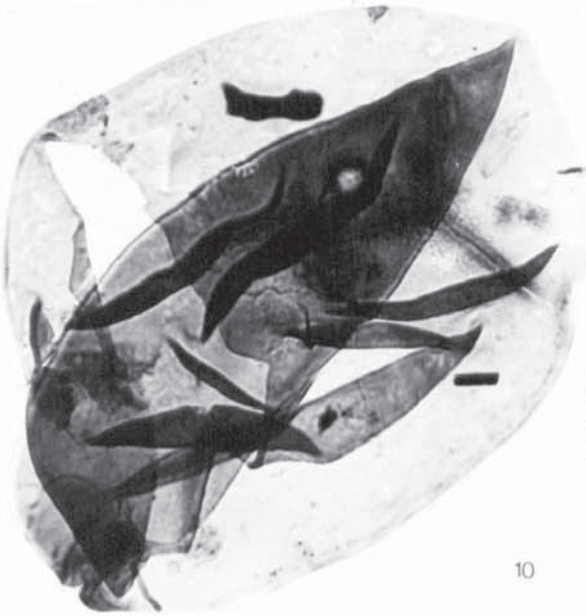

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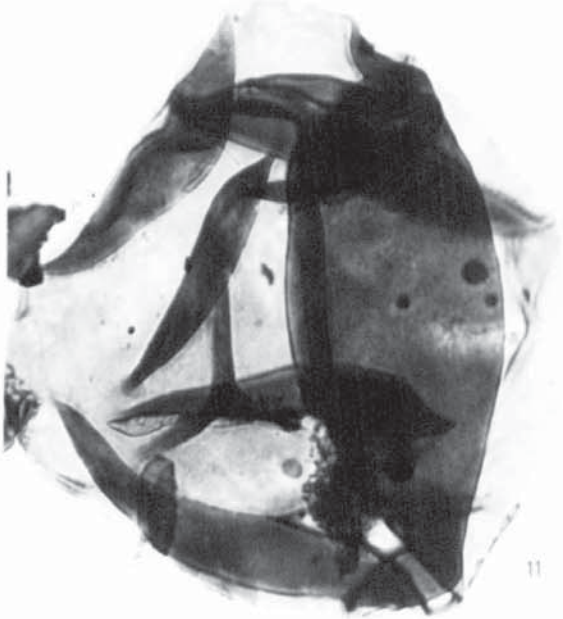

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Plate 4

1. Calamospora microrugosa (Ibrahim) Schopf,Wilson and Bentall 1944 A95[26] - 27.8/75.6
2. C. microrugosa - A95[18] - 30.4/72.9
3. C. microrugosa - A74[4] - Ro.1/76.1
4. C. nebulosa Ravn 1979 A84[1] - R8.6/78.6
5. C. nebulosa - A79[2] - 20.4/68.1
6. C. nebulosa - A131[2] - 18.7/76.9
7. C. nebulosa - A129[2] - 17.8/73.2
8. C. nebulosa - A144a- 26.0/82.8
9. C. nebulosa - A95[26] - 12.4/72.8
10. C. pallida (Loose) Schopf, Wilson and Bentall 1944 A95[23] - 19/66.3
11. C. pallida - A95[19] - 6.6/75.0
12. C. parva Guennel 1958 A95[7] - 22.3/82.7
13. C. parva - A95[17] - 14.6/81.4
14. C. pedata Kosanke 1959 A95[10] - 0.6/83.1
15. C. pedata - A95[11] - 17.8/81.7
16. C. pedata SEM Preparation A95, Distal view
17. C. cf. pedata Kosanke 1950, in Ravn 1979 A95[13] - 24.3/78.5
18. C. cf. pedata - A95[14] - 30.0/67.5
19. C. cf. pedata - A95[11] - R6.6/72.7
20. C. cf. pedata - A95[18] - 20.3/81.2
21. C. straminea Wilson and Kosanke 1944 A95[5] - 25.8/74.7
22. C. straminea - A95[13] - 27.3/79.5
23. C. straminea A80[1] - 26.6/71.1
24. C. straminea A95[15] - 25.8/74.7

PLATE 4

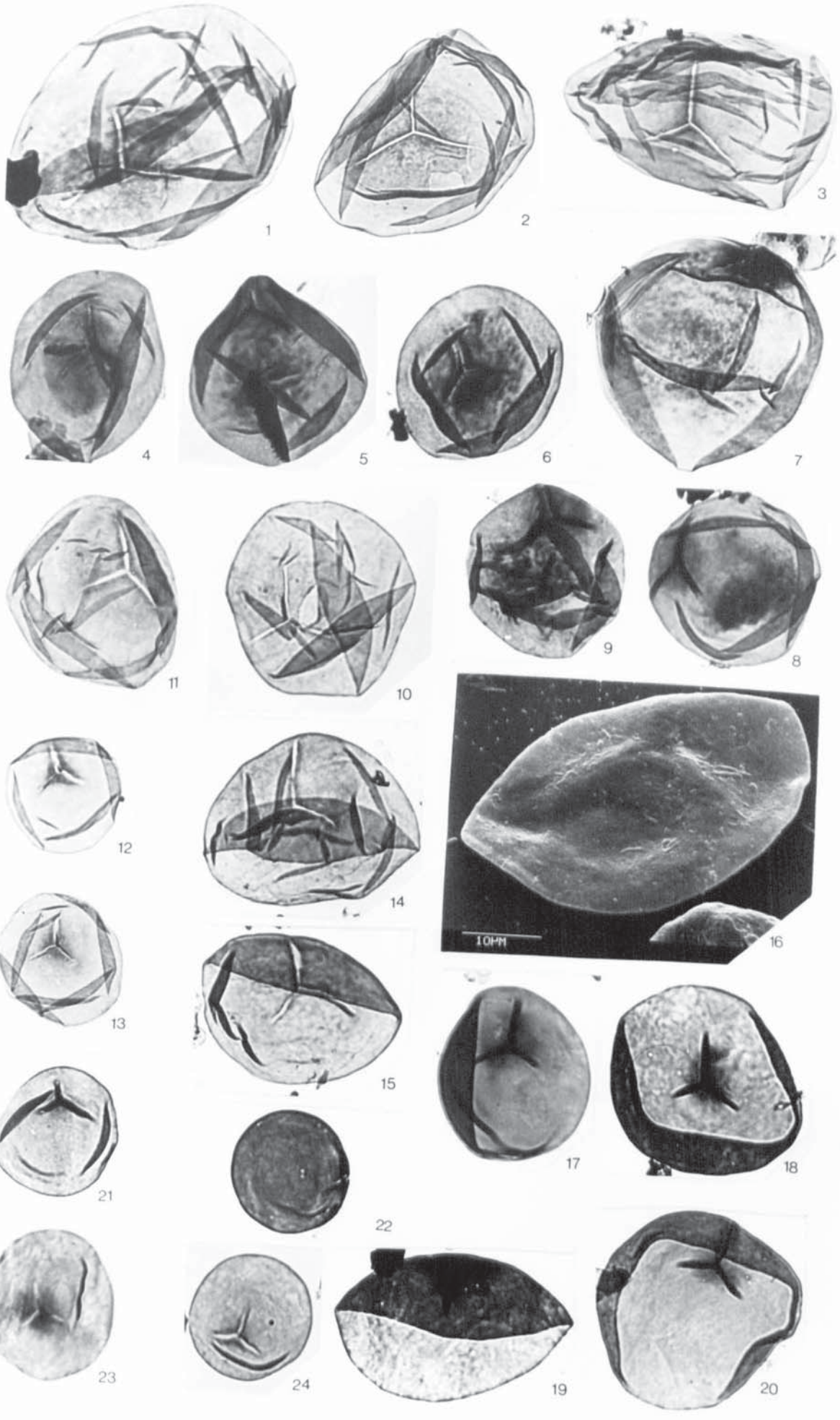


Plate 5

1. Calamospora sp.A. - A95[16] 22.0/69.6
2. C. sp.A.- A95[19] - 15.5/73.6
3. C. sp.A.- A95[20] - R4.5/78.0
4. C. sp.A.- Tetrad A95[6] - R5.6/75.9
5. C. sp.A.- A9[3] - 11.4/74.8
6. Adelisporites multiplicatus Ravn 1979 A89[8] - R8.4/69.1
7. A. multiplicatus - A11[1] - 7.5/66.5
8. A. multiplicatus - A95[2] - R3.7/75.4
9. A. multiplicatus - A144[1] - 20.0/78.5
10. A. multiplicatus -A144[2] - 0.0/74.1
11. Granulatisporites adnatoides (Potonié and Kremp) Smith and Butterworth 1967 - A11[3] - 24.7/70.1
12. G. adnatoides - A95[18] - 26.6/73.5
13. G. adnatoides - A11[3] - R7.9/76.0
14. G. granulatus Ibrahim A95[15] - 74.0/79.8
15. G. granulatus - A95[15] - 25.0/71.6
16. G. minutus Potonié and Kremp 1955 - A89[9] - 25.4/71.5
17. G. minutus - A95[12] - R0.1/82.6
18. G. minutus - A95[11] - 28/85.0
19. G. minutus - SEM Preparation A89, proximal view
20. G. microgranifer Ibrahim 1933 A95[15] - 29.6/67.1
21. G. microgranifer - A95[6] - 3.0/84.0
22. G. microgranifer - A95[11] - 24.4/79.3
23. G. pallidus Kosanke 1950 - A95[6] - 26.7/73.6
24. G. pallidus - A95[5] - 20.7/71.3
25. G. pallidus - A89[10] - 12.1/72.9
26. G. pallidus - A16[3] - 6.5/70.3
27. G. parvus (Ibrahim) Potonié and Kremp 1955 A95[4] - 10.1/70.8
28. G. parvus - A95[23] - 5.0/73.7
29. G. parvus A95[13] - 1.7/80.3
30. G. parvus - A95[10] - 27.0/74.8
31. G. parvus - A137[1] - 27.0/65.6
32. Cyclogranisporites aureus (Loose) Potonié and Kremp 1955 - A104[1] - 10.7/74.4
33. C. aureus - A9[12] - 12.3/73.3
34. C. aureus - A11[3] - 19.4/66.2
35. C. aureus - A104[1] - 6.3/79.9
36. C. aureus A91[4] - 3.0/78.9
37. C. aureus SEM, proximal view, preparation A104
38. C. lepoldi (Kremp) Potonié and Kremp 1955 A95[12] - 10.2/70
39. C. lepoldi - A95[16] - 29.0/74.7
40. C. lepoldi - A95[15] - 29.4/79.0

PLATE 5

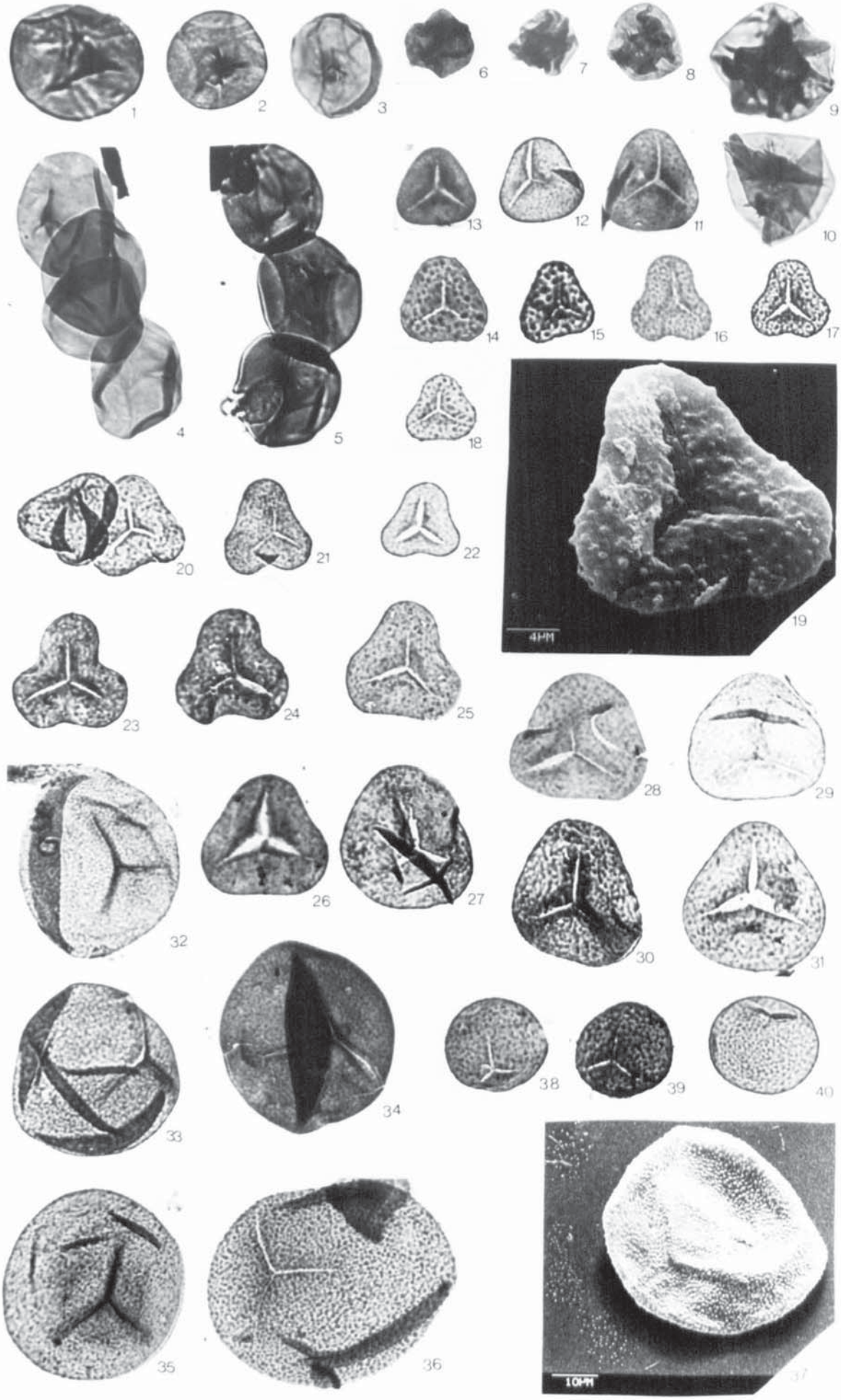

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Plate 6

1. Cyclogranisporites minutus Bharadwaj - A95[15] - 26.3/68.4
2. C. minutus - A91[5] - R0.1/70.2
3. C. minutus - A95[5] - 2.2/79.0
4. C. minutus - A104[4] - R27/81.8
5. C. cf. minutus Bharadwaj 1957 in Smith and Butterworth 1967 - A144a - 10.5/83.9
6. C. cf. minutus - A11[3] - R0.2/69.3
7. C. cf. minutus SEM, proximal view, preparation A89
8. C. multigranus Smith and Butterworth 1967 - A95[17] - 11.4/80.5
9. C. multigranus - A138[1] - 11.5/71.8
10. C. multigranus - A138a - 20.0/78.4
11. C. multigranus SEM - proximal view, preparation A104
12. C. multigranus SEM - proximal view, preparation A104
13. Apiculiretusispora sp.A. - A104[4] - 18.6/77.4
14. A. sp.A.- A104[5] - 27.9/74.3
15. A. sp.A.- A104[4] - 3.9/68.9
16. A. sp.A.- A104[3] - 17.3/75.4
17. A. sp.A.- SEM, proximal view, prepration A104
18. A. sp.A.- A104[8] - 23.0/62.8
19. A. sp.A.- A104[3] - 25.3/84.7
20. Apiculiretusispora sp.B. - A89[5] - 16.5/78.0
21. A. sp.B. - A89[10] - 20.5/68.2
22. A. sp.B. - A89$_2$ - R0.1/75.5
23. A. sp.B. - A89[10] - 25.3/70.0
24. A. sp.B. SEM distal view, preparation A89
25. A. sp.B. SEM proximal view, preparation A89
26. Converrucosisporites armatus (Dybova and Jachowicz) Smith and Butterworth 1967 A130a - R0.3/74
27. C. armatus - A130a x1000 R0.3/74.0
28. C. armatus - A128[5] - 29.2/77.4
29. C. armatus -A128[3] - 23.3/71.1
30. C. armatus - A130[2] - 27.1/70,4
31. C. armatus - A104[8] - 18.2/67.9

PLATE 6

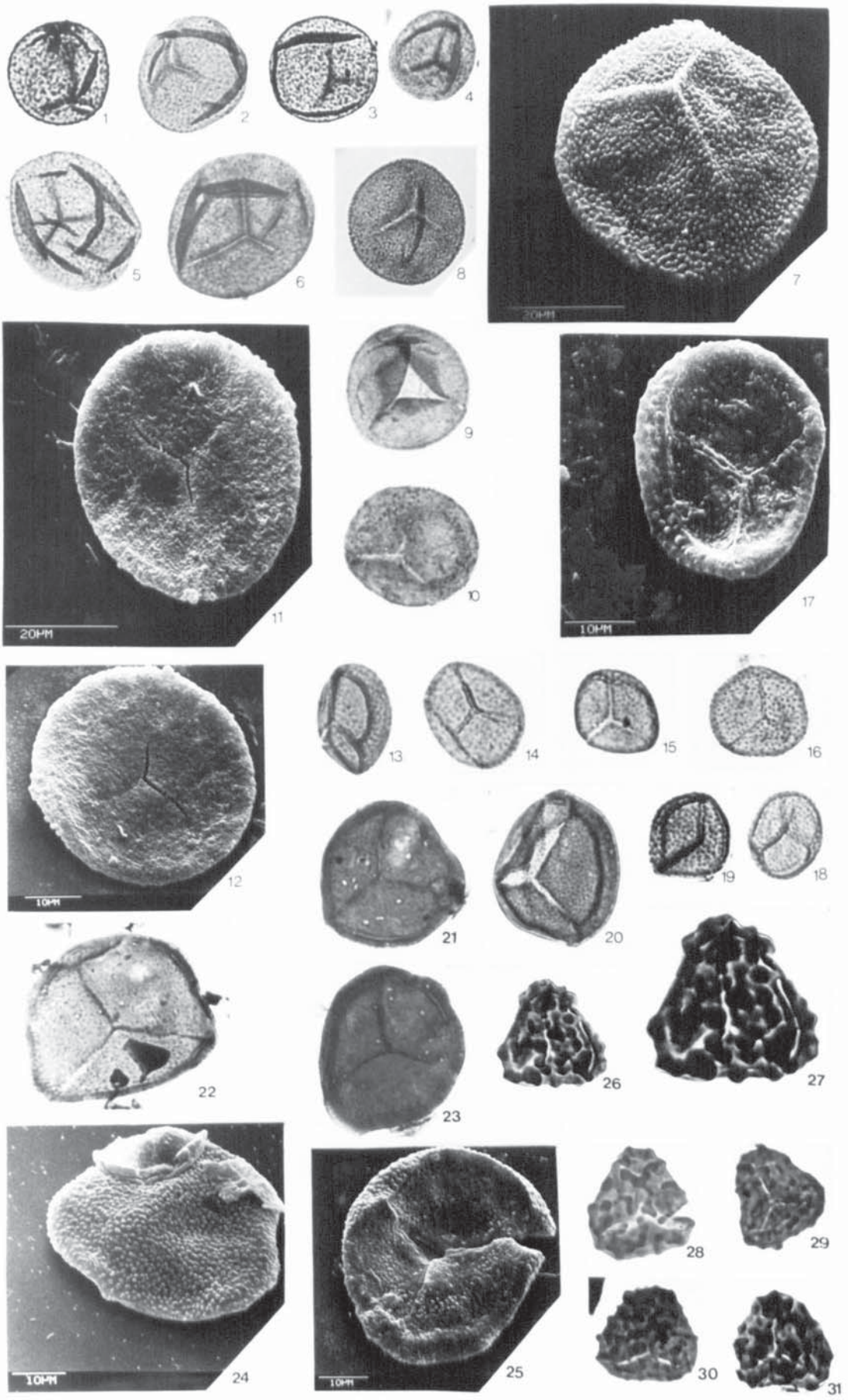

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Plate 7

1. Verrucosisporites donarii Potonié and Kremp 1955 A89[4] - 22.8/68.2
2. V. donarii - A95[2] - 5.4/79.1
3. Verrucosisporites microtuberosus (Loose) Smith and Butterworth 1967 - A128[4] - 30.3/70.1
4. V. microtuberosus - A95[16] - 29.0/74.9
5. V. microtuberosus - A137[3] - 10.6/72.7
6. V. microtuberosus SEM; Distal view, preparation A95
7. Verrucosisporites verrucosus (Ibrahim) Ibrahim 1933 A144[1] - R6.5/73.8
8. V. verrucosus - A128[2] - 29.5/73.0
9. V. verrucosus SEM, distal view, preparation A95
10. Verrucosisporites sifati (Ibrahim) Smith and Butterworth 1967 A89[4] - 12.6/71.8
11. Verrucosisporites sifati - A129[1] - 11.0/70.8
12. Verrucosisporites sp.A.- A89[5] - 18.0/81.4
13. Verrucosisporites sp.A. - A128[3] - R6.5/82.4
14. V. sp.A. - A89[10] - 19.6/74.3
15. V. sp.A. - A89[7] - 11/70.4
16. V. sp.A. - SEM, proximal view A89
17. V. sp.A. - SEM Proximal view, A89

PLATE 7

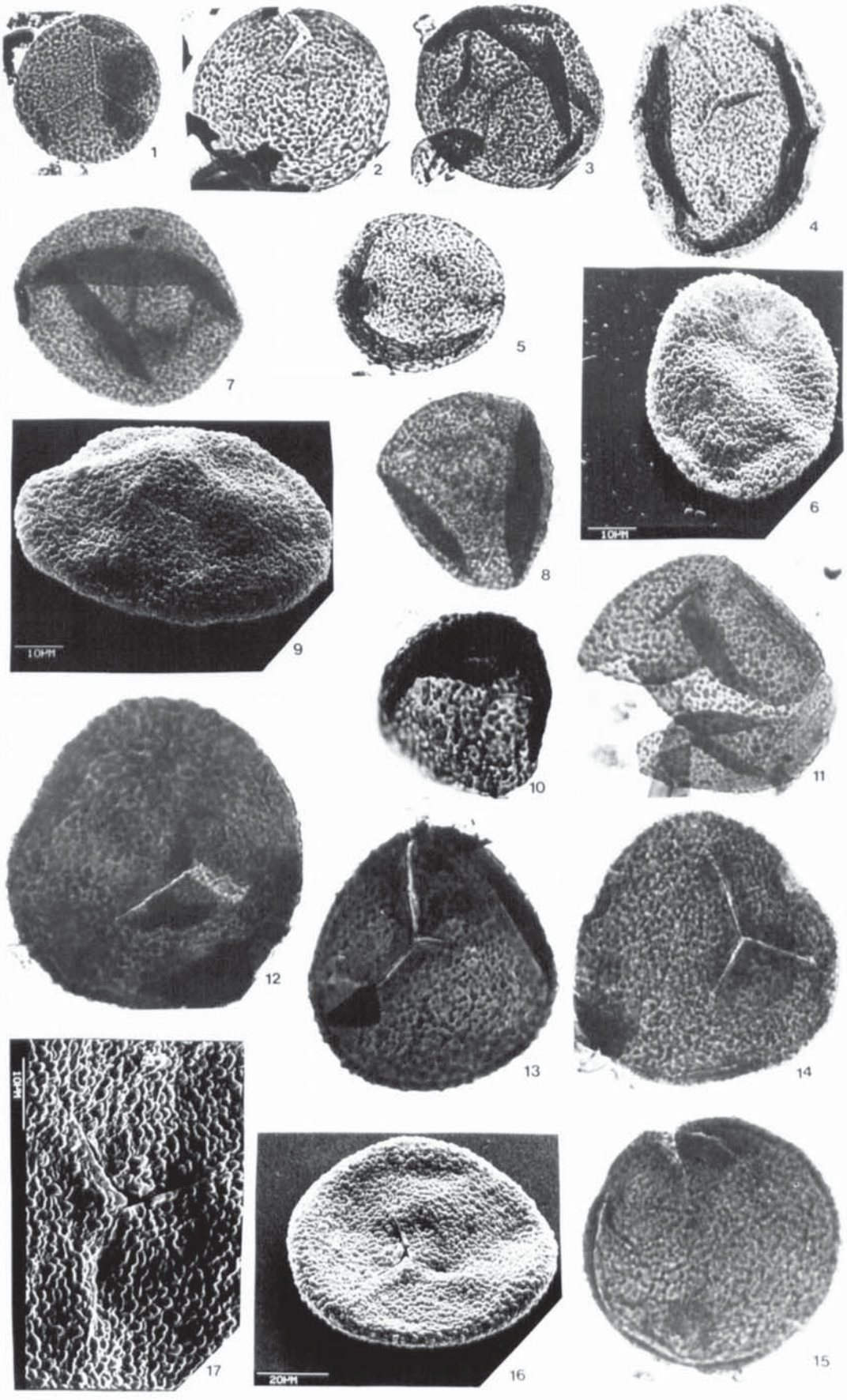


Plate 8

1. Lophotriletes commisuralis (Kosanke) Potonié and Kremp 1955 A11[1] - 8.8/76.3
2. L. commisuralis - A104[1] - 19.9/79.2
3. Lophotriletes cf. gibbosus (Ibrahim) Potonié and Kremp 1954, in Smith and Butterworth 1967 A135[1] - 5.5/68.3
4. L. cf. gibbosus - A89[1] - 7.3/84.4
5. Lophotriletes granoornatus Artüz 1957 A95[10] - 13.5/80.9
6. L. granoornatus - A95[26] - 15.6/84.3
7. L. granoornatus - A95[23] - 1.8/77.8
8. L. granoornatus - A95[7] - 16.2/79.8
9. L. granoornatus - A95[8] - 12.4/84.1
23. L. granoornatus - SEM, Proximal view, Preparation A89
10. Lophotriletes cf. microsaetosus (Loose) Potonié and Kremp 1955 in Smith and Butterworth 1967 A91[1] R10.5/82.2
11. L. cf. microsaetosus A95[18] - 11.4/69.6
12. L. cf. microsaetosus A95[5] - 0.0/78.3
13. Waltzispora prisca (Kosanke) Sullivan 1964 - A95[15] - 21.6/68
14. W. prisca - A95[23] - 22.9/68.9
15. W. prisca - A95[20] - 14.8/69.1
16. Anapiculatisporites minor (Butterworth and Williams) Smith and Butterworth 1967 A95[21] - 6.0/70.7
17. A. minor - A95[20] - 27.1/69.1
18. A. minor - A89[10] - 13.4/76.7
19. A. minor - A95[23] - 22.2/70.2
20. Anaplanisporites baccatus (Hoffmeister, Staplin and Malloy) Smith and Butterworth 1967 - A135[2] - 12.6/75.7
21. A. baccatus - A95[19] - 5.1/74.7
22. A. baccatus - A95[24] - 18.8/77.1
24. Anaplanisporites sp.A. - A89a - R2.2/75.2
25. A. sp.A. - A89[8] - 21.7/66.2
26. A. sp.A. - A89[10] - R8.2/83.8
27. A. sp.A. - A89[7] - 27.4/77.5
28. A. sp.A. - A89[4] - 20.1/77.1 - A135
29. A. sp.A. - A89[10] - R5.0/73.6
30. A. sp.A. SEM, Distal view preparation A89
31. A. sp.A. SEM, Lateral view preparation A89
32. Pustalatisporites papillosus (Knox) Potonié and Kremp 1955 A135a - R6.1/76.2
33. P. papillosus - A95[5] - 22.1/81.8
34. P. papillosus - A137[2] - 24.8/75
35. P. papillosus - A135[2] - R7.7/70.1
36. Pustulatisporites pustulatus Potonié and Kremp 1954 Distal view, A91[6] - RO.2/70.5
37. P. pustulatus proximal view - A91[6] RO.2/70.5
38. P. pustulatus - A95[24] - 6.7/83.9
39. P. pustulatus - A143[1] - R7.3/76.5
40. Pustulatisporites sp.A. - A95[10] - 2.7/79.8
41. P. sp.A. - A95[4] - 13.6/73.8
42. P. sp.A. - A95[8] - 10.3/73.9
43. P. sp.A. - A95[22] - 27.0/68.2
44. P. sp.A. - A95[23] - 22.5/79.0
45. P. sp.A. - A95[23] - R11/78.3
46. P. sp.A. - SEM, Distal view, preparation A95

PLATE 8

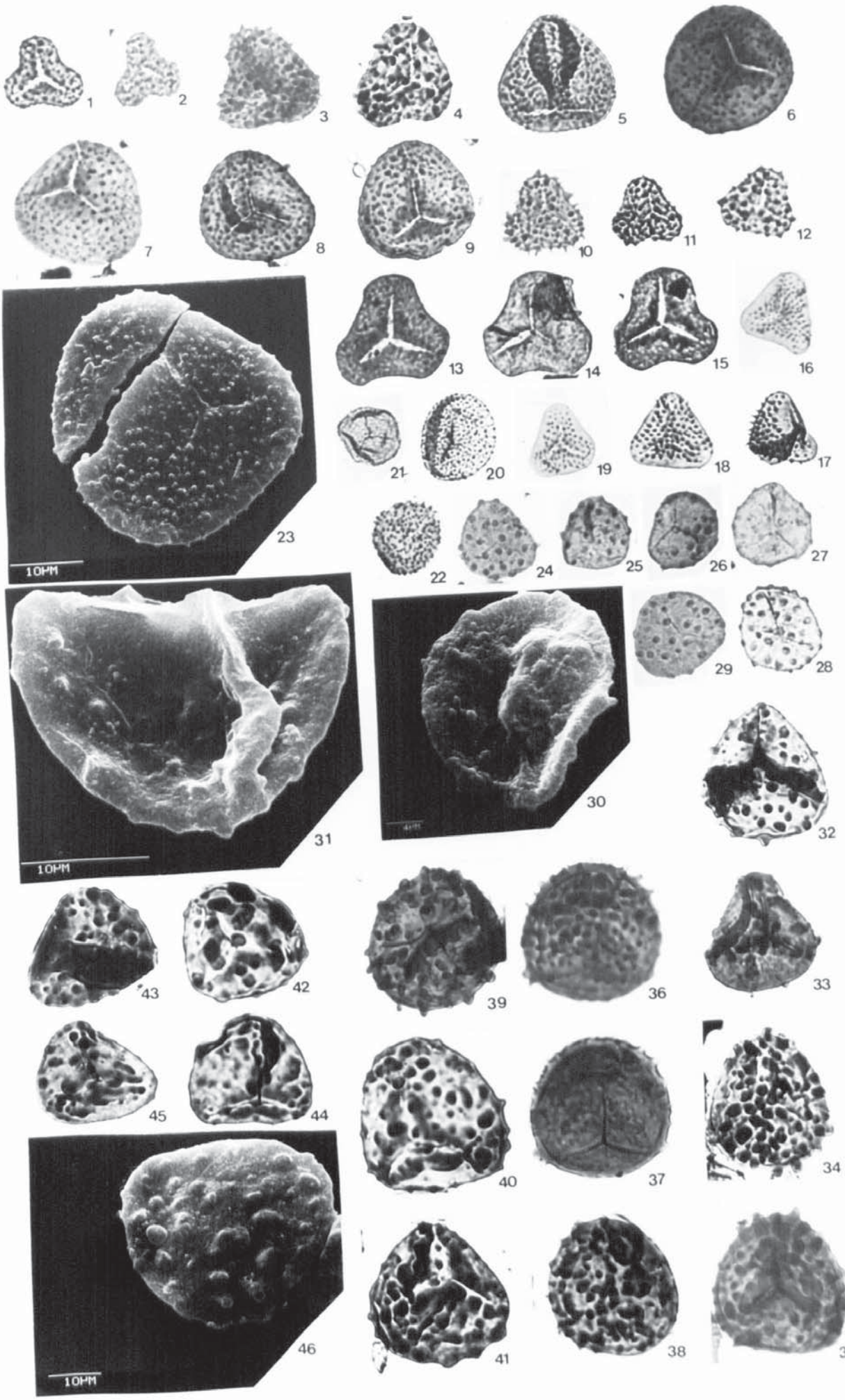

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Plate 9

1. Apiculatisporis abditus (Loose) Potonié and Kremp 1955 A95[7] - R 7.1/75.4
2. A. abditus - A95[4] - 14.6/78.7
3. A. abditus A95[10] - R 3.3/70.7
4. A. abditus A95[10] - 23.7/77.3
5. A. abditus SEM, equatorial view, preparation A95
6. A. abditus SEM, distal view, preparation A95
7. Apiculatisporis aculeatus (Ibrahim) Smith and Butterworth 1967 A104[4] - 25.4/74.4
8. A. aculeatus - A9[11] - 5.1/84.5
9. A. aculeatus - A126[1] - R 0.1/71.9
10. A. aculeatus - A9[3] - 2.0/73.6
11. A. aculeatus - A11[7] - 14.3/78.6
12. A. aculeatus - SEM, proximal view, preparation A11
13. Apiculatisporis irregularis (Alpern) Smith and Butterworth 1967 A144[2] - 29.5/83.9
14. A. irregularis Tetrad A104[8] - 15.5/69.5
15. A. irregularis Tetrad A104[8] - 13.1/77.8
16. A. irregularis A95[18] - R 2.3/67.8
17. A. irregularis A14[1] - 29.7/59.1
18. A. irregularis A95[24] - R 4.4/81.4
19. A. irregularis A138[3] - R 6.9/84.6
20. A. irregularis SEM, proximal view, preparation A104
21. Apiculatisporis cf. latigranifer (Loose) Potonié and Kremp 1955, in Smith and Butterworth 1967 A95[8] - 25.9/82.0
22. A. cf. latigranifer - A137[1] - R0.0/68.2
23. A. cf. latigranifer - A95[6] - 4.0/82.3
24. A. cf. latigranifer - A95[9] - 17.4/71.2
25. A. cf. latigranifer SEM Distal view - Preparation A95
26. A. cf. latigranifer SEM Proximal view - Preparation A95

PLATE 9

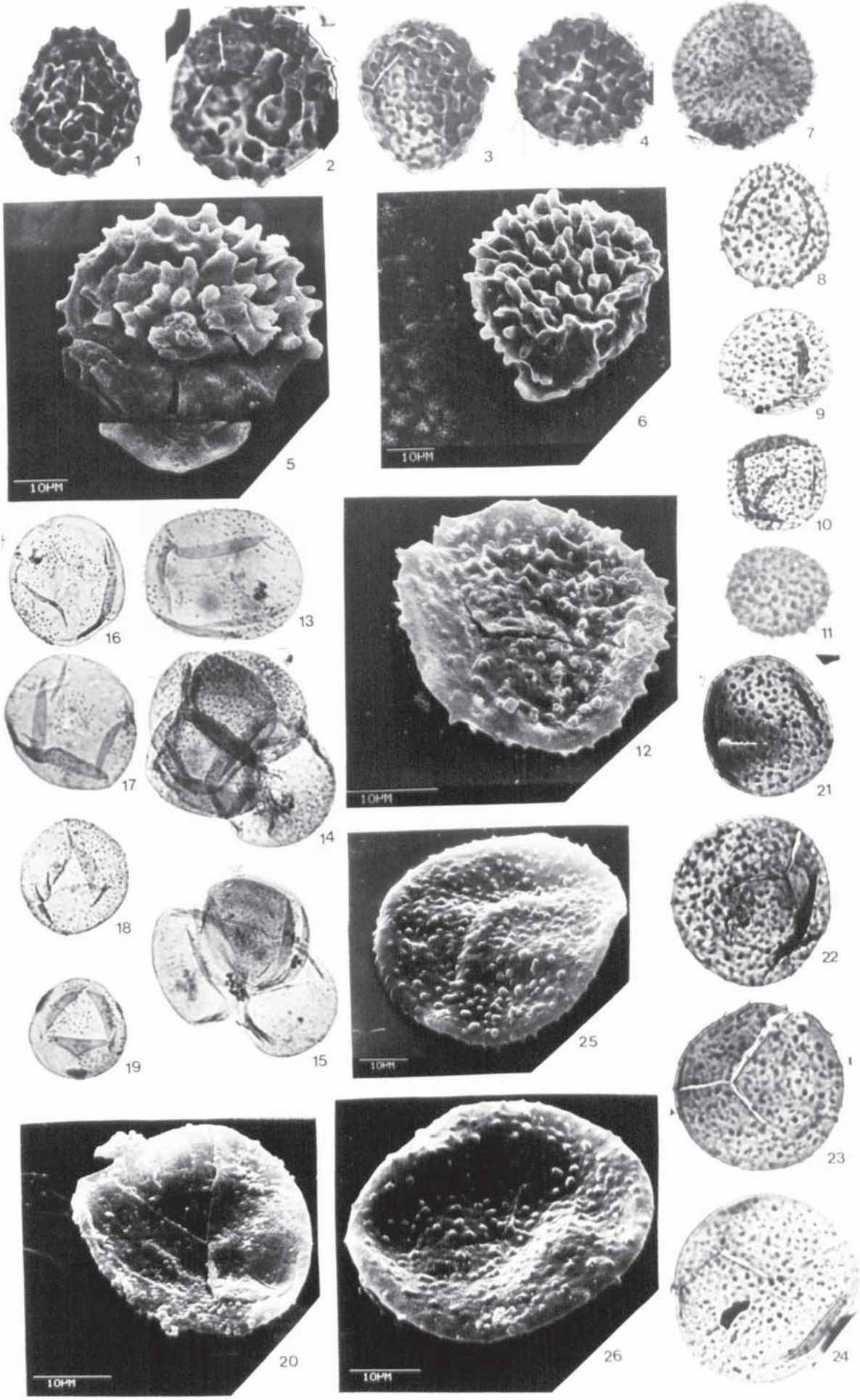

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Plate 10

1. Apiculatisporis spinososaetosus (Loose) Smith and Butterworth 1967 $A95^{3}$ - 25.2/67.9
2. A. spinososaetosus- $A95^{22}$ - 4.1/72.7
3. A. spinososaetosus- $A113^{3}$ - 28.2/58.7
4. A. spinososaetosus - $A95^{3}$ - 14.7/72.7
5. A. spinososaetosus SEM Distal view, Prepration A95
6. Apiculatisporis variocorneus Sullivan 1964 $A95^{15}$ - 9.2/78.5
7. A. variocorneus - $A95^{22}$ - 11.1/83.7
8. A. variocorneus - $A95^{17}$ - R7.9/71.4
9. A. variocorneus - $A95^{10}$ - 17.8/71.2
10. Apiculatasporites spinulistratus (Loose) Ibrahim 1933 $A16^{1}$ - 23.0/60.4
11. Apiculatasporites spinulistratus - $A95^{14}$ - 28.2/76.0
12. A. spinulistratus - $A113^{1}$ - R0.0/62.7
13. A. spinulistratus - A120 - 4.3/66.4
14. A. spinulistratus - SEM Distal view, preparation A104
15. A. sp.A. - A137a - R7.2/69.6
16. A. sp.A. - A137a - R18.4/64.4
17. A. sp.A.- $A137^{4}$ - 12.1/60.9
18. A. sp.A.- $A137^{2}$ - R5.9/70.5
19. Acanthotriletes echinatus (Knox) Potonié and Kremp 1955 $A89^{1}$ - 9.8/7.0 x1000
20. A. echinatus - $A89^{1}$ - 9.8/70.0
21. A. echinatus - $A11^{2}$ - 15.1/76.6
22. Acanthotriletes triquetrus - Smith and Butterworth 1967 $A11^{3}$ - 15.3/74.4
23. A. triquetrus - $A95^{22}$ - 4.1/68.2
24. Raistrickia firma (Loose) Smith 1971 - $A137^{2}$ - 20.9/60.8
25. R. firma - $A95^{10}$ - 19.3/71.6
26. Raistrickia fulva Artüz 1957 A113 - R2.8/64.4
27. R. fulva - $A124^{1}$ - R3.2/84.6
28. R. fulva - $A95^{19}$ - 22.8/77.3
29. R. fulva - $A104^{2}$ - 21.4/80.0
30. R. fulva - SEM Distal view, preparation A128

PLATE 10

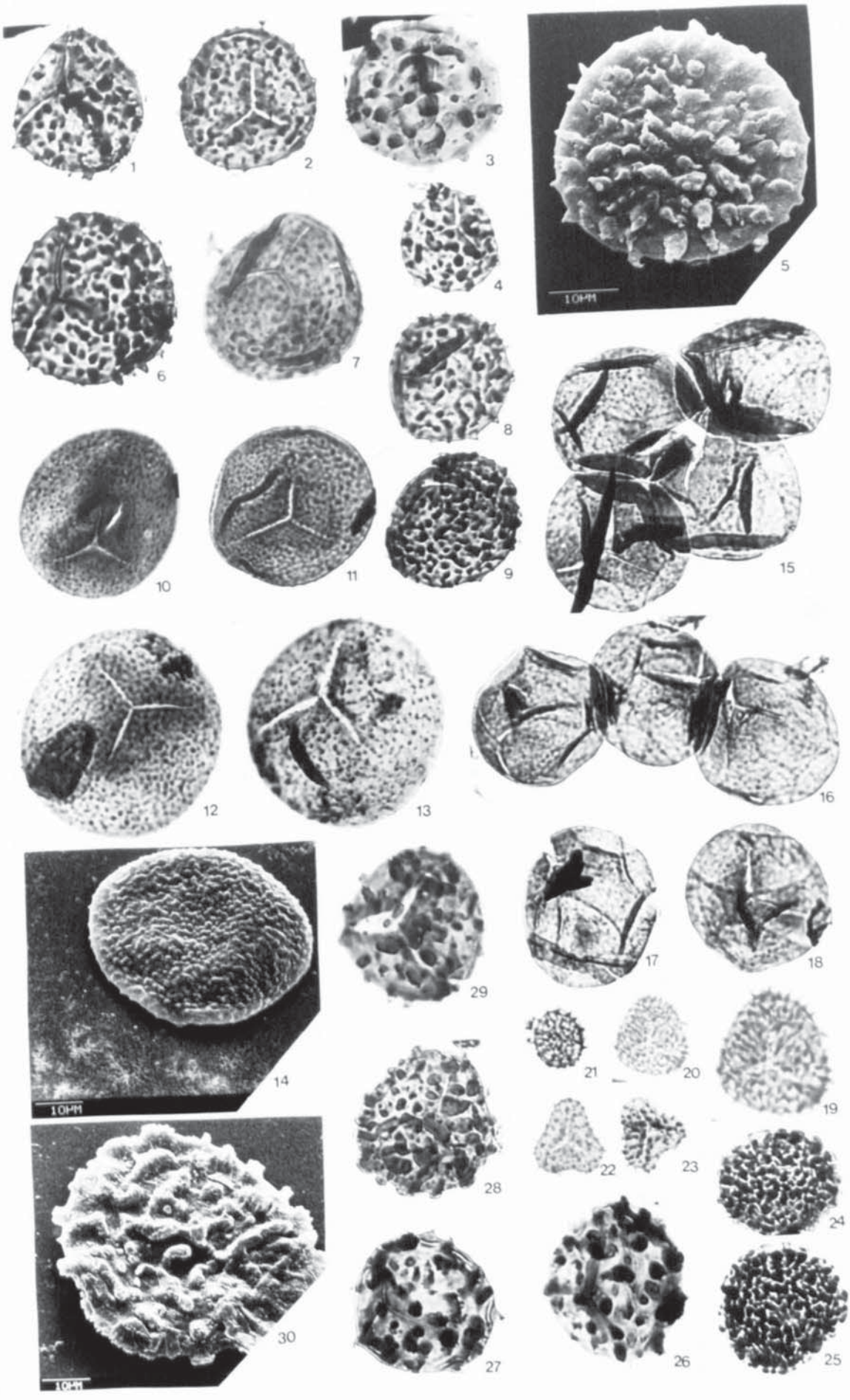

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Plate 11

1. Raistrickia lacerata Peppers 1970 A128[3] - 29.7/73.1
2. Raistrickia pilosa Kosanke 1950 A95[23] - 20.2/71.0
3. R. pilosa - A89[5] - 8.6/75.7
4. R. pilosa - A143a - 3.2/79.6
5. R. pilosa - A128a - 6.9/59.6
6. Raistrickia saetosa (Loose) Schopf, Wilson and Bentall 1944 A95[17] - R8.6/80.3
7. R. saetosa - A95[23] - 25.7/68.8
8. R. saetosa - A89[4] - 3.9/76.2
9. R. saetosa - SEM Distal view, Preparation A89
10. Raistrickia solaria Wilson and Hoffmeister 1956 A79[2] - 3.5/71.3
11. R. solaria - A129[4] - 28.8/69.3
12. Raistrickia sp.A. - A79[3] - 3.4/38.2
13. R. sp.A.- A79[1] - 22.1/81.2
14. R. sp.A.- A79[3] - 3.7/80.7
15. Spackmanites facierugosus (Loose) Habib 1966 A95[14] - 15.5/72.8
16. S. facierugosus - A71[1] - 17.9/82.7
17. Convolutisporites sp.A. - A128[1] - 19.0/72.1
18. C. sp.A. - A89[10] - 19.5/68.5
19. C. sp.A. - A89M$_1$ - R0.8/69.2
20. C. sp.A. - A137[3] - R3.8/63.9
21. Microreticulatisporites harrisonii Peppers 1970 A104[4] - R5.1/80.8
22. M. harrisonii - A89[5] - 6.1/68.2
23. M. harrisonii - A89[10] - 11.9/68.9
24. Microreticulatisporites nobilis (Wicher) Knox 1950 A11[2] - 7.4/67.5
25. M. nobilis - A104[3] - 27.9/74.4
26. M. nobilis -A104[2] - 21.7/79.3
27. Secarisporites remotus Neves 1961 A133[1] - R14.4/81.1
28. S. remotus A138a - 19.6/81.6
29. S. remotus - A95[22] - 25/66.2
30. S. remotus - A95[21] - 25.4/82.0
31. S. remotus - A104[8] - 11.3/61.6
32. Dictyotriletes bireticulatus (Ibrahim) Smith and Butterworth 1967 - A95[5] - 18.7/80.5
33. D. bireticulatus A95[14] - 1.8/73.4
34. D. bireticulatus A95[7] - 16.3/83.6
35. D. bireticulatus equatorial view - A95[22] - 25.5/83.9
36. D. bireticulatus - A130[1] - 0.0/74.3
37. D. bireticulatus - SEM, Proximal view, Preparation A95
38. D. bireticulatus - Tetrad - A9[14] - 5/83.6
39. Dictyotriletes castaneaeformis (Horst) Sullivan 1964 - A104[8] - 6.5/60.2
40. D. castaneaeformis - A104[1] - 6.4/74.3
41. Dictyotriletes falsus Potonié and Kremp 1955 - A95[12] - 29.6/80
42. D. falsus - A95[22] - R6.7/68.9
43. D. falsus - A95[20] - R1.8/72.2

PLATE 11

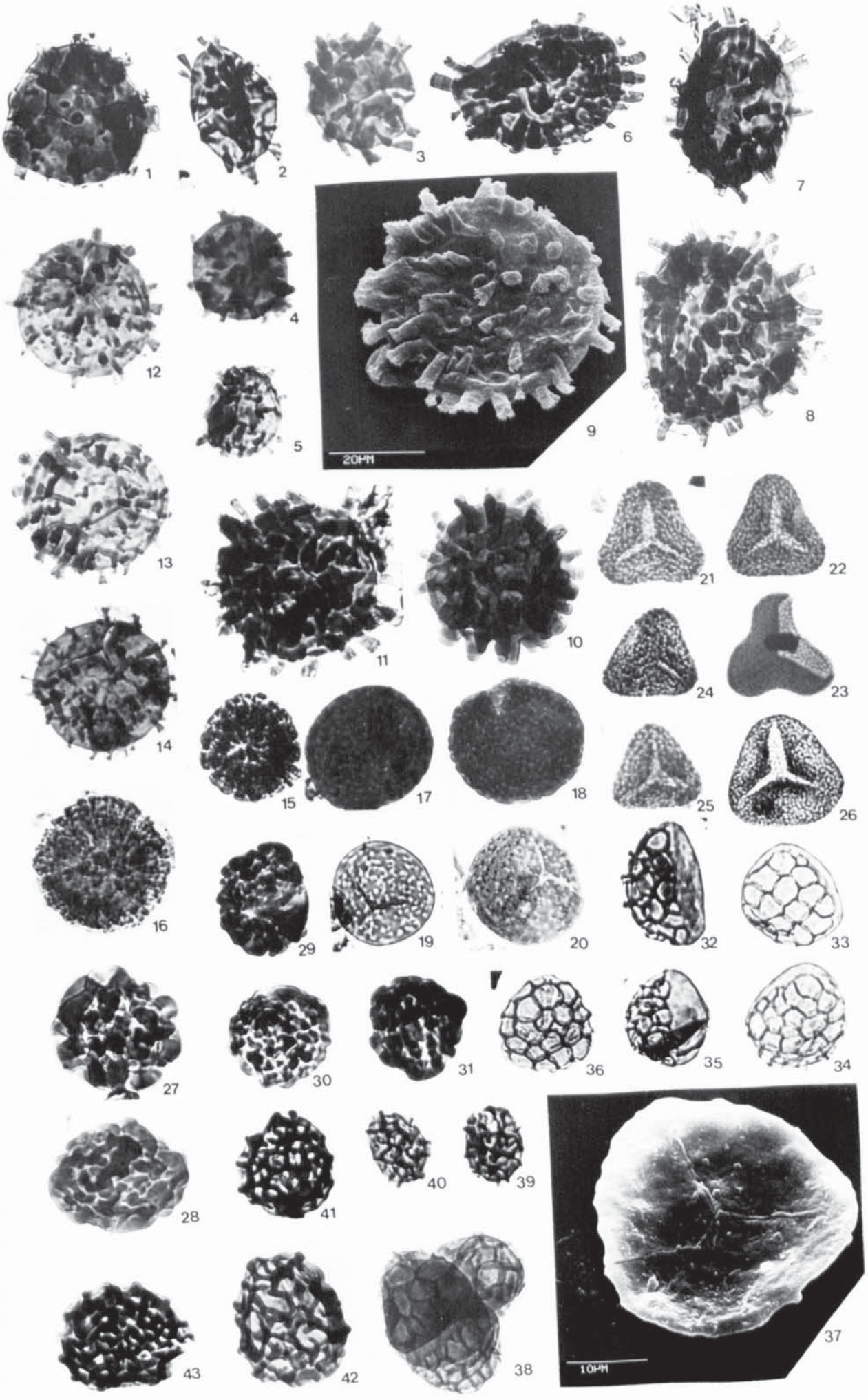

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Plate 12

1. Dictyotriletes muricatus (Kosanke) Smith and Butterworth 1967 A125[2] - R0.5/74.1
2. D. muricatus - A130[2] - 20·0/78.2
3. D. muricatus - A138[1] - R4.2/77.1
4. D. muricatus - SEM - Distal view, Preparation A91
5. D. muricatus - SEM - Distal view, Preparation A125
6. D. reticulocingulum (Loose) Smith and Butterworth 1967 - A9[1] - 7.4/74.7
7. D. reticulocingulum - A9[2] - 10.0/75.8
8. D. reticulocingulum - A89[8] - 0.2/82.7
9. D. reticulocingulum - A9[3] - 28.9/75.5
10. D. reticulocingulum A89[1] - 7.1/71.4
11. D. reticulocingulum SEM, Distal view, Preparation A9
12. D. reticulocingulum SEM, Distal view, Preparation A9
13. Camptotriletes bucculentus (Loose) Potonié and Kremp 1955 - A129[3] - 20.1/69.6
14. Camptotriletes bucculentus - A95[15] - 16.6/78.0
15. C. bucculentus - A120[3] - 5.2/70.7
16. C. bucculentus Tetrad - A134a - 27.3/71.2
17. C. bucculentus SEM, Distal view, Preparation A95
18. Camptotriletes corrugatus (Ibrahim) Potonié and Kremp 1954 A122[1] - 21.5/63.3
19. C. corrugatus - A95[13] - 19.5/72.2
20. C. corrugatus - A95[23] - 7.5/72.9
21. C. corrugatus - A138[2] - 29.4/72.3
22. Camptotriletes sp.A. - A95[24] - R20.7/74.2
23. C. sp.A.- A129[2] - 11.9/68.2
24. C. sp.A. - A95[21] - 20.6/66.8
25. C. sp.A.- A95[6] - R6.2/78.2
26. Ahrensisporites guerickei (Horst) Potonié and Kremp 1954 - A11[8] - 4.2/84.9
27. A. guerickei - A11[1] - 7.3/73.6
28. A. guerickei - A112[1] - 0.1/69.6
29. A. guerickei SEM - Distal view, Preparation A11
30. A. guerickei SEM - Distal view, Preparation A11

PLATE 12

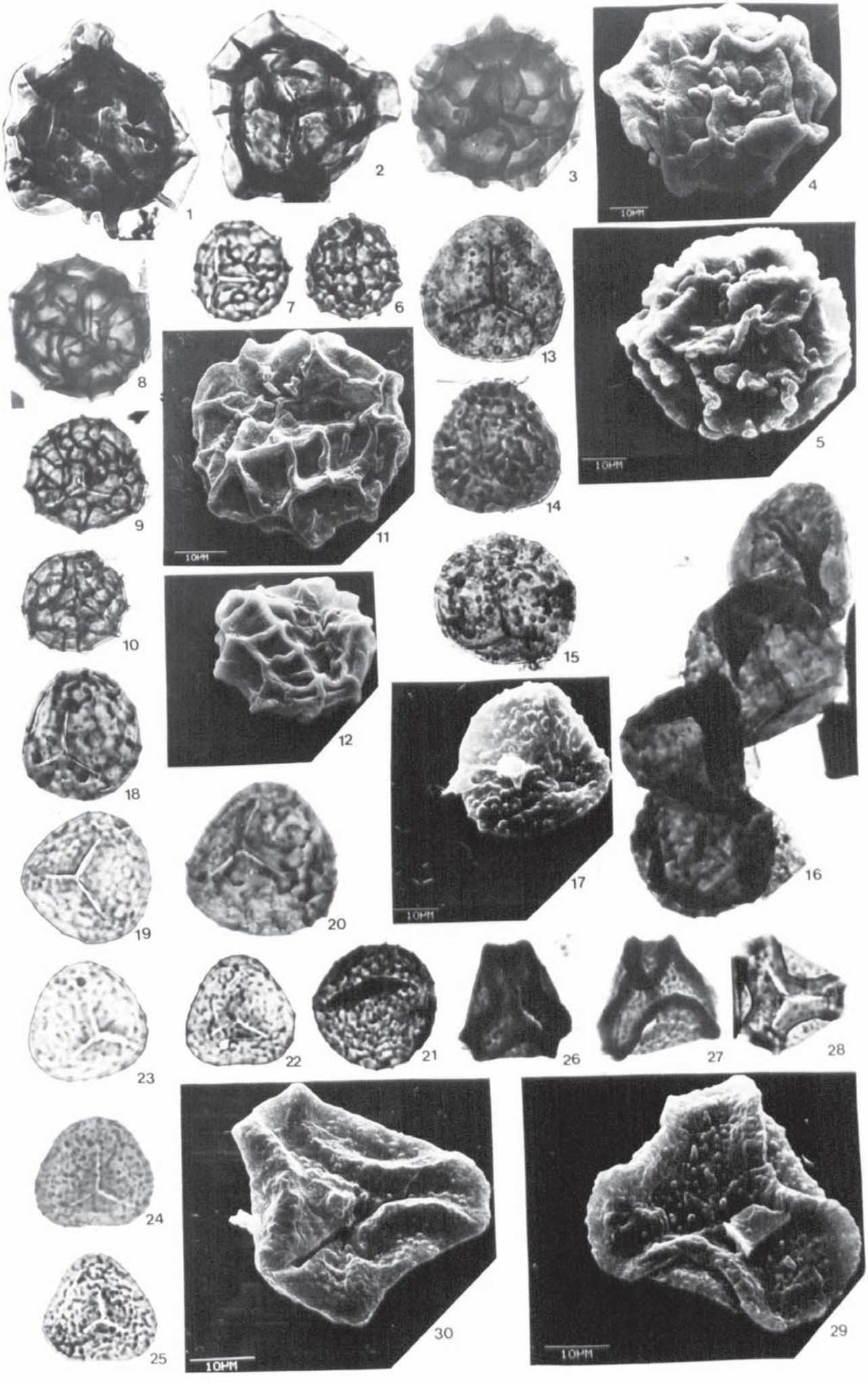

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Plate 13

1. Triquitrites protensus Kosanke 1950 A95[16] - 21.3/80.6
2. T. protensus - A95[16] - 22.1/69.6
3. T. protensus - A95[4] - 0.3/80.8
4. T. protensus SEM, Proximal view, Preparation A95
5. T. protensus - A9[8] - 23/71.8
6. Triquitrites tribullatus (Ibrahim) Schopf, Wilson and Bentall 1944 A89[5] - R0.6/81
7. T. tribullatus - A89[2] - R0.0/75.5
8. T. tribullatus - A89[9] - 19.5/78.8
9. T. tribullatus - SEM, Proximal view, Preparation A89
10. T. tribullatus - SEM, Proximal view, Preparation A89
11. Triquitrites sp.A. - A11[3] - R0.4/76.5
12. T. sp.A. - A11[2] - 17.1/76.9
13. T. sp.A. - A11[2] - 3.4/80.0
14. T. sp.A. - X1000 A11[2] - 3.4/80.1
15. T. sp.A. - A89[1] - R6.5/73.8
16. Tantillus triquetrus Felix and Burbridge 1967 A95[10] - 3.5/68.4
17. T. triquetrus - A134[2] - R2.5/76.1
18. Reinschospora speciosa (Loose) Schopf, Wilson and Bentall 1944 A9[10] - 10.9/79.9
19. R. speciosa - A89[1] - 3.9/74.7
20. R. speciosa - A89[4] - 10.8/80.5
21. R. speciosa - SEM, Distal view, Preparation A89
22. Reinschopspora triangularis Kosanke 1950 A95[7] - 10.1/77.1
23. R. triangularis - A9[1] - 4.1/67.5
24. R. triangularis SEM, Proximal view, Preparation A89
25. Knoxisporites triradiatus Hoffmeister, Staplin and Malloy 1955 A120[2] - 17.1/65.3
26. K. triradiatus - A89[10] - 27.6/70.1
27. K. triradiatus A89[7] - 17.3/77.6
28. K. triradiatus A89[10] - 5.9/79.4
29. K. triradiatus SEM, Distal view, Preparation A89
30. K. triradiatus SEM, Distal view, Preparation A89

PLATE 13

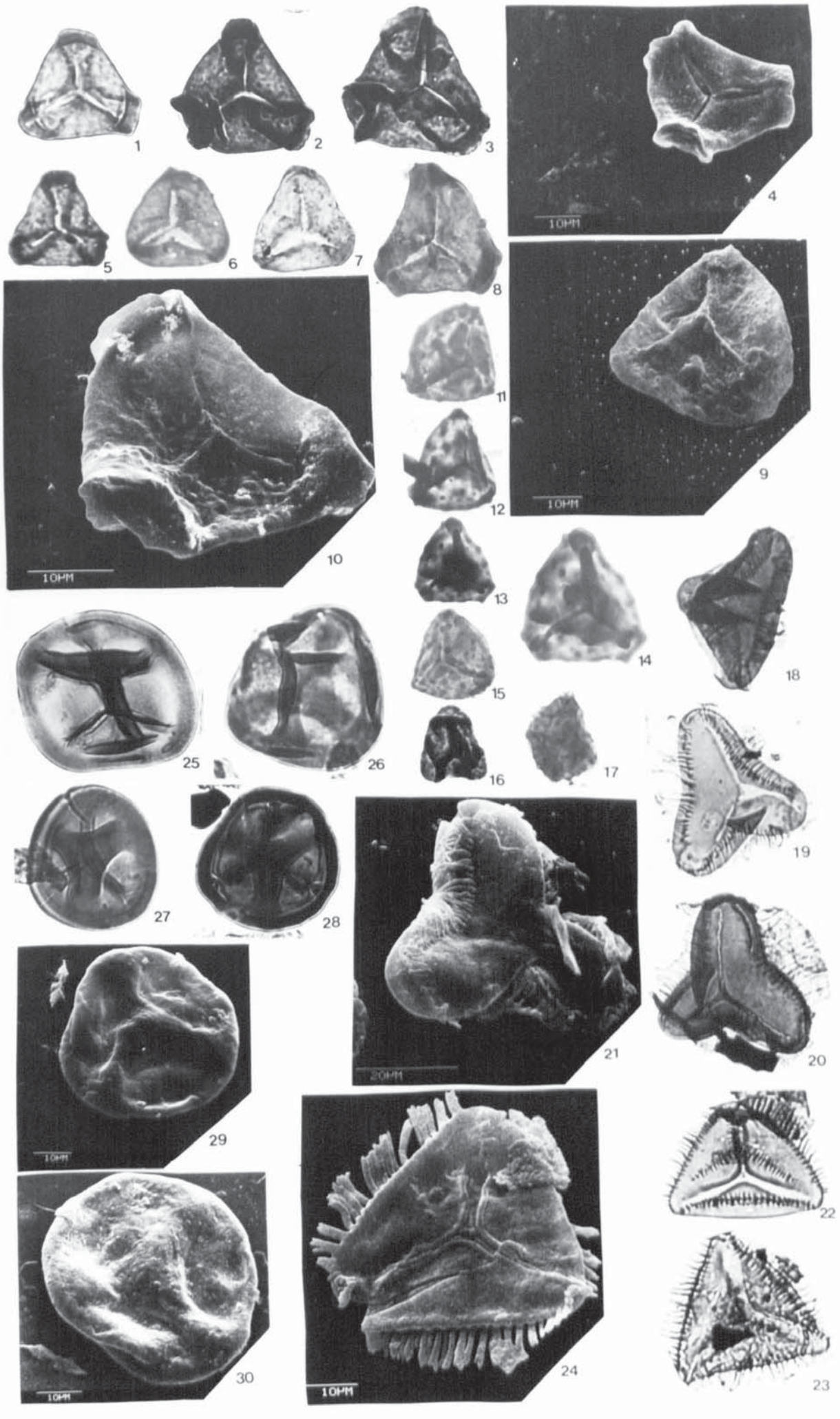

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Plate 14

1. Reticulatisporites polygonalis (Ibrahim) Smith and Butterworth 1967 A95[13] - 18/70.9
2. R. polygonalis - A128[4] - 29.0/74.2
3. R. polygonalis SEM, Proximal view, Preparation A95
4. R. polygonalis - A95[21] - 16.9/77.9
5. Reticulatisporites reticulatus SEM, Distal view, Preparation A95
6. R. reticulatus (Ibrahim) 1933 A95[11] - 28.8/80.4
7. Savitrisporites nux (Butterworth and Williams) Sullivan 1964 A95[21] - R2.8/70.7
8. S. nux - A95[3] - 13.2/76.1
9. S. nux - SEM, Proximal view, Preparation A95
10. S. nux - A20[4] - 23.0/73.6
11. S. nux - A18[1] - 21.7/66.7
12. S. nux - A91[2] - 26.5/75.6
13. S. nux - A95[25] - 13.0/67.3
14. S. nux - A95[12] - R2.1/78.6
15. S. nux - SEM, Proximal view, Preparation A95
16. Grumosisporites varioreticulatus (Neves) Smith and Butterworth 1967 A71[2] - 20.2/84.4
17. Grumosisporites varioreticulatus SEM, Distal View, Prepration A128
18. Grumosisporites varioreticulatus A128[1] - 18.5/59.2
19. G. varioreticulatus - A128a - 25.7/62.2
20. G. varioreticulatus SEM, Distal view, Preparation A128

PLATE 14

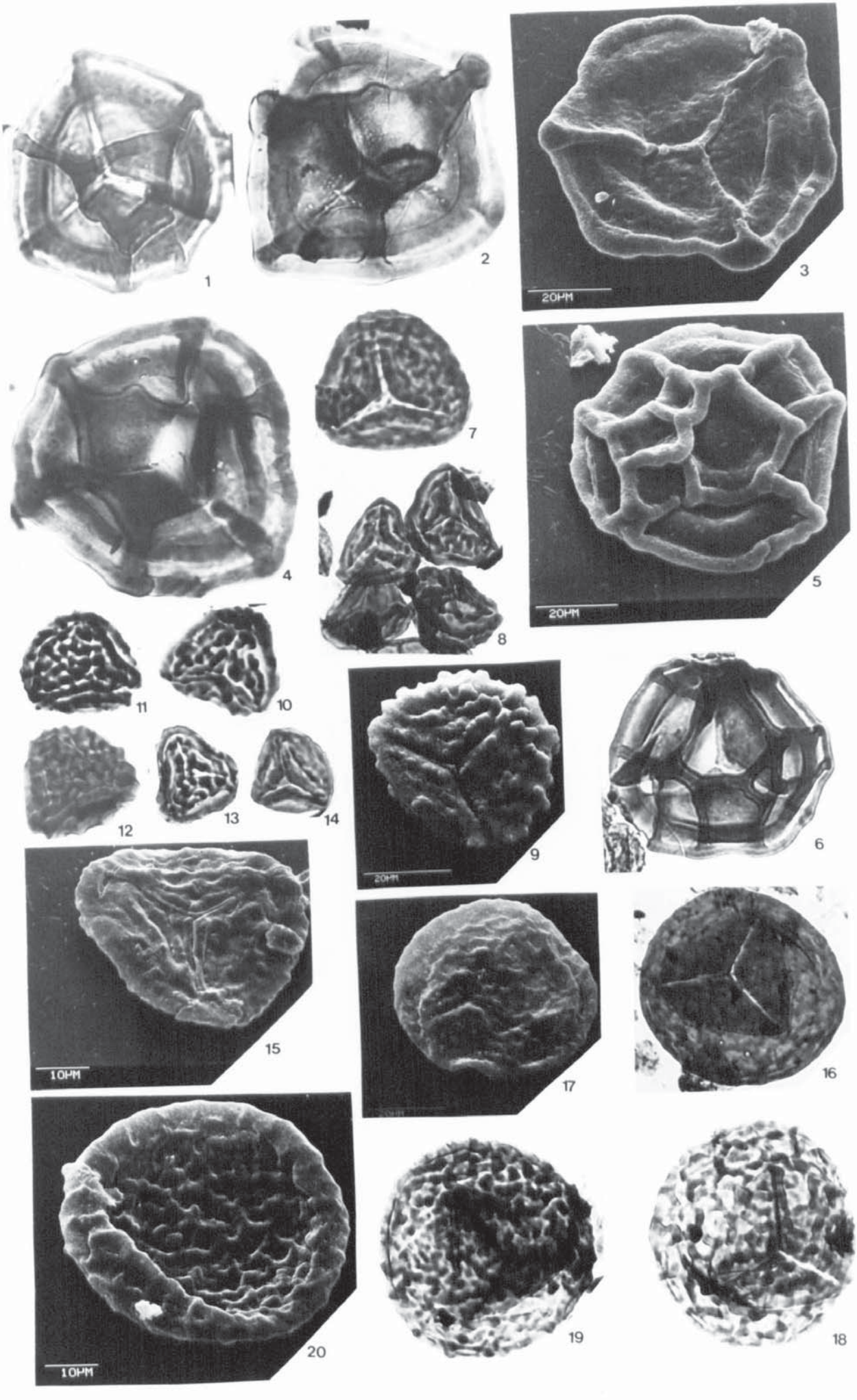
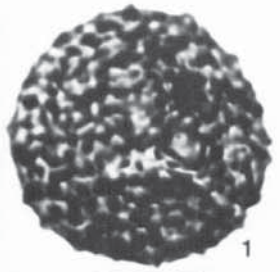
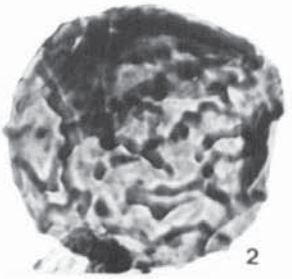

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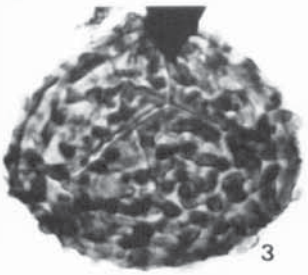
Plate 15

1. Grumosisporites papillosus (Ibrahim) Smith and Butterworth 1967 A23[1] - 30.2/72.5
2. G. papillosus - A116[2] - 29.9/63.2
3. G. papillosus - A116a - 1.4/72.2
4. G. papillosus SEM, Oblique view, Preparation A116
5. Diaphanospora parvigracila (Peppers) Ravn 1979 A128[2] - 4.8/67.3
6. D. parvigracila - A135[2] - R 1.9/73.8
7. D. parvigracila - A135[2] - R3.3/66.8
8. D. parvigracila - A11[4] - 5.1/82.1
9. D. parvigracila - A91[3] - R0.2/73.7
10. Diaphanospora sp.A. - A9[2] - 5.6/73.2
11. D. sp.A. - A9[10] - 6.8/75.2
12. D. sp.A. - A11[3] - 14/79.5
13. D. sp.A. - A95[7] - 16.7/77
14. D. sp.A. - A104[5] - 3.4/66.9
15. Diaphanospora sp.B. - A95[13] - 24.4/73.6
16. D. sp.B. - A95[14] - 23.2/79.3
17. D. sp.B. - A95[7] - R7.1/75.4
18. D. sp.B. - A113a - 29.6/62.2
19. D. sp.B. - A95[6] -27.3/70.1
20. D. sp.B. - A95[16] - R5.7/73.3
21. D. sp.B. SEM, Proximal view, Preparation A95
22. Hymenospora multirugosa Peppers 1970 A130[2] - 0.1/71.8
23. H. multirugosa - A135[2] - 0.2/80.5
24. H. multirugosa - A135[2] - 25/82.8
25. Crassispora annulata Ravn 1979 A11[1] - 8.0/77.4
26. C. annulata - A128[4] - 9.8/65.4
27. C. annulata - A95[20] - 26.7/71.6
28. Crassispora kosankei equatorial view - A79[3] - 24.4/71.4
29. C. kosankei equatorial view A9[3] - 12.8/69.4
30. Crassispora kosankei (Potonie and Kremp) Smith and Butterworth 1967 - 128[7] - 11.5/84.6
31. C. kosankei - A122[1] - 25/63.7
32. C. kosankei - A95[8] - 13.5/85.9
33. C. kosankei - Tetrad A104[4] - 22.2/74.3
34. Crassispora kosankei Tetrad - A122[2] - 19.4/72.9
35. C. kosankei SEM, Distal view, Preparation A138

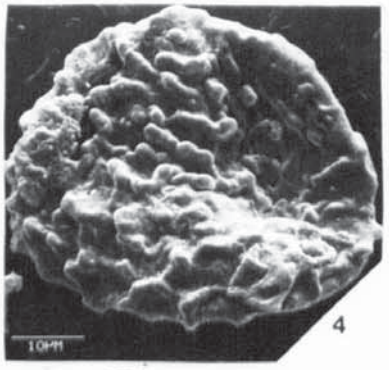
PLATE 15


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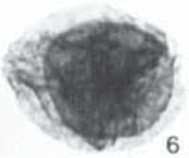

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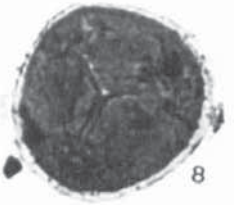

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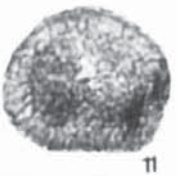


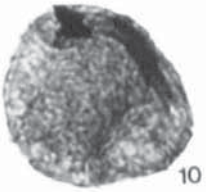
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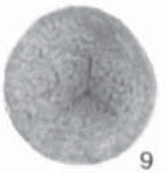

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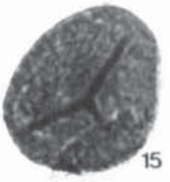

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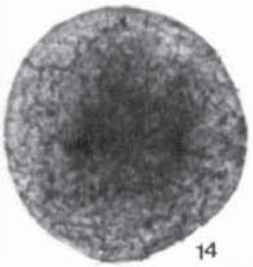

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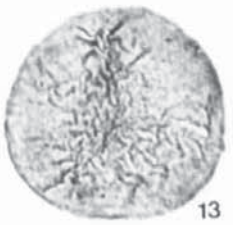

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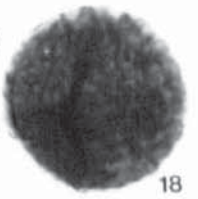

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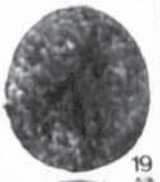

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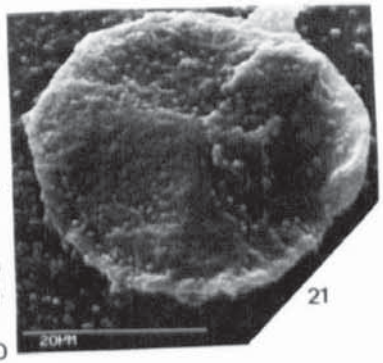

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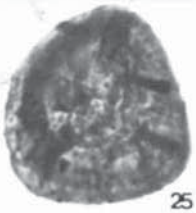

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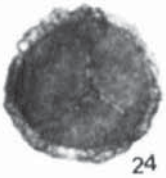

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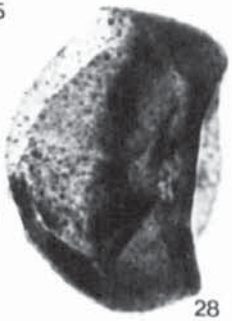

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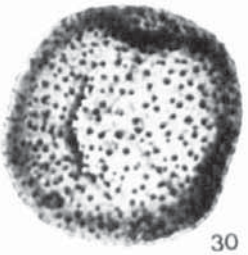

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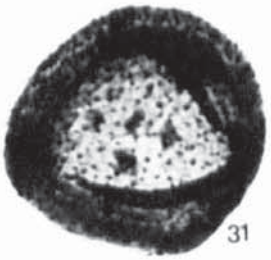

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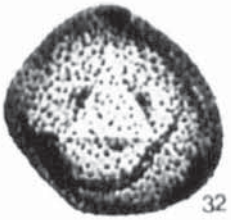

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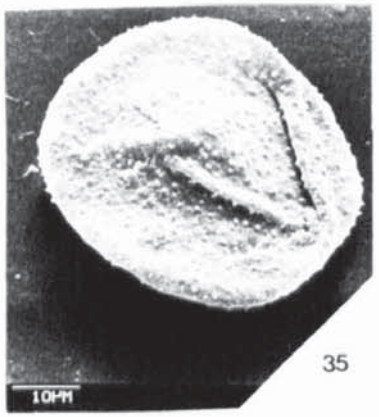

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Plate 16

1. Simozonotriletes intortus (Waltz) Potonié and Kremp 1954 - A95[10] - 13.7/71.1
2. S. intortus - A89[4] - 24.5/81.6
3. S. intortus var. intortus A89[10] - 0.0/74.4
4. S. intortus SEM, Proximal view, Preparation A89
5. S. intortus SEM, Proximal view, Preparation A89
6. S. intortus var. concavus A95[9] - 5.8/78.3
7. S. intortus A95[3] - 29.9/71.9
8. S. intortus A95[5] - 14.2/69.6
9. Densosporites anulatus (Loose) Smith and Butterworth 1967 - A13[6] - 12.4/65'
10. D. anulatus Tetrad A95[24] - 2.3/69.4
11. D. anulatus A95[23] - R5.9/68.1
12. Densosporites sphaerotriangularis Kosanke 1950 A95[5] - 23.5/72.8
13. D. sphaerotriangularis A95[25] - R5.2/71.7
14. D. sphaerotriangularis A95[8] - 22.0/78.3
15. D. sphaerotriangularis A95[6] - R5.0/72.6
16. D. sphaerotriangularis A95[11] - 25.8/83.0
17. D. sphaerotriangularis SEM, Distal view, Preparation A95
18. Lycospora orbicula (Potonié and Kremp) Smith and Butterworth 1967 - A91[1] - 15.5/68.2
19. L. orbicula - A11[3] - 22.4/68.3
20. L. orbicula - A91[1] - 9.3/67.8
21. L. orbicula A91[1] - 6.6/67.8
22. L. orbicula Tetrad A79[2] - 5.7/74.6
23. Lycospora pellucida (Wicher) Schopf, Wilson and Bentall 1944 A104[3] - 18.8/7-.3
24. L. pellucida - A104[2] - 26.0/74.9
25. L. pellucida - A95[8] - 8.3/79.7
26. L. pellucida Tetrad A104[2] - 4.0/73.3
27. L. pellucida SEM, Distal view, Preparation A104
28. Lycospora pusilla (Ibrahim) Somers 1972 - A13[3] - 27.8/64.3
29. L. pusilla - A13[4] - 19.8/70.2
30. L. pusilla Tetrad A95[5] - 15.7/66.0
31. L. pusilla SEM, Distal view, Prepration A95
32. Lycospora rotunda (Bharadwaj) Somers 1972 A9[3] - 19.3/69.4
33. L. rotunda A9[10] - 5.4/68.4
34. L. rotunda Tetrad A139[1] - 1.5/69.6
35. Lycospora rugosa Schemel 1951 in Smith and Butterworth 1967 A11[2] - 9/72.7
36. L. rugosa - A11[3] - 10.8/66.8
37. Cristatisporites connexus Potonié and Kremp 1955 - A89[7] - 10.9/67
38. Cristatisporites connexus - A9[1] - 17.0/74.4
39. C. connexus - A9[2] - 27.8/75.1
40. Cristatisporites indignabundus - (Loose) Staplin and Jansonius 1964 - A128[1] - 7.1/65.2
41. C. indignabundus A9[10] - 17.0/74.4
42. C. indignabundus SEM, Distal view, Preparation A128

PLATE 16

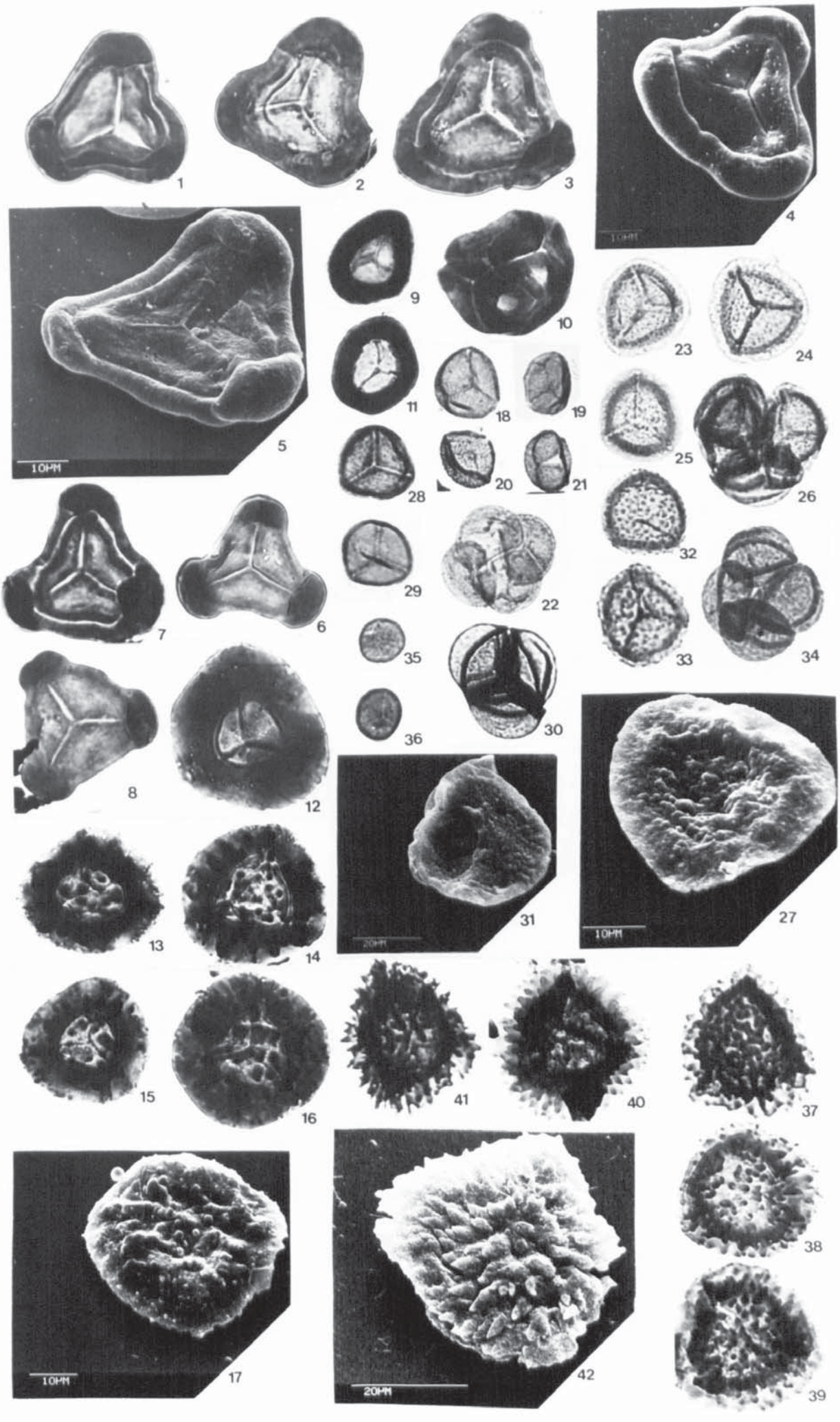

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Plate 17

1. Cirratriradiates saturni (Ibrahim) Schopf, Wilson and Bentall 1944 A9[5] - 2.0/84.1
2. C. saturni - A14[1] - 3.2/81.5
3. C. saturni equatorial view - A9[15] - 14.8/76.8
4. C. saturni - A95[12] - 4.1/75.4
5. C. saturni distal view, SEM, Preparation A9
6. C. saturni proximal view, SEM, Preparation A9
7. Cingulizonate loricatus (Loose) Butterworth and and Smith (in Butterworth et al 1964) A95[23] - 23,4/79.9
8. C. loricatus distal view - A95[17] - R2.4/79.9
9. C. loricatus - A20[4] - 24.8/64.1
10. Radiizonates striatus (Knox) Staplin and Jansonius 1964 A137[4] - 17.1/59.1
11. R. striatus - A137[2] - R5.9/70.1
12. R. striatus - A137[2] - 0.1/66.9
13. R. striatus - A137[2] - 0.0/77.2
14. R. striatus - A137a - 0.3/73.6
15. Radiizonates tenuis (Loose) Butterworth and Smith (in Butterworth et al 1964) A16a - 0.5/67.1
16. R. tenuis - A9[1] - 21.2/74.8
17. R. tenuis - A9[3] - 6.4/73.7
18. R. tenuis - A9[7] - 22.1/76.5
19. R. tenuis distal view, SEM, Prepration A9
20. Spencerisporites radiatus central body SEM, Preparation A89
21. Spencerisporites radiatus distal view SEM, Preparation A89
22. S. radiatus (Ibrahim) Felix and Parks 1959 A95[12] - 19.3/72.6 - X250
23. S. radiatus central body - A95[9] - 10.2/80.9

PLATE 17

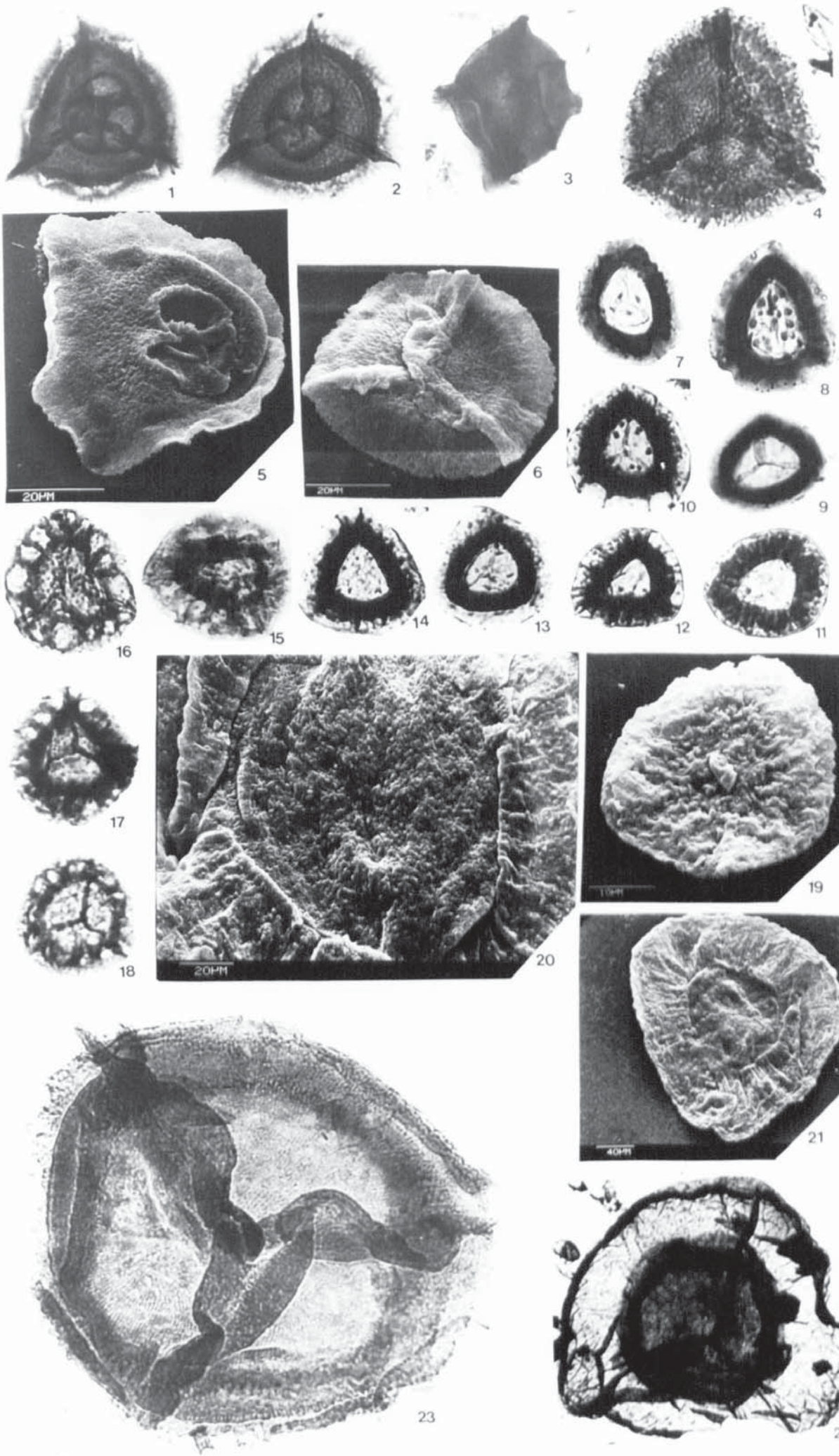

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Plate 18

1. Endosporites globiformis (Ibrahim) Schopf, Wilson and Bentall 1944 - $A79^{4}$ - 22.7/79.6
2. E. globiformis - $A104^{1}$ - 6.9/79.6
3. E. globiformis - $A104^{8}$ - 15.3/71.1
4. E. globiformis - $A71^{1}$ - 16.1/73.6
5. E. globiformis - $A79^{1}$ - 6.8/74.1
6. E. globiformis SEM, Distal view, Preparation A104
7. Endosporites staplinii - Gupta and Boozer 1969 $A95^{16}$ - 0.1/77.1
8. E. staplinii - $A95^{23}$ - 7.5/75.2
9. E. staplinii - $A95^{18}$ - 11.4/69.6
10. E. staplinii SEM, Proximal view, Preparation A95
11. Endosporites zonalis (Loose) Knox 1950 $A95^{11}$ - 18.1/76.3
12. E. zonalis - $A95^{16}$ - 0.0/68.0
13. E. zonalis - $A9^{13}$ - 3.9/69.4
14. E. zonalis SEM, Distal view, Preparation A95
15. Schulzospora rara Kosanke 1950 $A132^{2}$ - 29.4/76.5
16. S. rara -$A130^{2}$ - 24.7/79.9
17. S. rara - $A137^{2}$ - 20.0/61.8
18. S. rara - SEM, Distal view, Preparation A128
19. Schulzospora cf. rara Kosanke 1950 $A135^{2}$ - R8.5/72.1
20. S. cf. rara $A128^{2}$ - 16.4/68.3

PLATE 18

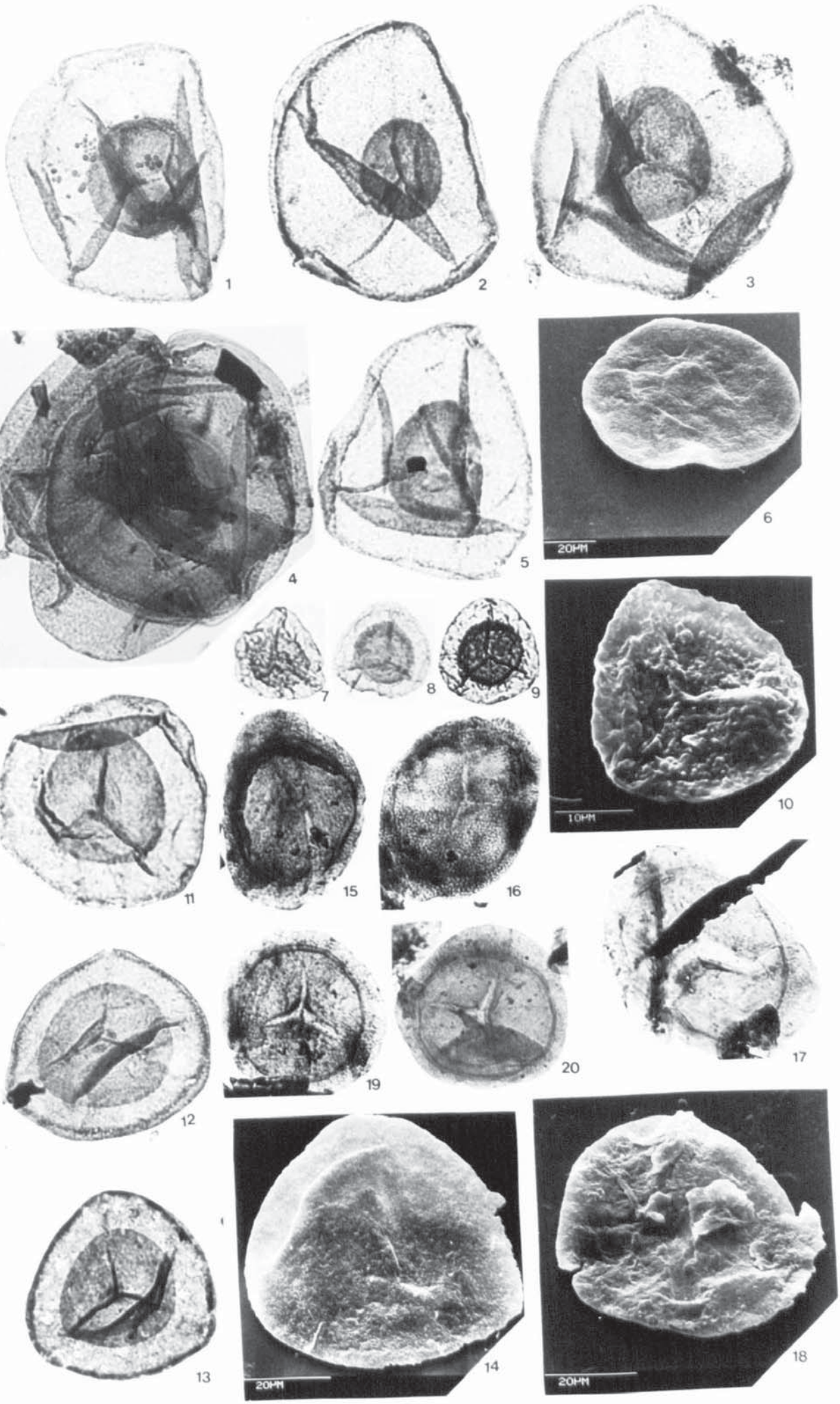


Plate 19

1. Alatisporites hoffmeisterii Morgan 1955 $A95^{5}$ - 0.0/72.3
2. A. hoffmeisterii - $A95^{22}$ - 14.5/74.6
3. A. hoffmeisterii - $A95^{22}$ - 1.9/77.5
4. A. hoffmesiterii SEM, Distal view, Preparation A9
5. Alatisporites pustulatus Ibrahim 1932 $A95^{25}$ - 26.2/81.2
6. A. pustulatus - $A9^{5}$ - 20.2/78.4
7. A. pustulatus $A129^{2}$ - 8.2/75.9
8. A. pustulatus $A89^{7}$ - 29.8/70.6
9. A. pustulatus SEM, Proximal view, Preparation A95
10. Laevigatosporites dunkardensis - Clendening 1970 $A95^{23}$ - 10.1/62
11. L. dunkardensis - $A116^{2}$ - 30.4/70.2
12. L. dunkardensis - $A79^{1}$ - 19.1/63.3
13. L. dunkardensis - $A89^{4}$ - 23.8/72.5
14. Laevigatosporites minor Loose 1934 $A95^{11}$ - 18.3/83.3
15. L. minor - $A9^{3}$ - 7.5/70.7
16. L. minor SEM, Preparation A9
17. Laevigatosporites striatus Alpern 1959 $A95^{15}$ - R4.1/69.9
18. L. striatus - $A95^{15}$ - 18.0/69.5
19. L. striatus - $A95^{8}$ - 15.9/75.8
20. L. striatus - $A95^{19}$ - 6.9/79.5
21. L. striatus - $A95^{16}$ - 28.0/77.3
22. L. striatus SEM, Distal view, Preparation A95
23. Laevigatosporites vulgaris Ibrahim 1933 $A89^{8}$ - 29.8/72.2
24. L. vulgaris - $A9^{3}$ - 9.3/70.5

PLATE 19

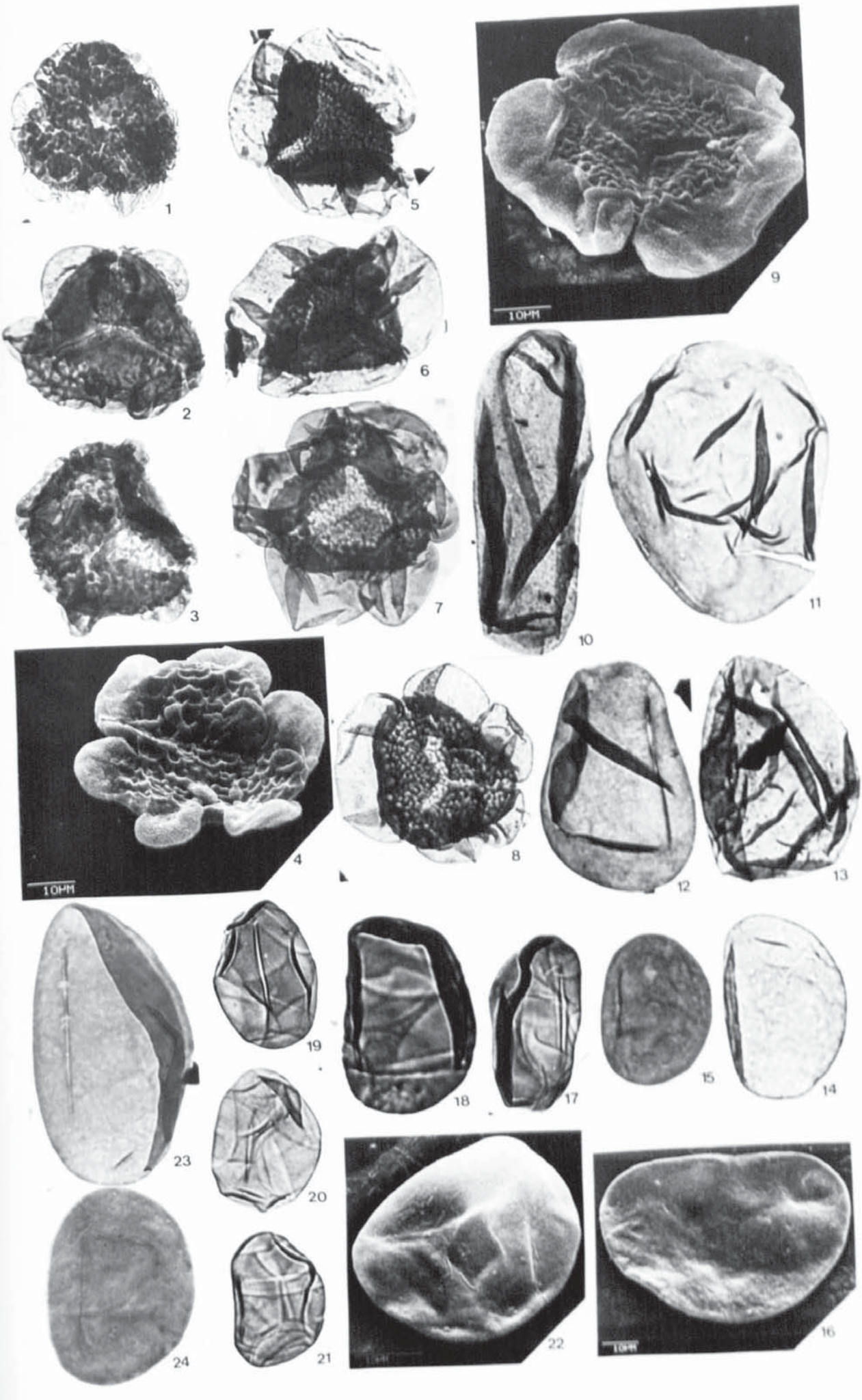

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Plate 20

1. Punctatosporites minutus Ibrahim 1933 A79[4] - 11.8/74.7
2. P. minutus - A79[2] - 22.8/58.1
3. P. minutus - A79[4] - 16.5/77.3
4. P. minutus - A79[1] - 17.5/63.7
5. Vestispora costata (Balme) Spode in Smith and Butterworth 1967 A128[2] - 4.9/76.3
6. V. costata - A138[3] - 2.0/78.4
7. V. costata - A104[3] - 27.0/80.2
8. V. costata - A129[2] - R3.5/69.6
9. V. costata - A131a - R1.0/68.3
10. V. costata - A138[5] - 25.6/73.6
11. Vestispora laevigata - Wilson and Venkatachala 1963 A138[1] - 27.4/74.2
12. V. laevigata - A89[8] - R0.2/67.3
13. V. laevigata - A79[4] - 22.6/72.0
14. V. laevigata SEM, Prepration A79
15. V. laevigata detached operculum - A79[2] - R0.5/72.8
16. Vestispora luminata Ravn 1979, SEM, Preparation A11
17. V. luminata - A11[2] - 6.9/71.4
18. V. luminata - A104[3] - 19.0/68.4
19. V. luminata - A139[1] - 6.7/81.8
20. Vestispora pseudoreticulata Spode in Smith and Butterworth 1967 A104[4] - 6.8/68
21. V. pseudoreticulata detached operculum A104[5] - 3.1/75.5
22. V. pseudoreticulata - A79[2] - 5.9/77.2
23. V. pseudoreticulata - A79[2] - 7.8/85.0
24. V. pseudoreticulata - SEM Preparation A79
25. V. pseudoreticulata SEM, detached operculum, Preparation A79
26. V. pseudoreticulata SEM, Prepration A79

PLATE 20

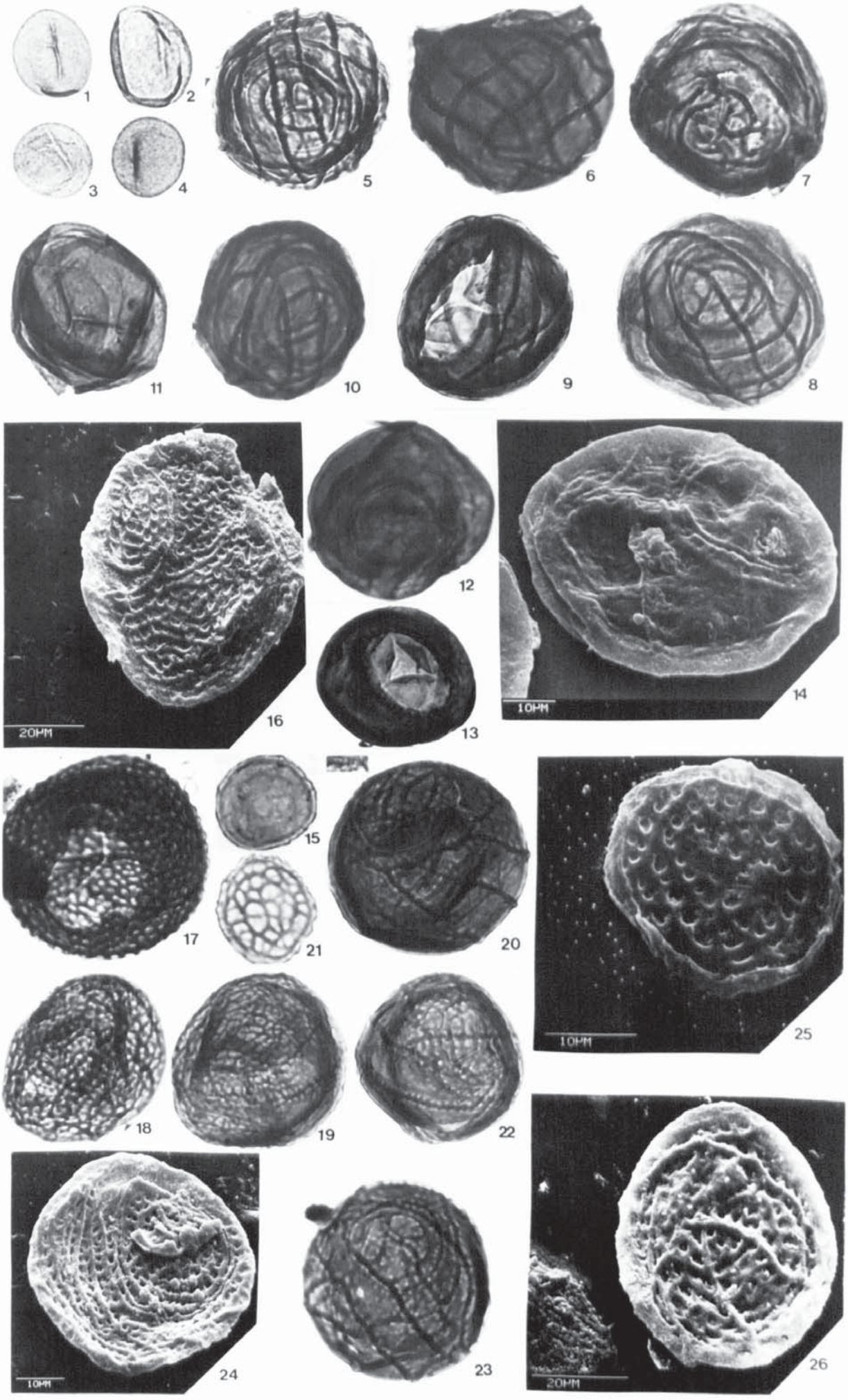

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Plate 21

1. Vestispora tortuosa (Balme) Spode in Smith and Butterworth 1967 A138[6] - 21.6/66.2
2. V. tortuosa - A129[3] - R0.5/71.4
3. V. tortuosa - A138a - 12.6/71.6
4. V. tortuosa - A125[2] - R1.3/70.7
5. V. tortuosa - A128[2] - 0.1/68.8
6. V. tortuosa SEM, Preparation A128
7. V. tortuosa SEM, Preparation A128
8. Fabasporites pallidus Sullivan 1964 A95[10] - 17.5/70.8
9. F. pallidus - Sullivan A9[14] - 5.3/84.2
10. F. pallidus - A135[2] - R0.1/70.1
11. Florinites cf. florini - Imgrund 1960 in Smith and Butterworth 1960 - A11[2] - 22.4/80.1
12. F. cf. florini - A113[3] - 26.1/65.1
13. F. cf. florini - A95[25] - R3.8/75.5
14. F. cf. florini SEM, Preparation A95
15. F. cf. florini SEM, Preparation A95
16. Florinites mediapudens - (Loose) Potonié and Kremp 1956 - A93[3] - 21.7/68.7
17. F. mediapudens - A95[21] - 0.0/78.3
18. F. mediapudens SEM, Prepration A89
19. F. mediapudens SEM, Preparation A95
20. F. mediapudens SEM, Preparation A89
21. Florinites millotti Butterworth and Williams 1954 A129[2] - 5.6/66.5
22. F. millotti - A89[4] - 13.5/77.8
23. F. millotti - A144[2] - 11.9/68.1
24. F. millotti - A104[8] - 27.1/63.8
25. F. millotti SEM, Preparation A144

PLATE 21

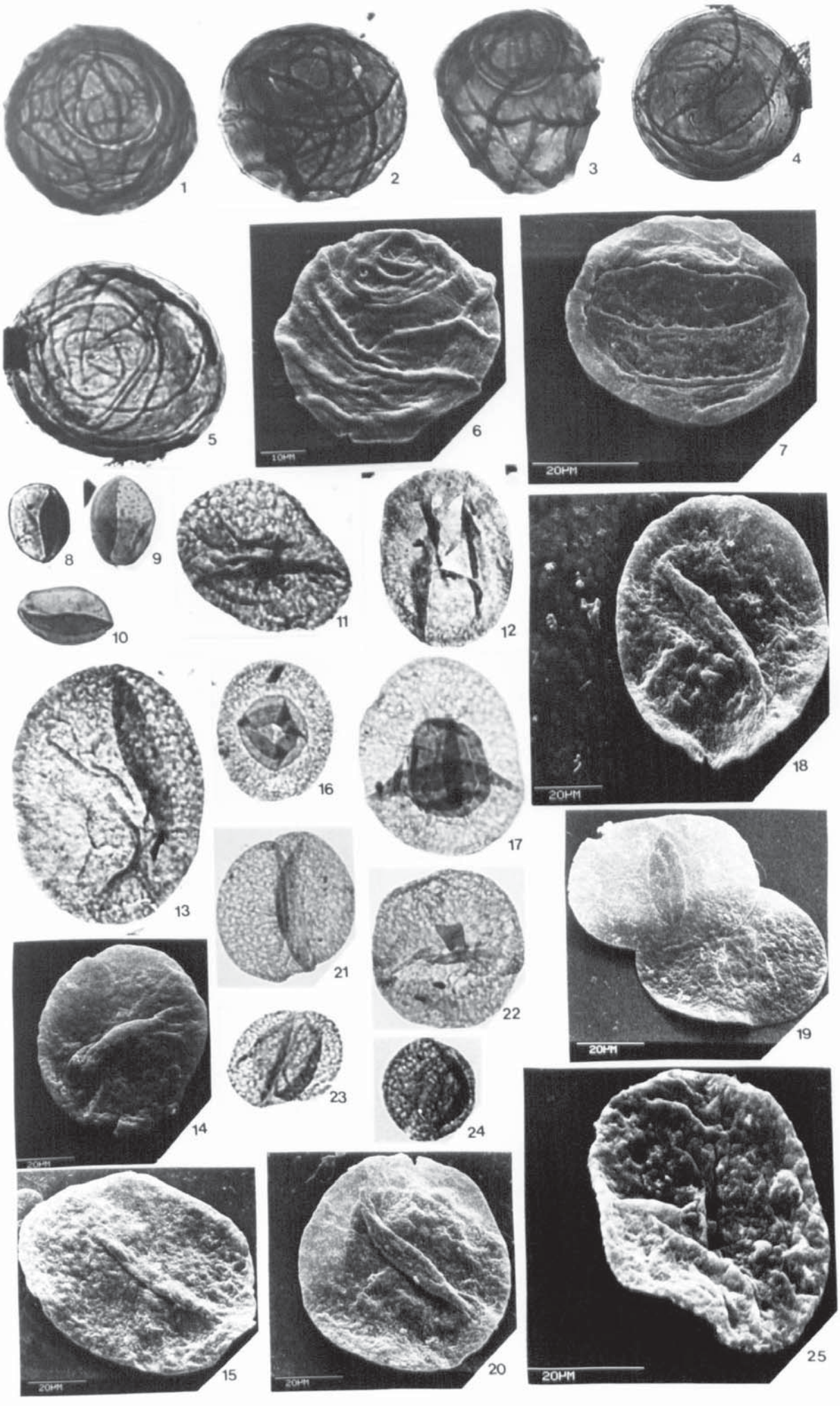

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Plate 22

1. Florinites pumicosus (Ibrahim) Schopf, Wilson and Bentall 1944 - $A79^{3}$ - 3.2/73.5
2. F. pumicosus - $A104^{1}$ - 12.7/73.9
3. F. pumicosus - $A104^{4}$ - 15.5/71.6
4. F. pumicosus - SEM, Prepration A89
5. Florinites similis Kosanke 1950 $A89_{2}$ - 28.5/83.4
6. F. similis - $A144^{2}$ - 16.8/60.0
7. F. similis SEM, Preparation A146
8. Florinites triletus Kosanke 1950 $A135^{1}$ - R2.0/69.9
9. F. triletus - $A89^{9}$ - R0.5/77.6
10. Florinites visendus (Ibrahim) Schopf, Wilson and Bentall 1944 - $A129^{4}$ - 20.8/66.6
11. F. visendus - $A104^{3}$ - 6.7/78.4
12. F. visendus SEM, Preparation A89

PLATE 22

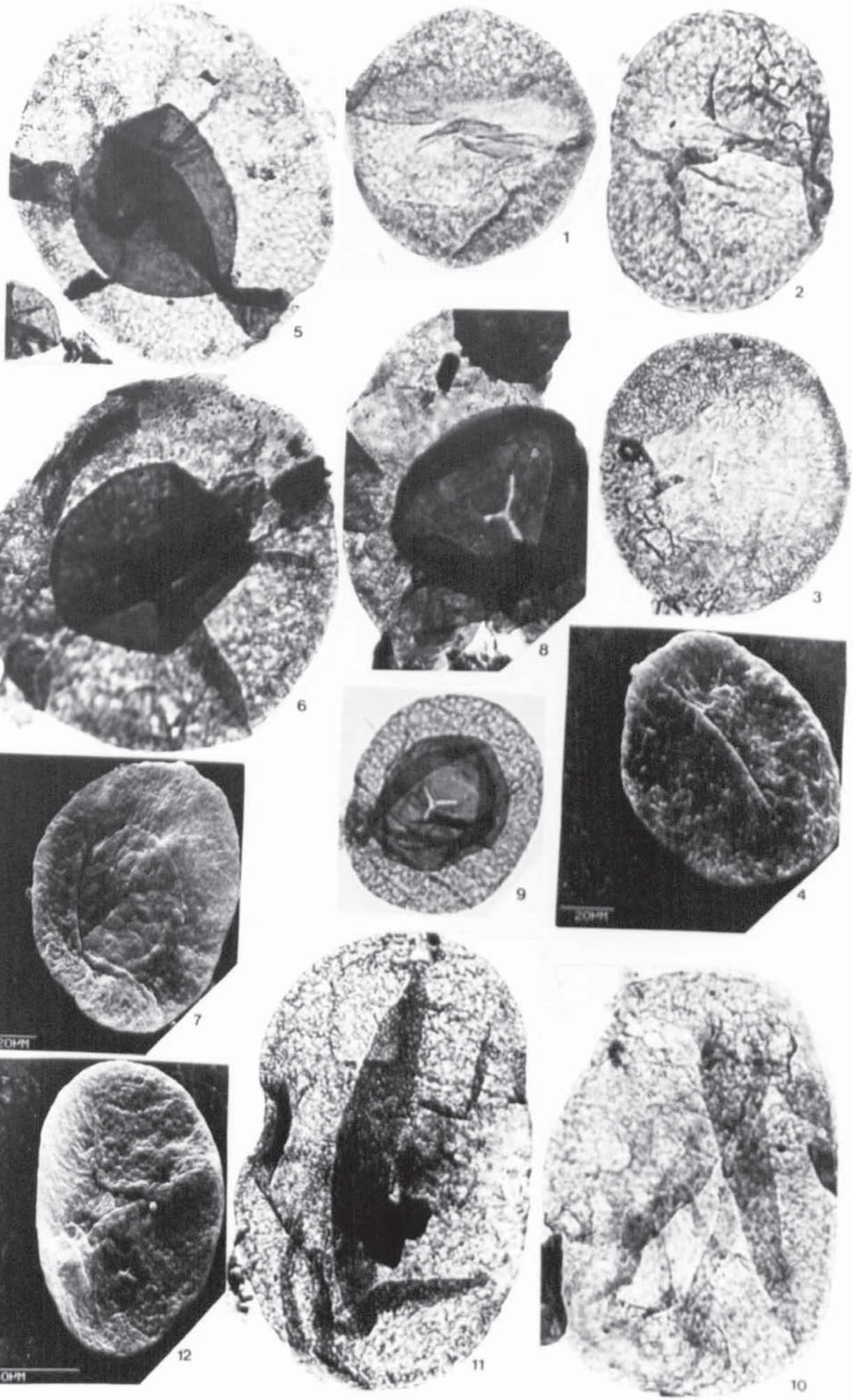


Plate 23

1. Wilsonites cf. delicatus Kosanke 1950 in Smith and Butterworth 1967 A84[1] - R11.2/80.1
2. W. cf. delicatus -A138[3] - 18.5/71.5
3. W. cf. delicatus - A138[1] - 21.2/77.1
4. W. cf. delicatus - A104[3] - 18.9/70.6
5. W. cf. delicatus - A104[7] - 22.2/63.4
6. Paleospora fragila Habib 1966 A95[10] - 25/68.0
7. P. fragila - A95[11] - 12.2/76.3
8. P. fragila - A95[24] - 10.2/78.3
9. P. fragila - A95[25] - 13.9/72.2
10. P. fragila - SEM, Preparation A95
11. P. fragila - SEM, Preparation A95
12. Potonieisporites elegans (Wilson and Kosanke) Habib 1966 - A128[2] - 28.8/67.2
13. P. elegans - A146a - 13.4/82.1
14. Potonieisporites sp.A. - A95[24] - 13.3/69.4
15. P. sp.A. - A128a - 23.2/66.8
16. P. sp.A. - A138[2] - 19.6/77.8

PLATE 23

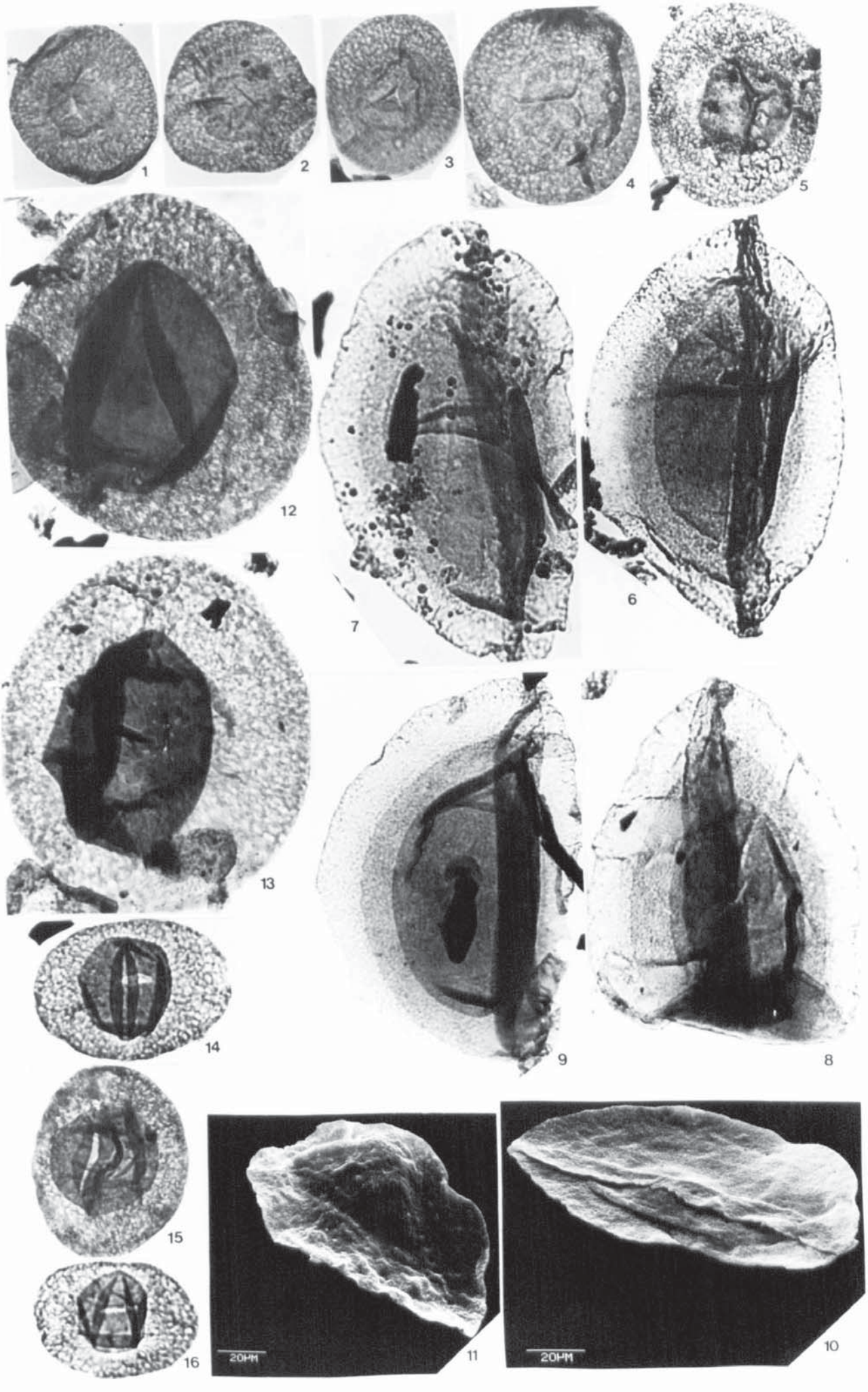
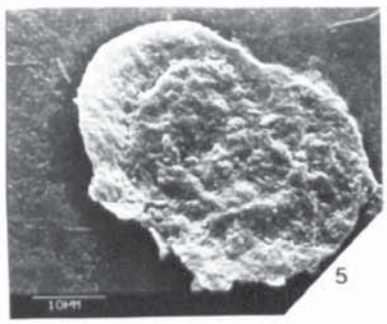


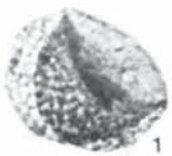
Plate 24

1. Pityosporites westphalensis Williams 1955 A104[3] - 10.5/83.5
2. P. westphalensis - A11[2] -15.3/70.7
3. P. westphalensis - A104[3] - 18.3/80.4
4. P. westphalensis - A144[2] - 24.5/74.0
5. P. westphalensis SEM, Preparation A9
6. Schopfipollenites ellipsoides (Ibrahim) Potonie and Kremp 1954 - A139[2] - 22.1/69.1
7. S. ellipsoides - A95[9] - 11.7/72.5
8. S. ellipsoides SEM, Preparation A95
9. Schopfipollenites ellipsoides var. corporeus Neves 1961 - A95[9] - 21.8/75.3
10. S. ellipsoides var. corporeus - A95[11] - 15.7/78.6
11. Spore type A. - A139[1] - 1.3/72.5
12. S. type A. - A135[2] - R7.7/70.1
13. S. type A. - A135a - R6.1/76.2
14. Spore type B. - A11[3] - 4.5/67.3
15. S. type B. - A11[3] - 28.7/68.6
16. Spore type B. - A133[1] - 0.2/68.5
17. Spore type B. - A13[1] - 26.2/64.7

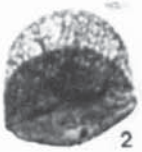
PLATE 24



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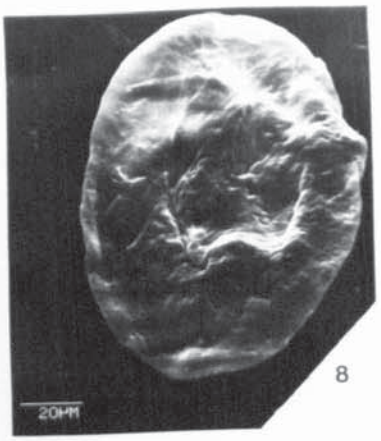
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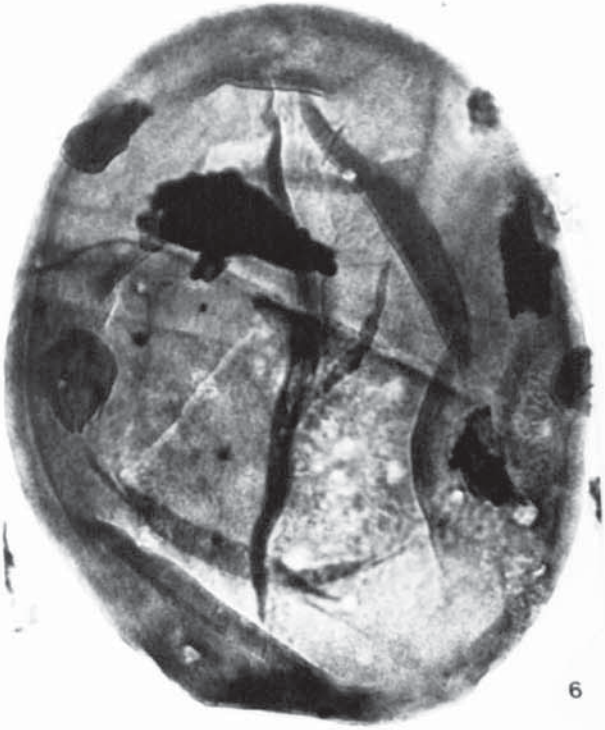
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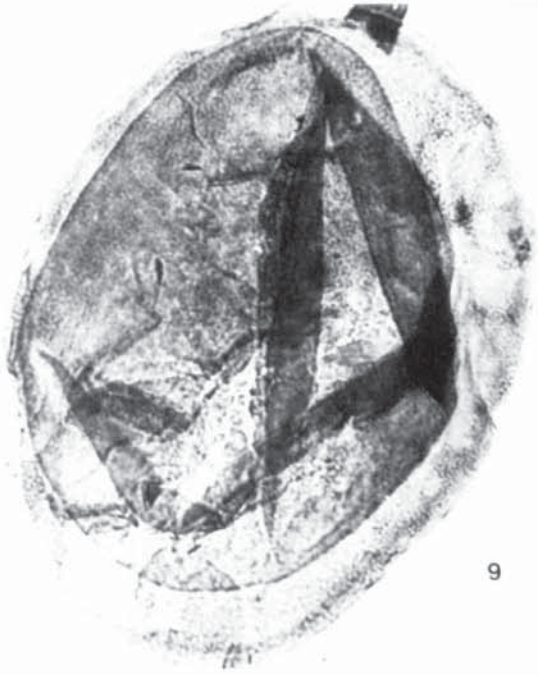
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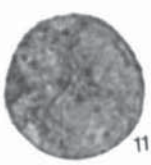
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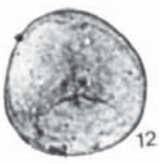
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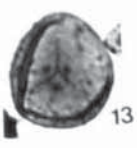
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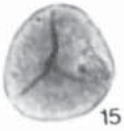
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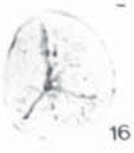
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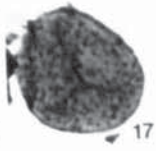
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