A palynological investigation of the Scalby Formation (Ravenscar Group, Middle Jurassic) and adjacent strata from the Cleveland Basin, north east Yorkshire.

Nicholas Mark Hogg
Department of Earth Sciences
University of Sheffield

Submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy

February 1993

CONTAINS

PULLOUTS

A palynological investigation of the Scalby Formation (Ravenscar Group, Middle Jurassic) and adjacent strata from the Cleveland Basin, north east Yorkshire.

Nicholas Mark Hogg
Department of Earth Sciences
University of Sheffield

Summary

One hundred and forty six samples collected from the Scalby Formation (Ravenscar Group, Middle Jurassic) and adjacent strata from eight separate outcrops in North East Yorkshire have been analysed for their palynological content. Diverse marine and non-marine palynomorphs were recovered from the majority of samples. Three new genera of spores and one new acritarch genus are formally described, eighteen new species of spores, six new species of acritarchs and eight new species of dinoflagellate cysts are described. In addition, four new combinations of spore species and three acritarch species are proposed.

Of the non-marine taxa, five spore species appear to have their range bases in the Bathonian.

An age for a substantial part of the Long Nab Member (Scalby Formation) of *discus* Zone (Upper Bathonian) has been proposed on the basis of the occurrence of 'key' dinoflagellate cyst species. Two 'key' dinoflagellate cyst species, *Ambonisphaera calloviana* Fensome 1979 and *Tabulodinium senarium* Dodekova 1990, are recorded for the first time in UK strata.

The results reinterpret the timing of deposition of the Scalby Formation and its relationship with the adjacent Scarborough and Cornbrash Formations. A revised correlation of the stratigraphy of the region has been proposed and the formations position within a sequence stratigraphic framework was considered.

The identification of probable zygospores of Zygnemataceae (Chlorophyceae) has been used in palaeoenvironmental interpretations of several of the outcrop sections. The application of assemblage associations was found to be of use in providing a broad overview of the assemblage characteristics for the majority of sections. Lateral correlation of sections was attempted following the results of the associations and further considerations.

Acknowledgements

Principally, the author would like to thank Dr Ted Spinner for advice and discussion over the three years of the project. Additionally Dr Dave Jolley has added useful comments regarding a plethora of problems but in particular the dreaded Tilia data processing program. Dr Martin Whyte accompanied the author to the Yons Nab section and his experience during the visit was greatly welcomed. Likewise Mr Duncan McLean stood back and shouted useful remarks during the collecting of the Talbot Wood and Crook Ness sections. Other people in the Department of Earth Sciences to whom the author feels indebted include the Head of Department, Professor Alan Spears, Mr Paul Higham, Miss Denise Darwin, Mr Steve Ellin, Mr Mike Cooper, Miss Pat Mellor and Mr Tony Loy.

At Shell Mex House, Dr Tim Potter and Dr Michel Gaillard have provided welcomed support during the annual visitations. This research was sponsored by a grant from Shell Expro, the receipt of which is greatly acknowledged.

Dr Jan Alexander at University College, Cardiff has continued welcomed correspondence over the three years and her comments were well heeded. Dr J.K. Wright at Royal Holloway and Bedford New College provided useful information concerning the outcrop of the Scalby Formation in the western part of the Cleveland Basin.

Paralleling the authors research in the department, Mr Sandy (Eeer) Smith and Mr Mike (Degsy) Snape have been doing their own thing (palynological research?) and their comments, humour and tales of sexual endeavour have never failed to instill confidence in the author; their company at Rother Valley Park will be sorely missed. Dr Robin Scott has ceaselessly shown up when he was needed and his craze for grammatical correctedness was extremely welcomed. C.P. Mascall provided the loan of a Macintosh computer, picnics under the fountains in the Generalife and company in remote Alpujarran hill villages.

Most of all, my parents are owed a great deal from me, for although their financial support has rightly dried up, their encouragement and love never ceases. It is to them that I dedicate this work.

Contents

Chapter 4

List of figures

List of Tables

Introduction.

The rocks comprising the Jurassic System in northeast Yorkshire dominate the coastline of the present day North Sea from Filey Bay in the south to Teeside in the north and crop out inland westwards to the Hambleton Hills. In the southwest the outcrop thins to a narrow strip which continues southwards via Market Weighton and South Cave into Lincolnshire (Fig. 1.1, 1.2). The present day outcrop pattern is a function of basin inversion during the Tertiary and subsequent erosion.

Strata from the Rhaetian Stage to Upper Kimmeridgian were deposited as syn-rift sediments in a subsiding half graben termed the Cleveland Basin (Dingle 1971). Due to erosion, no evidence remains in western and northern exposures to circumscribe the boundaries of the basin. To the south the boundary is defined by the Market Weighton Block, which acted as a buoyant northern hinge line to the East Midlands Shelf for much of the Jurassic System (Kent 1955)(Fig.1.3). This hinge is thought to link to the Craven Fault System in the west via a subsurface fault system, whose present day surface expression manifests itself as the Cretaceous 'crush zone' at Flamborough on the coast (Kent 1974). To the east the hinge line has been correlated with a tectonic boundary which crosses the southern North Sea through the Dutch sector and through Holland to link up with the Rhine Valley (Kent *op. cit.*). Likewise, seismic surveys suggest that the Cleveland Basin links to the east with the Sole Pit Basin which in turn links with the Southern North Sea Basin (Fig. 1.4). The location of the boundaries of the Cleveland Basin was considered by Kent (1974) to be controlled by deep-seated structures which were active during the Carboniferous. Indeed the inverted Cleveland Basin is considered to be located over the older Carboniferous Cleveland Basin whilst the East Midlands Shelf is considered to be coincident with a Carboniferous shelf area.

During the Lower Jurassic, accommodation potential increased in the Cleveland Basin following the world-wide Liassic transgression which established a shallow epicontinental sea over much of northwest Europe. The seas reached a maximum depth of 100 to 200 metres in the basin and deposition of marine mudstones dominated much of the Lower Jurassic (Hemingway 1974). Two periods of infilling of the basin are evident by the widespread occurrence of shallower water sandstone shoals overlying the mudstones at two levels within the sequence. During the latest Toarcian, the basin appears to have been affected by a shallowing and erosive event coincident with the 'Mid Cimmerian event' of Underhill & Partington (in press). Thus a period of doming resulting from the emplacement of a broad based mantle plume in the region of the central North Sea triple junction to the north of the Cleveland Basin appeared to leave a strong signature within the basin.

At a time approximating to the Lower / Middle Jurassic boundary, a complex group of sediments were laid down, firstly in hollows overlying the eroded surface of the Lower Jurassic, then more evenly over the whole basin. Onto these sediments encroached the first of four outbuildings of terrigenous sediment from the north which

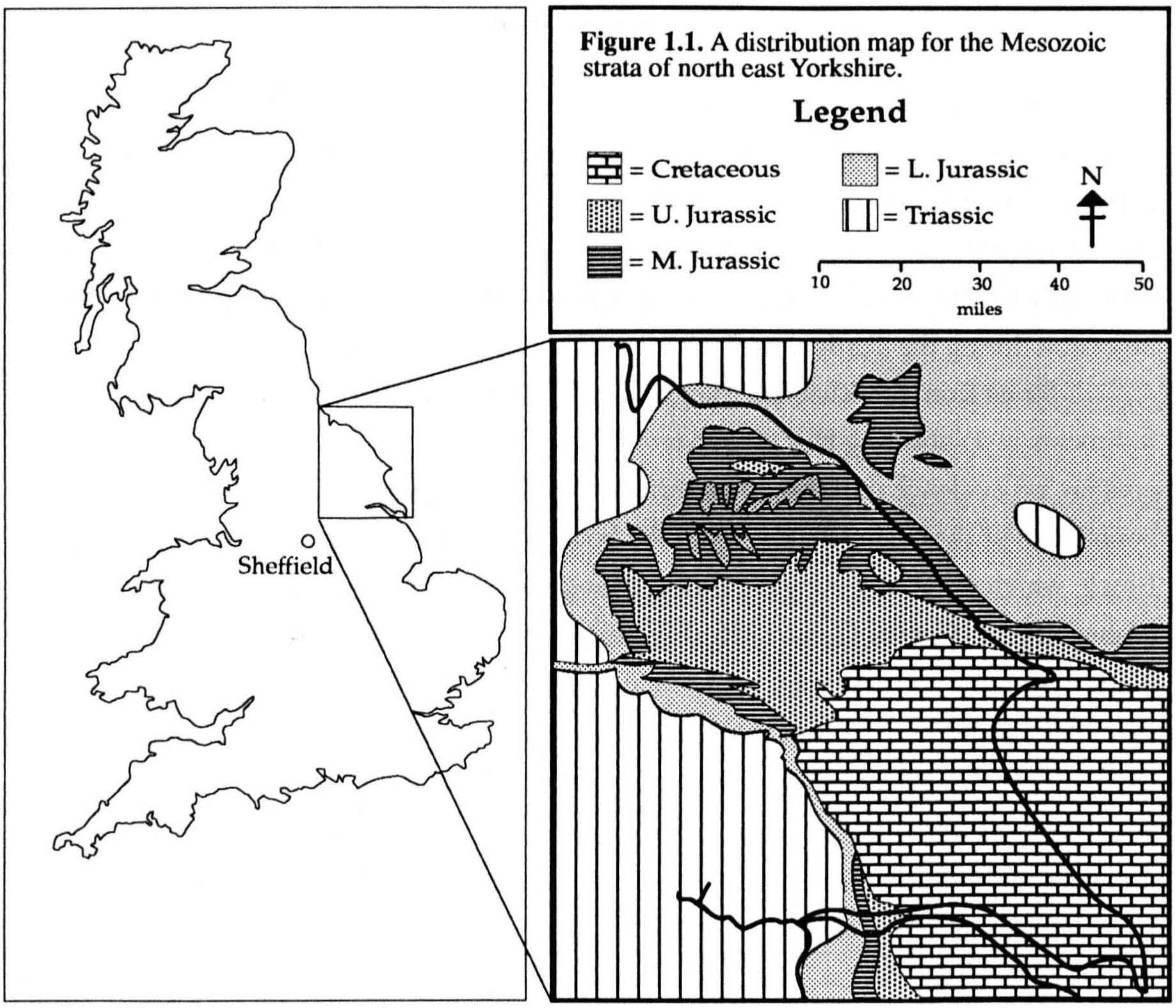


Figure 1.1. A distribution map for the Mesozoic strata of north east Yorkshire.

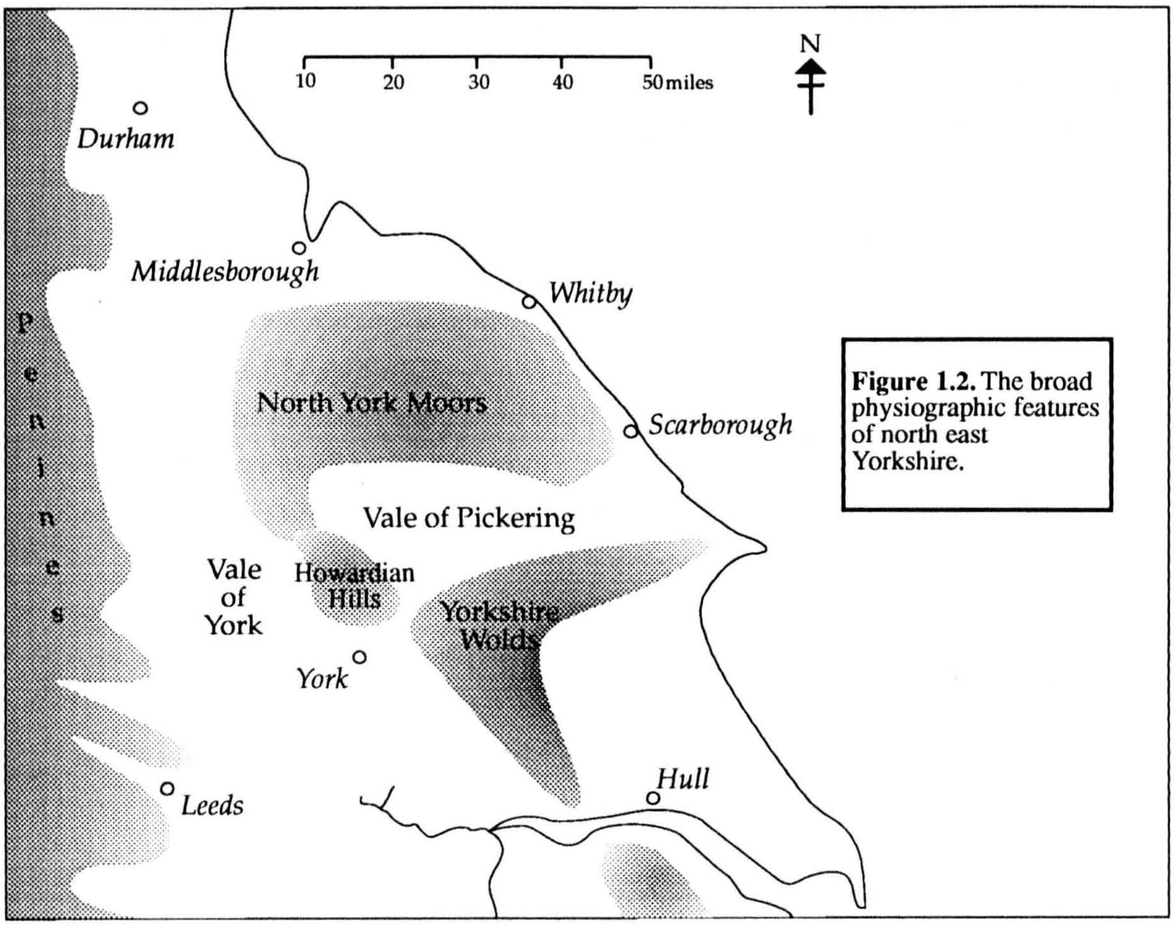


Figure 1.2. The broad physiographic features of north east Yorkshire.

characterised the paralic nature of much of the Middle Jurassic Epoch. For some 15 million years a dynamic interaction driven by tectono-eustacy took place between sediment outbuilding, largely in the form of deltas, and marine encroachment. A lush subtropical terrestrial vegetation is recorded in the deltaic deposits and whilst bivalve and brachiopod shells are numerous in the marine formations, only during one period, the Bajocian Stage, did the sea establish sufficiently normal open marine conditions suitable for the habitation of ammonites (Hemingway 1974).

The pan-European transgression at the base of the Callovian re-submerged the Cleveland Basin and resulted in deposition of shallow marine clastic and biogenic sediments. Full marine connections were re-established with neighbouring regions to the south. These conditions were maintained for much of the Callovian Stage although interrupted several times by periods of syn-sedimentary tectonism. Towards the end of the Callovian, the sea deepened and deposits indicative of an outer shelf setting were laid down during the Lower Oxfordian. Basin infilling is once again attested to by the gradual shallowing nature of the sediments throughout the Lower and Middle Oxfordian. Transgression at the top of the Oxfordian re-introduced a deeper shelf setting to the basin. This was maintained into the Kimmeridgian Stage. The youngest Jurassic sediments preserved in northeast Yorkshire at present are Upper Kimmeridgian in age (Cope *et al.* 1980). Whether Portlandian sediments were deposited remains a speculation.

The magnificent coastal exposures of the Jurassic have brought the regional geology to the attention of scientists for more than 150 years. York, Scarborough and Whitby became intellectual centres of considerable standing during the early 19th century. The geological accounts of the coastline by Young (1817), Young & Bird (1822), Phillips (1829) and Simpson (1843) attest to this. William Smith spent some time in the region and mapped the Hackness Hills between 1828 and 1834. His nephew, John Phillips, continued Smith's interests, completing the two volumed "Illustrations of the Geology of Yorkshire" in 1836. W.C. Williamson first came to light as an illustrator for Lindley & Hutton's work on the Carboniferous and Jurassic floras of the region. However throughout his later career he continued to research on Middle Jurassic palaeobotany (Williamson 1896).

The Geological Survey first mapped the region between 1845 and 1882, with subsequent publications of maps and memoirs between 1852 and 1892. Notable within the publications are the memoirs of Fox-Strangways (1892) on the Jurassic strata. The first catalogue of the Jurassic flora was that of Seward (1900) who acknowledged the contribution of Williamson (*op. cit.*) amongst others. Following the First World War, research resumed and the publication of Black (1929) is notable for its ecological interpretation of the Middle Jurassic plant beds. Broader topics are covered in Kendall & Wroot (1924) and the regional geology publication of the Institute of Geological Sciences

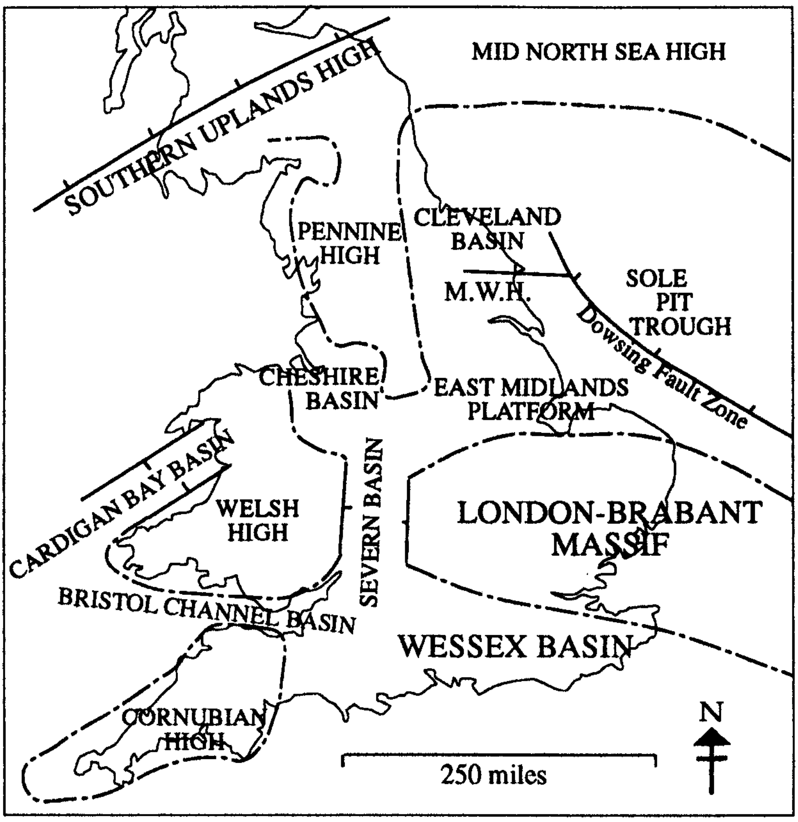


Figure 1.3. General structural features controlling Jurassic sedimentation (after Hallam 1992): M.W.H. = Market Weighton High; ticks mark the downthrow side of faults.

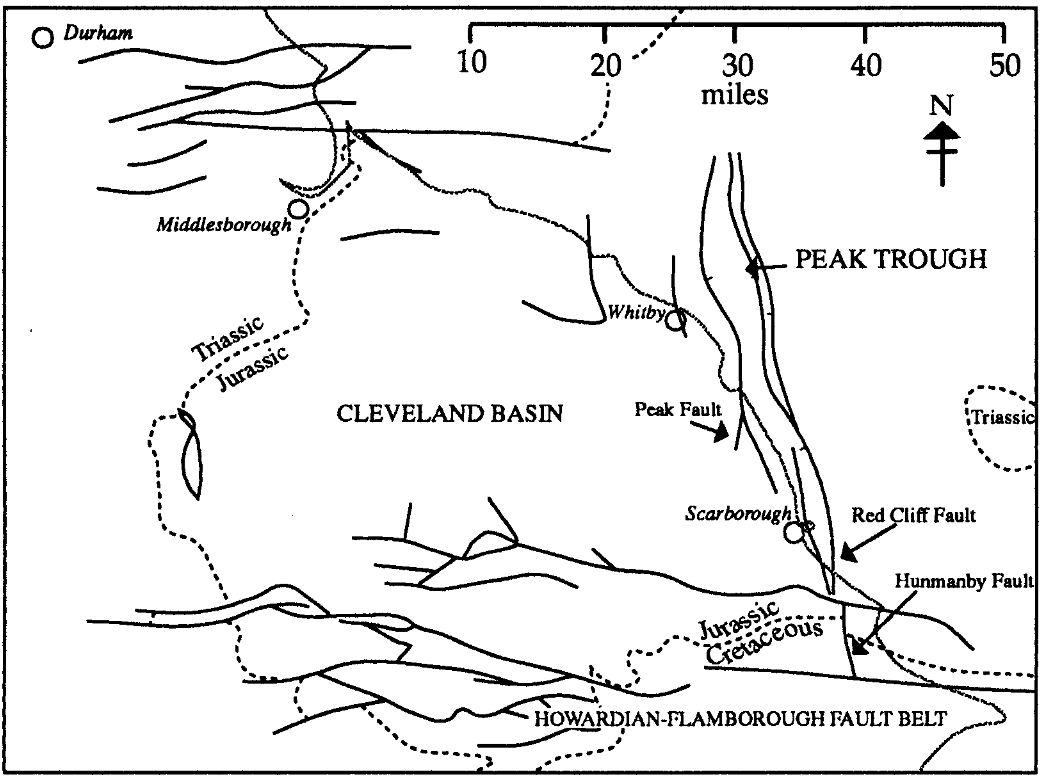


Figure 1.4. Structural setting of the Cleveland Basin (after Milsom & Rawson 1989): solid lines represent faults; those with ticks indicate the downthrow side. Note the converging boundaries of the Triassic / Jurassic and Jurassic / Cretaceous as the Market Weighton High is approached to the south of the map.

(1948). More recently an overview of Yorkshire geology may be found in Rayner & Hemingway (1974).

Over the last 30 years, publications have concentrated on more specific aspects of Yorkshire Geology. Pertinent to the present study are the lithostratigraphic revisions of Hemingway & Knox (1973), the sedimentological studies of Nami (1976), Nami & Leeder (1978), Livera (1981), Livera & Leeder (1981) and Alexander (1986a, 1986b, 1989, 1992a, 1992b), the palynofacies studies of Hancock & Fisher (1981) and Fisher & Hancock (1985) and the early palynological studies of Couper (1958) and more recently Riding & Wright (1989).

Detailed work on the palynofloras of the Middle Jurassic remains to be published. The present study was initiated to investigate the potential of non-marine palynology in biostratigraphic zonation. The comments of Couper (1958, p. 78) that " ... the following beds appear to be distinguishable from their spore and pollen floras: Lias, Lower Deltaic, Sycarham Beds, Gristhorpe Beds (Middle Deltaic), Upper Deltaic (Middle Deltaic), Oxford Clay, Purbeck Beds, Wealden and Lower Greensand ", remain as the basic statement of our knowledge of the palynofloras. It is an aim of the research to take into account the mechanisms in operation during the deposition of the Scalby Formation in the light of 35 years of geological research in Yorkshire since the work of Couper. Furthermore it is hoped that the study may help to resolve present disagreements as to the timing of a considerable hiatus apparent within the paralic sediments of the Middle Jurassic in the Cleveland Basin.

Previous work pertinent to this study is reviewed in the remainder of Chapter 1, an outline of the methods of investigation is covered in Chapter 2, the systematic palynology is dealt with in Chapter 3 and the results, discussion and conclusions will be presented in Chapter 4.

1.1. Middle Jurassic Lithostratigraphy and Biostratigraphy of the Cleveland Basin

The lithostratigraphic nomenclature adopted in the present study follows that of Cope *et al.* (1980) which is largely based on Hemingway & Knox (1973) with some modifications based on prior usage. The terms introduced by Fox-Strangways (1892) and Hemingway (1949) did not fulfil the recommendations of the Stratigraphy Committee of the Geological Society of London (Harland *et al.* 1972) and thus the genetic nomenclature of both authors was replaced by neutral nomenclature of geographical derivation (Fig. 1.5).

The traditional biostratigraphic zonation of the Middle Jurassic based on ammonites is difficult to apply in the Aalenian, Bajocian and Bathonian of the Cleveland Basin as only the Scarborough Formation has yielded zonal forms. Bate (1959, 1965, 1967) detailed the ostracode zonation of the Ellerbeck Formation, Millepore and Yons Nab Beds and the Scarborough Formation. On the basis of this work, Bate compared the formations with contemporary deposits south of Market Weighton. Woollam & Riding (1983) presented a palynological zonation of the Jurassic in the Cleveland Basin which was supplemented by Riding & Wright (1989) and Gowland & Riding (1991).The Dogger Formation, Ravenscar Group and the Cornbrash Formation are reviewed below.

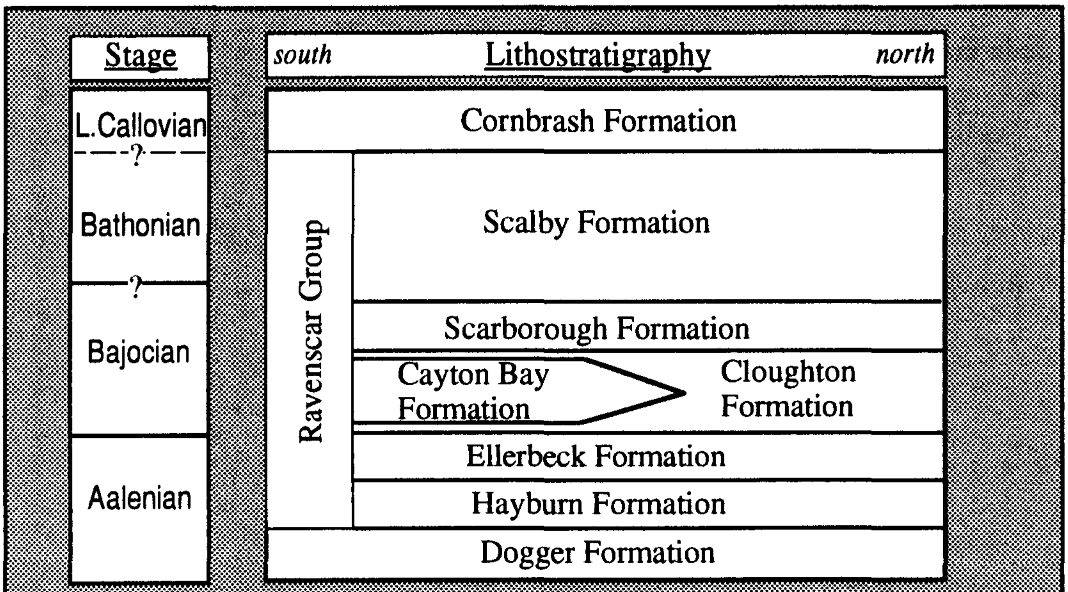


Figure 1.5. Aalenian to Lower Callovian Lithostratigraphy of the Cleveland Basin (after Cope *et al.* 1980).

The Dogger Formation.

The Dogger Formation is a heterolithic formation reflecting a great variation in facies at the time of deposition. It does, however, exhibit a consistently high iron content regardless of facies.

"Magnetite oolites" and "bioclastic oolites" appear to have been deposited in troughs and channels eroded into the Lias (Hemingway 1974). These localised facies are overlain by a series of Dogger Formation facies whose bases mark the 'Mid Cimmerian' unconformity over much of the area (Hemingway 1974, Underhill & Partington in press). In the southeast, the Whitby facies is a sideritic sandstone. In the central region, the Ajalon facies is a chamositic and oolitic sandstone which becomes finer and well bedded to the northwest with the development of shales (the Danby facies). Additionally, coral-rich limestones and conglomerates in the west suggest the proximity of a shoreline.

Hemingway (*op. cit.*) gave a *murchisonae* Zone age for the youngest beds and also for black shales overlying the lower beds. Cope *et al.* (*op. cit.*) recorded *opalinum* Zone age ammonites in an ironstone lithology from beneath the Danby facies and *murchisonae* Zone or possibly *haugi* Subzone age from a similar lithology, indicating a considerable time span represented within the Dogger Formation.

Knox *et al.*(1990) suggested that the formation may be divided into two parts, each representing different subsidence patterns. The sediments of *opalinum* Zone age are regarded as genetically related to the older Lias Group whilst those of *murchisonae* Zone age share affinities with the overlying Middle Jurassic sediments.

The Ravenscar Group.

The Ravenscar Group encompasses the remainder of the Aalenian rocks and the Bajocian and Bathonian rocks cropping out in the Cleveland Basin. Hemingway and Knox (1973) gave the following reasons for the separation of the Ravenscar Group from the Dogger Formation;

1) The Dogger Formation spans a relatively long period of time compared to other formations (*i.e.* it is condensed).

2) The subsidence pattern of the Dogger Formation differs from the predominantly east-west pattern of the other formations.

3) The sedimentation of the Dogger Formation was not affected by a southward influx of terrigenous sediments.

The second justification may now be in doubt following the remarks of Knox *et al.*(1990) and a thorough revision of the Dogger Formation and its relationship with the Ravenscar Group seems necessary.

Chapter 1

The Hayburn Formation

Hemingway (1974) described this as a non-marine formation, with a maximum thickness of 50 metres, immediately overlying the Dogger Formation with an erosive nature in places. The formation exhibits rapid lateral facies variations characteristic of the non-marine formations of the Ravenscar Group and the sediments are interpreted as having marsh and channel origins. Freshwater bivalve faunas indicate the lagoonal origins of some of the shale horizons. Fossilised plant remains are well preserved and locally abundant. Hancock & Fisher (1981) recorded the dinoflagellate cyst *Nannoceratopsis gracilis,* indicative of the Ng Zone of Woollam & Riding (1983), in samples from the coast south of Ravenscar.

The Ellerbeck Formation

Overlying the Hayburn Formation is a coarsening upwards group of sedimentary rocks, up to 8 metres thick consisting of marine ironstones, shales, siltstones and sandstones known as the Ellerbeck Formation. The ironstone which marks the base is a sideritic mudstone which in places develops a sparsely oolitic nature. It has been interpreted by Knox (1973) as representing a transgressive marine pulse onto the Hayburn Formation alluvial plain succeeded by a basinward migrating wave dominated shoreline (Hemingway 1974). The marine bivalve fauna including *Gervillia, Liostrea, Pholadomya* and *Astarte* is often best preserved in the ironstone.

Ammonites are absent from the formation but on the basis of ostracode dating of the 'Hydraulic Limestone' south of Market Weighton, Bate (1967) placed the correlative Ellerbeck Formation in the *discites* Subzone. Knox (1973) doubted Bate's correlation of the 'Hydraulic Limestone' with the Ellerbeck Formation on the basis of his own fieldwork and correlated the 'Hydraulic Limestone' with the Blowgill Member (Hemingway & Knox 1973), a localised basal marine unit of the Cloughton Formation found only in the region of Snilesworth Moor. Powell & Rathbone (1983) questioned the existence of the Blowgill Member as a separate unit from the Ellerbeck Formation on the basis of further fieldwork and followed Bate (*op. cit.*) in correlating the 'Hydraulic Limestone' with the Ellerbeck Formation The stratigraphy of the Lincolnshire Limestone Formation (Ashton 1980) suggests that the correlative Basal Hydraulic Limestone Member is possibly *discites* or pre-*discites* Zone age and thus the Ellerbeck Formation is of similar age.

Cloughton Formation.

The Cloughton Formation consists of the Gristhorpe and Sycarham Members and was first erected by Hemingway and Knox (1973) in an attempt to avoid previous genetic nomenclature. Cope *et al.* (1980) rejected the inclusion of Hemingway & Knox's Lebberston Member (Cayton Bay Formation herein) on the basis of the formation lacking a " ... degree of internal lithological homogeneity, or distinctive lithological features that constitute a form of unity by comparison with adjacent strata" when the member is included (Cope *et al., op. cit.* p. 18).

Gristhorpe and Sycarham Members.

These members represent a non-marine facies as indicated by the abundant terrestrial flora and freshwater bivalve fauna contained within. In the south, the Sycarham and Gristhorpe Members interdigitate with the marine Cayton Bay Formation whereas to the north, the marine formation is absent. Both are heterolithic members of "coal measure-type facies" (Hemingway & Knox 1973), often exhibiting rapid lateral facies variation. Livera & Leeder (1981, p. 242) recognised "laterally accreted channel sandstones with associated levee sediments", and suggest they "mark the influence of meandering distributaries on the flood plain." Establishment of vegetation appears to have been extensive on the deltaic floodplain. The plant beds within the members have been well documented by Seward (1900), Thomas (1915) and Harris (1943-53, 1961-9) particularly those of Gristhorpe, Cloughton and Whitby. Hancock & Fisher (1981) distinguished the influence of marine waters within the formations, including the occurrence of the dinoflagellate cyst *Nannoceratopsis gracilis.*

The Cayton Bay Formation.

This is a collective name for the Millepore Bed and Yons Nab Beds exposed on the coast from Yons Nab to Ravenscar. The formation is not present in the whole of the Yorkshire basin. It thins northwards eventually disappearing near Ravenscar and has been interpreted as representing a partial transgression from the south (Livera & Leeder 1981).

In the east of the basin, the Millepore Bed crops out extensively along the coast, especially in Cayton Bay. Here it consists of 5 metres of cross-bedded sandy oolite. Exposures can be traced northwards where, like its equivalent in the west of the Cleveland Basin, the Whitwell Oolite, it eventually passes into a sandstone facies. Livera & Leeder (1981) compared the deposition of these beds with modern Lily Bank sediments in the Bahamas. Both beds have long been correlated (Wright 1860; Fox-Strangways 1892) and work on the ostracode faunas (Bate 1967) indicated a correlation of the Millepore Bed and Whitwell Oolite with part of the Cave Oolite of Humberside and part of the Lincolnshire Limestone of Lincolnshire.

At the southern end of Cayton Bay, the Yons Nab Beds, a 7 metre thick coarsening upwards sequence of sandstone, siltstone and ironstone beds overlie the Millepore Bed. Some horizons exhibit a rich fauna of bivalves, ostracodes and transported plant debris. Northwards the beds pass through shoreface facies into non-marine equivalents just north of Cloughton Wyke (Bate 1959). Hancock & Fisher (1981) commented that the beds " ... mark a progressive return to swampy, delta top conditions" (*op. cit.*, p. 190).

Overlying the Whitwell Oolite in the west is the correlative of the Yons Nab Beds, the 'Upper Limestones'. Like the Millepore Bed, Bate (1967) correlated the Yons Nab Beds and the 'Upper Limestones' with part of the Cave Oolite and Lincolnshire Limestone to the south of Market Weighton. In earlier work the present author (Hogg 1989 MS) suggested, on the basis of dinoflagellate cyst assemblages, a *discites* or *laeviuscula* Zone age for the Yons Nab Beds.

Scarborough Formation.

This formation is very variable in thickness and sedimentological interpretations suggest that a spectrum of shallow marine environments are preserved within. Bate (1965) considered that a gradual marine incursion occurred from the east, inundating the delta plains represented by the Gristhorpe Member. Livera & Leeder (1981) interpreted the basal coarsening up unit at Cloughton Wyke as intertidal in origin. Higher up, bioturbation becomes prominent suggesting to the authors (*op. cit.*, p. 246) " ... a prograding tidal sand flat". However, the correlated horizon at Yons Nab was interpreted

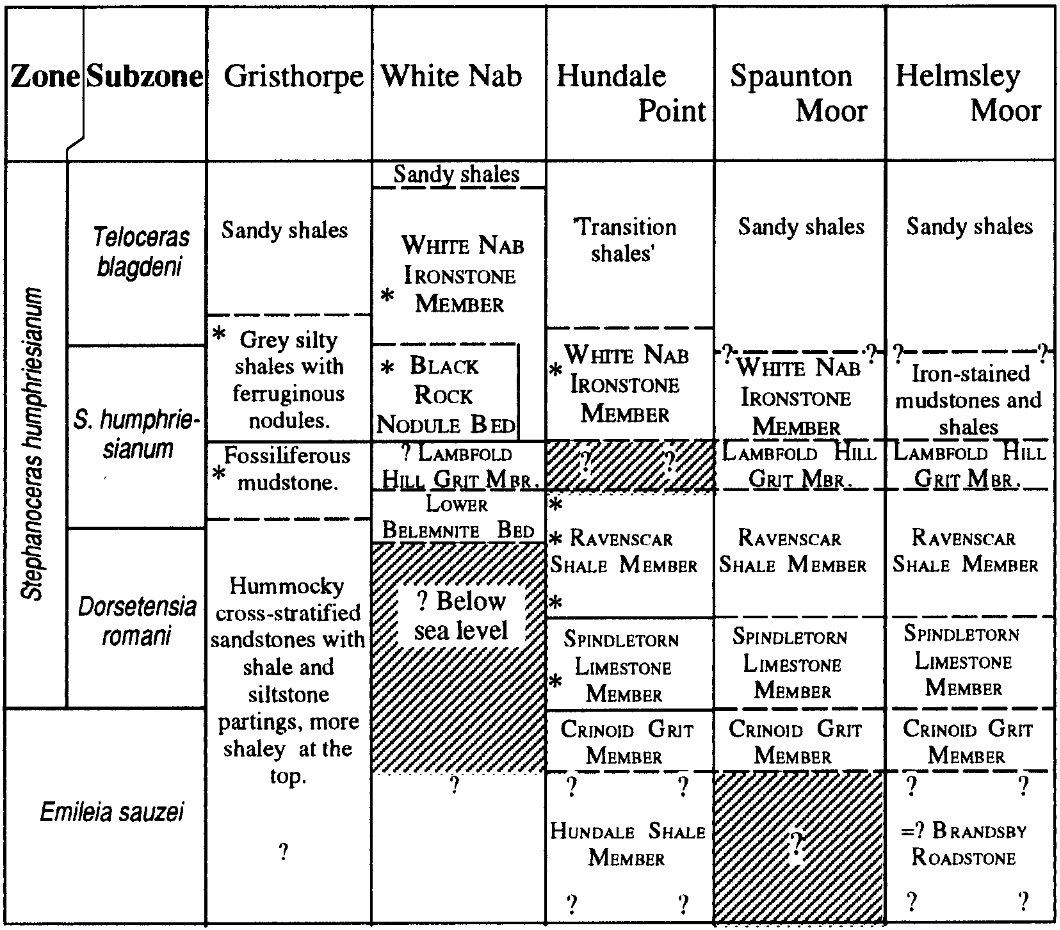


Figure 1.6. A correlation of the Scarborough Formation in the Cleveland Basin (after Parsons 1980). Asterisks mark the presence of Subzonal ammonites.

as subtidal. At a higher level in the formation, the predominance of shales containing a sparse ammonite fauna indicates the deepest water conditions reached in the Scarborough Formation. The top horizons of the formation coarsen upwards and are interpreted as a shallower water "offshore to beach deposit"(Livera & Leeder, *op. cit.*, p. 246). This top facies is reportedly absent at Yons Nab.

Hancock & Fisher (1981) used palynofacies to interpret the basal shale units as reflecting " ... only the establishment of a more open interdistributary bay rather than any dramatic transgressive regime"(*op. cit.*, p.190-192). A deepening of the water is indicated by a shallow subtidal sand sheet 4 metres thick. Although recognising Parson's work (1977) on the ammonite faunas of the calcareous shales and bioclastic limestones within the formation, Hancock & Fisher suggested that " ... the whole formation thus represents only a saline bay, like the nearshore parts of the bays bordering the Mississippi delta"(Hancock & Fisher 1981, p. 192).

Parsons (1980) synthesis of the information published up to that date is expressed in a diagram showing the correlation of beds within the formation (Fig.1.6). All three subzones of the *humphriesianum* Zone are recognised within the formation (Parsons 1977) and as such it is the best biostratigraphically defined formation in the Yorkshire Middle Jurassic.

Scalby Formation.

The Moor Grit Member is a sand body comprising the lowest ten metres of the formation at Cloughton Wyke. Sedimentary structures include giant cross-stratification and multi-storey channel fills. The overlying 4 metres of sandstones display epsilon cross-bedding and a variety of bed forms which repeatedly cross-cut . The shales above contain dinoflagellate cysts, acritarchs and leiospheres (Fisher & Hancock 1985). Footprint beds, mud cracks and root beds also occur. Black (1929) recorded a rich drifted terrestrial floral accumulation in the form of the Scalby Plant Bed. The designated Long Nab Member encompasses both the sandstone and shale lithologies above the Moor Grit Member. Alexander (1991) commented on the difficulty of defining the boundary of the two members and concluded " The boundary is defined from a change from sandstone with relatively large sedimentary structures, rip-up clasts and few fine beds to more muddy sandstone with generally smaller-scale current indicators, well developed lateral-accretion features and frequently a heterolithic character." (*op. cit.*, p. 341).

Nami & Leeder (1978) interpreted the Long Nab Member as being alluvial in origin. Hancock & Fisher (1981) questioned this interpretation on the basis of palynofacies and suggested " ... intermittently saline swamp conditions on what was probably a river dominated delta plain" (*op. cit.*, p. 192). The presence of acritarchs, leiospheres, and the dinoflagellate cyst *Nannoceratopsis gracilis* was used to discount Livera & Leeder's (1981) conclusions. In the discussion of a later re-examination of the Scalby Formation (Fisher & Hancock 1985), in which the authors recorded

Dichadogonyaulax sp. from the Long Nab Member, Leeder & Alexander (1985) re-stated a previous explanation (Livera & Leeder 1981) of marine influence " ... perhaps due to tidal-prism backup."(Leeder & Alexander *op. cit.*,, p.297)

The Cornbrash Formation.

The formation has been studied in detail by Wright (1977). Two lithological units are recognised in Yorkshire; the Cornbrash Limestone succeeded by the Shales of the Cornbrash. Within the limestone unit, Wright recognised several subdivisions based on lithology; a chamosite oolitic ironstone, a shelly oo-micrite with borings infilled with non-oolitic matrix, a bioclastite and a fossiliferous sandy or silty marl thought to be a transitional facies with the overlying Shales of the Cornbrash. Not all divisions are preserved in every outcrop. Complex cross-cutting and erosional relationships are found within the limestone unit (Wright *op. cit.*). A fifth subdivision older than the other lithologies is recorded in the area around Newtondale and is believed by Wright to represent a lateral equivalent of the top-most beds of the Scalby Formation on the coast. From Wright's observations, Cope *et al.* (1980) inferred that at Newtondale the Scalby Formation passes up into the Cornbrash Formation without a break. On the coast however, the junction between the two formations is sharp indicating a period of non-deposition (Wright *op. cit.*). The remarks of Cope *et al.* (*op. cit.*) were later discounted in Riding & Wright (1989).

The Shales of the Cornbrash pass upwards into the basal beds of the Kellaways Rock Member, the junction being marked by an increase in the percentage of fine sand and the appearance of *Teichichnus* burrows. Zonal fossils retrieved from both the Limestone and the shales of the Cornbrash indicate the formation to be of *kamptus* Subzone age. Wright (*op. cit.*) regarded the formation as the expression in the Yorkshire Jurassic of the world-wide marine transgression which began in the early Callovian and which transgressed over the Scalby Formation from the north east.

1.2. Previous work on the Scalby Formation.

The term 'Upper Estuarine Series' was first used by Fox-Strangways (1880) to define the strata above the Grey Limestone Series and below the Cornbrash. He described it as consisting "...principally of shale with a few irregular bands of sandstone of little commercial importance, and of one or more beds of granular ironstone. These rest on a massive bed of sandstone, which on account of its development over the moorlands has been called the 'Moor Grit'" (*op. cit.*, p.17). A measured section of the series was given at Gristhorpe Bay totalling 124 feet and he suggested that at Wheatcroft "...judging by the height of the cliff, they must be fully 200 feet in thickness " (*op. cit.*, p.17). The geographical outcrop of the series south of Scarborough was given in detail, as were observations regarding the nature of the series.

Of note were his observations on organic remains. " The Upper Estuarine Series is by far the most barren in organic remains of all the Lower Oolites. For some reason, which at present is not very apparent, the conditions that prevailed during this period do not appear to have been so favourable for plant life as those which preceded it. Of the above species (referring to a list of plant fossils recovered) only about half have continued from the series below " (*op. cit,,* p.18).

Bivalve shell remains were noted,"...depending from the roof of some of the caves near Scarborough. These were originally referred to *Unio*, but from the hinge being edentulous have since been stated to be an *Anodon*. From this circumstance the beds between White Nab and the Spa have been considered to be the remains of an extensive freshwater lake, but as the shells are only casts it is doubtful whether they are freshwater species at all, and may possibly be *Myacites*, which we have noticed occurs at about this horizon. In either case it is evident that these strata were deposited in very shallow water, which possibly oscillated between freshwater and estuarine conditions, or possibly that the two prevailed simultaneously, shallow lagoons being formed here and there along the margin of the estuary." (*op. cit.*, p.19).

An overview of the series outcrop was given in Fox-Strangways' "Jurassic rocks of Yorkshire" (1892). Considerable detail was presented of the Moor Grit at it's northern and western outcrops, noting the rock's well-cemented siliceous nature.

In further publications of the Geological Survey, the outcrop and nature of the Upper Estuarine Series were commented on. Fox-Strangways, Cameron & Barrow (1886) noted the thinning of the series to little more than 100 feet to the north-west. Fox-Strangways & Barrow (1915) acknowledged Hargreaves' (1914) discovery of casts of reptilian foot-prints on the coast, a mile south of Long Nab and went on to raise doubt over the classification of the Upper Estuarine Series in relation to the marine Oolitic sequence of the south of England; "...the question arises whether the interposed non-marine series, containing in itself no direct indication as to the age, should be classified as Great Oolite, or combined with the underlying strata as part of the Inferior Oolite. On the whole it appears to range best with the underlying series ... In notes on the subject expressed in Chap. V ... it is suggested that the Moor Grit may represent the upper part of the Inferior Oolite, and that the remainder of the Upper Estuarine Series should be correlated with the Fullers' Earth, which belongs to the Great Oolitic Series " (Fox-Strangways & Barrow 1915, p. 45-46).

Black (1929) described the drifted plant beds of the Upper Estuarine Series and gave a history of the stratigraphy and palaeobotany up to that date. The list of the flora was supplemented by his own collecting. The series was divided into three on the coast between Scalby Ness and Hundale Point; the Moor Grit, the Current Bedded Sandstone overlying and the Level Bedded Series. Detailed descriptions were presented of filled in channels in the Level Bedded Series and similar footprint beds to those described previously by Hargreaves (1914) were recorded inland at Loskey Beck, between Rosedale and Farndale and in Bloody Beck at the head of Harwood Dale.

Black (*op. cit.*) further noted the replacement of the Moor Grit lithology south of Scarborough with " ... a mixture of wedges of grit resembling the Moor Grit type, with interbedded silts and sandstones resembling the Current Bedded Sandstone of the north; in addition the series contains conspicuous washout structures and lenticles of fossiliferous shale. Thus, in this part of the section, the two members of the northern development seem to be intimately commingled, and it is thought that this is due to the rearrangement of an original grit by later channelling " (*op. cit.*, p. 401).

A long discussion was included regarding the conditions of deposition as deduced from the lithology. In essence, Black regarded the series as " having been deposited during one cycle in the formation of a large delta...the cycle begins with the deposition of the Moor Grit - a series of foreset beds built out over the floor of this (Grey Limestone Series) sea ... the Current Bedded Sandstone was then formed on top of the foreset beds, and owes its character to very variable current-action in the shallow water just behind the front of the delta. The Level Bedded Series represent the topset beds, which were formed during a period of renewed regressive sinking " (*op. cit.*, p. 405).

The origin of the sediment supply of the series was speculated upon, with interpretations based on measurements of the direction of flow of the streams which formed the washouts and from the direction in which the strata thicken. Although Black suggested that both lines of evidence indicated a northerly source for the sediment he noted that " ... the data available are not at present sufficient to give conclusive results " (*op. cit.*, p. 406).

With regards to the nature and distribution of the flora, Black noted the great dissimilarities to the Gristhorpe Plant Bed (Middle Estuarine Series) in terms of both preservation and composition of the flora. Compared to the Gristhorpe Beds, the flora from the 'Upper Estuarine Series' was dominated by remains derived from drifted plant fragments, with exceptional beds preserving either *Equisetites* alone or associated with *Coniopteris* inferred as representing *in-situ* material. Sorting and distribution of the drifted floral remains by differential floating, mechanical destruction and oxidation was suggested.

In his conclusions, Black noted the misleading results derived from comparing drifted and non-drifted plant beds, both in terms of relative ages and in reconstruction of the parent flora from the drifted beds.

Kendall & Wroot (1924) presented a general overview and discussion, including their thoughts on the derivation of the series' sediments. After dismissing the Pennines as a source for the sediment, the authors remarked on a personal comment from Dr Sorby who suggested to them that the current bedding within the series pointed to a northern origin. Thus, and in comparing the series with the Carboniferous Coal Measures, they concluded that " ... the source of the sediments was still, as in the earlier (Carboniferous) period, that great northern continent beyond the Grampians " (*op. cit.*, p. 311).

Hemingway & Knox (1973) proposed nomenclature for the Middle Jurassic strata which avoided the genetic connotations of previous terms such as 'Estuarine Series' or 'Deltaic Series' and which adopted the use of geographical names for the strata (Fig. 1.5). The Ravenscar Group was formally defined as comprising the series of strata overlying the Dogger Formation and underlying the Cornbrash Formation. The Upper Estuarine Series was renamed the Scalby Formation and a type section was proposed at Scalby Cliff [TA 031 924].

Nami (1976) described a 'newly discovered' meander belt in the Long Nab Member which was previously described by Black (1929) as his Current-Bedded Sandstone. In conclusion Nami suggested that " accretion of the meander belt point bars took place in highly sinuous streams varying in depth from 3-4 m and in width from 15-25 m. Meander wavelength was in the range 150 m and mean discharges around 0.5-10 $m^3 m s^{-1}$ were probably attained." (*op. cit.*, p. 51).

Leeder & Nami (1979) were first to publish sedimentary models for the Scalby Formation, based mainly on the work of Nami (1976a). The authors proposed an alluvial depositional model for the Scalby Formation in preference to Black's (1929) deltaic model. In addition, an alternative depositional model was offered, which genetically linked the Scalby Formation with the uppermost beds of the underlying Scarborough Formation in a wave-dominated deltaic model. However, the authors recognised the difficulty of refuting either model on sedimentary evidence alone, due to the incompleteness of outcrops and lack of boreholes away from the coastal area. Leeder & Nami based their models on an inferred 1 million year time period for the deposition of the formation , deduced from sedimentation rates, and observed the boundary of the formation with the overlying Cornbrash Formation as a " ... more-or-less gradational change with only minor reworking " (*op. cit.*, p. 473). In an initial conclusion they supported the alluvial model in preference to a newly proposed deltaic model.

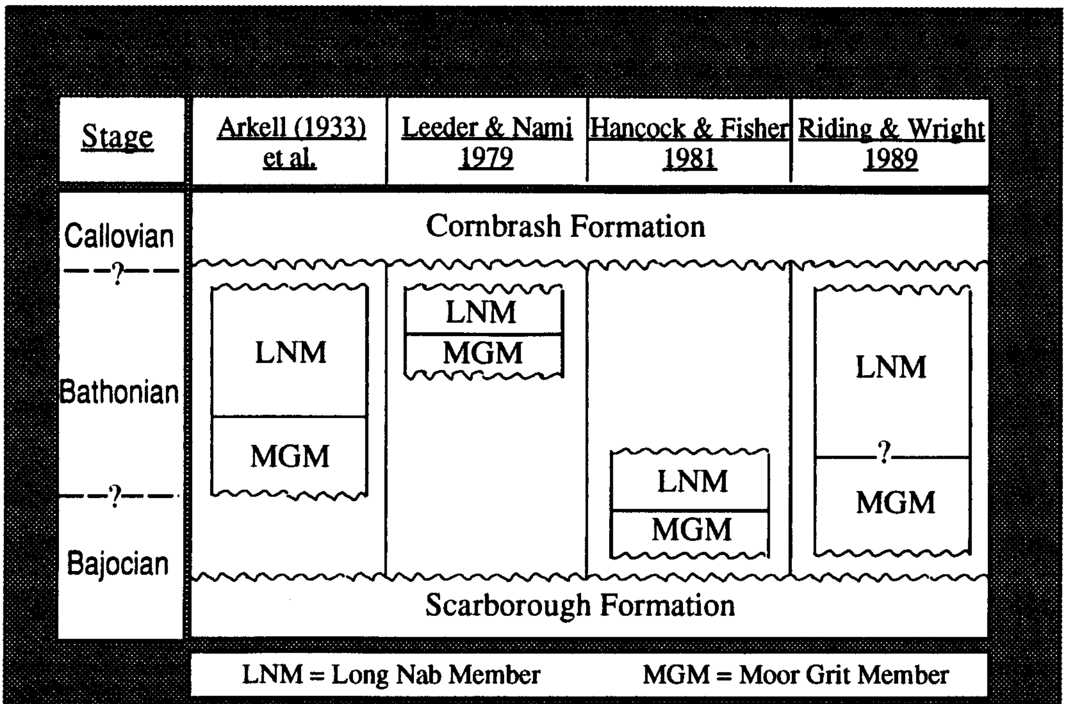


Figure 1.7. Previous age assignations for the Scalby Formation.

A consideration of the implications of their alluvial model choice led Leeder & Nami to discuss the origin of the erosive interval between the Scarborough Formation and the Moor Grit Member. The authors conclusively favoured a lengthy period of Upper Bajocian to Lower Bathonian non-deposition followed by the removal of a small amount of Scarborough Formation deposits by the channels of the Moor Grit Member (Fig. 1.7).

Leeder & Nami (1979) supported Black's northern derivation for the Scalby Formation with additional palaeocurrent evidence and proposed the postulated Pennine extension of the mid-North Sea High as the sediment hinterland. Data from mineral studies and the observation of abundant Upper Carboniferous plant spores in the Middle Jurassic led the authors to infer the weathering of multicycle Carboniferous sediments at source.

In a subsequent discussion, Dr P.F. Rawson (1979) concerned himself with Leeder & Nami's assignation of the 9 million year hiatus at the Scarborough Formation / Scalby Formation boundary on such limited evidence presented. "Other alternatives were that the interval lay between the Scalby Formation and the Cornbrash Formation, within the Scalby Formation, or split between the previous three possibilities. A critical comparison between the nature of the Scarborough Formation/Scalby Formation and Scalby Formation / Cornbrash Formation boundaries was clearly necessary." (*op. cit.*, p. 480-481.)

Following a field meeting held by the Geologists Association, Livera & Leeder (1981) presented new evidence to suggest that the Scalby Formation was not wholly alluvial. On the presence of *Ophiomorpha*- type burrows in the Long Nab Member, the very abundant bioturbation in certain channel deposits and the abundance of mud grade sediment in the channel deposits, the authors believed the points " ... raise the spectre of some tidal contribution to channel processes (tidal prism backup?) and to floodplain processes (storm surges on coastal plain?) and refocus thoughts upon the estuarine interpretation favoured by early workers (e.g. Fox-Strangways 1880), before the sedimentary studies of Black (1929) and Hemingway (1949) opted for a deltaic model" (*op. cit.*, p. 246).

Hemingway & Riddler (1982) noted that the silicified nature of the Moor Grit Member cropping out over the moorlands was 'lithologically aberrant'. The lithology broadly coincided with a zone of mineral impoverishment along the axis of the Cleveland Basin. An explanation of the " ... desilicification of iron-rich facies during the formation of magnetite oolite, and, in contradistinction, the migration and deposition of interstitial quartz in an arenaceous facies after it had been purged of its feldspar and clay minerals, ultimately to form the orthoquartzite 'white flint'" (*op. cit.*, p. 185) was offered by these authors.

Using sedimentological and palynofacies studies of the whole Ravenscar Group, Hancock & Fisher (1981) added little to the knowledge of the Moor Grit Member. With regard to the Long Nab Member however, the authors remarked " ... the shales a few feet above the point bar sands contain common marine palynomorphs, and these even occur questionably within the levée itself. Acritarchs, leiospheres and a variety of dinoflagellate cyst species are present, and they occur throughout the shale sequence which has been sampled. The well known Burniston Dinosaur Footprint Bed within this sequence yields acritarchs and the dinocyst *N. gracilis*. The shales locally become richly carbonaceous, and here and there they contain root beds. Combining this evidence with the palynofacies suggests intermittently saline swamp conditions on what was probably a river-dominated delta plain." (*op. cit.*, p. 192).

With reference to the channel sand bodies within the Long Nab Member, the authors inferred " ... deposition in a range of meandering and low sinuosity stream reaches which were small distributary channels crossing the delta plain. As far as can be determined, current directions within these distributaries were somewhat variable, but a general trend to the east of south is apparent." (*op. cit.*, p. 192).

In a following publication, Fisher & Hancock (1985) reassessed the age and depositional environment of the Scalby Formation. The authors expanded on their previous publication and noted the presence of acanthomorph acritarchs in shales interbedded with the meander belt sandstones at the top of the Moor Grit Member at Long Nab. On this evidence, the penetration of saline waters between the active channels in the high part of the Moor Grit Member was inferred. With regard to the Long Nab Member, rare acritarchs were noted in mud-cracked sandy shales of channel levees. Within the delta-plain shales, the dinoflagellate cyst *Nannoceratopsis gracilis* Alberti 1959 was recovered from a sample overlying the meander-belt sands and *Dichadogonyaulax* sp.

was reported from an argillaceous channel cutting through the shales. *N. gracilis* was recovered also from the Burniston Dinosaur Footprint Bed at Crook Ness.

Fisher & Hancock (1985) restricted the age of the Long Nab Member to the *garantiana* and *parkinsoni* ammonite zones on the dinoflagellate cyst evidence. They suggested that the presence of the *Dichadogonyaulax* sp. ruled out the possibility that the assemblages were due to reworking and, with reference to regional biostratigraphy south of the Market Weighton axis, concluded that the time interval *humphriesianum* Zone to *macrocephalus* Zone " ... accommodated a number of relatively small hiatuses. This could also include a hiatus immediately prior to deposition of the Cornbrash" (*op. cit.*, p. 296).

Fisher & Hancock (1985) deviated from the findings of Nami & Leeder (1979) and interpreted the shales of the Long Nab Member as deposits of " ... saline swamp and inter-distributary bay deposits with variable salinities occasionally achieving fully marine salinity. The distributary channels that traversed this delta plain may have been partly tidal and there is evidence of marine incursions occurring towards the end of the Moor Grit deposition " (*op. cit.*, p. 296-297).

In a following discussion, Leeder & Alexander (1985) acknowledged the authors' findings but suggested " ... that the term coastal plain alluvium still best fits the current data since Fisher & Hancock's frequent use of the term inter-distributary bay implies a predominately delta front environment for which there is little sedimentary evidence ... it seems probable that tidal prism backup effects provided only temporary marine-influenced floods in otherwise alluvial levees, backswamps and lake environments" (*op. cit.*, p. 297-298).

Kantorowicz (1985) investigated the petrology and diagenesis of the Yorkshire Middle Jurassic sediments, including the Scalby Formation. He suggested that diagenetic modification took place in three broad regimes; within the depositional groundwater (eogenesis), during burial (mesogenesis) and during uplift and erosion (telogenesis).

In further work, Kantorowicz (1990) related the effects of early diagenetic processes on the floodplain settings of the Long Nab Member to lateral (catena) variations in ground water chemistry within the original depositional environment. Kantorowicz related the catena variations to floodplain aggradation and abandonment. Near major channel sands (in this case in the Hayburn Formation) sediments were well drained and frequently flushed with fresh water. In more distal floodplain settings, the groundwater was influenced by freshwater but remained essentially suboxic and siderite cementation ensued. The sphaerosiderite commonly observed in the Long Nab Member was considered to be the result of elevated bacterial processes which supplied bicarbonate, with a characteristic $\delta^{13}C$ and $\delta^{18}O$ signature, to the groundwater system. Seawater introduced sporadically onto the floodplain entered the groundwater and was precipitated in a reduced state as pyrite in the siderite soil horizons.

Alexander (1986) introduced the idealised flow model to predict the concentrations of alluvial sandstone bodies within the Scalby Formation. She suggested that the local tectonic structures active during the Middle Jurassic distorted the floodplain surface. Drawing evidence from thickness variations, the distribution and intensity of soft sediment deformation, extensive erosion surfaces, incised channel sandstones, and facies variation, the author remarked " ... that on the Middle Jurassic coastal plain there were areas of relatively low subsidence rate that were expressed for part of the depositional period as slightly raised topographic areas. The surface deformation was controlled by movement on basement structures that remained active into the Tertiary." (*op. cit.*, p. 299). These conclusions were based in part on research carried out at the University of Leeds, including the work of Leeder & Nami (1979).

The idealised flow lines for the Scalby Formation constructed by Alexander (1986) did not distinguish between the Moor Grit Member and the Long Nab Member sandstones in the flow pattern diagrams. Also noted was the thinning of the Moor Grit south of Scarborough and its replacement with a facies similar to that of the basal Long Nab Member north of Scarborough. With reference to these facies, Alexander observed " ... the meander deposits south of White Nab are less deformed by soft sediment deformation than those further north and probably represent deposition in an environment with less marine influence. South of Yons Nab the base of the Scalby Formation is dominated by overbank deposits. This suggests that this was an area of relatively low subsidence which is supported by a condensed section of the Scarborough Formation at Yons Nab ... The idealised flow model for the Scalby Formation has diverging flow lines southeast of White Nab that may be used to explain why there is little sandstone in the Long Nab Member and no Moor Grit at this site." (*op. cit.*, p.305).

In further work, Alexander (1987) observed syn-sedimentary and burial-related deformation in the Scalby Formation. The syn-sedimentary structures were considered to be related to frequent discharge fluctuations and tectonic movement. Differential compaction was regarded as having caused the burial-related structures.

Riding & Wright (1989) presented palynological evidence indicating a Bathonian age for the uppermost Long Nab Member at Newtondale (Fig.1.7). Their re-examination of the samples of Fisher & Hancock (1985) from the coast north of Scarborough led them to suggest a late Bajocian to Bathonian age for that material. Contrary to previous observations on the junction of the Scalby Formation with the Cornbrash Formation at Saltergate (Wright 1977), Riding & Wright noted the presence of burrows, extending 5-10cm into the Scalby Formation. On this evidence Riding & Wright inferred compaction or lithification, uplift, erosion and burrowing before deposition of the Cornbrash Formation.

With reference to the samples of Fisher & Hancock (1985) , Riding & Wright (1989) refuted the presence of *Nannoceratopsis gracilis* Alberti 1959 in the basal Long Nab Member on the coast, particularly of one sample," ... sample 69 of Fisher &

Hancock (*op.cit.*) appears to be devoid of this taxon." (*op. cit.*, p. 353). In conclusion Riding & Wright envisaged " sedimentation from the early Bajocian Scarborough Formation into the Moor Grit Member with only a minor stratigraphical break ... possible hiatuses at the Moor Grit Member-Long Nab Member junction and above the Meander Belt Sandstone are of unknown duration. However, we propose the remainder of the Long Nab Member represents a period of almost continuous deposition followed by the stratigraphical break that separates it from the overlying Cornbrash." (*op. cit.*, p. 353).

Alexander (1992) presented detailed sedimentological work on the complex sandstone-dominated channel body which overlies the Moor Grit Member on the coast between Scalby Ness and Long Nab. A variety of deposits were recognised within the sediments including point bar, counter-point bar, channel plug, floodplain lake and sheet flood deposits. In conclusion, emphasis was placed on the heterogeneity of sedimentary environments represented in the deposits, as the author regarded the tendency for geologists to assume such sediments as representative solely of point bar deposits common.

Lott & Humphreys (1992) studied the stratigraphy and petrology of several Formations from the Ravenscar Group, including the Scalby Formation, in boreholes at Castle Head and Scalby Ness. The cores revealed a complete section of the Moor Grit Member and some 12 metres of the lower part of the Long Nab Member in the Scalby Ness borehole and 36 metres of the top part of the Long Nab Member in the Castle Head borehole. The authors corroborated the previous petrological observations of Hemingway & Riddler (1982), regarding the dissoluted nature of the Moor Grit Member which resulted in a relatively pure quartz arenite. A change in the composition of the clay mineral assemblages was noted in the Long Nab Member. Up to c.30 metres above its base, the assemblages consisted predominately of kaolinite, with subordinate mixed-layer chlorite-vermiculite and only traces of illite. However above this level, detrital kaolinite and illite, with subordinate mixed-layer illite-smectite dominated the clay mineral assemblages. These changes were considered by the authors to relate partly to changes in provenance and may have also been influenced by the diagenetic history of the rocks. The clay mineral chlorite in its discrete phase was recorded only from below the base of the Moor Grit Member. The authors remarked on this occurrence coinciding with the major hiatus proposed at the Scarborough / Scalby Formation by Leeder & Nami (1979).

1.3. Jurassic Worldwide Phytogeography and Palaeoclimatology.

Reconstruction of palaeoclimates requires a substantial database if it is to elucidate the distribution of past climatic zones. In addition to recognising climate controlled sedimentary facies, Vakhrameev (1991) rightly reminded us of the importance in the fossil record of plants and animals which are sensitive to climatic change. Furthermore, $\delta^{16}O/\delta^{18}O$ isotope ratios and Ca-Mg ratios are thought to be indicators of absolute annual temperature. The clearest understanding of past climates will be derived from an integration of all methodologies alongside a clear understanding of each of their limitations.

The most comprehensive reconstruction for the Mesozoic has been published by Vakhrameev (1991) whose findings clearly illustrate that throughout the whole of the Mesozoic the world-wide climate was warmer than at present. Evidence from thermophilic floral discoveries in both the Arctic and Antarctica negates the possibility of permanent polar ice build-up from the Upper Permian to Early Cretaceous. Vakhrameev (*op. cit.*) quotes oxygen isotope average annual temperatures of 15° to 17°C in the north of Siberia and 18° to 24°C in the Mediterranean area for the Mesozoic with a resulting temperature gradient of half that of the present day.

Following the world-wide period of aridity at the close of the Palaeozoic, replenishment of the Early Triassic reduced floras by families which became the basic stock for much of the Mesozoic appears to have occurred in the second half of the Triassic (Vakhrameev 1991). By the end of the Triassic, the flora was established world-wide with a remarkably balanced composition owing to extensive migration. Vakhrameev (*op. cit.*) recognised three climatic zones throughout the Mesozoic; temperate (moderate)-warm, subtropical and tropical (equatorial). In addition, according to the amount of humidity the zones are divided into humid (moist) and arid (or occasionally semi-arid)(Fig. 1.8).

The Lower to Middle Jurassic.

The warm temperate zone was characterised by deciduous trees exhibiting annual ring growth; the Ginkgoaceae, Czekanowskiaceae, Podozamitaceae and ancient Pinaceae. Evergreen forms were rare. Although winter temperatures may have approached zero in the northern part of the zone, greatly reduced insolation during the winter months is considered a strong driving force for the plants deciduous nature. The coeval ground level vegetation is assumed to have been herbaceous to overcome the annual climatic variations. Establishment of vast moist swamps led to the accumulation of peats, recorded in several major coal-bearing basins in Siberia and Khazakstan during the Lower and Middle Jurassic. The distribution of this zone is restricted to the northern hemisphere. The distribution during the Jurassic also differs for belemnites characteristic

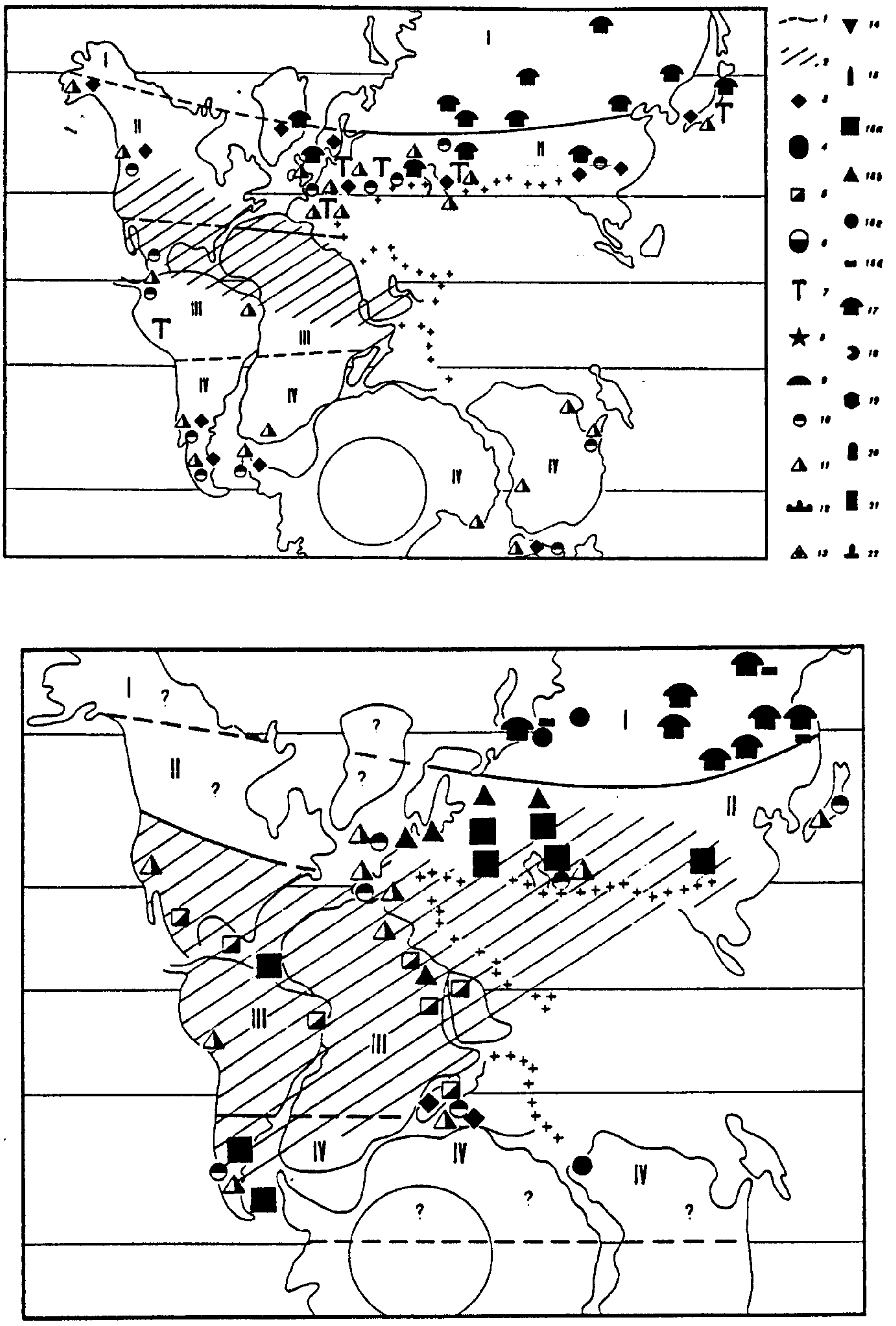


Figure 1.8. Climatic belts for the Lower Jurassic and Middle Jurassic (above), and the Upper Jurassic (below); I, belt of moderate-warm climate of the Northern Hemisphere; II, subtropical belt of the Northern Hemisphere (Euro-Sinian region); III, tropical belt (Equatorial region);IV, subtropical belt of the Southern Hemisphere (Austral or Notal region); 1, boundaries between climatic belts; 2, distribution of semi-arid or arid climate; 3, localities of *Dictyophyllum*; 4, *Phlebopteris, Matonidium*; 5, *Piazopteris*; 6, *Wiechselia*; 7, *Klukia*; 8, *Tempskya*; 9, other tree ferns; 10, *Ptilophyllum*; 11, *Otozamites* ; 12, *Ptilophyllum, Otozamites, Dictyozamites* ; 13, *Cycadeoidea*; 14, *Nilssonia*; 15, *Frenelopsis*; 16, *Classopollis* pollen percentages (a) over 50%, (b) over 25%, (c) over 10%, (d) rare grains; 17, *Czekanowskiales*(after Vakrhameev 1991).

of warm temperate and subtropical basins (Stevens 1973); in the northern hemisphere they rarely exceeded 45° latitude whilst in the southern hemisphere their extent was as far as 75°. These two observations have led Vakhrameev (1991) to suggest that the climate in the northern hemisphere was cooler than that of the southern hemisphere.

For much of the Lower and Middle Jurassic a humid climate predominated in the subtropical zone, as documented in localities from England, France, China and Japan. Species diversity in this zone approached twice that of the warm temperate zone. The main wood species were representatives of the Cheirolepidiaceae, Araucariaceae and Ginkgoaceae. The stem structure of the cycads and Bennettitales which formed the under storey vegetation is strongly suggestive of frost intolerance. A great diversity was attained within these groups and their distribution encroached into both warm temperate and tropical zones, albeit in reduced numbers and kinds. The most diverse of the ferns were representatives of the Marattiaceae, Matoniaceae and Dipteridaceae. Their distribution in both the northern and southern hemispheres was strongly suggestive of a trans-equatorial mobility; remains belonging to these groups are found in palaeo-equatorially positioned localities. This distribution was also true of the Caytoniales and the Pteridosperm *Pachypteris*, although the remains of the latter have not yet been recovered from equatorial regions. Differences from the southern subtropical zone were slight; Pinaceae and Czekanowskiales were absent and the Ginkgoaceae were poorly represented. Vakhrameev (1991) believed that within the subtropical zone two types of vegetation developed; moist lowland vegetation dominated by ferns, horsetails and Caytoniales, and a drier vegetation envisaged to have inhabited more upland topographies dominated by Cheirolepidiaceae, Araucariaceae, Bennettitales and cycads.

Evidence for tropical floras is poor due to lack of finds. Of the rare discoveries, the fern genera *Piazopteris* and *Weichselia* appear to be significant alongside Araucariaceae, Bennettitales, cycads and Cheirolepidiaceae.

Further Russian work (summarised in Vakhrameev 1991, p.250) has pointed out a slow cooling phase from the Norian to the Pliensbachian followed by a warming period in the Toarcian. This phase can be traced northwards with the Toarcian transgression into the moderate-warm climate of Siberia. The warming appears to have curtailed peat formation in the Siberian Khazakstanian basins probably due to the drying of the swamps. Further cooling was then witnessed from late Toarcian onwards, culminating in the Bajocian when average temperatures in the moderate-warm climate zone dropped to 10° to 12°C.

Late Jurassic.

The late Jurassic witnessed an extensive period of warming which peaked at the end of the Oxfordian. A shift of the northern boundary of the subtropical belt northwards by 10° to 15° accompanied this. Average temperatures in northern Europe rose to 17° to

22°C and in middle Asia to 22° to 26°C. *Classopollis* pollen grain percentages (an indicator according to Vakhrameev of warmer climatic conditions) in the southern European part of the former U.S.S.R. began to rise from the Bathonian onwards. Aridisation followed the warming and much of the Euro-Sinian region, previously subtropical, was affected from southern England through the Iberian Peninsula onwards to China. The altered composition of the flora is reflected in the absence of Czekanowskiales, a drastically reduced diversity of ferns, Ginkgoales and *Nilssonia* and the widespread occurrence of Bennettitales and *Classopollis* pollen grains representative of the Cheirolepidiaceae. Analogous equatorial regions are again uncommon but rare plant beds preserve *Weichselia* and *Piazopteris* ferns together with Bennettitales, Araucariaceae and Cheirolepidiaceae, assemblages inferred by Vakhrameev to indicate a semi-arid or arid climate. Moist tropical areas are thought to have been restricted to the northwest and north of South America. By Late Jurassic times the arid belts had extended equatorwards and were almost in contact with each other in the region of Brazil and northern parts of Africa. This marked the acme of aridity of the Upper Jurassic which was to give way in the Berriasian to climatic cooling and an associated increase in humidity.

The Yorkshire Jurassic Flora

The outcrops of Middle Jurassic strata in Yorkshire have been an intense area for palaeobotanical study since Brogniart's observations were published in the early nineteenth century (1828-1838). The culmination of the early works was Seward's catalogue in 1900. This century a major review has been undertaken by Harris (1961, 1964, 1969, 1974 and Harris *et al.* 1979) based on extensive re-collecting and re-examination of the earlier material. In addition, van Konijnenburg-van Cittert (1971, 1981, 1989) and Hill (1975) have added much to our knowledge of the flora.

All three terrestrial formations (Hayburn, Cloughton and Scalby) yield plant remains. Harris (1952) noted that the richest strata was that of the Gristhorpe Member, followed by the Hayburn Formation, Scalby Formation with the Sycarham Member yielding the poorest flora. Furthermore, Harris characterised five different types of deposit:

1. Truly autochthonous beds, where plants are preserved in the position of growth, either the root and the lower 1 metre or so of stem preserved (such as those occurring in the Hayburn Formation), or preserved as truncated root beds (frequent throughout the Ravenscar Group).
2. Lagoon and sluggish river channel deposits, where a mixture of large, delicate leaves, often with their reproductive organs, and water worn material is found.
3. River channel beds, which differ from group 2 in having a higher proportion of water worn plants.

4. Drifted plant beds, where all but the smallest of plants are severely worn.
5. Re deposited plant beds, where only tough cuticle remains.

Harris refuted the usefulness of the flora for zonation purposes. However, using the frequency of the distribution of a species (in terms of a presence or absence within an assemblage), he divided the flora into five different distribution patterns:

1. A few species ranging throughout the group without any striking change in abundance (e.g. *Brachyphyllum mamillare*).
2. A few common species absent only from the Scalby Formation (e.g. *Equisetum columnaris*).
3. A few species confined to the Hayburn Formation (e.g. *Sphenobaiera pecten*).
4. A large group of species which occur in the Hayburn Formation, are rare in the Cloughton Formation, but are common again in the Scalby Formation (e.g. *Pachypteris lanceolata*).
5. A large group of species which are common in the Cloughton Formation but are rare or absent from the Hayburn and Scalby Formations.

Despite the observations, Harris was unable to interpret the fluctuations in terms of floral successions and concluded that correlation based upon the flora was unreliable. He suggested that the flora should be taken as a whole for correlation.

Research by Hill (1975) on the Hasty Bank channel sandstone near the base of the Hayburn Formation combined a study of the palaeobotany with sedimentological analysis. Of interest was the abundance of the leaf *Pachypteris papillosa* which Harris (1964) previously suggested inhabited conditions similar to mangrove species of the present day. He regarded the association of this leaf with the leaf *Brachyphyllum crucis* as being significant. The theory that these (proposed) brackish water species would be observed above the base of marine transgressions was disproved in a review of the literature. Only *Brachyphyllum crucis* was observed at the base of the Millepore Bed, which led Hill to propose that the primary factor of the association was likely to be the availability of bases in the soil profile or perhaps openness of habit rather than the presence of a brackish environment. Further to this, two other species were nearly always associated with *P. papillosa*; *Cladophlebis harrisii* and *Nilssonia kendalliae*. These species were not thought to have inhabited the same environment as *P. papillosa* but Hill (op. cit.) concluded that they may be linked to salt water via a particular transport mechanism.

A review of both Harris's (1952) and Black's (1929) work on the Middle Jurassic floras brought the author to the conclusion that the previous workers had probably included drifted and *in situ* floras in their whole plant beds without realisation and thus

Hill viewed Harris's (1952) classification of the plant beds with a certain degree of suspicion.

Following a fine scale study of the sections at Hasty Bank, Hill concluded that vertical changes in three plant assemblages (III, IV and V) closely correlated with changes in lithology (cf. Scheihing & Pfefferkorn 1984). Of the species present within these assemblages, those that were abundant in all three were considered to represent the dominant vegetation whilst those which were characteristic of each assemblage may have been subordinate. Three assemblages were thought by the author to represent a vegetational succession related to delta progradation. All assemblages contained *Pterophyllum thomasii* and *Ptilophyllum hirsutum* and when combined with the brackish water indicators a progression was observed from assemblage II where *P. hirsutum* and *P. thomasii* were very rare but the brackish water species were abundant, through assemblage VI where *P. thomasii* was abundant and *P. hirsutum* along with the brackish species were present in moderate amounts to assemblage VII, where *P. hirsutum* and *P. thomasii* were abundant but the brackish water species were lacking.

Further work by Hill *et al.*(1985) on the Hayburn Formation at Wrack Hills documented a flora well preserved in three dimensions. The type of compression was attributed to an early diagenetic process. The discovery of reptilian, possibly crocodile remains alongside the plant fossils begged the author to consider the taphonomy of the sediments, in particular the role of acidic groundwaters in the sediments which would have favoured dissolution of the reptilian bone.

Research into the Cleveland Basin by van Konijnenburg-van Cittert (1971, 1981, 1989) has concerned itself with describing the morphology of the *in situ* spores and pollen grains from various fructifications. A summary of the associations reported is given in Appendix 2.3.

In further work on the Kimmeridgian fossil flora of Lothbeg Point, Sunderland (Van der Burgh & Van Konijnenburg-van Cittert 1984) the authors made use of floral analysis previously described by Van der Burgh (1983). Taxa were divided according to their ecology into brackish-water swamp, fresh-water swamp, moist lush vegetation, upland forest and heath. It was concluded that the high figures for brackish-water swamp and fresh-water swamp, and moderate figures for moist lush vegetation indicated that the flora was from a moist lowland habitat. Moderate figures for heathland taxa compared with low figures for upland forest species was considered to be a relict of preservation. Up to date no review of Harris's (1961-1979) volumes has been attempted with an aim to applying this analytical technique.

Within the volumes of Harris (1961-1979) *in situ* spores are described where present. Appendix 2.2 re-quotes the descriptions and offers a comparison with dispersed specimens.

Muir (1964) investigated the microspores of the Ravenscar Group with the intention of relating them to the lithology of the rocks in which they were found. She identified a strong controlling effect of the lithology over the assemblages and recognised three groups; species derived from the hinterland, those derived from the general delta area and species characterising the coal swamps. Assemblages recovered from non-marine sandstones compared more with marine rocks than non-marine shales and silts. She considered that the marine assemblages represented the general spore and pollen grain rain. On the basis of statistical comparisons of marine strata the author concluded that the Middle Jurassic flora remained remarkably constant and that at no time was an element of a specific vegetation able to dominate the marine assemblages.

Examination of the behaviour of individual species led the author to separate them into six groups; the first contained *Pityosporites spp.* and *Tsugaepollenites mesozoicus*, (both were only observed in marine rocks and non-marine sandstones). These were believed to have been derived from the hinterland. A second group of similar composition but including cycadophytic, lycopodialean and pteridospermous elements occurred very sparingly in coals but were common in marine rocks. Again these species were thought to inhabit the hinterland. The next two groups occurred equally in marine and non-marine rocks but were scarce in coals. The distribution suggested to the author that the parent vegetation producing the grains grew widely throughout the floodplain but were not common in coal forming environments. A further group was particular to the base of the coal seams sampled. This was characterised by Osmundaceous ferns which were believed to thrive in the establishment phase of the coal swamp but did not tolerate the later established conditions. The last group was a signature of coals and subordinately of non-marine shales. Within the coal lithologies two types were proposed; the first was rich in fern spores and associated with fragments of *Equisetum*, suggesting to the author to be the product of an *Equisetum* swamp. The second was characterised mainly by conifers with an abundance of tracheid remains and considered to represent a forest peat.

Muir commented upon the occurrence in the coals of *Cycadopites* pollen grains and suggested that the Middle Jurassic Cycadophytes were mainly swamp plants, contrary to the present day situation where cycads are predominately xerophytic. The author explained the differences as due to the lack of competition from angiosperms during the Jurassic.

The previous study of the Jurassic spores and pollen grains of the basin was that of Couper (1958). The author's aims were to systematically describe the spores and pollen grains from Jurassic and Cretaceous sediments in the UK. and to investigate the possibility of their use in stratigraphic correlation. The systematic treatment fell into two parts; the first dealt with grains separated from *in situ* material, the latter dealt with grains recovered from macerated whole rock samples. Appendix 2 lists the macro plant species alongside Couper's comparison with equivalent dispersed grains.

Couper (1958) considered that the floras from the Lower and Middle Deltaic Series (Hayburn and Cloughton Formations) were distinguishable from those of the

Liassic by the presence of *Klukisporites (al. Ischyosporites) variegatus, Spheripollenites (al. Exesipollenites) scabratus, Todisporites (al. Punctatisporites) minor* and *Eucommiidites troedssonii.* However, the usefulness of the latter species was questioned on the basis of the holotype material which was described from the Lias in NW Scania. The Hayburn Formation and Sycarham Member were thought to be indistinguishable on the basis of the spore and pollen assemblages, however the Gristhorpe Member appeared to be distinguishable on the basis of the relative abundance of *Monosulcites* (*al. Cycadopites*) *minimus* and spores referred to the *Osmundaceae.* Furthermore a number of species, including *Lycopodiumsporites gristhorpensis* (*al. Neoraistrickia truncata*) were known only from the Gristhorpe Member and younger sediments.

Correlation of the assemblages was attempted in two ways; by 'key forms' (stratigraphically restricted species) after Harris (1952) and by changes in relative abundances.

The Upper Deltaic Series (Scalby Formation) was distinguished from the older sediments in the Cleveland Basin by the presence of *Parvisaccites enigmaticus* (*al. Ovalipollis enigmatica*), and *Pteruchipollenites* (*al. Alisporites*) *microsaccus.* In addition the relative abundance of *Abietinaepollenites* spp. (*Alisporites* spp.) and *Tsugaepollenites* (*al. Cerebropollenites*) *mesozoicus,* combined with the relative paucity of *Classopollis torosus* and *Araucariacites australis* was considered to be characteristic. No comment was offered on the effects of facies on assemblages and so fully marine deposits (the Lias) were directly compared with the terrestrial deposits of the Ravenscar Group. The Upper Jurassic (Oxfordian and Kimmeridgian) samples studied revealed a low diversity assemblage characterised by *Foveotriletes irregulatus.* Couper (1958) noted a similarity of species with the Scalby Formation but a difference in diversity.

On the basis of the changes in relative abundances of coniferous pollen (*Alisporites* spp., *Cerebropollenites mesozoicus, Classopollis torosus, Araucariacites australis*), Couper postulated changes in the parent plant flora. During deposition of the Hayburn and Cloughton Formations the author envisaged Araucariaceous and *Classopollis* producing plants being dominant over 'pinaceous' plants (*Alisporites spp.* producing plants). In the Scalby Formation and the Upper Jurassic the position changed and *Cerebropollenites mesozoicus*, *Perinopollenites elatoides* and 'pinaceous' plants became dominant. The cause of these postulated vegetational changes was unknown.

1.4.Taphonomy and palaeoenvironmental reconstruction.

An understanding of the syn- and post -depositional processes affecting sediment in combination with an ability to discern the taphonomic processes of pollen grains and spores is viewed as a prerequisite to interpreting the organic assemblage recovered following acid digestion. Observations drawn from present day examples have been widely used as a tool for the interpretation of palaeoenvironments, however it is important to recognise that differences exist between past and present environments (Collinson & Scott 1987, p.78).

The realisation that spores and pollen grains, once released from the parent plant, act as sedimentary particles with settling velocities equivalent to silt grade sediment was first reported by Muller (1959). His work on the palynology of the Orinoco Delta remains one of the few comprehensive studies of the processes operating in contemporary systems. In interpreting results from fossil data it is inevitable that contemporary systems are used as analogues and comparisons. However difficulties arise due to the paucity of well documented present day tropical and subtropical floodplain and delta plain ecosystem studies. The work of Muller (1959) is widely referenced and, by way of introducing a contemporary comparison for the non-marine deposits in the Ravenscar Group, will bediscussed below.

Orinoco Delta Palynology.

The study of Muller (1959) was undertaken in order to investigate the transport and deposition of "pollen"* in an environment of clastic deposition. The study area was the Orinoco Delta, the Gulf of Paria and the eastern and northern shelves off the coast of north east South America. Emphasis was placed on obtaining a regional picture but it was noted that the physiography of the delta made accessibility difficult and thus the delta was sampled only to a limited extent.

A general description of the water circulation on the delta was outlined; water courses were identified as muddy main discharge and back-swamp "black" water which drained from the humus-rich back-swamps. A biannual pattern of water level was noted with a wet season maintaining widespread flooding of the delta whilst the dry season resulted in exposure of the levees. In the back-swamp environment, water movement was more restricted and lateral transport was assumed to be predominantly active during flood stages. Erosion of sub-recent delta deposits was recognised in the active main channels

Water discharged into the sea contained pollen of various origins in suspension. The grains could have originated from coastal vegetation along the estuaries or it could have had a longer history of air transport, water transport or reworking in one or more

---

* covering both pollen grains and spores

cycles. On meeting the marine waters of the Gulf of Paria the fresh water wedged out for some distance into the gulf. This freshwater wedge was exaggerated in the rainy season. A strong westward marine current was recognised along with strong tidal currents affecting the estuaries. In addition to active reworking of sediments in the channels further sources of reworked sediment in the cliff faces of Trinidad and on the sea floor in the Serpent's Mouth were distinguished.

On the delta, seven phytogeographical areas were differentiated; mangrove forest, mixed swamp forest, *Erythrina* swamp forest, palm swamp, herbaceous swamp dune, beach ridge vegetation and rain forest. The horizontal distribution of these areas led to the recognition of several regions: upper delta where seasonal fluctuations in water level predominate and levees are well developed. Here, rain forest was the dominant vegetation type; the back swamp areas where depending on water level, *Erythrina* swamp, palm swamp or herbaceous swamp forest was dominant; the central delta where levee building was much less pronounced and tidal influences were moderate, penetrating short distances into the backswamps; the outer delta where tidal influences were strongest and the vegetation consisted of an inner belt of mixed swamp and an outer of mangrove forest.

Physiographic differences were observed to have affected this general pattern, for example, a strong dissection of the lower delta by tidally influenced channels in the south eastern part of the delta led to a different distribution of vegetation and developed soil profile than that of the central delta where a few large, straight channels left largely undrained backswamp.

In terms of total pollen content of the samples on the delta, several cross sections (picas) were constructed to illustrate the distributions. The lowest pollen contents were found in levees and back-swamp peats where respectively high mineral content and organic accumulation of the sediments occurred. Maximum pollen content was found in sediments where mineral supply and organic content were at their minima. Prolific pollen producers were thought to affect the total pollen content since high percentages were correlated with peaks in total pollen content.

The distribution of selected pollen grains was further discussed. The pollen of the palm *Mauritia* was observed to be directly proportional to the parent plant, which inhabited the central and western delta. Muller concluded that atmospheric mixing was unable to equalise the locally variable pollen production to any degree. The pollen of *Avicennia nitida*, a main constituent of the inner mangrove swamp appeared to be relatively under-represented compared to *Rhizophora mangle*, the other main mangrove constituent. *Avicennia nitida* pollen distribution was closely related to the source area and water transport was envisaged to be dominant in its dispersal. *Rhizophora mangle* pollen distribution was of interest as it was strongly over-represented in the sediments. Its parent flora distribution was restricted to the mangrove areas, in particular the outer zone. The presence of *Rhizophora* pollen in backswamp deposits and in channel deposits at the upstream limits of its parent vegetation was an indication to Muller that the small sized pollen grains were adapted to distribution by wind.

The distribution patterns of several species thought to have originated from Trinidad and the peninsula of Paria were also discussed. These exhibited a different offshore distribution pattern than the preceding forms including evidence of a dominant wind transport mechanism from upland source areas. A further group of species whose source areas were dispersed over the islands and the mainland were isolated for discussion. The grains of *Symphonia globulifera* exhibited evidence of multiple sources and limited transport due to the large size of the grains. A strong correlation between parent plant and high pollen percentages was also observed. The small grains of *Terminalia* type, presumed to have been produced from several genera of the family Combretaceae exhibited a diffuse pattern of distribution with few discernible indications of the nature of transport. In addition to these examples, two species, *Erythrina* and *Pterocarpus* were observed to produce very little pollen in spite of their abundant parent flora and thus were poorly represented in the sediments. Evidence of transport from the montane regions in the Andes was witnessed by the discovery of low percentages of *Alnus* pollen in several samples. A fluviatile transport of some 500 miles was thus inferred.

The distribution of other microfossils was recorded including fungi, cuticle, dinoflagellate cysts (*Hystrix* of Muller) and foraminifera. Of note was the diminishing grain size and abundance of the cuticle away from the delta area. Only the smallest grains remained on the outer shelf. Three cores from offshore locations were studied to investigate the vertical variation in the microfossil assemblages. The results were inferred to represent climatic change reflected by variations in discharge of the distributaries and in the composition of the vegetation. In conclusion, Muller noted the high sensitivity of the palynological method combined with sedimentology and palaeogeography. However, caution was noted regarding the generalisation of the study as the results strictly applied only to the Orinoco Basin.

Further research of interest to the present study was that on the Orinoco Delta by Scheihing & Pfefferkorn (1984). In recording the taphonomy of the land plants, the authors concluded that ;

1. Aerial parts of plants were deposited relatively close to the site of growth but rarely in the actual soils in which the plant lived,

2. Plant parts were preserved preferentially in areas with slightly higher rates of sedimentation,

3. Natural levees were dry for half of the year and thus any buried organic matter was subjected to oxidation and bioturbation by plant roots leading to destruction,

4. Tidal processes were as significant as annual flooding in forming plant bearing deposits on the lower delta plain,

5. No storm generated deposits were known on the Orinoco Delta, indicating that non-storm deposition was important in the case study.

Further observations indicated that in the upper flood plain, levee and flood basin plant communities were preserved in different facies. The levee flora was commonly encountered in the channel deposits. The levee itself acted as a physical barrier between the mixing of levee vegetation and floodplain vegetation. Lower floodplain plants were best preserved in channel and channel margin facies. The authors pointed out the importance of carrying out taphonomic studies in physiographic areas similar to those of the fossilised sequence in consideration (in their case the Upper Carboniferous of North America and Europe).

An important point raised by the study was that of representation of the flora in the sediment when physical processes were subdued. It was noted that leaves of palms, although abundant in the forest, were rarely encountered in the sediment due to the way in which the leaves were retained on the plant after dying. Other species exhibited different forms of decay which would have lead to an aberrant representation in the sediment. Conversely, plants which possessed an ability to widely disperse large numbers of their parts would be excessively represented in the sediment. This led to the theory that the representation of a taxon in a sediment was a function of its standing biomass and more importantly plant part productivity and efficiency of the mechanism for transferring plant parts quickly into the distributary systems. Since the study was concerned with the plant macro parts, no mention of the spores and pollen grains was made. However it is important to appreciate the observations made when considering the taphonomy of palynomorphs in similar settings.

It is of interest to consider Sheihing & Pfefferkorn's (1984) results in the wake of Muller's (1959) study. Our understanding of the reproductive processes of the Orinoco Delta flora is poor; relative rates of pollen grain and spore production are but touched upon in Muller's work. The same situation is true of the majority of fossilised systems. It is questionable whether the knowledge of the taphonomy of the plant macrofossils will have any relevance to the plant palynomorphs. Over representation and under representation of selected grains within the sediment is rarely understood nor considered, yet it is clear from Muller's results of the significance of representation in elucidating the palaeoenvironmental setting and controls on the fossilised assemblages.

With regards to the physical processes affecting the sediments, far more studies are available concerning deltaic and alluvial systems. A comprehensive introduction may be found in Reading (1978, Ch. 3 & 5).

2. Methods.

2.1. Sampling methods.

Four sections of the Scalby Formation were chosen in order to recover as much stratigraphical coverage as possible, to encompass a wide geographical area and thus reduce the bias of coastal exposures. The location of the sections is indicated in figure 2.1 and the sample coverage is shown in figure 2.2.

The study was limited by the need to maintain a high density of sampling in the chosen sections and the desire to maintain at least two comparable sections. Sections of the Gristhorpe Member of the Cloughton Formation and the Scarborough Formation were sampled at Yons Nab for a comparison with the younger Scalby Formation. In addition, several samples of the Cornbrash Formation, Langdale Beds Member and Hackness Rock Member at Cunstone Nab (GR TW 1000 8302) were sampled in order to observe the change in assemblage following the Lower Callovian transgression. Graphical logs of the sections can be found in Appendix 2.

Samples from the sections were taken after removing the loose, weathered cover of strata which was inevitably present. Between 5cm and 10cm thickness of rock was retrieved for each sample and sufficient sample was bagged so that reprocessing of the sample was possible at a later stage if necessary. Precautions to prevent contamination were taken during all stages of sampling and processing. Sampling density was maintained at between 50cm and 100cm between samples or whenever a lithology change suggested the need for further sampling.

2.2. Processing Methods.

Processing followed the general procedure outlined in figure 2.3. Processing methods were kept as similar as possible for all samples in order to eliminate any bias resulting from differences of methods. Approximately 50 grams of sediment were taken from each sample: sandstones were processed in greater quantities as these commonly yielded smaller amounts of kerogen than mud and silt grade rocks. Sieving was undertaken with 10µm size mesh during all stages of the processing procedure.

2.3. Logging Methods

The method chosen for recording the data from a sample was a semi-quantitative determination in terms of absolute number of specimens recorded. The method employed follows that of Tschudy (1969) where 250 specimens were logged (Tschudy recommended between 200 and 500) followed by a scan of the rest of the slide (a second slide was scanned if the log involved the majority of the first slide) in order to identify specimens not recorded in the count.

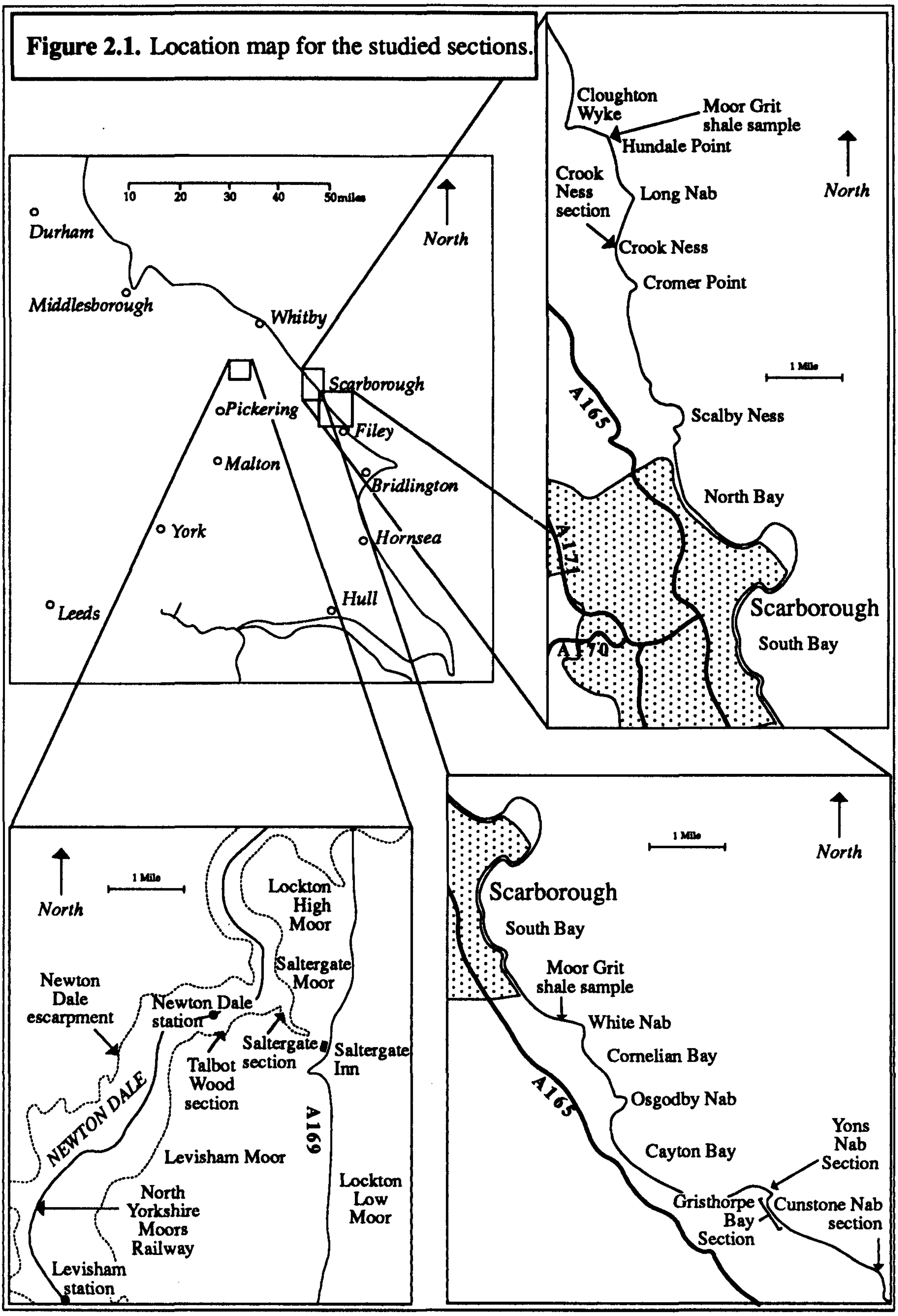


Figure 2.1. Location map for the studied sections.

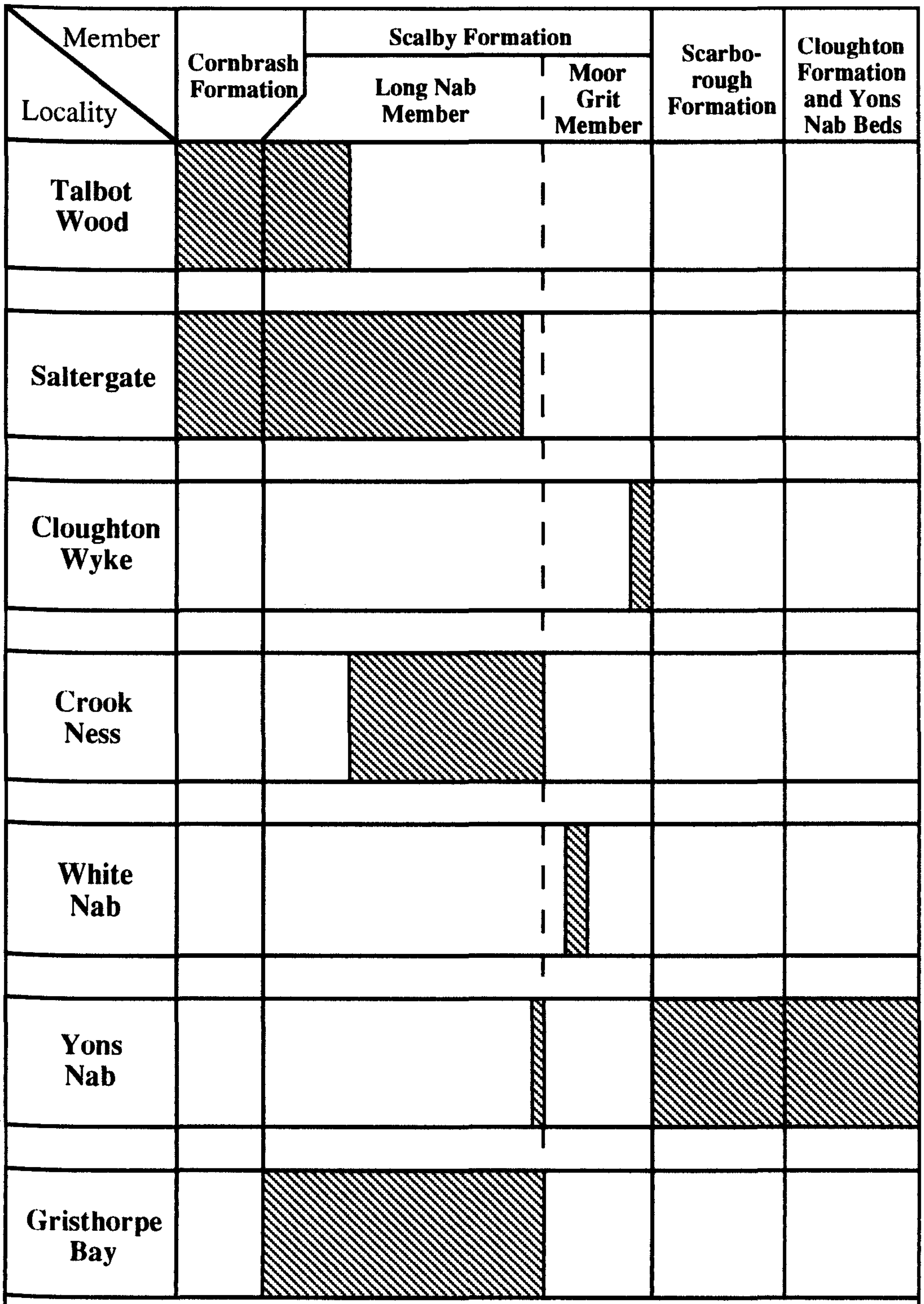


Figure 2.2. Sample coverage (shaded) for the present study.

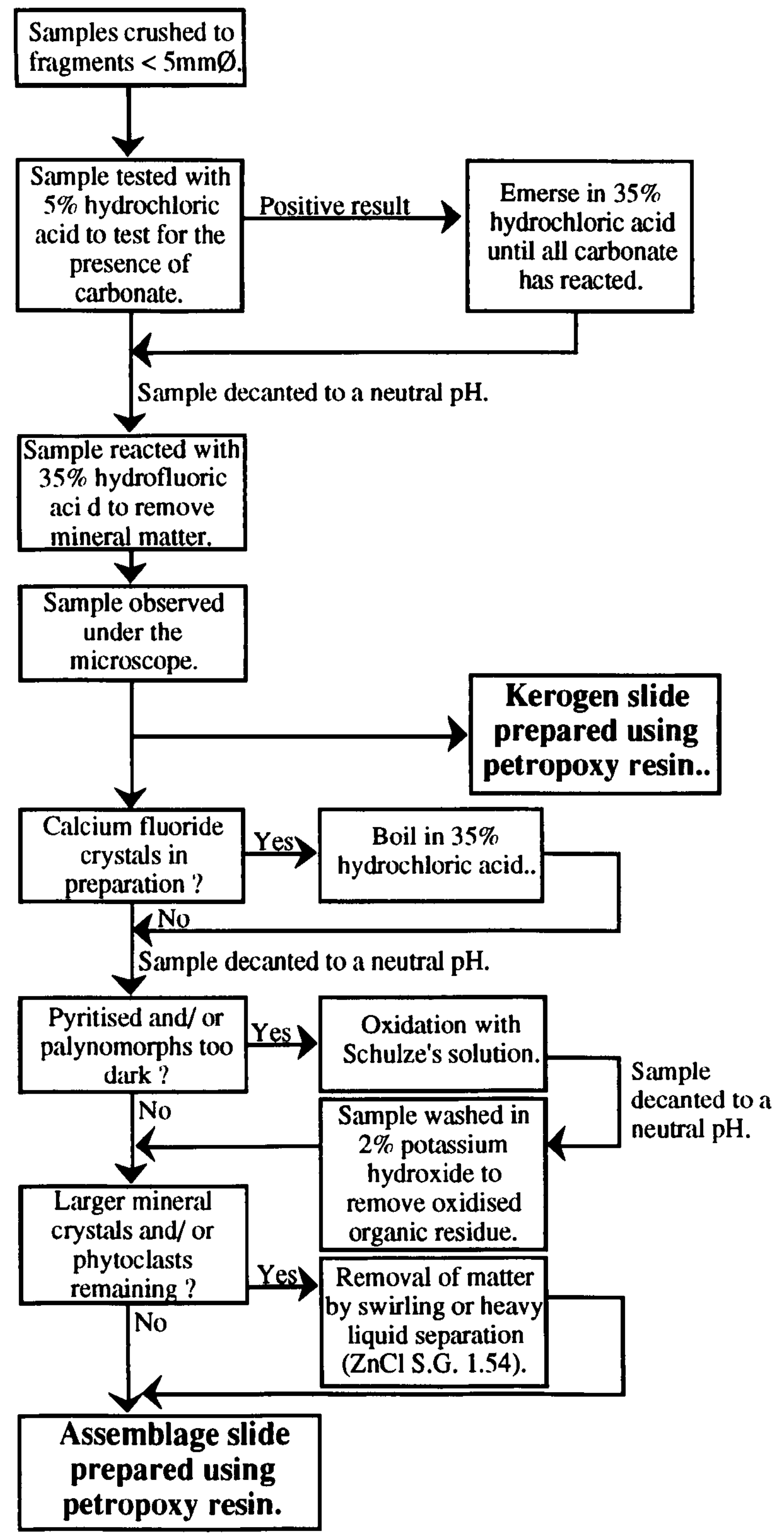


Figure 2.3. Sample processing procedure.

Wilson (1959) plotted the number of specimens against the number of species for various samples ranging from Carboniferous to Pleistocene in age. He termed the point where the curve flattened out the break off point. The break off point for the samples chosen ranged from 100 to 350 specimens.

2.4. Data analysis methods.

Data from each sample was entered onto a spreadsheet in the Tilia© data analysis program. This allowed further data analysis on Tilia.graph© and output to other data spreadsheet packages if necessary.

Each file consists of a single locality section. It was necessary to use depth measurements for column headings in order to obtain the correct spacing of samples in the outputted data. The highest sample in each section was assigned to a depth of 1.0 metres and subsequent samples were referenced to this level. In order to make uncommon species more recognisable in the saw tooth diagrams, an exaggeration factor of 5 was applied to the data. True values are shaded in black on the diagram whilst the exaggerated values are shaded with dots.

In order to standardise the data set, the raw data was converted into percentages using the Tilia package. Sums of different categories of palynomorphs (e.g. dinoflagellate cysts, pollen grains etc.) were also calculated. The resulting standardised data was analysed using the cluster analysis facility in Tilia. This used stratigraphically constrained cluster analysis by the method of incremental sum of squares (Grimm 1987). The results were represented in the form of a dendrogram. When represented in this way, the clusters compare the assemblage similarities of adjacent samples. To recognise the repetition of gross assemblage compositions between samples in the sections, associations based primarily on palynomorph groupings were identified from the Tilia.graphs. Where possible, the associations were further qualified on the presence of species considered to be significant in their occurrence

Due to their geographic isolation from the other sections, the samples of the Moor Grit Member at Hundale Point and White Nab were not incorporated into the tilia graphs and are considered separately.

© Tilia and Tilia.graph, version 1.1, copyright 1991, 1992, Eric C Grimm, Illinois State Museum, Research and Collectors centre, 1920 South 101/2 St., Springfield, IL62703, U.S.A., all rights reserved.

Chapter 3

3.1. A history of the systematic palynology of fossilised spores and pollen grains.

When considering the possible methods of grouping morphologically defined species above generic level, it was thought of relevance to review the previous published methods. This led to a consideration of the history of palaeobotany from which palynology evolved as a separate discipline towards the end of the nineteenth century.

The starting point of palaeobotany accepted by the International Code of Botanical Nomenclature (I.C.B.N.) is taken as the work of Von Sternberg in 1820 who was the first to apply the Linnaean binomial system. Adolphe Brongniart (1801-1876) was the first author to formulate certain general principles and to apply them to the fossil plants known up to that time. Of the three principles, his taxonomic principle stated that all fossil plants have to be studied as such and were not necessarily remains of species with living representatives. In many instances the fossil remains were fragments of plants and the connections between the various parts were often unknown. The characters must be derived from direct observation and not from speculative implication of relationship with other plants. It was important to concentrate on clearly visible characters and not confuse observation, interpretation and taxonomic belief. The concept of form genera was also conceived by Brogniart. He noted that it was better to have an artificial classification based upon a restricted number of characters derived from similar fragments than to speculate too soon upon natural relationships. However he stressed that it should always be the aim of the palaeobotanist to try to find the natural classification, whatever that may be.

Of his other principles, his stratigraphic principle stated that plant fossils can be used for stratigraphic purposes and his floristic principle stated that floras or combinations of species can be characteristic of geological periods.

With regard to palynomorph descriptions, the description of *Lepidodendron longibracteatus* Morris 1840 was the first to figure isolated macrospores, although Morris regarded them as sporangia. Göeppert described macrospores as *Carpolithes conformis* in 1848. Dawson (1886) proposed the provisional generic name *Sporangites* for spores or "spore cases" of *Lepidodendron, Calamites*, and similar plants. H. Potonié in 1893 proposed the name *Sporites* for dispersed spores; the remaining *Sporangites* were intended for dispersed sporangia.

In 1884, Dr P. F. Reinsch published two-volumes of detailed work. His first volume was devoted to the Trileteae and Stelideae of which the genera, *Triletes*, *Trichostelium* and *Stichostelium* were described respectively. Reinsch believed the latter two genera were plants of a parasitic nature which commonly parasitized the larger forms of Triletes. As later commented by Bartlett (1923) " ... it appeared obvious that the majority of them were merely fragments of the elaborately sculptured, complicated zonal appendages of the megaspores included under Triletes " (*op. cit.*, p.33-34). In his second volume, Reinsch described and figured various structures; spores, spore appendages, cuticles etc. from the Devonian through to the Tertiary. He considered them all as independant organisms. Many appear, according to Bartlett " ... to fall for the most part under Triletes " (*op. cit.*, p.34). Bartlett argued that Reinsch's reasoning," ... because one kind of spore is found both with and without appendages, and because a simple spore may be partly with and partly without an investiture, is very weak " (*op. cit.*, p.35).

Bennie & Kidston (1886) suggested that Reinsch's " ... *Triletes* must not be regarded as a genus, for the occurrence of a triradiate ridge, one of the chief characters of the group, though common to the spores of the Lycopodiaceae, also occurs on spores of other Orders " (*op. cit.*, p.86). However, their use of *Triletes* was due to their belief that all forms of the megaspores they described " ... are referable to some of the extinct *Lycopodiaceae* " (*op. cit.*, p.86). In their descriptions they divided *Triletes* into three divisions; **Laevigati** for megaspores whose outer surface was smooth or slightly granulated, **Apiculati** for megaspores whose outer surface was ornamented with mamillate spines and **Zonales** for megaspores with a zona. Within each division the forms were referred to as **Triletes** followed by a roman numeral. A new group **Lagenicula** was created for megaspores with a " ... neck-like projection which eventually splits into three subtriangular segments"(*op. cit.*, p.114-115).

Potonié (1931), some thirty years following, classified all Tertiary spores and pollen grains within the form genera **Sporites** and **Pollenites**. Specific names within these genera were derived from some morphological characteristic.

Ibrahim (1933) modified Potonié's system for use on Palaeozoic spores. The generic names were based on a morphological prefix combined with -sporites. Type species for each genus was created. Thus *Reticulatisporites* was described as a genus for reticulate (*Reticulat-*), trilete (*-i-*), spores (*-sporites*). The combining letter indicated the spore type, thus *i* for trilete, *o* for monolete and *a* for alete spores. Ibrahim also introduced the turma **Monoletes** and **Aletes** to expand upon Reinsch's **Triletes.**

Raistrick and Simpson (1932-3) and Raistrick (1934-5, 1936-7, 1938-9) and Knox (1938) used an alphabetic system of seven categories (A to G), which were further subdivided by numerical subscripts, for grouping Palaeozoic spore morphologies. It was believed that these corresponded to the species of Potonié and Ibrahim. The scheme proved useful in coal seam correlation, although it was used arbitarily. The forms lacked type designation, some were figured in line drawings, some in photographs and some were not figured at all.

Wodehouse (1933) introduced the suffix *-pites*, a contraction of pollenites, to specific, generic and family names of extant taxa in a study of the pollen from the Eocene Green River Shales in North America. In the late 1930's and early 1940's a group of

German workers modified Potonié's **Sporites** and **Pollenites** to uncontracted suffixes on the family or generic names of extant taxa e.g. *Ericaceae-pollenites.*

Miner (1935) used morphological terms to name new forms that had unknown generic affinities. He also contracted *-sporites* to *-spora,* e.g. *Deltoidospora.*

Schopf, Wilson and Bentall (1944) revised much of the previous literature, especially the Ibrahim classification. Morphologically similar groups were assembled into genera, each with a genotype. Species within the genera were defined by a holotype. The new genera were created on a number of inconstant characters and were usually of a commemorate nature e.g. *Raistrickia.* As a result this action broke Ibrahim's strict system of morphological names.

In Russia, Naumova (1937) proposed two phyla, **Sporae** (Pteridophyta) with germination usually by a split of dehiscence and **Pollina** (Spermatophyta), gymnosperm and angiosperm pollen with no definite split of dehiscence. The phylum **Sporae** was sub-divided into the classes **Rimales** and the **Irrimales**, based on the presence or absence of a dehiscence mark. The class **Rimales** was further sub-divided into the groups **Monoletes** and **Triletes**, according to the nature of the dehiscence mark. The class **Irrimales** had one group, **Aletes**. Further sub-divisions were established on the presence or absence of a fringe (zona) e.g. Zonotriletes, Azonotriletes, Zonomonoletes and Azonomonoletes. Naumova's genera were based on characters of ornamentation and her specific groups were based on smaller features e.g. character and distribution of ornament.

The phylum **Pollina** was sub-divided into **Aporosa** (without pores, considered to be gymnosperm pollen) and **Porosa** (with pores, regarded as angiosperm pollen). The class **Aporosa** was further divided into seven groups, based on the presence or absence of sacci, folds, plications and lobes, and thirteen subgroups.

Naumova did not establish any genotypes and the descriptions of the subgroups often consisted of just a few words. A great variety of species were placed in each subgroup and Naumova's illustrations indicated that spores of greatly differing structure were included in the same subgroups. Naumova attempted to relate the different phyla to a natural classification and claimed that trilete marks were a Pteridophyte feature. Following Russian workers further broadened Naumova's generic groups.

Luber and Waltz (1938) asserted the importance of the dehiscence mark. Their three principle groups were **Triletes**, **Monoletes** and **Aletes**. The sub-groups, approximating to genera, equated with those of Naumova and were similarly as broad.

Erdtman (1947) published an artificial morphographical classification scheme for Tertiary pollen grains and spores. The genera were based on shape groups called **sporomorphs**. Included in the definition "shape" were such features as aperture type and aperture position e.g. *Tricolporites protrudens* Erdtman in Ross 1949. The suffix *-ites* was used when apertural characteristics upon which the genus was based were apparent, and *-idites* when the interpretation was uncertain.

Cookson (1947, 1950, 1953, 1954, 1956) and Couper (1953, 1958) modified Erdtman's system, using the endings to indicate their degree of confidence in material they referred to recent genera or families (e.g *Dacrydiumites* Cookson 1953 being a genus for pollen probably derived from *Dacrydium* and *Liliacidites* Couper 1953, a genus for pollen that was similar to liliaceous pollen but was probably not derived from the Liliaceae).

Suprageneričally, both workers arranged dispersed genera into natural families where a high degree of certainty was apparent and created large inhomogeneous groups, *incertae sedis*, where they were less certain. Both workers had little hesitation in applying modern generic names to forms collected from the Tertiary of New Zealand.

Thomson & Pflug (1953) adopted a purely morhographical approach to Tertiary spore and pollen grains. They adopted the rules of the I.C.B.N. and made use of previously published species as well as creating numerous of their own. Botanical affinities were but commented upon and kept separate from the systematics. As a result the work remains an important North West European Tertiary reference.

Pant (1954) proposed a classification based upon the ideas of several of the preceeding authors. Naumova's classification was used to a large degree but some suprageneric terms were taken from other authors. Erdtman's term **Sporopollenites** was adopted as a group name to include all spores, prepollen and pollen grains. In addition to the phyla **Pollenites** and **Sporites** of Potonié, Pant proposed the new group **Prepollenites** for pollen grains which were triradiate and had a proximal germinal aperture. The class **Rimales** Naumova was divided into two sub-classes **Tririmosa** and **Monorimosa**. Sub-class **Tririmosa** was further divided into **Microsporites** Dykstra (spores less than 200μ in diameter) and **Triletes** Reinsch (spores greater than 200μ in diameter). Many of Naumova's genera were emended to include megaspores only, but type species were not proposed and no forms were figured.

Potonié & Kremp (1954) re-emended Naumova's subgroups, designating type species. The system put forward by Potonié & Kremp (1954) and later amplified by these authors in 1955 and 1956 and by Potonié in 1956, 1958 and 1960, attempted to collate all the information produced upto that date so that all described genera of dispersed spores and pollen grains were included (figures 3.1 and 3.2).

The suprageneric divisions had a hierarchial structure. The highest level was the **Anteturma (Oberat)**. Divisions of the anteturma **Sporites** at **Turma (Abteilung)** level were based on aperture, lip and equatorial features. Likewise the division of the **Turma** level to **Subturma (Unteraht)** units was based on lip and equatorial features and wall stratification. The further division to **Infraturma (Riehe)** level was based on lip and equatorial features and exine sculpture. The Anteturma **Pollenites** was divided into five **Turmae** on the presence or absence of sacci and type of aperture. The turmae **Saccites**, **Plicates** and **Poroses** were divided at **Subturmae** level on the number of sacci, colpi or pori present respectively. The **Napites** were divided on whether they were zonate or azonate. The **Jugates** were pollen grains which were united into groups of two, four or more, hence **Dyadites, Tetradites** and **Polyadites.**

SPORAE DISPERSAE

Anteturma SPORONITES (R. Potonié) Ibrahim 1933

Anteturma SPORITES H. Potonié 1893
Turma TRILETES (Reinsch 1881) Pot. & Kremp 1954
Subturma Azonotriletes Luber 1935
Infraturma Laevigati (Bennie & Kidston 1886)Potonié 1956
Infraturma Apiculati (Bennie & Kidston 1886)Potonié 1956
Subinfraturma Granulati Dyb. & Jach. 1957
Subinfraturma Verrucati Dyb. & Jach. 1957
Subinfraturma Nodati Dyb. & Jach. 1957
Subinfraturma Baculati Dyb. & Jach. 1957
Infraturma Murornati Potonié & Kremp 1954
Infraturma Perinotriliti Erdtman 1947
Subturma Lagenotriletes Potonié & Kremp 1954
Subturma Pyrobolotriletes Potonié 1956
Subturma Capulitriletes Potonié 1956
Turma ZONALES (Bennie & Kidston 1886) Potonié 1956
Subturma Auritotriletes Potonié & Kremp 1954
Infraturma Auriculati (Schopf 1938) Potonié & Kremp 1954
Infraturma Appendiciferi Potonié 1956
Subturma Zonotriletes Waltz 1935
Infraturma Cingulati Potonié & Klaus 1954
Infraturma Zonati Potonié & Kremp 1954
Turma BARBATES Mädler 1954
Turma MONOLETES Ibrahim 1933
Subturma Azonomonoletes Luber 1935
Infraturma Psilamonoleti Van der Hammen 1955
Infraturma Ornati Potonié 1956
Infraturma Perinomonoliti Erdtman 1947
Subturma Zonomonoletes Luber 1935
Turma CYSTITES Potonié & Kremp 1954

Figure 3.1 Classification of the Anteturmas Sporonites and Sporites after Potonié & Kremp (1954, 1955, 1956) and Potonié (1956, 1958, 1960).

Some of the form genera of Potonié & Kremp were based on characteristics that overlapped from one genus to another. In a few cases, type species of genera proposed by American authors were placed in synonymy with similar species that occur in Europe.

Traverse (1955) used generic names of extant taxa for classifying Tertiary spore and pollen grains when the affinity to a modern genus was thought to be certain. When uncertain, a new organ genus was created and placed in an existing family. No attempt was made to refer to previously described genera and species.

Van der Hammen (1956) proposed a system of classification based on aperture and sculptural features whilst working on Upper Mesozoic and Tertiary samples. The descriptive terms used were those of Iversen and Troels-Smith (1950) and supposed natural relationships were never used in construction of generic and specific names. His groups were broad, for instance zonate and azonate forms were not distinguished at generic level, and names of validly instituted genera were ignored, breaking the rules laid down in the I.C.B.N.. A similar classification was adopted by Pierce (1961).

SPORAE DISPERSAE

- Anteturma POLLENITES Potonié 1931
  - Turma SACCITES Erdtman 1947
    - Subturma Monosaccites (Chitaley 1951) Pot. & Kremp 1954
      - Infraturma Triletesacciti Leschik 1955
        - Subinfraturma Intromati Butt. &Will. 1958
        - Subinfraturma Extromati Butt. & Will. 1958
      - Infraturma Vesiculomonoraditi (Pant 1954) Bharad.1956
      - Infraturma Aletesacciti Leschik 1955
      - Infraturma Saccizonati Bharadwaj 1957
    - Subturma Disaccites Cookson 1947
    - Subturma Polysaccites Cookson 1947
  - Turma ALETES Ibrahim 1933
    - Subturma Azonaletes (Luber 1935) Potonié & Kremp 1954
      - Infraturma Psilonapiti Erdtman 1947
      - Infraturma Tuberini Pant 1954
      - Infraturma Granulonapiti Cookson 1947
      - Infraturma Subpilonapiti (Erdtman 1947) Vimal 1952
    - Subturma Zonaletes Luber 1935
  - Turma PLICATES (~Naumova 1937, 1939)
    - Subturma Praecolpates Potonié & Kremp 1954
    - Subturma Polyplicates Erdtman 1952
    - Subturma Monocolpates Iverson & Troels-Smith 1950
    - Subturma Dicolpates Erdtman 1947
    - Subturma Triptyches (~Naumova 1937, 1939)
    - Subturma Polyptyches (~Naumova 1937, 1939)
    - Subturma Ptychotriporines (~Naum. 1937,1939) Potonié 1956
      - Infraturma Prolati Erdtman 1943
      - Infraturma Sphaeroidati Erdtman 1943
      - Infraturma Oblati Erdtman 1943
  - Turma POROSES (~Naumova 1937, 1939)
    - Subturma Monoporines (~Naumova 1937(1939?))
    - Subturma Diporines (~Naumova 1937(1939?))
    - Subturma Triporines (~Naumova 1937?, 1939)
    - Subturma Polyporines (~Naumova 1937, 1939)
      - Infraturma Stephanoporiti (~Van der Hammen 1954)
      - Infraturma Periporiti (~Van der Hammen 1956)
  - Turma JUGATES (~Erdtman 1943?)
    - Subturma Dyadites Pant 1954
    - Subturma Tetradites Cookson 1947
    - Subturma Polyadites Pant 1954

Figure 3.2. Classification of the Anteturma Pollenites after Potonié 1960.

Dettmann (1963) revised the classification system of Potonié & Kremp 1954, (figure 2). The turmal units **Triletes**, **Monoletes** and **Hilates** were established on aperture characteristics; the suprasubturmal units were based on wall stratification; the subturmal units were based on equatorial features and the infraturmal units were based on sculpture and equatorial thickening and/or extension. By doing this, all units became mutually exclusive and so the problems encountered in Potonié & Kremp's classification were eliminated.

- Anteturma **SPORITES** H. Potonié 1893
  - Turma TRILETES (Reinsch 1881) Pot.&Kr.1954
    - Suprasubturma Acavatitriletes Dettmann 1963
      - Subturma Azonotriletes (Luber 1935) Dettmann 1963
        - Infraturma Laevigati (Ben. & Kid. 1886) Potonié 1956
        - Infraturma Apiculati (Ben. & Kid. 1886) Potonié 1956
        - Infraturma Murornati Potonié & Kremp 1954
      - Subturma Zonotriletes Waltz 1935
        - Infraturma Auriculati (Schopf 1938)Dettmann 1963
        - Infraturma Tricrassiti Dettmann 1963
        - Infraturma Cingulati (Pot. & Klaus 1954) Dettmann 1963
        - Infraturma Patinati Butterworth & Williams 1958
    - Suprasubturma Perinotrilites (Erdtman 1947) Dettmann 1963
  - Turma MONOLETES Ibrahim 1933
    - Suprasubturma Acavatomonoletes Dettmann 1963
      - Subturma Azonomonoletes Luber 1935
        - Infraturma Laevigatomonoleti Dyb. & Jach. 1957
        - Infraturma Sculptatomonoleti Dyb. & Jach. 1957
      - Subturma Zonomonoletes Naumova 1937
    - Suprasubturma Perinomonoletes Dettmann 1963
  - Turma HILATES Dettmann 1963

Figure 3.3. Classification of the Anteturma Sporites after Dettmann 1963.

Richardson (1960) criticised Dettmann's emended suprasubturma **Perinotrilites** for consisting of a group of some genera previously included within the subturma **Monosaccites** (Chitaley 1951) Potonié & Kremp 1954, in addition to other spores with a diaphanous outer membrane. The use of the group name in another sense was considered confusing and in the authors view, spores with a 'perispore'-like outer membrane, e.g. *Perotrilites*, are sufficiently distinct to be classified separately. Richardson (*op. cit.*) proposed a new subturma **Pseudosaccititriletes** for trilete spores with a well developed cavity separating any two layers of the exine and which do not have, in addition, a solid flange. The two subturma **Extrornati** and **Intrornati** of Butterworth and Williams (1958) were used for subdividing the turma. **Perinotrilites** Erdtmann 1947 (sensu Potonié & Kremp 1954) was retained by Richardson for spores which had a thicker, more rigid membrane, e.g. *Endosporites*. The term 'cavate' used previously for similar arrangements, was not adopted since its' original definition by Faegri & Iversen 1950 was used for pollen grains with a columellate structure. As a consequence, Richardson placed it in synonymy with the term saccate.

Neves and Owens (1966) proposed the term **camerate** to replace the term **cavate** (*sensu* Dettmann 1963), thus the suprasubturma **Acavatitriletes** of Dettmann was replaced by **Acameratitriletes**. The suprasubturma **Perinotrilites** (*sensu* Erdtmann 1947) was retained. **Cameratitriletes** was further subdivided, on the degree of separation of the wall layers, into **Solutitriletes**, where the intexine and exoexine were attached proximally only, and **Membranatitriletes**, where the layers were attached both proximally and distally. Forms which showed a progressive development of cameration were assigned to **Membranatitriletes** since Neves & Owens (*op. cit.*) considered that they differed fundamentally from members of **Solutitriletes**.

Smith and Butterworth (1967) modified Dettmann's scheme, adopting the use of her controversial cavate terms and, in addition, employing the suprasubturma **Pseudosaccititriletes** of Richardson (1965). The distinction between the suprasubturmas **Pseudosaccititriletes** and **Laminatitriletes** was based on the degree of separation of the layers of the exine and no criteria were stated for the limits of each group. The subinfraturmal units employed suggest ornament was a stable feature within a species.

Hughes (1963) presented the first of several papers which described a new method for recording pre-Quaternary palynological data created to bring about more efficient use of the abundance of palynomorphs in fine stratigraphy. The work was in response to the following difficulties he saw in the science at that time and which, he anticipated, would occur in the future;

1. It was becoming impossible to make, in reasonable time, a full literature survey necessary for fully effective publication; " ... more time is being spent in search and interpretation of the literature than in observing fossil assemblages; the dangers of the increasing abundance of publications and of new taxa, and their very diverse standards, were emphasised by speakers at the First International Conference on Palynology "(Hughes & Moody Stuart 1967 p.347).
2. The accuracy of stratigraphical correlation was only improving very slowly, due to out of date handling techniques.
3. There was an urgent need to make full use of the great potential of 'modern data storage and retrieval methods'.

Hughes and Moody-Stuart (1967) stated that palaeopalynology was based on the routine of palaeontology, devised in the last century for handling macrofossils, which were often rare, and that gross stratigraphical determinations were still usually necessary.

When recording, the authors recommended the use of at least 100 specimens from one rock sample to be used for the basis of a palynological species and that only topotype material may be used for emendation. Help through palynological associations and editors of journals was suggested to make these measures obligatory. The author questioned the use of the word 'species' in the scheme and suggested the term 'record' as an alternative.

An example of a record was presented (*op. cit.*, p.349). The description consisted of details of the type sample of rock, a record diagnosis, a record holotype (included only to comply with the Rules of Botanical Nomenclature), a record description (which covers all the qualifications of the diagnosis), preservation and compression (eventually to be omitted when the warnings became more routine and obvious), and distinction (submitted for comparison which was used elsewhere).

In the following years, Hughes (1969, 1971, 1973, 1975) and with co-workers Moody-Stuart (1969) and Croxton (1967) attempted to improve and apply the system mainly to the early Cretaceous rocks of the Wealden Group and in particular, the Genus *Cicatricosisporites*. In his 1975 publication, Hughes gave a summary of the difficulties of the current practice and the recommended method of the classification developed upto that date;

Difficulties of the present method.

"1. Weak basis of reference taxa. There is as yet no obligation on authors to quantify observations, to organise them logically, or to make the statistical significance available.
2. Balloon taxa. Observations made to very diverse standards are added progressively to the reference taxon. Quoted time and geographic ranges of the taxon inevitably extend until each taxon is stratigraphically useless. Discrimination between records is very laborious and seldom successful.
3. Comparison records. The slight existing standard for this, concerning the use of cf. and aff., is vague and stratigraphically aimless.
4. Refinement of taxa. Further observations with new equipment usually improve the understanding of a taxon, but it is difficult to incorporate the results *effectively*, owing to priority rules.
5. Holotype tradition. As has been discussed elsewhere, the use of a holotype, while it is confined to a single specimen, prevents the *automatic* use of variation data.
6. Information retrieval. This is dependent solely on the unstable name of the holotype. There is no method for updating other records, which have been added at various times during the existence of the taxon name.
7. Genus, family, etc. These are unstable concepts because they are clusters defined from a randomly selected "center". This is another aspect of unsuitability of the type method.
8. Stratigraphic zonal schemes preclude progressive refinement of the zones as information is recieved.
9. Time correlation by *equating* events is inaccurate and even logically wrong.
10. Rapid expansion of the interpretation difficulties of data records leads to the dangerous position of spending more time on literature search than on records." (Hughes *op. cit.*, p.141-142).

Hughes' recommended method.

"1. Palynologic event. This is the individual time correlation item. It is interpretative from the author, and has been raised from a selected miospore assemblage. It is unique to the occasion and should be replaced by another event if that proves desirable or necessary.

2. Assemblage type. A rapid survey of assemblage type for each sample should be used for prediction of suitability of samples or preparations, thus avoiding waste of time.

3. Biorecord. This is a reference taxon erected in the same way as a palaeo-species, well based on a significant (but not fixed) number of specimens with variation stated. The extent of the rock sample involved is carefully stated. The difference is that a biorecord is both unchangeable after publication and completely devoid of priority; subsequent authors may therefore disregard it and erect others freely.

4. Comparison record. This is the crux of the stratigraphic procedure from which time correlations are built. All specimen records published must be placed in formal graded comparison with a biorecord. Their individual significance is lower than a biorecord, but the number of specimens should not be less than a quarter of the number agreed for a biorecord of the same fossils. The grades are: cfA-No qualitative difference of character measurement. This amounts to a *positive* interpretation of similarity to be used as a stratigraphic indicator. cfB-Minor qualitative difference of any kind. This was designed to be *neutral* in confining the scope of cfA. It may be of minor stratigraphic value. cfC-Indicates greater differences that would call for creation of a new biorecord *when the need to do so arises.* Its stratigraphic implication is therefore negative. For filing purposes the same comparison record of specimens may be graded cfC to two or more biorecords.

This subdivision may not seem to be ambitious enough but improvement should *not* take the form of drawing and attempting to define more comparison "circles". Rather should cfB be elaborated by additional qualifications of palaeo-geographic direction from the reference or geologic distance in time as indicated in Hughes (1973).

5. Event compilation. Events are composed of (graded) comparison records, and occasional biorecords. The data may be tabulated for brevity and clarity.

6. Bracket correlation. Each event is correlated with events on the reference scale concerned by means of an "after and before" bracket. The bracket may be narrowed as soon as relevant new events are available; this refinement can be a continuous process.

7. Nomenclature. Each record bears the authors initials and a number, corresponding to a specific epithet. As in the Linnéan system, a generic epithet is required (obligatory) for immediate filing; this takes the form of a seven letter pronounceable expression, abbreviated from an existing generic or other name.

8. Higher taxa. The term "genusbox" is used instead of genus to mark the fact that no type is used. Instead, morphographic limits against other taxa are defined, and also stratigraphic time limits are selected. This procedure is intended to provide stability. As the purpose of higher taxa is solely for filing and communication, no stepped hierarchy is required, and one large group with an abbreviated name such as SPOR will suffice.

9. Rules. Because of the removal of priority and all its consequences, new data-handling rules for palaeontology can be expressed on one printed page.

10. Compatibility. The method described is intended to provide effective data handling for present and future stratigraphic use. At the same time, species, biorecords, comparison records, etc, may be assembled into Linnéan taxa for such purposes as palaeoecology without them interfering as they do at present with refinement in stratigraphy."(Hughes *op. cit.*, p.142-144).

Traverse (1975) and Jansonius (1980) denounced Hughes *et al.* work, for its criticism of the Linnéan system which was, as Traverse stated " ... criticizing ... the application of biological nomenclature used by all modern systematists, which for palaeobotanists was governed by the International Code of Botanical Nomenclature" (Traverse *op. cit.*, p.145). Jansonius saw Hughes actions as reflecting " ... inadequacies of the various authors, not on any deficiency of the rules" (Jansonius *op. cit.*, p.444).

Of Hughes proposals, Jansonius suggested his objections to 'balloon' taxa were unsubstantiated since " ... not all taxa will balloon, no matter how diverse the standards, and those taxa then become the more valuable for bucking the trend. But, 'adding observations to diverse standards' cannot be prevented by legislation" (Traverse *op. cit.*, p.145). Hughes proposed names were criticised; types such as '9CICATR' were " ... not mnemonically much if any better than their legal cousins ... The Hughesian names would in time compose at least as cumbersome a file as do existing names-and would not be as managable, just because they would not be subject to priority or typification, but only to 'dealers choice'" (Jansonius *op. cit.*, p.445).

The creation of an international committee to plan a special office for approving the standards of description was argued to be unfeasible. Higher standards could be achieved by educating palynologists and journal editors " ... to the point where they will apply higher standards to their own work" (*op. cit.*, p.445).

Perhaps most important of all, Hughes' publications question us about our aims in stratigraphy and remind us of our present applications.

The suprageneric classification of Bharadwaj and Venkatachala (1968) attempted to use natural affinities for classifying dispersed spores. Studies of *in situ* material from the Carboniferous formed the basis for the classification. Plant classes were divided into alphabetical groupings according to particular features. The authors considered that the features could be used to group dispersed spores into a suprageneric classification which would be a morphological classification based on morphology and phylogeny. Organisations of some classes overlapped considerably and the classification split some established spore genera into separate groupings thus apparently necessitating taxonomic revision.

Filatoff (1975) attempted to apply a similar 'natural' classification to the Jurassic of the Perth Basin in Western Australia. The following 'types' were used to group genera;

- Spores;
  - Bryophytic spores
    - Sphagnaceae-type.
  - Lycopodialean spores
    - Lycopodiaceae / Selaginellaceae-type.
    - Lycopodialean Megaspores.
  - Sphenopsid
  - Filicalean Spores
    - Marattiaceae-type.
    - Osmundaceae-type.
    - Cyatheaceae/Dicksoniaceae-type.
    - Dipteridaceae/Matoniaceae-type.
    - Gleicheniaceae-type.
    - Hymenophyllaceae-type.
    - Schizeaceae-type.
  - Pteridophytic Spores of Unknown Affinity.
    - Abortive spores.
- Pollen;
  - Cycadopsida/Pteridospermopsida-type.
  - Saccate Conifer Pollen.
  - Araucariaceae-type.
  - Chierolepidaceae-type.
  - Cupressaceae/Taxaceae/Taxodiaceae-type.

No justification was given for placing the genera in the various 'suggested' families and few comparisons with *in situ* spore and pollen grains were attempted.

The suprageneric classification of Ravn (1986), suggested that the recent advances in palaeobotany allowed the assignment of most major (in his case Carboniferous) miospore genera at least to major plant groups. A classification based on known palaeobotanical relationships was employed using twelve basic categories;

1. Trilete filicineans, marratialeans and lyginopterids.
2. Trilete sphenopsids.
3. Trilete Lycopsids.
4. Trilete of unknown affinity.
5. Monolete marratialeans, sphenopsids and lyginopterids.
6. Monolete of unknown affinity.
7. Alete of unknown affinities.
8. Polyplicate probable gymnosperms.

9. Monosaccate gymnosperms.
10. Bisaccate gymnosperms.
11. Medullosan pteridosperms.
12. Fungi.

Within these groups, the genera were organised from the less ornamented to the more complexly ornamented forms in order " ... to facilitate comparison with the most commonly used suprageneric morphological classification system" (*op. cit.*, p.21). An alphabetical index was included at the back of the publication in order to aid referencing genera. The genera were arranged in increasing complexity; the plates indicated that this method has a great visual advantage. The most triangular species and genera were placed at the beginning of the plate and forms graded through to circular forms towards the end of the plate. An increase in complexity of ornament mirrored this progradation.

Ravn's specimens were retrieved mostly from coal balls in the Carboniferous of Iowa. Many spores had been described from fructifications retrieved from coal balls and this data appears to have been fully integrated in the publication.

Burden and Hills (1989) produced a key to genera, based on McAndrews *et al.* (1973), in their work on Lower Cretaceous palynomorphs of Western Canada. Burden & Hills (*op. cit.*) took all the previously published records up to that date on the Lower Cretaceous in Canada and compiled them in a manner " ... that permits palynologists to identify rapidly 126 of the currently recognised genera" (*op. cit.*, p.3). The key was suggested to be applicable in Canada and mainland U.S.A.

The 126 genera were divided into 9 palynomorph categories which were" ... based in part on the Turma system developed by Potonié and Kremp (1954) (*et al.*) ... Entry into a palynomorph category was based on recognition of aperture type, wall stratification and the presence of perines and sacci. Identification of the gross features of an unknown palynomorph was necessary when choosing a starting point in this guide. Nevertheless, to facilitate identifications, genera with indistinct characters (eg. inaperturate, alete and hilate spores with a non-functional trilete mark) were displayed in more than one category ... For each category there was a separate dichotomous key. Generic identifications were based on differences in wall sculpture and structure, the style of aperture development and amb shape. The order of importance of these morphologic features changes somewhat between palynomorph categories. In general, the variations in the style of equatorial and distal ornamentation should be examined first. Subsequently, details of the aperture and proximal ornamentation should be examined. Once a specimen has been keyed to a genus or group of genera, an identification may be verified by comparison with the photographs and sketches provided." (Burden and Hills 1989, p. 3).

3.2. Introduction to Systematic Palynology.

The following section deals with the systematic treatment of palynomorphs encountered during the study. The rules of the International Code of Botanical Nomenclature (I.C.B.N.) are adhered to throughout. Comment regarding the status and history of the palynomorph taxa in question is made where necessary but if the taxon circumscription is considered satisfactory, no comment is offered. With regard to the previous records of the palynomorphs, a North West European range is recorded where possible, succeeded by a worldwide range.

Following a thorough literature review it was observed that several examples existed where genera were erected on the basis of palaeobotanical inferences (eg *Todisporites* Couper 1958, *Cyathidites* Couper 1958). Such cases are not acceptable for dispersed sporomorphs and the rules of priority have prevailed.

It is clear from Chapter 3.1 that, in previous works, the aims of suprageneric classification of spores and pollen have been either to group genera on the basis of morphological similarity, or on botanical affinity. Suprageneric classification *sensu* Potonié *et al.* is not followed; it is the authors opinion that systems such as that proliferate with unecessary verbiage. Conversley, adopting a system which does not accord with the I.C.B.N., such as that developed by Hughes (1963 etc.), is not desirable because of the lack of a standard set of rules to which all workers must conform. Despite the advances in the natural classification of dispersed fossilised spores and pollen grains, significant numbers of dispersed genera and species still remain to be found in in-situ material. For this reason, a natural classification system is not followed. A summary of the known botanical affinities of Mesozoic form genera is given in Appendix 2.1.

During the study the author developed a key similar to that of Burden & Hills (1989). Despite the recognition that Burden & Hills (*op. cit.*) key is based in part on the Turma system of Potonié & Kremp (1954), it avoids the termal language of the latter system in favour of plain scientific terms, whilst still allowing morphologically similar forms to be grouped together. The systematic descriptions of spores and pollen grains follow the organisation of the key but omit repetition of genera and do not include representatives of the Acritarchs, presumed *Prasinophyceae* and *Zygmenataceae* which are included in the key. Some pollen species may show remnant trilete structures and are thus difficult to split from true trilete spores (previous authors e.g. Couper 1958, have described *Callialasporites* spp. as spores, e.g. *Cingulatisporites dubius* Couper 1958). These may be keyed more than once but are grouped in the respective pollen grain grouping in the systematic palynology section.

Acritarch genera are divided into two broad categories, genera with circular to subcircular outlines and genera with conspicuous processes, which cover the gross morphologies of the genera recorded in the study. Due to their relative morphological simplicity and remarkable similarities with extanct species, candidate representatives of the*Prasinophyceae* (*Crassosphaera, Tasmanites* and *Pterospermella*), *Chlorophyceae* (*Botryococcus*) and presumed *Zygnemataceae* (*Chomotriletes*, *Hemisphaerium*, *Lecaniella* and *Tetraporina*) are organised under a biological classification which follows Tappan (1980).

Dinoflagellate cysts are separated from other palynomorph groups on the basis of the clear recognition of paratabulation and / or an excystment aperture. This aperture, the archaeopyle, is normally operculate, with a constant shape (normally angular) and location in any one species. Like spores and pollen grains, the suprageneric classification of dinoflagellate cysts has been covered extensively in the past. Two main schools of thought may be recognised at present; that which organises genera into higher morphological groups (eg. Evitt 1985) and that which make use of a palaeobiological grouping of families and uses informal suprageneric families (eg. Feist-Burkhardt & Wille 1992). In the present study, neither systems are adopted as both require the usage of their respective suprageneric terms. Instead, a key is provided which groups genera primarily according to the location of the archaeopyle and subsequently on the basis of wall features. This allows the recognition and comparison of morphologically similar forms without the necessary knowledge of any suprageneric terms. The systematic treatment of the dinoflagellate genera follows the organisation of the key.

Dispersed fossilised grains cannot technically be called spores and pollen grains as the definitions are based on biological rather than morphological attributes. However, as these terms are used widely in works dealing with dispersed fossilised spores and pollen grains, they are used in the following keys but are enclosed in quotes in recognition of the discrepancy with the correct definition.

Morphological terms for 'spores' and 'pollen' grains follow Grebe (1971), whilst the terminology in the dinoflagellate cyst systematics accords with Evitt (1985).

3.3. Key to 'spores', 'pollen' grains, acritarchs, presumed chlorophyceae, prasinophyceae and zygnemataceae.

This is not intended to be a generic diagnosis but a key to representative species of various genera encountered in the present study. Genera may be keyed more than once if species variability necessitates.

Trilete grains	**1**
Monolete grains	**2**
Inaperturate grains	**3**
Monoporate grains	**4**
Bisaccate grains	**5**
Sulcate and leptomate grains	**6**
Aperturate grains	**7**

1. Trilete grains

Wall clearly differentiated into two layers	**1a**
Wall undifferentiated	**1b**

1a Unornamented	**1a1**
Ornamented zonate spores with distal surface elements	**1a2**
Ornamented camerate (cavate) spores	**1a3**

1a1 Outer wall layer well to poorly attached to inner wall layer. An internal vacuolate structure to the outer wall layer may be apparent, giving a sponge-like apearance.	*Densoisporites*
Walls separated at the equator only. The trilete mark is a non-germinal structure and is not consistent	*Callialasporites*
1a2 Ornament of rugulae and / or flange-like elements	*Varivaginaspora*
Ornament consists of spines	*Kraeuselisporites*
1a3 Contact areas smooth; distal and equatorial ornament consists of a reticulum or pseudoreticulum formed by positive elements	*Pararetispora*

1b Unornamented	**1b1**
Wall ornamented with foveolae (negative ornament)	**1b2**
Ornament consists predominately of muromate elements	**1b3**
Ornament consists of granules, verrucae, baculae or spinae	**1b4**

1b1 Lips simple slits or bordered by membranaceous lips <2µm high	**1b1a**
Lips with well developed bordering elements	**1b1b**

1b1a Predominantly circular outline. Exine thin ≤1µm thick. Laesurae simple slits <1/2 diameter (Ø) of grain	*Calamospora*
Deltoid spores with simple laesurae or narrow membranaceous lips <2µm high	*Deltoidospora*
Apices conspicuous by the presence of distal fold normal or subnormal to the laesurae.	*Cibotiumspora*

Laesurae simple or membranaceous <2µm high and bordered by folds convex to the proximal pole and which may link beyond the terminations of the laesurae	*Concavisporites*
Simple or membranaceous lips <2µm high. Inter-radial crassitudes are consistently present	*Gleicheniidites*
Wall is aberrantly thick and an internal structure consisting of 'canals' is developed	*Obtusisporis*
Predominantly circular outline, the laesurae are simple slits and extend >1/2 spore diameter	*Punctatisporites*
Laesurae simple slits, the outline is conspicuous in possessing an angular junction between the apices and the inter-radial margins.	*Waltzispora*
Deltoid spores whose wall is thickened at the equator to form a cingulum	*Murospora*
1b1b Lips as broad as wide	*Biretisporites*
Membranaceous lips >2µm high, bordered by a furrows and thickenings parallel to the laesurae (kyrtomes)	*Dictyophyllidites*
Wall grossly thickened at the equator. Membranaceous lips and kyrtomes well developed	*Iraqispora*
Wall thickened at the equator in the region of the apices only	*Matonisporites*
Grains predominantly circular in outline with a consistent cingulum. The laesurae may be bordered by lips with width≥ height	*Stereisporites*
1b2 Foveolae regular to irregular. Grains circular in outline and with simple laesurae. Ornament developed proximally and distally	*Foveosporites*
Grains conspicuous in exhibiting a distal ornament of variably developed foveolae. Laesurae bordered by thick lips. Equatorial inter-radial crassitudes and membranaceous extensions may be developed	*Sestrosporites*
Wall layer differentiated but this may be obscure. Outer wall layer sponge-like due to the presence of a vacuolate infraornament	*Densoisporites*

1b3 Proximal tangential muri are conspicuous	**1b3a**
Muri interconnect to form a predominant reticulum	**1b3b**
Muri form rugulae and may interconnect	**1b3c**

1b3a Distal muri are connected by a transverse tangential murus	*Striatella*
Distal muri run parallel to each other and are not connected	*Contignisporites*
1b3b Muri width : lumina Ø <1/4. Ornament may or may not be present on the proximal surface	*Retitriletes*
Reticulum attached to the spore wall by isolated rods and thus forms a distal mesh	*Kekryphalospora*
Muri width : lumina Ø >1/4, ornament developed outside the contact areas	*Ischyosporites*
Muri width : lumina Ø >1/4, ornament well developed only on the apices	

	Trilobosporites
1b3c Rugulate elements coalesce to form a distal thickening surrounded by an irregular concentric element	*Staplinisporites*
Rugulate elements anastomose and coalesce. A much reduced ornament exists in the region of the proximal pole	*Lycopodiacidites*
1b4 Exine simple	**1b4a**
Grains with conspicuous proximal kyrtomes and a fine variable ornament proximally and distally	*Trachysporites*
Finely verrucate grains with consistently developed inter-radial crassitudes	*Ornamentifera*
Ornament of proximal surface differentiated from that of the distal surface	*Nevesisporites*
1b4a Ornament present only outside the contact areas	**1b4a1**
Ornament composed predominately of spinae and conae	**1b4a2**
Grains with a circular outline and simple laesurae which extend >3/4 Ø of grain	**1b4a3**
Deltoid grains with an ornament of fine, evenly spaced granules	*Granulatisporites*
'Spores' with a deltoid to circular outline and an ornament consisting of relatively large ganulae and verrucae	*Tuberositriletes*
1b4a1 Ornament consists of verrucae	*Leptolepidites*
Cingulum is present which may exhibit a radial infrastructure	*Antulsporites*
Ornament consists of blunt tipped baculae	*Neoraistrickia*
1b4a2 Grains consistently trilete, ornament <5µm in length	*Anapiculatisporites*
Grains inconsistently trilete, ornament >5µm in length	*Echinatisporis*
1b4a3 Ornament consisting predominately of baculae	*Baculatisporites*
Ornament consisting predominately of granules	*Osmundacidites*
Ornament consisting predominately of rugulae	*Rugulatisporites*
Ornament consisting predominately of verrucae	*Verrucosisporites*
2. Monolete grains	
Grains smooth, bean shaped	*Monolites*
Grains finely verrucate	*Marattisporites*
3. Inaperturate grains	
Grains with an apparently simple wall and without ornament	**3a**
Grains with an apparently simple wall differentiated at the equator	*Callialasporites*
Grains with spinose elements	**3b**
Sphaerical grains with a punctate wall	**3c**
Wall ornamented with elements of low relief	**3d**
Wall ornamented with flange-like elements	**3e**
3a Grains circular to subcircular in outline, wall >1.5µm thick	*Araucariacites*
Grains circular in oultline, commonly folded wall <1.5µm thick	*Leiosphaeridia*

Grains circular to lenticular in outline, wall >1.5μm thick, with a fine line of weakness (lines apparently form germinal mechanism)	*Hemisphaerium*
Grains small (<35μmØ), circular, often grouped into clusters	*Microsporonites*
Grains roughly quadrangular in outline, may show the presence of pores at the angles	*Tetraporina*
3b Spinose elements hollow, with a small central body	*Micrhystridium*
Spinose elements solid, elongate relative to the small central body	*Solisphaeridium*
Spinose elements solid, reduced on one surface (contact areas which may have poorly developed haptotypic features)	*Echinatisporis*
3c Pores clustered into groups, forming pseudohexagonal wall elements	*Crassosphaera*
Pores randomly distributed over the grains surface	*Tasmanites*
3d Both surfaces with fine concentric muri. Equatorial area may be thickened	*Chomotriletes*
Grains elongate oval in outline with a thin wall and a very fine reticulation	*Scalbiella*
Both surfaces covered with low, wide interconnecting rugulae which may coalesce to form foveolae. Equatorial area may be thickened	*Lecaniella*
Grains with differentiated surface ornament consisting of distal rugulae and proximal micro-foveolae	*Enigmaspora*
3e Single equatorial flange	*Pterospermella*
Flanges forming a reticulum	*Cymatiosphaera*
4. Monoporate grains	
Simple circular grains with a central pore	*Exesipollenites*
Grains with a distal pore and a zonosulcus. An infrastructure may be apparent	*Corollina*
Wall differentiated. Outer layer thin and variably loose. Inner layer thicker with simple pore	*Perinopollenites*
5. Bisaccate grains	
Large grains haploxylenoid with an unthickened distal junction between the saccus and the corpus. The distal leptoma forms a narrow slit extending fully across the corpus	*Abietinaepollenites*
Grains haploxylenoid with an unthickened distal junction between the sacci and the corpus. Leptoma broadly elongate across the corpus	*Alisporites*
Grains ovoid to rounded quadrangular, distally sulcate, bordered by two elongate variably developed sacci. Proximal surface with two conspicuous circular to oval tenuitates orientated parallel to the distal sulcus	*Ovalipollis*
Grains diploxylenoid, corpus elongate oval. Sacci distally attached, sphaerical and reduced in size relative to the corpus	*Pinuspollenites*
Corpus circular to subcircular in outline. Grains extremely dipolxylenoid; sacci much larger than the corpus	*Podocarpidites*
Small diploxylenoid grains with a thickened distal junction between the sacci and the corpus	*Vitreisporites*

6. Sulcate and leptomate grains

Ellipsoidal grains with a simple elongate sulcus with accompanying folding along the sulcus margin	*Cycadopites*
Oval grains with an oval sulcus lacking folding along the margins	*Chasmatosporites*
Ellipsoidal grains with an elongate distal sulcus and two equatorially positioned zonosulci	*Eucommiidites*
Ovoidal to elongate grains with a distal sulcus. Wall elaborated into a saccate structure outside the sulcal area. Two equatorially positioned ovoidal to circular areas of thinning are conspicuous	*Ovalipollis*
Grains subcircular with a wall differentiated into numerous irregular hemisphaerical vesicles. Distal region conspicuously leptomate.	*Cerebropollenites*

7. Aperturate grains

Grains simple unornamented with a circular or helicoidal equatorial split	*Hemisphaerium*
Discoidal grains with fine concentric muri with an equatorial split. Often preserved as a single surface	*Chomotriletes*
Discoidal grains with an low surface relief consisting of rugulate elements. An equatorial split often results in the grain being preserved as a single surface	*Lecaniella*
Grains with a differentiated wall. The outer layer is thin and variably loose. The inner layer is commonly split into two hemispheres	*Perinopollenites*

3.4. Key to dinoflagellate cyst genera.

This is not intended to be a generic diagnosis, but an index to the dinoflagellate cyst forms present in the study. They are separated off from the acritarchs identified as all the dinoflagellate species have a recognisable angular excystment aperture.

Cysts with an apical archaeopyle	**1**
Cysts with a precingular archaeopyle	**2**
Cysts with a combination archaeopyle	**3**
Cysts with an intercalary archaeopyle	**4**
Cysts with one to two hypocystal horns, a much reduced epicyst with a correspondingly enlarged hypocyst, and a cingular archaeopyle	*Nannoceratopsis*

1. Cysts with an apical archaeopyle

Proximate acavate cysts	**1a**
Proximate cavate cysts	**1b**
Proximochorate acavate cysts	**1c**
Chorate acavate cysts	**1d**

1a Operculum lost; gonyaulacoid paratabulation indicated by the precingular plates which are delimited by accessory archaeopyle fissures; ornament consists of granular elements which may coalesce into more elaborate elements	*Batiacasphaera*
Operculum lost; cysts small, sphaerical and lacking accessory archaeopyle fissures; pronounced sulcal notch usally visible	*Orobodinium*
Operculum lost; cysts small, relatively thick-walled, with slight indication of paratabulation. Wall gradually thins towards the archaeopyle	*Jansonia*
Operculum lost; gonyulacoid paratabulation indicated on the epicyst by the outline of the archaeopyle; prominent surface ornament of reticulate elements; lumina variable in size, sphaerical to ovoidal; no paratabulation indicated	*Valensiella*
Operculum lost; gonyulacoid paratabulation indicated on the epicyst by the outline of the archaeopyle and accessory archaeopyle fissures; prominent surface ornament of elongate elements; elements variable in form,; no paratabulation indicated	*Sentusidimium*
Operculum attached; gonyaulacoid paratabulation indicated by the outline of the operculum and accessory archaeopyle fissures which delimit the precingular plates	*Kallosphaeridium*
Operculum variably attached to lost; gonyaulacoid paratabulation well defined by parasutural elements	*Lithodinia*
1b Operculum attached to lost; gonyaulacoid paratabulation indicated by low parasutural elements on the ectophragm	*Ambonosphaera*
Operculum attached to lost; gonyaulacoid paratabulation poorly indicated; cingulum usually conspicuous; a well developed pylome is present in the antapical region	*Sirmiodinium*
1c Operculum lost; gonyulacoid paratabulation indicated on the epicyst by the outline of the archaeopyle and accessory archaeopyle fissures;	

prominent surface ornament of elongate elements; elements variable in form,; no paratabulation indicated

Sentusidimium

Operculum lost; paratabulation indicated by the outline of the archaeopyle; a prominent parasutural ornament is developed and an antapical corona is prominent

Stephanelytron

Operculum variably attached to lost; gonyaulacoid paratabulation well defined by parasutural elements

Lithodinia

1d Operculum lost; cysts have well developed plate-centred polytubular processes which are reduced around the cingulum

Compositosphaeridium

Operculum lost; cysts have elaborate processes which are solid to hollow, tubular to funnel-shaped, not plate centred, distally branching and variably connected

Adnatosphaeridium

Operculum lost; gonyaulacoid paratabulation indicated by the outline of the archaeopyle; processes numerous, elongate closed distally with terminations which may be variably developed

Cleistosphaeridium

Operculum lost; processes plate centred, solid, distally furcate and interconnected

Rigaudella

Operculum lost; body elongate with numerous simple nontabular processes, distally closed. Intervening wall ornamented with low granules and verrucae

Prolixosphaeridium

2. Cysts with a precingular archaeopyle

Archaeopyle 1P **2a**

Archaeopyle 1P-5P **2b**

2a. Cysts proximate with a wall which appears under transmitted light to be spongiform; a slight apical projection is usually present; paratabulation indicated by archaeopyle only

Aldorfia

Cysts proximate, epicavate, with a well defined gonyaulacoid paratabulation; parasutural septa ornamented with variable spinose elements

Gonyaulacysta

Cysts proximate, bicavate, with a poorly defined gonyaulacoid paratabulation; a four sided pericoel is prominent on the hypocyst

Tubotuberella

2b. Cysts proximate, smooth to granulate with a variable precingular archaeopyle; a gonyaulacoid paratabulation is indicated by the outline of the archaeopyle and the opercular pieces

Dissiliodinium

Cysts proximate to proximochorate; a gonyaulacoid paratabulation is indicated by parasutural crests and by the outline of the archaeopyle; an apical horn is vaiably developed

Durotrigia

3. Cysts with a combination archaeopyle

Cysts proximate; hypocysts atabulate; epicyst with a tAtI archaeopyle; 1'' and 7'' commonly retained

Mancodinium

Cysts proximochorate; gonyaulacoid paratabulation indicated by well developed parasutural crests; (tAtp) archaeopyle

Ctenidodinium

Cysts proximate; gonyaulacoid paratabulation indicated by low parasutural crests; intratabular growth bands well developed; (tAtP) archaeopyle

Korystocysta

4. Cysts with intercalary archaeopyles

Cysts acavate	**4a**
Cysts cavate	**4b**

4a	Cysts proximate atabulate, ellipsoidal in outline with an apical horn; archaeopyle 1P-3P	*Pareodinia*
	Cysts proximate, ellipsiodal in outline with a prominent apical horn; tabulation indicated by spongiform intratabular pads	*Tabulodinium*
	Cysts proximate, ovoidal in outline without an apical horn; archaeopyle commonly obscured by a dense covering of kalyptea	*Caddasphaera*
	Cysts characteristically small, thin; precingular, postcingular and antapical plates indicated by blunt protuberances	*Susadinium*
4b	Cysts epicavate, characteristically small, pyriform in outline; two antapical protuberances may be variably developed	*Phallocysta*
	Cysts circumcavate, lenticular	*Moesiodinium*

3.5. 'Spore' systematics

3.5.1. Trilete 'spores' with a well developed two layered wall

Genus *Kraeuselisporites* (Leschik 1956) Scheuring 1974

Type species: *Kraeuselisporites dentatus* Leschik 1956.

Diagnosis: see Scheuring 1974, p. 199.

Remarks: The emendation of Jansonius (1972, p. 46) has been criticised by several authors for broadening the generic circumscription excessively. As Jansonius & Hills (1976, card 1404) commented " ... this emendation was based on (L-M Triassic) Canadian material, and may not be relevant with regard to the type material ". The later emendation of Scheuring (1974, p. 199) restricted the diagnosis and was based on a re-examination of the type material. With regard to the nature of the contact of the two wall layers, Scheuring states that the layers are azonate. The present author suggests that this condition is indeed the dominant case but slight cavation developing particularly where the zona contacts the intexine, which is the result perhaps of physical separation rather than any consistent morphological phenomenon, should be allowed for in a generic diagnosis (see Owens *et al.*1976, p. 147 for comments regarding *Kraeuselisporites echinatus* Owens *et al.*1976). Differs from *Varivaginaspora* n. Gen. on the type of wall structure developed on the distal part of the exoexine.

Kraeuselisporites scalbiensis n. sp.

pl. 2, figs 6, 7 & 9

Synonymy:

Kraeuselisporites hyalinus Fenton 1980 (MS), p. 141-142, pl. 8, figs 1-5.

Holotype: slide 89302.1, grid ref. 141.9 11.8, pl. 2, figs 6 & 7.

Diagnosis: Trilete microspores with two wall layers, a zona, well developed membranaceous lips bordering the laesurae and distal ornament of closely spaced spinose elements which may be present in a reduced nature on the distal part of the zona.

Description: Microspores trilete, triangular to sub-circular in equatorial outline. Laesurae membranaceous, extending almost to the equator where they may bifurcate to form curvaturae imperfectae. Exine two-layered, both layers are 0.5μm-1μm thick and in close contact. The intexine is subsphaerical in outline and unornamented. The exoexine is extended equatorially to form a zona 4-10μm wide which may develop a limbus on its outer part. Proximal surface is unornamented; distal surface strongly ornamented with baculae, spinae and coni with height varying between 2μm and 5.5μm and width varying between 1.5-3μm. The ornament density is consistently high which causes the individual elements to interlock. A lower density ornament is variably developed on the zona.

Size; mean inner body diameter 43.6 μm (maximum 48μm, minimum 36μm), mean outer body diameter 52.4μm (maximum 60μm, minimum 44μm)(10 specimens).

Remarks: As noted by Fenton (1980 MS) the first record of *K. scalbiensis* (al.*hyalinus*) was from the Scalby Formation, recorded by Dodd (1975 MS). *Cingulatisporites complexus* Couper1958 (al. *Couperisporites complexus* (Couper) Pocock 1962) may be synonymous but apparently differs in having a greater diameter than the present material (although Couper's processing methods may be responsible for this difference). The diagnosis of *Couperisporites* Pocock 1962 (restated in Pocock 1970, p. 63) is clearly incorrect, since the holotype is Couper's *C. complexus*: the " polygonal plates " (Pocock *op. cit.*) are simply the interlocking bases of the distal ornament; the " three distinct concentric zones " of Pocock are a misinterpretation of Couper's holotype specimen, which is badly damaged in the distal equatorial region (see Couper 1958, pl. 24, figs 1-2.).

Couperisporites complexus is frequently reported from the Cretaceous but the comments of Pocock (1970, p. 64), that " *Couperisporites complexus* and the related *Aequitriradites* and *Styxisporites* are very abundant in Lower Cretaceous sediments and may almost be regarded as characteristic Cretaceous genera ", is open to question on the basis of the present remarks. Differs from *Kraeuselisporites whitfordensis* n. sp. by the distribution of distal spines and the absence of strong development of spines at the equator.

Previous records: Middle Jurassic; Cleveland Basin and Lincolnshire.

Kraeuselisporites whitfordensis Backhouse 1988

pl.1, figs 1-6, pl. 2, fig. 1.

Holotype: *Kraeuselisporites whitfordensis* Backhouse 1988, p. 60, pl. 6, fig. 5.

Description: see Backhouse 1988, p. 60.

Remarks: Data from the present study was based on a larger population (46 specimens) than that of Backhouse (1988, p. 60). Backhouse (*op. cit.*) did not comment on the phenomenon recorded in the present study, where the membranaceous lips bordering the zona part in the region of the proximal pole to form a triangular inter-area (35% of the specimens observed displayed this feature). In addition to the comment regarding the connection of the distal elements by low ridges, specimens in the present study exhibited more elaborate connections which occasionally involved ridges only slightly lower than the processes themselves. These observations are not considered sufficient criteria to distinguish the present material from Backhouse's study, despite the disparate ages of the two studies.

Kraeuselisporites whitfordensis forms an apparent continuous morphological series in the present study with *Varivaginaspora spinoreticulata* sp. nov. through a progressive reduction in the height of the processes and the development of a crude reticulum which links the reduced processes. Brockley (1976 MS), whose work on the Upper Estuarine 'Series' of Leicestershire was the first to record this species, described the forms under the name of *Kraeuselisporites* sp. A. The holotype material was described from the Cretaceous of the Perth Basin, Western Australia. See also *K. scalbiensis* n. sp. for comparison remarks.

Previous records: Middle Jurassic; Cleveland Basin, Cretaceous; Western Australia.

Genus *Varivaginaspora* n. Gen.

Type species: *Varivaginaspora reticulata n. sp.*

Diagnosis: Trilete microspores with a well-developed two layered, acamerate exine and a circular to convex triangular amb under polar compression. Haptotypic features may be poor to well developed, with a trilete mark that may extend to the equator and which may be enclosed by membranaceous lips. The outer spore wall is usually thinner than the inner spore wall and is extended at the equator to form a zona. The inner spore body is +/- circular with a smooth to finely ornamented wall. The outer spore wall is folded into an ornament distal from the zona which may be variably developed into reticulate elements.

Derivation of name: *Vari*, contraction of *variabilis* (Latin) = variable, *vagina* (Latin) = sheath, referring to the variable outer layer.

Remarks: The genus differs from *Kraeuselisporites* on the basis of the distal ornament and from *Retitriletes* on the development of two wall layers.

Varivaginaspora reticulata n. sp.

pl. 2, figs 2, 3, 4 & 5

Holotype: Slide 89026.1, grid ref. 149.5 6.9, pl. 2, fig. 3

Paratypes: Slide 89026.1, grid ref. 142.2 16, pl. 2, fig. 4;, slide 89026.1, grid ref. 145.3 7.8, pl. 2, fig. 5.

Diagnosis: A species of *Varivaginaspora* with a variably developed zona and a well developed reticulate ornament.

Description: Microspores trilete, with a convex rounded triangular amb in equatorial compression. The laesurae extend almost to the equator and are bordered by membranaceous lips which extend up to 5µm in height in the region of the proximal pole. The exine is differentiated and in close contact; the intexine is circular in equatorial compression, smooth and between 1µm and 1.5µm in thickness; the exoexine is approximately 1µm in thickness and consists of a smooth proximal (contact) face and a distal reticulate surface separated by a variably developed zona at the equator. The distal reticulum consists of muri 1.5µm to 2µm in width and between 2µm and 2.5µm in height. The lumina are variable in diameter but commonly range between 4µm and 7µm.

Mean diameter of the exoexine 40µm (maximum 45µm, minimum 32.5µm), mean diameter of the intexine 35.25µm (maximum 37.5µm, minimum 30µm)(10 specimens).

Derivation of name: *reticulata* from *reticulum* (Latin) meaning mesh.

Remarks: The species differs from *Lycopodiacidites rugulatus* (Couper) Schulz 1967 in exhibiting flange-like reticulate sculptural elements, and from *Varivaginaspora spinoreticulata* n. sp. in its smaller size range, lower distal flange-like elements and more regular reticulation.

Varivaginaspora spinoreticulata n. sp.

pl.1, figs 7-8.

Holotype: slide 89302.1, grid ref. 157.7 14.0, pl. 1, fig. 7.

Paratype: slide 89302.1, grid ref. 135.8 7.8, pl. 1, fig. 8.

Diagnosis: A species of *Varivaginaspora* with well developed membranaceous lips which border the laesurae and a distal ornament of reduced spines which are linked to form a distal reticulum.

Description: Microspores trilete, with a convex circular to sub-triangular amb in equatorial compression. The laesurae are poorly to well developed, may extend to the equator and are bordered by membranaceous lips highest at the proximal pole (5µm to 7.5µm). The exine is differentiated and the two layers are in close contact; the intexine is circular to convex rounded triangular in equatorial compression, smooth and between 1µm and 1.5µm in thickness; the exoexine is less than 1µm thick and consists of a smooth proximal (contact) face and a distal reticulate surface separated by a variably developed zona at the equator. The muri are difficult to measure due to folding but appear to range from 5µm to 10µm in height. Low spines with sharp tips may develop at the intersections of the muri. The number of lumina is always less than 20.

Mean diameter of the exoexine 40µm (maximum 45µm, minimum 32.5µm), mean diameter of the intexine 39.5µm (maximum 42.5µm, minimum 32.5µm)(5 specimens).

Remarks: Out of a count of 51 specimens, 5 specimens were identified as *Varivaginaspora spinoreticulata* n. sp. on the basis of a much reduced distal spinose ornament. The rest were assigned to *Kraeuselisporites whitfordensis* on the presence of a well developed distal spinose ornament. The two species apperar to form a continuous morphological group. *V. spinoreticulata* is considered to be the rarer species of the two . The specific name refers to the outer wall ornament. The species differs from *Varivaginaspora reticulata n. sp.* in possessing a thinner outer wall layer and higher distal muri.

Genus *Pararetispora* n. gen.

Type species: *Pararetispora jurassica* n. sp.

Diagnosis: Trilete, camerate (cavate) microspores with a rounded triangular to subcircular amb in equatorial compression. Trilete rays are simple slits bordered by lips with approximately equal width to height and extend almost to the equator before separating to form curvatura perfecta. Intexine attached to the exoexine apparently only on the proximal surface. Contact area smooth; exoexine from the contact areas distally positively ornamented with rugulate elements which may coalesce to from a crude reticulum.

Derivation of name: In reference to the similarities of the genus to *Retispora* Staplin 1960.

Remarks: Differs from *Retispora* Staplin 1960, which bears a negative ornament on its exoexine.

Pararetispora jurassica n. sp.

pl. 2, fig. 2

Synonymy:

Kraeuselisporites mathurii (Srivastava) Fenton 1980 (MS).

Holotype: slide 89302.1, grid ref. 135.8 7.8, pl. 2, fig. 2.

Diagnosis: A species of *Pararetispora* bearing an exoexinal ornament of variably developed reticulation.

Description: Microspores trilete, convex rounded triangular in equatorial outline. The laesurae are bordered by membranaceous lips 1µm wide >1µm high, which extend almost to the equator and which join curvatura perfecta positioned approximately 3/4 total diameter of spore from the proximal pole. The exine is differentiated and a separation exists between the two wall layers; the intexine is smooth 1-1.5µm thick; the exoexine is 1-1.5µm thick and attached to the intexine apparently proximally only. The contact areas are smooth; the rest of the exoexine is ornamented with rugulate elements which may coalesce to form a poorly to well developed reticulum. Rugulae upto 3µm wide and 3µm in height.

Mean diameter of the intexine 37.9µm (maximum 42.5µm, minimum 35µm), mean diameter of the exoexine 67.1µm (maximum 75µm, minimum 60µm), Øexoexine:Øintexine ratio 1.53-2.07 (7 specimens).

Derivation of name: *jurassica*, after the Jurassic system.

Remarks: A rare but conspicuous spore which was encountered only in samples 89026.1, 305.1, and 89319. The species is used as a Bathonian marker in the North Sea (pers. obs.) under the name *Kraeuselisporites mathurii.* It was necessary to erect a new genus and species as the present author rejects Fenton's (1980 MS) transfer of *Staplinisporites mathurii* (Srivastava) Filatoff 1975 into the genus *Kraeuselisporites.* After examining the figures of the holotype (*Triangulatisporites mathurii* Srivastava 1966) the present author follows Filatoff (1975) in stating that *Staplinisporites mathurii* lacks wall differentiation. The specimens illustrated by Fenton (1980 MS, pl.7, figs 5,9) are identical to those recovered in the present study.

3.5.2. Trilete unornamented 'spores'

Genus *Calamospora* Schopf, Wilson & Bentall 1944

Type species: *Calamospora hartungiana* Schopf, Wilson & Bentall 1944.

Diagnosis: see Schopf, Wilson & Bentall 1944, p. 51.

Calamospora mesozoica Couper 1958

pl. 3, fig. 1

Holotype: *Calamospora mesozoica* Couper 1958, p. 132; pl. 15, fig. 3.

Diagnosis: see Couper 1958, p. 131.

Remarks: The present author agrees with the observations of Filatoff (1975, p. 56) which record the presence of granules on the contact areas.

Previous records: Lower Jurassic to Lower Cretaceous: Europe.

Genus *Deltoidospora* Miner 1935

Synonymy:

Leiotriletes (Naumova) Potonié & Kremp 1955
Cyathidites Couper 1953

Type species: *Deltoidospora hallii* Miner *ex* Potonié 1956, p. 13, pl.1, fig. 1.

Diagnosis: see Miner 1935, p.618.

Remarks: The author follows Pocock (1970, p. 27) in recognising the synonymy of *Leiotriletes* (Naumova) Potonié & Kremp 1955 and *Cyathidites* Couper 1953 with *Deltoidospora* Miner 1935. Further remarks to consider may be found in Pocock (1970, p.27-28) and Ravn (1986 p. 21).

Deltoidospora australis (Couper 1953) Pocock 1970

pl. 3, fig. 4

Synonymy:

Cyathidites australis Couper 1953, p. 27; pl. 2, figs 11-12.

Holotype: *Cyathidites australis* Couper 1953, p. 27; pl. 2, figs 11-12.

Diagnosis: see Couper 1953, p. 27.

Remarks: In Couper's 1958 work, *D. australis* differs from *D. minor* in its larger size. Couper's justification for the two species is the bimodal distribution of size ranges in observed specimens. Otherwise the species are identical. *D. australis* was rare in the present study.

Previous records: Middle Triassic to Maastrichtian; Europe.

Deltoidospora minor (Couper 1953) Pocock 1970

pl. 3, fig. 2 & 3

Synonymy:

Cyathidites minor Couper 1953, p. 28; pl. 2, fig. 13.

Holotype: *Cyathidites minor* Couper 1953, p. 28; pl. 2, fig. 13.

Diagnosis: see Couper 1953, p. 28.

Remarks: see *D. australis* .

Previous records: Mesozoic: Worldwide.Tertiary: Europe.

Genus *Cibotiumspora* Maljavkina *ex* Chang 1965

Type species: *Cibotiumspora paradoxa* (Maljavkina) Chang 1965.

Diagnosis: see Chang 1965, p. 165.

Remarks: Filatoff (1975, p. 61) gives an extensive list of forms assignable to *Cibotiumspora* Chang.

Cibotiumspora jurienensis (Balme) Filatoff 1975

pl. 3, fig. 5

Synonymy:

Concavisporites jurienensis Balme 1957, p. 20; pl. 2, fig. 30.

Holotype: *Concavisporites jurienensis* Balme 1957, p. 20; pl. 2, fig. 30.

Diagnosis: see Balme 1957, p. 20.

Remarks: *C. jurienensis* is distinguished from *Cibotiumspora* sp. SC1 by its rounded triangular outline.

Previous records: Jurassic to Lower Cretaceous: Worldwide.

Cibotiumspora sp. SC1

pl. 3, figs 7 & 8

Description: Microspores trilete, with a circular to rounded triangular outline in equatorial compression. Laesurae are simple slits in the exine which extend 2/3 diameter. The laesurae are interrupted by diagonal to orthogonal folds at their terminations. The apparently simple, smooth exine may be thinner beyond the fold at the apices. Exine generally 1μm in thickness.

Mean diameter 33.75μm (maximum 32.5μm, minimum 35μm)(4 specimens).

Remarks: The species differs from *C. jurienensis* in its outline and from *Punctatisporites minor* (Couper) Brenner 1986 in exhibiting orthogonal folding in the apical regions.

Genus *Concavisporites* Pflug *in* Thomson & Pflug 1953 *sensu* Delcourt & Sprumont 1955

Synonymy:

Auritulinasporites Nilsson 1958.

Type species: *Concavisporites rugulatus* Pflug in Thomson & Pflug 1953, p. 49.

Diagnosis: see Delcourt & Sprumont 1955, p. 22.

Remarks: Due to the broad circumscription of the original genus, the present author follows Delcourt & Sprumont (1955) in restricting the genus to include only forms that are smooth, concavely triangular and have a torus along the Y mark. *Auritulinasporites* Nilsson 1958 is herein considered a junior synonym of *Concavisporites* Pflug *sensu* Delcourt & Sprumont 1955. Nilsson's erection of the genus *Auritulinasporites* alongside an emended diagnosis of *Concavisporites toralis* in the same publication is viewed as a mis-interpretation of the structure of the sporomorphs in question.

Concavisporites toralis (Leschik) Nilsson 1958

pl. 3, fig. 6

Synonymy:

Laevigatosporites toralis Leschik 1956, p. 12, pl. 1, fig. 9.

Gleicheniidites senonicus Ross 1949 *in* Couper 1958, pl.11,12,13,15.

Auritulinasporites deltaformis Burger 1966, p. 236, pl. 15, fig. 4.

Gleicheniidites nilssonii Pocock 1970, p. 32, pl. 16, fig. 22.

Holotype: *Laevigatosporites toralis* Leschik 1956, p. 12, pl. 1, fig. 9.

Description: see Nilsson 1958, p. 34.

Remarks: *C. toralis* differs from *Matonisporites phlebopteroides* Couper 1958 in lacking radial crassitudes. In the present study, forms exhibiting slight development of a 'torus', forms with a well developed 'torus' and forms where the tori join equatorially beyond the extremities of the leasurae are identified as*Concavisporites toralis* .

Previous records: Anisian to Sinemurian; Europe.

Genus *Gleicheniidites* Ross 1949

Type species: *Gleicheniidites senonicus* Ross 1949.

Diagnosis: see Ross 1949, p. 31.

Gleicheniidites senonicus Ross 1949

pl. 3, fig. 10

Holotype: *Gleicheniidites senonicus* Ross 1949, p. 31, pl. 1, fig. 3.

Description: see Skarby 1964, p.66.

Remarks: The author follows Skarby (1964) who observed a wide range of variation in the morphology of spores attributed to *G. senonicus* which were derived from sporangial fragments. She concluded that all morphological features apart from the characteristic equatorial thickenings of the species were of doubtful diagnostic value.

Previous records: Upper Triassic to Maastrichtian; Europe.

Genus *Obtusisporis* Krutzsch 1954

Type species: *Obtusisporis obtusangulis* (Potonié) Krutzsch 1954.

Diagnosis: see Krutzsch 1954, p. 296.

Obtusisporis convexus Pocock 1970

pl. 3, fig. 9

Holotype: *Obtusisporis convexus* Pocock 1970, p. 36, pl. 5, figs `30-32.

Description: see Pocock 1970, p. 36.

Remarks: The species is diagnosed by its convex triangular amb with its sharp angles and the unusual structure of the exine which produces anastomosing, bifurcating lines of thinned exine, particularly at the apices.

Previous records: Callovian: Canada.

Genus *Punctatisporites* (Ibrahim) Potonié & Kremp 1954

Synonymy:

Todisporites Couper 1958.

Type species: *Punctatisporites punctatus* (Ibrahim) Ibrahim 1933.

Diagnosis: see Potonié & Kremp 1954, p.120.

Remarks: The author rejects Couper's genus *Todisporites* Couper 1958 as being distinct from *Punctatisporites*, despite the majority of Mesozoic publications since Couper accepting his genus.

Punctatisporites major (Couper 1958) Kedves & Simoncsics 1964

pl. 3, fig. 14

Synonymy:

Todisporites major Couper 1958, p. 134: pl. 16, figs 6-8.

Holotype: *Todisporites major* Couper 1958, p. 134: pl. 16, figs 6-8.

Diagnosis: see Couper 1958, p. 134.

Remarks: *P. major* is distinguished from *P. minor* by its larger size. Couper's justification for erecting the two species is that a frequency chart of sizes constructed by him exhibited a bimodal distribution. In all other respects, the two species are identical.

Dimensions: Equatorial diameter 58 (61) 64 µm (10 specimens).

Previous records: Lower Rhaetian to Upper Albian; Europe.

Punctatisporites minor (Couper 1958) Brenner 1986

fig. 3, pl. 14

Synonymy:

Todisporites minor Couper 1958, p. 135; pl. 16, fig. 9.

Holotype: *Todisporites minor* Couper 1958, p. 135; pl. 16, fig. 9.

Diagnosis: see Couper 1958, p. 135.

Remarks: see *P. major* .

Previous records: Lower to Middle Jurassic; Europe.

Genus *Waltzispora* Staplin 1960

Type species: *Waltzispora lobophora* (Waltz) Staplin 1960.

Diagnosis: see Staplin 1960, p. 18.

Remarks: The present author follows Sullivan (1964, p. 361) in considering " the tendancy of an angular junction, often with tangential expression between the blunted apices and the inter-radial margins as characteristic of the genus".

Waltzispora concava (Bolkhovitina) n. comb.

pl. 3, fig. 11

Synonymy:

Stenozonotriletes concavus Bolkhovitina 1953, p. 46, pl. 6, fig. 7.

Cyathidites concavus (Bolkhovitina) Dettmann 1963, p. 24.

Holotype: *Stenozonotriletes concavus* Bolkhovitina 1953, p. 46, pl. 6, fig. 7.

Diagnosis: see *Cyathidites concavus* (Bolkhovitina) Dettmann 1963, p. 24.

Remarks: Differing from the two species of *Deltoidospora* observed in having a strongly concave triangular amb. Conspicuous but rare in the present study.

Previous records: Middle Jurassic; Europe, Aptian: Worldwide.

Genus *Murospora* Somers 1952

Type species: *Murospora kosankei* Somers 1952.

Diagnosis: see Somers 1952, p. 21.

Murospora florida (Balme) Pocock 1961

pl. 3, fig. 13

Synonymy:

Cingulatisporites floridus Balme 1957, p. 26, pl. 5, figs 60-61.

Holotype: *Cingulatisporites floridus* Balme 1957, p. 26, pl. 5, figs 60-61.

Description: see Balme 1957, p. 26.

Remarks: *M. florida* differs from *Iraqispora speciosa* (Mädler) Lund 1977 in lacking kyrtomes.

Previous occurrence: Lias to Upper Jurassic; Europe.

Genus *Biretisporites* (Delcourt & Sprumont 1955) Delcourt, Dettmann & Hughes 1963

Type species: *Biretisporites potoniaei* Delcourt & Sprumont 1955.

Diagnosis: see Delcourt, Dettmann & Hughes 1963, p. 284.

Remarks: The emendation of the genus by Delcourt, Dettmann & Hughes 1963 is accepted here. Of their re-illustrations of the type species, plate 44, figure 11 clearly shows the nature of the thickenings along the laesurae and the absence of membranaceous lips (cf. *Dictyophyllidites spectabilis* n. comb.).

Biretisporites potoniaei (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963

pl. 3, fig. 16

Holotype: *Biretisporites potoniœi* Delcourt & Sprumont 1955, p.40, fig. 10.

Diagnosis: see Delcourt, Dettmann & Hughes 1963, p.284.

Remarks: The present author accepts the emendation of the holotype diagnosis by Delcourt, Dettmann & Hughes 1963 (p. 284). In the present study the equatorial outline of specimens varied from slightly concave triangular to slightly convex triangular.

Previous records: Lower Cretaceous; Europe, Upper Triassic to Campanian; worldwide.

Genus *Dictyophyllidites* Couper 1958

Type species: *Dictyophyllidites harrisii* Couper 1958.

Diagnosis: see Couper 1958, p. 140.

Remarks: *Dictyophyllidites* differs from *Gleicheniidites* Ross 1949 in lacking any equatorial inter-radial exinal thickenings, and from *Cyathidites* Couper 1953 in possessing kyrtomes and membranaceous lips.

Dictyophyllidites harrisii Couper 1958

pl. 4, fig. 2

Holotype: *Dictyophyllidites harrisii* Couper 1958, p. 140; pl. 21, fig. 6.

Diagnosis: see Couper 1958, p. 140.

Remarks: Differ from Deltoidospora minor (Couper) Pocock 1970 by the presence of inter-radial crassitudes.

Previous records: Hettangian to Berriasian; Europe.

Dictyophyllidites equiexinus (Couper 1958) Dettmann 1963

pl. 4, fig. 1

Synonymy:

Matonisporites equiexinus Couper 1958, p. 140, pl.20, figs 13,14.

Leiotriletes equiexinus (Couper) Döring 1965, p. 20, pl. 5, figs 4-6.

Harrisispora equiexina (Couper) Pocock 1970, p. 38, pl. 6, figs 10, 16, 17, 21.

Holotype: *Matonisporites equiexinus* Couper 1958, p. 140, pl.20, figs 13,14.

Diagnosis: see Couper 1958, p. 140.

Remarks: The author accepts Dettmann's emendation on the basis of Couper's equivocal botanical reasons for placing the species *equiexinus* in the genus *Matonisporites* Couper 1958.

Previous records: Middle Jurassic to Neocomian; North West Europe.

Dictyophyllidites spectabilis (Dettmann 1963) n. comb. and emend.

pl. 4, figs 4, 5 & 6

Holotype: *Biretisporites spectabilis* Dettmann 1963, p. 26, pl. 2, fig. 3-8.

Emended diagnosis: Microspores which are trilete, plano-convex, and with the distal surface strongly convex; the amb is triangular with rounded angles and straight to weakly concave or convex sides. The laesurae are straight, extending to the equator, and with conspicuous lips; the lips are membranaceous (2-3μm wide, 11-14μm high) for 2/3 of their length, set in a triradiate furrow of exinal thinning. The furrow closes abruptly 2/3 along the length of the laesurae. The borders of the furrow are slightly thickened. Distal 1/3 of the laesurae are simple slits in the exine. Exine is one layered, 3.3-5μm thick, homogeneous in structure, and with faint LO surface pattern under oil emersion.

Mean diameter 77 (104) 122 μm; polar diameter (9 specimens) 42 (65) 81μm.

Remarks: The species is re-combined and emended on the basis of the illustrations of the holotype which do not agree with the original description. Dettmann (1963, p.26) based the description of the haptotypic features on microtome sections of specimens which were not designated. The illustration of the holotype (pl. 2, figs 3-4) clearly shows membranaceous lips separated from an area of exinal thickening along the laesurae by an area of exinal thinning. In this respect *D. spectabilis* compares closely in haptotypic features with *D. equiexinus*. The microtome thin sections (*op. cit.*, pl. 2, figs 7,8) illustrate a spore wall which is simply upturned at the laesurae and thinned towards the top of the lips.

Previous records: Lower Albian; U.K., Upper Triassic to Campanian; worldwide.

Dictyophyllidites sp. SD1

pl. 3, fig. 12

Description: Microspores trilete, circular to rounded triangular in equatorial compression. The laesurae are bordered by narrow, low (less than 1μm x 1μm) lips and extend between 2/3 and 7/8 diameter of the spore. The furrow between the lips and the contact area is between 3.75μm to 5μm in width, of a consistent depth, has sharply defined borders and closes abruptly towards the ends of the laesurae. The borders of the furrow are very slightly thickened in a zone 1μm wide The exine is simple 1μm thick, sometimes slightly variable in thickess and unornamented.

Mean diameter 30.8μm (maximum 34μm, minimum 27.5μm)(6 specimens).

Remarks: This form exhibits a considerable variation in equatorial diameter but the wide, well defined furrow is characteristic.

Genus *Iraqispora* Singh 1964

Type species: *Iraqispora labrata* Singh 1964, p.243, pl. 44, fig. 7.

Diagnosis: see Singh 1964, p. 243.

Iraqispora speciosa (Mädler) Lund 1977

pl. 4, fig. 7

Synonymy:

Kyrtomisporis speciosus Mädler 1964, p. 188, pl. 3, figs 5-7.

Holotype: *Kyrtomisporis speciosus* Mädler 1964, p. 188, pl. 3, figs 5-7.

Description: see Lund 1977, p. 60.

Remarks: Differs from *Murospora florida* (Balme) Pocock 1961 by the absence of kyrtomes bordering the laesurae.

Previous records: Rhaetian to Hettangian; North West Europe.

Genus *Matonisporites* (Couper) Dettmann 1963

Type species: *Matonisporites phlebopteroides* Couper 1958.

Diagnosis: see Dettmann 1963, p. 58.

Remarks: Couper's original circumscription was excessively broad and thus the emendation of Dettmann is followed, with the resulting transfer of *Matonisporites equiexinus* to *Dictyophyllidites equiexinus* (Couper) Dettmann 1963.

Matonisporites phlebopteroides Couper 1958

pl. 4, fig. 3

Holotype: *Matonisporites phlebopteroides* Couper 1958, p. 140, pl. 20, figs 15-17.

Diagnosis: see Couper 1958, p. 140.

Remarks: *M. phlebopteroides* differs from *Matonisporites crassiangulatus* (Balme 1957) Dettmann 1963 in possessing exinal thickenings bordering the membranaceous laesurae, although the illustrations of Balme (1957, pl. 3 figs 39-41) suggest some thickening bordering the laesurae. *Matonisporites cooksoni* Dettmann 1963 appears to differ in having a more differentiated wall thickness between the apical and inter-apical regions at the equator. All three species are otherwise very similar.

Previous records: Rhaetian to Upper Cretaceous; Europe.

Genus *Stereisporites* (Pflug *in* Thomson & Pflug) De Jersey 1964

Type species: *Stereisporites stereoides* (Potonié & Venitz) Pflug *in* Thomson & Pflug 1953.

Diagnosis: see Pflug in Thomson & Pflug 1953, p. 53.

Remarks: The present author follows De Jersey's emendation, which allows for the inclusion of forms with a distal polar thickening. Krutzsch's 1963 subdivision of the genus, with the consequent erection of numerous subgenera, is not followed here due to the rarity of *Stereisporites* spp. preserved in the assemblages of the present study.

Stereisporites psilatus (Ross) Pflug *in* Thomson & Pflug 1953

pl. 4, fig. 8

Synonymy:

Trilites psilatus Ross 1949, pl. 1, figs 12 and 32.

Holotype: *Trilites psilatus* Ross 1949, pl. 1, figs 12 and 32.

Description: see Pflug in Thomson & Pflug 1953, p. 53.

Remarks: see *Stereisporites antiquasporites.*

Previous records: Hettangian to Miocene; Europe.

Stereisporites antiquasporites (Wilson & Webster) Dettmann 1963

pl. 5, fig. 1

Synonymy:

Sphagnum antiquasporites Wilson & Webster 1946, p. 273, fig. 2.

Holotype: *Sphagnum antiquasporites* Wilson & Webster 1946, p. 273, fig. 2.

Description: see Dettmann 1963, p. 25.

Remarks: Differs from S. psilatus by the development of a distal polar thickening.

Previous records: Upper Rhaetian to Cenomanian; Europe.

3.5.3. Trilete foveolate 'spores'

Genus *Densoisporites* (Weyland & Krieger 1953) Dettmann 1963

Type species: *Densoisporites velatus* Weyland & Krieger 1953.

Diagnosis: see Dettmann 1963, p. 83.

Densoisporites circumundulatus (Brenner) Playford 1971

pl. 5, fig. 5

Synonymy:

Psilatriletes circumundulatus Brenner 1963, p. 67, pl.20, figs 4-5.

Type species: *Psilatriletes circumundulatus* Brenner 1963, p. 67, pl.20, figs 4-5.

Description: see Brenner 1963, p. 67.

Remarks: The degree of folding of the distal surface was rather variable in the specimens recorded. Specimens with slight (i.e. single) folding were asigned to *D. velatus.*

Previous records: Lower Cretaceous; North America, China, Spain.

Densoisporites crassus Tralau 1968

pl. 5, fig. 8

Holotype: *Densoisporites crassus* Tralau 1968, p. 35, pl. XII, fig. 3.

Description: see Tralau 1968, p. 35.

Remarks: This species is distinguished on the thickness of the wall at the equator and its smaller dimensions.

Previous records: Bajocian; France, Sweden.

Densoisporites velatus Weyland & Krieger 1953

pl. 5, figs 6 & 7

Synonymy:

Densoisporites perinatus Couper 1958, p. 145, pl. 23, figs 6-9.

Selaginella telata (Weyland & Krieger) Krasnova *in* Samoilovitch *et al.* 1961, p. 35-36, pl. 7, figs 5-6.

Holotype: *Densoisporites velatus* Weyland & Krieger 1953, p. 12, pl. 4, figs 12-14.

Diagnosis: see Dettmann 1963, p. 84 (translation of Krasnova 1961).

Remarks: Considerable morphological variation was observed, both in the width of the cingulum and the development of the cameration. The punctate outer layer was quite diagnostic on a large percentage of specimens, allowing even the most corroded examples to be identified. Specimens were observed where the outer wall layer was completely removed resulting in a smaller thin spore exhibiting the three proximal inter-radial thickenings mentioned in the species description.

Previous records: Hettangian to Maastrichtian; Europe.

Genus *Foveosporites* Balme 1957

Type species: *Foveosporites canalis* Balme 1957.

Diagnosis: see Balme 1957, p. 17.

Foveosporites moretonensis de Jersey 1964

pl. 4, fig. 9

Holotype: *Foveosporites moretonensis* de Jersey 1964, p. 7, pl. 1, fig. 7.

Description: see de Jersey 1964, p. 7.

Remarks: The specimens identified in the present study agree with the description of de Jersey (1964).

Previous records: Rhaetian to Lias; Germany, Upper Triassic; Australia.

Foveosporites sp. SF1

pl. 4, fig. 10

Description: Microspores trilete, circular to convex rounded triangular in equatorial compression. Laesurae are commonly gaping but can be seen to be simple slits in the exine which extend 2/3 radius of spore. Exine 1µm thick and foveolate proximally and distally. The foveolae are irregular in outline and may coalesce to form canaliculae, but are usually ≤1µm in diameter. Arcuate folds concave to the proximal pole and which join the ends of the laesurae on gaping specimens are characteristic.

Mean diameter 38.8µm (maximum 42.5µm, minimum 30µm)(10 specimens).

Remarks: The irregular development of the foveolae suggests that some of the ornament may be the effect of chemical degradation. This form is remarkable in its distribution which is restricted to six samples in the Gristhorpe Bay section. It differs from *F. moretonensis* in exhibiting a predominantly circular outline, lacking lip developments bordering the laesurae and a smooth non-foveolate wall layer at the equator.

Genus *Sestrosporites* (Couper) Dettmann 1963

Synonymy:

Cingulatisporites Thomson *in* Thomson & Pflug 1953 (*in* Couper 1958)

Type species: *Sestrosporites irregulatus* (Couper) Dettmann 1963.

Diagnosis: see Dettmann 1963, p. 66.

Sestrosporites pseudoalveolatus (Couper) Dettmann 1963

pl. 5, figs 2, 3 & 4

Synonymy:

Cingulatisporites pseudoalveolatus Couper 1958, p.147, pl. 25, figs 5-6.

Foveosporites multifoveolatus Döring 1965 **Reference!**

Holotype: *Cingulatisporites pseudoalveolatus* Couper 1958, p.147, pl. 25, figs 5-6.

Description: see Dettmann 1963, p.66.

Remarks: It appears, according to Dettmann 1963, p.66, that prolonged maceration and/or compression brings about rupturing of the inter-radial crassitudes and formation of a membranaceous zona, as seen in the holotype. Un-ruptured specimens are comparable to *Foveosporites multifoveolatus* Döring 1965. The present author agrees with Tralau (1968, p. 61) in synonymising the two species on the basis of Dettmann's observations and also on observations from the present study where both morphotypes can be found in the same samples. Dettmann (1963, p. 66-67) complicated the structural interpretation of the spore by suggesting that the inter-radial crassitudes are cavate; clearly a contradiction in terms.

During the present study, specimens were observed exhibiting a radial arrangement of the foveolae. This observation was ascribed to the specimens in question exhibiting a convex distal surface due to three dimensional preservation rather than to a fundamental difference in the arrangement of the foveolae. In addition a slight thickening in the distal polar region was sometimes discernable.

In several populations of *Sestrosporites pseudoalveolatus*, the author came across forms almost identical but differing in lacking the well developed foveolation typical of the species. The author questions their specific validity on the basis of encountering them only where *S. pseudoalveolatus* was present in significant numbers and their identical description to *S. pseudoalveolatus* apart from the foveolae (they would need to be accomodated in a separate genus).

Previous records: Lower Toarcian to Lower Maastrichtian; Europe.

3.5.4. Trilete murornate spores

Genus *Striatella* (Mädler) Filatoff and Price 1988

Synonymy:

Duplexisporites Déak 1962

Type species: *Striatella seebergensis* Mädler 1964.

Diagnosis: see Filatoff and Price 1988, p. 101.

Remarks: The genus has been the subject of considerable synonymy since Mädlers' 1964 publication. A comprehensive list of the synonymies is given in Filatoff and Price 1988. Since several species of the genus were identified during the research, the key presented by Filatoff & Price 1988 is partly shown below;

Key to species of Striatella (Mädler) Filatoff & Price 1988
(after Filatoff & Price 1988).

1. non-parallel distal muri	
1.2. spiral / quasi-spiral distal sculpture	
1.2.1. proximally non verrucate	*S. seebergensis*
1.3. non-spiral distal sculpture	
1.3.1. distally muromate	
1.3.1.1. muri sinuous	*S. scanica*
1.3.1.2. muri anastomosing	*S. patenii*
2. parallel / subparallel distal muri	
2.1. disto-equatorial murus indistinct +/- entire	*S. balmei*
2.2. disto-equatorial murus indistinct, discontinuous	*S. jurassica*

Striatella balmei Filatoff and Price 1988

pl. 5 , fig. 9

Holotype: *Striatella balmei* Filatoff and Price 1988, p. 105, figs. 5L-R, 6A-J.

Diagnosis: see Filatoff and Price 1988, p. 107.

Previous records: Toarcian: U.S.S.R. Late Triassic to Middle Jurassic: China. Rhaetian to Bathonian: western Europe. Middle Jurassic: Afghanistan. Oxfordian: northwestern Canada. Rhaetian to early Middle Jurasssic: Australia.

Striatella jurassica Mädler 1964

pl. 5, fig. 13

Holotype: *Striatella jurassica* Mädler 1964, p. 192, pl.3, fig. 12.

Diagnosis: see Mädler 1964, p. 192.

Previous records: Toarcian to Callovian: Australia and U.S.S.R. Middle Jurassic: China. Rhaetian to Middle Jurassic: western Europe. Middle Jurassic: Afghanistan and Iran. Late Jurassic: northwestern Canada.

Striatella patenii Filatoff and Price 1988

pl. 5, fig. 12

Holotype: *Striatella patenii* Filatoff and Price 1988, p. 105, figs 5E-I.

Diagnosis: see Filatoff and Price 1988, p. 105.

Previous records: Late Triassic: China. Toarcian to Bathonian: Scandinavia. Late Early to early Middle Jurassic: Australia.

Striatella scanica (Nilsson) Filatoff and Price 1988

pl. 5, fig. 11

Synonymy:

Corrugatisporites scanicus Nilsson 1958

Holotype: *Corrugatisporites scanicus* Nilsson 1958.

Diagnosis: see Filatoff and Price 1988, p. 104.

Previous records: Late Triassic to Middle Jurassic: U.S.S.R., China, western Europe, east Greenland, U.S.A. and Australasia. Late Jurassic: U.S.S.R. and Canada.

Striatella seebergensis Mädler 1964

pl. 5, fig. 14

Holotype: *Striatella seebergensis* Mädler 1964, p. 189, pl. 3, fig. 8.

Diagnosis: see Mädler 1964, p. 189.

Previous records: Middle Triassic to Middle Jurassic: U.S.S.R. and Australasia. Late Triassic to Middle Jurassic: western Europe and China. Early Jurassic: Afghanistan. Middle and Late Triassic: Antarctica.

Striatella sp. SS1

pl. 6, fig. 1

Description: Microspores trilete, convex triangular in equatorial compression. The laesurae are obscure due to the ornament but are apparently bordered by membranaceous lips, upto 1µm wide, of indeterminate height and extend almost to the edge of the exine. The exine is of indeterminate thickness and ornamented with muri. Proximal muri are 2µm to 3µm in width and height, convex to the proximal pole and delimit the contact areas, joining the membranaceous laesurae at the apices. The equatorial murus (cingulum) is continuous. The distal muri consist of spirally arranged elements as in *Striatella seebergensis* Mädler 1964, however, the equatorial and distal muri are ornamented with blunt tipped processes upto 5µm in height and 4µm in width.

Diameter 43µm.

Remarks: A single but well preserved specimen was recovered of this interesting taxon.

Striatella sp. SS2

pl. 5, fig. 15

Description: Microspores trilete, rounded triangular in equatorial compression. Laesurae bordered by membranaceous lips 1µm wide of indeterminate height but which extend almost to the edge of the exine.The exine is of indeterminate thickness and ornamented with muri. Proximal muri are 2µm to 3µm in width and height, convex to the proximal pole and delimit the contact areas, joining the membranaceous laesurae at the apices. The equatorial murus (cingulum) is continuous. The distal elements consist of individual muri 2µm inwidth and height and upto 11µm in length. The elements are closely packed and adjacent muri may join. A crude alignment of the muri is apparent.

Diameter 40µm.

Remarks: This single specimen differs from *S. scanica* in possessing more distal elements and in exhibiting an alignment of the elements.

Genus *Staplinisporites* (Balme) Pocock 1962

Type species: *Staplinisporites caminus* (Balme) Pocock 1962.

Diagnosis: see Pocock 1962, p. 49.

Staplinisporites caminus (Balme) Pocock 1962

pl. 7 fig. 3

Synonymy:

Cingulatisporites caminus Balme 1957, p. 27, pl. 5, fig. 62.

Holotype: *Cingulatisporites caminus* Balme 1957, p. 27, pl. 5, fig. 62.

Diagnosis: see Pocock 1962, p. 49.

Remarks: *S. caminus* differs from *Staplinisporites telatus* (Balme) Döring 1965 in possessing a thinner wall of undifferentiated thickness, in lacking rugulate ornament between the distal leptoma and the distal zona and in possessing a generally reduced distal ornament relative to *S. telatus*.

Previous records: Rhaetian to Upper Aptian; Europe.

Staplinisporites telatus (Balme) Döring 1965

pl. 7, figs 4, 5 & 6

Synonymy:

Microreticulatisporites telatus Balme 1957, p. 25, pl. 4, figs 52-53.
Cingulatisporites valdensis Couper 1958, p.146, pl. 24, figs 6-7.
Coronatispora valdensis (Couper) Dettmann 1963, p. 67.
Coronatispora telata (Balme) Dettmann 1963, p. 67, pl. XIV, figs 1-4.
Staplinisporites jurassicus Pocock 1970, p. 56, pl. 10, fig. 4.

Holotype: *Microreticulatisporites telatus* Balme 1957, p. 25, pl. 4, figs 52,53.

Description: see Balme 1957, p. 25.

Remarks: The inter-radial crassitudes are herein not considered to be a stable morphological feature of this species, despite most specimens exhibiting some thickening (cf *Neoraistrickia truncata*). Thus it is the present author's opinion that this species should not be placed in the genus *Coronatispora* Dettmann 1963 which exhibits consistent interradial crassitudes.

Previous records: Lias to Lower Cretaceous; Europe.

Genus *Contignisporites* Dettmann 1963

Type species: *Contignisporites glebulentus* Dettmann 1963.

Diagnosis: see Dettmann 1963, p. 73.

Remarks: The genus differs from *Striatella* (Mädler) Filatoff & Price 1988 in lacking a 'disto-equatorial murus' (Filatoff & Price 1988, p. 89).

Contignisporites cooksoniae (Balme) Dettmann 1963

pl. 6, fig. 2

Synonymy:

Cicatricosisporites cooksoniae Balme 1957, p. 19, pl. 1, fig. 23, pl. 2, figs 25-26.

Holotype: *Cicatricosisporites cooksoniae* Balme 1957, p. 19, pl. 1, fig. 23.

Diagnosis: see Balme 1957, p. 19.

Remarks: *Contignisporites cooksoniae* differs from *Striatella jurassica* Mädler 1964 in lacking any distal equatorial muri or connections between the distal transverse muri. It is also generally thicker (darker) than most specimens of *Striatella* observed in the present study.

Previous records: Lower Aalenian to Lower Albian; Europe.

Genus *Lycopodiacidites* (Couper) Potonié 1956

Type species: *Lycopodiacidites bullerensis* Couper 1953.

Diagnosis: see Potonié 1956, p. 39.

Lycopodiacidites rugulatus (Couper) Schulz 1967

pl. 7, figs 7 & 8

Synonymy:

Perotriletes rugulatus Couper 1958, p. 147, pl. 25, fig. 7.

Holotype: *Perotriletes rugulatus* Couper 1958, p. 147, pl. 25, fig. 7.

Diagnosis: see Couper 1958, p. 147.

Remarks: *L. rugulatus* differs from *Coronatispora telata* (Balme) Dettmann 1963 in lacking a differentiation of the distal wall sculpture into zona.

Previous records: Lower Jurassic to Upper Cretaceous: Northwest Europe.

3.5.5. Trilete reticulate 'spores'

Genus *Retitriletes* (Van der Hammen *ex* Pierce) Döring *et al.* 1963

Synonymy:

Lycopodiumsporites Thiergart *ex* Delcourt & Sprumont 1955.

Retitriletes Van der Hammen 1956 (nomen nudum).

Retitriletes Pierce 1961.

Retitriletes (Van der Hammen 1956 *ex*. Pierce 1961) Döring *et al.* 1963.

Type species: *Retitriletes globosus* Pierce 1961.

Diagnosis: see Döring *et al.* 1963.

Remarks: There exists considerable confusion concerning the validity of the genus *Lycopodiumsporites* Thiergart *ex* Delcourt & Sprumont 1955 which is a possible synonym of this genus. Pre- 1961 literature refers forms now in *Retitriletes* to *Lycopodiumsporites* (eg. Delcourt & Sprumont 1955, Couper 1958). Krutzsch (1963, p. 11) suggested that the holotype *L. agathoecus* (Potonié) Delcourt & Sprumont 1955 is an extremely foveolate grain comparable with *Ischyosporites* Balme 1957. In conclusion, Krutsch (1963 p.11) proposed the genus *Lycopodiumsporites* a *nomen dubium.*

Srivastava (1977, p. 56-57) gave a brief review of the history of the genus *Retitriletes* Van der Hammen *ex* Pierce 1961 and suggested it's seniority with respect to *Lycopodiumsporites*. Srivastava restricted the latter genus to foveo-reticulate forms and used *Retitriletes* in the sense of Döring *et al.* 1963. The present author concurs with Srivastava but also with McKellar (1974) in recommending a thorough review of foveolate and reticulate trilete spores.

Retitriletes annotinoides (Tralau 1968) n. comb.

pl. 6, fig. 3

Synonymy:

Lycopodiumsporites annotinoides Tralau 1968, p. 50, pl. II, fig. 1.

Holotype: *Lycopodiumsporites annotinoides* Tralau 1968, p. 50, pl. II, fig. 1.

Description: see Tralau 1968, p. 50-51.

Remarks: The species is distinguished on the basis of its low, broad reticulate ornament. As can be seen on plate 6, figure 3, the low height of the ornament can make its recognition difficult.

Previous records: Bajocian to Bathonian; Scania.

Retitriletes austroclavitidites (Cookson) Döring *et al.* 1963

pl. 6, fig. 4

Synonymy:

Lycopodium austroclavatidites Cookson 1953, p. 469, pl. 2, fig. 35.

Lycopodiumsporites austroclavitidites (Cookson) Potonié 1956, p. 46.

Holotype: *Lycopodium austroclavatidites* Cookson 1953, p. 469, pl. 2, fig. 35.

Diagnosis: see Potonié 1956, p.46.

Remarks: Differs from *Retitriletes clavatoides* (Couper) Döring *et al.* 1963 by its more numerous, thinner lumina and poorer defined curvatura.

Previous records: Rhaetic to Lower Cretaceous: Worldwide.

Retitriletes clavatoides (Couper) Döring *et al.* 1963

pl. 6, fig. 5

Synonymy:

Lycopodiumsporites clavatoides Couper 1958, p. 132, pl. 15, figs 10-11.

Retitriletes scanicus Tralau 1968, p. 48, pl. I fig. 2.

Holotype: *Lycopodiumsporites clavatoides* Couper 1958, p. 132, pl. 15, figs 10-11.

Diagnosis: see Couper 1958, p. 132.

Remarks: Couper's illustrations record two specimens, the holotype and a second specimen. The present author regards the holotype as *R. clavatoides* and the second specimen as *R. austroclavatidites*(Cookson) Potonié 1956. See also *R. austroclavatidites.*

Previous records: Jurassic and Lower Cretaceous: Britain.

Retitriletes eminulus (Dettmann)Srivastava 1977

pl. 6, figs 7 & 8

Synonymy:

Lycopodiumsporites eminulus Dettmann 1963, p. 45, pl. VII, figs 8-12.

Holotype: *Lycopodiumsporites eminulus* Dettmann 1963, p. 45, pl. VII, figs 8-12.

Description: see Dettmann 1963, p. 46.

Remarks: Distinguished from other species identified by its smaller more numerous lumina.

Previous records: Cretaceous; Australia, U.S.S.R.

Retitriletes semimuris (Danzé-Corsin & Laveine 1963) McKellar 1974

pl. 6, figs 9, 10 & 11

Synonymy:

Lycopodiumsporites semimuris Danzé-Corsin & Laveine 1963, p. 79, pl. 4, figs 15a,b.

Holotype: *Lycopodiumsporites semimuris* Danzé-Corsin & Laveine 1963, p. 79, pl. 4, figs 15a,b.

Description: see Danzé-Corsin & Laveine 1963, p. 79.

Remarks: The rounded triangular outline and incomplete reticulation of this species distinguishes it from others in the present study.

Previous records: Liassic; France.

Genus *Kekryphalospora* Fenton & Riding 1987

Type species: *Ke kryphalospora distincta* Fenton & Riding 1987.

Description: see Fenton & Riding 1987, p. 428.

Kekryphalospora distincta Fenton & Riding 1987

pl. 6, figs 11, 12 & 13

Holotype: *Kekryphalospora distincta* Fenton & Riding1987, p. 428, pl. 1, figs 1-2.

Description: see Fenton & Riding 1987, p. 428.

Remarks: Of the few specimens recorded, one specimen exhibited connecting rods attaching the distal reticulum to the distal surface in numerous places. The degree of attachment of the distal mesh is questioned. In the type material the mesh was variably separated from the distal surface. Whether this was a function of mechanical damage remains to be proved.

Previous records: Pliensbachian to Bajocian; North West Europe.

Genus *Ischyosporites* Balme 1957

Type species: *Ischyosporites crateris* Balme 1957.

Diagnosis: see Balme 1957, p. 45.

Remarks: The present author follows Schulz (1967), Potonié (1967), Tralau (1968), Guy (1971) and van-Konijnenburg-van Cittert (1981) in placing *Klukisporites* Couper 1958 in synonymy with *Ischyosporites* Balme. Filatoff (1975) was of the opinion, as was Dettmann (1963), that the two genera were distinct; *Ischyosporites* Balme 1957 being valvate whilst *Klukisporites* Couper 1958 possessed an exine of uniform thickness. However, Filatoff's revealing S.E.M. illustrations of *Klukisporites variegatus* (plate 15, figs 3 and 5) and *Klukisporites lacunus* (plate 16, fig. 2a) clearly show the encroachment of the thick reticulate ornament onto the proximal surface in the radial regions. It is the present author's opinion that this phenomenon produces a pseudo-valvate effect on spores in equatorial compression which has been previously mis-interpreted as a valvate structure. The proximal distribution of the dense reticulate ornament, on the basis of Filatoff's S.E.M. images and of specimens from the present study, is a function of the shape and extent of the contact areas, within which the reticulate ornament is replaced by a smooth to verrucate exine surface.

Ischyosporites variegatus (Couper) Schulz 1967

pl. 6, fig. 15, pl. 7, fig. 1

Synonymy:

Klukisporites variegatus Couper 1958, p. 137, pl. 19, figs 6-7.
Ischyosporites scaberis Cookson & Dettmann 1958, p. 104, pl. 15, figs 7-9.
Klukisporites scaberis (Cookson & Dettmann) Dettmann 1963, p. 48, pl. VIII, figs 1-7.
Klukisporites neovariegatus Filatoff 1975, p. 69, pl. 15, figs 6-8.

Holotype: *Klukisporites variegatus* Couper 1958, p. 137, pl. 19, figs 6-7.

Description: see Couper 1958.

Remarks: Couper intended *K. variegatus* for dispersed spores " ... almost certainly belonging to the Jurassic schizaeaceous plants *Klukia exilis* and *Stachypteris hallei* " (p. 137). Of the spores of the two plants he comments " The spores of both these species are rather variable. Most spores of *K. exilis* show a distal sculpture pattern of smaller pits and thicker intervening walls and a better developed proximal sculpture than is the case in most spores of *S. hallei*. ... Some spores of both species are, however, extremely similar. Thus, although it may be possible to assign certain spores to one or other of the species, all cannot be consistently separated." (*op. cit.* p. 137).

Van Konijnenburg-van Cittert (1981, p. 169-174) re-studied the spores of the two plant species on the basis of new material from the Gristhorpe Member at Cloughton Wyke and the Gristhorpe Plant Bed in Gristhorpe Bay. In addition to Couper's description, she also observed verrucae at the bottom of the pits on the distal surface (c.f. *Klukisporites scaberis* (Cookson & Dettmann) Dettmann 1963). Her own comparison between *Klukia exilis* and *Stachypteris spicans* (syn. *hallei*) concluded that " thay are very similar, but ... *S. spicans* spores are slightly finer in most respects than those of *Klukia exilis* ..." (p. 178). With comparison to dispersed spores, Van Konijnenburg-van Cittert agreed with Couper, placing the spores of both species in *Ischyosporites variegatus* (Couper) Schulz 1967.

Previous records: Upper Pliensbachian to Lower Aptian; Europe.

Genus *Trilobosporites* Pant *ex* Potonié 1956

Type species: *Concavisporites hannonicus* Delcourt and Sprumont 1955.

Diagnosis: see Potonié 1956, p. 55.

Trilobosporites antiquus Reiser and Williams 1969

pl. 7, fig. 2

Holotype: *Trilobosporites antiquus* Reiser and Williams 1969, p. 8, pl. 3, fig. 15.

Diagnosis: see Reiser and Williams 1969, p. 8.

Remarks: Specimens exhibiting a low muromate/foveolate distal wall structure and valvae are included here. *Trilobosporites antiquus* may form an end member of a continuous series with *Ischyosporites* Balme 1957. The possibility that the species may represent immature or corroded specimens of *Ischyosporites* cannot be ignored.

Previous records: Jurassic: Australia.

3.5.6. Trilete verrucate, granulate, verrucate and spinate 'spores'

Genus *Trachysporites* (Nilsson 1958) emend.

Type species: *Trachysporites fuscus* Nilsson 1958, p. 38, pl. 2, fig. 1.

Emended diagnosis: Trilete microspores with a subcircular to rounded triangular equatorial amb and a simple exine of undifferentiated thickness. Laesurae are usually long and may be enclosed in low, membranaceous lips. Proximal arcuate folds are present parallel to the laesurae (convex towards the proximal pole). Ornament is present distally and proximally, although it may be reduced in the contact areas. Ornament is commonly irregular and may consist of grana, verrucae, baculae, clavae, spinae and murae. Ornament subdued (generally less than 5µm in height for elongate processes).

Remarks: The emendation is based on the holotype which clearly exhibits laesurae enclosed in membranceous lips and proximal folds convex towards the proximal pole. The present author also felt it necessary to further qualify the size of the ornament. *Trachysporites* differs from *Conbaculatisporites* Klaus 1960 in exhibiting proximal folds, no strong differentiation of the ornament at the angles and in a greater variety of ornament present.

Trachysporites fuscus Nilsson 1958

pl. 7, fig. 9

Holotype: *Trachysporites fuscus* Nilsson 1958.

Description: see Nilsson 1958, p.38.

Remarks: Specimens identified agree with the type material.

Previous records: Middle Rhaetian to Aalenian; Europe.

Trachysporites brevipapillosus (Couper 1958) n. comb. and emend.

pl. 7, figs 10 & 11

Synonymy:

Pilosisporites brevipapillosus Couper 1958, p.144, pl. 22, figs 11-12.

Holotype: *Pilosisporites brevipapillosus* Couper 1958, p.144, pl. 22, figs 11-12.

Emended description: Trilete microspores with a more or less rounded triangular amb, which may appear concave triangular due to compression. The exine is of undifferentiated thickness between 1.5µm and 2.5µm. Laesurae are long, extending almost to the equator, enclosed in membranaceous lips. The proximal surface is commonly with arcuate folds, concave to the proximal pole and running parallel to the laesurae, but not reaching the equator. Proximal and distal surfaces are ornamented with predominately spines 1µm to 1.5µm long but the ornament is commonly irregular and may include baculae and clavae of similar dimensions.

Remarks: The description is emended on the basis of the illustrations of the type species and on observations from the present study. *Pilosisporites brevipapillosus* Couper 1958 appears to be synoymous with *Acanthotriletes varius* Nilsson 1958. It is doubted whether Couper's species fits in the genus *Pilosisporites* Delcourt & Sprumont 1955; Couper described the ornament as "thick papillae" (1958, p.144) which disagrees with the generic diagnosis of "hair-like" ornament (Delcourt & Sprumont 1955, p.34). It is questioned whether the thick papillae that Couper described are not merely spinae or baculae. Couper's species has priority over Nilsson's since it was published earlier in 1958.

Previous records: Middle Jurassic; U.K.

Genus *Ornamentifera* Bolkhovitina 1966

Type species: *Ornamentifera echinata* Bolkhovitina 1966.

Diagnosis: see Bolkhovitina 1966, p.69.

Remarks: The present author agrees with the comments of Burden & Hills (1989, p. who follow Dettmann & Playford (1968) and Singh (1971) in separating forms referable to the genus *Gleicheniidites* Ross 1949 which possess sculptural elements.

Ornametnifera distalgranulata (Couper) Burden & Hills 1989

pl. 7, fig. 12

Synonymy:

*Trilites distalgranulatus*Couper 1958, p. 149, pl.25, figs 15-16.
Gleicheniidites distalgranulatus (Couper) Döring 1965.
Ceratosporites distalgranulatus (Couper) Kemp 1970, p. 86, pl. 11, figs 1-4.

Type species: *Trilites distalgranulatus*Couper 1958, p. 149, pl.25, figs 15-16.

Description: see Couper 1958, p. 149.

Remarks: The previous recordings of this species cover the Lower Cretaceous of Europe (Couper 1958, Dörhöfer & Norris 1977) and Late Valanginian to Aptian of Canada (Burden & Hills 1989). Couper's description agrees closely with those specimens encountered during the present study.

Previous records: Aptian to Albian; Europe, Bajocian to Bathonian of Egypt.

Genus *Nevesisporites* (De Jersey & Paten) Morbey 1975

Type species: *Nevesisporites vallatus* De Jersey & Paten 1964.

Diagnosis: see Morbey 1975, p. 19.

Remarks: Morbey's emendation brings the genus close to *Taurocusporites* Stover 1962. However, *Nevesisporites* differs in lacking a clearly defined tri-zonate structure of its distal ornament. *Stereisporites* subgen. *Stereigranisporis* Krutzsch 1963 differs in its smaller size range and absence of coarse verrucate ornament on its distal surface. *Foraminisporis* Krutzsch 1959 differs in exhibiting proximal inter-radial foramen.

Nevesisporites bigranulatus (Levette-Carette) Morbey 1975

pl. 7, figs 13 & 14

Synonymy:

Cingulatisporites bigranulatus Levette-Carette 1965, p. 290. pl. XXV, figs 1-4.

Polycingulatisporites bigranulatus (Levette-Carette) Orbell 1973, p. 9, pl. 3, fig. 13.

Holotype: *Cingulatisporites bigranulatus* Levette-Carette 1965, p. 290. pl. XXV, figs 1-4.

Description: see Morbey 1975, p. 19.

Remarks: A conspicuous species in the diverse assemblages of the samples studied.

Previous records: 'Middle Keuper' to Aalenian; Europe.

Genus *Granulatisporites* (Ibrahim) Potonié 1954

Type species: *Granulatisporites granulatus* Ibrahim 1933.

Diagnosis: see Potonié 1954, p. 126.

Granulatisporites subgranulosus (Couper 1958) n. comb.

pl. 7, fig. 15

Synonymy:

Concavisporites subgranulosus Couper 1958, p. 143, pl. 22, fig. 6.

Holotype: *Concavisporites subgranulosus* Couper 1958, p. 143, pl. 22, fig. 6.

Description: see Couper 1958, p. 143.

Remarks: The species is re-combined on the basis of the present authors concept of the Genus *Concavisporites* Pflug *in* Thomson & Pflug 1953 *sensu* Delcourt & Sprumont 1955. It differs from *Tuberositriletes aequiverrucatus* n. sp. in its smaller dimensions and ornament.

Previous records: Lower to Middle Jurassic; Great Britain.

Genus *Tuberositriletes* Döring 1964

Type species: *Tuberositriletes montuosus* Döring 1964.

Diagnosis: see Döring 1964, p. 1103.

Tuberosistriletes aequiverrucatus n. sp.

pl. 8, fig. 1

Holotype: Slide 89411.1, grid ref 143.5 18.2., pl. 8, fig. 1.

Diagnosis: A species of *Tuberositriletes* with a variable compressed outline bearing a dense ornament of verrucae.

Description: Microspores trilete, concave to convex rounded triangular under equatorial compression. Laesurae are simple splits in the exine and extend to 7/8 radius of the grain. The laesurae are bordered by a margo, variable in development, 2.5μm to 5μm in width and of indeterminate height. Exine apparently single layered, upto 2.5μm thick.

An ornament is present on the proximal and distal surfaces without any apparent differentiation in distribution and consists of closely packed smooth surfaced verrucae, circular to irregular in outline and 1.25µm to 3.75µm in diameter. The ornament is commonly present on the margo.

Mean diameter 55.5µm (maximum 75µm, minimum 47.5µm)(10 specimens).

Derivation of name: *aequi-* from *aequus* Latin meaning equal, *-verrucatus* from *verruca* Latin, referring to the equal sized ornament.

Remarks: A distinctive species, common in populations along with *T. horridus* and *T. perverrucatus*. It differs from *Concavissimisporites penolaensis* Dettmann 1963 in exhibiting a more variable equatorial outline, from *T. variverrucatus* (Couper) n. comb. in exhibiting a less variable, more closely packed ornament and from *Granulatisporites subgranulosus* in a more variable equatorial outline, ornament and overall dimensions.

Tuberosistriletes horridus n. sp.

pl. 8, figs 2, 3, 4, 5 & 6

Holotype: Slide 89411.1, grid ref. 145.1 22.9., pl. 8, figs 2 & 3.

Paratypes: Slide 89411.1, grid refs 145.5 21.5, 126.2 21.6, 130.8 21.4, pl. 8, figs 4, 5 & 6.

Diagnosis: A variable species of *Tuberositriletes* bearing an ornament of coalesced verrucae.

Description: Microspores trilete, circular, concave to convex rounded triangular under equatorial compression. Laesurae are simple splits in the exine and extend 2/3 to 7/8 radius of the grain. The laesurae are bordered by a margo, variable in development, mean width 5.4µm (maximum 7.5µm, minimum 3.8µm)(50 specimens) and of indeterminate height. Exine apparently single layered, thick but indeterminate due to the ornament.

An ornament is present on the proximal and distal surfaces without any apparent differentiation in distribution and consists of verrucae which coalesce to form large irregular elements with a mean diameter of 5.9µm (maximum 10µm, minimum 2.5µm). The exine between these elements is variably ornamented with small irregular verrucae of variable size but smaller than the coalesced elements. The ornament is commonly present on the margo. On specimens where the margo is poorly defined, a row of coalesced elements may poorly define a margin.

Mean diameter 55.3µm (maximum 87.5µm, minimum 42.5µm)(50 specimens).

Derivation of name: *horridus* Latin, referring to the rough, rugged ornament.

Remarks: A very distinctive species, identifiable from even the smallest of fragments on account of its characteristic ornament. It differs from other species recognised in this study by the structure of the verrucae.

Tuberositriletes perverrucatus (Couper 1958) n. comb.

pl. 9, figs 1 & 2

Synonymy:

Lygodioisporites perverrucatus Couper 1958, p. 144, pl. 23, figs 4-5.

Holotype: *Lygodioisporites perverrucatus* Couper 1958, p. 144, pl. 23, figs 4-5.

Description: see Couper 1958, p. 144.

Remarks: Great variation in the ornament and equatorial contour was encountered during the present study. Couper (1958, p. 144) remarked on the variation in the size of the ornament in his description but makes no mention of variation in equatorial contour. The large, smooth verrucae are characteristic. Differs from *Leptolepidites bossus* in overall dimensions and the presence of ornament on the contact areas.

Previous records: Midldle Jurassic; Great Britain.

Tuberositriletes variverrucatus (Couper 1958) Döring 1964.

pl. 8, fig. 7

Synonymy:

Concavisporites variverrucatus Couper 1958, p. 142, pl. 22, figs. 4-5.

Holotype: *Concavisporites variverrucatus* Couper 1958, p. 142, pl. 22, figs. 4-5.

Diagnosis: see Couper 1958, p.142.

Remarks: Couper (1958, p. 142) originally described the species in the genus *Concavisporites* Pflug in Thomson & Pflug 1953 which, in its original diagnosis, was erected for " mostly smooth, less commonly structured spores". Norris (1969, p. 585) combined Couper's species into the genus *Converrucosisporites* Potonié & Kremp 1954. Potonié & Kremp's diagnosis of this genus stated " Trilete iso- or microspores, with ornamentation as in *Verrucosisporites*, but with a +- triangular amb". The ornamentation of *Verrucosisporites* sensu Potonié & Kremp was described as " closely spaced warts on the exine" (Potonié & Kremp 1954, p. 137). Couper's species was noted for its " great variation in the size and spacing of the verrucae" (Couper 1958, p. 142) and thus does not fit satisfactorily into the genus *Converrucosisporites* Potonié & Kremp 1954. The genus *Tuberositriletes* Döring 1964 has a rather broader circumscription than *Converrucosisporites* Potonié & Kremp 1954, in particular no mention of the spacing of the verrucae is made. It is herein proposed to combine *Concavisporites variverrucatus* Couper 1958 into *Tuberositriletes variverrucatus.*

Previous records: Bajocian to Middle Albian; Europe.

Genus *Leptolepidites* (Couper 1953) Norris 1968

Type species: *Leptolepidites verrucatus* Couper 1953.

Diagnosis: see Norris 1968, p.316.

Remarks: The author follows the emendation of Norris, who re-examined Couper's type material and observed smooth contact areas, an observation agreed with in the present study on recognising *L. major* Couper 1958.

Leptolepidites argenteaeformis (Bolkhovitina) Morbey 1975

pl. 8, figs 8 & 9

Synonymy:

Stenozonotriletes argenteaeformis Bolkhovitina 1953, p. 51, pl. 7, fig. 9.

Uvaesporites argenteaeformis (Bolkovitina) Schulz 1967, p. 560, pl. II, figs 10-11.

Holotype: *Stenozonotriletes argenteaeformis* Bolkhovitina 1953, p. 51, pl. 7, fig. 9.

Diagnosis: see Morbey 1975, p. 14.

Remarks: The author accepts Morbeys emendation of the species *argenteaeformis* in preference to Schulz's recombination into the genus *Uvaesporites* (Schulz 1967, p.560). *Uvaesporites* differs in exhibiting an equatorial thickening. *Leptolepidites argenteaeformis* possesses a strong distal ornament of interlocking verrucae which overlaps onto the proximal surface and at the equator, giving the impression of an equatorial thickening.

Previous records: Anisian to Lower Cretaceous; Europe.

Leptolepidites bossus (Couper) Schulz 1967

pl. 9, figs 3 & 4

Synonymy:

Trilites bossus Couper 1958, p. 148, pl. 2, figs 4-6.

Holotype: *Triletes bossus* Schulz 1967, p. 559, pl. 2, figs 4-6.

Diagnosis: see Couper 1958, p. 148.

Remarks: See *Leptolepidites equatibossus* (Couper) Tralau 1968..

Previous records: Toarcian to Bajocian; Europe, Bathonian to Callovian; Western Australia.

Leptolepidites equatibossus (Couper) Tralau 1968

pl. 9, fig. 5

Synonymy:

Trilites equatibossus Couper 1958, p. 148, pl. 25, figs 13-14.

Holotype: *Trilites equatibossus* Couper 1958, p. 148, pl. 25, figs 13-14.

Description: see Tralau 1968, p. 43.

Remarks: *T. equatibossus* differs from *T. bossus* in exibiting ornament only in equatorial regions.

Previous records: Bajocian; Europe.

Leptolepidites macroverrucosus Schulz 1967

pl. 9, fig. 6

Holotype: *Leptolepidites macroverrucosus* Schulz 1967, p. 559, pl. 2, figs 7-9.

Description: see Schulz 1967, p. 559.

Remarks: The relatively large, sparse verrucae serve to distinguish this species from other representatives of the genus identified in the study.

Previous records: Lias to Aalenian; Europe, Lower Cretaceous, Argentina.

Leptolepidites major Couper 1958

pl. 9, fig. 8

Holotype: *Leptolepidites major* Couper 1958, p. 141, pl. 21, fig. 7.

Diagnosis: see Couper 1958, p. 141.

Remarks: The specimens observed in the samples from the present study have consistently smooth contact areas. This is in agreement with Norris's (1968, p. 316) emendation of the type species. The description of *L. major* should also be emended on the basis of the present specimens which have been observed in samples from identical localities to those of Couper (although this should await a re-study of the holotype).

Previous records: Upper Triassic to Upper Albian; Europe.

Leptolepidites obscuriverrucatus n. sp.

pl. 9, fig 7

Synonymy:

Retusotriletes mesozoicus Klaus 1960 in Filatoff 1975, pl.17, fig. 2.

Leptolepidites sp. Filatoff 1975, pl. 20, fig. 10.

Holotype: Slide 89010.1, grid ref. 136.1 19.9, pl. 9, fig. 7.

Paratypes: Slide 89010.1, grid refs 127.8 6.6, 145.2 3.2.

Diagnosis: A species of *Leptolepidites* with an obscure ornament of verrucae.

Description: Microspores trilete, circular to oval in compression, originally sphaerical. Laesurae moderately to poorly defined by lips 1µm high, 1µm wide which extend to the edge of the contact areas. Contact areas are smooth, well defined by a lack of ornament and are 2/3 to 7/8 diameter of the spore. Exine apparently single layered and of indeterminate thickness at the equator due to the development of an ornament.

An ornament is present distal from the contact areas and consists of poorly defined verrucae of variable diameter but consistent thickness. Often the only indication of the ornament are sinuous thinnings in the exine which delimit the edges of the verrucose element. Average total exine thickness (exine plus ornament thickness) at the equator 2.3µm (maximum 3.9µm, minimum 1.25µm)(10 specimens).

Mean diameter 41.25µm (maximum 47.5µm, minimum 32.5µm)(10 specimens).

Derivation of name: *obscuri-* from *obscurus* Latin, *-verrucatus* from *verruca* Latin, referring to the obscure nature of the ornament.

Remarks: The specimens illustrated in Filatoff 1975 (see synonymy above) are almost certainly the same spore type. The size limitation for the verrucae has not been qualified since it is the authors opinion that the obscure nature of the ornament is the most diagnostic characteristic rather than the size of the individual elements.

Leptolepidites sp. SL1

pl. 9, figs 9, 10, 11, 12 & 13

Description: Microspores trilete, circular to concave rounded triangular in compression. Laesurae moderately to poorly defined by lips 1µm wide at the base, becoming membranaceous away from the base and extending upto 2.5µm in height. Laesurae extend to the edge of the contact areas. Contact areas are smooth, well defined by a lack of ornament and >7/8 diameter of the grain. Exine apparently single layered and of indeterminate thickness at the equator due to the development of an ornament.

An ornament is present distal from the contact areas and consists of well defined verrucae which may coalesce and form short rugulae. Verrucae typically 2.5µm in height and upto 3.75µm in width.

Mean diameter 31.8μm (maximum 37.5μm, minimum 30μm)(4 specimens).

Remarks: Compares with *Camarozonosporites ramosus* (de Jersey) McKellar 1975 but differs in lacking ornament in the contact areas.

Spore form 1

pl. 9, figs 16 & 17

Description: Spores questionably trilete, spherical in shape. The haptotypic features are typically obscured due to gaping laesurae. The exine is apparently single layered and thick (up to 4μm) due to the development of an ornament. The ornament consists of elements with a flat, smooth upper surface and an angular outline. The elements may coalesce and interlock densely, sometimes resulting in a false negative ornament.

Mean diameter 40.6μm (maximum 47.5μm, minimum 35μm)(4 specimens).

Remarks: The obscure nature of the haptotypic features may be due to its delicate nature. The form may eventually be accomodated in *Leptolepidites* but further observations on the contact areas are first necessary.

Genus *Antulsporites* Archangelsky & Gamerro 1966

Type species: *Antulsporites baculatus* (Archangelsky & Gamerro) Archangelsky & Gamerro 1966.

Diagnosis: see Archangelsky & Gamerro 1966, p. 369.

Antulsporites saevus (Balme) Archangelsky & Gamerro 1966

pl. 9, fig. 13

Synonymy:

Cingulatisporites saevus Balme 1957, p. 26, pl. 4, fig. 57, pl. 5, figs 58-59.

Heliosporites saevus (Balme) Archangelsky & Gamerro 1966a, p.203.

Holotype: *Cingulatisporites saevus* Balme 1957, p. 26, pl. 4, fig. 57, pl. 5, figs 58-59.

Description: see Balme 1957, p. 26.

Remarks: Specimens identified in the present study conform to the original description of Balme (1957).

Previous records: 'Domerian'; France, Hettangian to Valanginian; Australia.

Antulsporites varigranulatus (Levette-Carette) Reiser & Williams 1969

pl. 9, figs 14 & 15

Synonymy:

Lycopodiacidisporites varigranulatus Levette-Carette 1964, p. 110, pl. 18, fig. 11.

Punctatosporites varigranulatus (Levette-Carette) Kemp in Kemp & Harris 1977, p. 30, pl. 3, figs 10-13.

Holotype: *Lycopodiacidisporites varigranulatus* Levette-Carette 1964, p. 110.,pl. 18, fig. 11.

Description: see Reiser & Williams, p. 11.

Remarks: The uncommon specimens encountered in the present study agree with the original description.

Previous records: Lower Jurassic to Upper Jurassic; Australia.

Genus *Neoraistrickia* Potonié 1956

Type species: *Neoraistrickia truncatus* (Cookson) Potonié 1956.

Diagnosis: see Potonié 1956, p. 34.

Neoraistrickia truncata (Cookson) Potonié 1956

pl. 9, fig. 18, pl. 10, figs 1 & 2

Synonymy:

Trilites truncatus Cookson 1953, p. 471, pl. 2, fig. 36.
Lycopodiumsporites gristhorpensis Couper 1958, p. 133, pl. 15, figs 14-16.
Neoraistrikia gristhorpensis (Couper)Tralau 1968, p. 470, fig. 1.
Neoraistrikia samuelssoni Tralau 1967, p. 470, text-figs 1A-B.

Holotype: *Trilites truncatus* Cookson 1953, p. 471, pl. 2, fig. 36.

Diagnosis: see Cookson 1953, p. 471.

Remarks: Couper described *Lycopodiumsporites gristhorpensis* in 1958 from the Cloughton Formation of the Cleveland Basin. It compares closely with *N. truncata* and has been considered synonymous by various authors (eg. Dettmann 1963, Filatoff 1975, Vigran & Thusu 1975). In the present study, specimens of *N. truncata* exhibited considerable variation in the thickness of the exine at the equator and in size range of the truncate distal processes. In extreme cases inter-radial crassitudes comparable to those present in *Staplinisporites telatus* (Balme) Döring 1965 and *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963 were observed (pl. 10, fig. 1). With reference to the distal processes a continuous morphological series was observed from short, stout equidimensional processes (c.f. *Neoraistrickia samuelssoni* Tralau 1967) to narrow, relatively elongate processes exhibiting the characteristic blunt tips. Variation within a single specimen, however was uncommon. A similar morphological variation has been recorded by R.A. Couper *et al.*(unpublished spore manual, pers. obs.). In very rare specimens a slight thickening of the exine at the distal pole was observed.

Two of these observations (exinal inter-radial thickening and development of a distal leptoma) draw comparisons with other species recorded, notably *Staplinisporites telatus* and *Sestrosporites pseudoalveolatus*. The present author acknowledges the comment of Couper (1958, p. 133) that *C. telata* (al. *Lycopodiumsporites cerniidites* (Ross) Delcourt & Sprumont 1955), and *N. truncata* (al. *L. gristhorpensis*) spores represent mesozoic lycopods along with *Lycopodiumsporites* spp. Further to his comments the present author suggests that *S. pseudoalveolatus* could also belong to this group.

Previous records: Rhaetian to Lower Albian; Europe.

Neoraistrickia sp. SN1

pl. 10, fig 3 & 4

Description: Microspores trilete, rounded triangular to slightly concave rounded triangular in equatorial compression. Laesurae are simple slits bordered by lips 1μm x 1μm and extend almost to the equator. The proximal surface is smooth. The distal surface is covered in an ornament of hollow smooth verrucae and baculae upto 5μm long and 2.5μm in width. Elongate elements may be wider at their extremities than at their bases.

Diameter 22μm and 27μm.

Remarks: A distinctive species as the hollow elements give the impresion of annular elements on low magnification.

Genus *Anapiculatisporites* Potonié & Kremp 1954

Type species: *Anapiculatisporites isselburgensis* Potonié & Kremp 1954.

Diagnosis: see Potonié & Kremp 1954, p.133.

Anapiculatisporites dawsonensis Reiser & Williams 1969

pl. 10, fig. 5

Holotype: *Anapiculatisporites dawsonensis* Reiser & Williams 1969, p. 3, pl. 1, figs 9-11.

Diagnosis: see Reiser & Williams 1969, p. 3.

Remarks: Filatoff (1975, p.63) questioned Reiser & Williams' circumscription of *A. dawsonensis*, in particular the reference to the lack of proximal ornament. The present author agrees with Filatoff in observing a reduced proximal ornament. In rare specimens, the irregular development of verruca in the centre of each contact face was noticed. This morphological feature was not consistent and specimens exhibitng three equally well developed verrucae were not observed. In this respect it is of interest to note the comments of Filatoff (1975, p.63) " *Foraminisporis tribulosus* Playford & Dettmann 1965 is indistiguishable from *Anapiculatisporites dawsonensis* except for the presence of a verruca on the centre of each contact face." The present author suggests a thorough review of the type material of both species is in order.

Previous records: Rhaetian to Aalenian; Europe, Lower Jurassic; Australia.

Genus *Echinatisporis* Krutzsch 1959

Type species: *Echinatisporis longechinus* Krutzsch 1959.

Diagnosis: see Krutzsch 1959 p. 132.

Remarks: The present author disagrees with Burden & Hills (1989, p. 72) who synonymised *Echinatisporis* with *Ceratosporites* Cookson & Dettmann 1958. The original diagnosis of *Echinatisporis* allows for forms with proximal as well as distal ornament, as in the present case.

Echinatisporis baculatus n. comb. and emend.

pl. 10, figs 6, 7, 8 & 9

Synonymy:

Lycopodiacidites baculatus Pocock 1962, p. 34-35, pl. 1, figs 10-11.
Lycopodiacidites irregularis Pocock 1970, p. 62, pl. 12, figs 8.
Lycopodiacidites spinatus Pocock 1970, p. 62, pl. 12, figs 5-7.

Holotype: *Lycopodiacidites baculatus* Pocock 1962, p. 34-35, pl. 1, figs 10-11.

Diagnosis: A species of *Echinatisporis* bearing variably developed haptotypic features and an ornament of variable spines.

Emended description: Microspores which are sub-spherical to ovoidal, with a circular to rounded triangular equatorial amb. Mean diameter 38 µm (range 25µm-58µm, standard deviation 5.9, all measurements based on 177 specimens). The trilete laesurae are poorly defined or obscure; they are indicated inconsistently by simple slits in the exine or by irregular membranaceous lips enclosing the simple slits. The contact areas are delimited by a reduced exinal ornament and occupies greater than 3/4 radius area of the proximal surface in polar view.

The thickness of the exine is difficult to observe due to the strong development of an ornament but appears to range from 0.5µm to 1.5µm. The exine is strongly ornamented with spines whose bases are hollow. Mean length of the mean spine length of the dataset is 5.4 µm (overall range 1µm-17.5µm). The outline of the spines is consistent to inconsistent on any one specimen; morphologies observed range from simple spines with narrow to broad bases, simple spines possessing clavate tips, galeate to baculate processes with spinose tips, fused processes resulting in large joined structures and irregularly developed processes assuming a general spinose appearance. The ornament on the contact areas is reduced to less than half the length of the ornament outside the contact areas and may sometimes be seen to coalesce with the membranaceous lips of the laesurae.

Remarks: A study of 200 specimens of spinose spores from sample 89302.5 resulted in the recognition of a separate species (*Anapiculatisporites dawsonensis* Reiser & Williams 1969) whose regular conate ornament does not exceed 5µm in length and whose consistently developed trilete slits are diagnostic (Fig 3.6). Out of a population of 200 specimens 11.5% were identified as this morphon. The remaining specimens fell into the rather broadly subscribed *Echinatisporis baculatus* morphon.

A single broad grouping emerged from a scattergram plot of diameter versus average spine length (Fig. 3.5). When the range of the data was restricted to specimens that were consistently trilete, a dominant grouping could be seen with spine lengths less than 5µm (Fig. 3.6). The erection of the subdominant species is justified by its clear identification in preparations and its relative morphological stability in comparison to *Echinatisporis baculatus*.

In addition to *Lycopodiacidites baculatus* Pocock 1962, Pocock (1970, p. 62) described two new species, *Lycopodiacidites spinatus* and *L. irregularis*. The diagnoses of all three species state that the microspores are alete. This observation is questioned herein, as is the validity of all three species of *Lycopodiacidites* described by Pocock. In the present study all three process morphologies which distinguish Pocock's species are encountered within a broad morphological complex.

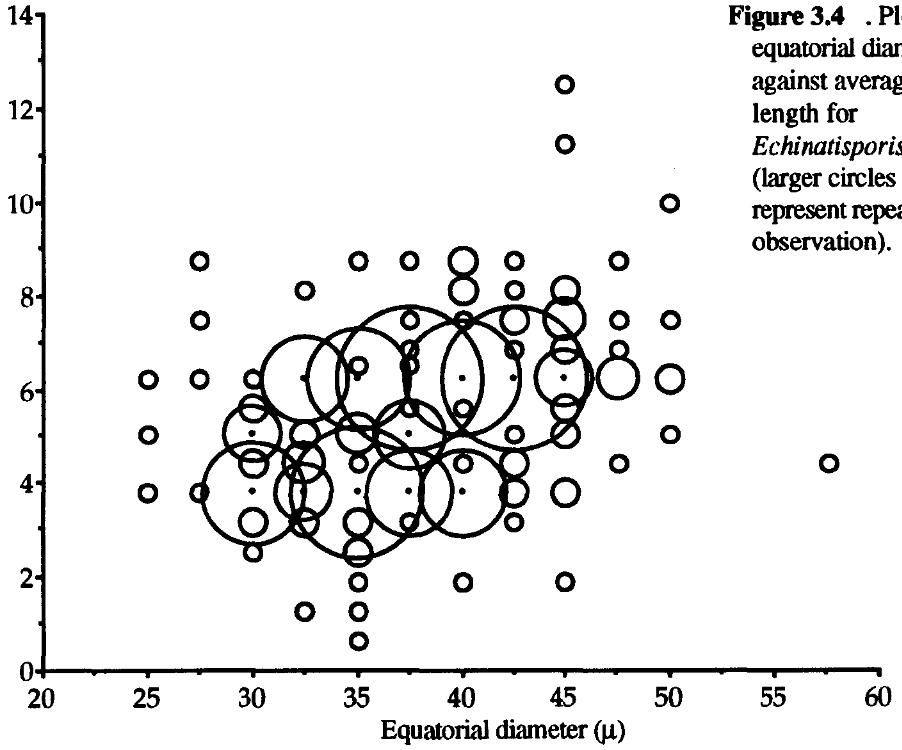


Figure 3.4 . Plot of equatorial diameter against average spine length for *Echinatisporis baculatus* (larger circles represent repeated observation).

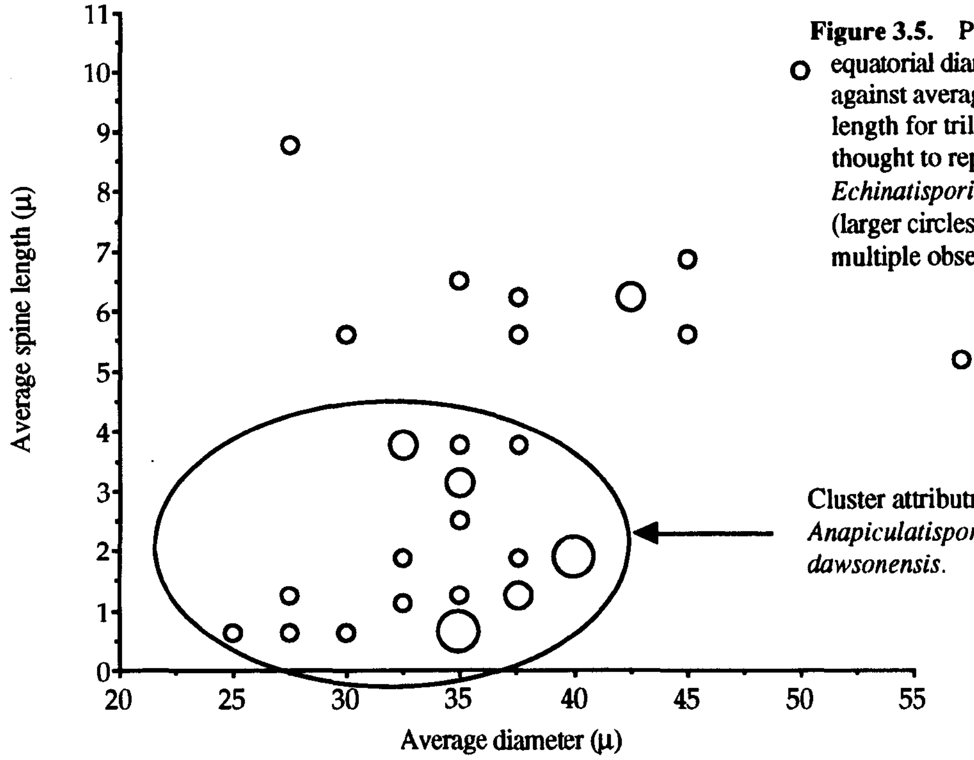


Figure 3.5. Plot of equatorial diameter against average spine length for trilete spores thought to represent *Echinatisporis baculatus* (larger circles represent multiple observations).

Cluster attibutred to *Anapiculatisporites dawsonensis.*

With regards to the nature of the ornament present on the contact areas, the present samples merely indicate an ornament of a reduced nature to that covering the rest of the spore. The author questions Pocock's description in the light of recognition of clear spinose processes on the plates of the holotypes of all of Pocock's species (1970, pl. 12, figs 5-11).

The present author questions the stability of Pocock's three species; apart from acknowledging the presence of baculae with clavate tips within the ornament of *L. spinatus*,, little comment is made of process variability in the original descriptions. However *L. spinatus* and *L. irregularis* appear very similar indeed (*L. irregularis* was recorded to be smaller and more irregular than *L. spinatus*). On the basis of the present study, *Lycopodiacidites spinatus* and *L. irregularis* are considered synonyms of *Echinatisporis* (*Lycopodiacidites*) *baculatus*.

Previous records: Middle to Upper Jurassic; worldwide.

Genus *Baculatisporites* Pflug *in* Thomson & Pflug 1953

Type species: *Baculatisporites primarius* (Wolff) Pflug in Thomson & Pflug 1953.

Diagnosis: see Pflug in Thomson & Pflug 1953, p. 56.

Remarks: The present author follows Filatoff 1975 in subdividing spores commonly referred to as 'Osmundaceous' (eg Filatoff 1975, p. 57). *Baculatisporites* possesses an ornament of predominantly baculate morphology, *Osmundacidites* Couper 1953 possesses predominantly irregularly spaced grana, *Rugulatisporites* Pflug in Thomson & Pflug 1953 exhibits predominantly rugulate sculptural elements and in *Verrucosisporites* Ibrahim 1933 verrucae are manifest. It is accepted that a spectrum of sculptural elements may be present on any one species but the ultimate identification rests upon the dominant element.

Baculatisporites comaumensis Cookson *ex* Potonié 1956

pl. 10, fig. 10

Holotype: *Baculatisporites comaumensis* Cookson *ex* Potonié 1956.

Description: see Potonié 1956, p. 33.

Remarks: The specimens conform with Cookson's original description.

Previous records: Carnian to Upper Valanginian; Europe.

Genus *Osmundacidites* Couper 1953

Type species: *Osmundacidites wellmanii* Couper 1953.

Diagnosis: see Couper 1953, p. 20.

Remarks: The author considers *Cyclogranisporites* Potonié & Kremp 1954 to be a junior synonym of *Osmundacidites*. See also *Baculatisporites* for remarks regarding 'Osmundaceous' spore types.

Osmundacidites wellmanii Couper 1953

pl. 10, fig. 11

Holotype: *Osmundacidites wellmanii* Couper 1953, p. 20, pl. 1, fig. 5.

Diagnosis: see Couper 1953, p. 20.

Previous records: Ladinian to Lower Albian; Europe.

Genus *Rugulatisporites* Pflug *in* Thomson & Pflug 1953

Type species: *Rugulatisporites quintus* Pflug *in* Thomson & Pflug 1953.

Diagnosis: see Pflug *in* Thomson & Pflug 1953, p. 56.

Remarks: See also *Baculatisporites* for remarks regarding 'Osmundaceous' spores.

Rugulatisporites nequenensis Volkheimer 1972

pl. 10, fig. 12

Holotype: *Rugulatisporites nequenensis* Volkheimer 1972, p.118, pl. 5, figs 38-39.

Diagnosis: see Volkheimer 1972, p.118.

Remarks: see generic remarks for *Baculatisporites*.

Previous records: Callovian; Argentina, Toarcian to Bathonian; Australia.

Genus *Verrucosisporites* Ibrahim 1933

Type species: *Verrucosisporites verrucosus* (Ibrahim) Ibrahim 1933.

Diagnosis: see Ibrahim 1933, p. 25.

Remarks: See *Baculatisporites* for remarks regarding 'Osmundaceous' spore types.

Verrucosisporites varians Volkheimer 1972

pl. 11, fig. 1

Holotype: *Verrucosisporites varians* Volkheimer 1972, p. 115-116, pl. 4, figs 31-34.

Description: see Volkheimer 1972, p. 115-116.

Remarks: Conforms to the original specific description.

Previous records: Lower to Middle Jurassic; worldwide.

3.5.7. Monolete 'spores'

Genus *Monolites* Cookson *ex* Potonié 1956

Type species: *Monolites major* Cookson ex Potonié 1956.

Diagnosis: see Potonié 1956, p. 77.

Monolites couperi Tralau 1968

pl. 11, fig. 3

Holotype: *Monolites couperi* Tralau 1968, p. 54, pl. XVI, fig. 2.

Description: see Tralau 1968, p. 54.

Remarks: Comparison with the type species of the genus suggests broad similarities but *M. couperi* differs in having greater dimensions. The paucity of specimens in both Tralau's study and the present study makes comparison difficult.

Previous records: Toarcian to Middle Jurassic; Sweden.

Genus *Marattisporites* Couper 1958

Type species: *Marattisporites scabratus* Couper 1958.

Diagnosis: see Couper 1958, p. 133.

Marattisporites scabratus Couper 1958

pl. 11, fig. 2

Holotype: *Marattisporites scabratus* Couper 1958, p. 133, pl. 15, figs 20-23.

Description: see Couper 1958, p. 133.

Previous records: Middle Rhaetian to Lower Cretaceous; Europe.

3.6. Inaperturate 'pollen' grains and 'spores'

Genus *Araucariacites* Cookson *ex* Couper 1953

Type species: *Araucariacites australis* Cookson 1947.

Diagnosis: see Cookson 1947, p. 130.

Remarks: The genus is retained as Courtinat's systematic solutions (1987) to the problems encountered with Araucariaceous and Podocarpaceous pollen are not adopted here. It was noted, however, that the two layered wall of several presumed specimens of *A. australis* was separated at points around the equator and thus by definition of the genus necessitated placement in the genus *Callialasporites* Dev 1961.

Araucariacites australis Cookson 1947

pl. 11, fig. 9

Holotype: *Araucariacites australis* Cookson 1947, pl. 13, fig. 3.

Diagnosis: see Couper 1958, p. 150.

Remarks: It is often difficult to discern poorly preserved specimens of *A. australis* from poorly preserved specimens of *Hemisphaerium giganteum* n. sp.

Previous records: Hettangian to Lower Albian; Europe.

Genus *Callialasporites* Dev 1961

Synonymy:

Applanopsis Döring 1961.
Triangulopsis Döring 1961.
Applanopsipollenites Levette-Carette 1964.

Holotype: *Callialasporites trilobatus* (Balme) Dev 1961.

Diagnosis: see Dev 1961, p. 48.

Remarks: For a comprehensive taxonomic review of the genus see Pocock (1970, p. 64). In the samples studied, species representative of the genus appear to form a continuous morphological series. *C. microvelatus* also shows morphological gradation with *Araucariacites australis* Cookson 1947, reflecting their probable identical botanical affinity (Van Konijnenburg-van Cittert 1971). Filatoff's (1975) treatment of the genus is followed here.

Callialasporites dampieri (Balme) Dev 1961

pl. 11, fig. 4

Synonymy:

Zonalapollenites dampieri Balme 1957, p. 32, pl. 8, fig. 88.

Pflugipollenites dampieri (Balme) Pocock 1962, p. 72, pl. 12, figs 183-184.

Tsugaepollenites dampieri (Balme) Dettmann 1963, p. 100.

Holotype: *Zonalapollenites dampieri* Balme 1957, p. 32, pl. 8, fig. 88.

Diagnosis: see Norris 1969, p. 595.

Remarks: *C. dampieri* is distinguished from *C. minus* by having the exoexine more separated from the intexine (the distance between the two layers is >3/4 of the pollen radius). Specimens observed may show the development of the radial folds only slightly and thus may be confused with *C. turbatus*.

Previous records: Toarcian to Upper Albian; Europe.

Callialasporites microvelatus Schulz 1966

pl. 11, fig. 5

Holotype: *Callialasporites microvelatus* Schulz 1966, p. 136, pl. 7, fig. 59.

Diagnosis: see Schulz 1966, p. 136.

Remarks: *C. microvelatus* may be confused with *Araucariacites australis* . Slight wall separation is difficult to observe on less well preserved specimens.

Previous records: Upper Toarcian to Lower Kimmeridgian; Europe.

Callialasporites minus (Tralau) Guy 1971

pl. 11, fig. 6

Synonymy:

Tsugaepollenites minus Tralau 1968, p. 96, pl. 13, fig. 4.

Holotype: *Tsugaepollenites minus* Tralau 1968, p. 96, pl. 13, fig. 4.

Description: see Tralau 1968, p. 96.

Remarks: *C. minus* differs from *C. microvelatus* in having the two layers separated around the complete circumference, rather than intermittent separation.

Previous records: Bajocian to Lower Kimmeridgian; Europe.

Callialasporites trilobatus (Balme) Dev 1961

pl. 11, fig. 7

Synonymy:

Zonalapollenites trilobatus Balme 1957, p. 32, pl. 7, figs 85-86, pl. 7, fig. 87.

Holotype: *Zonalapollenites trilobatus* Balme 1957, p. 32, pl. 7, figs 85-86, pl. 7, fig. 87.

Description: see Balme 1957, p. 32.

Remarks: The specimens observed in the present study agree with the original description of Balme (1957, p. 32).

Previous records: Toarcian to Upper Albian; North West Europe.

Callialasporites turbatus (Balme) Schulz 1967

pl. 11, fig. 8

Synonymy:

Inaperturopollenites turbatus Balme 1957, p. 31, pl. 7, figs 85-85, pl. 8, fig. 87.

Holotype: *Inaperturopollenites turbatus* Balme 1957, p. 31, pl. 7, figs 85-85, pl. 8, fig. 87.

Description: see Balme 1957, p. 31.

Remarks: *C. turbatus* differs from *C. dampieri* in lacking any radial folding.

Previous records: Upper Sinemurian to Valanginian; Europe.

Enigmaspora n. gen et sp.

Type species: *Enigmaspora bella* n. sp.

Description: Alete microspores originally sphaerical to discoidal in shape, circular to lenticular in compression. The exine is differentiated into two layers the outer of which may be variably ornamented with low elements (<5μm in height), particularly on the presumed distal surface.

Derivation of name: *Enigma-* from *aenigma* (Latin) meaning mystery, *-spora* referring to the mysterious affinities of the species encountered.

Remarks: Differs from *Peroaletes* Bharadwaj & Singh 1964 in exhibiting an ornament and from *Lycopodiacidites* Couper 1953 in lacking any indication of a trilete mark.

Enigmaspora bella n. sp.

pl. 14, figs 1, 2, 3, 4, 5, 6 &7

Holotype: Slide 89302.1, grid ref. 148.8 18.5, pl. 14, figs 1 & 2.

Paratypes: Slide 89302.1, grid refs. 135.6 21.6, 136.2 16.0, 156.5 11.1, slide 89302.5, grid refs 138.2 11.8, 136.3 8.3, pl. 14, figs 3, 4, 5 & 6.

Diagnosis: Alete 'spores' with a circular equatorial amb. A distal ornament of variable rugulae and a proximal ornament of microfoveolae and microreticulae are developed.

Description: Microspores alete, originally sphaerical to discoidal in shape, circular to lenticular in compression. No evidence of haptotypic features apparent. Exine differentiated; intexine is in close contact with exoexine and is upto 2μm thick at the equator. The surface of the intexine is apparently smooth and unornamented. The exoexine is 1μm thick and appears to exhibit a differentiated ornament. The inferred distal surface is folded into rugulae which are variably developed; on certain specimens the best development occurs around the inferred distal pole. The rugulae measure upto 2.5μm wide and are upto 3μm in height and may coalesce to form pseudoreticulae and reticulae. The proximal surface is ornamented with microfoveolae and microreticulae. The fovea/ lumina measure ≤1μm in diameter and the muri are <1μm in width. The transition from one sculptural type to another may be gradual and thus on some specimens the proximal ornament was observed in distal equatorial positions.

Mean diameter 50.9μm (maximum 68μm. minimum 36μm)(57 specimens).

Derivation of name: *bella* from *bellus*(Latin) meaning attractive, referring to the impressive appearance of the sporomorph.

Genus *Microsporonites* Jain 1968

Type species: *Microsporonites cacheutensis* Jain 1968.

Description: see Jain 1968, p. 8.

Microsporonites cacheutensis Jain 1968

pl. 12, fig. 6

Holotype: *Microsporonites cacheutensis* Jain 1968, p. 8, pl. 1, fig. 1.

Description: see Jain 1968, p. 8.

Remarks: The small (<20μm) round, smooth discs observed in the present study also commonly occured in groups like the holotype material (see Jain 1968, pl. 1, fig. 1). Wall (1965) recorded leiospheres of a similar size from the Lower Jurassic of England. Like *M. cacheutensis*, the species were occasionally observed to cluster into small groups. In the present study, the occurrence of *M. cacheutensis* does not correlate with the samples from marine strata. It therefore is more likely that the forms identified in the present study are from a non-marine source (fungal spores for example).

Previous records: Middle Triassic; Argentina.

3.7. Porate 'pollen' grains

Genus *Exesipollenites* (Balme 1958) Pocock 1970

Type species: *Exesipollenites tumulus* Balme 1958.

Diagnosis: see Pocock 1970, p. 99.

Remarks: *E. laevigatus* exhibits the simplest morphology of the species recognised with a smooth outer wall layer and a simple distal pore. *E. tumulus* has a slight thickening developed around the distal pore. *E. scabratus* lacks this thickening but has a characteristic microrugulate to scabrate internal wall ornament.

Exesipollenites laevigatus Pocock 1970

pl. 14, fig. 11

Holotype: *Exesipollenites laevigatus* Pocock 1970, p. 101, pl. 22, figs 5-6.

Diagnosis: see Pocock 1970, p. 101.

Previous records: Middle to Upper Jurassic: Canada, Egypt, Britain.

Exesipollenites scabratus (Couper) Pocock 1970

pl. 14, fig. 10

Synonymy:

Spheripollenites scabratus Couper 1958, p. 158, pl. 31, figs 11-12.

Holotype: *Spheripollenites scabratus* Couper 1958, p. 158, pl. 31, figs 11-12.

Diagnosis: see Couper 1958, p. 158.

Previous records: Middle Jurassic to Lower Cretaceous; Europe.

Exesipollenites tumulus Balme 1957

pl. 14, fig. 12

Holotype: *Exesipollenites tumulus* Balme 1957, p. 39, pl. 11, figs 123-125.

Diagnosis: see Balme 1957, p. 39.

Previous records: Toarcian to Middle Albian; Europe.

Genus *Perinopollenites* Couper 1958

Type species: *Perinopollenites elatoides* Couper 1958.

Diagnosis: see Couper 1958, p. 152.

Perinopollenites elatoides Couper 1958

pl. 15, fig. 1

Holotype: *Perinopollenites elatoides* Couper 1958, p. 152, pl. 27, fig. 9.

Diagnosis: see Couper 1958, p. 152.

Remarks: A very frequent species, *P. elatoides* exhibits a variable morphology, but is most commonly seen as a two layered palynomorph where the intexine (thicker than the exoexine) is oval to circular, commonly folded and exhibits a conspicuous transverse tear. The exoexine is very thin (<0.5 µm), commonly torn and wrinkled.

Similar, smaller forms were observed where the intexine was thicker (1-1.5µm) and untorn. Folding was common on these forms, giving the impression of a sulcal structure. However, no unambiguous sulcal areas were observed and , in view of the smaller diameter of the intexine of these specimens, the forms were ascribed to underdeveloped forms of *P. elatoides*.

Previous records: Ladinian to Lower Albian; Europe.

Genus *Corollina* (Maljavkina) Cornet & Traverse 1975

Synonymy:

Circulina Maljavkina 1949.

Classopollis Pflug 1953.

Type species: *Corollina compacta* Maljavkina 1949.

Description: see Cornet & Traverse 1975, p.15-16.

Remarks: Due to the problems of recognising incipient development of the striate belt on predominately non-striate specimens, the present author follows the views of Cornet & Traverse 1975 in synonymising *Circulina* and *Classopollis* with *Corollina*.

Corollina simplex (Danzé-Corsin & Laveine) Cornet & Traverse 1975

pl. 14, fig. 8

Synonymy:

Circulina simplex Maljavkina 1949, p. 124, pl. 46, figs 7-9.

Holotype: *Circulina simplex* Maljavkina 1949, p. 124, pl. 46, figs 7-9.

Description: see Cornet & Traverse 1975, p. 20.

Remarks: Specimens identified in the present study exhibit the non-striate zonosulcate morphology characteristic of *C. simplex.*

Previous records: Rhaetian to Pliensbachian ;USA, Lower Jurassic; Antarctica.

Corollina torosus (Reissinger) Cornet & Traverse 1975

pl. 14, fig. 9

Synonymy:

Pollenites torosus Reissinger 1950, pl. 14.

Classopollis torosus (Reissinger) Couper 1958, p. 156.

Holotype: *Pollenites torosus* Reissinger 1950, pl. 14, fig. 20.

Diagnosis: see Cornet & Traverse 1975, p. 17-18.

Remarks: Specimens identified as this taxon in the present study exhibit well developed striate characteristic of *C. torosus.*

Previous records: Upper Norian to Maastrichtian; Europe.

3.8. Bisaccate 'pollen' grains

Genus *Abietinaepollenites* Potonié *ex* Delcourt & Sprumont 1955

Type species: *Abietinaepollenites microalatus* (Potonié) Delcourt & Sprumont 1955.

Description: see Delcourt & Sprumont 1955, p. 51.

Abietinaepollenites dunrobinensis Couper 1958

pl.15, fig.15

Holotype: *Abietinaepollenites dunrobinensis* Couper 1958, p. 153, pl. 29, fig. 1.

Description: see Couper 1958, p. 153.

Remarks: *A. dunrobinensis* differs from *Alisporites grandis* (Cookson) Dettmann 1963 by the presence of a narrow distal leptoma. In addition, the proximal contact of the sacci with the corpus is not discernable on specimens of *A. dunrobinensis.*

Previous records: Lower Jurassic to Oxfordian; North West Europe.

Genus *Alisporites* (Daugherty) Jansonius 1971

Type species: *Alisporites opii* Daugherty 1941.

Diagnosis: see Jansonius 1971, p. 349.

Remarks: In the present study an attempt was made to segregate species based on measured parameters, since it was thought on the basis of observations that two groups existed; a morphotype with large dimensions comparable to *Alisporites grandis* (Cookson) Dettmann 1963 and a smaller morpotype comparable to *Alisporites similis* (Balme) Dettmann 1963.

Following the measuring of 400 specimens preserved in polar compression, various simple statistical comparisons were carried out. 5 parameters were recorded for each specimen; total transverse length, total longitudinal length, longitudinal length of saccus, longitudinal length of corpus and transverse length of saccus. All five datasets exhibited a unimodal distribution with a positive skew (Fig. 3.4). This skewness is to be expected when the mean lies to the left of a centre point in measurment variation, which was the case. A range of simple comparison plots were tried in order to detect any trends or groupings within the dataset. All results expressed a simple linear correlation suggesting correlation of the measurments with increasing size (Fig. 3.5). No clustering was observed and as a result it appears unjustifiable to separate *A. grandis* from *A. similis* on size range. As a result, an *Alisporites* complex is proposed to include specimens previously referred to as *A. grandis* and *A. similis.*

It is of interest to note Harris's (1964, p. 171) observation on pollen grains from a pteridosperm-like reproductive organ, *Pteroma thomasii*, collected from Hasty Bank (Saltwick Formation). These were comparable to *Alisporites.* His size range for the grains were 53µm-107µm longitudinal length and 46µm-61µm for the transverse length of the grain, compared with 30µm-100µm and 18µm-80µm respectively for the present study.

Species constituting the *Alisporites* complex;

Alisporites grandis (Cookson) Dettmann 1963

pl.16, fig.1

Synonymy:

Disaccites grandis Cookson 1953, p.471, pl.2, fig. 41.

Holotype: *Disaccites grandis* Cookson 1953, p.471, pl.2, fig. 41.

Diagnosis: see Dettmann 1963, p. 102.

Previous records: Rhaetian; Europe, Rhaetian to Palaeocene; worldwide.

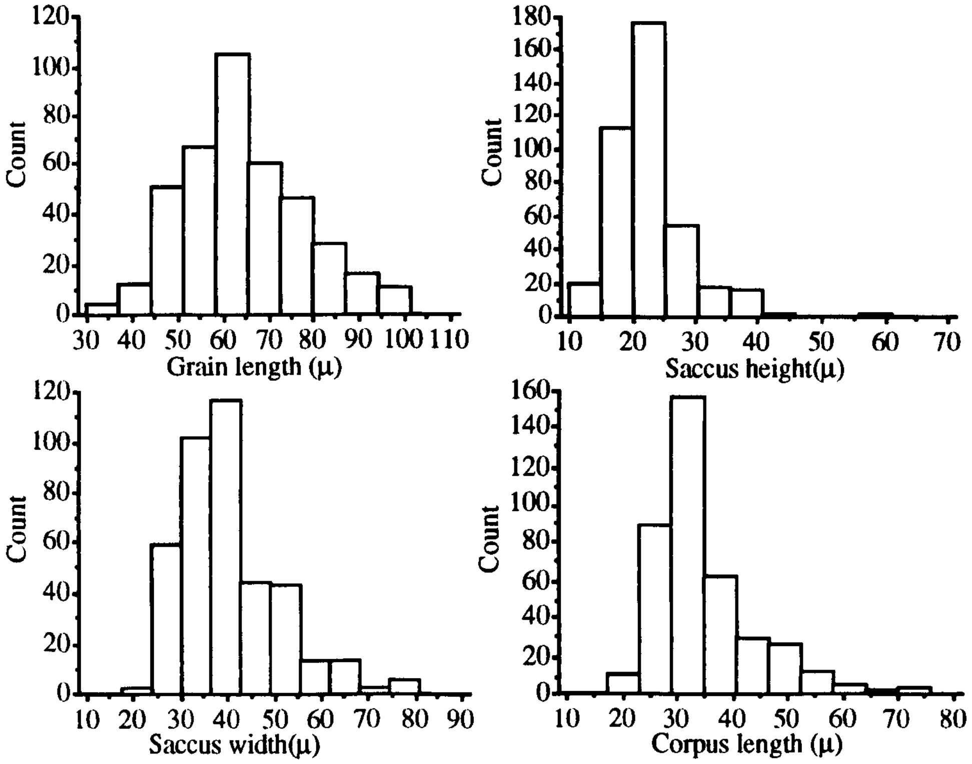


Figure 3.6. Frequency distribution charts for various parameters of *Alisporites* sp. pollen grain measurments.

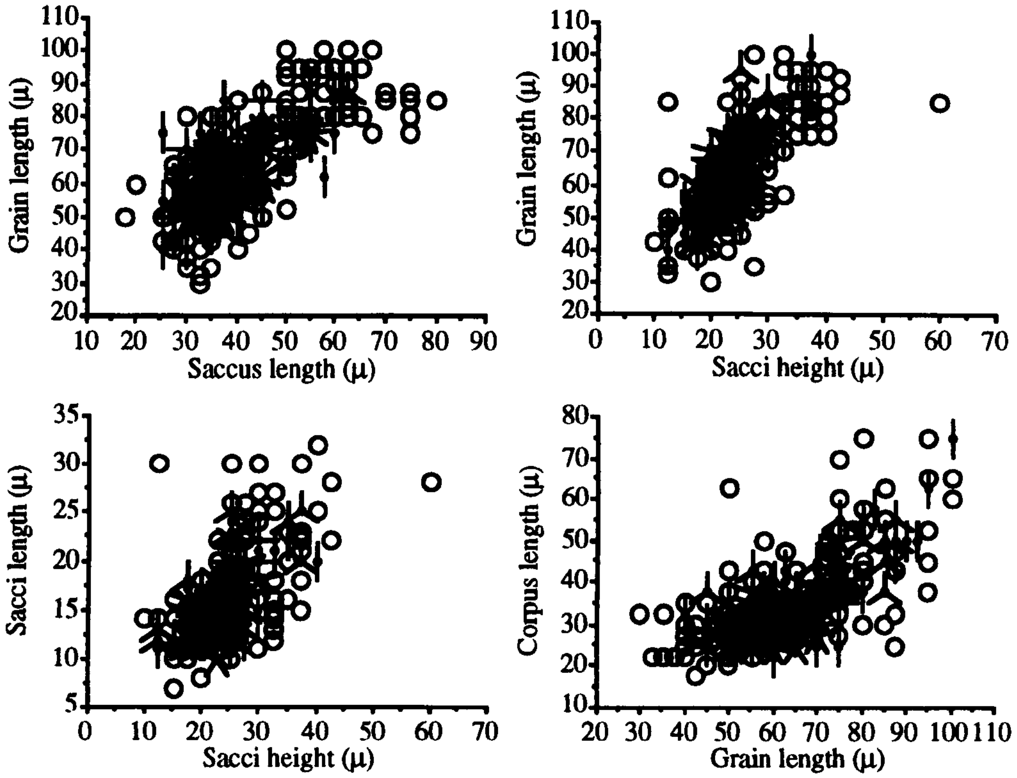


Figure 3.7. Scattergram plots for various *Alisporites* sp. pollen grain measurments (rayed points record multiple observations).

Alisporites similis (Balme) Dettmann 1963

pl. 16, fig. 4

Synonymy:

Pityosporites similis Balme 1957, p.36, pl.10, figs 108-109.

Type species: *Pityosporites similis* Balme 1957, p.36, pl.10, figs 108-109.

Description: see Dettmann 1963, p.102.

Previous records: Lower Albian; Spain, Middle Triassic to Tertiary; worldwide.

Other *Alisporites* species identified in the present study;

Alisporites microsaccus (Couper) Pocock 1962

pl.16, fig.3

Synonymy:

Pteruchipollenites microsaccus Couper 1958, p.151, pl. 26, figs 13,14.

Holotype: *Pteruchipollenites microsaccus* Couper 1958, p.151, pl. 26, figs 13,14.

Diagnosis: see Couper 1958, p.151.

Remarks: *A. microsaccus* is distinguished from other species of *Alisporites* in the present study by the reduced size of its sacci.

Previous records: Rhaetian to Cenomanian; Europe.

Genus *Ovalipollis* (Krutzsch) Pocock and Jansonius 1968

Type species: *Ovalipollis ovalis* Krutzsch 1955.

Diagnosis: see Pocock and Jansonius 1968, p. 158.

Remarks: The present author follows Pocock & Jansonius in placing emphasis on the sulcus rather than on the saccate wall structure in determining affinity of *Ovalipollis* pollen grains.

Ovalipollis ovalis (Krutzsch) Pocock and Jansonius 1969

pl. 16, fig. 7

Holotype: *Ovalipollis ovalis* Krutzsch 1955, p. 70, pl. 1, fig. 2.

Diagnosis: see Pocock and Jansonius 1968, p. 161.

Remarks: Previous records from the Middle and Upper Jurassic are questioned on the uncommon occurrence of the species in these sediments. This contrasts with the species ubiquity in Upper Triassic and Lower Jurassic strata (pers. obs.). It seems likely that the specimens observed in the present study are reworked.

Previous records: Anisian to Oxfordian; Europe.

Ovalipollis limbata (Maljavkina) Pocock and Jansonius 1969

pl. 16, fig. 8

Synonymy:

Quadraeculina limbata Maljavkina 1949, p. 110, pl. 39, fig. 2
Quadraeculina anellaeformis Maljavkina 1949, p. 110, pl. 39, fig. 3
Parvisaccites enigmaticus Couper 1958, p. 154, pl. 30, figs 3-5.

Holotype: *Quadraeculina limbata* Maljavkina 1949, p. 110, pl. 39, fig. 2

Diagnosis: see Pocock and Jansonius 1969, p. 163.

Remarks: see generic remarks.

Previous records: Upper Triassic to Lower Cretaceous; Europe.

Genus *Pinuspollenites* (Seward)Manum 1960

pl. 16, fig. 5

Type species: *Pinuspollenites labdacus* (Potonié) Raatz 1937.

Diagnosis: see Raatz 1937.

Remarks: Considerable disagreement exists in the published literature regarding the nomenclatue of bisaccate grains preserved in lateral compression. If we agree that specimens preserved in lateral compression possess a geometry which leads to their lateral preservation then we must assume that the specimens are indeed different from bisaccate grains preserved in polar compression. Observation of recent grains of *Pinus sylvestris* held in the collection at the University of Sheffield shows the variety of preservation that is possible from a single plant; polar compression, oblique compression and lateral compression; expanded sacci and unexpanded sacci, presumably immature grains. These observations led the present author to consider that many of the previously published genera are merely lateral compressions of genera described in polar compression. In particular this is the authors opinion of the type species of *Pityosporites* (Seward) Manum 1960. With the case of many *Pinuspollenites* species, the sacci are reduced relative to the corpus and resemble the immature grains of *Pinus sylvestris.*

In the present study, laterally compressed grains were uncommon. Laterally compressed grains comparable to *Pityosporites* are included in the *Alisporites grandis-similis* complex. Laterally compressed grains comparable to *Pinuspollenites* species (such as *P. globosaccus* Filatoff 1975) are noted separately, but it is the author's opinion that these are immature or abortive grains (this compares with the spore genus *Obtusisporis* Pocock 1970 within which many examples of abortive spores may be included).

Genus *Podocarpidites* Cookson 1947 *ex* Couper 1953

Type species: *Podocarpidites ellipticus* Cookson *ex* Couper 1953, p. 36.

Description: see Cookson 1947, p. 131.

Podocarpidites ellipticus Cookson *ex* Couper 1953

pl. 16, fig. 2

Holotype: *Podocarpidites ellipticus* Cookson ex Couper 1953, p. 131.

Description: see Cookson 1953, p. 131.

Remarks: Distinguished from all other bisaccate species in the present study by the size of the corpus which is small relative to the sacci.

Previous records: Lower Jurassic to Tertiary; worldwide.

Genus *Vitreisporites* (Leschik) Jansonius 1962

Type species: *Vitreisporites signatus* Leschik 1956.

Diagnosis: see Jansonius 1962, p. 55.

Vitreisporites pallidus (Reissinger) Nilsson 1958

pl. 16, fig. 6

Synonymy:

Pityosporites pallidus Reissinger 1938, p. 14 (nomen nudum).

Pityopollenites pallidus (Reissinger) Reissinger 1950, p. 115, pl. 15, figs 1-5.

Caytonipolleites pallidus (Reissinger) Couper 1958, p. 150, pl. 26, figs 7-8.

Holotype: *Pityosporites pallidus* (Reissinger) Nilsson 1958, p. 77, pl. 7, figs 12-14.

Diagnosis: see Nilsson 1958, p. 77.

Previous records: Middle Triassic to Upper Cretaceous; Europe.

3.9. Sulcate 'pollen' and grains with a distal thinning

Genus *Cycadopites* Wodehouse *ex* Wilson & Webster 1946

Synonymy:

Entylissa Naumova 1939.

Monosulcites Cookson *ex* Couper 1953.

Ginkgocycadophytus Samoilovitch 1953.

Type species:*Cycadopites follicularis* Wodehouse *ex*Wilson & Webster 1946.

Diagnosis: see Wilson & Webster 1946, p. 274.

Remarks: *Entylissa* Naumova 1939 *ex* Ischenko 1952 and *Monosulcites* Cookson *ex* Couper 1953 are herein regarded as junior synonyms since the variation in equatorial outline, which distinguishes the genera, is considered to be a function of compression.

Cycadopites carpentieri (Delcourt & Sprumont) Singh 1964

pl. 15, fig. 2

Holotype: *Monosulcites carpentieri* Delcourt & Sprumont 1955,p. 54, pl. 14, fig.3.

Diagnosis: see Delcourt & Sprumont 1955, p. 54.

Remarks: see *C. minimus.*

Previous records: Lower Triassic to Lower Maastrichtian; Europe.

Cycadopites minimus (Cookson) Pocock 1970

pl. 15, fig. 3

Synonymy:

Cycadopites nitidus (Balme) Volkheimer 1968, p.359.

Monosulcites minimus Cookson 1947, p. 135, pl. 15, figs 47-50.

Holotype: *Monosulcites minimus* Cookson 1947, p. 135, pl. 15, figs 47-50.

Diagnosis: see Pocock 1970, p. 108.

Remarks: *C. minimus* differs from *C. carpentieri* by its smaller size and smoother wall.

Previous records: Anisian to Upper Albian; Europe.

Genus *Chasmatosporites* (Nilsson) Pocock & Jansonius 1969

Type species: *Chasmatosporites magnolioides* (Erdtman) Nilsson 1958.

Diagnosis: see Pocock & Jansonius 1969, p. 155.

Chasmatosporites apertus (Rogalska) Nilsson 1958

pl. 15, figs 4 & 5

Synonymy:

Pollenites apertus Rogalska 1954, p.45, pl. 12, figs 13-15.

Holotype: *Pollenites apertus* Rogalska 1954, p.45, pl. 12, figs 13-15.

Description: see Nilsson 1958, p. 56.

Remarks: *C. apertus* differs from *C. hians* in its smaller dimensions and less elongate outline.

Previous records: Rhaetian to Bathonian; Europe.

Chasmatosporites hians Nilsson 1958

pl. 15, fig. 6

Holotype: *Chasmatosporites hians* Nilsson 1958, p. 55 pl. 4, fig. 4.

Diagnosis: see Nilsson 1958, p. 55.

Remarks: See *C. apertus*.

Previous records: Upper Triassic to Lower Bathonian; Europe.

Chasmatosporites sp. PC1

pl. 15, fig. 7

Description: Pollen grains monosulcate, circular to ovoidal in outline. Sulcus may be poorly to well developed and is rounded elongate to rectangular, extending .3/4 the diameter of the grain, with a width < 2/5 length. Exine thick, 2.5μm, apparently 2 layered but with little differentiation apparent.

Diameter 30μm (1 specimen).

Remarks: This uncommon form is difficult to distinguish from *Exesipollenites laevigatus* Pocock 1970 when poorly preserved. This morphotype differs from other species of *Chasmatosporites* recognised in the present study by the shape of its sulcus.

Genus *Eucommiidites* Erdtmann *ex* Couper 1958

Type species: *Tricolpites troedssonii* Erdtman 1948.

Description: see Couper 1958, p. 160.

Eucommiidites troedssonii Erdtman *ex* Couper 1958

pl. 15, fig. 8

Synonymy:

Tricolpites troedssonii Erdtmann 1948, p. 267-268, text figs 5-10, 13-15 (nomen nudum).

Holotype: *Tricolpites troedssonii* Erdtman 1948, p. 267-268, text figs 5-10, 13-15 (designated by Couper 1958, p. 160).

Description: see Couper 1958, p. 160.

Remarks: Differs from Cycadopites minimus (Cookson) Pocock 1970, by its smaller size and on the presence of two distal furrows which run parallel with the sulcus.

Previous records: Rhaetian to Lower Albian; Europe.

Genus *Cerebropollenites* Nilsson 1958.

Type species: *Cerebropollenites mesozoicus* (Couper) Nilsson 1958.

Diagnosis: see Nilsson 1958, p. 155.

Remarks: The present author has reservation over agreeing with Schulz's 1967 emendation of Nilsson's genus, particularly regarding the nature of the distal thinning; specimens encountered in samples from the present studies exhibited what the author would describe as a distal leptoma rather than a distal sulcus. Therefore Schulz's emendation, including his proposal to synonymise *Cerebropllenites mesozoicus* with *Cerebropollenites (Pollenites) macroverrucosus*, is not accepted.

Cerebropollenites mesozoicus (Couper) Nilsson 1958.

pl. 15, figs 9 & 10

Synonymy:

Tsugaepollenites mesozoicus Couper 1958, p. 155; pl. 30, fig. 8.

Holotype: *Tsugaepollenites mesozoicus* Couper 1958, p. 155; pl. 30, fig. 8.

Diagnosis: see Couper 1958, p. 155.

Remarks: A very common species, *C. mesozoicus* is quite morphologically distinct, lacking any expression of a trilete mark and possessing a thinned distal area of variable development surrounded by a multisaccate exine, most fully developed at the equator.

Previous records: Hettangian to Cenomanian; Europe.

3.10. Megaspores

Genus *Paxillitriletes* Hall & Nicholson 1973

Type species: *Paxillitriletes reticulatus* (Mädler) Hall & Nicholson 1973.

Diagnosis: see Hall & Nicholson 1973, p. 319.

Paxillitriletes phyllicus (Murray) Hall & Nicholson 1973

pl. 2 fig. 8

Synonymy:

Triletes phyllicus Murray 1939, p. 482, pl. text-figs 7-8.

Thomsonia phyllicus (Murray) Potonié 1956, p. 72, pl. 9, fig. 94.

Holotype: *Triletes phyllicus* Murray 1939, p. 482, pl. text-figs 7-8.

Description: see Murray 1939, p. 482.

Remarks: This uncommon species was the only megaspore species recovered from standard palynological processing procedures for microspores.

Previous records: Middle Jurassic; Europe, Barremian to Middle Albian; Canada.

3.11. Presumed representatives of the Chlorophyta

Genus *Botryococcus* Kützing 1849

Type species: *Botryococcus braunii* Kützing 1849, p. 892.

Description: see Kützing 1849, p. 892.

Botryococcus braunii Kützing 1849

pl. 15, fig. 11

Holotype: *Botryococcus braunii* Kützing 1849, p. 892.

Description: see Kützing 1849, p. 892.

Remarks: The present author concurs with Traverse 1988 (p. 6) in considering all fossil forms to represent a single species.

Previous records: Pre-Cambrian to Recent; worldwide.

3.12. Presumed representatives of the Zygnemataceae

Genus *Chomotriletes* (Naumova) ex Naumova 1953 (non Stover 1962)

Type species: *Chomotriletes vedugensis* (Naumova) ex Naumova 1953, p. 60, pl. 7, figs 21-22.

Diagnosis: see Naumova 1953, p. 60.

Chomotriletes minor (Kedves) Pocock 1970

pl. 13, fig. 3

Synonymy:

Schizaeoisporites minor Kedves 1961, p. 129, pl. 16, figs 11-12.
Chomotriletes fragilis Pocock 1962, p. 39, pl. 3, figs 30-32.
Schizaeosporites minor (Kedves) Briche, Danzé-Corsin & Laveine 1963, p. 62.
Circulisporites parvus de Jersey 1962, p. 15, pl. 5, figs 13-15.

Holotype: *Schizaeoisporites minor* Kedves 1961, p. 129, pl. 16, figs 11-12.

Description: see Pocock 1970, p. 61.

Remarks: The specimens identified agree with the type description.

Previous records: Maastrichtian; France, Jurassic and Cretaceous; worldwide.

Genus *Hemisphaerium* Hemer & Nygreen 1967

Synonymy:

Schizosporis Cookson & Dettmann 1959 (pars).
Brazilea Tiwari & Nivale 1967.
Psilospora Venkatachala & Kar 1968.
Schiozophacus Pierce 1976 (pars.).

Type species: *Hemisphaerium inominatum* Hemer & Nygreen 1967, p. 186, pl. 2, figs 7-8.

Diagnosis: see Hemer & Nygreen 1967, p. 186.

Remarks: *Hemisphaerium* has seniority over *Brazilea* since it was published in the spring of 1967 whereas the latter was published in the autumn. The description of *Brazilea* Tiwari & Nivale 1967, p. 593 states that the exine is pitted. This is considered, after observing the plates of the holotype, to be due to erosion of the exine and not a generic characteristic.

Hemisphaerium giganteum n. sp.

pl. 12, figs 1, 2 & 3

Holotype: Slide 89220.1, grid ref. 140.6 9.8, pl. 12, fig. 1.

Paratypes: Slide 89220.1, grid refs 141.3, 8.3, 143.9 10.5, 150.3 10.6, 159.5 10.5, pl.12, figs 2 & 3.

Diagnosis: Large originally sphaerical to ovoidal palynomorphs, circular to elliptical in compressed outline with a smooth to finely wrinkled wall and possessing a helicoidal suture.

Description: Palynomorphs originally sphaerical to ovoidal, circular to elliptical in compressed outline. Wall thin ≤0.5µm, finely undulose to wrinkled. Palynomorph may split by a helicoidal suture into several disarticulated fragments resulting in a variable compressed outline. When disarticulated, one side may be preserved as a single, circular to ovoidal disc exhibiting a triangular shaped flap on the outline of the split. When compressed, specimens may exhibit arcuate folds tangential to the ambitus.

Average dimensions 73µm (maximum 95µm) maximum length, 55.5µm (minimum37.5µm) minimum length (11 specimens).

Derivation of name: *giganteum* from *gigantum* (latin) referring to the large size of the species relative to the others recorded in the study.

Remarks: Differs from *Hemisphaerium spriggii* in the nature of the finely wrinkled wall, which often allows identification from small fragments.

Hemisphaerium parvum (Cookson & Dettmann) n. comb.

pl. 11, figs.12 &13

Synonymy:

Schizosporis parvus Cookson & Dettmann 1959, p. 211.
Psiloschizosporis parvus (Cookson & Dettmann) Jain 1968, p. 31.
Leiofusa deunffii Pocock 1972, p. 103.
Schizophacus parvus (Cookson & Dettmann) Pierce 1976, p. 30.
Brazilea parva (Cookson & Dettmann) Backhouse 1988, p. 111.

Holotype: *Schizosporis parvus* Cookson & Dettmann 1959, p. 211, pl. 1, figs 15-20.

Description: see Cookson & Dettmann 1959, p. 211.

Remarks: Differs from other *Hemisphaerium* species recognised in the study by its elongate outline.

Previous records: Triassic to Tertiary; worldwide.

Hemisphaerium simplex n. sp.

pl. 11, fig. 11, pl. 12, figs 4 & 5

Holotype: Slide 89220.1, grid ref. 140.2 9.8, pl. 11, fig. 11.

Paratypes: Slide 89220.1, grid refs 146.1 15.9, 159.4 15.6, pl. 12, figs 4 & 5.

Diagnosis: Small originally sphaerical palynomorphs, circular to ovoidal in compression, exhibiting a smooth wall and an equatorial suture which may divide the palynomorph into two halves.

Description: Palynomorphs sphaerical when uncompressed and circular to ovoidal in compression. Wall simple, single layered ≤0.5µm thick and without ornamentation. A suture is present which may split and divide the palynomorph into two halves. An arcuate fold may be present tangential to the split on compressed specimens.

Average diameter 24.5µm (maximum 27.5 µm, minimum 20µm)(10 specimens).

Derivation of name: *simplex* (latin) referring to the simple nature of the palynomorph.

Remarks: Differs from *Hemisphaerium spriggii* in its smaller size. *Hemisphaerium simplex* may be very difficult to distinguish from *Exesipollenites laevigatus* Pocock 1970 when compressed with the split running around the equator (see paratype, pl.12, fig. 5) but lacks the pore characteristic of the latter species

Genus *Lecaniella* (Cookson & Eisenack 1962) emend.

Synonymy:

Schizophacus Pierce 1976, p. 30 (pars.).

Emended description: Discoidal to lenticular palynomorphs which may be divided by an equatorial suture into two halves. Wall apparently simple consisting of a single layer. The outer surface of the palynomorph is delimited by elements of low relief (<5µm high) into a zone marginal to the suture and a central zone.

Type species: *Lecaniella margostriata* Cookson & Dettmann 1962.

Remarks: The genus *Schizophacus* Pierce 1976, is a superfluous genus since smooth walled forms are assignable to *Hemisphaerium* Hemer & Nygreen 1967 and ornamented forms are referable to *Lecaniella*. A zygnemataceous affinity for the genus is inferred, based on the work of van Neem 1967 (spore type E Zygnemtaceae, p. 343 is comparable to *Lecaniella*) and of P. Zippi (Dept. Geology, University of Toronto, pers. comm.1991).

Lecaniella foveolatus Filatoff 1975

pl. 13, fig. 2

Synonymy:

Lecaniella foveolatus Filatoff 1975, p. 93, pl. 30, fig 11-12.

Lecaniella foveolata Filatoff 1975 in Fensome *et al.* 1990, p. 260 (incorrect spelling).

Holotype: *Lecaniella foveolatus* Filatoff 1975, p. 93, pl. 30, fig 11-12.

Description: see Filatoff 1975, p. 93.

Remarks: An uncommon species in the present study, the forms agree with the species description of Filatoff.

Previous records: Middle Jurassic; Canada.

Lecaniella varireticulata n. sp.

pl. 13, fig. 5, 6, 7, 8 & 9

Synonymy:

Schizosporis rugulatus Cookson & Dettmann 1959 in Pocock 1962, p. 76, pl. 13, figs 203-204.

Lecaniella sp. Playford & Dettmann 1965, pl. 17, figs 65-66.

Schizosporis rugulatus (Cookson & Dettmann) Pierce 1976 in Fenton 1980 MS, p. 169, pl. 11, fig. 11.

Schizophacus cf. *S. rugulatus* (Cookson & Dettmann) Pierce 1976 in Burden & Hills 1989, p. 78, pl. 14, fig.15.

Holotype: Slide 89220.1, grid ref. 135.9 16.1, pl. 13, fig.5.

Paratypes: Slide 89220.1, grid refs 154.5 15.9, 148.3 15.8, 140.1 12.4, pl. 13, figs, 6, 7, 8 & 9.

Diagnosis: Discoidal to lenticular palynomorphs, divided by an equatorial suture into approximately two halves. The wall is apparently single layered with a surface relief of interlocking, continuous to discontinuous rugulae. A more or less continuous fold parallels the equatorial suture on both halves.

Description: Discoidal to lenticular palynomorphs which may develop an equatorial suture but which are seen preserved in all stages from an unfissured discoidal shell to two completely separated halves. The wall is apparently single layered, ≤1µm thick and characterised by a variably developed external surface relief of rugulae.

The rugulate elements are typically 1-3µm in width (2.5µm on the holotype) and of indeterminate height. A single continuous circular element delimits the marginal zone 2.5µm to 5µm in width,which exhibits radially orientated elements, from the central zone where the elements anastomose freely to form pseudoreticulae and reticulae. A poorly to strongly developed circular fold may coincide with the circular element.

Average size 41µm (maximum 52.5µm, minimum 32.5µm)(50 specimens).

Remarks: The circular fold is best preserved on unflattened specimens.

Derivation of name: *vari-* from *varietas* (Latin),-*reticulata*, referring to the variable nature of the sculptural elements.

Previous records: Middle Jurassic; England, Rhaetian to Lower Cretaceous; worldwide.

Genus *Tetraporina* (Naumova *ex* Bolkhovitina) Kar & Bose 1976

Synonymy:

Tetrapidites Klaus ex Mayer 1956.

Tetraporopollenites Frantz 1960.

Schizocystia Cookson & Eisenack 1962.

Balmeella Pant & Mehra 1963.

Pekmezcileripollenites Agrali 1969.

Type species: *Tetraporina pellucida* Naumova *ex* Bolkhovitina 1953, p. 102 (lectotype designated by Jansonius & Hills 1981, card 3197).

Description: restated from Kar & Bose (1976, p. 79);" Microfossils more or less square to rectangular in shape, rarely subcircular, oval or elliptical. Constriction at lateral ends on longer axis common, sometimes much folded at these regions. Pore-like opening present or absent, number of pores 1-4, placed at angles. Sometimes a slit-like structure at one of the lateral ends may also be present. Body wall laevigate, in some specimens granulose or intrastructured".

Remarks: The description is restated to express the wide variation in morphology which is accepted by the present author. Kar & Bose 1976 considered *Balmeella* Pant & Mehra 1963 and *Tetraporina* to represent different developmental stages of the same complex. The bewildering history of the taxonomy of *Tetraporina* is recorded in Jansonius & Hills (1981, cards 3917-3919). Certain species of *Tetraporina* are identical to modern Zygnematacean zygospores of the genus *Mougeotia* (van Geel 1976).

In addition to the genera synonymised above, several species of the genus *Horologinella* Cookson & Eisenack 1962 (the type species of which is a dinoflagellate cyst) should be transferred to the genus *Tetraporina* (Naumova *ex* Bolkhovitina) Kar & Bose 1976;

Tetraporina apiculata (Cookson & Eisenack 1962) n. comb.=*Horologinella apiculata* Cookson & Eisenack 1962, p.272, pl. XXXVIII, fig. 4.

Tetraporina incurvata(Cookson & Eisenack 1962) n. comb.=*Horologinella incurvata* Cookson & Eisenack 1962, p.272, pl. XXXVIII, fig. 5.

Tetraporina extrema (Cookson & Eisenack 1962) n. comb.=*Horologinella extrema* Cookson & Eisenack 1962, p.272, pl. XXXVIII, fig. 10.

Tetraporina obliqua (Cookson & Eisenack 1962) n. comb.=*Horologinella obliqua* Cookson & Eisenack 1962, p.272, pl. XXXVIII, fig. 4.

Tetraporina quadrispina (Jardiné *et al.* 1972) n. comb.=*Horologinella.quadrispina* Jardiné *et al.* 1972, p.296, pl. 1, figs 5-6.

Tetraporina rara (Playford & Dettmann 1965) n. comb.

pl. 12, fig. 7

Synonymy:

"Gramineenstaubbeutel?" Reissinger 1952, pl. 1, figs 43,44.

Schizocystia rara Playford & Dettmann 1965, p. 160-161, pl. 17, figs 67-69.

Holotype: *Schizocystia rara* Playford & Dettmann 1965, p. 160-161, pl. 17, figs 67-69.

Description: see Playford & Dettmann 1965, p. 160.

Previous records: Rhaetian to Lias; south Australia, Lias; Germany.

3.13. Presumed representatives of the Prasinophyta

Genus *Crassosphaera* Cookson and Manum 1960

Type species: *Crassosphaera concinna* Cookson & Manum 1960, p. 6-7, pl. 1, figs 1-3, 7-10, text-fig. 1.

Diagnosis: see Cookson & Manum 1960, p. 5-6.

Crassosphaera hexagonalis Wall 1965

pl. 13, fig. 1

Holotype: *Crassosphaera hexagonalis* Wall 1965, p. 164, pl. 9, fig. 10.

Diagnosis: see Wall 1965, p. 164.

Remarks: *Crassosphaera hexagonalis* is distinguished from species of *Tasmanites* by its wall structure, which consists of a thick wall punctated by pores, grouped in hexagonal clusters and bounded by a solid wall.

Previous records: Lower Jurassic: Britain.

Genus *Cymatiosphaera* Wetzel *ex* Deflandre 1954

Type species: *Cymatioshaera radiata* (Wetzel 1933) Sarjeant 1985, p. 161-162.

Diagnosis: see Deflandre 1954, p. 257-258.

Cymatiosphaera eupeplos (Valensi) Deflandre 1954

pl. 15, fig. 13

Holotype: *Micrhystridium eupeplos* Valensi 1949, p. 452, fig. 3.

Diagnosis: see Deflandre 1954, p. 258.

Remarks:*Cymatiosphaera* may be confused with species of the spore genus *Retitriletes* but differ in their smaller size and their lack of a trilete mark.

Previous records: Bajocian to Bathonian: England.

Genus *Pterospermella* Eisenack 1972

Type species: *Pterospermella aureolata* (Cookson & Eisenack) Eisenack 1972.

Description : see Eisenack 1972, p. 597.

Pterospermella helios (Sarjeant) de Coninck 1975

pl. 15, fig. 12

Holotype: *Pterospermella helios* Sarjeant 1959, p. 342, pl. 13, fig. 9.

Description: see de Coninck 1975, p. 44.

Remarks: The specimens agree with de Coninck's emended description.

Previous records: Kimmeridgian to Oligocene; northwest Europe.

Genus *Tasmanites* Newton 1875

Type species: *Tasmanites punctatus* Newton 1875.

Diagnosis: Newton 1875, p. 341.

Tasmanites newtonii Wall 1965

pl. 13, fig. 9

Holotype: *Tasmanites newtonii* Wall 1965, p. 163, pl. 9, fig. 11, text-fig. 3A-D.

Diagnosis: see Wall 1965, p. 163.

Remarks: *T. newtonii* is distinguished by having two types of wall pores; small pores with a relatively dense distribution; larger pores with a less dense distribution.

Previous records: Lower Jurassic: Britain.

3.14 Acritarchs

Genus *Leiosphaeridia* (Eisenack) Turner 1984

Type species: *Leiosphaeridia baltica* Eisenack 1958.

Diagnosis: see Turner 1984, p. 116.

Leiosphaeridia hyalina (Deflandre) Eisenack 1958

pl. 11, fig. 10

Synonymy:

Hyalinsphaeridium hyalina Bernier & Courtinat 1979, p. 103.

Holotype: *Leiosphaeridia hyalina* Deflandre 1941, p. 24, pl. 6, figs 12-13.

Description: see Eisenack 1958, p. 9.

Remarks: The 'granules' described in the original description are interpreted as an omphalos (organic globules of Tappan 1980, p. 293). This was variably present in the material studied where specimens lacking and exhibiting this cryptic structure were observed in the same sample. In certain samples from the Scarborough Formation, *L. hyalina* was recorded along with thin, smooth forms of *Kallosphaeridium* (De Coninck) Jan du Chêne *et al.* 1985, which differed only in exhibiting dinoflagellate excystment apertures.

Previous records: Lower to Middle Callovian; northwest Europe.

Scalbiella n. Gen. and Sp.

Type species: *Scalbiella reticulata* n. sp.

Diagnosis: Elongate rounded palynomorphs with a very thin, single layered wall The wall is ornamented with low continuous to discontinuous elements. No excystment aperture is apparent.

Derivation of name: Referring to the Scalby Formation in which the type material was discovered.

Remarks: *Scalbiella* n. gen. differs from *Navifusa* Combaz *et al.* 1967 *ex* Eisenack 1976 in possessing a thinner wall layer and in being generally shorter than most species of *Navifusa.*

Scalbiella reticulata n. sp.

pl. 13, fig. 4, pl. 23, figs 7, 8 & 9

Holotype: Slide 89302.1, grid ref. 157.1 15.4, pl. 13, fig. 4.

Diagnosis: A species of *Scalbiella* with a finely reticulate wall layer and two conspicuous circular elements which encircle the wall normal to the longest axis. An omphalos may be present located centrally.

Description: Palynomorphs with an elongate oval outline. Wall is thin <0.5µm thick and commonly wrinkled. The wall is ornamented with reticulae; muri are ≤0.5µm in height and diameter; the lumina are ≤5µm in diameter. Two conspicuous muri elements encircle the wall normal to the long axis of the palynomorph and divide the palynomorph into three fields. The central field is more or less square whereas the outer fields are semicircular in outline. The ornament is best developed in the outer two fields. An omphalos may be present positioned either in the central field or close to the circular elements.

Mean maximum length 47.5µm (maximum 71.3µm, minimum 30µm), mean width at meridional position 27.7µm (maximum 35µm, minimum 18.8µm), mean width at circular elements 27.4µm (maximum 32.5µm, minimum 17.5µm)(45 specimens).

Derivation of name: *reticulata* from *reticulum* (Latin) meaning mesh, referring to the ornament.

Remarks: An interesting palynomorph of unknown affinities, although the presence of an omphalos draws comparison with leiospheres and dinoflagellate cysts. This form has a very restricted occurrence at the base of the Long Nab Member at Burniston Wyke and Yons Nab.

Genus *Nummus* (Morgan) Backhouse 1988

Type species: *Nummus monoculatus* Morgan 1975.

Description: see Backhouse 1988, p. 112.

Nummus velumiferus n. sp.

pl. 22, figs 8, 11 & 15

Holotype: Slide SALT 17.2, grid ref. 150.7 15.2, pl. 22, fig.8.

Paratypes: Slide SALT 17.2, grid refs 158.5 4.6, 165 14.3, pl. 22, figs 11 & 15.

Diagnosis: A species of *Nummus* bearing a thin ventral surface which continues into a wide rim which encircles the dorsal wall and which is ≥1/4 of the total diameter.

Description: Lenticular palynomorphs, with a dominant direction of compression which results in an oval outline. The surfaces are differentiated into thicker (dorsal of Backhouse 1988) and thinner (ventral) faces. The thicker face is approximately 1µm thick at the compressional outline, the thinner face is of an indeterminate thickness and is commonly only visible through the pylome. The circular pylome is situated on the thicker surface and is offset towards the margin usually in the region of maximum curvature. Mean diameter of pylome 6.4µm (maximum 7.5µm, minimum 5µm)(10 specimens). A rim is variably present at the compressional outline and appears to be of a similar thickness to the thinner face. On well preserved specimens the rim may be ≥1/4 of the total diameter.

Mean diameter (maximum) 37.25µm (maximum 42.5µm, minimum 37.25µm)(10 specimens).

Derivation of name: *velum* = veil (Latin), *-iferus* = bearing, referring to the veil-like effect produced by the thin outer rim.

Remarks: *N. velumiferus* differs from all other species of *Nummus* in possessing a well developed rim. This is the oldest reported occurrence of the genus. The only previous occurence in the Jurassic is that of Jain *et al.* (1984) from the Kimmeridgian and Tithonian of India.

Palynomorph form 1

pl. 15, fig. 14

Description: Palynomorphs originally irregularly ovoidal in outline, commonly preserved in some relief and may appear irregular in compressed outline. Wall is apparently single layered, 1µm thick and finely granulate. The palynomorph is characterised by a shape which bulges without apparent regularity and an irregular opening which is commonly angular and approximately 1/3 total diameter of palynomorph in diameter.

Mean diameter 29.5µm (maximum 37.5µm, minimum 25µm)(10 specimens).

Remarks: The bulbous characteristics of the palynomorph may occasionally be due to diagenetic pyrite growth but the angular outline characteristic of this effect is not the dominant observation. The bulges differ from pyrite damage in being much smoother in outline. The occurrence of this palynomorph with marine elements is suggestive of a marine or saline influenced source.

Genus *Micrhystridium* (Deflandre) Lister 1970

Type species: *Micrhystridium inconspicuum* (Deflandre) Deflandre 1937.

Diagnosis: see Lister 1970, p. 77.

Micrhystridium fragile Deflandre 1937

pl. 12, fig. 8

Holotype: *Micrhystridium fragile* Deflandre 1937.

Diagnosis: see Deflandre 1937, also Sarjeant (1960) regarding intraspecific variability.

Remarks: The long, thin hollow spines easily differentiate this species from the others present.

Previous records: Middle Jurassic: England.

Micrhystridium stellatum Deflandre 1945

pl. 12, fig. 9

Holotype: *Micrhystridium stellatum* Deflandre 1945, p. 65, pl. 3, figs 16-19.

Description: see Deflandre 1945, p. 65.

Remarks: Despite the Silurian age assigned to the holotype, the Jurassic specimens observed differ little from the type material.

Previous records: Ordovician to Lower Triassic; northwest Europe; Ordovician to Upper Palaeocene; worldwide.

Genus *Solisphaeridium* (Staplin *at al.*) Sarjeant 1965

Type species: *Solisphaeridium stimuliferum* (Deflandre) Pocock 1972.

Diagnosis: see Sarjeant 1965, p. 222.

Remarks: Differs from *Micrhystridium* by possessing solid processes.

Solisphaeridium lymense Wall var. *lymense* (Wall) n. comb.

pl. 12, fig. 10

Synonymy: *Micrhystridium lymense* Wall var. *lymense* Wall 1965, p. 157, pl. 2, fig. 16, pl. 8, fig. 3.

Holotype: *Micrhystridium lymense* Wall var. *lymense* Wall 1965, p. 157, pl. 2, fig. 16, pl. 8, fig. 3.

Description: see Wall 1965, p. 157.

Remarks: The species is placed into the genus *Solisphaeridium* on the basis of the description which states that the spines are solid.

Previous records: Lower Jurassic; Great Britain.

3.15. Dinoflagellate cysts

3.15.1. Lateraly compressed cysts, with a reduced epicyst, a cingular archaeopyle and antapical horn development.

Genus *Nannoceratopsis* (Deflandre) Piel and Evitt 1980

Type species: *Nannoceratopsis pellucida* (Deflandre 1937) Evitt 1961.

Diagnosis: see Piel and Evitt 1980, p. 102.

Nannoceratopsis ambonis (Drugg) Riding 1984

pl. 23, fig. 6

Holotype: *Nannoceratopsis ambonis* Drugg 1978, pl. 6, fig. 3.

Description: see Riding 1984, p. 76.

Remarks: *N. ambonis* is characterised by an uninterrupted thickening around the hypocyst outline.

Previous records: Upper Pliensbachian to late Bajocian: Europe.

Nannoceratopsis gracilis (Alberti) Evitt 1961

pl. 23, fig. 4

Synonymy:

Nannoceratopsis senex van Helden 1977, p. 165, p. 42, pl. 33.1, figs 1-9, text-fig. 33.4.

Holotype: *Nannoceratopsis gracilis* Alberti 1961, p. 30, pl. 7 figs 16-17.

Description: see Evitt 1961, p. 1129-1130.

Remarks: *N. gracilis* differs from the other species observed in lacking any wall thickenings but possessing a punctate wall structure.

Previous records: Toarcian to early Bajocian: Europe.

Nannoceratopsis pellucida (Deflandre) Evitt 1961

pl. 23, fig. 5

Holotype: *Nannoceratopsis pellucida* Deflandre 1938, p. 183, pl. 8, figs 8-12.

Description: see Evitt 1961, p. 312.

Remarks: *N. pellucida* is similar to *N. spiculata* Stover 1966, but differs in lacking an apparent cavation in the extreme region of the antapical horns.

Previous records: Upper Bajocian to Lower Kimmeridgian: northwest Europe.

3.15.2. Proximate, acavate cysts with an apical archaeopyle

Genus *Jansonia* Pocock 1972

Type species: *Jansonia jurassica* Pocock 1972.

Diagnosis: see Pocock 1972, p. 97.

Jansonia jurassica Pocock 1972

pl. 17, fig. 8

Synonymy:

Jansonia manifesta Riding & Walton 1991 *in* Riding, Walton & Shaw 1991, p. 48, pl. 8, figs 1-16, text-fig. 4.

Holotype: *Jansonia jurassica* Pocock 1972, p. 97, pl. 29, figs 8-9, text-figs 14-15.

Description: see Pocock 1972, P. 97.

Remarks: The author rejects Riding & Waltons distinction between *J. jurassica* and *J. manifesta* on the basis of Jansonius' (1986), re-examination of Pocock's type material of *J. jurassica.* Contrary to Riding & Walton (1991, p. 148) *J. manifesta* falls within the size range of *J. jurassica.* Furthermore it is remarkable that the description of *J. jurassica* by Jansonius (1986, p. 212) recorded the presence of an ornament of low interrupted muri that form a shallow incomplete reticulum (cf. "an irregular reticulum formed by smooth, arcuate, anastomosing ridges..." (Riding, Walton & Shaw 1991, p. 148, regarding *J. manifesta*)), and the presence of a small thin apical operculum attached to one of the precingulars in a few specimens (cf. "the operculum is attached ventrally at the as paraplate ... the autophragm above the principle archaeopyle suture (i.e. the operculum) is thin and non tabulate" (Riding, Walton & Shaw 1991, p. 148, regarding *J. manifesta*)). The only distinction remaining between *J. jurassica* and *J. manifesta* is the presence of a well defined paratabulation on most specimens of *J. manifesta.* It is clear from Jansonius's re-examination that paratabulation is poorly indicated but discernable on the type material of *J. jurassica.*

Previous records: Bathonian; Scotland, Upper Bajocian; Canada.

Genus *Batiacasphaera* Drugg 1970

Type species: *Batiacasphaera compta* Drugg 1970.

Diagnosis: see Drugg 1970, p. 813-814.

Batiacasphaera sp. DB1

pl. 17, fig. 1

Description: Sphaerical to subsphaerical proximate acavate dinoflagellate cysts with a relatively thin autophragm (≤1μm) bearing a variable ornament of grana (≤1μm Ø). The ornament density is variable and when closely packed the elements may coalesce to form rugulae and subreticulae. The ornament of the epicyst is commonly less dense than the hypocyst.

The cingulum may be indicated by a differentiation in the density of the ornament. The only other indications of paratabulation are the accessory archaeopyle fissures which delimit the as and six precingular paraplates.

The archaeople is apical with an unknown number of paraplates being involved.

Size; average width 48.25μm (maximum 75μm, minimum 42.5μm), average antapical to apical measurment 46.7μm (maximum 52.5μm, minimum 42.5μm)(10 specimens).

Remarks: A common component in Bajocian, Bathonian and Callovian marine assemblages.

Batiacasphaera sp. DB2

pl. 17, figs 2 & 3

Description: Sphaerical to subsphaerical proximate acavate dinoflagellate cysts with a relatively thin autophragm (≤1μm) bearing an ornament of galeae and broad based spines (≤2.5μm long, ≤2μmØ at their bases). The ornament density is variable and some of the sculptural elements appear to consist solely of the process bases.

The only indications of paratabulation is the accessory archaeopyle fissures which delimit the as and six precingular paraplates.

The archaeople is apical with an unknown number of paraplates being involved.

Size; average width 36.8μm (maximum 45μm, minimum 30μm), average antapical to apical measurment 34.9μm (maximum 42.5μm, minimum 30μm)(10 specimens).

Remarks: *Batiacasphaera* sp. DB2 differs from *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover 1978 by possessing shorter processes and lacking any trabeculate connections between individual sculptural elements.

Batiacasphaera sp. DB3

pl. 17, fig. 3

Description: Originally subsphaerical proximate acavate dinoflagellate cysts. The autophragm is apparently simple, ≤1μm thick, densely covered in an ornament of fine baculae <2μm high and <1μm wide. Spacing between the elements is more or less equal to the width of the elements.

The archaeopyle is apical and free, apparently involving all apical paraplates and ?anterior intercalary paraplates in the operculum. Indications of paratabulation are formed by accessory archaeopyle fissures which delimit ?6 precingular paraplates.

Maximum transverse measurement 38μm, antapical to apical measurement 35μm (1 specimen).

Remarks: A single specimen of this morphotype has been recovered from the Gristhorpe Bay section. It differs from all other species of *Batiacasphaera* recovered in the present study in the density of the ornament.

Genus *Orobodinium* Gocht & Wille 1990

Type species: *Orbodinium automobile* Gocht & Wille 1990.

Description: see Gocht & Wille 1990, p. 698.

Orobodinium automobile Gocht & Wille 1990

pl. 17, figs 4 & 5

Holotype: *Orobodinium automobile* Gocht & Wille 1990, p. 699, fig. 4.

Description: see Gocht & Wille 1990, p. 699-702.

Remarks: Distinguished on its small size. The archaeopyle outline of this species is often difficult to determine.

Previous records: Upper Bajocian to Middle Callovian; Germany.

Genus *Valensiella* Eisenack 1963

pl. 17, fig. 7

Remarks: Proximate acavate cysts with a variably developed reticulation were sporadically encountered in the study. Due to the poor preservation of the specimens, it was not possible to speciate them. They are placed in open nomenclature as *Valensiella* sp..

Genus *Kallosphaeridium* (De Coninck) Jan du Chêne *et al.* 1985

Type species: *Kallosphaeridium brevibarbatum* De Coninck 1969.

Diagnosis: see Jan du Chêne *et al.* 1985, p. 8-9.

Kallosphaeridium sp. DK1

pl. 17, fig. 9

Description: Subsphaerical to ovoidal, acavate, proximate dinoflagellate cysts with a thin (<1μm) autophragm bearing a variable ornament of grana (<1μm Ø). The ornament density is variable from regular equally spaced elements to clustered elements forming larger but irregular grana, rugulae, reticulae and pseudoreticulae.

The cingulum is not indicated and the only suggestions of paratabulation are the accessory fissures which indicate the precingular plates (?6") and the outline of the attached operculum. Operculum poorly preserved precluding identification of paraplates.

Size small; length 35.3μm (maximum 47μm, minimum 25μm), width 33.5μm (maximum 49μm, minimum 25μm)(25 specimens).

Remarks: Of the specimens studied, poor preservation combined with the small size of the cysts precluded a confident identification of the number of opercular and precingular paraplates. Considerable variation of ornament was observed on slide 89016a.

Kallosphaeridium coniferum n. sp.

pl. 17, figs 10, 11, 13 & 14

Holotype: Slide BMGMCW2, grid ref. 129.6, 20.2,pl. 17, figs 10, 11, 13 & 14

Diagnosis: A small to medium sized species of *Kallosphaeridium* with an ornament of conae surrounded by fine grana. 5' paraplates are well defined on the operculum and the 6 precingular paraplates are indicated by accessory fissures.

Description: Originally subsphaerical to ovoidal, acavate, proximate dinoflagellate cysts. Autophragm thin (≤0.5μm), bearing an ornament of regularly spaced conae (≤1x1μm) and very fine grana (<0.5μm Ø). The grana may coalesce to form an irregular ornament between the conae. Paratabulation is expressed by the attached operculum and accessory fissures which define the precingular paraplates (6"). Five opercular paraplates are well defined by very narrow, low (<0.5x0.5μm) parasutural ridges. The 3" and 4" paraplates are camerate as a result of the opercular paraplate configuration. The operculum is attached by a narrow isthmus formed by the 1' paraplate in contact with the as paraplate. An insert condition can be observed on the operculum. OW/CD ratio 0.34.

Mean width of cyst at cingulum 40μm (maximum 47μm, minimum 35μm)(14 specimens).

Derivation of name: *con-*=contraction of conae, *-iferum*= bearing (latin) referring to the characteristic ornament.

Remarks: The parasutural crests visible on the operculum suggest two possible kofoidian paraplate notations (Figs 3.8 and 3.9, figures based on the holotype);

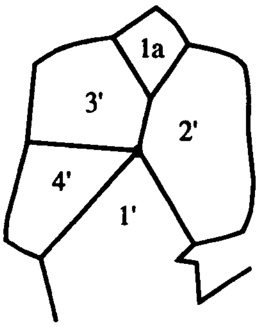


Figure 3.8. 1'-4', 1a.

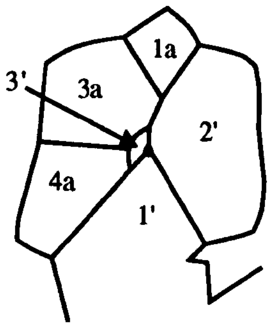


Figure 3.9. 1'-3', 1a-3a.

The size of the 1a plate is large for a species recorded from the Middle Jurassic. The detail of the apical region which would solve the present ambiguity is not visible under transmitted light and further observations await study under scanning electron microscopy.

The species differs from other Jurassic *Kallosphaeridium* species by the size of the intercalary plate and by the well defined parasutural crests on the operculum.

Kallosphaeridium tenuum n. sp.

pl.18, figs 1, 2 & 3

Holotype: Slide 89016a, grid ref. 147.9 21.5, pl. 18, fig. 1.

Paratypes: Slide 89016a, grid refs 150.5 1.2, 141.5 22.1, pl. 18, figs 2 & 3.

Diagnosis: A species of *Kallosphaeridium* with a characteristically thin autophragm.

Description: Originally subsphaerical to ovoidal, acavate, proximate dinoflagellate cysts. Autophragm thin (<0.5μm), commonly strongly folded and without ornament.

The only suggestion of paratabulation is indicated by the outline of the operculum and the accessory fissures which define the precingular paraplates. The operculum outline poorly defines four precingular and intercalary paraplate margins.

Mean width of cyst at the base of the accessory fissures 53.5μm (10 specimens).

Derviation of name: *Tenuum* from *tenui* (Latin) referring to the thinness of the cyst wall.

Remarks: The outline of the operculum is often slightly irregular which causes difficulty in recognising the outline of the operculum paraplates. This is also the case with the precingular paraplates indicated by the opercular fissure. However a prominent 1a intercalary paraplate is visible on most specimens. Like *K. tenuum* this paraplate is proportionately large to the apical series paraplates.

Genus *Lithodinia* (Eisenack) Gocht 1975

Type species: *Lithodinia jurassica* Eisenack 1935.

Diagnosis: see Gocht 1975, p. 353.

Remarks: The present author rejects the validity of *Meiurogonyaulax* Sarjeant 1966 since the majority of specimens observed do not consistently show the operculum and thus it's nature.

Lithodinia caytonensis (Sarjeant) Gocht 1975

pl. 17, figs 15 & 16

Synonymy:

Gonyaulax caytonensis Sarjeant 1959, p. 330.

Meiourogonyaulax caytonensis (Sarjeant) Sarjeant 1969, p. 14.

Holotype:*Gonyaulax caytonensis* Sarjeant 1959, p. 330, pl. 13, fig. 1, text-fig. 1.

Diagnosis: see Gocht 1975, p. 334.

Remarks: The present author considers that intraspecific variation is considerable within the assemblages observed. In addition, the fragility of the parasutural septa led to variable states of preservation in the studied assembages. It is the authors opinion that the specimens present in the assemblages represent the species *L. caytonensis* (Sarjeant) Gocht 1976.

Previous records: Upper Bajocian to Lower Oxfordian; northwest Europe.

3.15.3.Proximate, cavate cysts with an apical archaeopyle

Genus *Ambonosphaera* Fensome 1979

Type species: *Ambonosphaera calloviana* Fensome 1979.

Diagnosis: see Fensome 1979, p. 51.

Ambonosphaera calloviana Fensome 1979

pl. 18, figs 4 & 9

Holotype: *Ambonosphaera calloviana* Fensome 1979, p. 51-54, pl. 7, fig 3.

Description: see Fensome 1979, p. 51.

Remarks: The specimens identified agree with the original diagnosis.

Previous records: Lower Callovian to Oxfordian; Greenland and Spitzbergen.

Genus *Sirmiodinium* Alberti 1961

Type species: *Sirmiodinium grossii* Alberti 1961.

Diagnosis: see Alberti 1961, p. 22.

Sirmiodinium grossii Alberti 1961

pl. 18, fig. 5

Holotype: *Sirmiodinium grossii* Alberti 1961, p. 22, pl. 7, figs 5-7, pl. 12, fig. 5.

Description: see Alberti 1961, p. 22.

Remarks: Identifiable from other cavate cysts with apical archaeopyles by the presence of an antapical opistopyle.

Previous records: Upper Bathonian to Lower Cretaceous; northwest Europe.

3.15.4. Proximochorate, acavate cysts with an apical archaeopyle

Genus *Sentusidinium* Sarjeant & Stover 1978

Type species: *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover 1978.

Diagnosis: see Sarjeant & Stover 1978, p. 49.

Sentusidinium rioultii (Sarjeant) Sarjeant & Stover 1978

pl. 17, fig. 12

Selected synonymy:

Tenua rioultii Sarjeant 1968, p. 231.

Holotype: *Tenua rioultii* Sarjeant 1968, p. 231, pl. 1, figs 12, 22, pl. 2 figs 1-2, 4.

Description: see Sarjeant & Stover 1978, p. 231.

Remarks: The specimens observed agree with the original description.

Previous reecords: Upper Bajocian to Lower Callovian; northwest Europe.

Genus *Stephanelytron* Sarjeant 1961

Type species: *Stephanelytron redcliffense* (Sarjeant 1961) Stover *et al.* 1977, p. 331-332.

Diagnosis: see Stover *et al.* 1977, p. 331-332.

Stephanelytron sp. DS1

pl. 18, figs 7 & 8

Description: Proximate to proximo-chorate dinoflagellate cysts with an oval outline in compression. The autophragm is thin, ≤1μm thick and folded. The autophragm is ornamented with clavae and spinae upto 3μm in length. The processes appear to be arranged in lineaments across the autophragm but specimens are too poorly preserved to qualify this. A corona 14-15μm in diameter is present on the hypocyst. Corona rim is 1-2μm in height.

Archaeopyle ?apical. Number of plates involved indeterminate but a camerate, precingular paraplate margin is apparent on one specimen.

Dimensions 41-44μm in length, 29-34μm in width (2 specimens).

Remarks: Despite the poor preservation of the two specimens recovered, the well developed antapical corona and the presence of aligned clavate processes on the autophragm are sufficient characteristics to allow an assignation to the genus *Stephanelytron*. The position of the antapical corona, whether on the antapical plate or precingular series, remains uncertain.

Lagenadinium callovianum Piel 1985 has been reported from the Cornbrash Formation in the Cleveland Basin (S.W.Smith, Dept. Earth Sciences, University of Sheffield, pers. comm. 1992). It differs from the present specimens by lacking process alignment, having multiple coronas positioned on the postcingular series and in the presence of an ectophragm. S.W.Smith (pers comm. 1992) has suggested that specimens from the Cleveland Basin commonly exhibit removal of the ectophragm. In addition, some specimens were observed exhibiting a crude process allignment. Thus it is possible that the specimens observed may represent a *Lagenadinium* species with affinities to *L. callovianum*. This conclusion is not possible without reference to the material of S.W.Smith and as such, the material from the present study may still be accomodated in the genus *Stephanelytron*. It is of interest to note that the earliest published record of *Stephanelytron* spp. in Riding & Thomas (1992, fig. 2.11) is in the *koenigi* Zone of the Lower Callovian.

3.15.5. Chorate, acavate cysts with an apical archaeopyle

Genus *Compositosphaeridium* Dodekova 1974

Type species: *Compositosphaeridium polonicum* (Gorka) Erkmen & Sarjeant 1980.

Diagnosis: see Dodekova 1974, p. 25-26.

Compositosphaeridium polonicum (Gorka) Erkmen & Sarjeant 1980

pl. 19, fig. 1

Synonymy:

Hystrichosphaeridium polonicum Gorka 1965, p. 306-307.

Compositospheridium costatum (Davey & Williams) Dodekova 1974, p. 26.

Holotype: *Hystrichosphaeridium polonicum* Gorka 1965, p. 306-307, pl. 3, figs 5-6.

Description: see Gorka 1965, p. 306-307.

Remarks: The holotype was described from the Oxfordian. The author was surprised to recover the species from the samples studied. However, there is little reason to doubt the identification of the specimen observed, despite a relatively poor state of preservation. Woollam & Riding (1983) recorded a range of the species in England as *discus* Zone to *serratum* Zone (Upper Bathonian to Upper Oxfordian). Riding & Thomas (1991) revised the range and reported the first occurrence in the *herveyi* Zone (Lower Callovian) thus narrowing the range of the species. The present author suspects a strong facies influence on the range of species at the Bathonian / Callovian boundary in England and is compelled to suspect that the earlier range of *C. polonicum* was not the result of misidentification nor contamination as is inferred by the ranges presented in Riding & Thomas (*op cit.*).

Previous records: Upper Bathonian to Middle Oxfordian; North West Europe.

Genus *Adnatosphaeridium* Williams & Downie 1966

Type species: *Adnatosphaeridium vittatum* Williams & Downie 1966.

Diagnosis: see Williams & Downie 1966, p. 215.

Adnatosphaeridium caullyeri (Deflandre) Williams & Downie 1966

pl. 19, fig. 5

Synonymy:

Hystrichosphaeridium caullyeri Deflandre 1938, p. 138.

Holotype: *Hystrichosphaeridium caullyeri* Deflandre 1938, p. 138, pl. 11, fig. 2-3.

Description: see Williams & Downie 1966, p. 17.

Remarks: The single specimen recovered has suffered mechanical damage and is preserved in an oblique compression.

Previous records: Bathonian to Lower Cretaceous; northwest Europe.

Genus *Cleistosphaeridium* Davey *et al.* 1966

Type species: *Cleistosphaeridium diversispinosum* Davey *et al.* 1966.

Diagnosis: see Davey *et al.* 1966, p. 166.

Cleistosphaeridium varispinosum (Sarjeant) Woollam & Riding 1983

pl. 19, fig. 4

Synonymy:

Baltisphaeridium varispinosum Sarjeant 1959, p. 338-340.

Holotype: *Baltisphaeridium varispinosum* Sarjeant 1959, p. 338-340, pl. 13, fig. 7.

Description: see Woollam & Riding 1983, p. 3.

Previous records: Upper Bajocian to Lower Cretaceous; northwest Europe.

Genus *Rigaudella* Below 1982

Type species: *Rigaudella aemula* (Deflandre) Below 1982.

Diagnosis: see Below 1982, p. 139.

Rigaudella aemula (Deflandre) Below 1982

pl. 20, fig. 1

Synonymy:

Hystrichosphaeridium aemulum Deflandre 1938, p. 187-189, pl. 9, fig 12, pl. 10, figs 5.

Cannosphaeropsis aemulum (Deflandre) Deflandre 1947, p. 1576.

Adnatosphaeridium aemulum (Deflandre) Williams & Downie 1969, p. 17.

Cannosphaeropsis paucispinum Klement 1960, p. 72, pl. 10, fig. 9.

Adnatosphaeridium paucispinum (Klement) Gitmez & Sarjeant 1972, p. 234.

Holotype: *Hystrichosphaeridium aemulum* Deflandre 1938, p. 187-189, pl. 9, fig 12, pl. 10, figs 5.

Description: see Below 1982, p. 139.

Remarks: The speciemens identified were commonly broken and incomplete.

Previous records: Upper Bathonian to Mid Oxfordian: northwest Europe.

Genus *Prolixosphaeridium* (Davey *et al.*) Davey *et al.* 1969

Type species: *Prolixosphaeridium parvispinum* (Deflandre) Davey *et al.* 1969.

Description: see Davey *et al. 1966*, p. 171.

Prolixosphaeridium anasillum Erkmen & Sarjeant 1980

pl.18, figs 6 & 10

Holotype: *Prolixosphaeridium anasillum* Erkmen & Sarjeant 1980, p. 64-65, pl. 4, figs 2, 9, pl. 5, fig. 3.

Description: see Erkmen & Sarjeant 1980, p. 64.

Remarks: The holotype was recovered from late Callovian to Kimmeridgian strata. The two specimens recorded in the present study are the oldest occurrence of this species.

Previous records: Upper Callovian to Upper Kimmeridgian; Britain.

3.15.6. Cysts with a 1P precingular archaeopyle

Genus *Aldorfia* Stover & Evitt 1978

Type species: *Aldorfia aldorfensis* (Gocht) Stover & Evitt 1978.

Diagnosis: see Stover & Evitt 1978, p. 140.

Aldorfia aldorfensis (Gocht) Stover & Evitt 1978.

pl. 19, fig. 6

Synonymy:

Gonyaulacysta aldorfensis Gocht 1970, p. 136-138.

Holotype: *Gonyaulacysta aldorfensis* Gocht 1970, p. 136-138, pl. 30, fig. 9-11.

Description: see Stover & Evitt 1978, p. 140.

Remarks: The thick wall of this species often makes identification of the archaeopyle difficult.

Previous records: Upper Bajocian to Lower Callovian; northwest Europe.

Genus *Gonyaulacysta* (Deflandre) Stover & Evitt 1978

Type species: *Gonyaulacysta jurassica* (Deflandre) Norris & Sarjeant 1965.

Diagnosis: see Stover & Evitt 1978, p. 158 (=synopsis).

Gonyaulacysta jurassica subsp. *adecta* var. *adecta* Sarjeant 1982

pl. 20, fig. 2 & 3

Holotype: *Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* Sarjeant 1982, p. 30-31, pl. 1 fig. 2.

Description: see Sarjeant 1982, p. 30-31.

Remarks: The present specimens agree with the original description.

Previous records: Upper Bajocian to Upper Oxfordian; northwest Europe.

Genus *Tubotuberella* Vozzhennikova 1967

Type species: *Tubotuberella rhombiformis* Vozzhennikova 1967.

Diagnosis: see Vozzhennikova 1967, p.

Tubotuberella dangeardii (Sarjeant 1968) Jan du Chêne *et al.* 1986

pl. 20, fig. 3 & 4

Synonymy:

Gonyaulacysta dangeardii Sarjeant 1968, p. 226-227, pl. 37, figs 8-15, text fig. 3.

Dimidiadinium dangeardii (Sarjeant) Brideaux 1977, p. 37.

Holotype: *Gonyaulacysta dangeardii* Sarjeant 1968, p. 226-227, pl. 37, figs 8-15, text fig. 3.

Description: see Sarjeant 1968, p. 226-227.

Remarks: The faint, often incomplete paratabulation was characteristic of this species.

Previous records: Bathonian to Oxfordian; northwest Europe.

3.15.7. Cysts with a variable 1P-5P precingular archaeopyle

Genus *Dissiliodinium* (Drugg) Bailey & Partington 1991

Type species: *Dissiliodinium globulum* Drugg 1978.

Diagnosis: see Bailey & Partington 1991, p. 246.

Dissiliodinium cf. *willei* Bailey & Partington 1991

pl. 21, figs 2 & 4

Remarks: The specimens recorded in the present study differ from *Dissiliodinium willei* in lacking reticulate elements. However the other ornaments mentioned in the description of *D. willei* were observed. The specimens also compare with *Dissiliodinium* sp. A of Feist-Burkhardt 1990 but the lack of well preserved apical plates in the present material precludes positive identification. All specimens observed exhibited archaeopyles which involved the loss of most of the precingular series paraplates (4P and 5P).

Previous records: Lower Bajocian to Callovian; northwest Europe.

Genus *Durotrigia* Bailey 1987

Type species: *Durotrigia daveyi* Bailey 1987.

Diagnosis: see Bailey 1987, p. 89.

Durotrigia daveyi Bailey 1987

pl. 20, figs 6, 7, 8 & 9

Holotype: *Durotrigia daveyi* Bailey 1987, p. 89, pl. 2, figs 1, 4, 9.

Description: see Bailey 1987, p. 89.

Remarks: The loss of four precingular archaeopyles on specimens observed gives the impression of a combination archaeopyle in the style of *Ctenidodinium* as the remainig precingular paraplates develop accessory fissures along the base of the paraplates.

Previous records: Bajocian (laeviuscula-garantiana zones): Europe.

Durotrigia filapicata (Gocht) Riding & Bailey 1991

pl., fig.

Synonymy:

Gonyaulacysta filapicata Gocht 1970, p. 134, pl. 26, figs 4, 6-9, pl. 27, figs 1-3, 7, pl. 31, figs 1-5, text-figs 2a, 3,4.

Diacanthum filapicatum(Gocht) Stover & Evitt 1978, p. 152.

?*Dichadogonyaulax filapicata* (Gocht) Jan du Chêne *et al.* 1986, p. 11.

Holotype: *Gonyaulacysta filapicata* Gocht 1970, p. 134, pl. 26, figs 4, 6-9, pl. 27, figs 1-3, 7, pl. 31, figs 1-5, text-figs 2a, 3,4.

Description: see Riding & Bailey 1991, p. 101.

Remarks: Differentiated from *D. daveyi* by the lower, less regularly digitate style of the parasutural ornament.

Previous records: Bajocian to Callovian; northwest Europe.

3.15.8. Cysts with a combination archaeopyle

Genus *Mancodinium* (Morgenroth) Below 1987

Selected synonymy:

Dapcodinium Dörhöfer & Davies 1980, p. 23.

Type species: *Mancodinium semitabulatum* (Morgenroth) Below 1987.

Diagnosis: see Below 1987, p. 20.

Mancodinium semitabulatum (Morgenroth) Below 1987

pl. 22, fig. 9

Holotype: *Mancodinium semitabulatum* Morgenroth 1970, p. 352, pl. 12, figs 3-6, pl. 13, figs 1-4.

Descritpion: see Below 1987, p. 23.

Remarks: All but two precingular paraplates remain on the specimens identified in the present study.

Previous records: Toarcian to Lower Bajocian; northwest Europe.

Genus *Ctenidodinium* (Deflandre) Lentin & Williams 1973

Type species: *Ctenidodinium ornatum* (Eisenack) Deflandre 1938.

Diagnosis: see Stover & Evitt 1978, p. 204 (=synopsis).

Remarks: The generic diagnosis was not emended by Gocht (1970) despite him re-defining the genus and effectively synonymising it with *Dichadogonyaulax* Sarjeant 1966. Lentin & Williams (1973) transferred all the species from the latter genus in to *Ctenidodinium* on the basis of Gocht's work, but did not emend the diagnosis. The present author follows Gocht (1970), Lentin & Williams (1973) and Stover & Evitt 1978 and rejects the validity of the genus *Dichadogonyaulax* Sarjeant 1966, considering it a junior synonym of *Ctenidodinium* (Deflandre) Lentin & Williams 1973.

It is of interest to note that Woollam (1983) puts forward a convincing argument to unite the two genera but maintains them as separate entities. Lentin & Williams 1989 reinstated the genus *Dichadogonyaulax*, following personal communications with W.A.S. Sarjeant concerning *D. (C.) sellwoodii* and in spite of their earlier opinions. Few authors comment that in the commonest mode of preservation, where the epicyst and hypocyst are detatched from each other, observation of the symmetry of the paracingular crests is impossible on epicystal fragments.

Ctenidodinium combazii Dupin 1968

pl. 21, fig. 5

Holotype: *Ctenidodinium combazii* Dupin 1968, p. 2, pl. pl.1, figs 8-11.

Description: see Dupin 1968, p. 2, pl. pl.1, figs 8-11.

Remarks: *C. combazii* is distinguished by a reduced $1''''$ paraplate, the common presence of a rough plate-centred surface ornament and the development of a strong spinose ornament along the parasutures which, in the region of paraplate triple junctions, may be elaborated and extended.

Previous records: Upper Bajocian to Lower Callovian; northwest Europe.

Ctenidodinium sellwoodii (Sarjeant) Stover & Evitt 1978

pl. 21, figs 6 & 7

Synonymy:

Dichadogonyaulax sellwoodii Sarjeant 1975, p. 52.

Ctenidodinium sellwoodii (Sarjeant) Stover & Evitt 1978, p. 204.

Holotype: *Dichadogonyaulax sellwoodii* Sarjeant 1975, p. 52, pl. 1, figs A-H, pl. 2, figs I-K, pl. 3, figs L-Q.

Description: see Sarjeant 1975, p. 52.

Remarks: The author rejects the view of Lentin & Williams (1989, p. 86) whom, after conferring with Sarjeant (pers. comm.), reinstated the species in the genus *Dichadogonyaulax* Sarjeant 1966.

Previous records: Upper Bajocian to Upper Callovian; northwest Europe.

Genus *Korystocysta* Woollam 1983

Type species: *Korystocysta kettonensis* (Sarjeant) Woollam 1983.

Diagnosis: see Woollam 1983, p. 194.

Korystocysta cf. *kettonensis* (Sarjeant) Woollam 1983

pl. 21, fig. 8

Remarks: The incomplete specimens recovered during the study exhibit the inter-tabular growth lines characteristic of the genus. The lack of epicystal opercula precludes the observation of an apical horn. The specimens were attributed to *K. kettonensis* rather than *K. pachyderma* (Deflandre) Woollam 1983 on the basis of a thinner wall than is commonly observed in *K. pachyderma*.

Previous records: Bathonian; England.

3.15.9. Acavate cysts with intercalary archaeopyles

Genus *Pareodinia* (Deflandre) Stover and Evitt 1978

Type species: *Pareodinia ceratophora* Deflandre 1947.

Diagnosis: see Stover and Evitt 1978, p. 116-117.

Pareodinia ceratophora (Deflandre) Gocht 1970

pl. 22, fig. 2

Holotype: *Pareodinia ceratophora* Deflandre 1947, p. 4, text-fig. 1.

Diagnosis: see Gocht 1970, p. 153.

Remarks: The apical horn, with a length >1/4 the cyst length, is a diagnostic feature of this species

Previous records: late Bajocian to Cretaceous: Worldwide.

Pareodinia ceratophora subsp. *scopaea* (Sarjeant) Lentin & Williams 1973

pl. 22, fig. 1

Holotype: *Pareodinia ceratophora* var. *scopaeus* Sarjeant 1959, p. 337, pl. 13, fig. 10, text-fig. 5a.

Diagnosis: see Sarjeant 1959, p. 337.

Remarks: Differs from P. ceratophora by the shorter horn.

Previous records: Upper Bathonian to Lower Callovian; England.

Pareodinia prolongata Sarjeant 1959

pl. 22, figs 3 & 4

Holotype: *Pareodinia prolongata* Sarjeant 1959, p. 335-336, pl. 13, fig. 8, text-fig.4.

Description: see Sarjeant 1959, p. 335.

Remarks: Specimens from the present study agree with the original description.

Previous records: Upper Bathonian to Mid Oxfordian; northwest Europe.

Genus *Tabulodinium* Dodekova 1990

Type species: *Tabulodinium senarium* Dodekova 1990.

Diagnosis: see Dodekova 1990, p. 23-24.

Tabulodinium senarium Dodekova 1990

pl. 22, fig. 5

Holotype: *Tabulodinium senarium* Dodekova 1990, p. 24, pl. IV, figs 4-5.

Description: see Dodekova 1990, p. 24.

Remarks: The paraplate 'pads' are characteristic of this species and serve to distinguish it from *Pareodinia* This record appears to be the first in the U.K.

Previous records: Upper Bathonian to Lower Callovian; Bulgaria.

Genus *Caddasphaera* Fenton *et al.* 1980

Type species: *Caddasphaera halosa* (Filatoff) Fenton *et al.* 1980 .

Diagnosis: see Fenton *et al.* 1980, p. 164.

Caddasphaera halosa (Filatoff) Fenton *et al.* 1980

pl. 22, fig. 7

Synonymy:

Kalyptea halosa Filatoff 1975, p. 91.

Holotype: *Kalyptea halosa* Filatoff 1975, p. 91, pl. 29, figs 10-11.

Diagnosis: see Fenton *et al.* 1980, p. 164.

Remarks: The archaeopyle of specimens observed is typically obscured by kalyptea which surrounds the specimens and is a diagnostic feature of the species.

Previous records: Pliensbachian to Kimmeridgian: Europe.

Genus *Susadinium* Dörfhöfer & Davies 1980

Type species: *Susadinium scrofoides* Dörfhöfer & Davies 1980.

Diagnosis: see Döfhöfer & Davies 1980, p. 113.

Susadinium scrofoides Döfhöfer & Davies 1980

pl. 22, fig. 6

Holotype: *Susadinium scrofoides* Döfhöfer & Davies 1980, p. 28-29, fig. 13, 24F, H-I,K, 25 A-D.

Description: see Döfhöfer & Davies 1980, p. 28-29.

Remarks: Presently identified specimens agree with the illustrations of the holotype.

Previous records: Upper Toarcian to Lower Aalenian; northwest Europe.

3.15.10. Cavate cysts with an intercalary archaeopyle

Genus *Phallocysta* Dörhöfer & Davies 1980

Type species: *Phallocysta eumekes* Dörhöfer & Davies 1980.

Diagnosis: see Dörhöfer & Davies 1980, p.27.

Remarks: The author rejects the emendations of Riding (1984) and Below (1987) as neither authors undertook an examination of the type material. The genus appears to be extravagantly diagnosed considering the illustrations of the type material (see Dörhöfer & Davies 1980, p. 27, figs 12, 24D-E; 26 H-J; 27A-I). Despite a stated paratabulation, none of the illustrated material exhibits the slightest indication of paratabulation, nor does the type species exhibit the 3I archaeopyle stated in the diagnosis. In addition the illustrated material exhibits both the diagnosed 'periphragm' ornament (eg figs 27A-D) and a smooth periphragm (figs 27E,F & I). An acceptable emendation of the genus awaits re-examination of the type material.

The specimens recovered from the present study clearly share the same morphologic chatacteristics of the holotype and on this basis, they are assigned to the genus.

Phallocysta spinosa n. sp.

pl. 22, figs 12, 13 & 14, pl. 23, figs 1, 2 & 3

Holotype: Slide 89016a grid ref. 147.2 20.0, pl. 22, fig. 12.

Paratypes: Slide 89016a grid refs 132.1 17.9, 156.2 11.1, 145.7 20.5, 155.3 20.8, pl. 22, figs 13 & 14, pl. 23, figs 1, 2 &3.

Diagnosis: A species of *Phallocysta* sometimes exhibiting two antapical protuberances and bearing granules, fine spinae and baculae on the ectophragm. The elements may be arranged in rows suggesting the position of parasutures. The endophragm is thicker than the ectophragm and may be smooth to granulate. A 1I2a archaeopyle may be poorly to well developed.

Description: Elongate or rounded pyriform to rounded cylindrical dinoflagellate cysts lacking primary dorso-ventral compression commonly exhibiting two antapical protuberances. Epicavate. Periphragm thin (≤0.5μm), bearing an ornament of small grana and spinae (elements less than 1μm in height) randomly distributed. Baculae upto 2μm in length may occur, particularly on the epiperiphragm but are subdominant. The epicoel is commonly approximately half cyst length, maybe upto two thirds. The endophragm is thicker than the periphragm (≤1μm thick), circular to ovoidal in outline and is smooth to granulate (<1μm Ø), rarely with baculae upto 1.5 μm long. The endophragm may appear microfoveolate, due to an optical effect caused by the sculptural elements.

Indications of the 1' paraplate and the paracingulum may be suggested by alignment of the sculptural elements on the periphragm. Furthermore the cingulum may be indicated by a notch on the ambitus anterior to the antapical protuberances. An apical 'pore ring' is often present and is considered analogous with the structure formed by the COP plate in *Susadinium* spp. Periarchaeopyle intercalary 1I2a, operculum free. Accessory fissures delimiting the 1a/4", 1a/3', 3a/5"and 3a/4' paraplate boundaries may be discernable. Endoarchaeopyle ?1I2a.

Size; average apex to antapex measurment of periphragm 44.3μm (maximum 47.5μm, minimum 35μm); average apex to antapex measurment of endophragm 25.8μm (maximum 27.5μm, minimum 12.5μm); average width 30.6μm (maximum 35μm, minimum 27.5μm)(10 specimens).

Derivation of name: *spinosa* referring to the diagnostic ornament.

Remarks: Element variability was considerable within the population studied. *Phallocysta thomasii* Smelror 1991 from the Aalenian to Bajocian of the Barents Sea is very similar but differs from the present species in exhibiting a 3a archaeopyle and lacking indication of paratabulation. The two species may be conspecific but further observations on the type material of *P. thomasii* is necessary. The species was delimited from *Phallocysta* cf. *eumekes* by the presence of spinose and baculate sculptural elements, and a smaller size range.

Phallocysta cf. *eumekes* Dörhöfer & Davies 1980

pl. 20, figs 10 & 11

Description: Elongate or rounded pyriform to rounded cylindrical dinoflagellate cysts lacking primary dorso-ventral compression commonly exhibiting two antapical protuberances. Epicavate. Periphragm thin (≤0.5μm), bearing an ornament of small grana (elements less than 1μm in height) randomly distributed. Epicoel is commonly approximately half cyst length, maybe upto two thirds. The endophragm is thicker than the periphragm (≤1μm thick), circular to ovoidal in outline and is smooth to granulate (<1μm Ø). The endophragm may appear microfoveolate, due to an optical effect caused by the sculptural elements.

The cingulum may be indicated by a notch on the ambitus anterior to the antapical protuberances. An apical 'pore ring' is often present and is considered analogous with the structure formed by the COP plate in *Susadinium* spp. Periarchaeopyle intercalary 1I2a, operculum free. Endoarchaeopyle ?1I2a.

Size; average apex to antapex measurment of periphragm 44.25µm (maximum 47.5µm, minimum 40µm); average apex to antapex measurment of endophragm 28.25µm (maximum 32.5µm, minimum 25µm); average width 29.75µm (maximum 37.5µm, minimum 25µm)(10 specimens).

Remarks: *Phallocysta* cf. *P. eumekes* differs from *Phallocysta eumekes* Dörhöfer & Davies 1980 in its smaller size range and a non-punctate endophragm (although a re-examination of the type material may invalidate the latter observation).

Genus *Moesiodinium* Antonesçu 1974

Type species: *Moesiodinium raileanui* Antonesçu 1974.

Description: see Antonesçu 1974, p. 62.

Moesiodinium raileanui Antonesçu 1974

pl. 22, fig.10

Holotype: *Moesiodinium raileanui* Antonesçu 1974, p. 62-63, pl. 2, figs 10, 12.

Description: see Antonesçu 1974, p. 62-63.

Remarks: Specimens agree with the original description.

Previous records: Middle Jurassic; Romania.

BLANK PAGE
IN
ORIGINAL

Chapter 4

4.1.0. Aims of descriptive interpretation of the studied sections.

The interpretation of palaeodepositional environments from a consideration of the palynological assemblages in conjunction with published sedimentological data is considered an important goal in the present study. From this, it may be possible to detect changes in the palaeoenvironment which may be related to rises and falls in relative sea level. A palaeoenvironmental approach to palynological interpretation was first attempted in the Cleveland Basin by Muir (1964). At this point, it seems necessary to review the procedures previously adopted.

The most successful case studies of the effectiveness of palaeoenvironmental pollen and spore analysis can be seen in the Quaternary, where, for evolutionary reasons, the significance of a species presence can be interpreted in the context of the distribution of that species in contemporary environments. Thus the palynological association recovered from a sample can be interpreted in terms of the vegetation from which the association was derived.

In the Quaternary, the recognition of climate change in pollen profiles is a common goal. Climatic control of the plant community is assumed. This leads to the recognition of climatic sequences across a wide geographical area.

When the principle of uniformitarianism is assumed, this method may be applied back to the Tertiary. Thomson (1950) distinguished between types of brown coal on the basis of their petrology. He went on to prove that each coal type had its specific association of 'spores' and pollen grains. Similar results were arrived at by Traverse (1955). Kuyl, Muller & Waterbolk (1955) were concerned with correlating boreholes from which samples retrieved revealed facies of a marine to non-marine nature. The authors observed one group of pollen grains with a very erratic distribution and a further group with a more regular distribution. From this they interpreted that the first group were subject to rapidly varying local conditions and the second group were produced in a remote area from where they were deposited and were thus less subject to facies controls.

The desire to interpret pre-Tertiary spore assemblages in a different manner and to apply the interpretation to zonal schemes is apparent in literature from all over the globe. This particularly so in the Jurassic. This interpretation assumes that all grains are freely distributed by wind and are thus independent of facies. Clearly, if the principle of uniformitarianism is adhered to, this should not be the case. The same association of 'spores' and 'pollen' grains cannot be expected in a marine shale and a coal. There may be common species to both, but those in marine strata have clearly been subject to wind and water transport. The likelihood that some of the species present in the coal assemblage were deposited in situ is very high.

The work of Neves (1958), which was further discussed by Chaloner (1958) was concerned with Carboniferous marine to non-marine strata. Greatest species diversity was recorded in the marine strata, suggesting to Neves (*op. cit.*) that it was the product of a varied plant flora. The dominance of the monosaccate genus *Florinites* in the marine strata was suggested by Chaloner (*op. cit*) to be due to the obscuring of *Florinites* species in the non-marine strata by a grossly over-represented coal swamp flora. In this, *Florinites* was considered to be sourced from plants inhabiting hinterland areas. Further detailed work on spore phases in Carboniferous coals was carried out by Smith (1957).

With regards to Neves work, a similar trend can be observed in the Middle Jurassic with *Alisporites* complex bisaccate 'pollen' grains. These are common components in assemblages from marine strata. Based on Neves and Chaloner's work (1958), these grains are interpreted to be sourced from Gymnospermous plants inhabiting inland environments. Muller (1959) concluded that most 'pollen' is distributed by river and marine currents. Thus it is fair to assume that the presence of *Alisporites* complex 'pollen' grains is a result of river transport from an upland source and their presence in floodplain / deltaplain mudstones is a result of fluvial transport into that environment. Problems with this model arise with Harris's (1964) observation of *Alisporites* complex 'pollen' grains in the fertile reproductive organ *Pteroma thomasii.* This part and its associated leaf *Pachypteris papillosa* was considered by Harris (*op. cit.*) to inhabit habitats equivalent to those of present day mangrove swamps. Thus when interpreting the presence of *Alisporites* complex 'pollen' grains, it is important to consider both possible sources.

At this point, it is clear that *in situ* studies are valuable in the role of relating dispersed grains back to parent plants. An outline of the known natural affinities of Jurassic dispersed 'spores' and 'pollen' grains is given in Appendix 2.1.

Representatives of the Dicksoniaceae / Cyatheaceae / Matoniaceae (*Deltoidospora*, *Biretisporites*, *Cibotiumspora*, *Concavisporites* and *Dictyophyllidites* (in part)) are common elements in some samples and on the basis of modern homologues, are considered to inhabit moist floodplain environments. To these it is possible to add representatives of the Dipteridaceae (*Dictyophyllidites*), Schizeaceae (*Ischyosporites*) and Osmundaceae(*Todisporites*, *Osmundacidites*, *Baculatisporites*, *Verrucosisporites* and *Rugulatisporites*). The Gleicheniaceae (*Gleicheniidites*, *Ornamentifera*) are considered to inhabit brackish water swamps on the basis of the macroplants xerophyllic characteristrics (Van der Burgh & van Konijnenburg-van Cittert 1984). 'Pollen' groups remain a little more problematical. The Cheirolepidaceae (*Corollina*) are abundant in the hypersaline deposits of Purbeck age (Norris 1969). *Perinopollenites* was considered to be produced from freshwater swamp inhabiting Taxodiaceous parent plants (van Konijnenburg-van Cittert & Van der Burgh 1989). The ecology of the Cycadaceae is open to question. Due to the great diversity of species and the similarities of their monosulcate 'pollen' grains also with the Bennittitales, Ginkgoales, Pentoxylales, Cycadeoidales and Czeckanowskiales, the problem is not alleviated.

From this rather broad view of Jurassic plant ecology, it was the present authors intention to interpret the tilia diagrams in terms of broad associations of species which were hoped to relate to the parent plant communities. In the following descriptions and interpretations of the outcrop sections, samples are interpreted palaeoenvironmentally on the basis of the palynological assemblages and the available sedimentological data. At the end of the section, correlation between sections and further palaeoenvironmental interpretation is discussed.

To make the interpretation more visually comprehensible, the sections have been interpreted in terms of associated groups of species. The groupings are identified based on the proportions and presence or absence of individual species and groups of species. This method of grouping compares closely to the definition of an association, defined by Lockley (1983) after Pickerill & Brenchley (1979) as, " a group of assemblages all showing similar recurrent patterns of species composition: its origin, like that of its component assemblages, may vary from one association to the next."

In defining the associations, 'spore' and 'pollen' grains have been grouped into broad categories. The definitions of the associations do not necessarily total 100% of the assemblages: a 20% presence of a group may be of sufficient significance in the authors opinion. Clearly, where sedimentological interpretation is well documented, the palynomorph assemblages will complement the previous interpretations. However, in monotonous mudstone sequences such as those encountered ion the Scalby Formation, sedimentological interpretation becomes much broader and it is in this area where the palynological assemblages may elucidate the depositional scenario.

Data collected from the studied sections are displayed as saw tooth diagrams using the Tilia.graph program (see enclosures). Data from each sample locality is presented in both raw (numerical) and standardised (percentage) forms. Raw data output allowed the recognition of samples with low total counts which were later omitted from the standardised dataset in order to avoid misrepresentation by impoverished samples. Dendrograms calculated on the percentage data were included in the standardised dataset for each locality. For both types of data, combined sums were calculated to facilitate the recognition of general trends within specific groups (e.g. bisaccate 'pollen', porate 'pollen', 'spores' etc.).

Each sample locality is considered separately below.

4.1.1. Cunstone Nab [G.R. TW1000 8302]

Samples of the Cornbrash Formation and the Osgodby Formation (Langdale Beds and Hackness Rock Member) were collected for a palynological investigation of the marine microplankton by S.W. Smith (Department of Earth Sciences, University of

Sheffield). Six samples were analysed for terrestrial taxa. All dinoflagellate cyst species were grouped into an undifferentiated category in order to avoid overlap with the work of Smith.

Abundant terrestrial assemblages were obtained from all samples (see enclosure 1). With reference to the raw data, the vertical distribution of dinoflagellate cysts is of interest; their consistent dominance in the Langdale Beds Member and Hackness Rock Member changes down section to decrease in the Cornbrash Formation. Furthermore, an upward decrease in the marine and undifferentiated acritarch categories in the Cornbrash Formation is apparent; the lower most sample in the section is dominated by leiospheres, here considered a marine component of the assemblages.

The bisaccate 'pollen' grain content exhibits a bimodal distribution up-section; highest percentages are encountered from the sample in the Hackness Rock Member, following a minor peak recorded in the second sample from the Cornbrash Formation. The distribution of porate 'pollen' grains appears to be antithetic to the bisaccate 'pollen' distribution; the highest percentages are encountered at the base of the Langdale Beds Member (peaks of *Corollina torosus* and *Exesipollenites tumulus*) and the Cornbrash Formation (peaks of *Perinopollenites elatoides* and *Cerebropollentites mesozoicus*). The distribution of inaperturate 'pollen' grains differs from the previous categories. Relatively high numbers (greater than 15 specimens per count) in the Cornbrash Formation are followed by lower numbers at the base of the Langdale Beds Member. A second minor peak is apparent in the second sample of the Cornbrash Formation. The distribution in the Langdale Beds and Hackness Rock Member is almost exclusively due to the presence of *Callialasporites microvelatus* and *C. turbatus*. whereas the presence in the Cornbrash Formation is the result of several other species of *Callialasporites* in addition.

Spore distribution differs between the formations; species abundance and diversity are much greater in the Cornbrash Formation than in the Langdale Beds and Hackness Rock Member (only 65% of the species present in the Cornbrash Formation are present in the Osgodby Formation). *Deltoidospora minor* and *Dictyophyllidites harrisii* are the commonest species; however the majority of other species are recorded as single specimens.

Interpretation of the data

The presence in all formations of subzonal ammonites (Wright 1968, 1977) suggests that normal marine salinities existed during deposition. Thus all terrestrial species are present as a result of offshore sediment transport within the Cleveland Basin. The study of Muller (1959) showed that the distribution of terrestrial species in offshore settings was dependant upon the proximity of the terrestrial source (river or estuary) and the effect of offshore currents. Highest numbers of terrestrial species were naturally encountered closest to the source. However, in more distal settings the distribution of terrestrial species was controlled predominantly by current action.

Previous authors have considered the ratio of marine to non-marine taxa. Of note is the work of Mebradu (1978) on the Upper Jurassic of Dorset. He suggested that the distributions of four categories of palynomorphs (dinoflagellate cysts, tasmanitids, micro-foraminiferal test linings and 'spores' and 'pollen') were not controlled by lithology but were influenced by shoreline proximity, depth of the basin, changes in the direction of transporting mechanisms, rate of miospore production and dissemination and availability of miospores. Mebradu (*op. cit.*) concluded that there was a relationship between the relative abundance of dinoflagellate cysts and transgressive / regressive phases in the Upper Jurassic sediments of Dorset.

Muir (1964) considered several species of 'spores' and 'pollen' grains to be indicators of marine environments. In particular *Pityosporites* and *Tsugaepollenites* were noted. This conclusion is supported in the present study where *Alisporites* spp. and *Cerebropollenites mesozoicus* (alias *Pityosporites* spp. and *Tsugaepollenites mesozoicus*) are dominant in the terrestrially derived assemblages. In the Langdale Beds Member and Hackness Rock Member, an upward increase in the bisaccate 'pollen' content is accompanied by an upward decrease in *Corollina torosus* and *Exesipollenites tumulus*. This is picked out on the dendrogram which clusters the top two samples closer than the bottom most sample in the top cluster.

The cluster for the Cornbrash Formation is quite separate from the Langdale Beds Member and Hackness Rock Member which perhaps points to the increase in species diversity in the former samples. However, like the Langdale Beds Member and Hackness Rock Member, the upper two samples are clustered closer than the lower most sample. The cause for this clustering appear to be an increase in *Leiosphaeridia hyalina*, *Cerebropollenites mesozoicus* and *Perinopollenites elatoides* in the lower-most sample, accompanied by a sudden decrease in *Alisporites* spp..

Using the conclusions of Mebradu (1978), the assemblages recovered from the Formations would apparently reflect the effects of the Lower Callovian transgression. Of the two formations, the Cornbrash Formation records the greater terrestrial influence. This is taken to indicate closer proximity to the terrestrial source. In the Langdale Beds Member and Hackness Rock Member, 'spores' and 'pollen' grains appear to be a more sensitive indicator of shoreline progradation than the total dinoflagellate cyst count. As the dinoflagellate cyst assemblages were not speciated, the usefulness of the composition of the dinoflagellate assemblages for offering an equally sensitive indicator remains inconclusive.

4.1.2. Gristhorpe Bay [TW 0900 8312 to 0811 8410]

A comparison between the raw and the standardised datasets reveals the extent of impoverished samples retrieved from the Gristhorpe Bay section. In addition to the impoverished assemblages, samples barren of palynomorphs were also recorded in the lower part of the section (samples GB91.4, GB91.7 and GB91.10). These are considered to reflect extreme degradation of organic matter. The composition of the impoverished samples is outlined below (Table 4.1).

Sample 89206 is dominated by leiospheres and non-marine acritarchs. A non-marine acritarchous affinity is proposed for the leiospheres on the basis of this informal association. A subdominant spore flora includes Carboniferous reworked elements (*Lycospora* sp.).

Table 4.1. Composition of the impoverished samples in the Gristhorpe Bay section. Most common to least common species.

Sample number	Species
89206; medium grey mudstone.	*Leiosphaeridia hyalina, Hemisphaerium giganteum, Alisporites* complex, *Perinopollenites elatoides, Deltoidospora minor, Callialasporites minus, Exesipollenites tumulus, Alisporites microsaccus, Araucariacites australis, Biretisporites potoniaei, Concavisporites toralis, Corollina torosa, Densoisporites velatus, Lycospora* spp., *Nevesisporites bigranulatus, Punctatisporites minor.*
89207; white to light grey siltstone / fine sandstone.	*Densoisporites velatus, Lycospora* spp., *Perinopollenites elatoides, Araucariacites australis, Hemisphaerium giganteum, Leiosphaeridia hyalina, Neoraistickia* sp. indet., *Alisporites* complex, *Corollina simplex, Chasmatosporites hians, Deltoidospora minor, Exesipollenites tumulus, Corollina torosus, Hemisphaerium simplex, Knoxisporites* sp., *Osmundacidites wellmanii, Prolixosphaeridium anasillum, Punctatisporites minor.*
89209; medium grey mudstone.	*Deltoidospora minor, Alisporites* complex, *Callialasporites dampieri, Callialasporites minus, Callialasporites turbatus, Cleistosphaeridium varispinosum, Corollina simplex, Densoisporites velatus, Exesipollenites tumulus, Hemisphaerium simplex, Lycospora* sp., *Retitriletes* sp. indet.
89210; light to medium grey silty mudstone.	*Lycospora sp., Callialasporites turbatus, Araucariacites australis, Deltoidospora minor, Alisporites* complex, *Cycadopites carpentieri, Perinopollenites elatoides.*

Sample 89207 witnesses a peak of *Densoisporites velatus*. Clearly the fine sandstone facies lay close to the habitat of the parent plant. The rather eclectic assemblage with a large Carboniferous reworked component (*Lycospora* sp., *Knoxisporites* sp.), non-marine acritarchs, uncommon 'pollen' grains (*Chasmatosporites hians*) and marine dinocysts is interpreted as representing a mixed source dominated by upland reworking and 'pollen' input, with floodplain 'pollen' and spore floras forming a significant input and minor marine influence. This correlates well with the sedimentological interpretation of the facies as being deposited in a meandering distributary channel (Liver & Leeder 1981).

Sample 89209 reflects a mixed source, dominated by floodplain elements ('spores' and 'pollen' grains), with minor marine influence from dinocysts.

Sample 89210 is extremely impoverished, again with a mixed source (upland reworking and 'pollen' grains and floodplain 'spores' and 'pollen' grains). Both samples 89209 and 89210 are interpreted as being deposited within the influence of a distributary channel analogous to sample 89207 in order to explain the interpreted upland sourced presence.

Standardised data.

The lowest four samples 89241, 89243, 89245 and 89247 have clustered closely on the dendrogram of enclosure 2, indicating compositional similarity. The assemblages are dominated by 'pollen' and non-marine acritarchs (~40% each). Differences within the cluster are a result of a peak of bisaccate 'pollen' (mainly *Alisporites* complex) in sample 89245.

The overlying sample GB91.2 differs significantly from both nearest neighbours. It's signature is a low percentage of non-marine acritarchs and a high percentage of 'pollen', in part due to a high percentage of the inaperturate 'pollen' *Araucariacites australis*. This continues as a trend into the overlying cluster which is relatively poorly delimited on the dendrogram, suggesting that the constituent samples are rather dissimilar in composition. Sample GB91.5 is distinctive at the base of the cluster. It is characterised by a peak (>40%) of non-marine acritarchs, moderate percentages of inaperturate 'pollen' and low percentages of 'spores'. Overlying this, sample GB91.9 and 91.10 have clustered closely on the basis of high percentages of undifferentiated acritarchs (>30%) and inaperturate 'pollen' (>30%). The sample above, GB91.12, continues the trend upwards of high percentages of undifferentiated acritarchs. However a peak of bisaccate 'pollen' (>30%) occurs at the expense of inaperturate grains.

Up section, samples GB91.13 and GB91.14 witness a return to inaperturate 'pollen' and undifferentiated acritarchs dominated assemblages (~30% and >30% respectively). This broad assemblage characteristic continues with samples GB91.15

and 89231. However, a decrease in the inaperturate 'pollen' and undifferentiated acritarch percentages can be seen, mirrored by an increase in porate 'pollen'. The top most sample of the cluster is sample 89230. Overlying this, a major change in the composition of the assemblages is suggested by the wide separation of the clustering in the dendrogram. Sample 89230 is characterised by peaks of inaperturate 'pollen' and non-marine acritarchs (>30% and >35% respectively).

Sample 89229 defines the base of the third cluster of samples from the bottom of the section. The four constituent samples are the least similar group in the section. Sample 89229 differs from the underlying sample by the absence of bisaccate and inaperturate 'pollen' grains. In contradistinction, porate 'pollen' and non-marine acritarchs are common. Loosely grouped with this on the dendrogram is the overlying sample 89227. However this sample is distinct on the basis of the presence of dinocysts (10%) and commoner 'spores' (>20%). Samples 89224 and 89225 exhibit a low level of clustering. Both record the presence of dinocysts (in sample 89225 they dominate the assemblage), however the broad compositions of the assemblages are distinctively dissimilar. Sample 89225 records bisaccate 'pollen' as a dominant non-marine element with subordinate 'spores' whereas 89224 witnesses dominant inaperturate 'pollen' and undifferentiated acritarchs.

Higher up in the section, samples 89221 and 89222 have grouped closely and are defined by high (>30%) porate 'pollen' grain and non-marine acritarch percentages with minor percentages of 'spores'. This composition also defines sample 89219. The intervening sample 89220 differs in being dominated by non-marine acritarchs with lesser percentages of porate and bisaccate 'pollen'. The top most sample of this small cluster on the dendrogram, 89218, shares a similar composition to sample 89220.

Samples 89217 and 89216 have grouped closely on the basis of abundant non-marine acritarchs (>35%) and bisaccate 'pollen' (>25%). In this respect they compare with sample 89245 situated near the base of the section. Sample 89215 witnesses a change to dominance by sulcate 'pollen' grains. It differs from the overlying two samples in lacking dinocysts. The absence of dinocysts from the assemblages is quite distinct, being restricted to two samples. Non-marine acritarchs still dominate the assemblage in 89215, with subordinate sulcate 'pollen'. The overlying sample 89212 has clustered closely with 89213 but can only be poorly defined on the basis of ≥20% inaperturate 'pollen' and >30% non-marine acritarchs. Sample 89211 continues the trend of common inaperturate 'pollen' grains and non-marine acritarchs but in addition displays relatively high percentages of undifferentiated acritarchs. Overlying this, a return to dinocyst influenced assemblages is witnessed in sample 89208. The assemblage reflects inputs from numerous groups (bisaccate and porate 'pollen' grains, 'spores' and non-marine acritarchs), all present in low percentages.

Higher up above the channel sandstone body at the top of the formation, sample 89205 records the continuation of dinocyst influence. However this sample differs from 89208 in the presence of undifferentiated acritarchs (>20%) and increased bisaccate 'pollen' grains. Between sample 89208 and 89204, the terrestrial input changes with continued common undifferentiated acritarchs but in addition, a noticeable presence of 'spores' (>15%) in 89204. Above this in sample 89203, porate 'pollen' and non-marine acritarchs become the dominant constituents. The highest sample in the section, 89201, witnesses domination by dinocysts with subdominant (>15%) porate and bisaccate 'pollen'.

Interpretation

The samples have been interpreted in terms of associations. Table 4.2 summarises the associations recognised in the section. These are related to the dendrogram and sample numbers in Figure 4.1. Many of the associations represent a single sample which perhaps suggests that the use of associations in the present sense is unable to provide a broad overview of the change in assemblages in the Gristhorpe section. However the importance that variations in assemblages take place predominantly in grey mudstone lithology in a single section cannot be ignored and interpretation of such changes should be attempted.

Table 4.2. A summary of the associations identified at Gristhorpe Bay.

Associations **Group**	G1	G2	G3	G4	G5	G6	G7	G8
'spores'	>20%	>20%	>25%		>20%	>10%	>10%	
Bisaccate 'pollen'		≥25%	>15%				>30%	
Porate 'pollen'	>15%		>15%	>20%	>10%			
Inaperturate poll.			≥30%	>20%	≥20%	≥20%		>15%
Non-marine acritarchs	>30%	>35%		>20%				
Acritarchs undiff.					≥20%	>30%	>30%	>30%
Species								
E. bella	?							
K. whitfordensis	?							
K. scalbiensis	?							
V. spinoreticulata	?							

Associations G1 and G2 are interpreted as representing floodplain deposition in an environment receiving 'spores' and 'pollen' from a diverse range of habitats. 'spores' of possible significance are notable in G1. The bisaccate percentage of G2 is interpreted as an allochthonous element from a hinterland or marginal marine habitat. Association G3 is interpreted as resulting from floodplain deposition receiving grains from *Araucariacites australis* and *Deltoidospora minor* parent plants in particular.

Again, bisaccate 'pollen' grains are considered an allochthonous element on the floodplain setting.

continued...

Associations Group	G9	G10	G11	G12	G13	G14	G15	G16
'spores'		>20%	>15%	>15%	≥15%			
Bisaccate 'pollen'			>30%			>10%		
Porate 'pollen'		>20%			>30%	>15%		
Sulcate 'pollen'							>20%	<10%
Inaperturate poll.	>35%			>20%				
Non-marine acritarchs	>30%	>20%			>30%	>35%	>35%	>30%
Acritarchs undiff.	>20%			>20%				
Dinocysts		≥10%	>35%	≥10%				≤5%

continued...

Associations Group	G17	G18	G19	G20	G21	G22	G23
'spores'			>20%		≥15%		
Bisaccate 'pollen'			>15%	>25%			>15%
Porate 'pollen'			>10%			>30%	>15%
Inaperturate poll.	>20%	>30%					
Non-marine acritarchs	>30%	>15%	≥20%	>15%		>20%	
Acritarchs undiff.		>20%		>20%	>25%	>15%	
Dinocysts			≥10%	<5%	<5%	<5%	≥35%

Association G4 is dominated by non-marine acritarchs. The constituent species of this group are tentatively considered to represent zygospores of Zygnematacean algae (Van Neem 1967; Head 1992, P. Zippi, University of Toronto, pers. comm. 1991). Contemporary representatives may be encountered in a spectrum of freshwater habitats. The presence of comparable forms in this study along with a moist floodplain spore and 'pollen' flora is interpreted as indicating the existence of freshwater bodies on the hypothesised floodplain environment. G4 has been interpreted as a floodplain freshwater-body assemblage, with a dominance of presumed zygospores at the expense of *Perinopollenites elatoides* and *Araucariacites australis* producing parent plants. The latter may have inhabited marginal habitats or may alternatively have entered the water body during a period of water refreshment (flood conditions) from regions external to the site of deposition.

In Association G6, the *Leiosphaeridia hyalina* grains are tentatively related to *Araucariacites australis*, but their preservation suggests considerable alteration (oxidation during eogenetic pedogenic processes) prior to preservation (Kantorowicz

1990). A tentative suggestion of deposition in a floodplain environment on which *A. australis* producing parent flora grew is proposed. Association G7, judging by its dominating bisaccate 'pollen' percentage, represents a strong allochthonous input onto the floodplain (channel avulsion or similar process). The possibility that such an assemblage represents the products of *Pachypteris papillosa* vegetation (Hill 1975) in a marginal marine environment is discounted by the lack of any marine or marginal marine indicators. Instead a hinterland source for the grains is preferred.

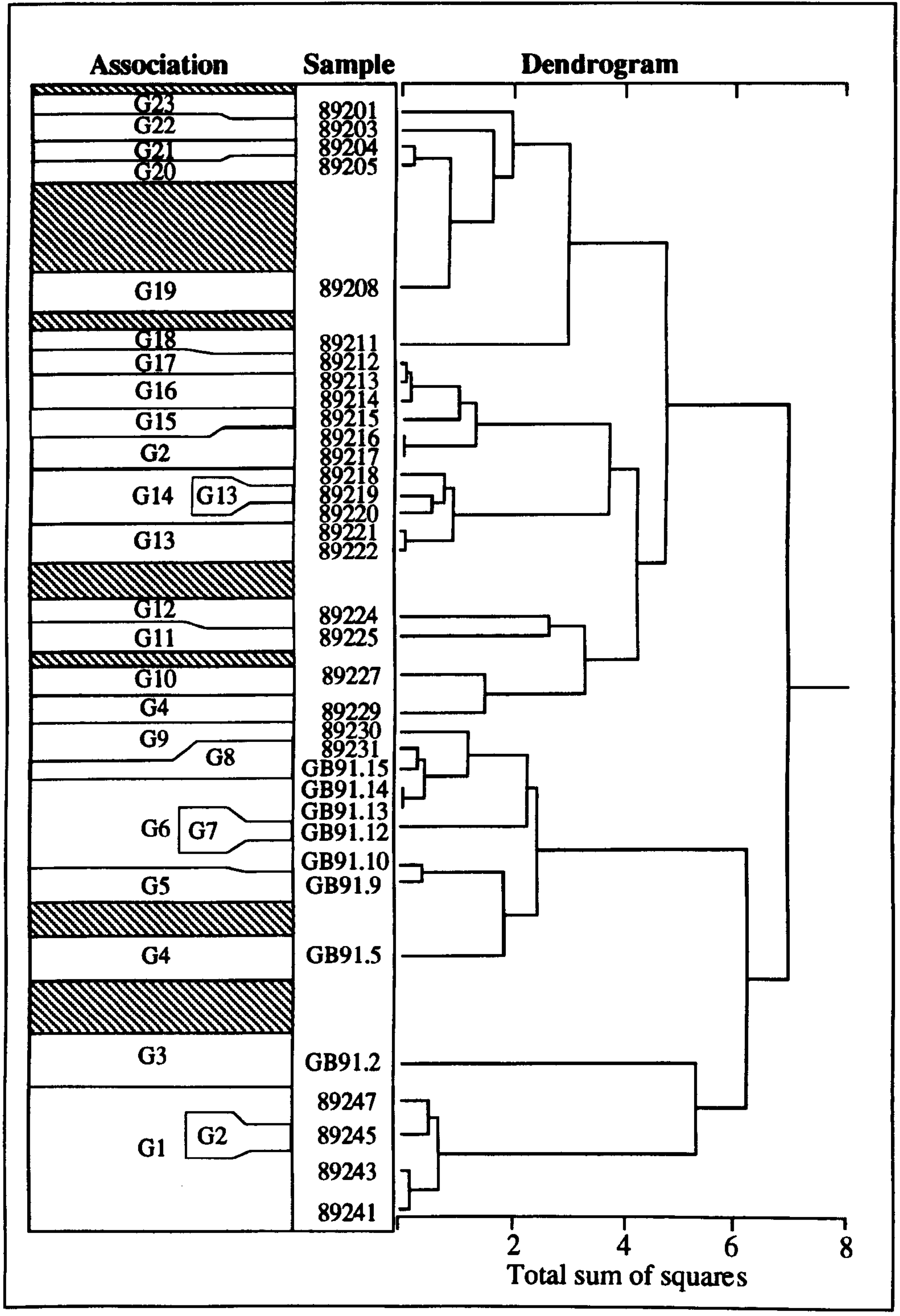


Figure 4.1. Distribution of associations in the Gristhorpe Bay section.

Association G8 is interpreted in a similar manner to G6. The lower percentage of 'spores' compared to G6 suggests the relative rarity of the parent plants in the region during the time of deposition. A similar floodplain environment suggested for G4 is postulated for Association G9. *Leiosphaeridia hyalina* may represent eroded specimens of *Araucariacites australis* or *Hemisphaerium* spp. in this association. Dinocysts influence Association G10. This is interpreted, in the light of the dominant spore and 'pollen' flora, as an allochthonous element possibly introduced onto the floodplain by tidal or storm surge processes.

The dominance of dinocysts (>35%) in Association G11, however, is better interpreted as deposition in a marginal marine environment. This is supported by high percentages of bisaccate 'pollen' (>30%) whose parent flora may have either inhabited coastal habitats analogous to contemporary mangrove ecosystems (Harris 1964), or may have been transported by distributary channels from upland (hinterland) habitats. The dominance of a single species in the dinocyst assemblage is interpreted as representing a monospecific flood event equivalent to the findings of Morzac-Kerfourn (1977), Goodman (1979) and Wall *et al.* (1977) of low diversity, high abundance opportunistic assemblages in inshore waters.

Association G12 again records the influence of marine waters. However the dinocysts are subdominant in an assemblage of 'spores', inaperturate 'pollen' and undifferentiated acritarchs. Thus deposition in a floodplain environment within the influence of tidal or storm surge processes seems most appropriate. Association G13 witnesses a return to floodplain assemblages dominated by *Perinopollenites elatoides* producing parent plants, with additional influence from floodplain water bodies. Co-mingled with the samples representing this association is Association G14 which is interpreted as reflecting deposition in a floodplain freshwater body judging by the dominance of non-marine acritarchs. Transport mechanisms are suggested to be responsible for bringing porate and bisaccate 'pollen' grains into such an environment

Association G15 is again dominated by non-marine acritarchs. However a significant input from sulcate 'pollen' suggests either the proximity of a parent flora producing such 'pollen' (see Appendix 2.1) or avulsion processes in action close proximity to the site of deposition. In Association G16, dinocysts return in minor percentages. The presence of a moderate diversity of cyst forms construed as inhabiting ‘normal’ open marine conditions is interpreted as an indicator of storm surge or tidal processes active within the realm of the floodplain water body. Above this dinocyst influenced association, assemblages are interpreted as representing a return to floodplain water body environments with inputs from *Araucariacites australis* and *Perinopollenites elatoides* producing parent plants in Associations G17 and G18 respectively. Dinocysts return above this event to influence Association G19. Moderate percentages of dinocysts are interpreted along with bisaccate and porate 'pollen' grains, 'spores' and non-marine acritarchs as a mixed source assemblage, which may possibly represent a spectrum of marine influenced floodplain environments.

Marine influences continue upwards towards the top of the section in Association G20. The dominance of bisaccate 'pollen', undifferentiated acritarchs and non-marine acritarchs is interpreted as representing deposition in a floodplain freshwater-body within the influence of distributary waters and occasionally storm surge or tidal waters. In the overlying Association G21, 'spores' and undifferentiated acritarchs dominate along with minor dinocyst percentages. Since non-marine acritarchs are more numerous than inaperturate 'pollen' grains in the assemblage represented by the association, it is possible that the *Leiosphaeridia hyalina* grains which dominate the undifferentiated acritarch category may represent degraded specimens of non-marine acritarchs. Conversely, the leiospheres may also be interpreted as a marine element due to the presence of dinocysts. An environmental interpretation is not proposed because of these ambiguities.

The penultimate association G22 is dominated by porate 'pollen' and non-marine acritarchs along with subordinate undifferentiated acritarchs and dinocysts. Deposition in an environment similar to Association G13 is envisaged with additional influence from marine waters. A marginal marine environment is proposed for the top most Association, G23, which is dominated by dinocysts (≥35%). It is compelling to suggest that this association preempts the worldwide transgressive event which manifests itself in the Cleveland Basin at the base of the Cornbrash Formation a few centimetres overlying Association G23.

4.1.3. Yons Nab section GR [TW 0804 8405]

An important feature of the raw data is a lack of the impoverished assemblages encountered in the Yons Nab Beds, Gristhorpe Member and Scarborough Formation (see enclosure 3). All samples from the Yons Nab Beds, Gristhorpe Member and Scarborough Formation yielded abundant palynomorphs. Thus the phenomena producing the impoverished assemblages is confined to the Scalby Formation in the present study.

Standardised data

The cluster analysis has highlighted some pertinent details of the dataset. All formations are well recognised by the clustering. The groups can be recognised beneath a value of 2.5 sum of squares, with significant breaks in the groupings occurring at the formation boundaries. The dataset suffers from large sample intervals in the Scarborough Formation. It was not possible to further analyse the Scarborough Formation in the present study due to time constraints. The facies at the base of the

Scalby formation (medium grained cross-stratified sandstone) prevented finer scale sampling and comparison with the single sample recovered.

The lowest cluster occurring in the Yons Nab Beds consists of the bottom three samples. They are characterised by the presence of dinocysts and marine acritarchs and moderate percentages of 'spores' and 'pollen' grains. The middle sample, 89002, exhibits a peak of bisaccate 'pollen' at the expense of 'spores'. The following group consists of four samples, 89004 to 89007. The middle two samples exhibit the greatest similarities with high percentages (>40%) of bisaccate 'pollen' at the expense of porate 'pollen' and 'spores' (dinocysts are inconsistently present within the group). The lowest sample, 89004, is notable for its peak of inaperturate 'pollen' (*Callialasporites* spp.). The top most sample, 89007, is significant for exhibiting the highest percentages of 'spores' in the group.

Samples 89008 and 89009.4 have grouped closely on common (>30%) 'spores' and a peak of inaperturate 'pollen' (*Araucariacites australis* in particular), with a consequential low percentage of bisaccate 'pollen'. These two are the first samples devoid of marine palynomorphs and are interpreted as representing the initial non-marine sediments of the Gristhorpe Member. A second close statistical similarity between the samples 89009.5 and 89010 overlies this group. They are characterised by consistently high 'spores' (>40%), <20% inaperturate 'pollen', and the absence of marine elements. These contrast sharply with the overlying four samples (89011 to 89014) which are characterised by marine influence (dinocysts and marine acritarchs), high percentages of porate 'pollen' (in particular *Perinopollenites elatoides*) and low percentages of 'spores'. The laminated sandstone lithology of the samples is distinct from other samples taken from the Gristhorpe Member. The presence of the spore *Neoraistrickia truncata* consistently within this cluster may be of significance. The top most sample of the group, 89014, is outstanding for the occurrence of a peak of the porate 'pollen' *Perinopollenites elatoides*.

Samples 89015 and 89020, the top most samples from the Gristhorpe Member witness a return to spore dominated assemblages (predominately *Deltoidospora minor*) with an absence of marine species.

The basal sample of the Scarborough Formation, 89019, overlies an impersistent intraformational conglomerate at the top of the Gristhorpe Member. It is regarded as representing the reworked top most part of the Gristhorpe Member. This is corroborated by the composition of the palynomorph assemblage, which records a diverse spore and 'pollen' grain assemblage, lacking marine influence. The dominant species present is *Perinopollenites elatoides* and accounts for the high percentage of porate 'pollen'. 'spores' are relatively subdominant to 'pollen' and marine elements are lacking. The remaining three samples of the Scarborough Formation group closely. They are characterised by relatively low percentages of 'spores' and consistently present marine microplankton. The 'pollen' *Perinopollenites elatoides* dominates the assemblages. Other grains consistently present include *Corollina torosus*, *Cerebropollenites mesozoicus*, *Cycadopites minimus* and *Alisporites* complex. The 'spores' *Neoraistrickia truncata* and *Sestrosporites pseudoalveolatus* are considered significant.

The Scalby Formation differs considerably from the underlying Scarborough Formation as indicated by the dendrogram. The assemblage is dominated by 'spores', significantly *Deltoidospora minor*. A number of species previously unencountered in older sediments have their inception in sample 89026. These include *Echinatisporis baculatus*, *Kraeuselisporites scalbiensis*, *Kraeuselisporites whitfordensis*, *Enigmaspora bella*, *Scalbiella reticulata* and *Pararetispora jurassica*. In this respect it compares favourably with sample 89302 from Crook Ness.

Table 4.3. A summary of the Yons Nab associations. X signifies the presence of the form / species is significant; - signifies the absence of the form is significant.

Association Group	Y1	Y2	Y3	Y4	Y5	Y6
'spores'	>40%	<40%	<20%		>40%	>35%
Porate 'pollen'	≤30%	>30%	>30%	>40%	>30%	<10%
Dinocysts	X	X				
Inaperturate 'pollen'			>30%	>10%		>40%
Marine acritarchs		X		-		-
Acritarchs undiff.		X				
Species						
C. minus			X			
C. torosus			X		X	
D. minor	X				X	X
L. hyalina		>5%				
P. elatoides			X	X		

Table 4.3 continued

Association Group	Y7	Y8	Y9	Y10	Y11	Y12	Y13
'spores'	>40%	<20%		>50%	>30%		>40%
Bisaccate 'pollen'				<5%			>25%
Sulcate 'pollen'						>5%	
Porate 'pollen'	≤30%	>40%	>60%		>30%	≥30%	
Dinocysts		X				>5%	
Marine acritarchs	-						
Species							
C. mesozoicus						X	
C. minimus						X	
C. torosus						X	
D. minor				>40%			
E. baculatus							X
E. bella							X
K scalbiensis							X
K. whitfordensis							X
N. truncata						X	
P. elatoides		>30%	>50%				
P. jurassica							X
S. pseudoalveolatus						X	
S. reticulata							X

Interpretation

Thirteen associations have been recognised in the Yons Nab section and are summarised in table 4.3. Figure 4.2 illustrates the distribution of associations compared to the dendrogram.

It is pertinent to consider previous interpretations of the sedimentary facies at Yons Nab due and compare them with facies in the Scalby Formation. The sandstone and siltstone facies of the Yons Nab Beds and basal Gristhorpe Member have been interpreted as shoreface deposits preempting the floodplain sediments which predominate in the Gristhorpe Member (Bate 1967, Hancock & Fisher 1981, Hogg 1989 MS). In this facies alone, six associations have been recognised (see Table 4.3 above). This strongly suggests that such a facies is unreliable for statistical analysis. The strong reworking element encountered in the facies is considered an explanation for the variable and inconsistent assemblages, which lead to the erection of the associations.

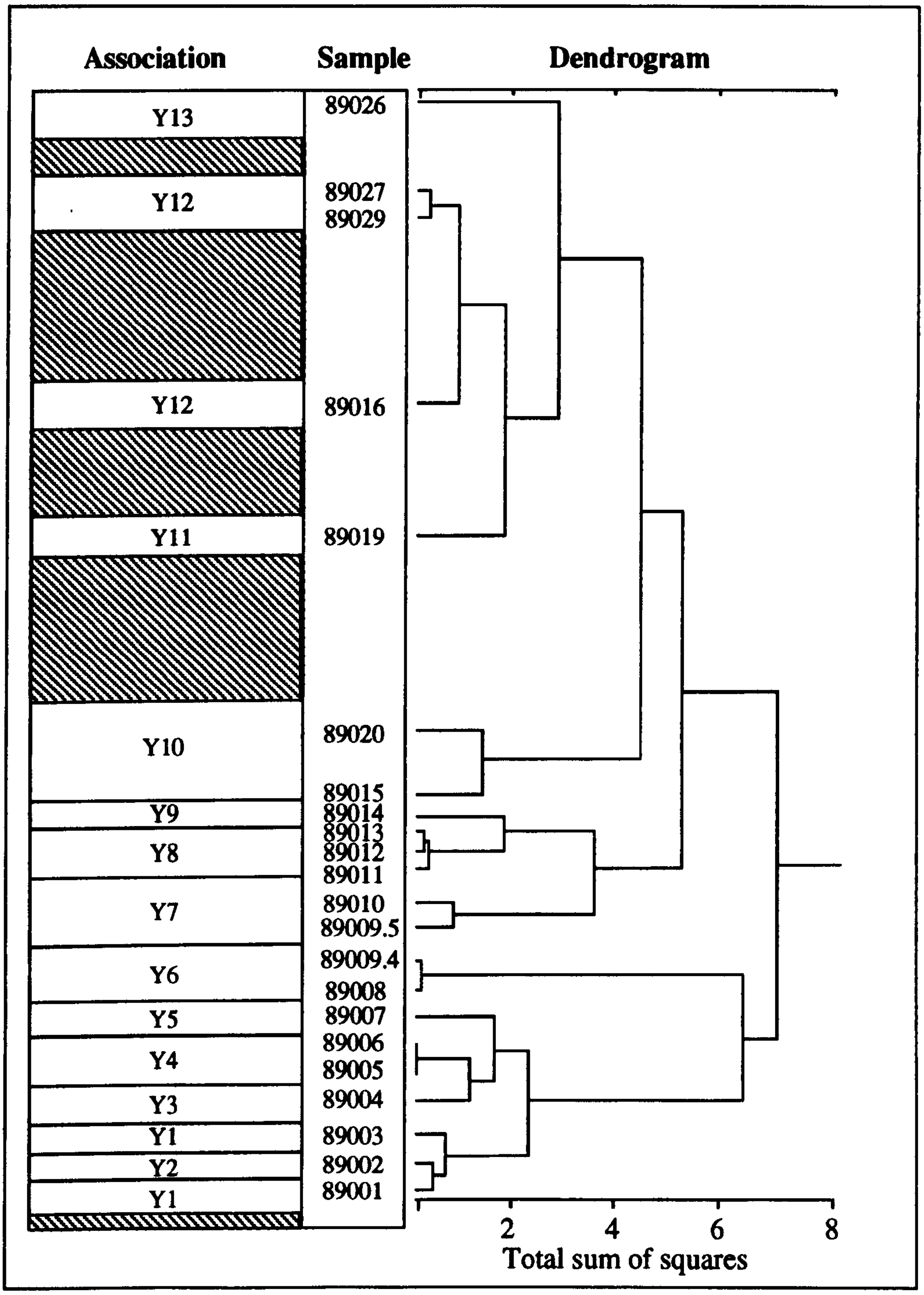


Figure 4.2. Distribution of associations in the Yons Nab section.

The overlying mud dominated sediments of the Gristhorpe Member appear to reflect variable correlations between facies and associations. Association Y6, which is relatively well defined is characteristic of both the uppermost part of a bioturbated sandstone and a silty mudstone the latter of which constitutes part of the Gristhorpe Plant Bed. The overlying Association Y7 is a similar case. Association Y8 exhibits the best correlation with its constituent facies. This sandstone has been interpreted as representing a crevasse splay onto the Gristhorpe Member floodplain (Livera & Leeder 1981, p. 249). Due to the consistent occurrence of marine elements in this association, a causal mechanism invoking tidal surge onto the floodplain is proposed.

Association Y9 is interpreted as representing the re-establishment phase of a moist floodplain flora following the crevasse splay. It lacks marine elements to its assemblage. Association Y10 is interpreted as representing the establishment of a moist floodplain flora, dominated by *Deltoidospora minor* producing plants.

Association Y11 overlies an erosion surface at the top of the Gristhorpe Member and immediately underlies a hummocky cross-stratified sandstone at the base of the Scarborough Formation. It is interpreted as a reworking of the underlying Gristhorpe Member sediments which preceeds the basal Scarborough Formation sand sheet.

Association Y12 is interpreted as representing fully marine sediments in the Scarborough Formation. The previous contention of Hancock & Fisher (1981) that the formation at Yons Nab represents brackish lagoonal conditions cannot be substantiated on the basis of the present assemblages. An open marine environment is proposed for the samples constituting Association Y12. The previous recordings of *Phallocysta* spp. (Smelror 1991, J. Keating pers. comm.) from sediments interpreted as representing normal salinities corroborates this.

Association Y13 records a diverse floodplain flora. The occurrence of the association in a laminated shale in the basal sand body is interpreted as representing a phase of mud deposition during a low flow regime in the river or possibly following channel abandonment.

4.1.4. Crook Ness [TW 0215 9307]

A single sample from the 27 studied at Crook Ness (89313) yielded an impoverished assemblage. The thirteen specimens recovered from the sample are dominated by leiospheres and inaperturate 'pollen' (*Araucariacites australis*). The assemblage is comparable with the underlying assemblage in sample 89312. High sample density in the section around the dinosaur footprint bed of Hargreaves (1914) causes the saw tooth diagrams to become extremely serrated in that part of the section.

Standardised data

All the groupings apparent on the dendrogram can be recognised at the level of 2 sum of squares (see enclosure 4). The lowest grouping clusters the three samples 89301-89303 and is characterised by moderate percentages of 'spores', present in high diversity, bisaccate and porate 'pollen'. Sample 89303 is distinctive on the basis of a peak in the porate 'pollen' *Perinopollenites elatoides*. The overlying sample 89304 differs significantly in exhibiting a considerably reduced diversity in the spore flora.

The inaperturate grain *Araucariacites australis* dominates the assemblage. The subsequent three samples 89305, 89306 and 89318 bear few statistical similarities with each other. This reflects an alternation between the two assemblage types; spore dominated assemblages (89305, 89318) versus assemblages dominated by *A. australis* (89306).

The overlying cluster contains both strongly similar and strongly dissimilar groupings. Samples 89318, 89319 and 89320 are dominated by 'spores' (significantly *Deltoidospora minor*) and apart from a peak of the 'pollen' grain *Perinopollenites elatoides* in sample 89318, they are significantly similar. The overlying sample 89321 is characterised by a peak of the bisaccate 'pollen' *Alisporites* complex at the expense of other 'pollen' groups and 'spores'. Samples 89322 and 89324 are dominated by *A. australis*. The two samples are considered dissimilar, however, on the basis of the presence of dinocysts and marine acritarchs in sample 89324. Sample 89323 witnesses a return to 'spores' dominated assemblages. As with sample 89324, the presence of dinocysts and marine acritarchs is regarded as significant.

The great dissimilarities between sample 89323 and the overlying sample 89326 reflect a change from spore dominated assemblages to an assemblage with the 'pollen' grain *Araucariacites australis* abundant. The overlying part of the dendrogram for the section suggests that the constituent samples share greater similarities with each other than with those of the lower part of the section. The lower most cluster of this group consists of samples 89327, 89328 and 89329 and is characterised by dominant 'spores' (particularly *D. minor*) in conjunction with moderate percentages of inaperturate 'pollen'. The lower most sample is the least similar of the group due to a minor peak of *D. minor* and a relatively low percentage of bisaccate 'pollen' compared to others in the group. Overlying this group, sample 89307 sees a return to a spore dominated assemblage (*D. minor* and *Dictyophyllidites harrisii* in particular), in conjunction with moderate inaperturate 'pollen' percentages and low bisaccate 'pollen' percentages. This contrasts with the overlying sample 89308 which displays a co-dominance of 'spores' and bisaccate 'pollen' at ~40%. The predominant species remain *A. australis, D. minor* and *D. harrisii*. Strong similarities between the overlying samples 89309 and 89310 appear to be due to high percentages of 'spores'. Subtle differences between the samples are manifest with 89309 revealing minor peaks of *P. elatoides* and *Densoisporites velatus*, and sample 89310 displaying a peak of *D. minor*. As with sample 89308, sample 89312 witnesses a peak of inaperturate 'pollen' (*A. australis*) at the expense of the spore sum. The sulcate 'pollen' peak is primarily a function of a minor peak of *Cerebropollenites mesozoicus*.

The top most grouping consists of samples 89314 to 89317. The least similar of the bunch, 89317, sees a major peak of bisaccate 'pollen' along with moderate percentages of 'spores'. The underlying group of three samples reflects the dominance of 'spores' (*D. minor* and *D. harrisii* in particular). Minor differences within the group are due to peak of 'spores' in the lowermost sample 89314, a peak of *Alisporites* complex in sample 89315 and a peak of *Perinopollenites elatoides* in sample 89316.

Table 4.4. A summary of the associations at Crook Ness. X indicates significant occurrence; ? indicates species of possible significance.

Association Groups	C1	C2	C3	C4	C5	C6	C7
'spores'	>40%	<20%	>50%	>60%	>40%	>30%	>30%
Bisaccate 'pollen'	>15%		>10%		>40%		
Porate 'pollen'	>10%		>10%				
Dinocysts							X
Inaperturate 'pollen'		>40%				>30%	>30%
Species							
Echinatisporis baculatus	?						
Enigmaspora bella	?						
Kraeuselisporites scalbiensis	?						
Kraeuselisp. whitfordensis	X						
Scalbiella reticulata	?						
Varivaginaspora reticulata	?						

Table 4.4 continued.

Association Groups	C8	C9	C10	C11	C12	C13	C14
'spores'	>50%		>50%	<50%	>40%	>50%	>50%
Bisaccate 'pollen'	>10%		<10%	≥20%		>20%	
Porate 'pollen'	>10%						>20%
Dinocysts	X						
Inaperturate 'pollen'		>70%	>15%	>15%	>40%	>10%	
Species							
Echinatisporis baculatus							X
Enigmaspora bella							X
Kraeuselisporites scalbiensis							X
Kraeuselisp. whitfordensis							X

Interpretation

The thirteen associations recognised in the section are summarised in table 4.4. Their distribution is shown in figure 4.3.

The diverse spore flora recorded in Association Cl is considered to represent a moist floodplain flora. Furthermore, the association of abundant macro-palaeobotanical material in the silty mudstone lithology is interpreted as the result of deposition in moist, possibly waterlogged conditions. High species diversity, particularly in sample 89302 may indicate that the site of deposition received spore and 'pollen' grains from several floodplain habitats.

Association C2 is considered to represent deposition on the floodplain in an environment dominated by *Araucariacites australis* producing parent plants. A single recording of a marine acritarchs in sample 8906 is not considered significant.

Association C3 is interpreted as indicating deposition in a floodplain environment dominated by *Deltoidospora minor* and *Dictyophyllidites harrisii* producing parent plants. The presence of bisaccate 'pollen' is inferred as an allochthonous element. Likewise, Association C4 is interpreted in a similar way. However it lacks a significant allochthonous element.

Equal percentages of 'spores' and bisaccate 'pollen' characterise Association C5. A significant input from upland or coastal floral elements (bisaccate 'pollen') is interpreted from this. Association C6 is deciphered as representing sediment receiving dominant inputs from *Araucariacites australis, Deltoidospora minor* and *Dictyophyllidites harrisii* parent floras. This is also the case for Association C7 but the latter differs in exhibiting marine influence (dinocysts). Thus a terrestrial environment within the influence of marine water (e.g. a floodplain exposed to storm surge or tidal flood events) is proposed.

Marine influence is also characteristic of Association C8. However the terrestrial flora is dominated by 'spores', with a minor bisaccate and porate 'pollen' grain input. A similar environment to C7 is envisaged for Association C8, despite the differences in the composition of the land flora. Association C9 is interpreted as representing a floodplain setting receiving an overwhelming input from *A. australis* producing parent vegetation. Association C10 is dominated by 'spores' (*D. minor* and *D. harrisii*) and inaperturate 'pollen' (*A. australis*). In addition, a minor percentage of bisaccate 'pollen' is characteristic. A floodplain setting is envisaged, with minor inputs from channel avulsion to explain the presence of bisaccate 'pollen'. Association C11 is similar but witnesses a greater input of bisaccate 'pollen' with a resulting reduction in the spore percentage.

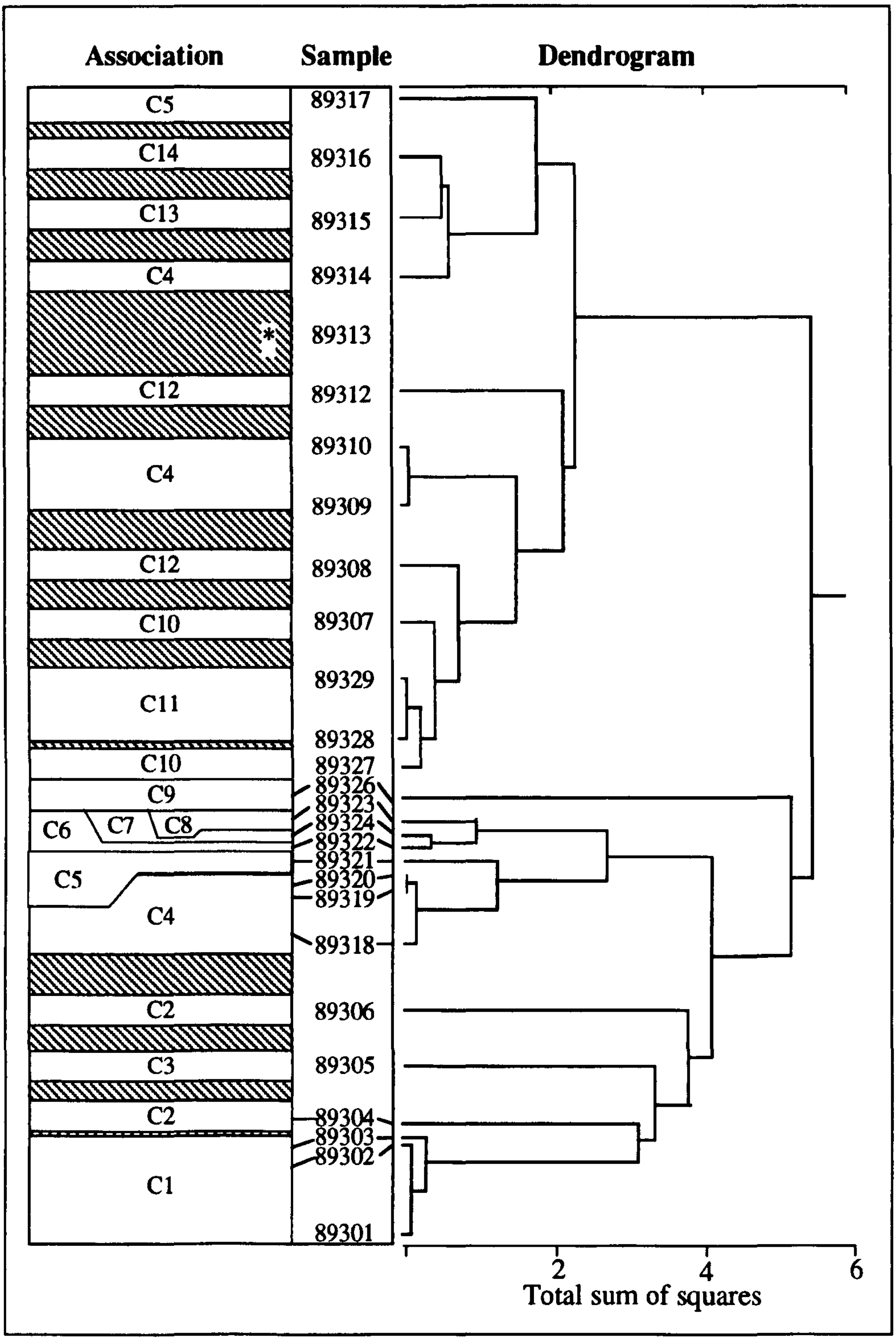


Figure 4.3. Distribution of associations in the Crook Ness section.

Association C12 compares closely with C6 and the latter's interpretation is followed here. Association C13 is dominated by 'spores' (*D. minor* and *S. harrisii*), bisaccate 'pollen' and inaperturate 'pollen' (*A. australis*). A similar floodplain environment as proposed for associations C10 and C11 is envisaged. The ultimate association, C14, witnesses a return to a diverse spore flora as encountered in C1. A similar floodplain scenario is again proposed.

4.1.5. Saltergate [NZ 9501 8415]

Nine samples yielded insufficient palynomorphs for statistical methods to be applicable. Thus samples SALT3, 5, 6, 8, 12, 20, 29, 34 and 36 have been excluded from the standardised data set. These assemblages will be discussed in the raw data section. In addition, the contact of the Long Nab Member with the overlying Cornbrash Formation was not identified in the field due to poor exposure. Based on the assemblage characteristics, the boundary is placed between samples SALT17 and 18 (this is based on the dramatic increase in the occurrence of *Ctenidodinium combazii* and *Lithodinia caytonensis* in samples SALT17 and 16).

Raw data

The non-standardised (raw) data set shows the presence of impoverished assemblages in several samples in the section (see Table 4.5). Species diversity in these samples varies from 3 (SALT3) to 15 (SALT6). Microplankton were identified in samples SALT 5, 6, 12 and 34. All samples are dominated by 'spores' and 'pollen' grains, particularly *Deltoidospora minor*, *Concavisporites toralis* and *Perinopollenites elatoides*. The samples do not appear to reflect dramatic changes in the composition of the parent floras producing the species. It appears more likely that some species-independent control may have affected the primary assemblages and thus lead to the preservation of an impoverished assemblage.

Standardised data

Cluster analysis undertaken using the percentage data is represented in the form of a dendrogram at the end of enclosure 5. The Saltergate outcrop will be described from the base to the top of the section.

The lowest group covers the bottom eight metres of the section and can be defined by the consistent low occurrence of non-marine acritarchs (≤10%), porate and sulcate 'pollen' and common (≥50%) 'spores'.

The cluster analysis has grouped the lowermost two samples, SALT1 and 4, indicating compositional similarity. Both samples have high percentages of 'spores' (≥70%), dominated by *C. toralis*, *D. minor* and *T. aequiverrucatus* . SALT4 differs from SALT1 in the absence of dinocysts and the presence of non-marine acritarchs. SALT9 and 10 have been grouped by virtue of the consistent sparsity of non-marine acritarchs, porate and sulcate 'pollen'. However a less similar cluster compared to the lowest two samples considered is due to differences in the percentages of 'spores', bisaccate and inaperturate 'pollen' grains between SALT9 and 10.

Table 4.5 Composition of statistically insignificant assemblages in the Saltergate section; most common species to least common.

Sample and lithology	**Species**
SALT3; grey silty mudstone	*Deltoidospora minor, Concavisporites toralis, Alisporites grandis*
SALT5; grey silty mudstone	*Deltoidospora minor, Dictyophyllidites equiexinus, Lecaniella varireticulata, Perinopollenites elatoides, Concavisporites toralis, Hemisphaerium simplex, Densoisporites velatus, Tuberositriletes aequiverrucatus, Densoisporites circumundulatus, Callialasporites dampieri*
SALT6; grey silty mudstone	*Concavisporites toralis, Dictyophyllidites spectabilis, Deltoidospora minor, Densoisporites circumundulatus, Alisporites* complex, *Lecaniella varireticulata, Lithodinia* sp. indet., *Callialasporites dampieri, Tuberositriletes perverrucatus, Dictyophyllidites equiexinus, Araucariacites australis, Perinopollenites elatoides, Dictyophyllidites harrisii, Tuberositriletes aequiverrucatus, Ctenidodinium combazii*
SALT8; grey mudstone	*Deltoidospora minor, Densoisporites velatus, Tuberositriletes aequiverrucatus, Concavisporites toralis*
SALT12; grey mudstone	*Deltoidospora minor, Deltoidospora australis, Alisporites* complex, *Dictyophyllidites spectabilis, Biretisporites potoniaei, Lecaniella varireticulata, Dictyophyllidites harrisi, Corollina simplex, Densoisporites velatus, Tuberositriletes aequiverrucatus, Chasmatosporites hians, Nannoceratopsis gracilis, Botryococcus braunii, Leptolepidites major*
SALT20; grey mudstone	*Perinopollenites elatoides, Cerebropollenites mesozoicus, Deltoidospora minor, Lecaniella varireticulata, Concavisporites toralis, Alisporites* complex, *Tuberositriletes variverrucatus, Tuberositriletes perverrucatus, Araucariacites australis, Callialasporites microvelatus, Callialasporites dampieri*
SALT29; grey mudstone	*Alisporites* complex, *Lecaniella varireticulata, Deltoidospora minor, Dictyophyllidites harrisii, Biretisporites potoniaei, Hemisphaerium sprigii, Dictyophyllidites spectabilis, Tuberositriletes aequiverrucatus*
SALT34; grey siltstone / fine sandstone	*Concavisporites toralis, Araucariacites australis, Deltoidospora minor, Tuberositriletes aequiverrucatus, Lecaniella varireticulata, Dictyophyllidites harrisii, Dictyophyllidites spectabilis, Ctenidodinium combazii*

SALT36; grey mudstone	*Araucariacites australis, Hemisphaerium giganteum, Lecaniella varireticulata, Exesipollenites laevigatus, Deltoidospora minor*

SALT11 is significantly dissimilar to its neighbouring samples. The occurrence of ≥20% bisaccate and inaperturate 'pollen' and relatively low 'spores' percentage is conspicuous. SALT46 to 41 samples above have some of the closest clustering observed on the dendrogram. Here the consistent high frequency of 'spores' (≥70%) and low occurrence of bisaccate 'pollen', non-marine acritarchs (both ≥10%) and inaperturate 'pollen' (≤5%) appears to be the distinguishing factor. The conspicuous assemblage of SALT11 has apparently divided an otherwise relatively homogeneous grouping.

The episode of marine influence recorded in sample SALT1 (the presence of *C. varispinosum*, *C. combazii*, *Lithodinia* spp. and *P. prolongata*) has not been picked out on the dendrogram. This suggests that the occurrence of dinocysts in low numbers in an otherwise spore and 'pollen' grain dominated assemblage is of little statistical significance; little variation in the spore and 'pollen' grain assemblage is apparent. The dinocysts are therefore interpreted as an allochthonous element in a predominately terrestrial setting.

Samples SALT38, 39 and 40 are distinguished from the underlying group of samples by an increase in sample dissimilarity (increase in the total sum of squares). An increase in non-marine acritarchs (in particular *H. giganteum*, *H. parvum* and *L. varireticulata*) is characteristic of these samples. This is in contradistinction to a decrease in the percentage of 'spores'. Such an assemblages change preempts the overlying SALT37 sample which records the dominance of non marine acritarchs (especially *L. varireticulata* and *H. simplex*) at the expense of the majority of other palynomorph species.

The overlying samples SALT35 and SALT32 are grouped on the basis of a dramatic reduction in the percentage of non-marine acritarchs and the consequent increase in 'spores' and bisaccate 'pollen'. The 'pollen' are most abundant in the lower SALT35 sample whereas the 'spores' dominate SALT32. Of particular significance is the occurrence of the 'spores' *T. aequiverrucatus* and *T. horridus* in significant numbers (>10%) in SALT32. In the overlying samples SALT30 and SALT31, a rapid increase in non-marine acritarchs is once again apparent (*H. simplex* and *L. varireticulata* predominate). The coincidence of *Araucariacites australis* along with non-marine acritarchs may reflect forms of non-marine acritarch affinity rather than Araucariaceous affinity (the simple morphology of *A. australis* can be difficult to differentiate from forms of *Hemisphaerium* species).

The overlying grouping inlcudes SALT24 to SALT27. SALT27 is least similar of the group and is characterised by a dominance of 'spores' (of significance here is *N. truncata* in sizeable numbers along with *D. harrisii*). *Batiacasphaera* sp. DB1 was also recovered from this horizon in small numbers. It is of interest to compare the distribution of *N. truncata*: there appears to be an association with marine microplankton, especially in the Scarborough Formation (see Yons Nab section). Additionally, a change in the non-marine assemblage is clear ; *E. tumulus, P. elatoides, C. torosus, C. minimus, L. argenteaeformis* and *R. clavatoides* all appear to be significant in this respect. Thus the occurrences of dinocysts and marine acritarchs are less likely to be allochthonous elements when the assemblage change and separate grouping of the dendrogram are considered. The occurrence of a seaward shift in facies at this point is compelling. SALT24 to 26 bear closer similarities to each other, with a decrease in the number of 'spores' compared to SALT27 and a consequential increase in inaperturate 'pollen' (*A. australis* and *Callialasporites* spp.) in SALT26 and an increase in bisaccate 'pollen' grains (*Alisporites* complex) in SALT25 and 24.

A further dramatic change in assemblage is reflected in the cluster of samples SALT21 and 22. Here non-marine acritarchs dominate the assemblage (*L. varireticulata* and *Hemisphaerium* spp.). The distance between the SALT23 to 26 cluster and SALT21 to 22 cluster is in excess of 22 total sum of squares (indicating significant dissimilarities). The distance between SALT21 to 22 cluster and the overlying SALT 16 to 19 cluster is almost equally as large. A significant change occurs at the base of the SALT16 to 19 cluster, with the incoming of dinocysts and marine acritarchs which are consistently present to the top of the section. Associated with this and giving rise to the dissimilarity in clusters is the decrease in abundance of 'spores' (diversity is not affected) along with the dramatic increase in porate 'pollen' (*P. elatoides*), sulcate 'pollen' (*C. mesozoicus*) and inaperturate 'pollen' (*A. australis* and *Callialasporites* spp.). Of the spore species, *K. whitfordensis, K. scalbiensis* and *S. pseudoalveolatus* appear to be of significance. The SALT16 to 19 cluster is subdivided into two on the basis of <15% dinocysts, <10% bisaccate 'pollen', <5% sulcate 'pollen' and high inaperturate 'pollen' grains typical of SALT18 and 19. This distribution is reversed with SALT16 and 17, with >20% dinocysts, <10 % 'spores', ≥10% bisaccate 'pollen', >20% sulcate 'pollen' and <10% inaperturate 'pollen'. The association of *C. mesozoicus* and *C. minimus* in SALT16 and 17 is regarded as significant.

Interpretation

Eight groupings have been identified based on the proportions and presence or absence of individual species and groups of species. The associations are depicted in Figure 4.4 and Table 4.6 summarises the associations.

Association SA1 is considered to reflect the predominant input from a moist floodplain flora dominated by spore producing parent plants. A similar scenario is proposed for SA2. However, common bisaccate 'pollen' (considered an upland floral element and possible marginal marine signature) in an otherwise moist humid floodplain assemblage is considered an allochthonous element. A mechanism such as channel avulsion would explain the presence of hinterland and / or marginal marine elements in the assemblages.

Table 4.6. A summary of associations from the Saltergate section. X marks significant species; ? marks questionably significant species.

Association **Groups**	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8
'spores'	>50%	>35%	>40%			<30%		<10%
Bisaccate 'pollen'	<15%	>20%				>20%	<10%	≥10%
Porate 'pollen'	≤10%	<10%						
Sulcate 'pollen'	<5%	<5%					<5%	>20%
Inaperturate 'pollen'							>15%	<10%
Non-marine acritarchs	<10%		>30%	>80%				
Marine acritarchs								
Dinocysts					X		<15%	>20%
Significant taxa								
A. australis						≥20%		
C. mesozoicus								>15%
C. minimus					X			X
C. toralis	X							
C. torosus					X			
D. harrisii					>10%			
D. minor	X							
D. spectabilis		?						
D. velatus	X							
E. tumulus					X			
I. variegatus					X			
K. scalbiensis							X	
K. whitfordensis							X	
L. argentaeformis					X			
N. truncata					>5%			
M. couperi			?					
R. clavatoides					X			
S. pseudoalveolatus							X	

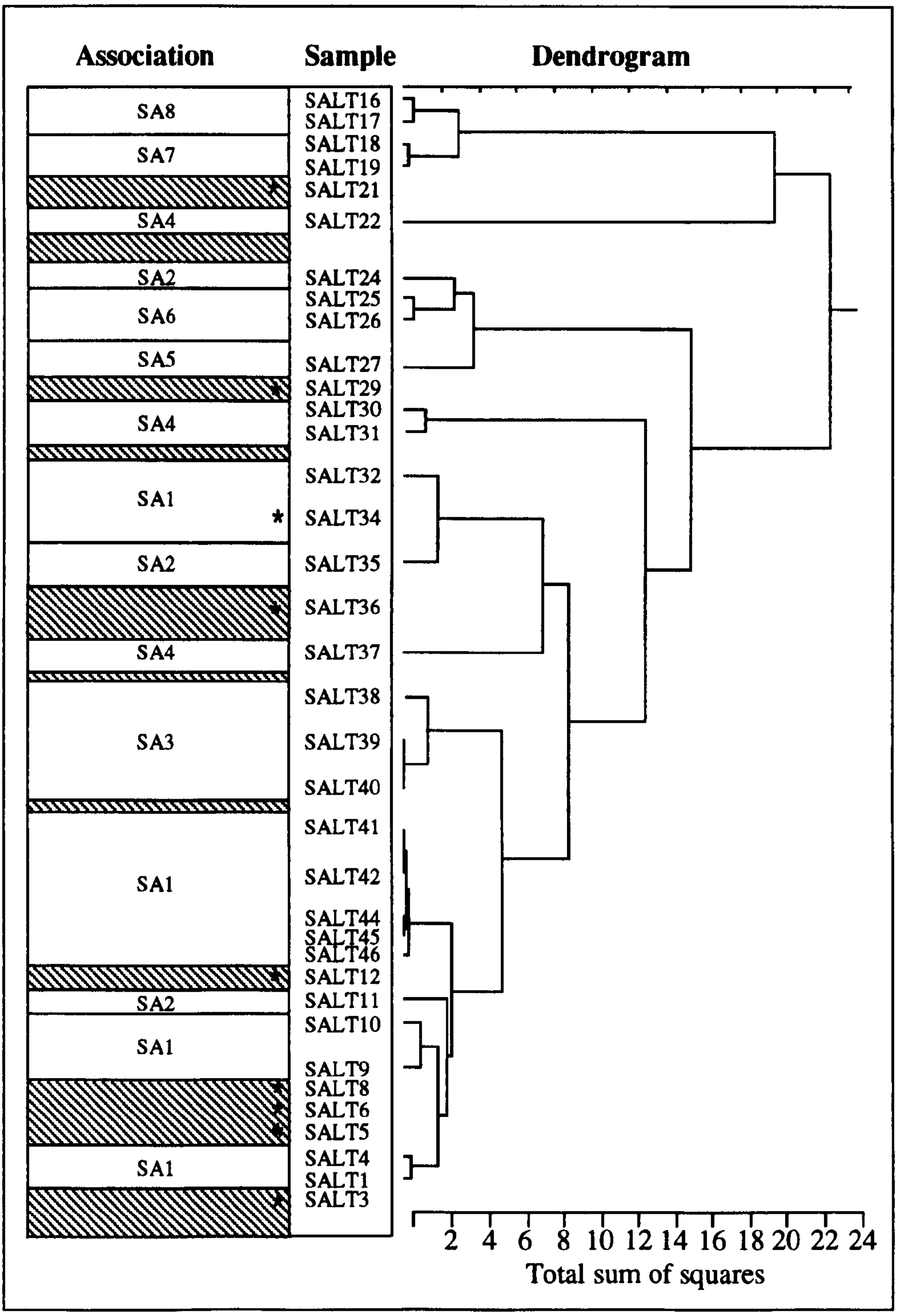


Figure 4.4. Distribution of associations in the Saltergate section; asterisks indicate the position of impoverished samples.

SA3 is characterised by an admixture of moist floodplain floral elements and non-marine acritarchs. The presence of presumed zygospores of Zygnemataceae in this study along with a moist floodplain spore and 'pollen' flora is interpreted as indicating the existence of freshwater bodies on the hypothesised floodplain environment. The mixing of moist floodplain floral elements and non-marine acritarchs may indicate a marginal lake assemblage. SA4 has been interpreted as a freshwater lake assemblage, channel avulsion is a potential explanation for the introduction of the 'pollen' grains.

with a dominance of presumed zygospores at the expense of other palynomorph groups.

The SA5 association is quite distinct from the underlying association. The presence of dinocysts and marine acritarchs along with a distinctive spore and 'pollen' flora is interpreted as representing a marginal marine influenced floodplain environment. Thus the change from a floodplain lake association to a marine influenced floodplain association is interpreted as a seaward shift in facies. The overlying SA6 association is interpreted as a landward progression into a less marginal marine floodplain flora.

SA8 is considered to represent a fully marine shelf setting. In this section, SA8 is confined to the Cornbrash Formation. The distinction between SA8 and SA7 associations portrayed on the dendrogram is relatively small. Thus the SA7 association is interpreted as a saline influenced coastal swamp environment. The relatively close clustering of SA8 and SA7 has further implications. It suggests that the palynomorph assemblages of the top Long Nab Member and the Cornbrash Formation are relatively similar. This is considered to support evidence stated elsewhere (see Marine Palynostratigraphy section) of a relatively small time gap between the Scalby and the Cornbrash Formations.

4.1.6. Talbot Wood [NZ 9512 8317]

A restricted outcrop consisting of the top six metres of the Long Nab Member was sampled at Talbot Wood (see enclosure 6). This section, along with the Saltergate section, provided the material for the study of Riding & Wright (1989). Eleven samples were taken for the present study, with the top-most sample lying above the bored surface considered by Riding & Wright (1989) to represent the boundary between the Scalby Formation and the Cornbrash Formation. Despite general abundance of palynomorphs in the samples, two (samples 89405 and 89407) of the twelve samples yielded an impoverished asssemblage. The composition of the assemblage is given in table 4.7.

Consideration of the causes of palynomorph impoverishment in samples have not concerned previous publications. Muller (1958) recognised that palynomorphs acted as sedimentary particles of silt grade in the depositional environment. It is likely therefore that sedments with low percentages of silt grade material are likely to be lacking in palynomorphs relative to those rich in silt grade sediment. This is a possible explanation for sample 89405. However, in the mudstone sample 89407, alternative mechanisms for the absence of organic matter must be proposed. Kantorowicz (1990) postulated that a spectrum of eogenetic processes were in operation during the deposition of the Scalby Formation. These included pedogenesis in well drained soil profiles. In such a regime, oxidation of organic material would dominate, leading to an impoverishment of the organic matter preserved. Pedogenic processes such as this are tentatively suggested to be the cause of the impoverished assemblage in sample 89407.

Table 4.7. Composition of statistically insignificant assemblages from the Talbot Wood section; most common species to least common.

Sample and Lithology	Assemblage
89405; olive green fine sandstone, brittle	*Deltoidospora minor, Dictyophyllidites harrisii, Araucariacites australis, Alisporites* complex, *Concavisporites toralis, Cycadopites carpentieri, Densoisporites velatus, Perinopollenites elatoides, Tuberositriletes horridus.*
89407; medium grey mudstone with iron staining.	*Tuberositriletes horridus, Concavisporites toralis, Alisporites* complex, *Deltoidospora minor, Lithodinia* sp. indet., *Cerebropollenites mesozoicus, Perinopollenites elatoides, Araucariacites australis, Ctenidodinium combazii, Leptolepidites argenteaeformis, Callialasporites dampieri, Callialasporites minus, Cibotiumspora jurienensis, Cleistosphaeridium varispinosum, Cycadopites minimus, Densoisporites velatus, Exesipollenites tumulus, Gleicheniidites senonicus, Hemisphaerium simplex, Neoraistrickia truncata, Punctatisporites minor, Sestrosporites pseudoalveolatus.*

Standardised data

The most significant point regarding the dendrogram (enclosure 6, figure 4.5) is the general similarities of the assemblages indicated by the low total sum of squares values of the clusters. Other sections in the study illustrate considerably higher levels of sum of squares. The low values in the Talbot Wood section are attributed to the small dataset relative to other sections . The lowest two samples, 89401 and 89402 have clustered very closely and are characterised by high values of 'spores' and bisaccate 'pollen' (both groups ≥40%). The overlying sample 89403 differs in exhibiting a peak in the percentage of dinocysts at the expense of bisaccate 'pollen'. The dinocysts *Ctenidodinium combazii* and *Lithodinia caytonensis* are particularly prevalent in this sample. Minor peaks of porate, sulcate and inaperturate 'pollen' are additionally apparent.

Sample 89404 is dominated by non-marine acritarchs (>60%), in particular *Hemisphaerium simplex*. All other groups are reduced in their dominance, with only 'spores' and dinocysts present in any significant percentages. The high percentages of non-marine acritarchs produce the large dissimilarities in the dendrogram both with the underlying and overlying samples. The subsequent sample (89406) is characterised by relatively high percentages (>20%) of sulcate 'pollen', in particular *Cycadopites* *carpentieri*. The presence of dinocysts (>5%) is of importance. Additionally, 'spores', bisaccate and inaperturate 'pollen' are present in moderate percentages. Intervening between these two samples is the impoverished sample 89405, which lacks the influence of dinocysts and non-marine acritarchs (compare with 89406 and 89404) and is dominated by 'spores' and 'pollen' grains. It is interesting to compare the three assemblages considering that they are all of the same lithology. Sample 89407 is dominated by 'spores' with a noticable input from 'pollen' grains and dinocysts. The succeeding sample 89408 sees a return to dominance by 'spores' (>60%), in particular *Deltoidospora minor*, with porate 'pollen', *Perinopollenites elatoides* and *Corollina torosus*, present in significant percentages (>20%).

Sample 89409 is dominated by 'pollen' grains; bisaccate, porate and inaperturate 'pollen' grains are all present in moderate percentages. The species *Alisporites* complex, *Perinopollenites elatoides* and *Araucariacites australis* are predominant. The overlying sample (89410) is similar but differs in having a greater percentage of 'spores' (>50%). The dominant spore species are *Concavisporites toralis* and *Tuberositriletes horridus*. The increase in 'spores' is accompanied by a reduction in the percentages of porate and bisaccate 'pollen', although the inaperturate 'pollen' *Araucariacites australis* is still present in significant percentages. The penultimate sample in the section (89411)

Table 4.8. A summary of the Talbot Wood associations.

Association Group	T1	T2	T3	T4	T5	T6	T7	T8	T9
'spores'	>40%				>60%	>40%	>50%	>60%	
Bisaccate 'pollen'	>40%					>30%			
Porate 'pollen'						>20%			>20%
Sulcate 'pollen'				>20%					>20%
Inaperturate poll.							>20%		
Marine acritarchs									
Non-marine acrit.			>60%						
Dinocysts		>20%		>5%					>20%
Significant species									
C. carpentieri				>20%					
C. mesozoicus									>20%
T. horridus								>40%	

witnesses a peak of 'spores' approaching 80%. The dominant constituent is *Tuberositriletes horridus*, with *Tuberositriletes aequiverrucatus* simultaneously attaining a minor acme. Sample 89412 was collected from the basal sediments of the Cornbrash Formation. The assemblage reflects a significant facies change, with the sudden increase in the dinocyst percentage to >20%. Synchronous with this are increases in the porate and sulcate 'pollen' percentages. The 'pollen' *Perinopollenites elatoides*, *Exesipollenites tumulus* and *Cerebropollenites mesozoicus* all experience dramatic increases in their abundances.

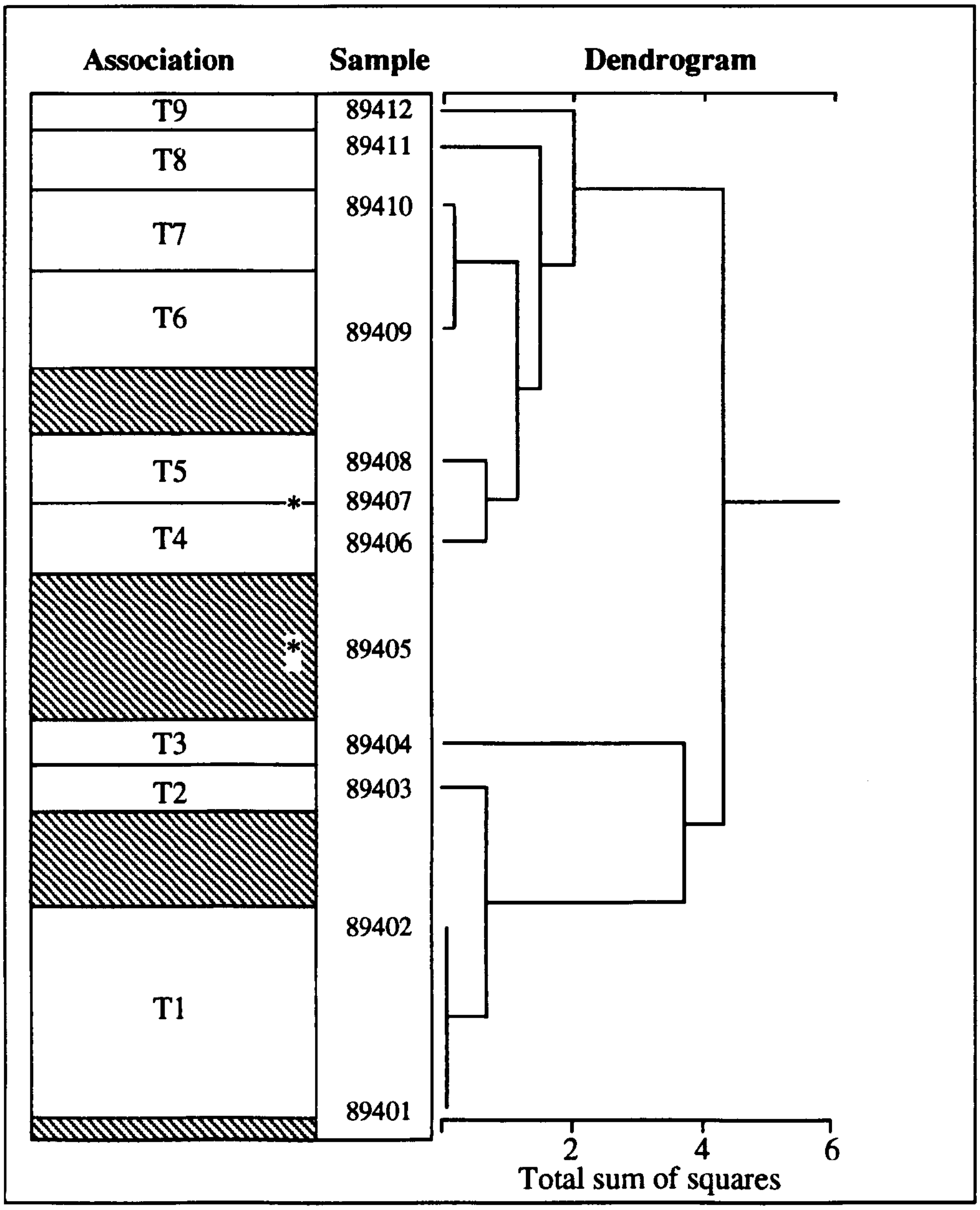


Figure 4.5. Distribution of associations in the Talbot Wood section; asterisks mark impoverished assemblages..

Interpretation

Eight associations are identified in the section (Table 4.8, figure 4.5).

Association T1 is considered to represent a terrestrial sediment by virtue of its high spore and 'pollen' grain content. The presence of dinocysts is considered an allochthonous element in the assemblage. Due to the relatively diverse spore flora represented in the association, the bisaccate 'pollen' are also possibly a signature of particle transport into the area of sediment deposition. A moist floodplain environment with external input from distributary channel avulsion is a possible scenario.

Association T2 contains a significant amount of dinocysts along with 'spores'. In other associations with a large percentage of dinocysts, biasaccate 'pollen' are present in significant numbers. This is not the case with Association T2. Despite this, a paralic or marine influenced swamp environment is proposed as a suitable analogue, based on the common occurrence of dinocysts.

Association T3, is dominated by non-marine acritarchs. As remarked previously, the affinity of certain species is suggested to be with zygospores of the Zygnemataceae. This is tentatively proposed for the dominating species in association T3, *Hemisphaerium simplex*. Other notable occurences in the association include dinocysts and 'spores'. An environment supporting zygnemataceae is proposed for this assemblage, with inputs from external sources explaining the presence of the dinocysts. A floodplain freshwater-body, susceptible to periodic drying and nearby distributary channel avulsion is proposed.

Association T4 is notable for its high percentage of sulcate 'pollen' grains along with moderate percentages of 'spores', bisaccate 'pollen' and dinocysts. A marine influenced floodplain environment is suggested as an analogue on the basis of the dominating spore and 'pollen' grains.

Association T5 is interpreted as a moist floodplain flora on the basis of the dominating spore assemblage. A minimum allochthonous element is represented by negligible percentages of dinocysts and bisaccate 'pollen'.

Association T6, with an admixture of 'spores', bisaccate and porate 'pollen' is considered to represent a mixed source assemblage. However, since the dominant porate 'pollen', *Perinopollenites elatoides*, is commonly associated with spore floras, the bisaccate 'pollen' component may be interpreted as an external input into a moist floodplain environment dominated by parent plants producing 'spores' and *P. elatoides*.

Association T7 is interpreted as a moist floodplain assemblage, based on high percentages of 'spores'. The inaperturate 'pollen' *Araucariacites australis*, present in significant numbers in this association, is considered to represent 'pollen' of araucariaceous affinity, and a possible floodplain species.

Association T8 is similarly interpreted as a moist flooodplain assemblage. However the domination by the spore *Tuberositriletes horridus* clearly reflects a habitat favouring the growth of the parent species, which as of yet is unknown.

Association T9 is interpreted as a fully marine shelf sediment on the basis of the dominating dinocysts, porate and sulcate 'pollen'. It differs from AssociationT2 by virtue of the lower percentages of 'spores'. This is interpreted to be due to Association T9 being deposited at a greater distance from the source of the 'spores' than Association T2.

4.1.7. Moor Grit Member sample, White Nab [TW 8413 8611]

The plant rich mudstone from which the sample was recovered shares lithological similarities with the samples from the Whitby plant Bed (89301 and 89302). The assemblage recovered is dominated by 'spores' (predominately *D. minor*, *D. harrisii* and *L. argenteaeformis*) and porate 'pollen' (mainly *P. elatoides*) with minor bisaccate 'pollen' (*Alisporites* complex)(Table 4.9). Comparison with the samples from the base of the Long Nab Member at Yons Nab, Gristhorpe Bay and Crook Ness are made on the presence of *Kraeuselisporites scalbiensis*. However the absence of other species considered diagnostic at the base of the Long Nab Member precludes confident correlation of the assemblages. The position of the mudstone facies interbedded with the Moor Grit Member sandstone is interpreted as deposition of floodplain mud sediments immediately adjacent to the channel or possibly within an abandoned channel. Thus the sample records the input from flora growing adjacent to the channel (presumably the spore assemblage) and also probably brought down from the hinterland by the distributary (bisaccate 'pollen'). The absence of marine palynomorphs suggests that marine waters did not penetrate into the area.

Table 4.9. Composition of the sample from the Moor Grit Member at White Nab.

Species	Raw data	Percentage
Kraeuselisporites scalbiensis	1	0.4
Deltoidospora australis	1	0.4
Deltoidospora minor	77	29.1
Concavisporites toralis	1	0.4
Punctatisporites minor	1	0.4
Biretisporites potoniei	2	0.8
Dictyophyllidites equiexinus	1	0.4
Dictyophyllidites harrisii	13	4.9
Dictyophyllidites spectabilis	1	0.4
Stereisporites antiquasporites	1	0.4
Densoisporites velatus	1	0.4
Sestrosporites pseudoalveolatus	1	0.4
Striatella seebergensis	1	0.4
Staplinisporites telatus	1	0.4

Lycopodiacidites rugulatus	1	0.4
Retitriletes clavatoides	1	0.4
Retitriletes semimuris	1	0.4
Ischyosporites variegatus	1	0.4
Trachysporites fuscus	1	0.4
Ornamentifera distalgranulata	1	0.4
Nevesisporites bigranulatus	1	0.4
Tuberositriletes perverrucatus	1	0.4
Leptolepidites argentaeformis	7	2.6
Leptolepidites major	1	0.4
Neoraistrickia truncata	1	0.4
Baculatisporites comaumensis	1	0.4
Osmundacidites wellmanii	1	0.4
Rugulatisporites nequenensis	4	1.5
Monolites couperi	1	0.4
Callialasporites minus	1	0.4
Callialasporites turbatus	1	0.4
Exesipollenites tumulus	1	0.4
Perinopollenites elatoides	69	26.0
Corollina simplex	1	0.4
Corollina torosus	1	0.4
Abietinaepollenites dunrobinensis	1	0.4
Alisporites complex	46	17.4
Alisporites microsaccus	1	0.4
Ovalipollis limbata	1	0.4
Podocarpidites ellipticus	1	0.4
Cycadopites carpentieri	1	0.4
Cerebropollenites mesozoicus	13	4.9

4.1.8. Moor Grit sample, Hundale Point [TW 0212 9418]

The Hundale Point sample is located at a slightly lower stratigraphic position than the previous Moor Grit sample from White Nab. The lithologies bear close resemblances with each other. However the assemblage from Hundale Point differs considerably. Most noticable is the presence of dinocysts in moderate percentages. All species present (*Batiacasphaera* spp., *Dissiliodinium* spp. and *Kallosphaeridium* spp.) are interpreted as inshore high stress species due to the presence of such forms, often in flood abundances, in paralic sediments (pers .obs., J. Keating pers. comm. 1992). In addition to common *Deltoidospora* spp. 'spores', *Neoraistrickia truncata* and *Retitriletes* spp. are notable in their presence. The association of *Neoraistrickia* spp. and *Retitriletes* spp. with dinocysts has been noted at other sections (see Yons Nab and Saltergate for example). Thus, on the basis of the palynomorphs, the muds interbedded with the Moor Grit Member at Hundale Point appear to have subjected to saline waters. Local vegetation was probably dominated by *Deltoidospora* producing parent plants. The common bisaccate 'pollen' may have been sourced from the hinterland or, alternatively, have been derived from saline influenced environments downstream. *Neoraistrickia* spp. and *Retitriletes* spp. are tentatively considered to represent parent vegetation growing downstream. This conclusion is based on their common presence in saline influenced sediments but their relative rareness in non-saline influenced sediments in the present study.

Table 4.10. Composition of the assemblage from the Moor Grit Member at Hundale Point.

Species	Raw data	Percentage
Deltoidospora australis	1	0.4
Deltoidospora minor	71	25.7
Concavisporites toralis	3	1.1
Gleicheniidites senonicus	1	0.4
Punctatisporites minor	1	0.4
Waltzispora concava	1	0.4
Biretisporites potoniei	1	0.4
Dictyophyllidites harrisii	5	1.8
Dictyophyllidites spectabilis	2	0.7
Sestrosporites pseudoalveolatus	2	0.7
Striatella patenii	1	0.4
Staplinisporites telatus	1	0.4
Lycopodiacidites rugulatus	1	0.4
Retitriletes annotinoides	12	4.3
Retitriletes semimuris	1	0.4
Ischyosporites variegatus	1	0.4
Trachysporites fuscus	1	0.4
Leptolepidites argentaeformis	2	0.7
Neoraistrickia truncata	11	4.0
Baculatisporites comaumensis	1	0.4
Osmundacidites wellmanii	1	0.4
Callialasporites minus	1	0.4
Exesipollenites laevigatus	6	2.2
Exesipollenites scabratus	1	0.4

Perinopollenites elatoides	4	1.4
Corollina simplex	1	0.4
Corollina torosus	1	0.4
Abietinaepollenites dunrobinensis	1	0.4
Alisporites complex	48	17.3
Ovalipollis ovalis	1	0.4
Podocarpidites ellipticus	1	0.4
Cycadopites minimus	23	8.3
Cerebropollenites mesozoicus	11	4.0
Chasmatosporites hians	1	0.4
Crassosphaera hexagonalis	1	0.4
Tasmanites newtonii	1	0.4
Pterospermella helios	1	0.4
Cymatiosphaera eupeplos	1	0.4
Hemisphaerium simplex	33	12.0
Lecaniella varireticulata	1	0.4
Solisphaeridium lymense var. gliscum	2	0.7
Nannoceratopsis ambonis	2	0.7
Batiacasphaera DB1	10	4.0
Kallosphaeridium sp. DK1	1	0.4
Kallosphaeridium coniferum	1	0.4
Dissiliodinium sp. DS1	1	0.4

4.1.9. Correlation of the studied sections on the basis of palynomorph associations.

Various studies reviewed in Chapter 1 (e.g. Muller 1958, Scheihing & Pfefferkorn 1984) have shown that in contemporary floodplain and deltaplain environments the existence of a single ecosystem over the whole of the region does not occur. The use of 'spores' and 'pollen' in stratigraphic correlation traditionally involves lateral correlation of peaks of abundances of selected species (pers. obs.). The likelyhood that a chronostratigraphic correlation is achieved using such a method is less than the likelyhood that similar facies are being correlated. Depending on the physiographic settings, it is possible that environments characterised by a particular assemblage may exist in a region for a relatively short period of time.

Muller (*op. cit.*) concluded that cores drilled in the Orinoco Delta revealed a dynamic response of vegetation reacting to changes in environment brought about by the movement of the delta to more landward and seaward positions through time. Thus it is fair to assume that assemblages preserved through geological time may possibly reveal similar trends. Perhaps the most obvious signature on a low lying delta would be a relative rise in sea level. This in effect would drown the delta top, increase accomodation potential and introduce saline conditions into the region. Alternatively, a relative drop in sea level would drain swampy areas and lead to channel incision. Pedogenic laterisation would likely ensue in tropical and subtropical environments leading to extensive oxidation of organic matter. It is proposed that both effects can be recognised in the Scalby Formation. However, to propose that the effects can be traced laterally is assuming that these processes were solely in operation.

Alexander (1992) and Kantorowicz (1990) have both published results to the contrary. Localised drainage of floodplain sediments takes place in raised areas such as those which occur proximal to levée development (Kantorowicz, *op. cit.*). Additionally, marine waters may enter the floodplain as a result of storm or tidal surge mechanisms or as a result of differential compaction of deltaplain sediments (Alexander, *op. cit.*). The possibility that these localised mechanisms are able to be separated from more general processes is low. To attempt such correlation may be proving non-relationships just as much as true relationships.

On a floodplain / deltaplain, it should be possible at any one time to recognise a spectrum of depositional environments through a landward-seaward cross section. Upper floodplain, lower floodplain, backswamp, saline swamp, lagoon, beach / barrier, upper shoreface, lower shoreface are typical environments predicted from contemporary studies. In the present study, it was considered only possible to recognise a general floodplain/ deltaplain flora, floodplain / deltaplain freshwater body, fluvial channel and marginal marine facies on the basis of sedimentology and palynology. Due to the sparsity of data, it is not possible to further qualify the types of freshwater body in which Zygnematacean algae would have flourished. Our knowledge of the ecology of contemporary species is poor (Head 1992).

The general consensus (e.g. Alexander 1986b) is that the Scalby Formation floodplain drained from a northerly source to the south. Thus we can assume such a geometry for the floodplain / deltaplain. In order to correlate approximate time lines between the studied sections, making use of systems tracts of facies (see Vail *et al.* 1977 for terminology), it is of utmost importance to correlate the correct levels from section to section. The variable sampling distances in different sections should also be taken into account when correlating. It was considered that the top of the Long Nab Member was much more likely to represent a real time line than the bottom, due to the problematical variable development of the Moor Grit Member at Gristhorpe Bay. The following is an attempt to reconstruct the palaeoenvironment of the Cleveland Basin during the deposition of the Scalby Formation. Correlation of the sections is attempted in figure 4.5.1.

At the top of the Long Nab Member, strong marine influence is observed at all sections except at Talbot Wood, where non marine assemblages are dominated by *Tuberositriletes* spp. 'spores'. Thus a saline influenced swamp, lagoon or estuarine environment appears to have prevailed, but was bordered as at Talbot Wood by a marginal floodplain / deltaplain environment inhabited by *Tuberositriletes* spp. producing plants. Further down section at Talbot Wood, marine influence can be detected. This suggests the the position of the marine - non-marine transition varied. Only at Gristhorpe Bay are the assemblages consistently marine influenced in the top part of the Long Nab Member. Thus a slightly older time line from the initial scenario would witness the development of freshwater dominated floodplain / deltaplain environments further south. Continuing down the sections of the Long Nab Member at Talbot Wood, Saltergate and Gristhorpe Bay, this trend can be seen to continue until floodplain / deltaplain habitats can be recognised at all localities.

It is difficult to tie in the top of the Crook Ness section with the Saltergate and Gristhorpe sections but it best fits at where floodplain / deltaplain environments are widely established. The marine influenced associations C7 and C8 at Crook Ness are not recognised at other sections. It is possible that syn-tectonic subsidence of the Peak Trough graben may have lowered the topography at Crook Ness, leading to deposition of marine influenced assemblages at the time of the deposition of the Dinosaur Footprint Beds.

At the base of the Long Nab Member, several of the associations represent a diverse floodplain flora (G1 at Gristhorpe, Y13 at Yons Nab and C1 at Crook Ness). Thus at that time, despite a lack of marine influence, southerly sections were accumulating sediments from a wide variety of floodplain / deltaplain habitats. The proximity of the sections to distributary channels may partly explain the assemblages.

The two samples from the Moor Grit Member suggest that following abandonment of subchannels of the braided river, deposition of muds ensued, which in the case of the Hundale Point sample, were occasionally influenced by marine waters.

Figure 4.5.1. A correlation of the studied sections based on palaeoenvironmental interpretation;
undulating fill pattern indicates marginal marine environments;
unpatterned areas indicate floodplain / deltaplain palaeoenvironments;
correlation lines between the Gristhorpe Bay and Yons Nab section and the Yons Nab and Crook Ness section is based on similarities between associations G1, Y13 and C1;
top correlation line between Satlergate and Talbot Wood sections defines the Scalby Formation / Cornbrash Formation boundary;
lower correlation line between Saltergate and Talbot Wood is based on vertical thickness correlations between sections;
dashed correlation line between the Crook Ness and Saltergate sections indicates uncertainty.

4.2. Discussion of previous palynological work on the Scalby Formation.

Couper (1958) studied 13 samples of the Scalby Formation from Yons Nab, Gristhorpe Bay, and from between Cloughton Wyke and Scalby Ness. He withdrew from offering a formalised zonation based on the microspores but as has been mentioned in Chapter 1, suggested that the flora may be distinguished from other Mesozoic floras on the basis of relative abundances of certain species combined with the presence and / or absence of others. Little notice of the effects of facies appears to have been considered.

A further problem encountered with his work is the processing methods employed. The system now widely adopted does not make use of lengthy periods in Schulze's Solution to oxidise the sample (Couper, 1958, p. 98, states oxidation times between five hours and seven days for his samples; in the present study, oxidation times varied between three and five minutes). In addition, the strengths of both nitric acid (concentrated) and potassium hydroxide (10%) are now only used when dealing with exceptionally mature material and such strengths were not necessary in the present study. The effects of excessive treatment on spore and pollen grains include an increase in the size of the grains, disintegration and in extreme cases, partial or total dissolution. Thus not only should characteristics such as porosity and foveolation of the walls of grains in Coupers study be questioned, but also the size delimitations of many of the species described.

Fisher & Hancock (1985) re-examined the Scalby Formation using integrated palynofacies and sedimentology. They reported the presence of dinoflagellate cysts in both the Moor Grit Member and the Long Nab Member. The dinoflagellate cyst *Nannoceratopsis gracilis* was identified from several samples of the Long Nab Member together with an unspeciated record of *Dichadogonyaulax* sp. from their sample 80. The findings led the authors to postulate an age restriction of the formation to the *garantiana* and *parkinsoni* Zones of the Bajocian. "This age is based on concurrent ranges; as *Dichadogonyaulax* sp. is not recorded in sediments of pre-*garantiana* age, its presence precludes any reworking of older sediments. Moreover the palynological data provide conclusive evidence of marine influence within Leeder & Nami's (1979) postulated *subfurcatum* to ?*retrocostatum* zones hiatus."(*op. cit.*, p. 296). Based on regional considerations to the south of the Market Weighton axis, the authors concluded that " ... it does therefore appear more likely that the time interval from the *humphriesianum* Zone(Scarborough Formation) to the *macrocephalus* Zone (Cornbrash Formation) accomodated a number of relatively small hiatuses."(*op. cit.*, p. 296).

As Riding & Wright (1989) commented, the conclusions of Fisher & Hancock (*op. cit.*) are open to some criticism. The presence of *N. gracilis* and *Dichadogonyaulax* sp. does not restrict the age determination to the Upper Bajocian; both species have been reported from the Bathonian (Riding *et al.* 1985, Riding &

Thomas 1992). In addition, Riding & Wright (1989) re-examined some of Fisher & Hancock's slides and failed to identify *N. gracilis* in sample 69. This observation, if correct, throws doubt onto much of the palaeoenvironmental interpretations offered by Fisher & Hancock and questions the integrity of the rest of their work in the Cleveland Basin (Hancock & Fisher 1981).

Riding & Wright (1989) studied the upper part of the Long Nab Member at Saltergate and two samples from the lower part of the Long Nab Member from coastal exposures. Diverse microplankton assemblages were recovered from the sections at Saltergate. Species recorded included *Ctenidodinium combazii* Dupin 1968, *Adnatosphaeridium caullyeri* (Deflandre 1938) Williams & Downie 1969, *Ellipsoidictyum cinctum* Klement 1960, *Gonyaulacysta jurassica* (Deflandre 1938) Norris & Sarjeant 1965 subsp. *adecta* var. *adecta* Sarjeant 1962, *Meiourogonyaulax caytonensis* (Sarjeant 1959) Sarjeant 1969, *Nannoceratopsis pellucida* Deflandre 1938, *Pareodinia* Deflandre 1947 spp. and *Sentusidinium* Sarjeant & Stover 1978 spp. These occurrences led the authors to conclusions based partly on their findings. These will now be critically considered.

The authors inferred that " ... the presence of *C. combazii* with *A. caullyeri* in strata unconformably below proven earliest Callovian sediments (Cornbrash) indicates a Bathonian age." (Riding & Wright 1989, p. 353). This assumes that the Upper Cornbrash Formation occupies the very base of the *macrocephalus* Zone. At present this cannot be confirmed and thus it is possible that in addition to the samples being Bathonian in age, they could also plausibly be of earliest Callovian (*macrocephalus* Zone) age. The authors contention that the sediments were " .. compacted or lithified, slightly uplifted, eroded and burrowed, before the Cornbrash Formation was deposited" (*op. cit.*,p. 351) is complicated and implies a significant time gap present between the top of the Long Nab Member and the base of the Cornbrash Formation. The comment that " ... there was a steady marine transgression across this erosion surface under low energy conditions." (*op. cit.*) is herein reinterpreted.

It is plausible that the unconsolidated or semi-lithified topmost part of the Scalby Formation was removed to a more resistant level by the trangression. The level of erosion would likely to be dependant on the erodability of the sediment and the distribution of high energy erosive environments in the pre-Cornbrash sea. The base level of erosion became the boring surface for various organisms which were preserved following further deepening of the Cornbrash sea which reworked the topmost muds of the Scalby Formation and perhaps additionally, introduced mud grade sediments at the base of the Cornbrash Limestones. The discontinuous α_0 unit recognised at the base of the Cornbrash Formation by Wright (1977) is herein considered to represent these redeposited sediments. Their restricted distribution in the Cleveland Basin may be a function of variable accomodation space in the basin at the start of Cornbrash Formation sedimentation (i.e. subsidence was restricted to basin centre at this time).

Thus very little time is required for the development of a bored surface and indeed such surfaces could be envisaged to have formed during transgression (Dr S. Hesselbro, University of Oxford, pers comm. 1992).

Riding & Wright (1989) commented upon the occurrence of *C. combazii* in the Scalby Formation; " The presence of *C. combazii* in these supposed saline swamp deposits is not consistent with the palaeoenvironmental model proposed for this taxon by Riding *et al.*(1985); who suggested that, on the basis of modern analogues, *C. combazii* was restricted to stable marine environments. This may still be the case where *C. combazii* occurs abundantly, but the taxon must have been more environmentally tolerant than previously supposed". It is again unnecessary to alter the previous interpretation of Riding *et al.* (1985), but to suggest the influence of strong circulatory currents offshore, combined with macrotidal conditions, which would allow the possibility of the deposition of forms inhabiting normal salinity marine environments on the coastal plain / flood plain, during high tides and / or storm conditions (*cf.* tidal prism backup effects of Leeder & Alexander (1985), see also Prentice *et al.* (1968)). In addition, the use of modern analogues to predict the behaviour of Mesozoic dinoflagellate cysts should be viewed along with all the possible limitations of such a technique (Riding *et al.* (1985) did not actually suggest that *C. combazii* had one and to the present authors' knowledge there is no modern analogue).

Riding & Wright 1989 use their identification of Hancock & Fisher's *Dichadogonyaulax* sp. (*?Ctenidodinium sellwoodii* (Sarjeant 1975) Stover & Evitt 1978 of Riding & Wright) to relate the Long Nab Member to the underlying 'transition shales' of the Scarborough Formation, in which " .. morphotypes similar to the *?C. sellwoodii* ... have been encountered ... (J.B.R., personal observation)" (Riding & Wright *op. cit.*, p. 353). This is used to suggest that the specimen recovered from the Long Nab Member may have been reworked from the Scarborough Formation. This reasoning is questioned by the present observations and those of W. Wille (whose knowledge of the palynology of the Scarborough Formation is based on a considerable amount of unpublished work). Neither the present author nor W. Wille (pers. comm. 1992) have identified *C. sellwoodii* from the Scarborough Formation. However, a similar morphotype, *Durotrigia daveyi* Bailey 1987 is relatively common in the Scarborough Formation, especially forms which have lost several precingular plates, which gives the appearance of an epicystal archaeopyle. It is suggested that the identification of Hancock & Fisher's *Dichadogonyaulax* sp. may still be open to reinterpretation (the fact that the specimen under discussion has never been illustrated does suggest a poor state of preservation and thus the increased risk of misidentification).

In conclusion, Riding & Wright (1989) make a series of comments on both the age and the possible locations of hiatuses; " Since the Long Nab Member is separated from the Scarborough Formation by the Moor Grit Member, it is probable that it is no older than late Bajocian (and possibly as young as Bathonian) in age.

Sedimentation from the early Bajocian Scarborough Formation into the Moor Grit Member with only a minor stratigraphical break is envisaged. Possible hiatuses at the Moor Grit Member-Long Nab Member junction and above the Meander Belt Sandstone (basal Long Nab Member ...) are of unknown duration. However we propose that the remainder of the Long Nab Member ... represents a period of almost continuous deposition followed by the stratigraphical break that separates it from the overlying Cornbrash." (Riding & Wright *op. cit.*, p. 353). All but the last comment are not proved by work presented in their paper and as such should be regarded as an untested hypothesis. If the paper is critically reviewed, the work by Riding & Wright simply suggests that the uppermost part of the Long Nab Member is Bathonian or lowermost Callovian in age; all other findings and reinterpretations are inconclusive.

4.3. Palynostratigraphy

Comparison with previous records.

Previous publications on Middle Jurassic palynostratigraphy have predominately made use of dinoflagellate cyst ranges to define biozones in preference to spores and pollen. Over the last twenty years or so, however, petroleum exploration in the Northern North Sea in the Brent and adjacent fields has necessitated a reconsideration of non-marine palynostratigraphy in the light of the discovery of thick deposits of non-marine and paralic strata. This area has recently been addressed by Whittaker *et al.* (1992), Mitchener *et al.* (1992) and Williams (1992).

Three types of previous work have been considered when comparing taxa recorded from the present study: previously published regional data, previously published extra-regional data and previously unpublished regional data. Additionally consideration of facies control on assemblages and provinciality, particularly of dinoflagellate cysts is taken into consideration.

The most extensive regional publication dealing with dinoflagellate cysts is Woollam & Riding (1983) and more recently Riding & Thomas (1992), which revises the former publication. In addition, regional Middle Jurassic dinoflagellate cyst publications include Riding & Wright (1989) and Gowland & Riding (1991), covering the Cleveland Basin and Riding *et al.* (1985), dealing with the Bathonian type area in south west England.

Comprehensive extra-regional dinoflagellate cyst studies (herein restricted to North West Europe and Greenland) were considered to be lacking by Riding & Thomas (1992). However Feist-Burkhardt & Wille (1992) have published selected range charts for the Jurassic in south west Germany.

Several unpublished dissertations stored at the University of Sheffield deal with various stratigraphical ranges in the Cleveland Basin and elsewhere in Britain. The dissertations pertinent to the present study include Davis 1981, Fenton 1980, Hooker 1982, Pearce 1982, Porter 1981, Riccardiello 1985, Riding 1986, Walton 1988 and Woollam 1982.

Marine Palynostratigraphy

The occurrence of marine taxa in the present study is shown in Figure 4.6; the previously published palynostratigraphy of the Scarborough and Scalby Formation is provided for comparison in Figure 4.7. Greater sampling density combined with a wider geographical coverage is considered to be the dominant cause of the increased species diversity recorded in the present study.

Chapter 4

Scarborough Formation

There appears to be considerable divergence in the assemblages recorded compared to that of Gowland & Riding (1991). This is considered to be due to the difference in outcrops sampled; Gowland & Riding (1991) sampled the type section of the Scaborough Formation at Hundale Point whereas the present study sampled the much thinner section at Yons Nab. The type section is located within the Peak Trough graben structure of Milsom & Rawson (1989) and the succession there was considered by those authors (*op. cit.*, p. 704) to be atypical of the Cleveland Basin as a whole. The section of the Formation at Yons Nab is the most southerly outcrop in the Cleveland Basin and its correlation with more northerly outcrops is shown in Figure 1.6.

In addition to locality differences, the sampling density of Gowland & Riding is of a sufficiently low nature (eight samples were studied from the ± 30 metre type section) as to make the publication at best a preliminary study of the palynology at the type section.

At the Yons Nab section, *Mancodinium semitabulatum* (Morgenroth) Below 1987, *Moesiodinium raileanui* Antonesçu 1974, *Phallocysta* cf. *eumekes* Dörhöfer & Davies 1980, *Phallocysta spinosa* n. sp., *Susadinium scrofoides* Döfhöfer & Davies 1980 are conspicuous in their presence. Conversely, *Energlynia acollaris* (Dodekova) Sarjeant 1978, *Gongylodinium hocneratum* Fenton *et. al.* 1980 and *Rhyncodiniopsis*? *regalis*? (Gocht) Jan du Chêne *et* . *al* . 1985 are absent in the studied samples but were present in those of Gowland & Riding (1991). Until unambiguous visual evidence is published, *Ctenidodinium sellwoodii*? (Sarjeant) Stover & Evitt 1978 of Gowland & Riding (1991) is considered synonymous with *Durotrigia daveyi* Bailey 1985 in the present study. Pending further publication of data from other sections of the formation, the variances in assemblages are suggested to be due to sampling differences.

When compared to the published ranges in North West Europe (Riding & Thomas 1992, Feist-Burkhardt & Wille 1992) the present study shows greater similaritites to that of southwest Germany than England. The ranges presented in Riding & Thomas (1992) are updated by Riding, Walton & Shaw (1991)(despite the differences in publication dates). The latter authors identified *Moesiodinium raileanui* Antonesçu 1974 from the *discites* Zone and *Mancodinium semitabulatum* (Morgenroth) Below 1987 from the *humphriesianum* Zone of the Hebrides Trough. Despite these updates in the ranges of the species, there remains some range disparities. This perhaps reflects the paucity of published data on Scarborough Formation-type facies in the Bajocian of the U.K. rather than real distributional disparities (the sample base for Riding & Thomas (1992) was largely that of Woollam & Riding (1983), with additions from U.K. publications upto 1992 and from BGS unpublished data on Western Scotland). It is clear that published data from the Bajocian of the Cleveland Basin would considerably update the presently published ranges presented in Riding & Thomas (1992).

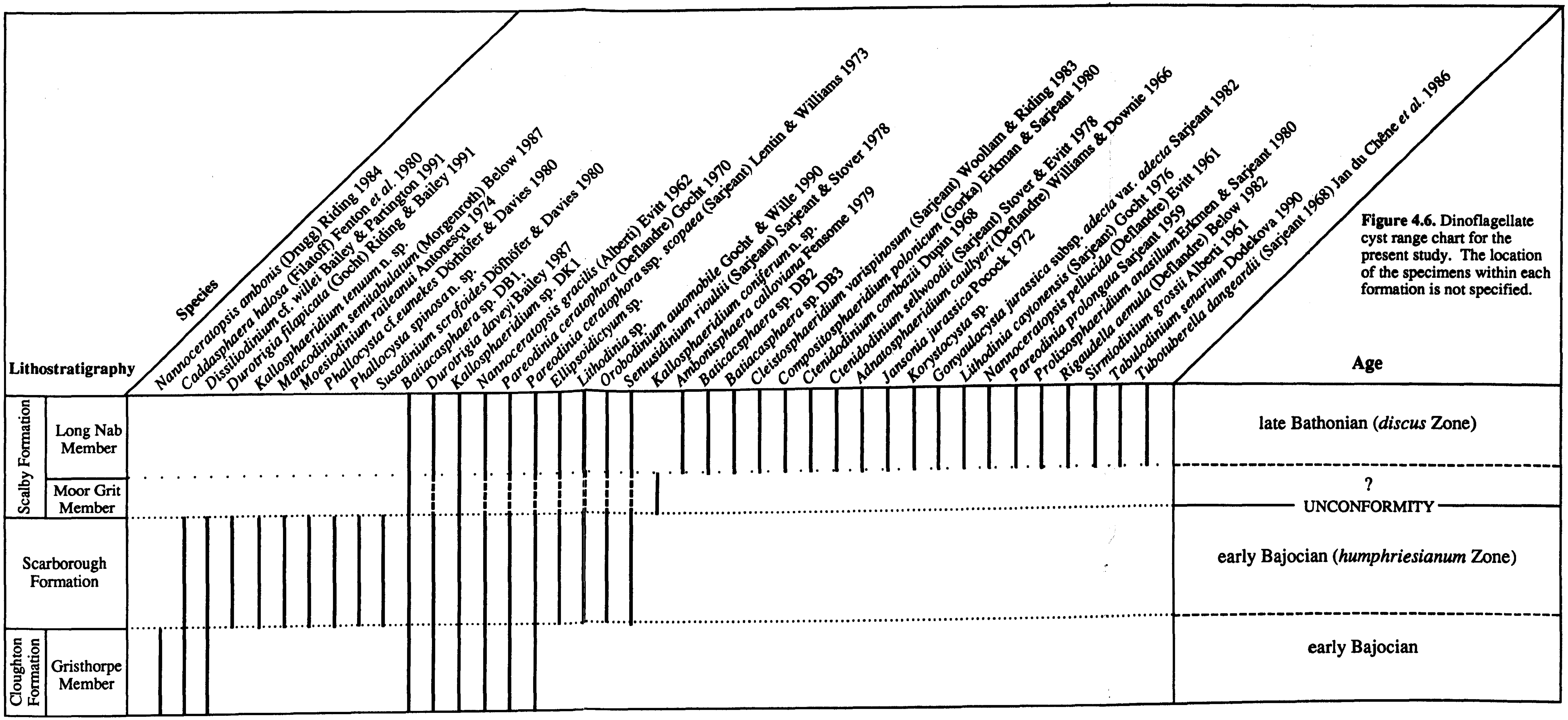


Figure 4.6. Dinoflagellate cyst range chart for the present study. The location of the specimens within each formation is not specified.

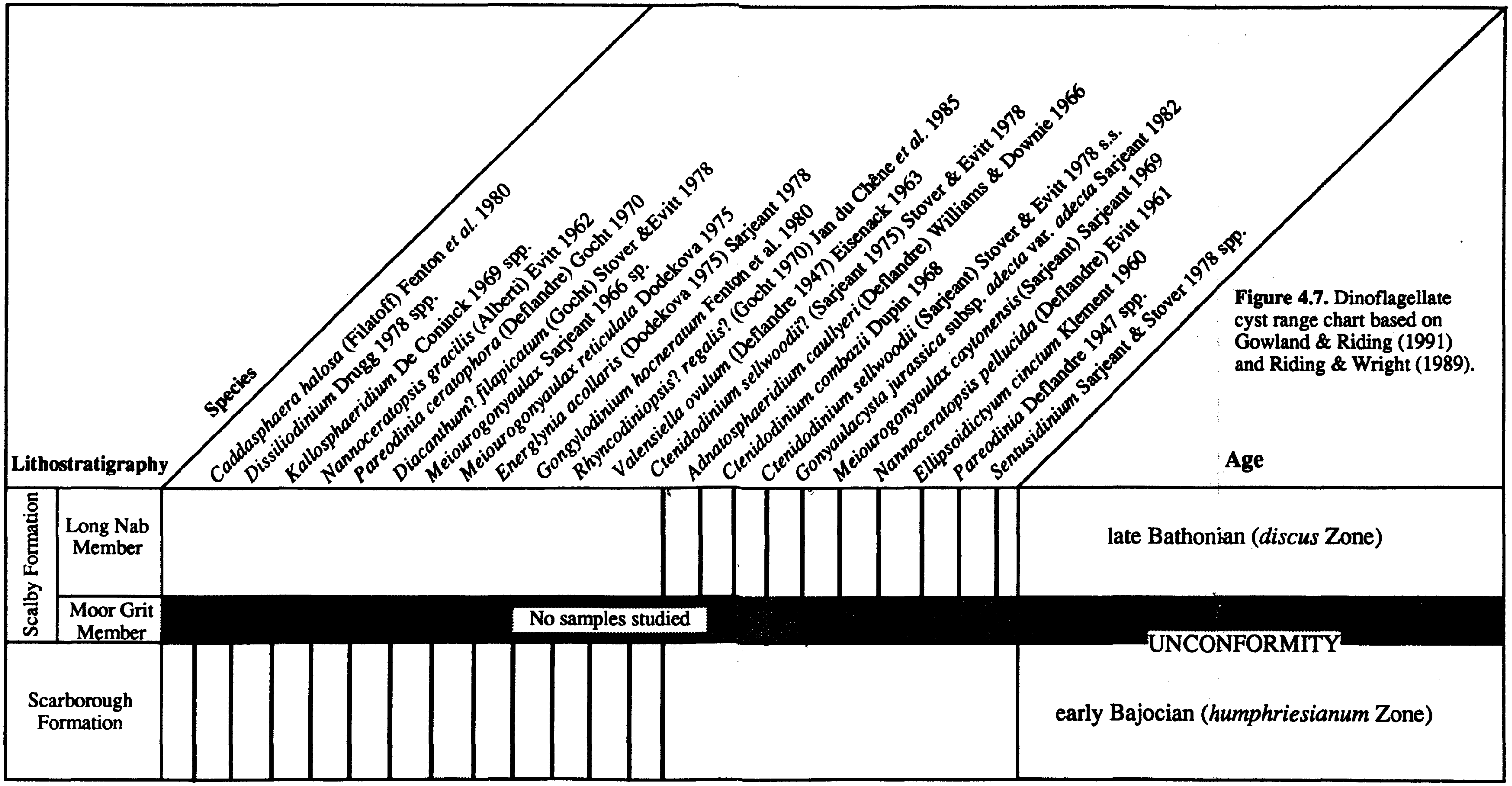


Figure 4.7. Dinoflagellate cyst range chart based on Gowland & Riding (1991) and Riding & Wright (1989).

Scalby Formation.

The published recordings of dinoflagellate cysts from the top of the Long Nab Member (Riding & Wright 1989) have been supplemented by the present study. Furthermore, samples from the sections at Saltergate, Crook Ness and Gristhorpe Bay have recorded the occurrence of dinoflagellate cysts at much lower levels in the Long Nab Member than previously reported. Dinoflagellate cysts recovered from the shale wedge in the Moor Grit Member at Hundale Point provide the first substantiated evidence of marine influence in the Moor Grit Member (the findings of Hancock & Fisher (1985) are herein viewed with suspicion following Riding & Wright's (1989) partial re-study of the previous authors material).

Several of the species recorded appear to be of value in restricting the possible age of the Scalby Formation. This method relies upon the previously published ranges and, as mentioned before regarding the Scarborough Formation, is to some degree controlled by facies. The species to be considered are *Ambonisphaera calloviana* Fensome 1979, *Cleistosphaeridium varispinosum* (Sarjeant) Woollam & Riding 1983, *Compositosphaeridium polonicum* (Gorka) Erkmen & Sarjeant 1980, *Pareodinia prolongata* Sarjeant 1969, *Prolixosphaeridium anasillum* Erkmen & Sarjeant 1980, *Rigaudella aemula* (Deflandre) Below 1982, *Sirmiodinium grossii* Alberti 1961, and *Tabulodinium senarium* Dodekova 1990. Selected published ranges of the aforementioned taxa are depicted in figure 4.8 and their occurrence in the present study is given in table 4.11.

Table 4.11. Occurrences of key dinoflagellate cyst taxa in the Long Nab Member.

Species	Locality
A. calloviana	5m above meander belt sandstone, Crook Ness (sample 89323), top of the formation, Gristhorpe Bay
C. polonicum	5m above meander belt sandstone, Crook Ness (sample 89323).
C. varispinosum	2.5m below the top of the member, Talbot Wood; 24m below the top of the member, Saltergate
R. aemula	Top of the Member, Gristhorpe Bay and Saltergate.
S. grossii	7m below the top of the member, Gristhorpe Bay.
P. anasillum	7m & 8m below the top ofthe member, Gristhorpe Bay.
T. senarium	7m below top of the member, Gristhorpe Bay

It is clear that three species, *A. calloviana*, *C. polonicum* and *P.anasillum* have not apparently been previously recorded from the Bathonian. *C. polonicum* and *P.anasillum* have their first appearance datums (FAD), according to Riding & Thomas (1992), at the base of the *herveyi* (al. *macrocephalus*) Zone of the Lower Callovian. *A. calloviana* has only previously been recorded from undifferentiated Callovian strata in Spitzbergen and Greenland (Smelror 1988, Fensome 1979). Thus it is somewhat early to recover these taxa from the Scalby Formation if the presently published data is correct. The possibility that *P. anasillum* may be present due to contamination of the sample material is doubted since specimens were recovered from two separate samples; the probability that a single identical species has contaminated two different samples is very low. This is also true for *A. calloviana*. The likelyhood that *C. polonicum* was a contaminant is less convincing. Only a single specimen was identified confidently. However, the same sample yielded a relatively diverse microplankton flora including *Adnatosphaeridium caullyeri, Ambonisphaera calloviana, Batiacasphaera* spp. *Caddasphaera halosa, Lithodinia* sp. and *Valensiella* sp. amongst others.

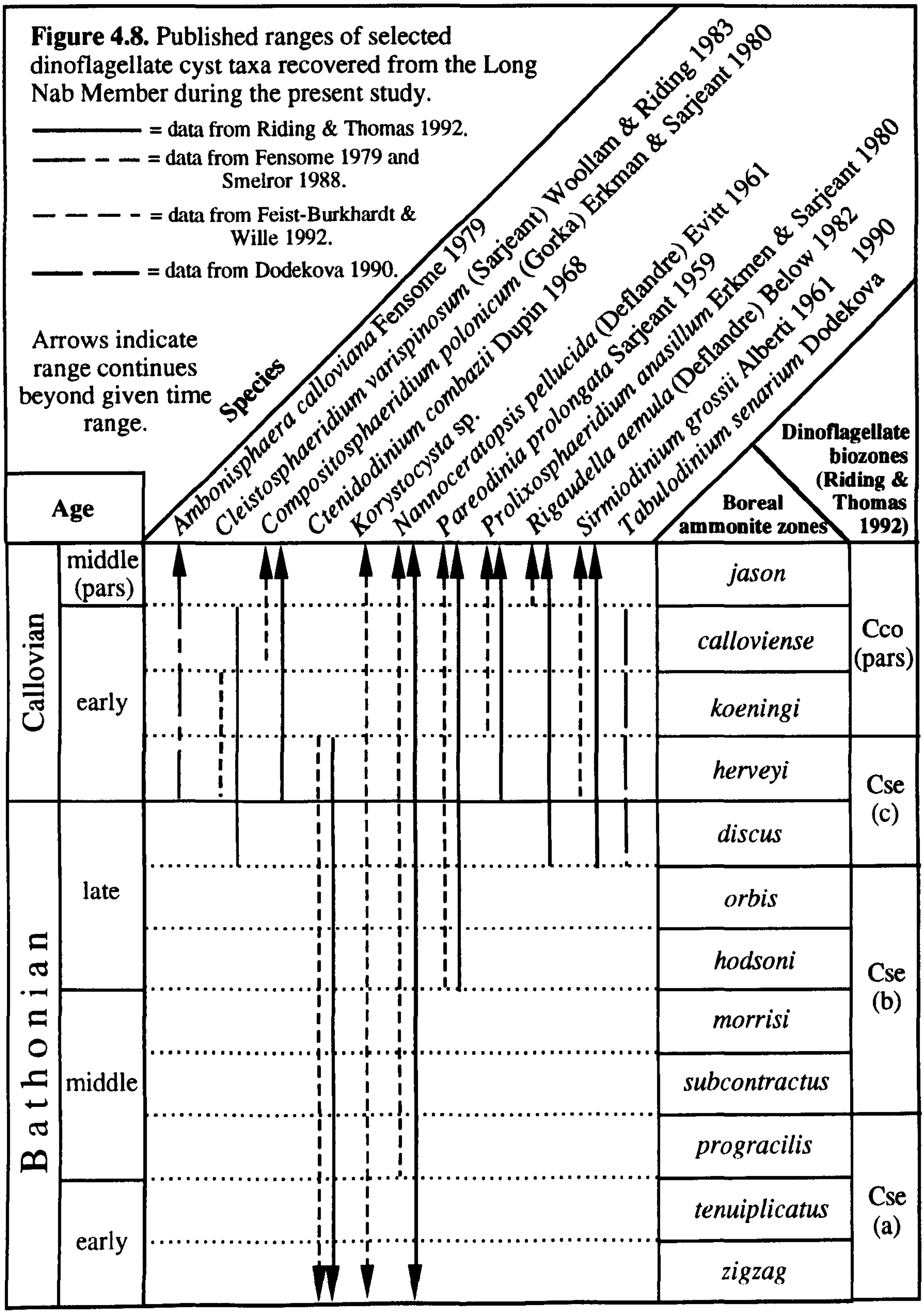


Figure 4.8. Published ranges of selected dinoflagellate cyst taxa recovered from the Long Nab Member during the present study.

———— = data from Riding & Thomas 1992.
—— – — = data from Fensome 1979 and Smelror 1988.
– – – – = data from Feist-Burkhardt & Wille 1992.
—— —— = data from Dodekova 1990.

Arrows indicate range continues beyond given time range.

Several species recovered have their FAD's at the base of the *discus* Zone according to Riding & Thomas (1992); *C. varispinosum, S. grossii* and *R. aemula*. In addition, *T. senarium* , previously unpublished from U.K. strata, was described from the *discus* Zone of Bulgaria (Dodekova (1990), it is also used as a late Bathonian marker in the North Sea (annon. pers. comm., 1991). *P. prolongata* has its FAD at the base of the *hodsoni* Zone according to Riding & Thomas (1992). It is perhaps interesting at this point to consider the unpublished occurences of *P. prolongata* from M.Sc. dissertations at the University of Sheffield (Table 4.12). The numerous reports of *P. prolongata* suggests its presence in strata from Central and Northern England from the *progracilis* Zone (upper Lower Bathonian) onwards, thus extending it's presently published range.

The species observed are strongly suggestive of a late Bathonian age, more precisely *discus* Zone, for the Long Nab Member. It is of interest to note the occurrence of the key taxa within the section (Table 4.11). The ranges are not confined to the upper part of the member. Thus on the basis of the presently published ranges of selected taxa, the majority of the Long Nab Member, at least down to a level five metres above the meander belt sandstones of Nami (1976) at Crook Ness and 24 metres below the top of the member at Saltergate, is *discus* Zone age.

Table 4.12. Previous unpublished occurrences of *Pareodinia prolongata* in Central and Northern England.

Reference	**Age/ Formation and locality**
Davis, J.A., 1981MS.	*progracilis* Zone, Taynton Stone & Hampen Marly Beds, Woodeaton, Oxfordshire.
Fenton, J.P.G., 1980.	Rutland Formation to Blisworth Clay Formation, Lincolnshire and Northamptonshire.
Hooker, N.P., 1982.	*progracilis* Zone, Sharp's Hill Member, Sharp's Hill, Oxfordshire.
Pearce, J.M., 1982.	Blisworth Limestone-Kellaways Formation, Bicker borehole, Lincolnshire.
Riccardiello, G.A., 1985.	Blisworth Clay & Cornbrash Formation, Worlaby borehole, South Humberside.

An explanation for the enigmatic presence of *A. calloviana, P. anasillum* and *C. polonicum* is perhaps less controversial if the *discus* Zone age is accepted. The worldwide late Bathonian / early Callovian transgression has an effect on both the ranges of Riding & Thomas (1992) and Feist-Burkhardt & Wille (1992) of recording numerous range bases. The areal extent of the seas covering North West Europe dramatically increased during this interval, allowing the migration of species into new regions (Feist-Burkhardt & Wille 1992). The range bases of species are herein considered to be dependant upon the extent and thus the presence of the transgressive seas in a particular region.

The Cleveland Basin extends eastwards to link with the Sole Pit Trough. Judging by the thickness of sediments preserved there, this was apparently undergoing rapid subsidence during the Jurassic and a more normal marine salinity in that area, especially during transgressive events, is judged a reasonable assumption. It is conceivable that the transgression entered the Cleveland Basin from the Sole Pit Trough to the east.

Some of the genera with later range bases (*herveyi* (al. *macrocephalus*) Zone) are tentatively considered to have been euryhaline / eurythermal intolerant types (cf. Riding *et al.* 1985, Woollam 1982 MS, p. 52). Their presence in *discus* Zone sediments is attributed to transport mechanisms (e.g. strong circulatory currents) conveying more environmental intolerant species into inshore environments. Deposition on floodplain environments is achieved by tidal and / or storm mechanisms (Leeder & Alexander 1985, Prentice *et al.* 1968). Thus the absence of *A. calloviana, P. anasillum* and *C. polonicum* in the *discus* Zone of the presently published range charts does not preclude their existence in related areas such as the Sole Pit Trough.

In the Cleveland Basin, the first lithological signature of the Callovian transgression is the fossiliferous (*herveyi* (al. *macrocephalus*) Zone) shales of the Cornbrash Limestone overlying the Scalby Formation. South of the Market Weighton Structure the transgression is marked lithologically by the Lower Cornbrash Formation with a macrofauna of *discus* Zone age. Clearly from the results of the present study, this earlier increase in accomodation potential occurred in the Cleveland basin but its signature was apparently obscured by the availability of a large amount of siliciclastic sediments from a northerly derivation (Leeder & Nami 1979). Thus the deposition of the Scalby Formation in a largely transgressive regime (transgressive systems tract of Mitchum *et al.* 1977 terminology) is herein proposed. Furthermore the formation is considered to correlate with the Lower Cornbrash Formation south of the Market Weighton Structure.

Non-Marine Palynostratigraphy

A Middle Jurassic non-marine palynostratigraphic zonation scheme for England remains to be published. Couper (1958) employed two methods of stratigraphic correlation; correlation by species with a restricted range ('key forms') and correlation by changes in abundance. According to his results, *Perotrilites* (al. *Lycopodiacidites*) *rugulatus* and *Trilites* (al. *Leptolepidites*) *equatibossus* were considered 'key forms' for the Gristhorpe Member and *Foveotriletes microreticulatus* and *Parvisaccites enigmaticus* (al. *Ovalipollis limbata*) were deemed 'key forms' for the Scalby Formation. The present author considers Couper's illustrated holotype of *F. microreticulatus* to represent an eroded (pitted, possibly due to processing methods) specimen of *Dictyophyllidites spectabilis* and a further illustrated specimen (plate 22, figure 8) to represent a specimen of *Murospora florida*.

With reference to Couper's (*op. cit.*) correlation by changes in relative abundances, the Gristhorpe Member was thought to be distinguishable from the underlying strata on the relative abundance of *Monosulcites* (al. *Cycadopites*) *minimus* and Osmundaceae (al. *Punctatisporites*, *Osmundacidites*, *Baculatisporites* and *Rugulatisporites*). In addition, *Lycopodiumsporites* (al. *Neoraistrickia*) *gristhorpensis* was not encountered in older or younger sediments. In the Scalby Formation, *Parvisaccites enigmaticus* (al. *Ovalipollis limbata* in the present study) and *Abietinaepollenites* (al. *Alisporites*) *microsaccus* had their first appearances. Furthermore, the relative abundance of *Abietinaepollenites* spp. and *Cerebropollenites mesozoicus* together with the rarity of *Classopollis* (al. *Corollina*) *torosus* and *Araucariacites australis* was thought to be indicative of the formation.

Results from the greater sampling density of the present study do not support Couper's (*op. cit.*) observations of abundant *Cerebropollenites mesozoicus* and rare *Araucariacites australis* in the Scalby Formation. The contention that *Alisporites microsaccus* was not present in older sediments is tentatively agreed with herein, although the species was never recorded in abundance from any single sample. *Ovalipollis limbata* was recovered from both the Gristhorpe Member and Scalby Formation.

With regard to the Gristhorpe Member, the range of *Lycopodiacidites rugulatus* continued into the Scalby Formation in the present study. However *Leptolepidites equatibossus*, a rare component in assemblages, does appear to be restricted to the Gristhorpe Member. Abundant 'Osmundaceae' were encountered in samples from the Scalby Formation and the distribution of abundant *Cycadopites minimus* was not restricted to the Gristhorpe Member.

The most important result from the present study is the recognition of a spectrum of forms restricted to the Scalby Formation and not recorded by Couper (*op. cit.*). These include *Echinatisporis baculatus*, *Enigmaspora bella*, *Kraeuselisporites scalbiensis*, *K. whitfordensis*, *Pararetispora jurassica*, *Tuberositriletes aequiverrucatus*, *T. horridus*, *Varivaginaspora reticulata* and*V. spinoreticulata*. A review of unpublished palynology theses held at the Department of Earth Sciences, University of Sheffield has revealed previous recordings of some of these species (Table 4.13).

The previous distribution of *Pararetispora jurassica* and *Tuberositriletes horridus* appears to be restricted to the Bathonian. To this one can add *Enigmaspora bella*, *Tuberositriletes aequiverrucatus* and *Varivaginaspora reticulata* from the present study. In addition to a common previous occurence in the Bathonain, *Echinatisporis baculatus* has been recorded from the Toarcian of the Cleveland Basin (Stronach (1983)). Supplementing this, Riding & Wright (1989) reported previous occurrences in the Aalenian in southern England. Thus, although the species is commonly recorded in the Bathonian in central and north east England, records suggest a facies control on the species occurrence rather than a true evolutionary distribution through time.

Kraeuselisporites whitfordensis and *Varivaginaspora spinoreticulata* have a previous record from the Aalenian to the Bathonian. It is remarkable that Couper (1958) did not come across these striking species during his study. *Kraeuselisporites scalbiensis* has been commonly recorded from the Bathonian, although its range apparently extends into the Toarcian (Rutherford 1982). The validity of this single recording may be open to question on the basis of a lack of Aalenian and Bajocian recordings.

Table 4.13. Previous unpublished occurrences of selected spore taxa.

Species Author	***Tuberositriletes horridus***
Dodd, M., 1975.	as *Leptolepidites major*, Scalby Formation.
Fenton, J.P.G., 1980.	as *Concavissimisporites* sp. A., *Verrucosisporites obscurilaesuratus* and *Tuberositriletes major*; Rutland Fm-Blisworth Clay Fm..
Riccardiello, G.A., 1985.	as *Concavissimisporites southeyensis;* Blisworth Clay Formation.

Species Author	***Echinatisporis baculatus***
Brockley, P., 1976	as *Lycopodiacidites baculatus* & *Acanthotriletes levidensis,* Upper Deltaic Series
Davis, J.A., 1981.	as *Lycopodiacidites baculatus; progracilis* Zone, Taynton Stone & Hampen Marly Beds.
Fenton, J.P.G., 1980.	as *Lycopodiacidites baculatus* and *spinatus*; Rutland Formation to Blisworth Clay Fm..
Hooker, N.P., 1982.	as *Lycopodiacidites baculatus; progracilis* Zone, Sharp's Hill Member.
Humble, E.M., 1982.	as *Lycopodiacidites spinatus;* Forest Marble.
Pearce, J.M., 1982.	as *Lycopodiacidites spinatus;* Rutland Formation (Stamford Member)-Cornbrash Formation.
Renshaw, D.K., 1982.	as *Lycopodiacidites spinatus; tenuiplicatus* Zone, Stonesfield Slate Beds.
Riccardiello, G.A., 1985.	as *Lycopodiacidites spinatus;* 'Calcareous Beds', Great Oolite, Blisworth Clay.
Stronach, C.H., 1983.	as *Lycopodiacidites spinatus; bifrons* Zone, Alum Shales.
Tykoezinski, H.G.R., 1982.	as *Lycopodiacidites baculatus* & *L. irregularis; hodsoni -discus* Zone, Forest Marble.

Species Author	***Kraeuselisporites whitfordensis***
Brockley, P., 1976	as *Kraeuselisporites* sp. A, Upper Deltaic Series.
Dodd, M., 1975.	as Spore type A., Scalby Formation.
Fenton, J.P.G., 1980.	as *Kraeuslisporites* sp. A.; Grantham Formation.

Species Author	*Kraeuselisporites scalbiensis*
Brockley, P., 1976	as *Kraeuselisporites* sp. B, Upper Deltaic Series.
Dodd, M., 1975.	as *Kraeuselisporites* sp. A & B., Scalby Formation
Fenton, J.P.G., 1980.	as *Kraeuselisporites hyalinus*; Rutland Formation to Blisworth Clay Formation.
Forbes, G.A., 1981.	as *Kraeuselisporites hyalinus; progracilis* Zone, Sharp's Hill Formation.
Hooker, N.P., 1982.	as *Kraeuselisporites hyalinus; progracilis* Zone, Sharp's Hill Member.
Pearce, J.M., 1982.	as *Kraeuselisporites majus;* Stamford Member (Rutland Fm.).
Riccardiello, G.A., 1985.	as *Cadargasporites baculatus;* Lower Sandy Beds, Great Oolite.
Rutherford, M., 1982.	as ?*Kraeuselisporites hyalinus;* blue shales, Toarcian.
Todd, C., 1985.	as *Kraeuselisporites hyalinus;* Upper Bathonian-Callovian.
Tykoezinski, H.G.R., 1982.	as *Kraeuselisporites* sp. A; *aspidioides-discus* Zone, White Limestone-Lower Cornbrash.

Species Author	*Pararetispora jurassica*
Fenton, J.P.G., 1980.	as *Kraeuselisporites mathuri;* Rutland Formation to Blisworth Clay Formation.
Hooker, N.P., 1982.	as *Limbosporites lundbladii; progracilis* Zone, Sharp's Hill Member.
Pearce, J.M., 1982.	as Spore type A.; Stamford Member & rhythmic sequence (Rutland Formation).

From the present study it can be concluded that *Enigmaspora bella*, *Pararetispora jurassica* , *Tuberositriletes horridus* , *Tuberositriletes aequiverrucatus* and *Varivaginaspora reticulata* have range bases in the Bathonian. It may be possible to add *Kraeuselisportes scalbiensis* to this group depending on whether the recording by Rutherford (1982) is accepted. *Kraeuselisporites whitfordensis* and *Varivaginaspora spinoreticulata* are recorded in Bajocian and Bathonian strata, although they were not encountered in the Gristhorpe Member in the present study. The ranges of selected species are summarised in figure 4.9. It is not possible to define the range tops of species within the Scalby Formation. The effect upon the assemblages of different floodplain facies presumed present within the Scalby Formation is considered a dominant determining force over the species present.

Chapter 4

Comparison with previously published regional studies

Tralau (1968) considered the spore and pollen grains recovered in Fyledalen, Scania to indicate rocks of Bajocian and Bathonian age. He used previous published ranges from England, France and Germany, identifying both 'old elements' with stratigraphic ranges from the Lower to Middle Jurassic and 'new elements', whose ranges commence in the Middle Jurassic and extend through the Upper Jurassic and into the Cretaceous. Furthermore, Tralau considered the upward disappearance of *Lycopodiacidites rugulatus*, *Calamospora mesozoica*, *Trilites rariverrucatus*, *Eucommiidites granulosus* and *Leptolepidites equatibossus* to indicate the transition from Bajocian (erroneously referred to as "Bathonian elements") to Bathonian aged strata.

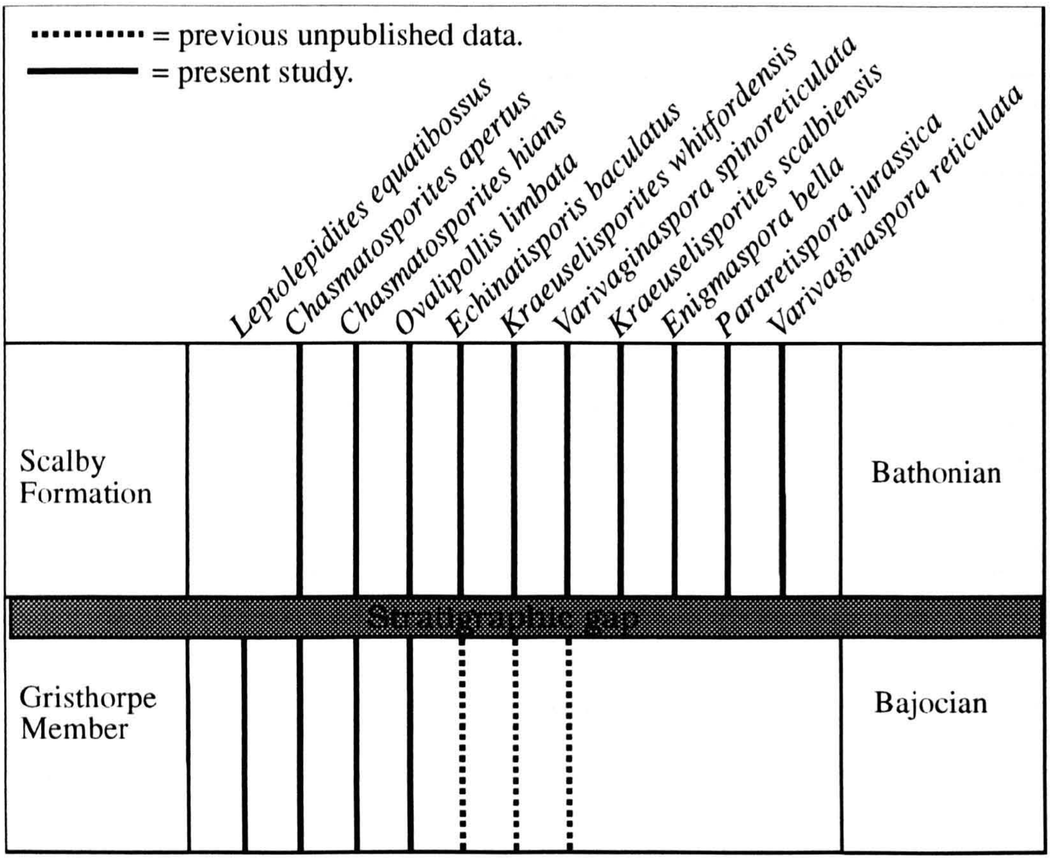


Figure 4.9. Ranges of selected spore and pollen grains in the Ravenscar Group

It is difficult to compare the present results with those of Tralau (*op. cit.*). He considered *Lycopodiacidites spinatus* (al. *Echinatisporis baculatus*), amongst others, typical of Kimmeridgian sediments in the nearby Baltic region. However, as has been proved earlier in this chapter, the range of this species extends down into the Toarcian in central and north east England. This combined with misidentification of species considered 'key elements' (e.g.the illustrations of *Tsugaepollenites trilobatus*, *Leptolepidites equatibossus* and *Gleicheniidites conspeciendus* are considered synonymous with *Callialasporites turbatus*, *Leptolepidites bossus* and *Gleicheniidites* *senonicus* respectively in the present study) throws doubt on the results of Tralau (*op. cit.*) and the relevance of his work in Scania to the present study.

Vigran & Thusu (1975) declined to define the Middle Jurassic strata identified in Norway on the basis of spore and pollen grain ranges. This is despite the dating of the lower part of the Ramså Formation solely on the basis of palynomorphs. In addition, a plethora of species are recorded in the publication which were not encountered in the present study. This could be interpreted either that the rocks of Andøya are not Middle Jurassic in age or that the composition of the floras are significantly different than those of the Cleveland Basin. Since the Upper part of the Ramså Formation appears to be dated by ammonites the latter option is preferred.

Implications of the Scarborough Formation Marine Palynostratigraphy for previous work

The strong divergence in the composition of the assemblages recorded from the Scarborough Formation between the present study and that of Gowland & Riding (1991) suggests that much greater resolution may be obtainable from a comprehensive study of the the Formation from as many localities as possible. This data will also supplement the published ranges of taxa in the Bajocian of the UK, which clearly require revision on the basis of the present findings. This is more important considering that the formation is well dated by ammonites (Parsons 1980). The ranges of species in the present study agree more with those of Feist-Bukhardt & Wille (1992) from South West Germany than with Riding & Thomas (1992).

Implications of the Scalby Formation Marine Palynostratigraphy for previous work

Data regarding the Moor Grit Member does not elucidate the timing of it's deposition, despite the present record of dinoflagellate cysts. The relatively sparse marine flora does not include any age diagnostic species. The previous contention that the member is Upper Bajocian or Lower Bathonian age (Riding & Wright 1989) is discounted herein due to a lack of substantiative evidence. The sedimentological suggestions of Leeder & Nami (1979, p. 469) and Leeder & Alexander (1985) are herein followed.

The palynostratigraphic conclusions for the Long Nab Member do not diverge from those of Riding & Wright (1989) but merely substantiate those authors findings and offer a tighter age restriction for the deposition of the Long Nab Member. The results deviate strongly with those of Fisher & Hancock (1985). This is considered further discounting evidence of their results following the doubts cast by Riding & Wright (1989).

The present findings agree with the sedimentological preferences of Leeder & Nami (1979). Their conclusions favoured a lengthy period of Bathonian non-deposition followed by removal of a small amout (a maximum of 10 metres) of Scarborough Formation deposits by Moor Grit channel erosion. Substantiating evidence in favour of this is suggestive from the nature of the non-marine assemblages.

Leeder & Nami (1979) cited futher evidence in support of their conclusions. To the south of the Cleveland Basin in North Humberside, the Bajocian Cave Oolite has been extensively weathered, decalcified and eroded before deposition of the 'White Sands' which are of probable Bathonian age (Brasier & Brasier 1978). Even further south, evidence for a late Bajocian / Bathonian hiatus is suggested by the non-marine 'Upper Estuarine Series' which lie between the Lower Bajocian Lincolnshire Limestone and the Upper Bathonian (*retrocostatum* Zone) Great Oolite Limestone (Cope *et al.* 1980). Leeder & Nami (1979) compared the scenario to the North Sea area where during a similar time span, " ... the combination of regressional facies, development of linear basins and the occurrence of basaltic volcanics in the Middle Jurassic of the North Sea area have tempted Sellwood & Hallam (1974) and Whiteman *et al.* (1975) to view the development of the Viking, southern North Sea and Dutch Basins as mantle driven plume rifts ... it links up the broad regional evidence for late Bajocian to Bathonian non-deposition in the Yorkshire area with an uplift mechanism to explain the formation of a large drainage basin and transport of a large volume of detrital clastic sediments deposited as the Scalby Formation." (Leeder & Nami (1979, p. 475)).

4.4. Sequence Stratigraphy

As a result of petroleum exploration, developments in seismic stratigraphy in the 1960's and 1970's led to the recognition by Vail *et al.* (1977) that primary seismic reflectors paralleled stratal surfaces and unconformities. Furthermore, sediment packages bounded by unconformities and their correlative conformities were considered primary units with chronostratigraphic significance. Vail *et al.* (*op cit.*) used sediment package geometries and patterns of onlap, downlap, truncation and basinward shifts of coastal onlap to interpret sea level histories along various continental margins. Since the publication of the first sea level curves (Vail *et al.* (*op. cit.*)) and the subsequent development of sequence stratigraphy (Mitchum *et al.* (1977)) debate has continued over the accuracy of the sea level curves and the underlying assumption that eustacy is the driving force behind the changes in sea level.

> Sequence stratigraphy is the study of genetically related facies within a framework of chronostratigraphically related surfaces.
>
> (Van Wagoner *et al.* 1990).

A sequence is defined as a relatively conformable, genetically related succession of strata bounded by unconformities or their correlative conformities (Mitchum 1977, p.210).

Parasequences can be recognised within sequences. These are defined as containing a genetically related succession of beds bounded by a marine flooding surface and are generally upward shoaling. Parasequence sets are genetically related parasequences which are bounded by major marine-flooding surfaces (Van Wagoner *et al.* 1990).

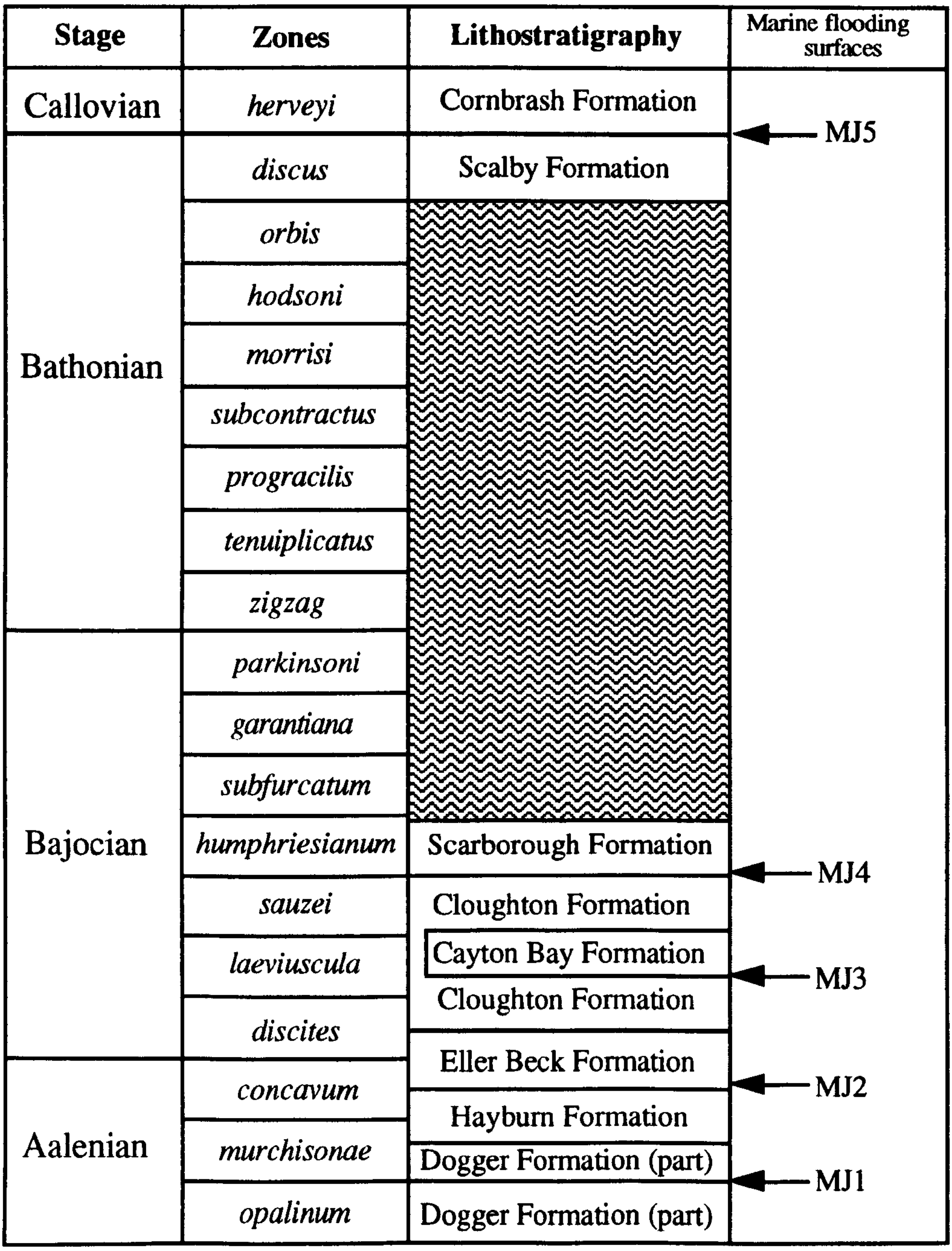
Both parasequence and parasequence set boundaries form in response to an change in water depth (as do sequence boundaries). Therefore, while sequences contain both parasequences and parasequence sets, in certain situations, the bounding surfaces of the parasequence (or parasequence set) can coincide with that of the sequence.

Galloway (1989) defined genetic stratigraphic sequences as flooding surface bounded depositional units. The author's main aim was to define stratigraphic sequences without the necessary recognition of classic sequence boundaries. Correlation employing microfossils (particularly dinoflagellate cysts) within a genetic sequence stratigraphic framework has recently been applied to the North Sea (Partington *et al.* in press).

Walker (1992) recognised that the concept of allostratigraphy coincided with the sequence concept of Mitchum *et al.* (1977). An allostratigraphic unit is defined as," ... a mappable stratiform body of sedimentary rock that is defined and identified on the basis of its bounding discontinuities" (Walker *op. cit.*, p. 9). The concept emphasises the processes external to the depositional system that initiate and terminate the deposition of a sedimentologically related sucession of facies. However," ... there is no implication in allostratigraphy as to what those external processes might be" (Walker *op. cit.*, p. 9).

The Cleveland Basin

Application of sequence stratigraphy to the Cleveland Basin was considered by Knox *et al.* (1990). They commented on the problems of applying classic sequence stratigraphic concepts, developed on continental margins, to the Cleveland Basin which was situated in an epicontinental area during the Jurassic (Hallam 1992). Despite this,



Stage	**Zones**	**Lithostratigraphy**	Marine flooding surfaces
Callovian	*herveyi*	Cornbrash Formation	MJ5
Bathonian	*discus*	Scalby Formation	
	orbis	▨	
	hodsoni	▨	
	morrisi	▨	
	subcontractus	▨	
	progracilis	▨	
	tenuiplicatus	▨	
	zigzag	▨	
Bajocian	*parkinsoni*	▨	
	garantiana	▨	
	subfurcatum	▨	
	humphriesianum	Scarborough Formation	MJ4
	sauzei	Cloughton Formation	
	laeviuscula	Cayton Bay Formation	MJ3
	discites	Cloughton Formation Eller Beck Formation	
Aalenian	*concavum*	Eller Beck Formation Hayburn Formation	MJ2
	murchisonae	Dogger Formation (part)	MJ1
	opalinum	Dogger Formation (part)	

Figure 4.10. Middle Jurassic marine flooding surfaces in the Cleveland Basin.

Knox *et al.* (*op. cit.*) recognised three major transgressive-regressive cycles in the Cleveland Basin; base 'upper' Dogger Formation Formation to top Saltwick Formation, base Ellerbeck Formation to top Cloughton Formation and base Scarborough Formation to top Scalby Formation. The authors considered the Lebberston Member (presumably referring to the Cayton Bay Formation) as a minor localised marine event. However, the Cayton Bay Formation can be correlated southwards with the Cave Oolite of North Humberside and with the Lincolnshire Limestone (in part) in Lincolnshire (Fox-Strangways 1892, Bate 1967). The location of marine flooding surfaces ("a surface separating younger and older strata across which there is evidence of abrupt increase in water depth", Van Wagoner *et al.* 1990) in the Ravenscar Group is shown in figure 4.10.

It is possible to define the maximum flooding surface within the Scarborough Formation based on the type section (Gowland & Riding 1991, Fig. 4). The stratigraphy above and below the remaining marine flooding surfaces in the Ravenscar Group does not allow the recognition of maximum flooding surfaces elsewhere.

The base of the Ravenscar Shale Member records rapid deepening. Below the Ravenscar Shale Member, the Helwath Beck Member, Hundale Shale Member and Hundale Sandstone Member are stacked in a retrogradational manner suggestive of a transgressive systems tract. Above the Ravenscar Shale Member, the White Nab Ironstone Member and Bogmire Gill Member are stacked in a progradational manner suggestive of a high stand systems tract (pers. obs. based on Gowland & Riding 1991, Fig. 4). The Ravenscar Shale Member is laterally traceable beyond the type section (Parsons 1980)(Fig. 1.6). However, at the Yons Nab section sampled for the present study, the nomenclature used at the type section is not applied (presumably due to the difficulty of correlating the thinner section preserved at Yons Nab). The apparent stratigraphic disparity between the type section at Hundale Point and the Yons Nab section is considered to be due to syn-depositional subsidence along the Peak Trough Graben (Milsom & Rawson 1989). It is arguable that the parasequences developed at the type section are in part a result of this subsidence rather than global eustatic sea level changes or orbital forcing mechanisms which are implicit in the sequence stratigraphic model.

It was not possible to recognise the maximum flooding surface at Yons Nab on the basis of the palynological assemblages (it has been suggested that species diversity reaches a maximum during the condensed sequence which forms at and above the maximum flooding surface (Jan du Chêne pers. comm. 1991)). However the lack of its recognition may in part be due to the sampling density achieved in the present study.

Underhill & Partington (in press) correlated the unconformity recognised within the Dogger Formation with the sequence boundary separating the Absaroka and Zuni first order megacycles of Haq *et al.* (1987, 1988). Underhill & Partington (in press) doubted the likelyhood that eustacy was responsible for the development of the

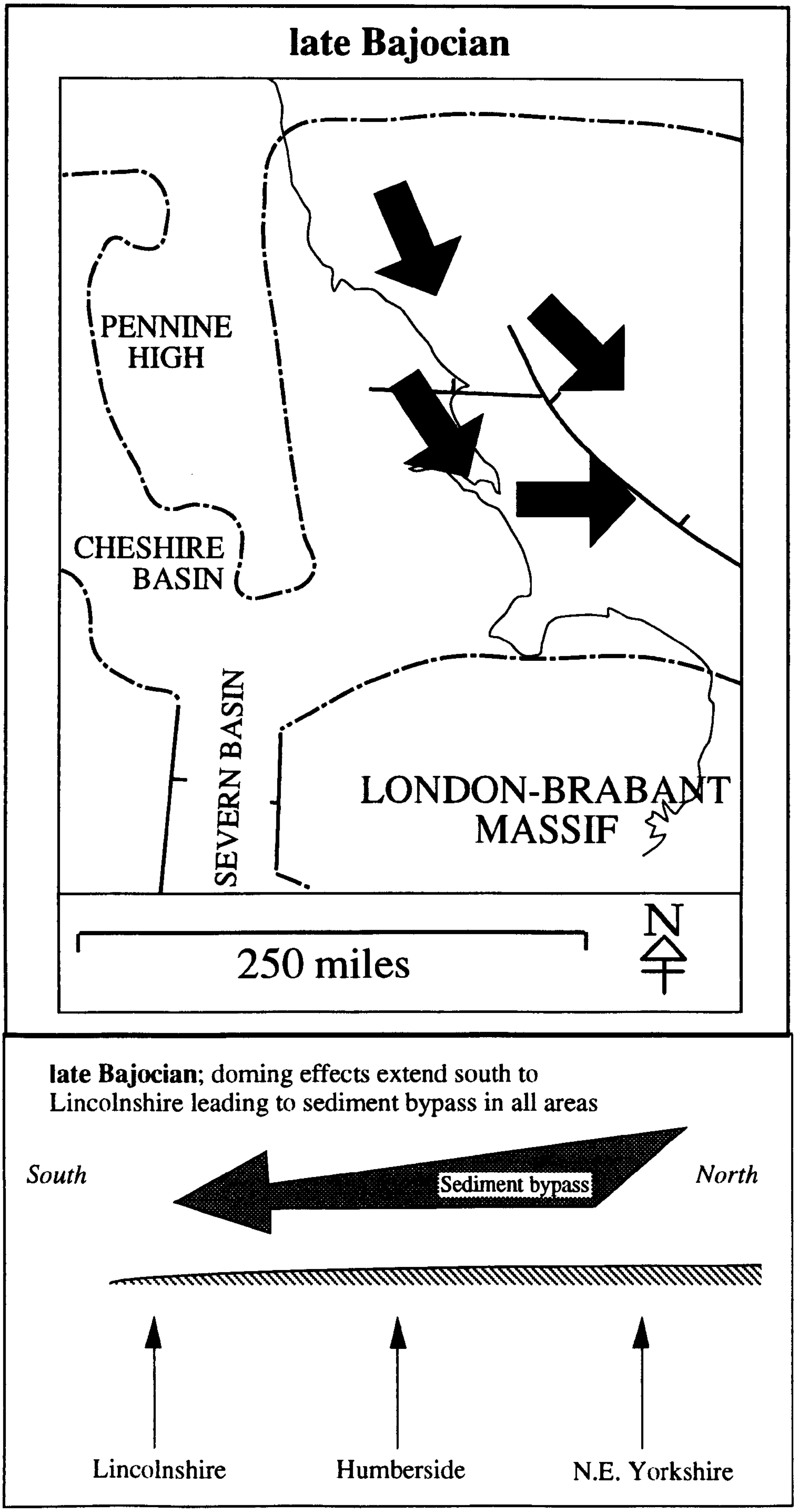
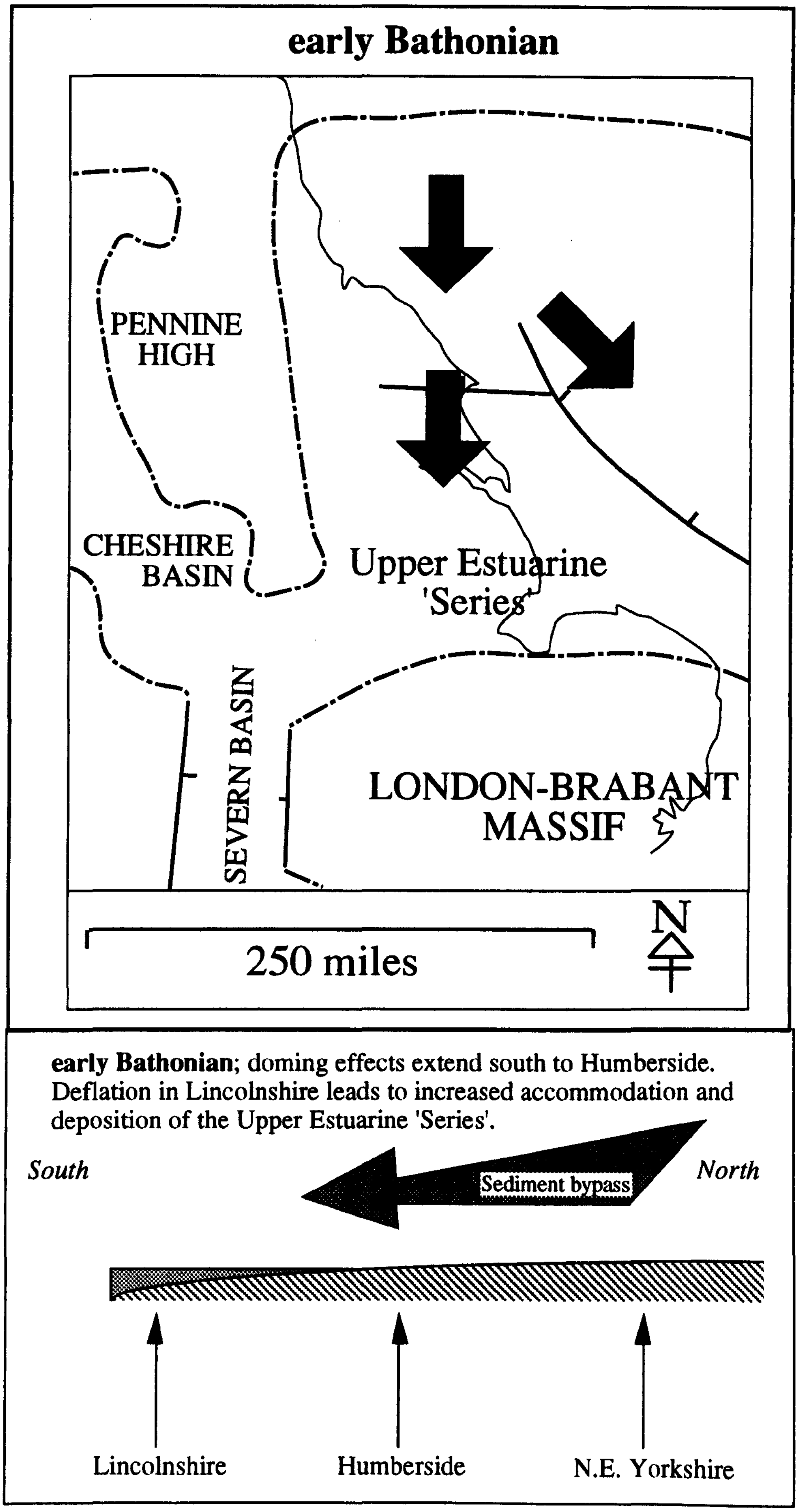


Figure 4.11. Regional depositional scenario for late Bajocian times.



early Bathonian; doming effects extend south to Humberside. Deflation in Lincolnshire leads to increased accommodation and deposition of the Upper Estuarine 'Series'.

Figure 4.12. Regional depositional scenario for early Bathonian times.

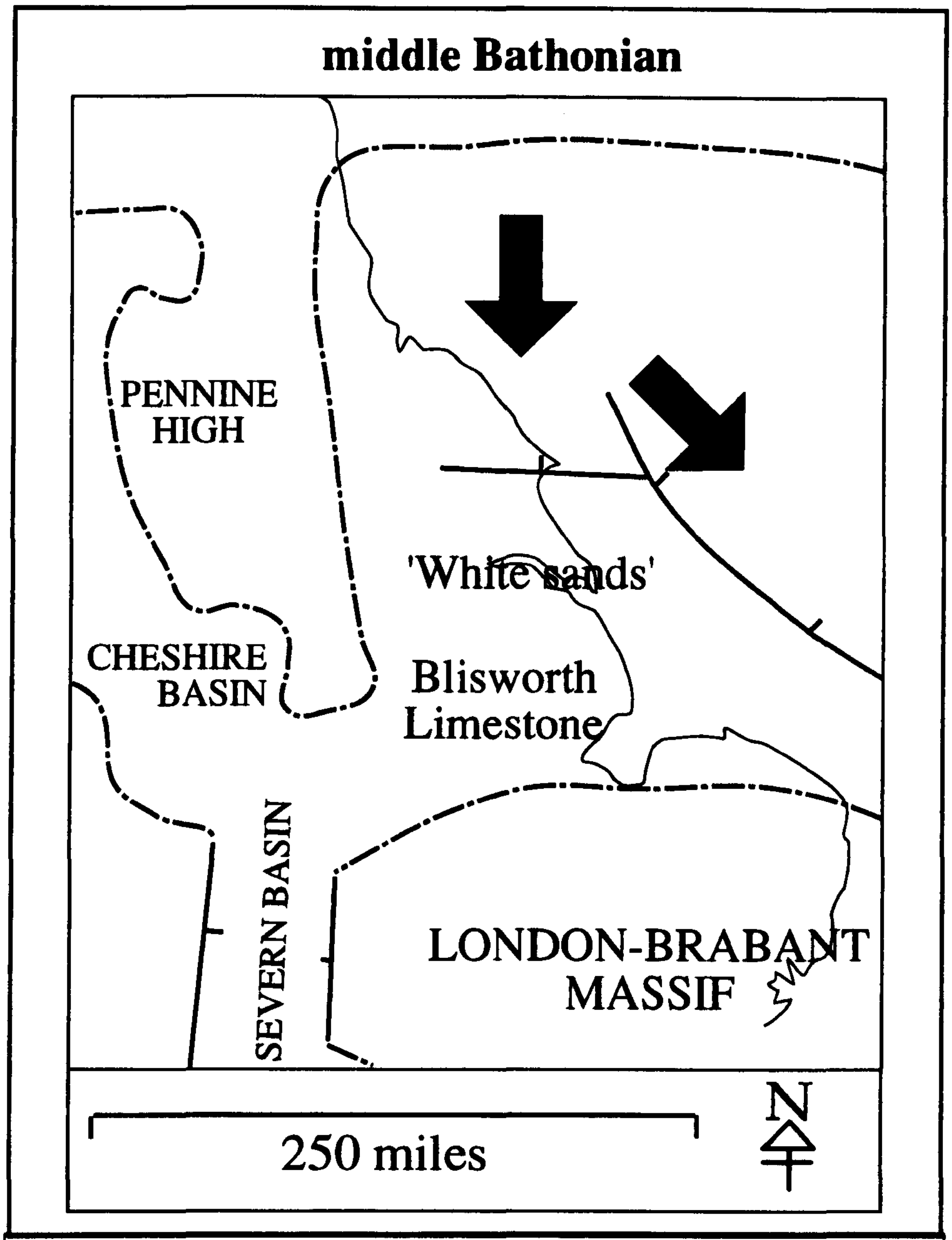
sequence boundary in the North West European region. These authors suggested that the emplacement of a mantle driven plume head or 'blob' into the asthenosphere in the region of the North Sea Graben triple junction was the driving force behind the sequence boundary separating the Absaroka and Zuni first order megacycles. This unconformity (commonly referred to as the Mid Cimmerian unconformity or event) overlies rocks of increasing age towards the triple junction. From this evidence, Underhill & Partington (*op. cit.*) inferred progressive truncation of the stratigraphy towards the triple junction. Uplift related to the plume head affected a region in excess of 4000 km^2.

A revision of the depositional characteristics of Bajocian and Bathonian sedimentation in the Cleveland Basin

The palynostratigraphic results of the present study suggests a lengthy period of non-deposition and / or erosion from late Bajocian to late Bathonian times. This corroborates the preferred hypothesis of Leeder & Nami (1979) and the petrological observations of Lott & Humphreys (1992). The unconformity recognised at the base of the Moor Grit Member has been interpreted as the result of erosion associated with a major basinward shift in facies (Eschard *et al.* 1989). To propose a type 1 sequence boundary at this level requires the recognition of the deposits of a lowstand or transgresive systems tract geometry overlying the unconformity. Eschard *et al.* (*op. cit.*) regarded the Moor Grit Member as an incised valley fill deposit (presumably deposited in late lowstand or early transgressive systems tract conditons). This contention is herein questioned since lateral facies variations do not appear to have been taken into account by those authors.

Coastal exposure bias is suggested as an explanation for the apparent architecture of the Moor Grit Member. It is of note that the excellent exposures of the Scalby Formation in Gristhorpe Bay and the lack of Moor Grit Member type facies there are rarely commented upon. The rapid disappearance of the Moor Grit Member south of White Nab is best explained by Peak Trough graben related tectonic control of the Scalby Formation distributary channels (Alexander 1986b, Milsom & Rawson 1989). In Gristhorpe Bay, the exposures of the Scalby Formation are situated outside the area of tectonic influence of the Peak Trough structure and thus here the lithologies contrast with those in the exposures on the coast between Scalby Ness and Crook Ness.

In order to explain the stratigraphic gap at the base of the Moor Grit Member, a doming mechanism similar to the 'Mid Cimmerian' event, described by Underhill & Partington (in press), is favoured. The unconformity at the base of the Scalby Formation is herein considered to be a signature of uplift related to a final phase of North Sea centred doming prior to the Callovian to Kimmeridgian deflation proposed by Underhill & Partington (in press). Underhill & Partington's observation of progressive onlap of post-unconformity sediments onto older sediments is supported by



middle Bathonian; doming effects extend south to the Market Weighton Structure. Further deflation in Lincolnshire leads to increased accommodation and deposition of the Blisworth Limestone in Lincolnshire and possibly the 'White Sands' in North Humberside.

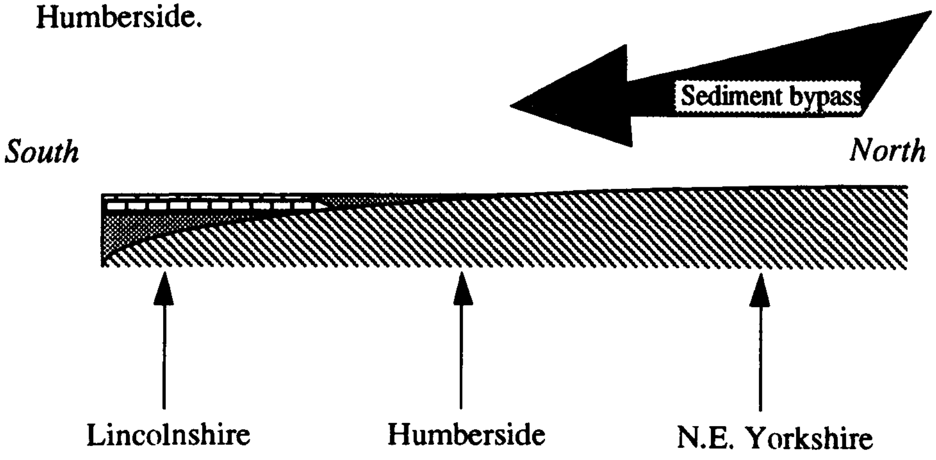
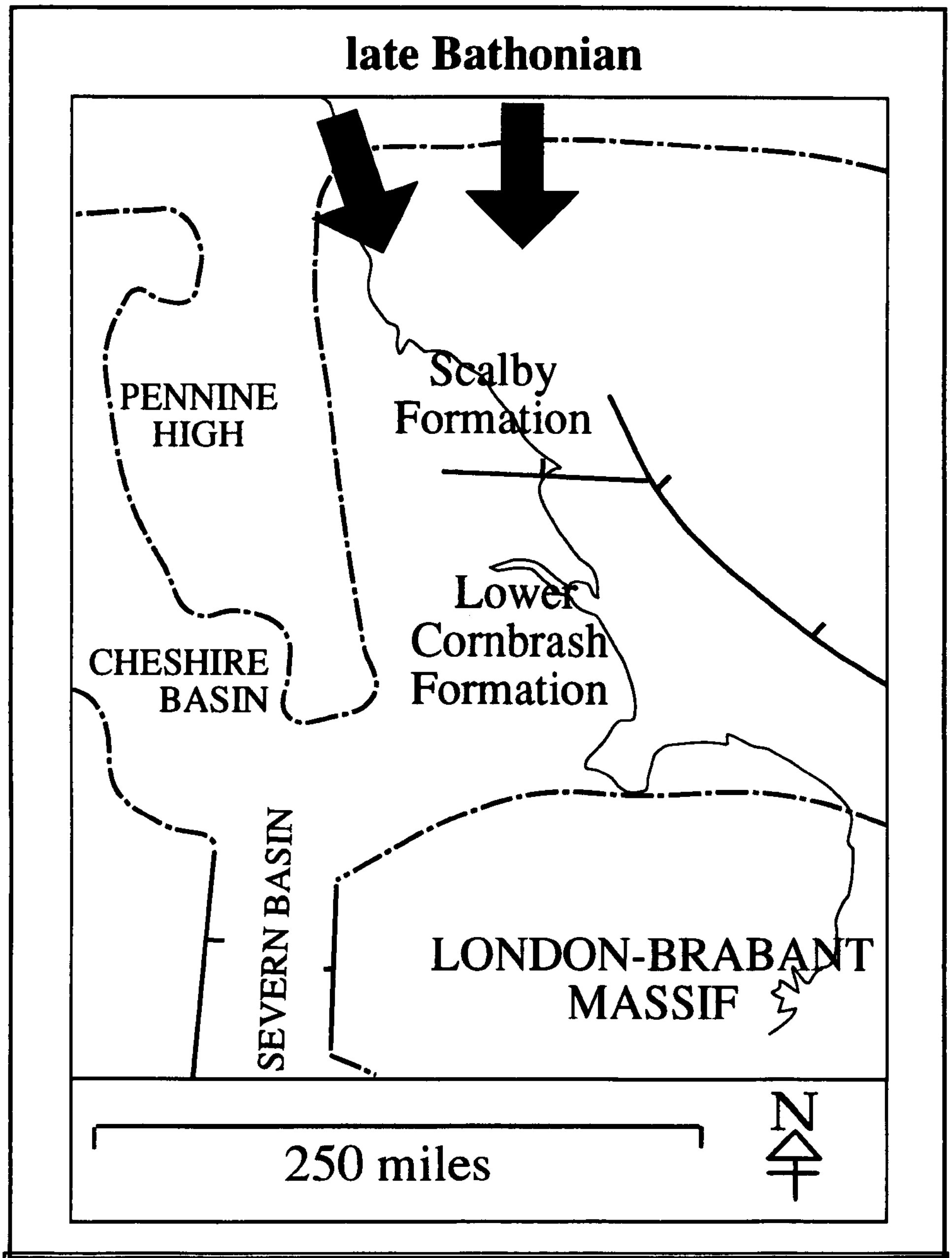


Figure 4.13. Regional depositional scenario for middle Bathonian times.



late Bathonian; Extensive deflation in all areas leads to increased accommodation. Deposition of the Lower Cornbrash in Lincolnshire and Humberside and the Scalby Formation in the Cleveland Basin.

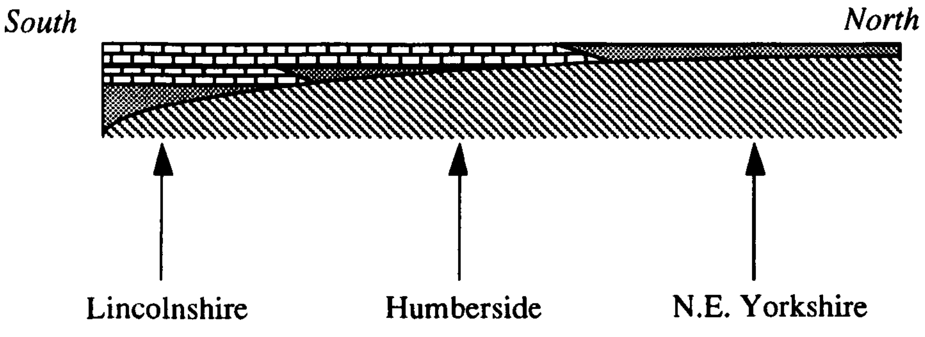


Figure 4.14. Regional depositional scenario for late Bathonian times.

evidence from Lincolnshire. Here, the Lower Bathonian aged Upper Estuarine 'Series' (Cope *et al.* 1980) unconformably overlie upper Lower Bajocian aged sediments (Lincolnshire Limestone). In North Humberside, the Cave Oolite was exposed to subaerial weathering before the deposiion of the 'White Sands' (Brasier & Brasier 1978). The age of the 'White Sands' has proved somewhat equivocal due to the lack of zonal fossils within the sediments. In the following hypothesised series of events, the age of the 'White Sands', as a result of the genetic model proposed, is suggested to be middle or early late Bathonian

It is envisaged that following the deposition of the Scarborough Formation and equivalent aged strata on the East Midlands Platform (late Bajocian), the whole region was affected by a mantle implacement-related doming event with a focus probably in the region of the Mid North Sea High or the North Sea Graben triple junction. This led to a decrease in accomodation potential throughout the region and sediment bypass, which was probably re-directed towards the Sole Pit Trough (Fig. 4.11). Subaerial erosion of the Cave Oolite commenced.

By early Bathonian times, deflation of the dome had commenced on the East Midlands Platform, leading to increased accomodation in that area and thus deposition of the Upper Estaurine 'Series' (Fig. 4.12).

By middle Bathonian times, deflation had continued northwards leading to progressive onlap of sediments. In Lincolnshire, the lithosphere had deflated sufficiently to allow deposition of the Blisworth Limestone, whereas in North Humberside, subaerial erosion had ceased and the 'White Sands' began to accumulate (Fig. 4.13).

By late Bathonian times, further deflation, possibly enhanced by the effects of the worldwide pre-Callovian transgression, led to continued onlap northwards and deposition of the Scalby Formation in the Cleveland Basin (Fig. 4.14). On the basis of the palynomorph assemblages recovered from the Scalby Formation, the 'Callovian transgression' in the area may have commenced in the *discus* Zone of the Upper Bathonian. This is supported by the observations of other workers (Jan du Chêne pers. comm. 1993, Riding pers. comm. 1993).

The Long Nab Member of the Scalby Formation is considered to represent aggraded sediments deposited in a transgressive systems tract on the basis of the scenario described above. The increasing occurrence of dinoflagellate cysts towards the top of the formation in the studied sections may indicate that the formation was becoming slightly retrogradational by this time. This is not possible to prove on a lithological basis as the region appears to have been lacking a coarse clastic source. It may be possible that this was due to the suppression of the sediment source area to the north as a result of the deflation of the dome and / or the effects of the Callovian transgression.

A revision of the regional stratigraphy is given in figure 4.15.

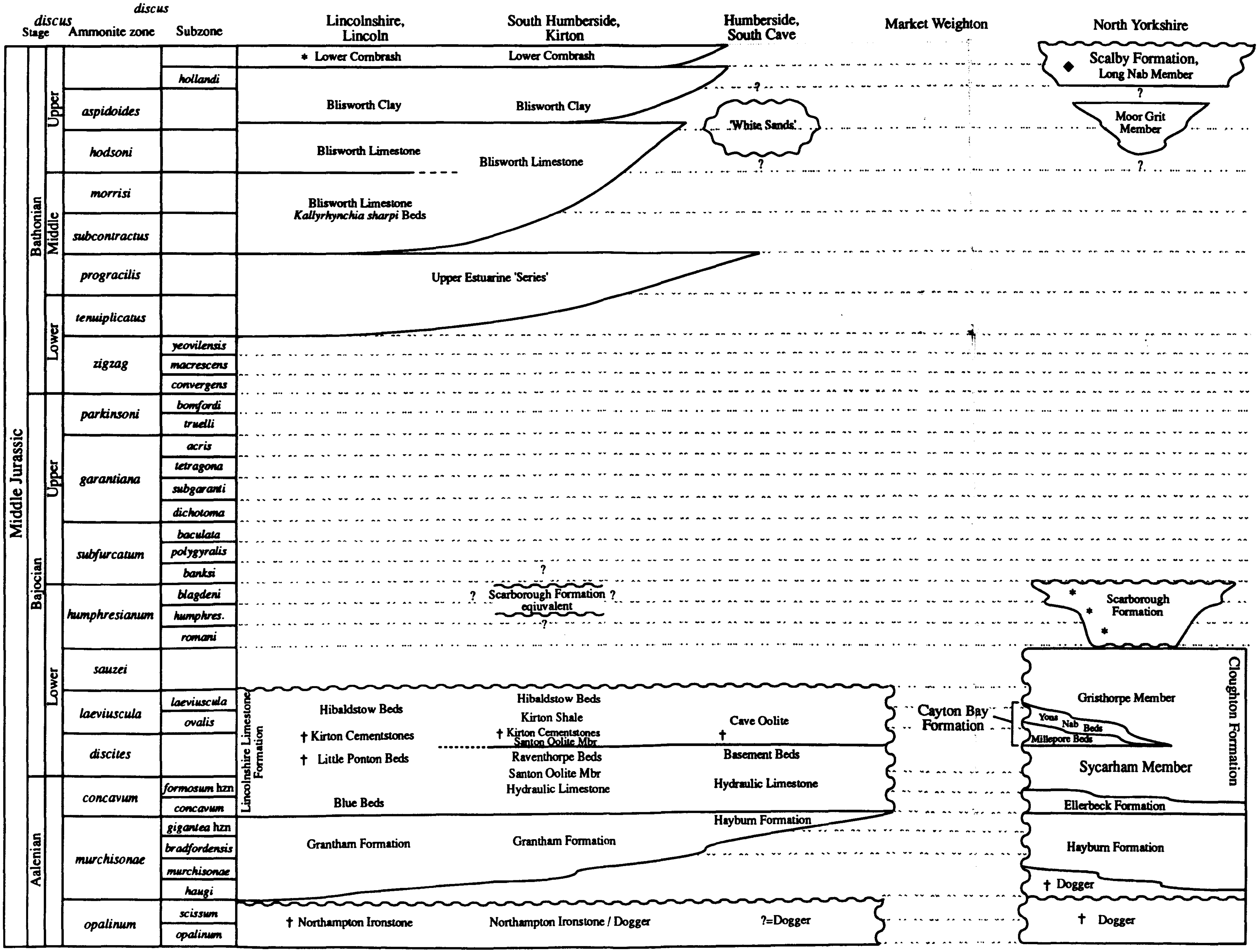


Figure 4.15. A revised stratigraphy for Lincolnshire, Humberside and north east Yorkshire (after, Cope *et al.* 1980 and Bradshaw & Bate 1983).

4.5. Conclusions and future work

One hundred and forty six samples collected from logged sections of the Scalby Formation (Ravenscar Group, Middle Jurassic) and adjacent strata from eight separate outcrops in North East Yorkshire have been analysed for their palynological content. Diverse marine and non-marine palynomorphs were recovered from the majority of samples. Three new genera of spores and one new acritarch genus are formally described, eighteen new species of spores, six new species of acritarchs and eight new species of dinoflagellate cysts are described. In addition, four new combinations of spore species and three acritarch species are proposed.

Of the non-marine taxa, five spore species appear to have their range bases in the Bathonian. A further one species may be of value pending a re-examination of a single unpublished recording. On the basis of the presence and absence of these species, the Scalby Formation can be clearly recognised from the underlying Gristhorpe Member.

An age for a substantial part of the Long Nab Member (Scalby Formation) of *discus* Zone (Upper Bathonian) has been proposed on the occurrence of 'key' dinoflagellate cyst species. Two 'key' dinoflagellate cyst species, *Ambonisphaera calloviana* Fensome 1979 and *Tabulodinium senarium* Dodekova 1990, are recorded for the first time in UK strata.

The results reinterpret the timing of deposition of the Scalby Formation and its relationship with the adjacent Scarborough and Cornbrash Formations. A revised correlation of the stratigraphy of the region has been proposed and the formations position within a sequence stratigraphic framework was considered.

The identification of probable zygospores of Zygnemataceae (Chlorophyceae) has been used in palaeoenvironmental interpretations of several of the outcrop sections. Both dinoflagellate cysts and impoverished samples have been recognised in the floodplain sediments and interpreted on the basis of modern floodplain and delta top processes.

The application of assemblage associations was found to be of use in providing a broad overview of the assemblage characteristics for the majority of sections. Lateral correlation of sections was attempted following the results of the associations and further considerations. Palaeoenvironmental interpretations for each association have been offered.

Future work

The present study has highlighted the advantages of increased sample coverage in recording the presence of marine influence on floodplain environments. The need to achieve a wide geographical sample coverage necessarily reduces the sample density achievable at any location in the study. It would be of great interest to record the assemblages changes in a single section with a sample density of between 10cm and 20cm.

The discovery of numerous dinoflagellate cyst species beneath the Callovian transgression, which are normally encountered above the flooding surface, is of interest. A re-study and review of pre-Callovian post-Middle Bathonian strata regionally may shed more light on these cyst distributions.

At the time of submission, the author has received a paper by Alexander (1992[1]) documenting the lithofacies recognised in the Scalby Formation. The work clearly improves on previous publications regarding facies recognition. A combined study of lithofacies and palynology would improve the present knowledge of facies-palynology relationships.

---

[1] Alexander, J.A., 1992. A discussion of alluvial sandstone body characteristics related to variations in marine influence, Middle Jurassic of the Cleveland Basin, UK, and the implications for analogous Brent Group strata in the North Sea Basin. In Morton, A.C., Hazeldine, R.S., Giles, M.R. & Brown, S. (Eds.), Geology of the Brent Group. *Geological Society Special Publication*, **61**; 149-167.

Agrali, B., 1969. Amsara Karbonifer havzasindaki bazi münferit kömür seviyelerinin palinolojik etüdü ve yas tayinleri. *Türkiye Jeoloji Kurumu Bülteni,* **12**; 10-28.

Alberti, G., 1961. Zur kemtnis mesozoischer und alttertiäer Dinoflagellaten und Hystrichosphaerideen von nord und Mitteldeutschlands sowie einigen anderen europäischen Gebieten. *Palaeontographica, Abteilung B* , **116**: 1-58.

Alexander, J., 1986a. Sedimentary and Tectonic Controls of alluvial facies distribution: Middle Jurassic, Yorkshire and the North Sea Basins and the Holocene, SW Montana, USA.*Unpublished PhD thesis, University of Leeds.*

Alexander, J., 1986b. Idealised flow models to predict alluvial sandstone distribution in the Middle Jurassic Yorkshire Basin. *Marine and Petroleum Geology,* **3**: 298-305.

Alexander, J., 1987. Syn-sedimentary and burial related deformation in the Middle Jurassic non-marine formations of the Yorkshire Basin. in; Jones, M.E., Preston, R.M.F., (eds), *Deformation of Sediments and Sedimentary Rocks, Geological Society Special Publication* 29; 315-324.

Alexander, J., 1989. Delta or coastal plain? With an example of the controversy from the Middle Jurassic of Yorkshire. *in*: Whateley, M.K.G. and Pickering, K.T. (eds). *Deltas: Sites and Traps for Fossil Fuels.* Geol. Soc. Lond. Sp. Pub. No. **41**.

Alexander, J., 1992. Nature and origin of a laterally extensive alluvial sandstone body in the Middle Jurassic Scalby Formation. *Journal of the Geological Society of London,* **149**: 431-441.

Antonesçu, E., 1974. Un nouveau genre de Dinoflagellé dans le Jurassique moyen de Roumanie. *Revue de Micropaléonologie.*, **17**: 61-65.

Archangelsky, S., & Gamerro, J.C., 1966. Estudio palynol6gio de la Formaci6n Baquer6 (Cretácio), Provincia de Santa Cruz. I. *Ameghiniana,* **4**: 201-209.

Archangelsky, S., & Gamerro, J.C., 1966. Estudio palynol6gio de la Formaci6n Baquer6 (Cretácio), Provincia de Santa Cruz. II. *Ameghiniana,* **4**: 363-370.

Ashton, M., 1980. The stratigraphy of the Lincolnshire Limestone Formation (Bajocian) of eastern England. *Proceedings of the Geological Society of London,* **91**: 203-223.

Backhouse, J., 1988. Late Jurassic and Early Cretaceous palynology of the Perth Basin, Western Australia. *Geological Survey of Western Australia, Bulletin* **135**: 1-51.

Bailey, D., 1987. *Durotrigia daveyi* gen. *et* sp. nov.; an Early Bajocian dinocyst with a variable pre-cingular archaeopyle. *Journal of Micropalaeontology,* **6**: 89-96.

Bailey, D.A. and Partington, M., 1991. Some Middle Jurassic dinocysts from the Brent Group of the Northern North Sea. *Journal of Micropalaeontology,* **9** (2): 245-252.

Balme, B.E., 1957. Spores and pollen grains from the Middle Mesozoic of Western Australia. *Comm. Scient. Ind. Res. Org., Coal Research sect., Aust,* 50 pp.

Barale, G., 1982. Le genre Cycadopites Zigno au Jurassique dans l'ouest Europeén. *Palaeontographica, Abteilung B,***183**: 8-56.

References

Bartlett, H.H., 1923. The Genus Triletes, Reinsch. *Papers from the Department of Botany of the University of Michigan*, **253**:.29-38.

Bate, R.H., 1959. The Yons Nab Beds of the Middle Jurassic of the Yorkshire coast. *Proceedings of the Yorkshire Geological Society*, **32**, 153-164.

Bate, R.H., 1965. Middle Jurassic ostracoda from the Grey Limestone Series, Yorkshire. *Bulletin of the. British Museum of Natural History (geology)*, **11**: 73-133.

Bate, R.H., 1967. Stratigraphy and palaeogeography of the Yorkshire Oolites and their relationships with the Lincolnshire Limestone. *Bulletin of the. British Museum of Natural History (geology)*, **14**: 111-141.

Below, R., 1982. *Rigaudella,* ein neues genus von Dinoflagellaten-Zysten. *N. Jb. Geol. Palaeont., Mh.*: 137-150.

Below, R., 1987. Evolution und Systematik von Dinoflagellaten-Zysten aus der Ordnung Peridiniales, II. Cladopyxiaceae und Valvaeodiniaceae*Palaeontographica , Abteilung B*, **206**: 1-135.

Bennie, J., & Kidston, R., 1886. On the occurrence of Spores in the Carboniferous Formation of Scotland. *Proceedings of the Royal Physics Society, Edinburgh*, **9**: 82-117.

Bernier, P., & Courtinat B., 1979. Le microplancton (Leiosphaeridae) et la matière organique des calcaires d'arrière-récif du Kimmeridgien supérieur dans le Jura méridional Systematique, conditions de genese et d'environment. *Documents des laboratoires de géologie de la Faculté des sciences de Lyon*, **75**; 95-117.

Bharadwaj, D. C., & Singh, H. P., 1964. An Upper Triassic miospore assemblage from the coals of Lunz, Austria. *Palaeobotanist*, **12**(1963): 28-44.

Bharadwaj, D.C., Venkatachala, B.S., 1968. Suggestions for a morphological classification of sporae dispersae. *Revue of Palaeobotany and Palynology*, **6**; 41-59.

Black, M., 1929. Drifted Plant Beds of the Upper Estuarine Series of Yorkshire. *Quarterly Journal of the Geological Society of London*, **34**: 389-439.

Bolkhovitina, N. A., 1953. Characteristic spores and pollen from the Cretaceous of the central part of the USSR. *Trudy Inst. Geol. Nauk, Akad. Nauk SSSR, ed. 145, Geol. Ser.* **61**: 1-184 (in Russian).

Bolkhovitina, N. A., 1966. Fossil spores of the family Gleicheniaceae (taxonomy and distribution). 65-75, *in* Neustadt, M.I. (ed.): *The importance of palynological analysis for stratigraphic and palaeobotanic investigations*. Nauka, Moscow, (in Russian).

Boulter, M.C., 1979. Taxonomy and Nomenclature of fossil pollen from the Tertiary. *Taxon*, **28**; 337-344.

Boulter, M.C., Wilkinson, G.C., 1977. A system of group names for some Tertiary pollen., *Palaeontology*, **20**; 559-579.

Brasier, M.D. & Brasier C.J., 1978. Littoral and fluviatile facies in the 'Kellaways Beds' on the Market Weighton Swell. *Proceeding of the Yorkshire Geological Association*, **42**: 1-20.

Brenner, G. J., 1963. The spores and pollen of the Potomac Group of Maryland. *Maryland Deptartment of Geology, Mines and Water Resources Bulletin* **27**: 1-215.

Brenner, W., 1986. Bemerkungen zur Palynostratigraphie der Rhät-Lias-Grenze in SW-Deutschland. *N. Jb. Geol. Paläont., Abh.***173**; 131-166.

Briche, P., Danzé-Corsin, P., & Laveine, J. P., 1963. Flore infraliasique du Boulonnais (macro- et microflore). *Soc. Géol. Nord, Mém.*, **13**; 1-143.

Brideaux, W. W., 1977. Taxonomy of Upper Jurassic-Lower Cretaceous microplankton from the Richardson Mountains, District of Mackenzie, Canada. *Bulletin of the Geological Survey of Canada*, **281**; 1-89.

Brockley, P., 1976. A palynological study of sediments of the Upper Estuarine Series (Bathonian), Clipsham Quarry, Leicestershire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Burden, E. T., & Hills, L. V. 1989. Illustrated key to genera of Lower Cretaceous terrestrial palynomorphs (excluding megaspores) of Western Canada. *American Association of Stratigraphic Palynologists, Contribution Series*, **21**; 1-147.

Burger, D., 1966. Palynology of uppermost Jurassic and lowermost Cretaceous strata in the Eastern Netherlands. *Leidse Geol. Meded.*, **35**; 211-276.

Burger, D., 1988. Early Cretaceous environments in the Eromanga Basin; palynological evidence from GSQ Wyandra-1 corehole. In Jell, P. A., & Playford, G., (eds.), *Association of Australasian Palaeontologists, Memoir.* **5**: 173-186.

Butterworth, M.A., Williams, R.W., 1958. The small spore floras of coals in the Limestone Coal Group and Upper Limestone Group of the Lower Carboniferous of Scotland. *Transactions of the Royal Society of Edinburgh*, **63**; 353-392.

Chaloner, W.G., 1958. The Carboniferous Upland Flora. *Geol. Mag.*, **95**: 261-262.

Chaloner, W.G., 1986. The Palaeoecology of fossil spores. In Drake, E.T., (Ed.) *Evolution and Environment.* New Haven, Conneticut: Yale University Press. 125-38.

Chang, L., 1965. Spore-pollen complexes of the Yima coal-bearing series in western Hunan Province. *Acta Palaeontologica Sinica,* **13**: 160-196.

Collinson, M.E.,& Scott, A.C.,1987. Implications of vegetational change through the geological record on models for coal-forming environments. *in* Scott, A.C. (ed.) *Coal and coal-bearing strata: Recent Advances.*Geol. Soc. Sp. Pub. No. 32: 67-85.

Cookson, I.C., 1947. Plant microfossils from the lignites of the Kerguelen Archipelago. *B.A.N.Z. Antarctic Resources Expedition 1929-31, Report A2*, 127-142.

Cookson, I.C., 1950. Fossil pollen grains of the proteaceous type from Tertiary deposits in Australia. *Australian Journal of Scientific Research*, **3**; 166-177.

Cookson, I.C., 1953. Difference in microspore composition of some samples from a borehole at Comaum, south Australia. *Australian Journal of Botany,* **1**: 462-473.

Cookson, I.C., 1953. The identification of the sporomorph *Phyllocladidites* with *Dacrydium* and its distribution in southern Tertiary deposits. *Australian Journal of Botany*, **1**, pp.64-70.

References

Cookson, I.C., 1954. A palynological examination of No. 1 bore, Birregurra, Victoria. *Proceedings of the Royal Society of Victoria* **66**; 119-128.

Cookson, I.C., 1956. Pollen grains of the Ephedra type in Australian Tertiary deposits. *Nature.,* **177**; 47-48.

Cookson, I. C., & Dettmann, M. E., 1958. Some trilete spores from Upper Mesozoic deposits in the eastern Australia Region. *Proceedings of the Royal Society Victoria,* **70**: 95-108.

Cookson, I. C., & Dettmann, M. E., 1959. On *Schizosporis*, a new form genus from Australian Cretaceous deposits. *Micropalaeontology*; **5**; 213-216.

Cookson, I. C., & Eisenack, A., 1962. Additional microplankton from Australian Cretaceous sediments. *Micropaleontology,* **8**: 485-507.

Cookson, I. C., & Manum, S., 1960. On *Crassosphaera,* a new genus of microfossils from Mesozoic and Tertiary deposits. *Nytt Magasin for Botanikk* **8**, 5-8.

Cope, J.C.W., Duff, K.L., Parsons, C.F., Torrens, H.S., Wimbledon, W.A. & Wright, J.K., 1980. *A correlation of Jurassic rocks in the British Isles. Part two.* Geological Society of London Special Report No. **15**.

Cornet, B., & Traverse, A. 1975. Palynological contributions to the chronology and stratigraphy of the Hartford Basin in Connecticut and Massachusetts. *Geoscience and Man,* **11**: 1-33.

Couper, R.A., 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *New Zealand Geological Survey Palaeontological Bulletin,* **22**, 77 pp.

Couper, R.A., 1956. Evidence of a possible gymnospermous affinity for *Tricolpites troedsonii* Erdtman., *New Phytologist.* **55**; 280-285.

Couper, R.A., 1958. British Mesozoic microspores and pollen grains: A systematic and stratigraphic study. *Paläontographica, Abteilung B,* **103**: 75-179.

Courtinat, B., 1987. Interprétation des grains de pollen du groupe *Araucariacites* Cookson, 1947. Comparison avec les formes actuelles. (*Araucaria excelsia* R. Brown). *Revue de Micropaléontologie,* **30**: 79-90.

Danze-Corsin, J & Laveine, J.P., 1963. Étude palynologique d'une argile provenant de la limite Lias Dogger, dans un sondage à Boulogne-sur-Mer. *Ann. Soc. Geol. Nord.* **83**: 79-90.

Daugherty, L.H., 1941. *The Upper Triassic flora of Arizona.* Carnegie Institute, Washington. Publication 526, 108 pp.

Davey, R. J., Downie, C., Sarjeant, W. A. S., & Wiliams, G. L., 1966a. Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bulletin of the British Museum of Natural History (Geology), Supplement 3*: 1-248.

Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L., 1966b. Fossil dinoflagellate cysts attributed to *Baltisphaeridium*.. In, Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L. (Eds). Studies on Mesozoic & Cainozoic dinoflagellate cysts. *Bulletin of the British Museum of Natural History (Geology), Supplement 3*: 157-175.

Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L., 1969. Generic reallocations. *Bulletin of the British Museum of Natural History (Geology), Appendix to Supplement 3*: 15-17.

Davey, R.J. & Williams G.L., 1966. The genus *Hystrichodinium* and its allies. In, Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L. (Eds). Studies on Mesozoic & Cainozoic dinoflagellate cysts. *Bulletin of the British Museum of Natural History (Geology), Supplement 3*: 53-106.

Davis, J.A., 1981. A palynological investigation into Middle to Upper Bathonian strata from Woodeaton, Oxfordshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

De Coninck, J., 1969. Dinophyceae et Acritarcha de l'Yprésien du Sondage de Kallo. *Inst. Roy. des Sci. Nat. de Belgique, Memoire,* **161**: 1-67.

De Coninck, J., 1975. Microfossiles à paroi organique de l'Yprésien du Bassin Belge. *Serv. Géol. Belg., Prof. Pap.* **12**: 1-151.

De Jersey, N. J., 1960. Jurassic spores and pollen from the Rosewood Coalfield. *Geological Survey of Queensland Publication 294*: 1-14.

De Jersey, N. J., 1962. Triassic spores and pollen from the Ipswich Coalfield. *Geological Survey of Queensland Publication 307*: 1-18.

De Jersey, N. J., 1964. Triassic spores and pollen grains from the Bundamba Group. *Geological Survey of Queensland Publication 321*: 1-21.

De Jersey, N. J., & Paten, R. J., 1964. Jurassic spores and pollen grains from the Surat Basin. *Geological Survey of Queensland Publication 322*: 1-18.

De Jersey, N.J. & Raine, J.I., 1990. Triassic and earliest Jurassic miospores from the Murihiku Supergroup, New Zealand. *New Zealand Geological Survey, Palaeontological Bulletin,* **62**: 1-164.

Deflandre, G., 1937. Microfossiles des silex cretaces. II: Flagelles *incertae sedis* . Hystrichosphaeridés. Sarcodines. Organismes divers. *Annales de Paleontologie,* **26**:51-103.

Deflandre, G., 1938. Sur le microplankton des mers Jurassiques, conservé à l'état de matiére organique dans les marnes des Villers sur Mer. *Comptes rendus de l'Académie des Sciences, Paris,* **206**: 678-689.

Deflandre, G., 1941. Le microplancton kiméridgien d'Orbagnoux et l'origine des huiles sulfurées naturelles. *Mémoires de l'Académie des sciences, Paris,* **65** 1-32.

Deflandre, G., 1945. Microfossiles des calcaires Siluriens de la Montagne Noire. *Annales de Palaeontologie* ,**31**, 41-75.

Deflandre, G., 1947. Sur quelques microorganismes planctoniques des silex jurassiques. *Bulletin du Institut océanographique, Monaco,* **921**: 1-10.

Deflandre, G., 1954. Systématique des hystrichosphaeridés: sur l'acception du genre *Cymatiosphaera* O. Wetzel. *Comptes rendus de la société géologique de France.* **12**: 257-258.

References

Delcourt, A., Dettmann, M.E., Hughes, N.F., 1963. Revision of some Lower Cretaceous microspores from Belgium. *Palaeontology*, **6**: 282-292.

Delcourt, A., Sprumont, G., 1955. Les spores et grains de pollen du Wealdien du Hainaut. *Mem. Soc. Belg. Geol.*, **4**, 73 pp.

Delevoryas, T. & Hope, R.C., 1973. Fertile coniferophyte remains from the late Triassic Deep River Basin, North Carolina. *American Journal of Botany*, **60**: 810-18.

Dettmann, M.E., 1963. Upper Mesozoic microfloras from southeastern Australia. *Proceedings of the Royal Society of Victoria, new series*, **77**: 1-148.

Dettmann, M.E., 1986. Early Cretaceous palynofloras of subsurface strata correlative with the Koonwarra Fossil Bed, Victoria. *Memoirs of the Association of Australasian Palaeontologists*, **3**: 74-110.

Detmann, M.E. & Playford, G., 1968. Taxonomy of some Cretaceous spores and pollen grains from Eastern Australia. *Proceedings of the Royal Society of Victoria*, **81**: 69-93.

Dev, S., 1961. The fossil flora of the Jabalpur Series, 3. Spores and pollen grains. *Palaeobotanist*, **8**: 43-56.

Dev, S., 1980. Evaluation of *in situ* spores and pollen grains from Jurassic andCretaceous fructifications. *4th Inst. Paly. Conf. LUCKNOW (1976-1977)*, **2**: 753-786.

Dingle, R.V., 1971. A marine geological survey off the northeast coast of England (western North Sea). *Journal of the Geological Society.*, **127**, 303-338.

Dodd, M., 1975. Spores and pollen from uppermost Bajocian, Bathonian and Lower Callovian rocks of East Yorkshire. *Unpublished M.Sc. dissertation, University of Sheffileld.*

Dodekova, L., 1974. *Compositosphaeridium* gen. n.-a new dinoflagellate cyst. *Bulgarian Academy of Science, Ministry of Heavy Industry, Bulletin of the Geological Institute, Palaeontology series*, **23**: 25-30.

Dodekova, L., 1975. New upper Bathonian dinoflagellate cysts from north-eastern Bulgaria. *Bulgarian Academy of Science, Paleontological Stratigraphy and Lithostratigraphy*, **2**: 17-34.

Dodekova, L. 1990. Dinoflagellate cysts from the Bathonian-Tithonian (Jurassic) of North Bulgaria. I. Taxonomy of Bathonian and Callovian dinoflagellate cysts. *Geologica Balcanica*, **20**; 3-45.

Dörhöfer, G., Davies, E.H., 1980. *Evolution of archaeopyle and tabulation in Rhaetogonyaulacinean dinoflagellate cysts*. Royal Ontario Museum, Life Sciences, Miscellaneous Publications, 91pp.

Dörhöfer, G., & Norris, G., 1977b. Discrimination and correlation of highest Jurassic and lowest Cretaceous terrestrial palynofloras in Northwest Europe. *Palynology*, **1**: 79-93.

Döring, H., 1961. Planktonartige Fossilien des Jura. 1 Kreide-Grenzebereiches der Bohrungen Werle (Mecklenburg). *Geol. Beih.*, **32**: 16-17.

Döring, H., 1964. Trilete Sporen aus dem Oberen Jura und dem Wealden Norddeutschlands. *Geologie,* **13**: 1099-1129.

Döring, H., 1965. Die sporenpaläontologische Gliederung des Wealden in Westmecklenburg (structur werle). *Geologie,* **14**: 1-118.

Döring, H., Krutzsch, W., Schulz, E., Mai, D.H., 1963, *in* Krutzsch, W.(Ed.), Atlas der mittel-und jungtertiären dispersen sporen und Pollen sowie Mikroplanktonformen des nördlichen Middleuropa. *Lieferung III, V.E.B., Deutsch. Verl. Wiss.*, Berlin, 128 pp.

Drugg, W.S., 1970. Some new genera, species, and combinationof phytoplankton from the Lower Tertiary of the Gulf Coast, U.S.A.. *North American Palaeontological Convention, Chicago 1969; Proceedings G*: 809-843.

Drugg, W. S., 1978. Some Jurassic dinoflagellate cysts from England, France and Germany. *Palaeontographica, Abteilung B,* **168**: 61-79.

Dupin, F., 1968. Deux nouvelles espèces de dinoflagellés du Jurassique d'Aquitaine. *Cah. Micropaléont., Arch. Origin. Cent. Doc., Cent. Nat. Rech. Sci.*, **45**: 1-5.

Eisenack, A., 1935. Mikrofossilien aus Doggergeschieben Ostpruessens. *Z. Geschiebef.*, **11**: 167-184.

Eisenack, A., 1958. Microplankton aus dem norddeutschen Apt; *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen,* **106**: 383-422.

Eisenack, A., 1963. Zur *Membranilarnax*-Frage. *Neues Jahr. Geol. Paläont., Monat.*, 98-103.

Eisenack, A., 1972. Kritische Bemerkung zur Gattung *Pterospermopsis* (Chlorophyta, Prasinophyceae). *Neues Jahr. Geol. Paläont. Monat.*, **10**: 596-601.

Erdtman, G., 1947. Suggestions for the classification of recent pollen grains and spores. *Svensk. Bot. Tidskr.*, **41**; 104-114.

Erdtman, G., 1948. Did Dicotyledenous plants exist in Early Jurassic Times? *Geol. Foren. Forhandl.,* **70**: 265-271.

Erkmen, U., & Sarjeant, W. A. S., 1980. Dinoflagellate cysts, acritarchs and tasmanids from the uppermost Callovian of England and Scotland; with a reconsideration of the "*Xanthidium pilosum*" problem. *Geobiosphere,* **13**: 45-99.

Eschard, R., Houel, P. & Rudkiewicz, J.L., 1989. Three dimensional architecture and geostatistic simulation of a fluvial to estuarine valley fill complex (Middle Jurassic, Cleveland Basin). *Abstract volume of the 4th International conference on Fluvial Sedimentology.*

Evitt, W. R., 1961. The dinoflagellate *Nannoceratopsis* Deflandre; morphology, affinities and infraspecific variability. *Micropaleontology,* **7**: 305-316.

Evitt, W.R., 1985. Sporopollenin dinoflagellate cysts: their morphology and Interpretation. *American Association of Stratigraphic Palynologists Foundation.*333pp.

Faegri, K. & Iversen, J., 1950. Text-book of modern pollen analysis. *Ejnar Munksgaard, Copenhagen.*,168 pp.

References

Feist-Burkhardt, S., 1990. Dinoflagellate cyst assemblages of the Hausen Coreholes (Aalenian to Early Bajocian), South-West Germany. *Bull.Centres Rech., Explor. Prod. Elf-Aquitaine* **14**: 611-633.

Feist-Burkhardt, S. & Wille, W. 1992. Jurassic palynology in southwest Germany- state of the art. *Cahiers de Micropaléontologie.* **7**; 141-164.

Fensome, R. A., 1979. Dinoflagellate cysts and acritarchs from the Middle and Upper Jurassic of Jameson Land, east Greenland. *Grínl. Geol. Unders., Bull.* **132**: 1-98.

Fensome, R.A., Williams, G.L., Sedley Barss, M., Freeman, J.M.& Hill J.M., 1990. Acritarchs and fossil prasinophytes: an index to genera, species and intraspecific taxa. *A.A.S.P. contributions series 25*, 771pp.

Fenton, J. P. G., 1980. A palynological investigation of the Middle Toarcian-Lower Callovian strata of Lincolnshire and Northamptonshire, Eastern England. *Unpublished Ph.D. thesis, University of Sheffield.*

Fenton, J.P.G., Neves, R. and Piel, K.M., 1980. Dinoflagellate cysts and acritarchs from Upper Bajocian to Middle Bathonian strata of central and southern England. *Palaeontology,* **23**: 151-170.

Fenton, J. P. G., & Riding, J. B., 1987. *Kekryphalospora distincta* gen. et sp. nov., a trilete spore form the Lower and Middle Jurassic of north-west Europe. *Pollen et Spores,* **29**: 427-434.

Filatoff, J., 1975. Jurassic palynology of the Perth Basin, Western Australia. *Palaeontographica, Abteilung B,* **154**: 1-113.

Filatoff, J. and Price, P.L., 1988. A pteridacean spore lineage in the Australian Mesozoic. In Jell, P. A., & Playford, G., (eds.), *Association of Australasian Palaeontologists, Memoir.* **5**: 89-124.

Fisher, M.J., & Hancock N.J., 1985. The Scalby Formation (Middle Jurassic, Ravenscar Group) of Yorkshire: reassessment of age and depositional environment. *Proceedings of the Yorkshire Geological Society,* **45**: 293-298.

Forbes, G.A., 1981. Palynology of the Snowshill Quarry section (Lower-Middle Bathonian), Gloucestershire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Fox-Strangways, C. 1880. The Geology of the Oolitic & Cretaceous rocks South of Scarborough. *Memoirs of the Geological Survey, U.K., 1st ed.*

Fox-Strangways, C., 1892. The Jurassic rocks of Great Britain. Volume 1, Yorkshire. *Memoirs of the Geological Survey, U.K.*

Fox-Strangways, C., Barrow, G., 1915. The Geology of the country between Whitby and Scarborough. *Memoirs of the Geological Survey, U.K.*

Fox-Strangways, C., Cameron, A.G., Barrow, G., 1886. The Geology of the country around Northallerton and Thirsk. *Memoirs of the Geological Survey, U.K.*

Francis, J.E., 1983. The dominant conifer of the Jurassic Purbeck Formation, England. *Palaeontology,* **26**: 277-294.

Francis, J.E., 1984. The seasonal environment of the Purbeck (Upper Jurassic) fossil forests. *Palaeogeography, Palaeoclimatology and Palaeoecology*,**48**: 285-307.

Franz, U., 1960. Über das Vorkommen von Olaceen-Polenkörnen in der Braunkohle von Lohsa/Niederlausitz. *Deutsche Akademie der Wissenschaften zu Berlin, Monatsberichte*, **2**; 558-564.

Galloway, W.E., 1989. Genetic stratigraphic sequences in basin analysis 1:architecture and genesis of flooding-surface bounded depositional units. *American Association of Petroleum Geologists, Bulletin*, **73**; 125-142.

Gamerro, J.C., 1965. Morfología del pollen de la conifera *Trisacocladus tigrensis* Archang. de la formaci6n Baquer6, provincia de Santa Cruz. *Ameghiniana*,**4**: 31-36.

Gitmez, G.U. & Sarjeant, W.A.S., 1972. Dinoflagellate cysts and acritarchs from the Kimmeridgian (Upper Jurassic) of England, Scotland &France. *Bulletin of the British Museum of Natural History (Geology)*,**21**: 171-257.

Gocht, H., 1970. Dinoflagellaten-Zysten aus dem Bathonium des Erdölfeldes Aldorf (N-W Deutschland). *Palaeontographica Abteilung B*, **129**: 125-165.

Gocht, H., 1975. Morphologie und Wandstruktur von *Lithodinia jurassica* Eisenack 1935 (Dinoflagellata, Oberjura). *N. Jb. Geol. Paläont., Mh.*, **6**: 343-359.

Gocht, H. & Wille, W. 1990. *Orobodinium* gen. nov., a new dinoflagellate genus from the Middle Jurassic of Southwest Germany. *N. Jb. Geol. Paläont. Mh.*; 695-706.

Goodman, D.K., 1979. Dinoflagellate "communities" from the Lower Eocene Nanjemoy Formation of Maryland, U.S.A. *Palynology*, **3**;169-190.

Gorka, H., 1965. Les microfossiles du Jurassique supérieur de Magnuszew (Pologne). *Acta Palaeontologica Polonica*, **10**: 291-327.

Gowland, S. & Riding, J.B., 1991. Stratigraphy, sedimentology and palaeontology of the Scarborough Formation (Middle Jurassic) at Hundale Point, North Yorkhire. *Proceedings of the Yorkshire Geological Society*, **48**; 375-392.

Grebe, H., 1971. A recommended terminology and descriptive method for spores. In *Les Spores*, C.I.M.P. Microfossiles Organiques du Paléozoique, Part 4, 11-34, Paris; C.N.R.S.

Grimm, E.C., 1987. CONSISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. *Computers in Geosciences*, **13**: 13-35.

Guy, D.J.E., 1971. Palynological investigations in the Middle Jurassic of the Wilhelmsfält boring, southern Sweden. *Publication of the Institute of Min. Palaeont. Quatern. Geol. Lunds. Univ.*, **168**:1-104.

Hacquebard, P. A., 1957. Plant spores in coal from the Horton Group (Mississippian) of Nova Scotia. *Micropaleontology*, **3**: 301-324.

Hall, J. W., & Nicolson, D. H., 1973. *Paxillitriletes*, a new name for fossil megaspores hitherto invalidly named *Thomsonia*.. *Taxon*, **22**: 319-329.

References

Hallam, A., 1992. The Jurassic. In; Duff, P.McL.D. & Smith, A.J., (eds.), *The Geology of England and Wales*. The Geological Society, London. 651 pp.

Hancock, N.J. and Fisher, M.J., 1981. Middle Jurassic North Sea Deltas with Particular Reference to Yorkshire.186-195, *in* Illing, L.V., & Hobson, G.D.(eds). *Petroleum Geology of the Continental Shelf of North West Europe.* Institute of Petroleum, London.

Haq, B.U., Hardenbol, J. & Vail, P.R., 1987. Chronology of fluctuating sea levels since the Triassic. *Science*, **235**; 1156-1166.

Haq, B.U., Hardenbol, J.R. & Vail, P.R., 1988. Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In Wilgus, C.K., Hastings, C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.): *Sea-Level Changes- an integrated approach.* SEPM Special Publication, **42**;71-108.

Hargreaves, J.A., 1914. Fossil Footprints near Scarborough. *Naturalist*, **688**, 154-156.

Harland, W.B., Cox, A.B., Llewellyn, P.G., Pickton, C.A.G., Smith A.G. & Walters, P.A., 1982. *Geologic Time Scale.* Cambridge University Press.

Harris, T.M., 1931. The Fossil Flora of Scoresby Sound, East Greenland. Part 1. *Medd. Om. Gronland*, **85**: 1-133.

Harris, T.M., 1952. The zonation of the Yorkshire Jurassic Flora. *Palaeobotanist*, **1**, 207-211.

Harris, T.M., 1961. *The Yorkshire Jurassic Flora. Part I.* British Museum (Natural History)

Harris, T.M., 1964. *The Yorkshire Jurassic Flora. Part II.* Ibid.

Harris, T.M., 1969. *The Yorkshire Jurassic Flora. Part III.* Ibid.

Harris, T.M., 1979. *The Yorkshire Jurassic Flora. Part V.* Ibid.

Harris, T.M., Millington, W., & Miller, J., 1974. *The Yorkshire Jurassic Flora. Part IV.* Ibid.

Head, M.J., 1992. Zygospores of the Zygnemataceae and other freshwater algal spores from the Uppermost Pliocene Beds of Cornwall. *Micropalaeontology*, **38**:237-266.

Hemer, D. O., & Nygreen, P. W., 1967. Algae, acritarchs and other microfossils *in certae sedis* from the Lower Carboniferous of Saudi Arabia. *Micropaleontology*, **13**: 183-194.

Hemer, D.O. & Nygreen, P.W., 1967. Algae, acritarchs and other microfossils incertae sedis from the Lower Carboniferous of Saudi Arabia. *Micropalaeontology*, **13**: 183-194.

Hemingway, J.E., 1974. Jurassic. In; Rayner, D.H. & Hemingway, J.E.(Eds), 1974. *The Geology and Mineral Resources of Yorkshire.* Yorkshire Geological Society, Leeds, 405 pp.

Hemingway, J.E. & Knox, R.W.O'B., 1973. Lithostratigraphic nomenclature of the Middle Jurassic strata of the Yorkshire basin of northeast England. *Proceedings of the Yorkshire Geological Society*, **39**: 527-535.

Hemingway, J.E.& Riddler, G.P., 1982. Basin inversion in North Yorkshire. *Transactions of the Institute of Miners and Metallurgists*, **91**; 175-186.

Hill, C.R., 1975. A palaeobotanical investigation of the Middle Jurassic plant beds at Hasty Bank, North Yorkshire. *Unpublished PhD. Thesis, University of Leeds.*

Hill, C.R., Moore, D.T., Greensmith, J.T., & Williams, R., 1985. Palaeobotany and petrology of a Middle Jurassic ironstone bed at Wrack Hills, North Yorkshire. *Proceedings of the Yorkshire Geological Society*, **45**: 277-292.

Hogg, N.M., 1989. A palynological investigation of the Yons Nab Beds (Ravenscar Group), Middle Jurassic, North East Yorkshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Hooker, N.P., 1982. The palynology of the Chipping Norton and Sharp's Hill Formations (early-Middle Bathonian), Sharp's Hill Quarry, Oxfordshire, England. *Unpublished M.Sc. dissertation, University of Sheffield.*

Hughes, N.F., 1963. The assignment of species to fossils to genera. *Taxon*, **12**; 336-337.

Hughes, N.F., 1969. Suggestions for a better handling of the genus in palaeopalynology. *Grana palynologia.*, **9**; 137-146.

Hughes, N.F., 1971. Remedy for the general data handling failure of palaeontology, in: J.L. Cutbill (ed.),*Data Processing in Biology and Geology*, Systematics Association Special Publication, **3**; 321-330.

Hughes, N.F., 1973. Towards effective data handling in palaeopalynology, in: *Morphology and Systematics of Fossil Pollen and Spores, 3rd International Palynological Congress, Novosibirsk (July 1971), Proc.*, 9-14.

Hughes, N.F., 1975. The challenge of abundance in palynomorphs. *Geoscience and Man.*, **11**; 141-144.

Hughes N.F.& Croxton, C.A., 1973. Palynologic correlation of the Dorset 'Wealden'. *Palaeontology*, **16**; 567-601.

Hughes, N.F., Moody-Stuart, J.C., 1967. Proposed method of recording pre-Quaternary palynological data. *Review of Palaebotany and Palynology*, **3**; 347-358.

Hughes, N.F., Moody-Stuart, J.C., 1969. A method of stratigraphic correlation using early Cretaceous spores. *Palaeontology*, **12**; 84-111.

Humble, E.M., 1982. A palynological investigation into Upper Bathonian strata from Elm Farm Quarry, Stratton Audley, Oxfordshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Ibrahim, A. C., 1933. Sporenformen des Ägir-horizontes des Ruhrreviers. *Diss. Tech. Hochsch. Berlin, Konrad Triltsch, Würzburg:* 47pp (privately published).

International Code of Botanical Nomenclature adopted by the ninth International Botanical Congress, Montreal, August 1959-Utrecht 1961.

References

Ishchenko, A. M., 1952. Atlas of microspores and pollen of the Middle Carboniferous of the western part of the Donets Basin, *Akademiya Nauk SSR, Institut Geologischeskikh Nauk, Trudy, Seriya Geologicheskaya*; 1-83 (in Russian).

Iversen, J.& Troels-Smith, J., 1950. *Pollenmorphologiske definitioner og typer.*

Jain, R. K., 1968. Middle Triassic pollen grains and spores from Minas de Petroleo Beds of the Cacheuta Formation (Upper Gondwana), Argentina. *Palaeontographica, Abteilung B*, **122**: 1-47.

Jain, K.P., Garg, R., Kumar, S., & Singh I.B., 1984. Upper Jurassic dinoflagellate biostratigraphy of Spiti Shale (Formation), Malla Johar area, Tethys Himalaya, India. *Journal of the Palaeontological Society of India*, **29**; 67-83.

Jan du Chêne, R., Masure, E., *et al.*, 1986. *Guide practique pour la détermination de kystes de Dinoflagellés fossiles: Le complexe Gonyaulacysta.* Bull. Cent. Rech. Expl.-Prod. Elf-Aquitaine, Mém. **12**: 1-479.

Jan du Chêne, R., Stover, L. E.& De Coninck, J., 1985. New observations on the dinoflagellate cyst genus *Kallosphaeridium* De Coninck 1969. *Cahiers de Micropaléontologie, C.N.R.S.*, **4**: 1-18.

Jansonius, J., 1962. Palynology of Permian and Triassic sediments, Peace River area, Canada. *Palaeontographica , Abteilung B*, **110**: 35-98.

Jansonius, J., 1971. Emended diagnosis of *Alisporites* Daugherty 1941. *Pollen et Spores*, **13**: 349-357.

Jansonius, J., 1980. Linnaean Nomenclature-Universal language of Taxonomists-and the *Sporae dispersae* (with a commentary on Hughes' proposal). *Taxon*, **30**; 438-448.

Jansonius, J., 1986. Re-examination of Mesozoic Canadian dinoflagellate cysts published by S. A. J. Pocock (1962, 1972). *Palynology*, **10**: 201-223.

Jansonius, J., & Hills, L. V., 1976. *Genera file of fossil spores.* Spec. Pub., Dept. Geol., Univ. Calgary, Calgary, Alberta, Canada.

Jansonius, J., & Hills, L. V., 1977. *Genera file of fossil spores-suplement.* Spec. Pub., Dept. Geol., Univ. Calgary, Calgary, Alberta, Canada.

Jansonius, J., & Hills, L. V., 1981. *Genera file of fossil spores-supplement.* Spec. Pub., Dept. Geol., Univ. Calgary, Calgary, Alberta, Canada.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G. & Vachey, G., 1972. Acritarches du Silurien terminal et du Dévonien du Sahara Algérien. *Comptes rendus 7ieme Congrès international de stratigraphie et de géologie du Carboniére, Krefeld, August 1971*, **1**: 295-311.

Kantorowicz, J.D., 1985. The Petrology and diagenesis of Middle Jurassic clastic sediments, Ravenscar Group, Yorkshire. *Sedimentology*, **32**: 833-853.

Kantorowicz, J.D., 1990. Lateral and vertical variations in pedogenesis and other early diagenetic phenomena, Middle Jurassic Ravenscar Group, Yorkshire. *Proceedings of the Yorkshire Geological Society*, **48**: 61-74.

Kar, R.K., & Bose,M.N., 1976. Palaeozoic sporae dispersae from Zaïre (Congo): Assisé à couches de houille from Greinerville region. *Musée royal de l'Afrique central, Annales, sér. in-8, sciences géologiques,* **77**; 23-133.

Kedves, M., 1961. Études palynologiques dans le Bassin de Dorog - II. *Pollen et Spores,* **3**: 101-153.

Kedves, M., & Simoncsics, P., 1964. Spores nouvelles extraités de minérai de manganäse Jurassique de la région d'Urkut (Hongrie). *Pollen et Spores,* **6**: 605-610.

Kemp, E. M., 1970. Aptian and Albian miospores from southern England. *Palaeontographica, Abteilung B,* **131**: 73-143.

Kemp, E. M., & Harris, W. K., 1977. The palynology of Early Tertiary sediments, Ninety East Ridge, Indian Ocean. *Special Papers in Palaeontology,* **19**: 1-69.

Kendall, P.F., & Wroot H.E., 1924. *The Geology of Yorkshire.* 2 vols, xxI + 995 pp. Hollineck Brothers, Vienna.

Kent, P.E., 1955. The Market Weighton Structure. *Proceedings of the Yorkshire Geological Society,* **30**: 197-223.

Kent, P.E., 1974. *In* Rayner, D.H. & Hemingway, J.E. (eds) *The Geology and Mineral Resources of Yorkshire.* Yorkshire Geological Society, Leeds, 405 pp.

Klaus, W., 1960. Sporen der Karnischen Stufe der ostalpinen Trias. *Jb. Geol. Bundesanst. (Wien), Sonderb.* **5**: 107-184.

Klement, K. W., 1960. Dinoflagellaten und Hystrichosphaerideen aus dem unteren und mittleren Malm Sudwestdeutschlands. *Palaeontographica , Abteilung B,* **114**: 1-104.

Knox, E. M., 1938. The spores of the Pteridophyta, with observations on microspores in coals of Carboniferous age. *Transactions and Proceedings of the Botanical Society of Edinburgh,* **35**; 437-449.

Knox, R.W.O'B., 1973. The Ellerbeck Formation (Bajocian) of the Ravenscar Group of N.E.Yorkshire. *Geological Magazine.* **110**: 511-534.

Knox, R.W.O'B., Howard, A.S., Powell, J.H., & van Buchem, F.S.P., 1990. *Lower and Middle Jurassic sediments of the Cleveland Basin N.E. England: Shallow marine and paralic facies seen in their sequence stratigraphic context.* International Association of Sedimentologists, Field Guide No. 5.

Kovach, W.L. & Dilcher, D.L., 1985. The systematics and palaeoecology of the Cretaceous Megaspore *Paxillitriletes. Palynology,***10**: 250-251.

Krutzsch, W., 1954. Bermerkungen zur Bennung und klassifikation fossiler (unsbesondere tertiarer) Pollen et Spores. 2. *Geologie,* **3**: 258-311.

Krutzsch, W., 1959. Einige neue Formgattungen und Arten von Sporen und Pollen aus der mitteleuropäischen Oberkreide und dem Tertiär. *Palaeontographica, Abteilung B,* **105**: 125-157.

Krutzsch, W., 1963. *Atlas der mittelund jungertiären dispersen sporen und pollen-sowie der Mikroplanktonformen des nördlichen Mitteleuropas.* Mitteilung aus dem Zentrulen Geologischen Institut, Berlin.

References

Kützing, F.T., 1849. *Species algarium*. Lipsiæ.

Kuyl, O.S., Muller, J. & Waterbolk, H.T., 1955. The application of Palynology to Oil Geology, with reference to W. Venezuela. *Geol. en Mijnbouw.*, **17**: 49-76.

Leeder M.R., & Alexander, J., 1985. Discussion of Fisher & Hancock 1985 (*q.v.*).

Leeder, M.R.& Nami, M., 1979. Sedimentary models for the non-marine Scalby Formation (Middle Jurassic) and evidence for late Bajocian/Bathonian uplift of the Yorkshire Basin. *Proceedings of the Yorkshire Geological Society,* **42**; 461-482.

Lentin, J. K., & Williams, G. L., 1973. Fossil dinoflagellates: Index to genera and species. *Geological Survey of Canada Paper 73-42:*, 176pp.

Lentin, J. K., & Williams, G. L., 1989. Fossil dinoflagellates: Index to genera and species, 1989 edition. *American Association of Stratigraphic Palynologists, Contribution Series,* **20**: 1-473.

Leschik, G., 1956. Die Entstehung der Braunkohle der Wetterau und ihre Mikro- und Makroflora. *Palaeontographica, Abteilung B,* **100**: 26-64.

Levette-Carette, J. 1964. Étude de la microflore Bajocienne d'un sondage effectué dans le sous-sol de Boulogne-sur-Mer (P.-de-C.). *Annales du Societie Géologie du Nord,* **84**: 91-121.

Lister, T. R., 1970. The acritarchs and chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millichope areas, Shropshire, I. *Palaeontographical Society Monograph,* 100pp.

Livera, S.A., 1981. Sedimentology of the Bajocian rocks from the Ravenscar Group of Yorkshire. *Unpublished Ph.D. thesis, University of Leeds.*

Livera, S.E. and Leeder, M.R., 1981. The Middle Jurassic Ravenscar Group ('Middle Deltaic') of Yorkshire: recent sedimentological studies as demonstrated during a field meeting, 2nd-3rd May, 1980. *Proceedings of the Geologists Association,* **92**: 241-250.

Lockley, M.G. 1980. The Caradoc faunal associations of the area between Bala and Dinas Mawddwy, north Wales *Bulletin of the British Museum of Natural History (Geology).* **33**: 165-235.

Lund, J. J., 1977. Rhaetic to Lower Liassic palynology of the onshore southeastern North Sea Basin. *Dansk Geol. Unders.*, II **109**: 1-128.

Mädler, K., 1964 Bermerkenswerte sporenformen aus dem Keuper und unteren Lias. *Fortschl. Geol. Rheinl. Westf.*, **12**: 169-200.

Maljavkina, V.S., 1949. Determinations of spores and pollen from the Jurassic and Cretaceous. *V.N.I.G.R.I. Trudy,* **33**: 1-137.

Manum, S., 1960. On the genus *Pityosporites* Seward 1914 with a new description of *Pityosporites antarcticus* Seward. *Nytt Mag. Bot.*, **8**: 11-15.

McAndrews, J.H., Berti, A.A., Norris, G., 1973. Key to the Quaternary pollen and spores of the Great Lakes Region. *Royal Ontario Museum of Life Sciences, Miscellaneous Publication,* 61pp.

McKellar, J.L., 1974. Jurassic miospores from the upper Evergreen Formation, Hutton Sandstone and basal Injune Creek Group, northeastern Surat Basin. *Publication of the Geological Survey of Queensland., 361, Palaeontological paper* **35**: 1-89.

Mebradu, S. 1978. Stratigraphic palynology of the Upper Jurassic of the Dorset coast, England. Part 1:statistical variables. *Palinologia numero extraordinario*; **1**;327-333.

Milsom, J., & Rawson P.F., 1989. The Peak Trough - a major control on the geology of the North Yorkshire coast. *Geology Magazine*, **126**; 699-705.

Miner, E. L., 1935. Palaeobotanical examinations of Cretaceous and Tertiary coals. Part I. Cretaceous coals from Greenland. Part II. Tertiary coals from Montana. *American Midland Naturalist*, **16**; 585-625.

Mitchener, B.C., Lawrence, D.A., Partington, M.A., Bowman, M.B.J. & Gluyas, J., 1992. Brent Group: sequence stratigraphy and regional implications. In; Hazeldine, R.S., Giles, M.R. & Brown, S. (Eds), *Geology of the Brent Group. Geological Society Special Publication*, **61**; 169-202.

Mitchum, R.M., Vail, .R. & Thompson, S.III 1977. Seismic stratigraphy and global changes of sea level, Part 1: Glossary of terms used in seismic stratigraphy. 205-212. In C.E. Payton (ed.) *Seismic stratigraphic applications to hydrocarbon exploration.* AAPG Memoir **26** Tulsa, Oklahoma.

Morbey, S. J., 1975. The palynostratigraphy of the Rhaetian Stage, Upper Triassic in the Kendelbachgraben, Austria. *Paleontographica , Abteilung B*, **152**: 1-75.

Morgan, R., 1975. Some Cretaceous organic-walled microplankton from the Great Artesian Basin, Australia. *Journal of the Proceedings of the Royal Society of New South Wales*, **108**: 157-167.

Morgenroth, P., 1970. Dinoflagellate cysts fron the Lias Delta of Lühnde, Germany. *N. Jb. Geol. Paleontol., Abh.*, **127**: 1-53.

Morzac-Kerfourn, M.T., 1977. Les kystes de dinoflagellés dans les sédiments Récents le long des côtes Bretonnes. *Revue de Micropaléontologie*, **20**;157-166.

Muir, M.J., 1964. The palaeoecology of small spores of the Middle Jurassic of Yorkshire. *Unpublished Ph.D. thesis, University College, London.*

Murray, N., 1939. The microflora of the Upper and Lower Estuarine Series of the East Midlands. *Geological Magazine*, **76**: 478-489.

Nami, M., 1976a. Sedimentology of the Scalby Formation (Upper Deltaic Series) in Yorkshire. *Unpublished PhD thesis, University of Leeds.*

Nami, M., 1976b. An exhumed Jurassic meander belt from Yorkshire. *Geological Magazine*, **113**: 47-52.

Nami, M., & Leeder, M.R., 1978. Changing channel Morphology and Magnitude in the Scalby Formation (M. Jurassic) of Yorkshire, England. 431-440, *in* Miall, A.D. (ed) *Fluvial Sedimentology.* Memoir of the Canadian Society of Petroleum Geologists, **5**.

Naumova, S. N., 1937. Spores and pollen from the coals of the U.S.S.R.*17th Int. Geol. Cong., Moscow.* **1**; 354-364.(English translation by A.S. Brashina).

References

Naumova, S. N., 1953. Sporo-Pollen complexes of the Upper Devonian of the Russian Platform and their stratigraphic significance. *Trudy Inst. Geol. Nauk, Akad. Nauk SSSR, 143* (Geol. Ser. 60) 204pp (in Russian).

Neves, R., 1958. Upper Carboniferous plant spore assemblages from the Gastrioceras subcrenatum horizon, North Staffordshire. *Geol. Mag.,* **95**: 1-19.

Neves, R.& Owens, B., 1966. Some Namurian camerate miospores from the English Pennines. *Pollen et Spores,* **8**; 337-360.

Newton, E. T., 1875. On Tasmanite and Australian white coal. *Geological Magazine* **2**: 337-342.

Nilsson, T., 1958. Über das Vorkommen eines Mesozoischen sapropelgesteins in schonen. *Lunds. Universitets, Årsskrift., N.F., 2, Bd 54* **(10)**: 1-127.

Norris, G., 1968. Palynology of the Jurassic-Cretaceous boundary in southern England. *Geoscience and Man,* **1**: 57-66.

Norris, G., 1969. Miospores from the Purbeck Beds and the marine Upper Jurassic from Southern England. *Palaeontology,* **12**: 574-620.

Norris, G. & Sarjeant, W.A.S., 1965. A descriptive index of genera of fossil Dinophyceae and Acritarcha. *New Zealand Geological Survey, Palaeontological Bulletin,* **40**, 72pp.

Orbell, G., 1973. Palynology of the British Rhaeto-Liassic. *Bulletin of the Geological Survey of Great Britain,* **44**: 1-44.

Owens, B., Michell, D. R. F., & Marshall, J. 1976. *Kraeuselisporites* from the Namurian of Northern England. *Pollen et Spores,* **18**: 145-156.

Pant, D.D., 1954. Suggestions for the classification and nomenclature of fossil spores and pollen grains. *Botanical Review,* **20**: 33-60.

Parsons, C.F., 1977. A stratigraphic revision of the Scarborough Formation. *Proceedings of the Yorkshire Geological Society,* **41**: 203-222.

Partington, M.A., Mitchener, B.C., Milton, N.J. & Fraser A.J. In press. A genetic stratigraphic sequence stratigraphy for the North Sea Late Jurassic and Early Cretaceous: Stratigraphic distribution and prediction of Kimmeridgian- Late Ryazanian Reservoirs in the Viking Graben and Adjacent Areas. *Barbican Volume on the Petroleum Geology of Northwest Europe.*

Pearce, J.M., 1982. A palynological investigation of the Bathonian-Callovian interval in the Bicker borehole, Lincolnshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Phillips, J., 1829. *Illustrations of the geology of Yorkshire. Part I. The Yorkshire Coast.* xvi + 192 pp. Printed privately, York.

Phillips, J., 1829. *Illustrations of the geology of Yorkshire. Part II. The Mountain Limestone.* xx + 253 pp. John Murray, London.

Pickerill, R.K. & Brenchley, P.J. 1979. Caradoc marine benthic communities of the south Berwyn Hills, north Wales. *Palaeontology* **22** 229-264.

Piel, K.M., 1985. *Lagenadinium*, a new dinocyst from British Middle-late Callovian rocks, a possible evolutionary intermediate between *Stephanelytron* and *Gardodinium*. *Review of Palaeobotany and Palynology*, **45**: 107-119.

Piel, K.M. and Evitt, W.R., 1980. Paratabulation in the Jurassic dinoflagellate genus *Nannoceratopsis* and a comparison with modern taxa. *Palynology*, **4**: 79-104.

Pierce, R.L., 1961. Lower Upper Cretaceous plant microfossils from Minnesota. *Bulletin of the Minnesota Geological Survey*, **42**, 86 pp.

Pierce, S. T., 1976. Morphology of *Schizosporis reticulatus* Cookson and Dettmann, 1959. *Geoscience and Man*, **15**: 25-33.

Playford, G., 1971. Palynology of Lower Cretaceous (Swan River) strata of Saskatchewan and Manitoba. *Palaeontology*, **14**: 533-565.

Playford, G., & Dettmann, M. E., 1965. Rhaeto-Liassic plant microfossils from the Leigh Creek Coal Measures, South Australia. *Senckenb. Leth.*, **46**: 127-181.

Pocock, S. A. J., 1961. Microspores of the genus *Murospora* Somers from Mesozoic strata of western Canada and Australia. *Journal of Paleontology*, **35**: 1231-1234.

Pocock, S. A. J., 1962. Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the Western Canada Plains. *Palaeontographica Abteilung B*, **111**: 1-95.

Pocock, S.A.J., 1970. Palynology of the Jurassic sediments of Western Canada. Part 1: Terrestrial species. *Palaeontographica, Abteilung B*, **130**: 12-136.

Pocock, S.A.J., 1972. Palynology of the Jurassic sediments of Western Canada. Part II: Marine species. *Ibid.*, **137**: 85-153

Pocock, S.A.J. & Jansonius, J., 1969. Redescription of some fossil gymnospermous pollen (*Chasmatosporites*, *Marsupipollenites*, *Ovalipollis*). *Canadian Journal of Botany*, **47**: 155-165.

Potonié, R., 1931. Zur Mikroscopie der Braunkohlen. Tertiäre Sporen-und Blütenstaubformen. *Zur Braunkohle*, **41**; 554-556.

Potonié, R., 1956. Synopsis der Gattungen der Sporae dispersae. Teil I: *Sporites. Beih. Geol. Jb.*, 103pp. Hannover.

Potonié, R., 1958. Synopsis der Gattungen der Sporae dispersae. Teil II: *Sporites. Beih. Geol. Jb.*, 114 pp. Hannover.

Potonié, R., 1960. Synopsis der Gattungen der Sporae dispersae. Teil III: Nachträge Sporites., Fortzetzung Pollenites mit Generalregister zu Teil I-III. *Beih. Geol. Jb.*, **39**; 189 pp.

Potonié, R.& Kremp, G., 1954. Die gattungen der palaozoischen sporae dispersae und ihre stratigraphie. *Beih. Geol. Jb.*, **69**: 11-194.

Potonié, R.& Kremp, G., 1955. Die sporae dispersae des Ruhrkarbons, ihr Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte. Teil I. *Palaeontographica, Abteilung B* , **98**; 1-136.

References

Potonié, R.& Kremp, G., 1956a. Die sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte. Teil II. *Palaeontographica, Abteilung B* , **99**; 85-191.

Potonié, R.& Kremp, G., 1956b. Die sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie mit Ausblicken auf Arten anderer Gebiete und Zeitabschnitte. Teil III. *Palaeontographica, Abteilung B* , **100**; 65-121.

Powell, J.H. & Rathbone, P.A., 1983. The relationship of the Eller Beck Formation and the supposed Blowgill Member (Middle Jurassic) of the Yorkshire Basin. *Proceedings of the Yorkshire Geological Association,* **44**: 365-373.

Prentice, J.E., Begg, I.R., & Colleupriest, C. *et al.* 1968. Sediment transport in estuarine areas. *Nature*, **218**: 1207-1210.

Raatz, G.V., 1937. Mikrobotanisch-stratigraphische Untersuchung der Braunkohle des Muskauer Bogens. *Abh. preuss. geol. Landesant.,* **183**: 1-48.

Raine, J.I., De Jersey, N.J. & Ryan, K.G., 1988. Ultrastructure and lycopsid affinity of *Densoisporites psilatus* from the Triassic of New Zealand and Queensland. *Memoirs of the Association of Australasian Palaeontologists,* **5**: 79-88.

Raistrick, A., 1934. The correlation of coal seams by microspore-content: pt I. The seams of Northumberland. *Transactions of the Institute of Mining Engineers, London,***88**; 142-53.

Raistrick, A., 1935. The correlation of coal seams by microspore-content: pt I. The seams of Northumberland. *Transactions of the Institute of Mining Engineers, London,***88**; 259-64.

Raistrick, A., 1936-7. The microspore content of some lower Carboniferous coals. *Transactions of the Leeds Geological Association,* **5**; 221-6.

Raistrick, A., 1938. The correlation of coal seams by microspore-content: pt II. The Trencherbone seam, Lancashire and the Busty seam Durham. *Transactions of the Institute of Mining Engineers, London,* **97**; 425-37.

Raistrick, A., 1939. The correlation of coal seams by microspore-content: pt II. The Trencherbone seam, Lancashire and the Busty seam Durham. *Transactions of the Institute of Mining Engineers, London,* **98**; 95-99.

Raistrick, A., 1939. The correlation of coal seams by microspore-content: pt II. The Trencherbone seam, Lancashire and the Busty seam Durham. *Transactions of the Institute of Mining Engineers, London,* **98**; 171-5.

Raistrick, A., Simpson, J., 1932-3. The microspores of some Northumberland coals, and their use in the correlation of coal seams. *Transactions of the Institute of Mining Engineers, London,* **85**; 225-35 and **86**, p.55.

Ravn, R. L., 1986. Palynostratigraphy of the Lower and Middle Pennsylvanian coals of Iowa. *Iowa Geological Survey Technical Paper,* **7**: 1-245.

Rawson, P.F., 1979. Discussion of Leeder & Nami 1979 (*q.v.*).

Rayner, D.H. & Hemingway, J.E.(Eds), 1974. *The Geology and Mineral Resources of Yorkshire.* Yorkshire Geological Society, Leeds.405 pp.

Reading, H.G., 1978 (ed.). *Sedimentary Environments and Facies..* Blackwell Scientific Publications. 569 pp.

Reinsch, P.F., 1884. *Micro-palæo-phytologia formationis Carboniferæ.* Vols 1 and 2. Erlangen & Co., London. 80 pp.

Reiser, R.F.& Williams, A.J., 1969. Palynology of the Lower Jurassic sediments of the northern Surat Basin, Queensland. *Geological Survey of Queensland, Palaeontological paper* **39**: 1-189.

Reissinger, A., 1950. Die pollen analyse ausgedehunt auf alle sedimentgesteine der geologischen vergangenheit: II. *Palaeontographica, Abteilung B* , **90**: 99-126.

Renshaw, D.K., 1982. A palynological investigation of the Lower to Middle Bathonian sediments of the Hampen railway cutting, near Cheltenham, Gloucestershire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Riccardiello, G.A., 1985. A palynological investigation into the Middle Jurassic of the Worlaby Borehole, South Humberside, England. *Unpublished M.Sc. dissertation, University of Sheffield.*

Richardson, J. B. 1960. Spores from the Middle Old Red Sandstone of Cromarty, Scotland. *Palaeontology,* **3**; 45-63.

Richardson, J. B. 1962. Spores with bifurcate processes from the Middle Old Red Sandstone of Scotland. *Palaeontology,* **5**; 171-194.

Riding, J.B., 1984. Observations on the Jurassic dinoflagellate cyst *Nannoceratopsis ambonis* Drugg 1978. *Journal of Micropalaeontology,* **3**: pp 75-79.

Riding J.B.& Bailey, D.A., 1991. *Durotrigia filapicata* comb. nov. for *Gonyaulacysta filapicata* (Fossil *Pyrrhophyta:Dinophyceae). Taxon,* **40:** 100-102.

Riding J.B., & Wright, J.K., 1989. Palynostratigraphy of the Scalby Formation (Middle Jurassic) of the Cleveland Basin, north-east Yorkshire. *Proceedings of the Yorkshire Geological Society,* **47**: 349-354.

Riding, J.B., & Thomas J.E., 1992. Jurassic *in* Powell A.J. (ed.), *A Stratigraphic index of Dinoflagellate Cysts.* Chapman Hall, 290 pp.

Riding, J.B., Penn, I.E., Woollam, R., 1985. Dinoflagellate cysts from the type area of the Bathonian Stage (Middle Jurassic, south west England). *Review of Palaeobotany and Palynology,* **45**;149-169.

Riding, J.G., Walton, W., & Shaw, D., 1991. Toarcian to Bathonian (Jurassic) palynology of the Inner Hebrides, northwest Scotland. *Palynology,* **15**; 115-179.

Riley, L. A., & Fenton, J. P. G. 1982. A dinocyst zonation for the Callovian to middle Oxfordian succession (Jurassic) of Northwest Europe. *Palynology,* **6**: 193-202.

Rogalska, M., 1954. Analiza sporowa-pylkova liasowego wegla Blanowickiego z gornego Slaska. *Instytut Geologiczny Pologne, Biuletyn,* **89**, 46pp.

Ross, N., 1949. Investigations of the Senonian of the Kristanstad District, S. Sweden. On a Cretaceous pollen and spore-bearing clay deposit of Scania. *Bulletin of the Geological Institute of the University of Upsala,* **34**: 25-44.

References

Rouse, G.E., 1959. Plant microfossils from Kootenay coal-measures strata of British Columbia. *Micropalaeontology*, **5**: 303-324.

Rutherford, M., 1982. Palynomorphs from Toarcian, Aalenian and Lower Bajocian sediments of Rosedale, North Yorks Moors. *Unpublished M.Sc. dissertation, University of Sheffield.*

Samoilovich, S.R. & Mtchedlishvili, N.D. (eds) 1961: Pyl'tsa i spory Zapadnoy Sibiri, Yura-Paleosten. *Trudy VNIGRI*, **177**, 659p.

Sarjeant, W. A. S. 1959. Microplankton from the Cornbrash of Yorkshire. *Geological Magazine*, **96**: 329-346.

Sarjeant, W. A. S., 1961. Microplankton from the Kellaways Rock and Oxford Clay of Yorkshire. *Palaeontology*, **4**: 90-118.

Sarjeant, W.A.S., 1965. Microplankton from the Callovian (*S. calloviense* Zone) of Normandy. *Revue de Micropaléontologie*, **8**: 175-184.

Sarjeant, W. A. S. 1966. Dinoflagellate cysts with *Gonyaulax*- type tabulation. In Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L., 1969. Generic reallocations. *Bulletin of the British Museum of Natural History (Geology), Appendix to Supplement 3*: 15-17.

Sarjeant, W. A. S. 1968. Microplankton from the Upper Callovian and Lower Oxfordian of Normandy. *Revue de Micropaléontologie*, **10**: 221-242.

Sarjeant, W.A.S., 1969. Taxonomic changes *in* Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L. 1969 (*q.v.*).

Sarjeant, W. A. S., 1975. Stratigraphic range charts: Triassic and Jurassic dinoflagellates. In Evitt, W. R. (ed.), *Forum on dinoflagellates held at Anaheim, California*, 1973. American Association of Stratigraphic Palynologists, Contribution Series, **4**: 51-63.

Sarjeant, W. A. S. 1976. English Jurassic dinoflagellate cysts and acritarchs: A re-examination of some type and figured specimens. *Geoscience and Man*, **15**: 1-24.

Sarjeant, W. A. S. 1982b. Dinoflagellate cyst terminology, a discussion and proposals. *Canadian Journal of Botany*, **60**: 922-945.

Sarjeant, W. A. S., 1982a. The dinoflagellate cysts of the Gonyaulacysta group: A morphological and taxonomic restudy. *American Association of Stratigraphic Palynologists, Contribution Series*, **9**: 1-81.

Sarjeant, W. A. S., 1985. A restudy of some dinoflagellate cyst holotypes in the University of Kiel collections: VI. Late Cretaceous dinoflagellate cysts and other palynomorphs in the O. Wetzel collections. *Meyniana*, **37**: 129-185.

Sarjeant, W. A. S., & Stover, L. E. 1978. *Cyclonephelium* and *Tenua*: A problem in dinoflagellate cyst taxonomy. *Grana*, **17**: 47-54.

Scheihing, M.H., & Pfefferkorn, H.W., 1984. The taphonomy of land plants in the Orinoco Delta: a model for the incorporation of plant parts in clastic sediments of late Carboniferous age in Euramerica. *Revue of Palaeobotany and Palynology*, **41**: 205-240.

Scheuring, B., 1974. *Kraeuselisporites* Leschik and *Thomsonisporites* Leschik -a revision of the type material of two disputed genera. *Revue of Palaeobotany and Palynology,,* **17**: 187-203.

Schopf, J.M., Wilson L.R., Bentall, R., 1944. An annotated synopsis of Palaeozoic fossil spores and the definition of generic groups. *Illinois Geological Survey, Report of Investigation,* **91**, 73 pp.

Schulz, E., 1966. Erlaüterungen zur Tabelle der Stratigraphischen verbreitung der Sporen und Pollen von oberen Perm bis untersten Lias. *Abh. Zent. Geol. Inst.,* **8**: 3-26.

Schulz, E., 1967. Sporenpaläontologische Untersuchungen rhatoliassischer Schichten in Zentral teil des Germanischen Beckens. *Palaeontographica, Abteilung B Abt. B,* **2**: 547-633.

Seward, A.C., 1900. The Jurassic Flora. I: The Yorkshire Coast. *Catalogue of Mesozoic Plants, Department of Geology, British Museum of Natural History,* **3**, 341 pp. London.

Seward, A. C., 1914. Antarctic fossil plants. Nat. Hist. Rep. Brit. Antarctic Exped. 1910, *Geology,* **1**: 1-49.

Simpson, M., 1843. *A monograph of the ammonites of the Yorkshire Lias.* 60 pp. Simpkin Marshall, London.

Singh, C., 1964. Microflora of the Lower Cretaceous Mannville Group, east Central Alberta. *Bulletin of the Research Council of Alberta,***15**: 1-239.

Singh, C., 1971. Lower Cretaceous microfloras of the Peace River area, northwestern Alberta. *Bulletin of the Research Council of Alberta,* **28**: 1-542.

Singh, H.P., 1964. A miospore assemblage from the Permian of Iraq. *Palaeontology,***7**: 240-265.

Skarby, A., 1964. Revision of *Gleicheniidites senonicus* Ross. *Publ. Geol. Inst. Stock. Univ.*: 59-77.

Smelror, M. 1991. Two new dinoflagellate cysts from the Middle Jurassic of the Barents Sea Region. *Journal of Micropalaeontology,* **10**; 175-180.

Smith, A.H.V., 1957. The sequence of microspore assemblages associated with the ocurrence of crassidurite in coal-seams of Yorkshire.*Geol. Mag.* **94**: 345-363.

Smith, A.H.V., Butterworth, M.A., 1967. Miospores in the coal seams of the Carboniferous of Great Britain. *Special Papers in Palaeontology,* **3**: 324 pp.

Somers, G., 1952. Fossil spore content of the Lower Jubilee seam of the Sydney coalfield, Nova Scotia. *Nova Scotia Research Foundation*; 1-30.

Srivastava, S.C., 1984. *Lelestrobus*: a new microsporangiate organ from the Triassic of Nidpur, India. *The Palaeobotanist,* **32**: 86-90.

Srivastava, S. K., 1977. Microspores from the Fredericksburg Group (Albian) of the southern United States. *Paléobiologie Continentale,* **6**(1975): 1-119.

References

Srivastava, S.K., 1987. Jurassic spores-pollen assemblages from Normandy (France) and Germany. *Geobiosphere*, **20**: 5-79.

Staplin, F. L., 1960. Upper Mississippian plant spores from the Golata Formation, Alberta, Canada. *Palaeontographica , Abteilung B*, **107**: 1-40.

Stevens, G.R., 1973. Jurassic Belemnites. 259-274, *in*: Hallam A., (ed.) *Atlas of Palaeobiogeography*. Elsevier, Amsterdam.

Stewart, W.M., 1983. *Palaeobotany and evolution of plants*. Cambridge University press.

Stover, L. E., 1962. *Taurocusporites*, a new trilete spore genus from the Lower Cretaceous of Maryland. *Micropaleontology*, **8**: 1-28.

Stover, L.E., 1966. *Nannoceratopsis spiculata*, a new dinoflagelllate cyst species from the Middle Jurassic of France. *Journal of Palaeontology*, **40**: 41-45.

Stover, L.E.& Evitt, W.R., 1978. Analyses of pre-Pleistocene organic-walled dinoflagellates. *Stanford University Publications, Geological Sciences*, **15**, 300pp.

Stover, L. E., Sarjeant, W. A. S., & Drugg, W. S., 1977. The Jurassic dinoflagellate genus *Stephanyletron*: : Emendation and discussion. *Micropaleontology*, **23**: 330-338.

Stronach, C.H., 1983. Palynomorphs from the Toarcian and Aalenian of Hasty Bank, Yorkshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Sullivan, H. J., 1964. Miospores from the Drybrook Sandstone and associated measures in the Forest of Dean Basin, Gloucestershire. *Palaeontology*, **7**: 351-392.

Tappan, H., 1980. *Palaeobiology of the Plant Protists*. Freeman, San Fransisco, 1028 pp.

Thomas, H.H., 1915. The Thinnfeldia leaf-bed of Roseberry Topping. *Naturalist*, 7-13.

Thomson, P.W., 1950. Grudsätzliches zur Tertiären Pollen-und Spores-mikrostratigraphie auf Grung eiher Untersuchung des Hauptflözes der Rheinische Braunkohlin. *Liblar, Neurat, Fortuna und Brühl. Geol. Jb.*, **65**: 113-126.

Thomson, P.W., Pflug, H., 1953. Pollen und spores des Mitteleuropäischen tertiärs. *Palaeontographica, Abteilung B* , **89**: 1-34.

Tiwari, R.S. & Nivale, G.K.B., 1967. Pollen and spore assemblages in some coals of Brazil. *Pollen et Spores*. **9**: 583-605.

Todd, C., 1985. A palynological study of an Upper Bathonian to Middle Callovian sequence in the Peterborough area, Cambridgeshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Townrow, J.A., 1962. On some disaccate pollen grains of Permian to Middle Jurassic age. *Grana Palynologia*, **3**: 13-44.

Tralau, H., 1968. Botanical Investigations in the Fossil Flora of Eriksdal in Fyledalen, Scania. *Sveriges Geologiska Undersökning , Ser. C*, 633: 185 pp.

Traverse, A., 1955. Pollen analysis of the Brandon lignite of Vermont. U.S. *Bureau of Mines, Report investigation number 5151*. 107 pp.

Traverse, A., 1975. The challenge of abundance in palynomorphs: A critique. *Geoscience and Man*, **11**; 145-147.

Traverse, A., 1988. *Palaeopalynology*. Unwin Hyman, Boston. 600pp.

Tryon, R.M. & Tryon, A.F., 1982. *Ferns and related plants with special reference to tropical America*. Springer-Verlag, New York, 857pp.

Turner, R.E., 1984. Acritarchs from the type area of the Ordovician Caradoc Series, Shropshire, England. *Palaontographica Abteilung B*, **190**: 87-157.

Tykoezinski, H.G.R., 1982. A palynological study of Middle and Upper Bathonian sediments of the cement works quarry at Shipton on Cherwell, Oxfordshire. *Unpublished M.Sc. dissertation, University of Sheffield.*

Underhill, J. R. & Partington, M.A., In Press. Use of maximum flooding surfaces in determining a Regional Tectonic Control on the Intra-Aalenian ("Mid Cimmerian") Sequence Boundary: Implications for the North Sea basin development and Exxon's Sea-Level Chart. Submitted to; *American Association of Petroleum Geologists Memoirs.*

Vail, P.R., Mitchum, R.M. & Thompson, S. III 1977. Seismic stratigraphy and global changes of sea level, part 3: relative changes of sea level from coastal onlap. 63-97. In C.E. Payton (ed.) *Seismic stratigraphic applications to hydrocarbon exploration.* AAPG Memoir **26** Tulsa, Oklahoma.

Vakhrameev, V.A., 1991. *Jurassic and Cretaceous floras and climates of the Earth.* Cambridge University Press, 318 pp.

Valensi, L., 1947. Note préliminaire Ö une étude des microfossiles des silex Jurassiques de la région de Poitiers. *C. r. Acad. Sci. Paris*, **225**: 816-818.

Valensi, V., 1949. Sur quelques microorganismes planctoniques des silex jurassiques de la région de Poitiers. *Comptes rendus de l'Académie des Sciences, Paris*, **225**: 816-818.

Van der Burgh, J., 1983. Allochthonous seed and fruit floras from the Pliocene of the lower Rhine basin. *Revue of Palaeobotany and Palynology*, **40**: 33-90.

Van der Burgh, J., & Van Konijnenburg-Van Cittert, J. H. A., 1984. A drifted flora from the Kimmeridgian (Upper Jurassic) of Lothbeg Point, Sutherland, Scotland. *Revue of Palaeobotany and Palynology*, **43**: 359-396.

Van der Hammen, T., 1956. A palynological systematic nomenclature. *Boletin Geologico, Colombia.* **4**; 63-101.

Van Geel, B., 1976. Fossil spores of the Zygnemataceae in ditches of a prehistoric settlement in Hoogkarspel (The Netherlands). *Review of Palaeobotany and Palynology*, **22**: 337-344.

Van Helden, B. G. T., 1977. Correlation of microplankton assemblages with ammonite faunas from the Jurassic Wilkie Point Formation, Prince Patrick Island, District of Franklin. *Geological Survey of Canada Paper*,**77-1B**: 163-171.

Van Konijnenburg-Van Cittert, J. H. A., 1971. *In situ* gymnosperm pollen from the Middle Jurassic of Yorkshire. *Acta Botanica Neerlandica*, **20**: 1-97.

References

Van Konijnenburg-Van Cittert, J. H. A., 1978. Osmundaceous spores *in situ* from the Jurassic of Yorkshire, England. *Revue of Palaeobotany and Palynology*, **26**: 125-141.

Van Konijnenburg-Van Cittert, J. H. A., 1981. Schizaeaceous spores in situ from the Jurassic of Yorks, England. *Revue of Palaeobotany and Palynology*, **33**: 169-181.

Van Konijnenburg-Van Cittert, J. H. A., 1989. Dicksoniaceous spores *insitu* from the Jurassic of Yorkshire, England. *Revue of Palaeobotany and Palynology*, **61**: 273-301.

Van Konijnenburg-Van Cittert, J. H. A. & Van der Burgh, J., 1989. The flora from the Kimmeridgian (Upper Jurassic) of Culgower, Sutherland, Scotland. *Revue of Palaeobotany and Palynology*, **61**: 1-51.

Van Wagoner, J.C., Mitchum, R.M., Campion, K.M. & Rahmanian, V.D. 1990. Siliciclastic sequence Stratigraphy in Well logs, Cores, and Outcrops: Concepts for High-Resolution Correlation of Time and Facies. *AAPG Methods in Exploration Series No. 7.*

Venkatachala, B. S., & Kar, R. K., 1968. Palynology of the Karanpura Sedimentary Basin, Bihar, India - 1. Barakar Stage at Badam. *Palaeobotanist*, **16** (1967): 56-90.

Volkheimer, W., 1972. Estudio palinologico de un carbon Calloviano de Nequén y consideraciones sobre los paleoclimas Jurasicos de la Argentina. *Rev. Mus. de la Plata*, **6**: 101-157.

Vozzhennikova, T. F., 1967. Fossil peridinians of the Jurassic, Cretaceous and Paleogene deposits of the U.S.S.R. *Akad. Nauk S.S.S.R. Sibirskoe Otdel. Inst. Geol. Geofiz.*: 1-347.

Walker, R.G., 1992. Facies, Facies Models and Modern Stratigraphic concepts. In Walker, R.J. & James, N.P. (Eds.) *Facies Models: response to sea level change.* Geoloical Association of Canada. 409pp.

Wall, D., 1965. Microplankton, pollen and spores from the Lower Jurassic in Britain. *Micropaleontology*, **11**: 151-190.

Wall, D., Dale, B., Lohmann, G.P. & Smith, W.K., 1977. The environmental and climatic distribution of dinoflagellate cysts in modern marine sediments from regions in the North and South Atlantic Oceans and adjacent seas. *Marine Micropalaeontology*, **2**; 121-200.

Wetzel, O., 1933. Die in organischer Substanz erhalteen Mikrofossilien des baltischen Kriede-Feuersteins mit einem sediment-petrographischen und stratigraphischen Anhang. *Palaeontographica, Abteilung A*, **78**; 1-110.

Weyland, H. & Krieger, W., 1953. Die Sporen und Pollen der Aachener Kriede und ihre Bedeutung für die Charakterisierung des Mitleren Senons. *Palaeontographica, Abteilung B*, **95**; 6-29.

Whittaker, M.F., Giles, M.R. & Cannon, S.J.C., 1992. A palynological review of the Brent Group, U.K. sector, North Sea. In; Hazeldine, R.S., Giles, M.R. & Brown, S. (Eds), *Geology of the Brent Group. Geological Society Special Publication*, **61**; 169-202.

Wilce, J.H., 1972. Lycopod spores; general spore patterns and generic segregates of *Lycopodium. American Fern Journal,* **2**: 65-79.

Williams, G. 1992. Palynology as a palaeonenvionmental indicator in the Brent Group, northern North Sea. In; Hazeldine, R.S., Giles, M.R. & Brown, S. (Eds), *Geology of the Brent Group. Geological Society Special Publication,* **61**; 169-202.

Williams, G. L., & Downie, C., 1966. Further dinoflagellate cysts from the London Clay. In Studies on Mesozoic and Cainozoic dinoflagellate cysts. *Bulletin of the British Museum of Natural History (Geology), Supplement 3*:: 215-235.

Williams, G.L. & Downie, C., 1969. Generic re-allocations. In, Davey, R. J., Downie, C., Sarjeant, W. A. S., & Williams, G. L. (Eds). Appendix to 'Studies on Mesozoic and Cainozoic dinoflagellate cysts".*Bulletin of the British Museum of Natural History (Geology), Supplement 3*: p.17.

Williamson, W.C., 1896. *Reminiscences of a Yorkshire naturalist.* xii + 238 pp. George Redway, London.

Wilson. L.R., 1959. A method of determining a useful microfossil assemblage for correlation. *Oklahoma Geology Notes,* **19**: 91-93.

Wilson, L.R. & Webster, R.M., 1948. Plant microfossils from a Fort Union coal of Montana. *Amer. J. Bot.,* **83**: 271-287.

Wilson, V., 1948. East Yorkshire and Lincolnshire. *British Regional Geology.* iv + 94 pp. H.M.S.O. London.

Wodehouse, R. P., 1933. Oil shales of the Green River formation. *Bulletin of the Torrey Botanical Club.,* **60**; 479-524.

Woollam, R., 1983. A review of the Jurassic dinocyst genera *Ctenidodinium* Deflandre 1938 and *Dichadogonyaulax* Sarjeant 1966. *Palynology,* **7**: 183-196.

Woollam, R. & Riding, J.B., 1983. Dinoflagellate cyst zonation of the English Jurassic. *Report of the Institute of Geological Sciences* No. **83/2.**

Wright, J.K., 1977. The Cornbrash Formation (Callovian) in North Yorkshire and Cleveland. *Proceedings of the Yorkshire Geological Society,* **41**; 325-346.

Wright, T., 1860. On the subdivisions of the Inferior Oolite in the south of England, compared with equivalent beds of that formation on the Yorkshire coast. *Quarterly Journal of the Geological Society of London,* **16**: 1-48.

Young, G., 1817. *A history of Whitby and Streoneshalh Abbey with a statistical survey of the vicinity to the distance of twenty five miles.* 2 vols, x + 593 pp. Clark & Medd, Whitby.

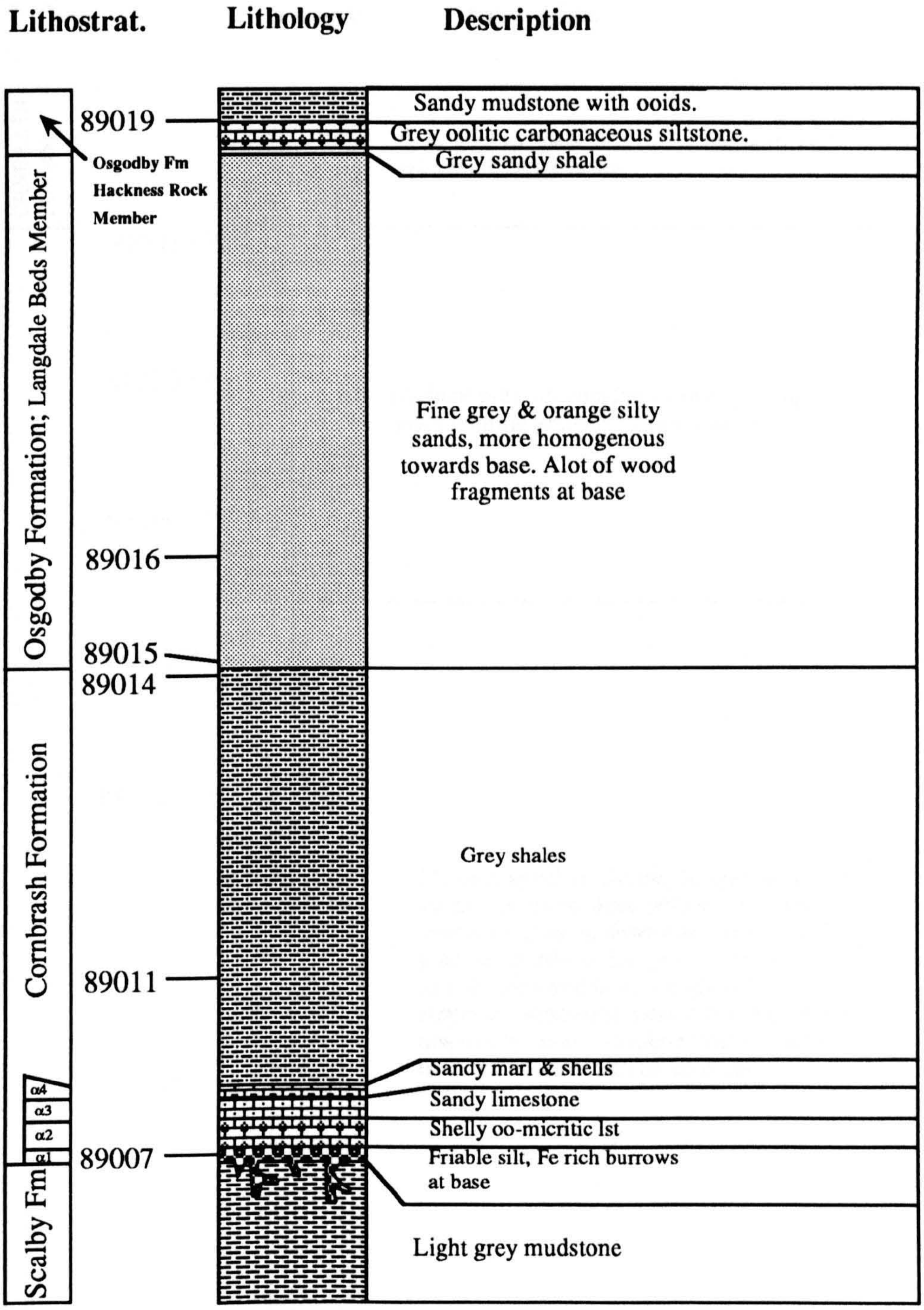
Young, G. & Bird, J., 1822. *A geological survey of the Yorkshire coast.* iv + 332 pp. Clark, Whitby.

Appendix 1.Graphical logs of the sections

Legend

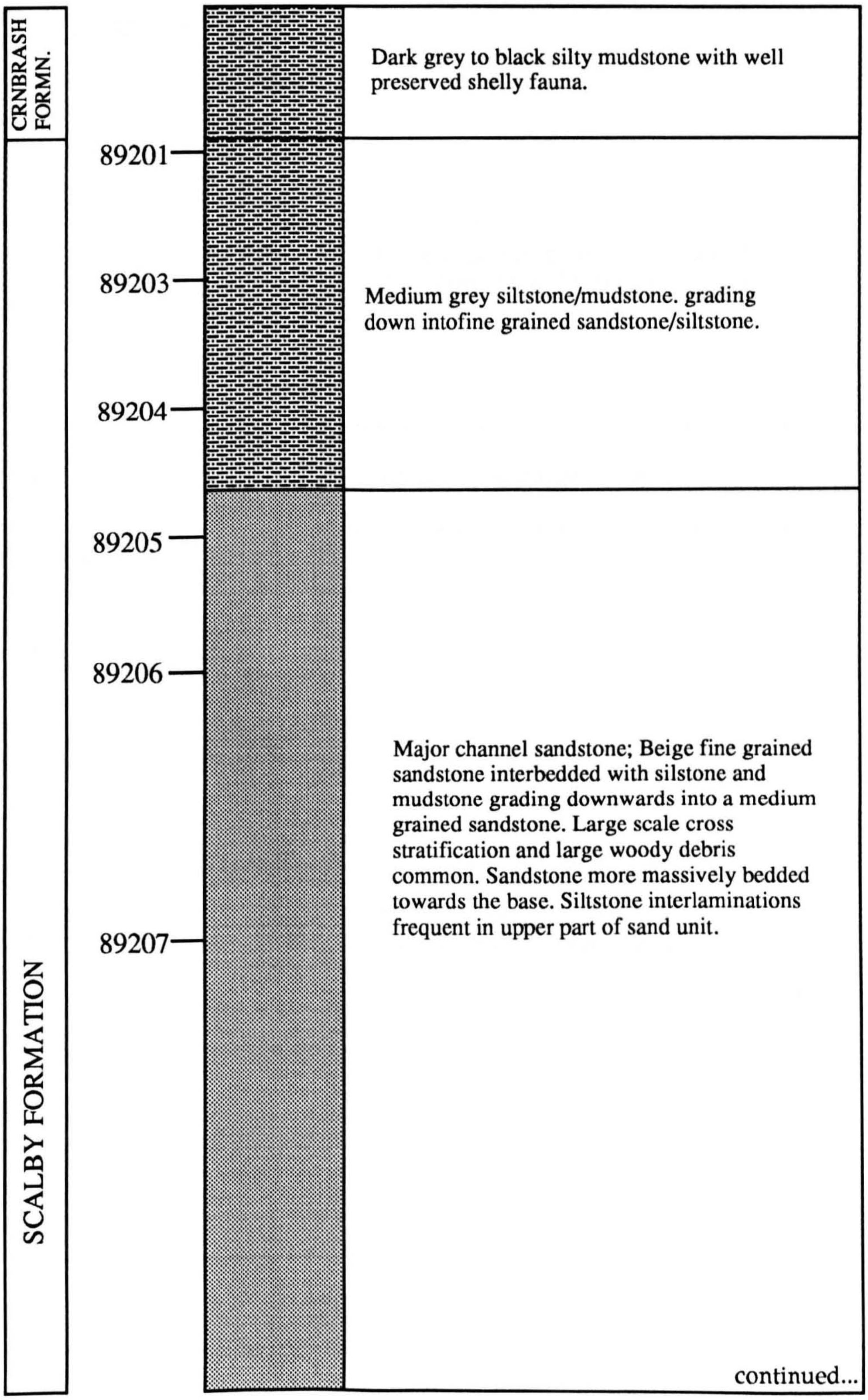
▤	Mudstone	▩	Laminated mudstone, siltstone, sandstone.
▤	Silty mudstone	▩	Sphaerosideritic mudstone
■	Siltstone	▩	Ironstone
▓	Fine sandstone	▦	Sandy marl
▒	Medium sandstone	▦	Oolitic marl
░	Coarse sandstone	▦	Marl

Scale 3cm = 1m   Cunstone Nab section



Scale 1:25 **Gristhorpe Bay graphical log number 1**

Lithostrat. **Lithology** **Description**



Dark grey to black silty mudstone with well preserved shelly fauna.

Medium grey siltstone/mudstone. grading down intofine grained sandstone/siltstone.

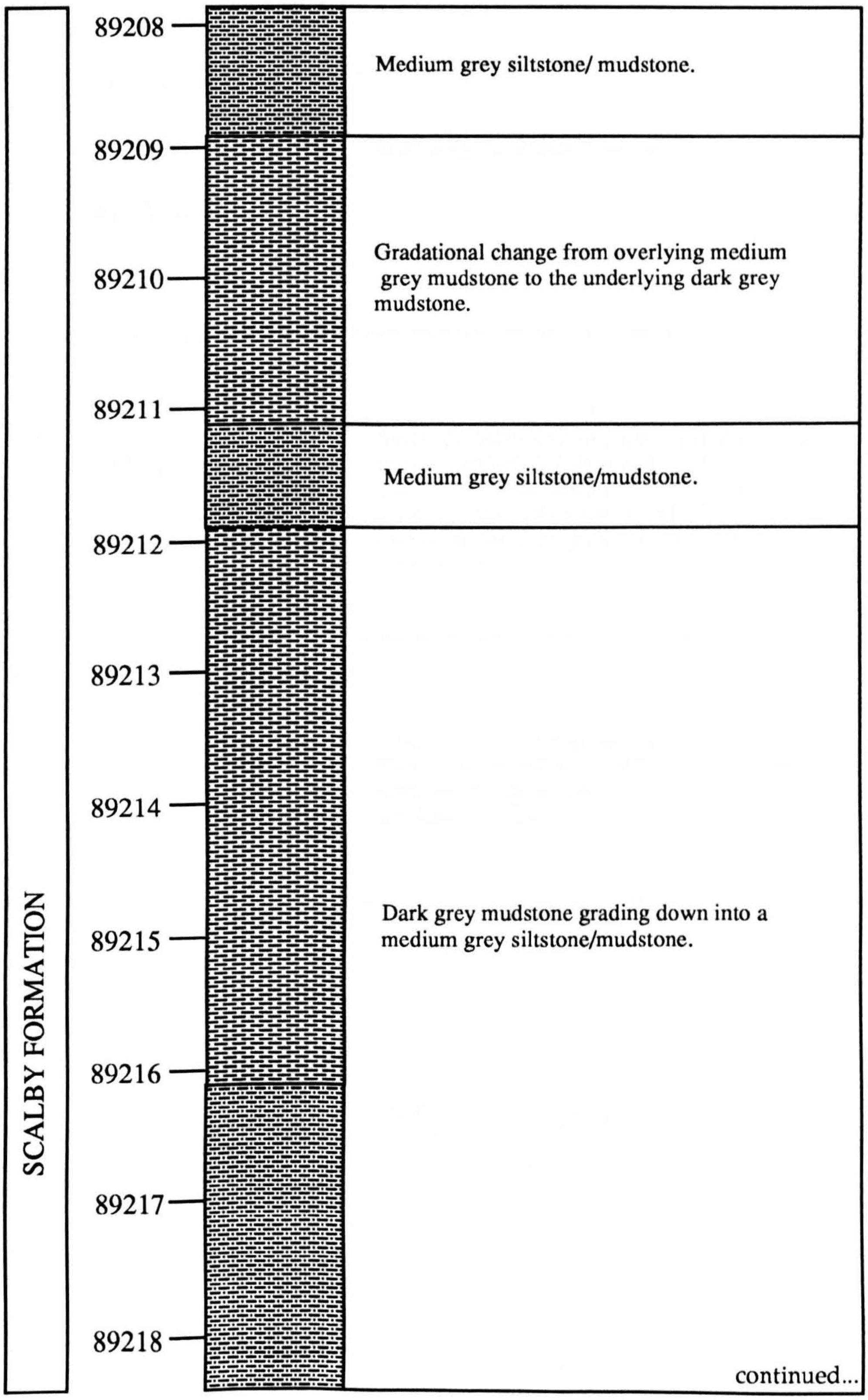
Major channel sandstone; Beige fine grained sandstone interbedded with silstone and mudstone grading downwards into a medium grained sandstone. Large scale cross stratification and large woody debris common. Sandstone more massively bedded towards the base. Siltstone interlaminations frequent in upper part of sand unit.

continued...

Scale 1:25

Gristhorpe Bay graphical log number 2

Lithostrat. **Lithology** **Description**



Medium grey siltstone/ mudstone.

Gradational change from overlying medium grey mudstone to the underlying dark grey mudstone.

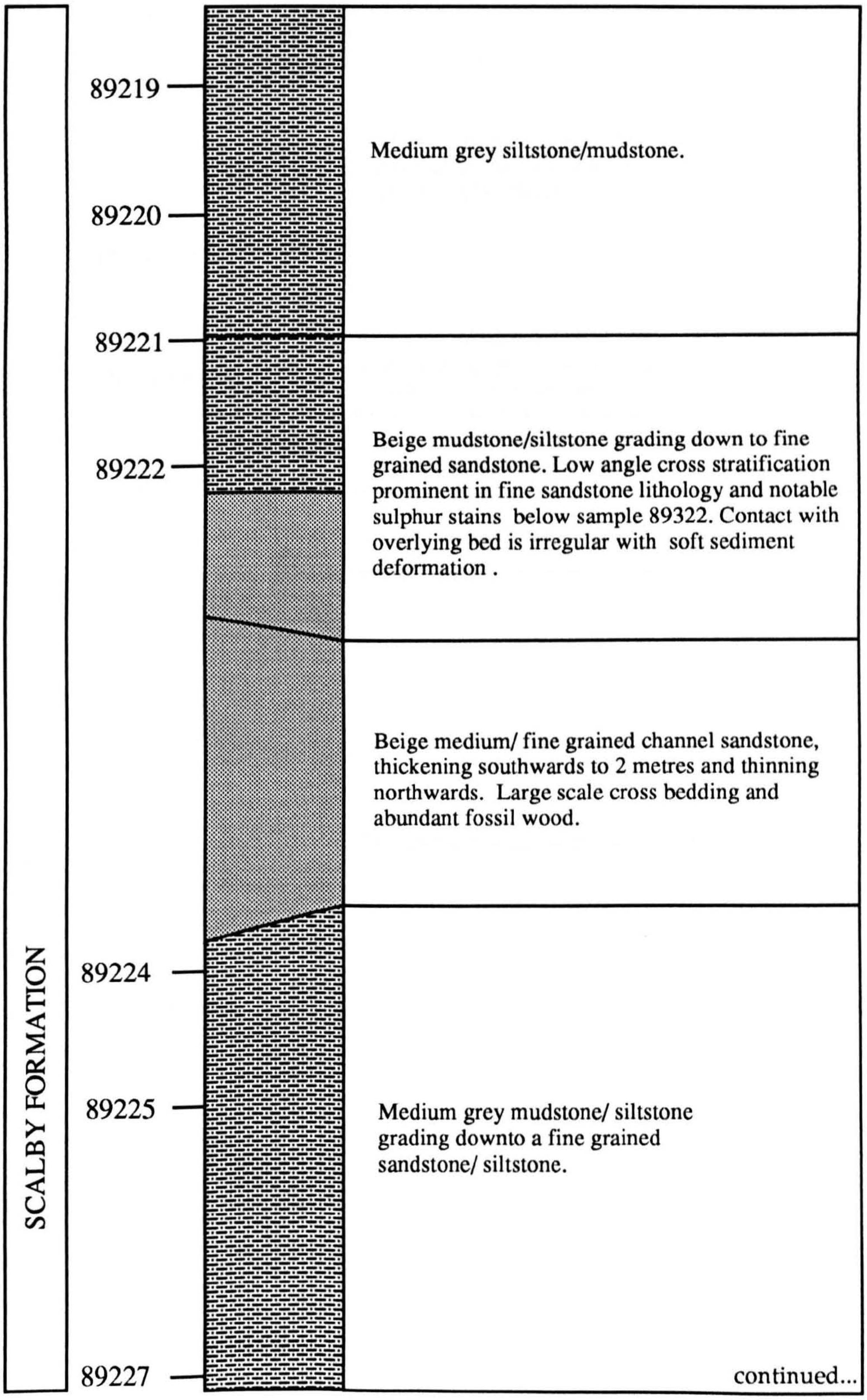
Medium grey siltstone/mudstone.

Dark grey mudstone grading down into a medium grey siltstone/mudstone.

continued...

Scale 1:25 **Gristhorpe Bay graphical log number 3**

Lithostrat. **Lithology** **Description**



Medium grey siltstone/mudstone.

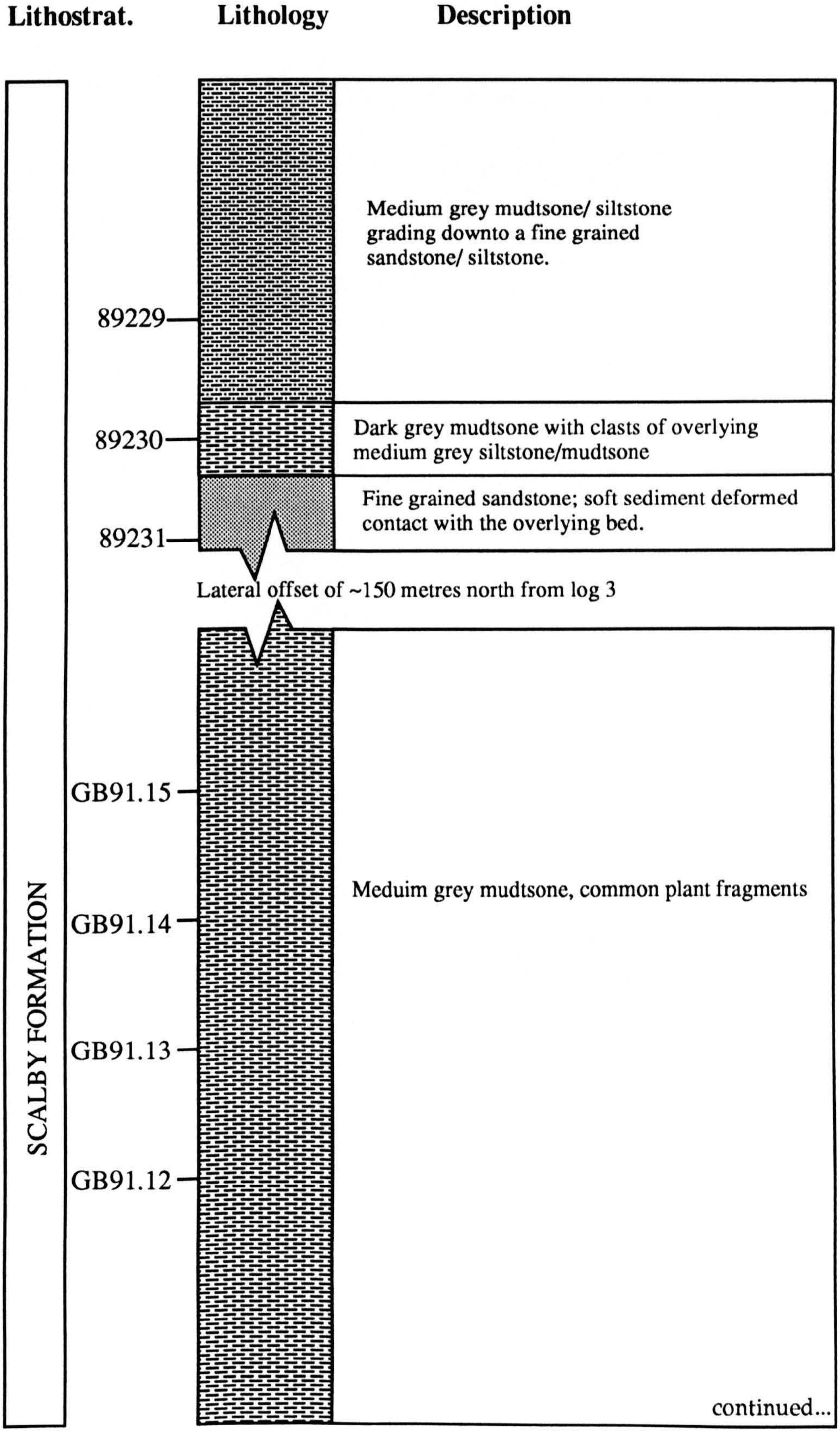
Beige mudstone/siltstone grading down to fine grained sandstone. Low angle cross stratification prominent in fine sandstone lithology and notable sulphur stains below sample 89322. Contact with overlying bed is irregular with soft sediment deformation .

Beige medium/ fine grained channel sandstone, thickening southwards to 2 metres and thinning northwards. Large scale cross bedding and abundant fossil wood.

Medium grey mudstone/ siltstone grading downto a fine grained sandstone/ siltstone.

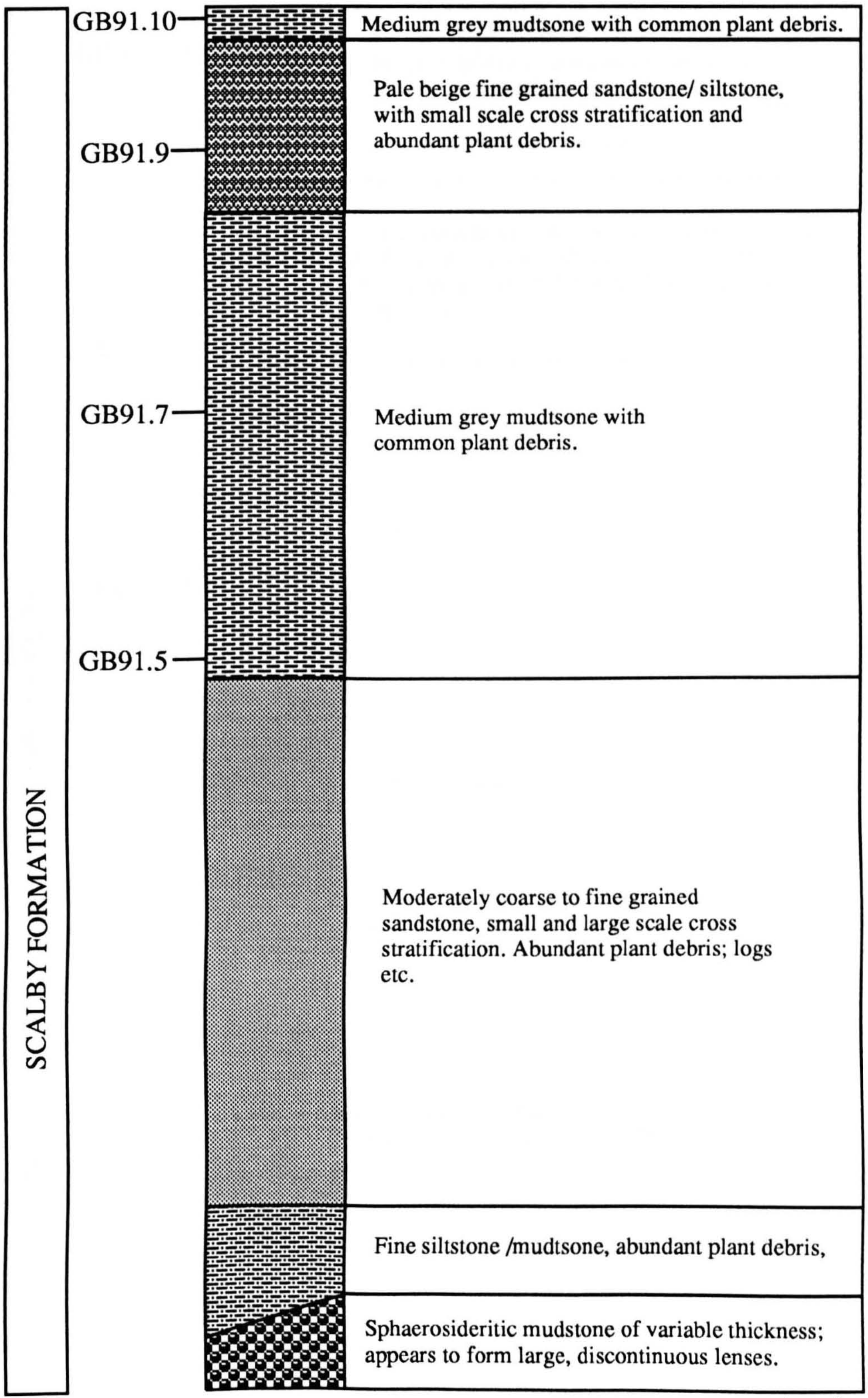
continued...

Scale 1:25 **Gristhorpe Bay graphical log number 4**



Scale 1:25 **Gristhorpe Bay graphical log number 5**

Lithostrat. **Lithology** **Description**



Medium grey mudtsone with common plant debris.

Pale beige fine grained sandstone/ siltstone, with small scale cross stratification and abundant plant debris.

Medium grey mudtsone with common plant debris.

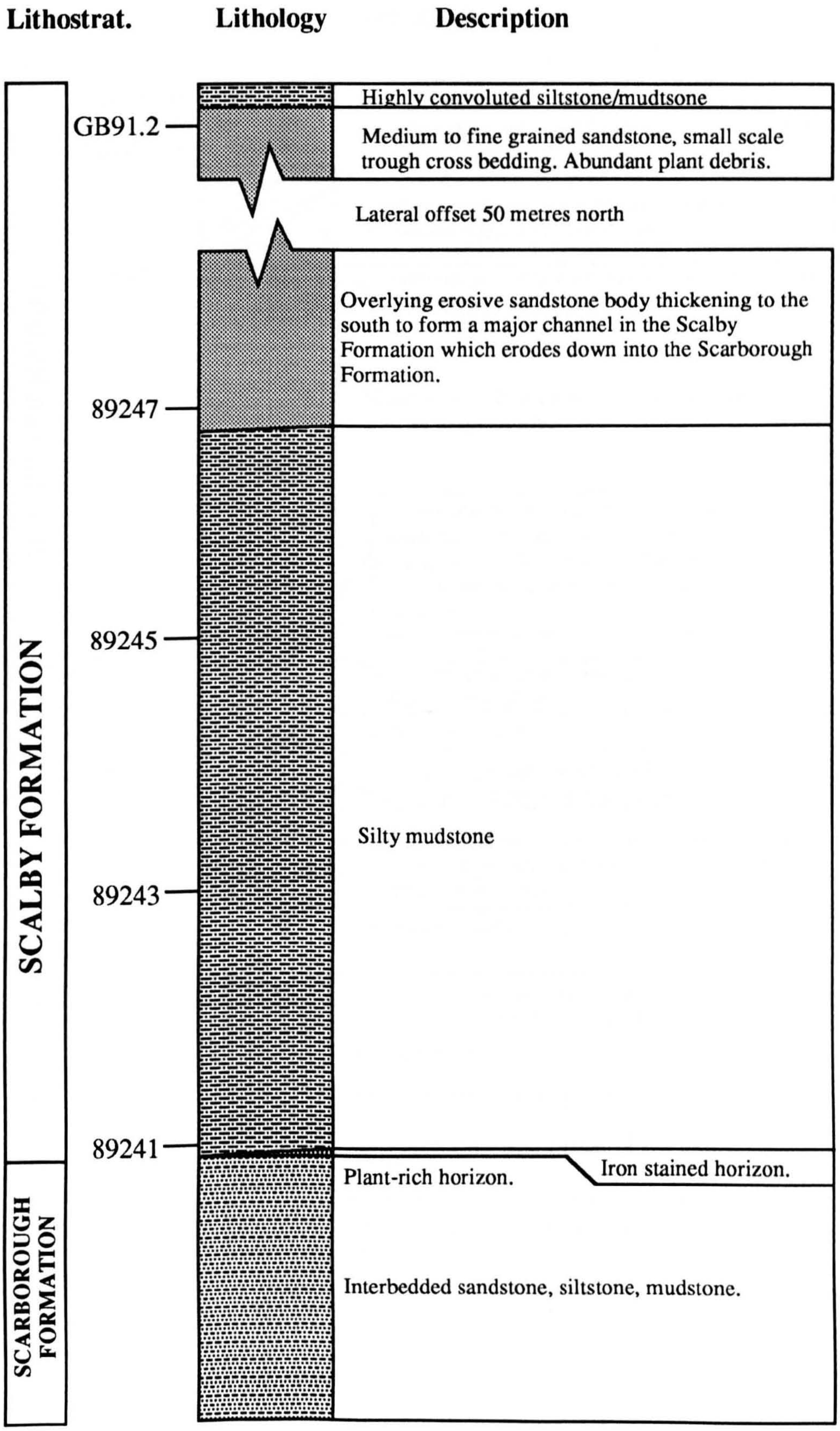
Moderately coarse to fine grained sandstone, small and large scale cross stratification. Abundant plant debris; logs etc.

Fine siltstone /mudtsone, abundant plant debris,

Sphaerosideritic mudstone of variable thickness; appears to form large, discontinuous lenses.

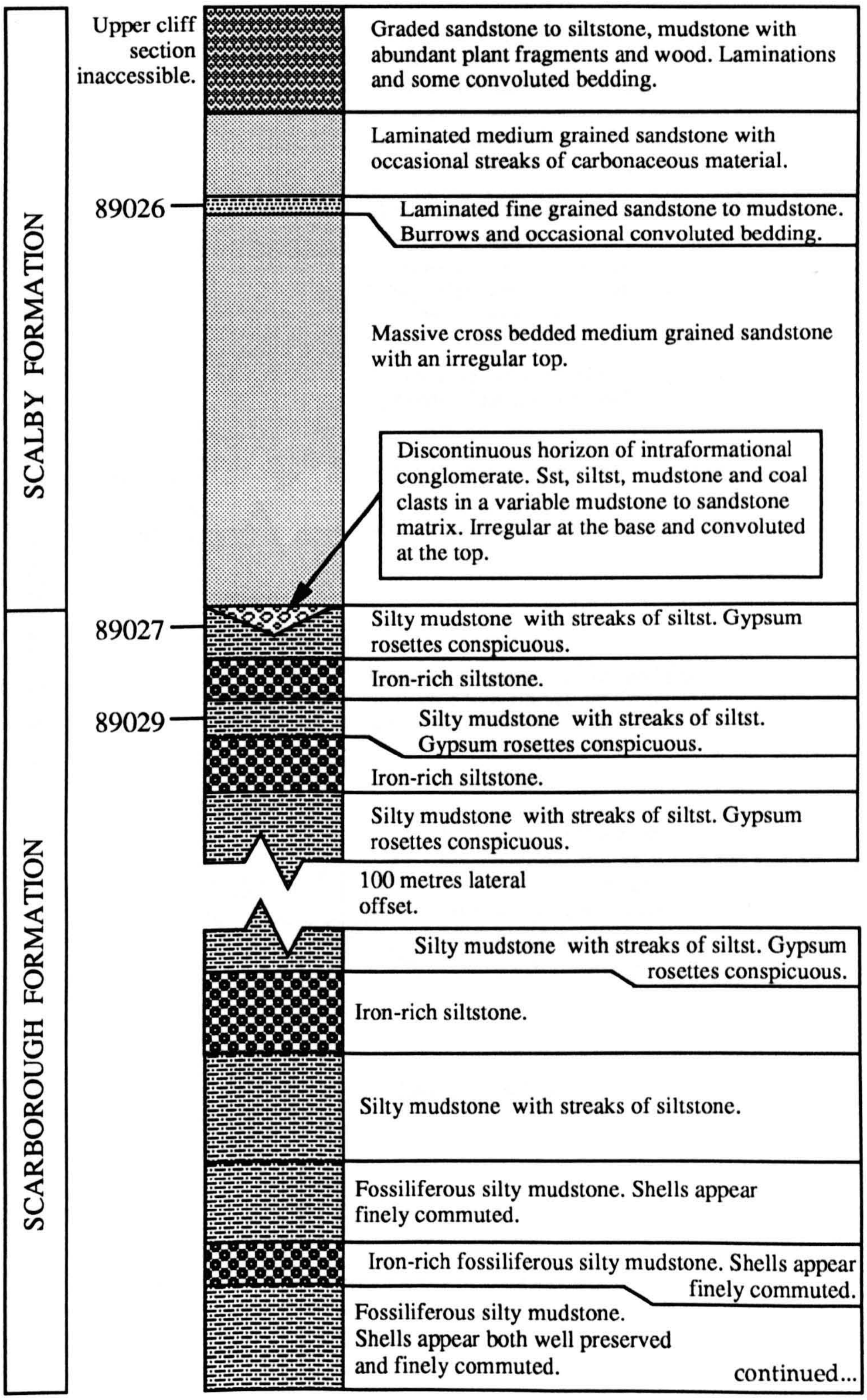
continued...

Scale 1:25 **Gristhorpe Bay graphical log number 6**



Scale 1:25 **Yons Nab graphical log number 1**

Lithostrat. **Lithology** **Description**



Graded sandstone to siltstone, mudstone with abundant plant fragments and wood. Laminations and some convoluted bedding.

Laminated medium grained sandstone with occasional streaks of carbonaceous material.

Laminated fine grained sandstone to mudstone. Burrows and occasional convoluted bedding.

Massive cross bedded medium grained sandstone with an irregular top.

Discontinuous horizon of intraformational conglomerate. Sst, siltst, mudstone and coal clasts in a variable mudstone to sandstone matrix. Irregular at the base and convoluted at the top.

Silty mudstone with streaks of siltst. Gypsum rosettes conspicuous.

Iron-rich siltstone.

Silty mudstone with streaks of siltst. Gypsum rosettes conspicuous.

Iron-rich siltstone.

Silty mudstone with streaks of siltst. Gypsum rosettes conspicuous.

Silty mudstone with streaks of siltst. Gypsum rosettes conspicuous.

Iron-rich siltstone.

Silty mudstone with streaks of siltstone.

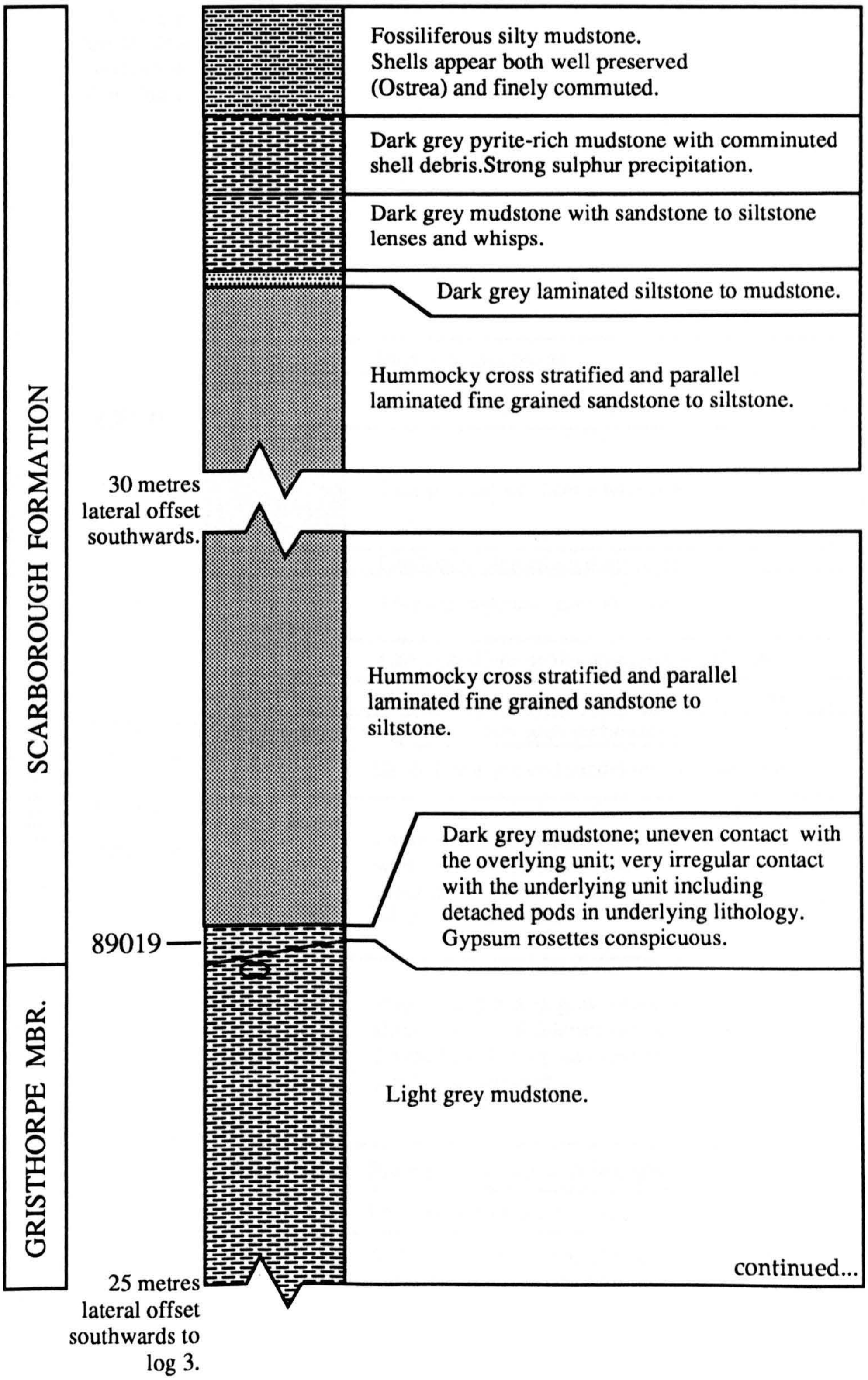
Fossiliferous silty mudstone. Shells appear finely commuted.

Iron-rich fossiliferous silty mudstone. Shells appear finely commuted.

Fossiliferous silty mudstone. Shells appear both well preserved and finely commuted.

Scale 1:25 **Yons Nab graphical log number 2**

Lithostrat. **Lithology** **Description**



Fossiliferous silty mudstone. Shells appear both well preserved (Ostrea) and finely commuted.

Dark grey pyrite-rich mudstone with comminuted shell debris.Strong sulphur precipitation.

Dark grey mudstone with sandstone to siltstone lenses and whisps.

Dark grey laminated siltstone to mudstone.

Hummocky cross stratified and parallel laminated fine grained sandstone to siltstone.

Hummocky cross stratified and parallel laminated fine grained sandstone to siltstone.

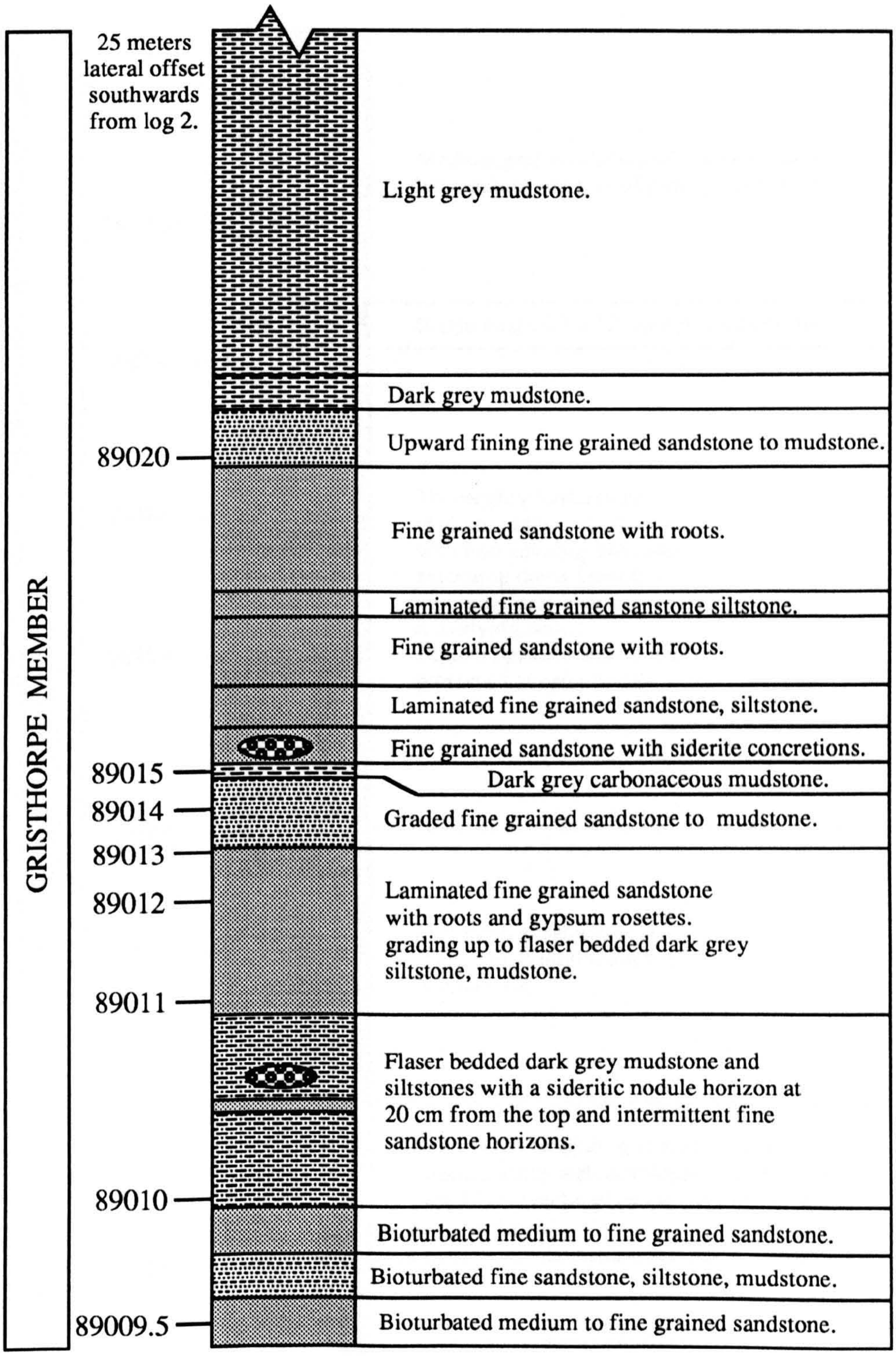
Dark grey mudstone; uneven contact with the overlying unit; very irregular contact with the underlying unit including detached pods in underlying lithology. Gypsum rosettes conspicuous.

Light grey mudstone.

continued...

Scale 1:25 **Yons Nab graphical log number 3.**

Lithostrat. **Lithology** **Description**



Light grey mudstone.

Dark grey mudstone.

Upward fining fine grained sandstone to mudstone.

Fine grained sandstone with roots.

Laminated fine grained sanstone siltstone.

Fine grained sandstone with roots.

Laminated fine grained sandstone, siltstone.

Fine grained sandstone with siderite concretions.

Dark grey carbonaceous mudstone.

Graded fine grained sandstone to mudstone.

Laminated fine grained sandstone
with roots and gypsum rosettes.
grading up to flaser bedded dark grey
siltstone, mudstone.

Flaser bedded dark grey mudstone and
siltstones with a sideritic nodule horizon at
20 cm from the top and intermittent fine
sandstone horizons.

Bioturbated medium to fine grained sandstone.

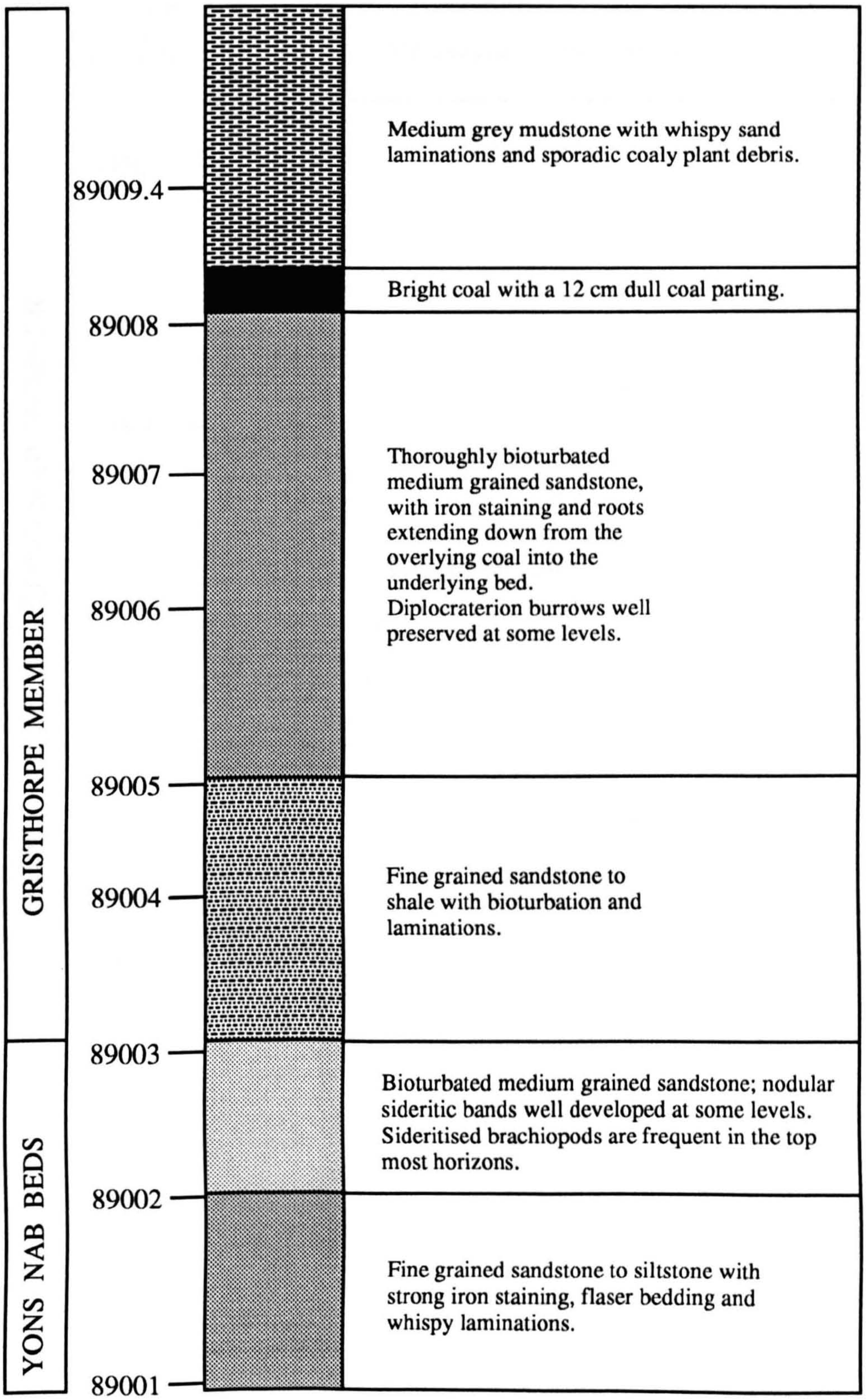
Bioturbated fine sandstone, siltstone, mudstone.

Bioturbated medium to fine grained sandstone.

continued...

Scale 1:25 **Yons Nab graphical log number 4**

Lithostrat. **Lithology** **Description**



Medium grey mudstone with whispy sand laminations and sporadic coaly plant debris.

Bright coal with a 12 cm dull coal parting.

Thoroughly bioturbated medium grained sandstone, with iron staining and roots extending down from the overlying coal into the underlying bed. Diplocraterion burrows well preserved at some levels.

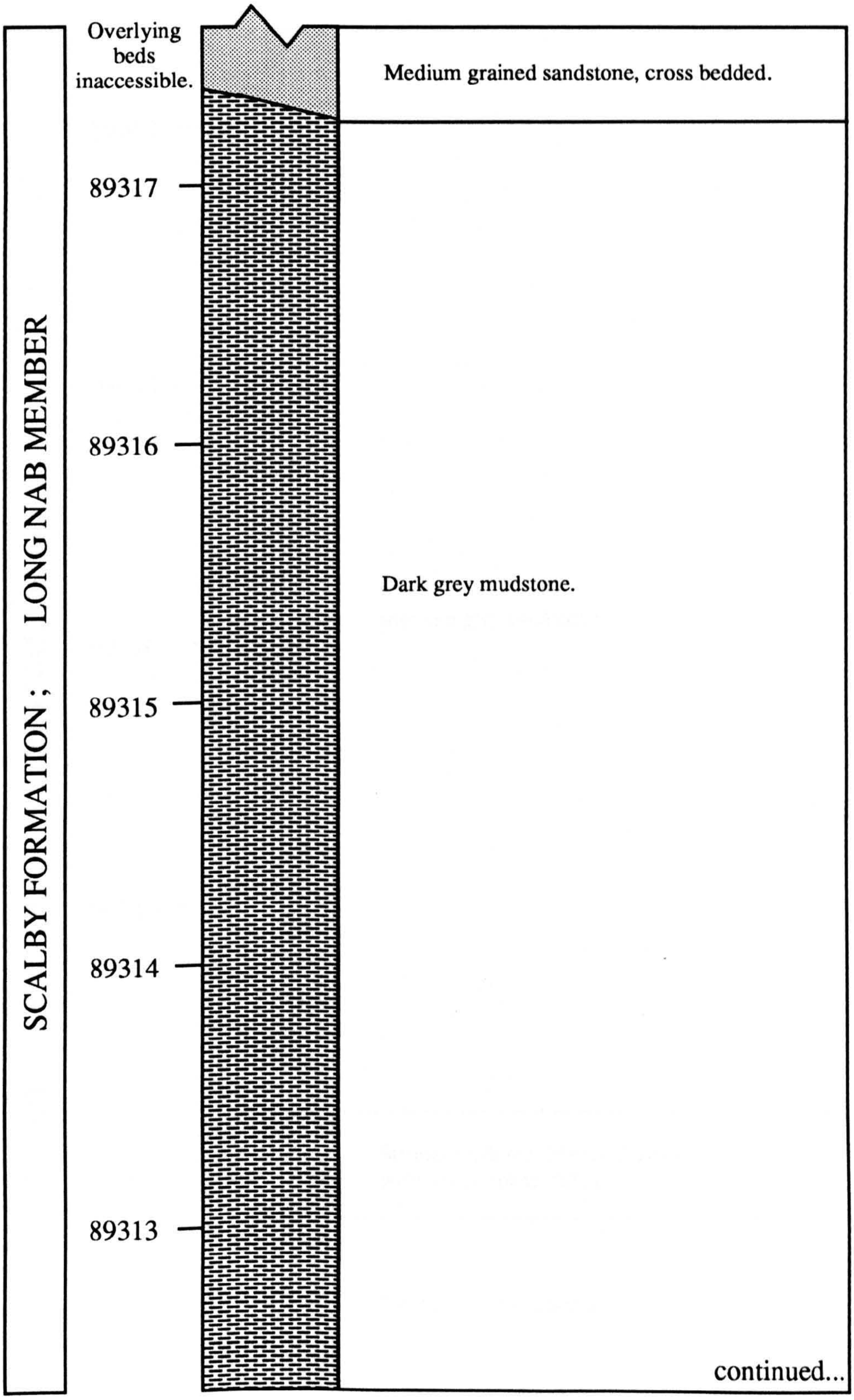
Fine grained sandstone to shale with bioturbation and laminations.

Bioturbated medium grained sandstone; nodular sideritic bands well developed at some levels. Sideritised brachiopods are frequent in the top most horizons.

Fine grained sandstone to siltstone with strong iron staining, flaser bedding and whispy laminations.

Scale 1:25 **Crook Ness graphical log number 1**

Lithostrat. **Lithology** **Description**

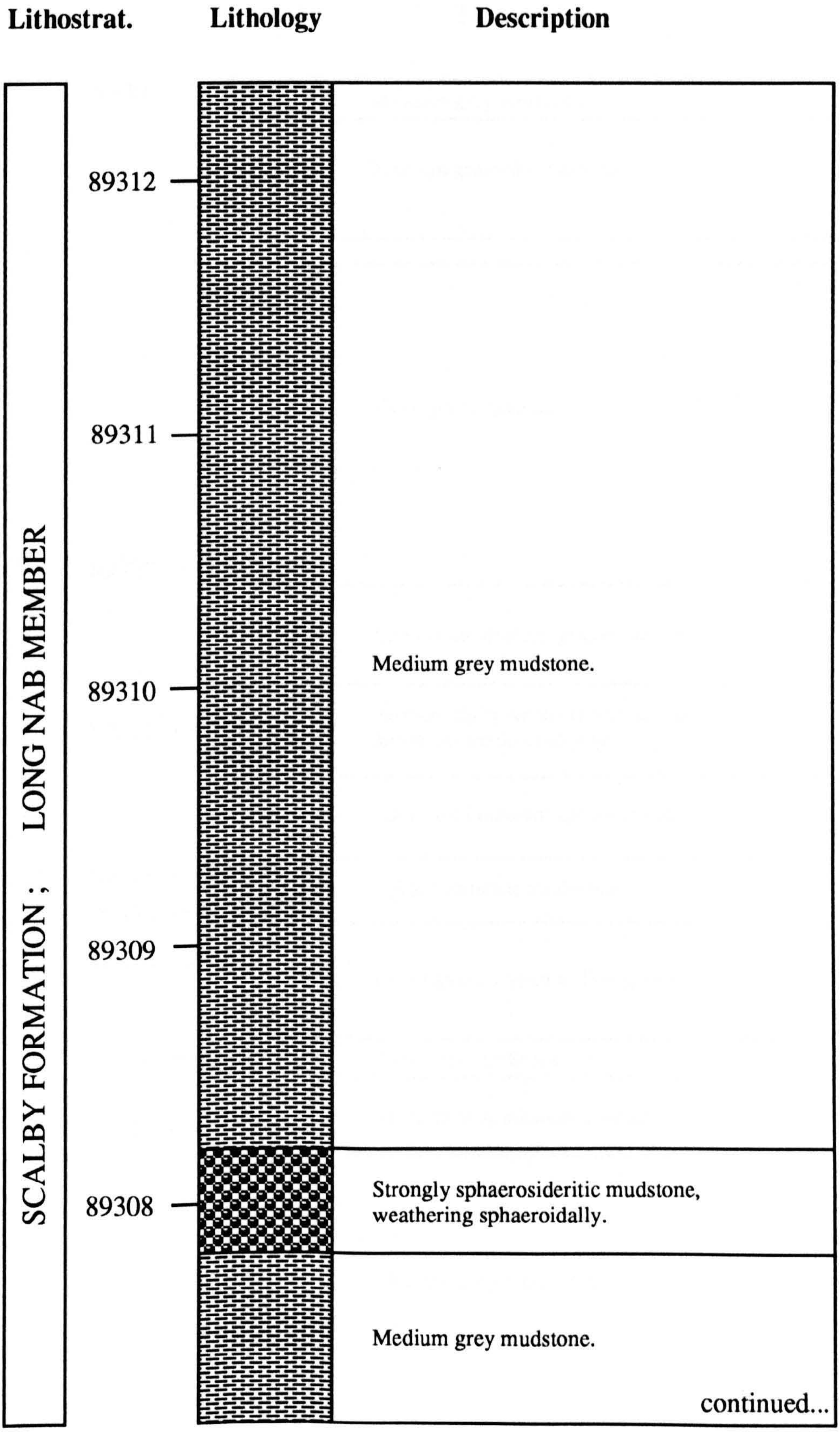


Medium grained sandstone, cross bedded.

Dark grey mudstone.

continued...

Scale 1:25 **Crook Ness graphical log number 2.**



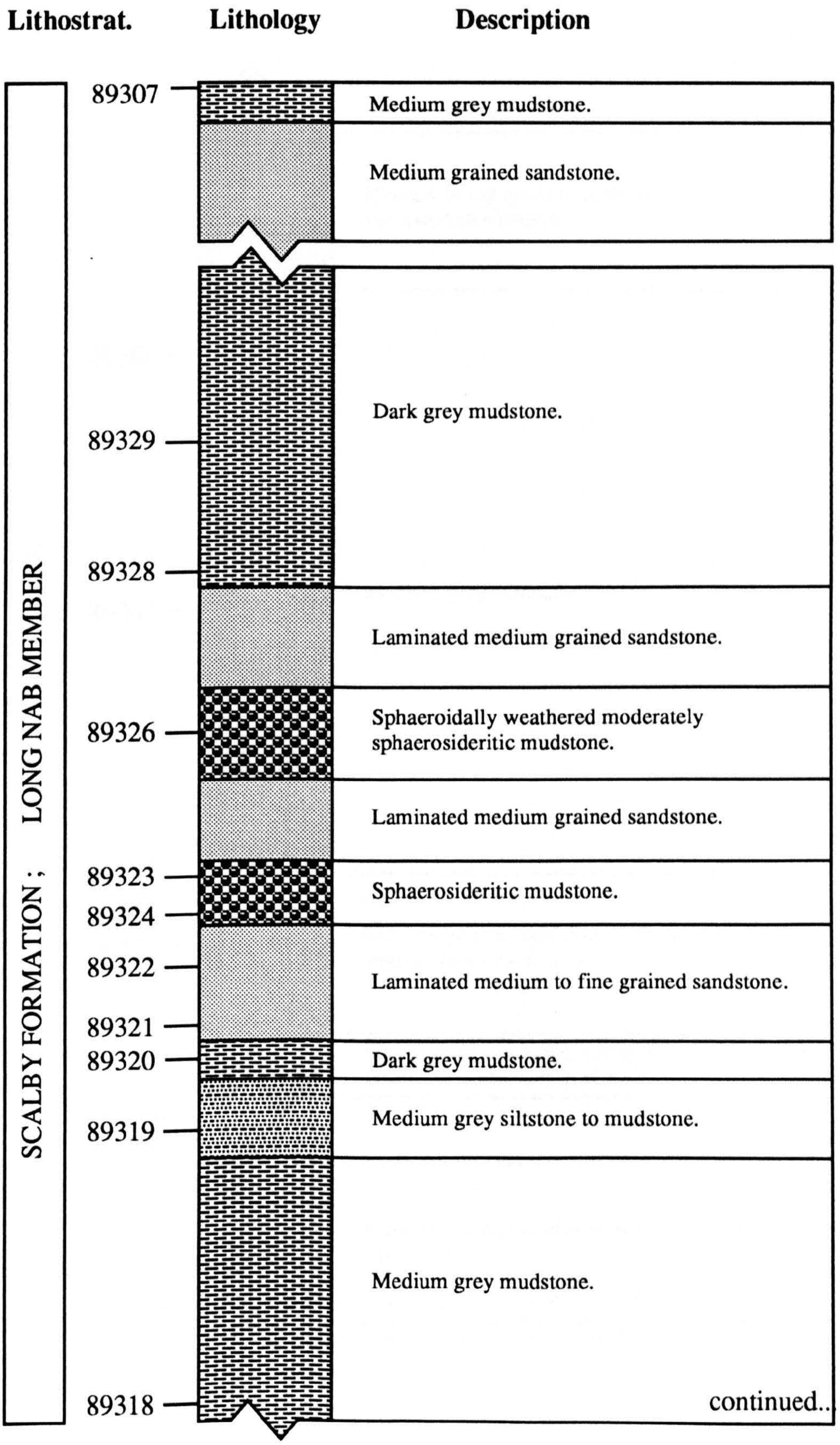
Medium grey mudstone.

Strongly sphaerosideritic mudstone, weathering sphaeroidally.

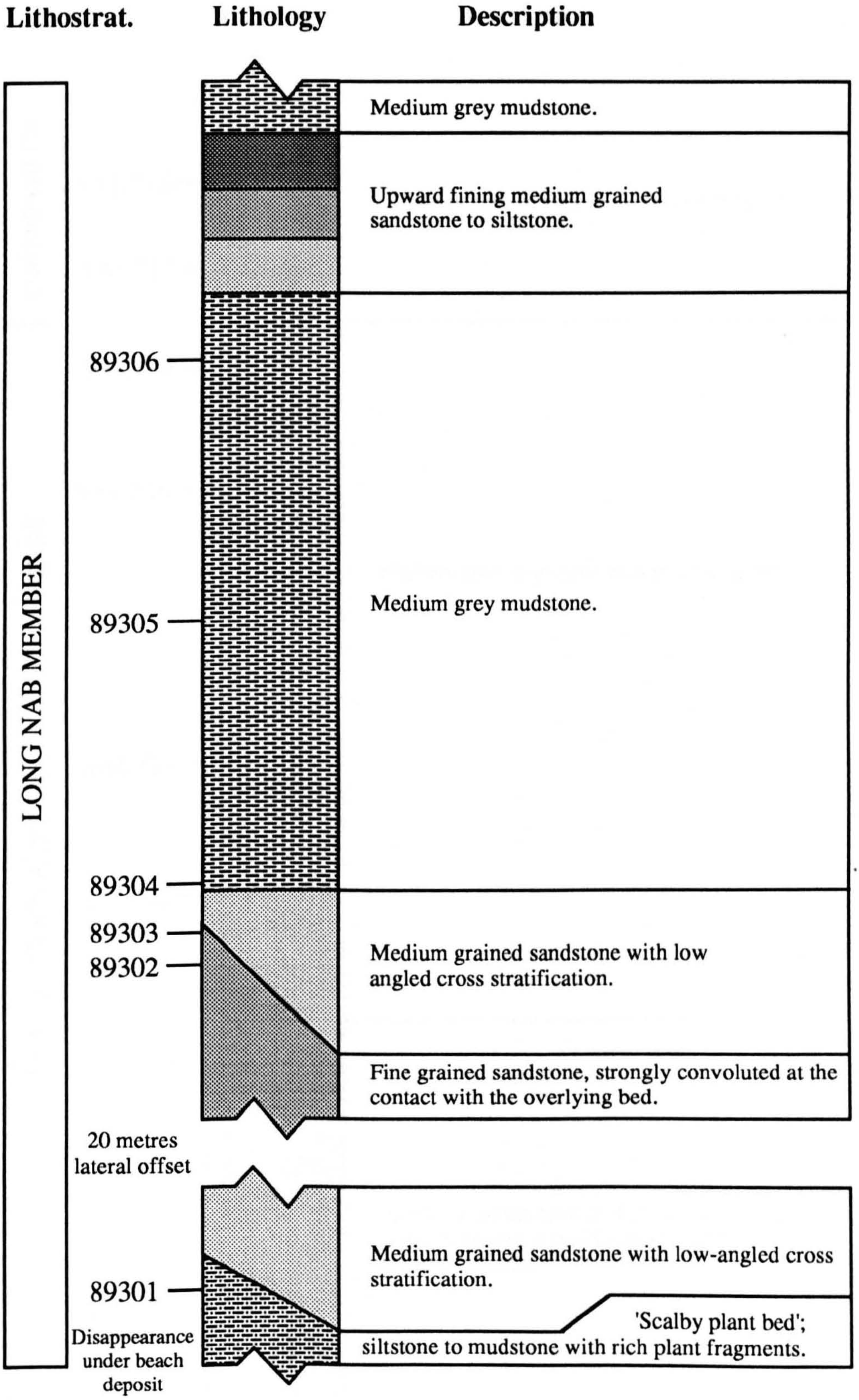
Medium grey mudstone.

continued...

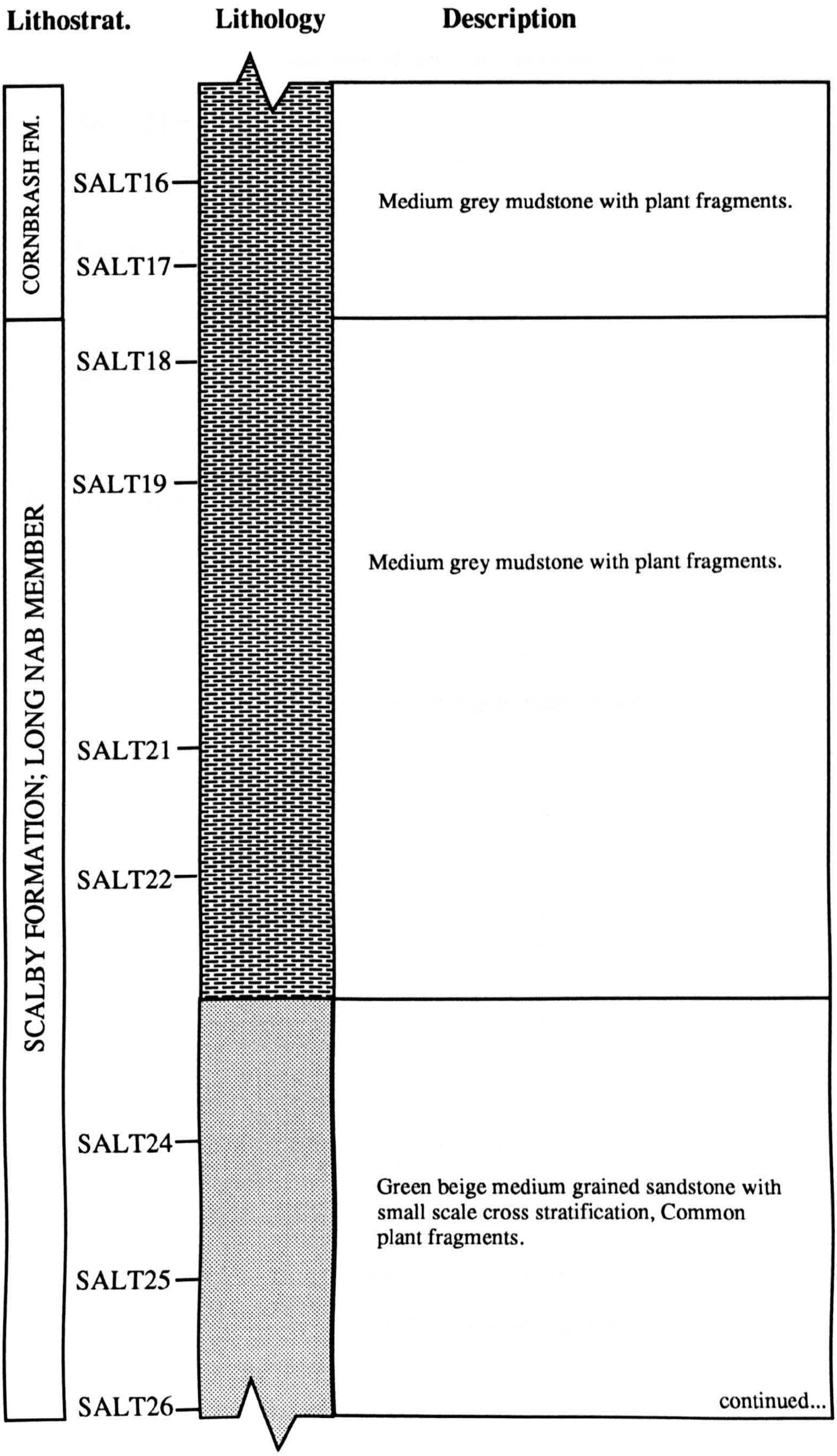
Scale 1:25 **Crook Ness graphical log number 3**



Scale 1:25 **Crook Ness graphical log number 4**



Scale 1:25 **Saltergate graphical log number 1**

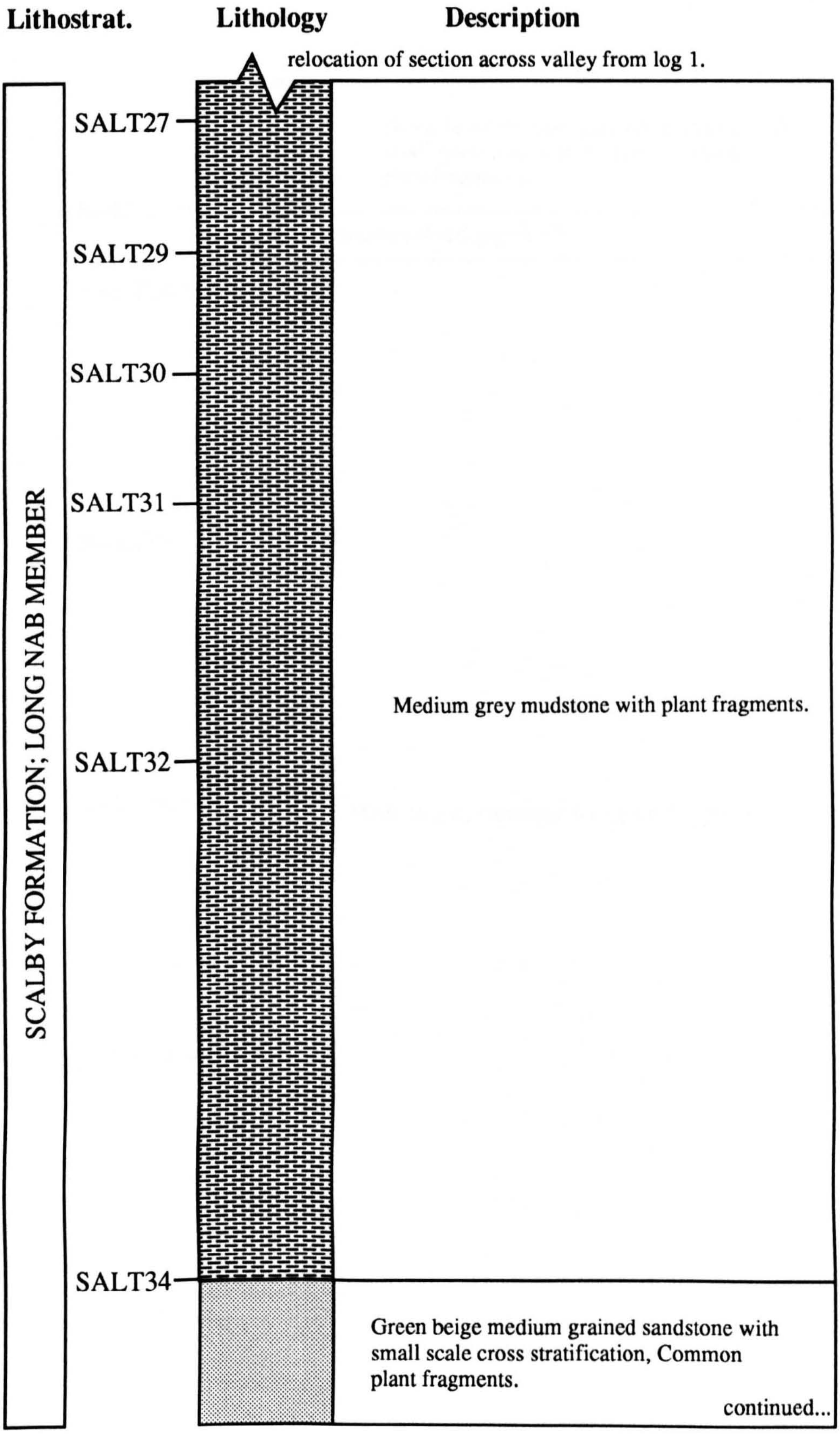


Medium grey mudstone with plant fragments.

Medium grey mudstone with plant fragments.

Green beige medium grained sandstone with small scale cross stratification, Common plant fragments.

Scale 1:25 **Saltergate graphical log number 2**



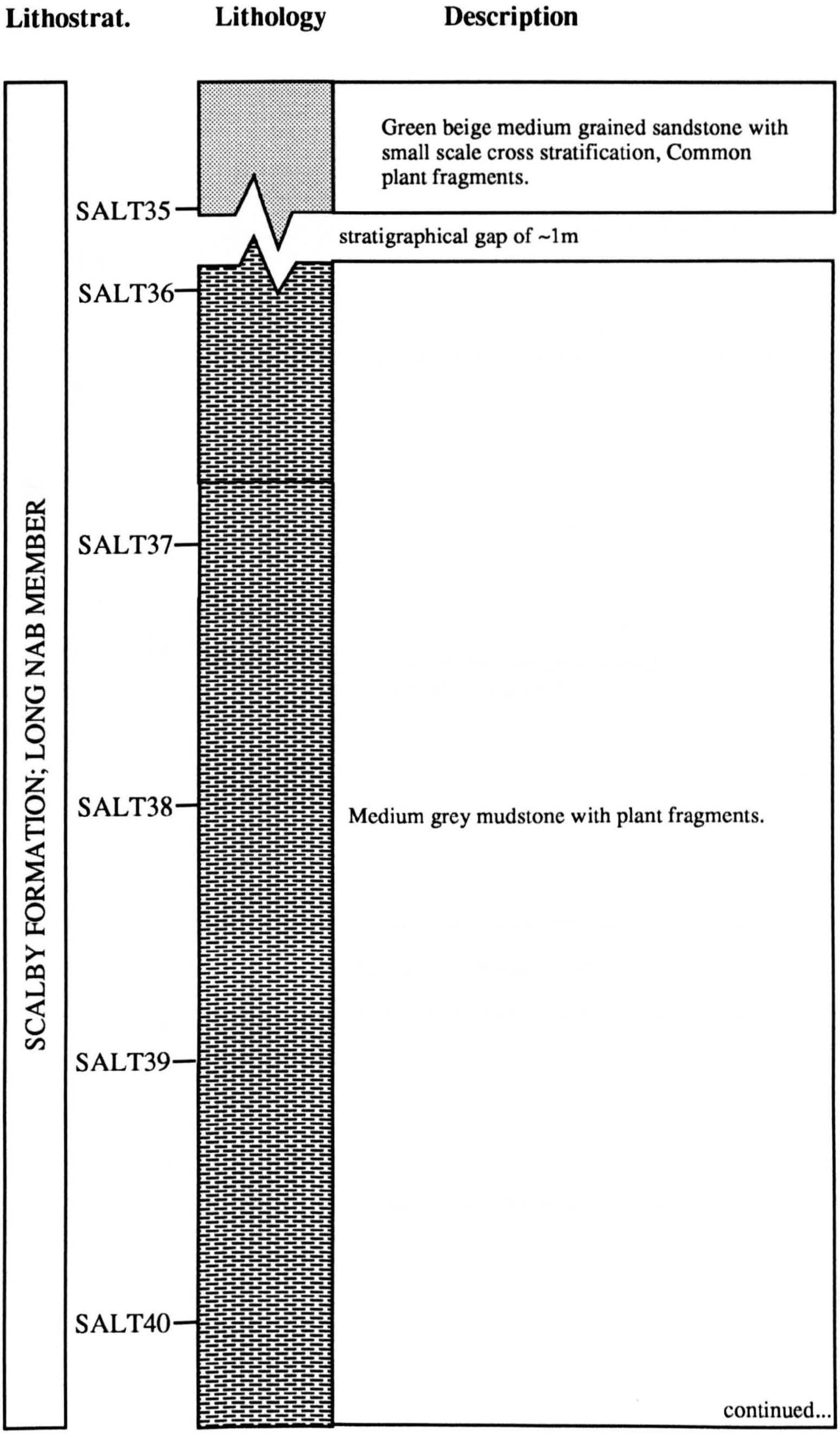
relocation of section across valley from log 1.

Medium grey mudstone with plant fragments.

Green beige medium grained sandstone with small scale cross stratification, Common plant fragments.

continued...

Scale 1:25 **Saltergate graphical log number 3**



Green beige medium grained sandstone with small scale cross stratification, Common plant fragments.

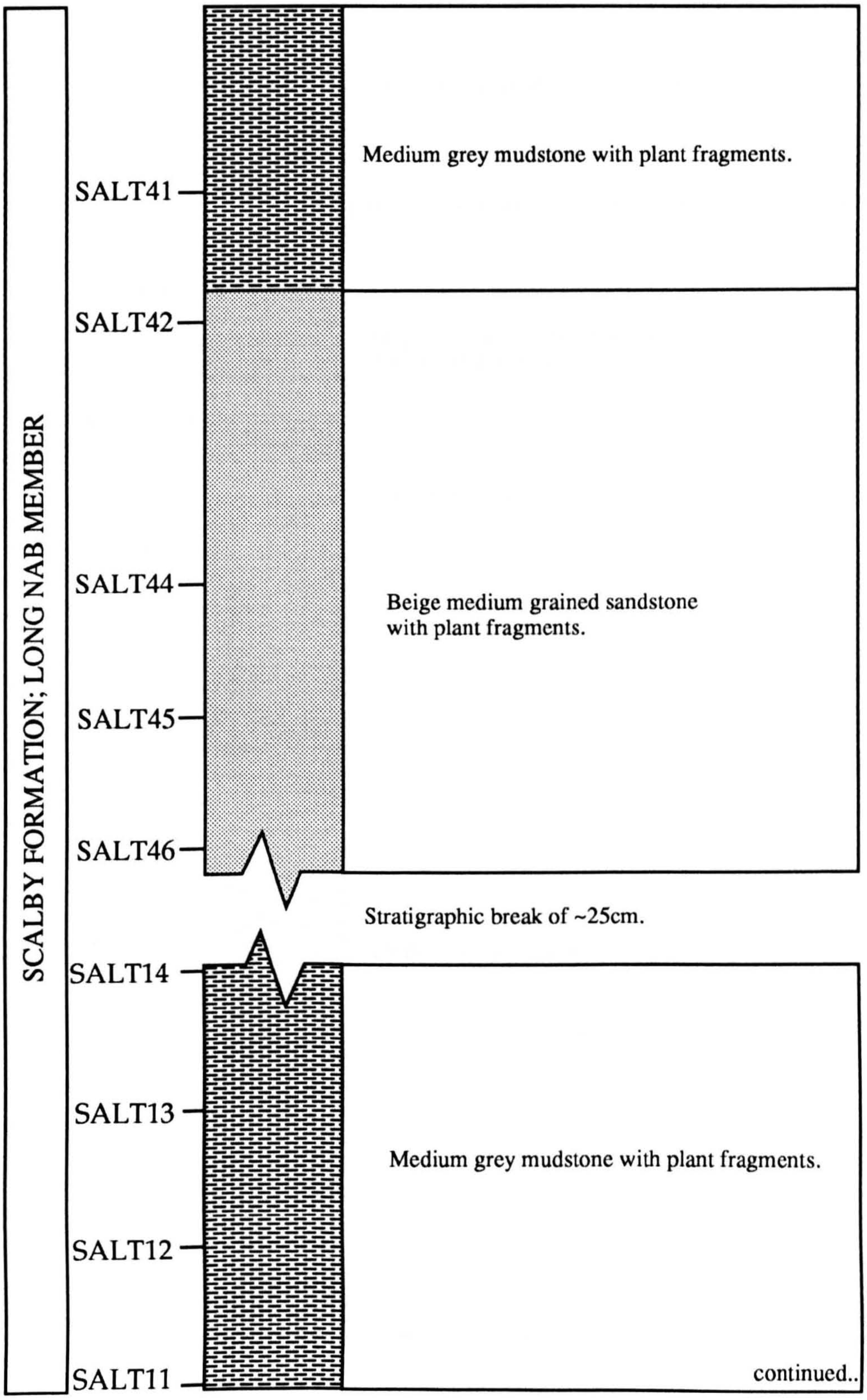
stratigraphical gap of ~1m

Medium grey mudstone with plant fragments.

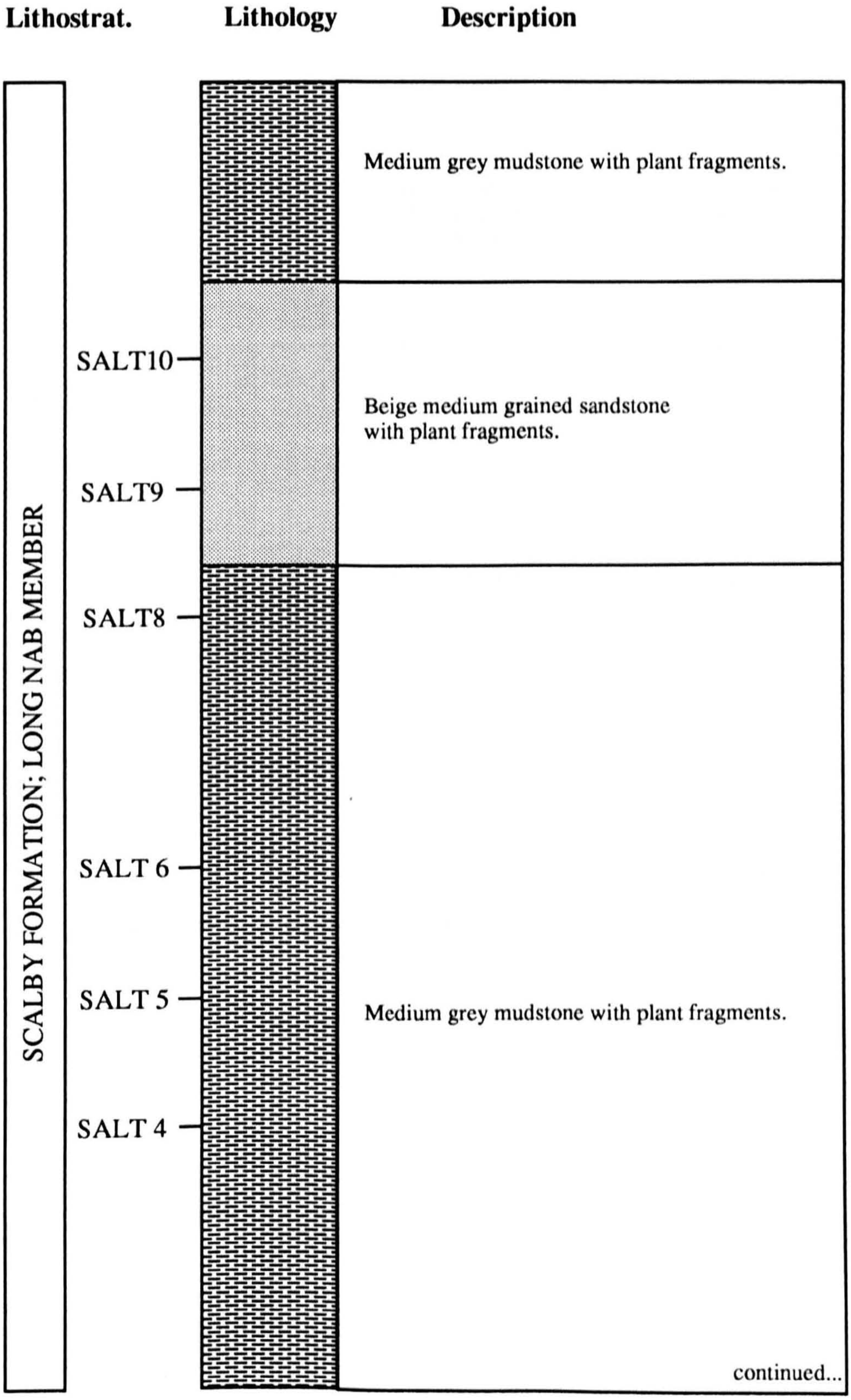
continued...

Scale 1:25 **Saltergate graphical log number 4**

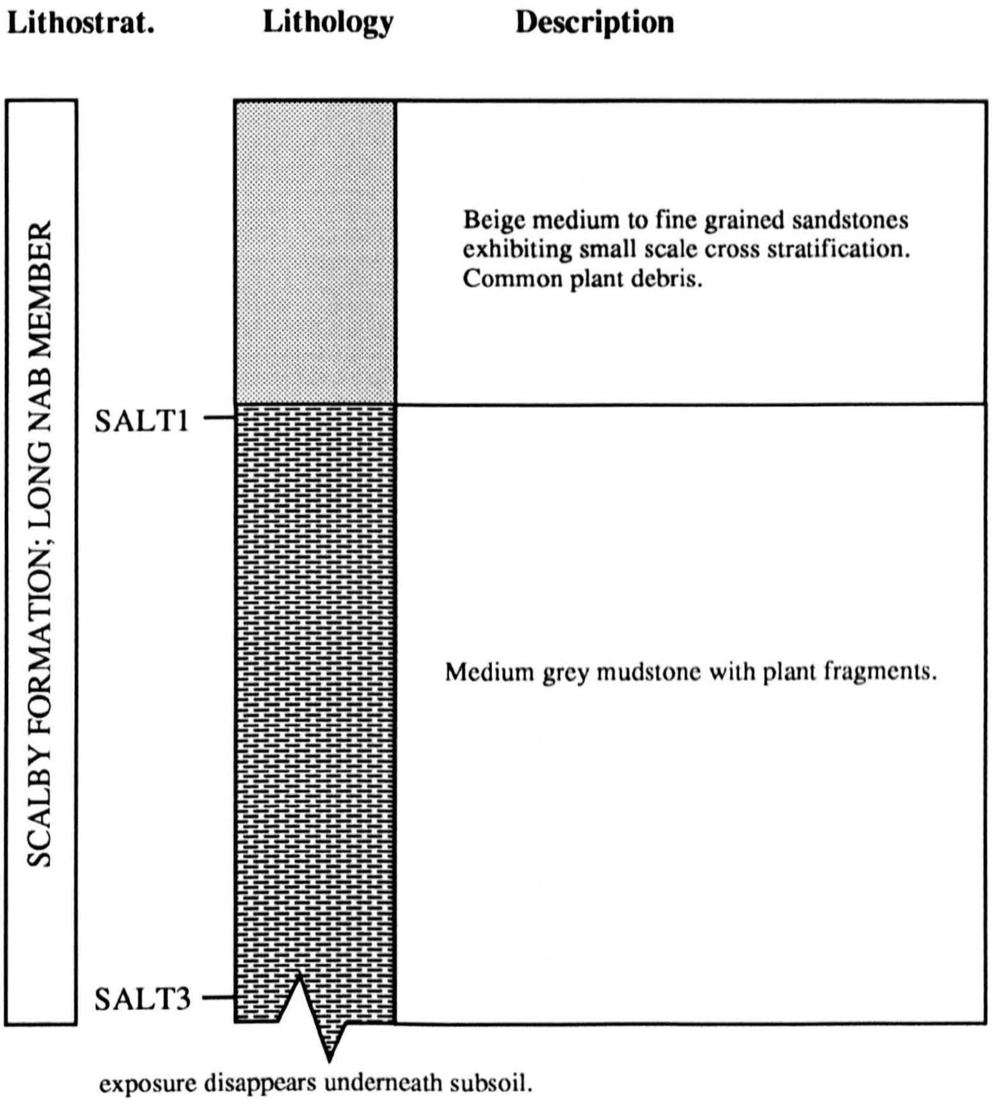
Lithostrat. **Lithology** **Description**



Scale 1:25 **Saltergate graphical log number 5**



Scale 1:25 **Saltergate graphical log number 6**

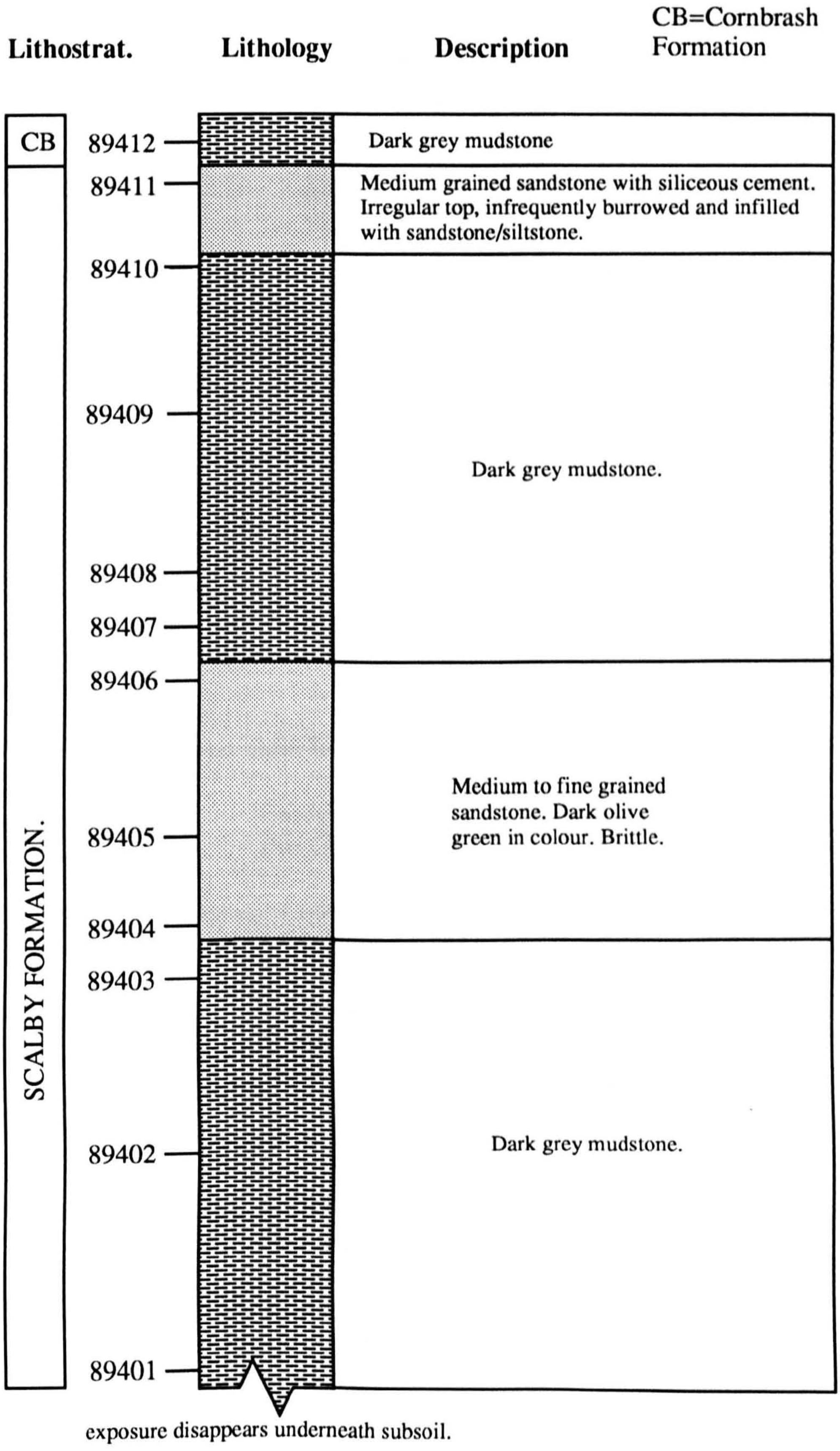


Beige medium to fine grained sandstones exhibiting small scale cross stratification. Common plant debris.

Medium grey mudstone with plant fragments.

exposure disappears underneath subsoil.

Scale 1:25 **Talbot Wood graphical log**



Natural classification of spores and pollen grains

Such classification is ideally derived at solely by in-situ spore and pollen studies. However, due to a lack of a complete record of fossil in-situ material, homologies with contemporary forms and morphological comparisons are additionally employed. Assignations based on the latter methods are remarked upon. Genera with question marks have been placed on a tentative basis in the respective taxonomic groups. The classification follows De Jersey & Raine (1990). Genera may appear in more than one catergory if parallel morphologies are considered to be possible between groups.

The work of Harris (1961a, b, 1964, 1969, 1979 and Harris *et al.* 1974) is not included as the identification of genera has been undertaken by the present author from Harris's written and commonly un-illustrated descriptions. These are documented after the footnotes to the following classification.

Kingdom PLANTAE

Division BRYOPHYTA

Antulsporites[1]
Foveosporites (*moretonensis*)[1]
Stereisporites[1]

Division TRACHEOPHYTA
Class LYCOPSIDA
Order ISOETALES

Densoisporites[2]
Paxillitriletes[3]

Order LYCOPODIALES

? *Kekryphalospora*[4]
Lycopodiacidites[5]
Neoraistrickia[6]
Retitriletes[7]

Order SELAGINELLALES

Kraeuselisporites[8]
Leptolepidites[9]

Undifferentiated Lycopsids
? *Anapiculatisporites*[10]
Foveosporites[11]
? *Kekryphalospora*
Sestrosporites[11]
Staplinisporites[12]

Appendix 2.1

Class SPHENOPSIDA
    Order EQUISETALES
        Calamaspora[13]

Class FILICOPSIDA
    Order MARATTIALES

        Marattisporites[14]

    Order FILICINALES
        Family Gleicheniaceae

            Gleicheniidites[15]
            ?*Ornamentifera*[15]

        Family Osmundaceae

            Osmundacidites[16]
            Rugulatisporites[16]
            Punctatisporites[16]
            Verrucosisporites (*varians*)[16]

        Family Matoniaceae. Dipteridaceae,Cheiropleuriaceae

            Biretisporites[17]
            Concavisporites[18]
            Dictyophyllidites[19]

        Family Dicksoniaceae, Cyatheaceae

            ? *Biretisporites*[20]
            ? *Cibotiumspora*[20]
            Deltoidospora[20]

        Family Schizeaceae
            Ischyosporites[21]

        Family Pteridaceae

            Contignisporites[22]
            Striatella[22]

    Undifferentiated Filicaleans

            ? *Biretisporites*
            Tuberositriletes

Class GYMNOSPERMOPSIDA
    Order CAYTONIALES
        Family Caytoniaceae

            Vitreisporites[23]

Family Corystospermaceae

Alisporites[24]

Orders BENNITTITALES, CYCADALES, GINKGOALES, PENTOXYLALES, CYCADEOIDALES, ? and CZEKANOWSKIALES

Chasmatosporites[25]
Cycadopites[26]
Eucommiidites [27]
?*Callialasporites*[28]

Order LYGINOPTERIDALES

Alisporites[29]

Order CONFIERALES

Family Podocarpaceae

Podocarpidites[30]

Family Araucariaceae

Araucariacites[31]
Callialasporites[28]

Family Abietineaenaceae

? *Pityosporites*
? *Abietineaesporites*

Family Cupressaceae /Taxodiaceae

Perinopollenites[32]
Exesipollenites[33]

Family Cheirolepidaceae

Corollina[34]

Undifferentiated possible Coniferaleans

? *Abietineaepollenites*
Alisporites[24]
Cerebropollenites[35]
? *Exesipollenites*
? *Pityosporites*

Appendix 2.1

---

[1] Filatoff (1975) considered *Antulsporites, Foveosporites moretonensis* and *Stereisporites* amongst others to be Bryophytic "Sphagnaceae-type spores". Miller (1982) considered it likely that Filatoff (1975) had grouped together both true mosses and hepatics. The former regarded it possible, for example, that *Polycingulatisporites* may have originated from the hepatics or moss groups other than the Sphagnaceae.

[2] Raine, De Jersey and Ryan (1988) suggested an Isoetalean (Pleuromeiaceae) affinity for the Triassic species *Densoisporites psilatus* (De Jersey 1964). Potonié (1956) and Balme (1963) suggested a Lycopodiaceous, possibly Selaginellid, affinity for forms of *Densoisporites.* Filatoff (1975) grouped the genus within "Lycopodiaceae/Selaginellaceae-type spores".

[3] Kovach and Dilcher (1985) suggested *Paxillitriletes* was an Isoetalean megaspore.

[4] *Kekryphalospora* is tentatively placed within the Lycopodialeans as it displays morphological similarity to *Retitriletes.*

[5] Filatoff (1975) regarded *Lycopodiacidites* as Lycopodialean spores, without further qualification.

[6] Dettmann(1963) considered *Neoraistrickia* to be of possible *Lycopodium* or *Selaginella* affinity. Forms of *Neoraistrickia* closely resemble spores of the modern *Lycopodium deuterodensum* Hekier (cf. Wilce 1972).

[7] The morphology of the species of *Retitriletes* recorded herein is consistent with that of spores of *Lycopodium* (Wilce 1972, Dettman 1986). Filatoff (1975) classified all the above as "Lycopodiaceae / Selaginellaceae-type spores".

[8] Schulz (1967) compared *Kraeuselisporites reissingeri* (as *Heliosporites altmarkensis*) to spores of the extant *Selaginella selaginoides.* The work of Srivastava (1987) was also in agreement with this.

[9]The spores of *Leptolepidites* were regarded as of Lycopodialean / Selaginellean type by Filatoff (1975). Dettmann (1986) also considered such forms as possible Selaginellids, but cautioned that similar forms are produced at present by the Ophloglossaceae (cf. Tyron and Tryon 1982). Similarly Rogalska (1954) had described fossil forms as "Ophioglossaceae (cf. *Botrychium lunaria*)".

continued...

---

[10] After De Jersey and Raine (1990). Filatoff (1975) regarded *Anapiculatisporites dawsonensis* as a possible Hymenophyllacean spore.

[11] Dettmann(1986) considered *Sestrosporites pseudoalveolatus* to be comparable with spores of Lycopodium (Selago), whilst Filatoff (1975) placed both *S.pseudoalveolatus* and *Foveosporites multifoveolatus* (considered synonymous with *S. pseudoalveolatus* in the present study) in Lycopodiaceae/Selaginellaceae-type spores".

[12] Dettmann(1963) regarded *Staplinisporites caminus* as comparable with spores of the extant bryophyte *Encalypta ciliata.* However, Dettmann (1986) considered forms of *Coronatispora* (al. *Staplinisporites*) analogous to extant Lycopod spores. Filatoff (1975) had previously regarded *Staplinisporites* as a Lycopodialean/Selaginellean type.

[13] Spores of *Calamospora* type were described from *Equestites* recovered from Triassic strata by Halze (1908): *cf.* Couper (1958).

[14] Couper (1958) recorded *Marattisporites scabratus* from Triassic and Jurassic marattialean ferns.

[15] Couper (1958) described spores illustrated by Harris (1931), which the latter had recovered from the Liassic fern *Gleichenites nitida,* as comparable with the genus *Gleicheniidites.* Couper (1958) also compared *G.senonicus* Ross 1949 with the spores of modern *Gleichenia. Ornamentifera* is tentatively placed here on the basis of morphological similarities (some authors consider this genus to be synonymous with *Gleicheniidites* (see systematic palynology, Chapter 3)).

[16] Couper (1958) identified *Osmundacidites* type spores from Liassic and Middle Jurassic osmundaceous ferns of the genera *Osmundopsis* and *Todites. Punctatisporites* (al.*Todisporites*) types were recorded from *Todites* parent plants. The later studies of Van Konijnenberg-Van Cittert (1978) confirmed such relationships. Filatoff (1975) regarded the species *Osmundacidites wellmanii* , *Baculatisporites comaumensis, Verrucosisporites varians* and *Rugulatisporites nequensis* as probable Osmundaceous taxa, based on morphologic similarity and intergradation. As noted by Dettman (1986), however similar spores also occur within the Hymenophyllaceae.

[17] Tentatively placed in this category on the basis of morphologic similarity.

continued...

---

[18] Tentatively placed in this category on the basis of morphographic similarity and following the descriptions of Harris (1979).

[19] Couper (1958) recovered *Dictyophyllidites* from Jurassic Dictyophyllum (? Cheiropleuriaceae). Dev (1980) reported such spores from Jurassic *Phlebopteris* and Lower Cretaceous Weichselia, whilst Irwin (1985) obtained *Dictyophyllidites* from Triassic *Phlebopteris* (Matoniaceae).

[20] Although it is probable that a variety of ferns are capable of producing simple laevigate trilete spores there is a common association of *Deltoidospora* type spores with fossil Dicksoniaceae (particularly *Coniopteris*) in the British Middle Jurassic (eg. Couper 1958, Dettmann 1963, Van Konijnenburg-Van Cittert (1989). Filatoff (1975) regarded *Cibotiumspora* as a possible Cyatheacean/ Dicksoniacean.

[21] Spores of *Ischyosporites* type have been recovered from the Middle Jurassic Schizaceous ferns *Klukia* and *Stachypteris* (Couper 1958, Van Konijnenburg-Van Cittert 1981).

[22] Filatoff and Price (1988) give a discussion of the possible botanical affinities of the *Striatella-Contignisporites-Crassitudisporites* complex and conclude that a Pteridaceous relationship is likely. The presence of multiple proximal tangential muri are a feature characteristic of spores of the modern Pteridaceae (Tryon and Tryon 1982).

[23] *Vitreisporites* has been recovered from *Caytonanthus* (Couper 1958, Chaloner 1968).

[24] Pollen of *Alisporites* type has been obtained from parent plants of a variety of affinities including the Corystospermaceae (Stewart 1983, Traverse 1988), other pteridosperms (Townrow 1962) and conifers (Townrow 1962, Delevoryas & Hope 1973 and Srivastava 1984).

[25] *Chasmatosporites* was identified from the Cycad cone *Androstrobus prisma* by Van Konijnenburg-Van Cittert (1971).

[26] Couper (1958) reported *Cycadopites* like pollen from *Androstrobus* (a Jurassic cycadalean), from Rhaetian to Lower Cretaceous ginkgoaleans and Jurassic cycadeoids. Dev (1980) also obtained *Cycadopites* type pollen from *Sahnia* (a Jurassic pentoxylacean). Van Konijnenburg-Van Cittert (1971) recovered *Cycadopites* pollen grains from the Bennittitalean *Williamsoniella* and *Weltrichia*.

continued...

[27] Van Konijnenburg-Van Cittert (1971) recovered *Eucommiidites troedssonii* from *Hastystrobus murii*, a cone of presumed Cycadalean affinity.

[28] Illustrations in Van Konijnenburg-Van Cittert (1971) of *Leptostrobus cancer* pollen grains can be identified as *Callialasporites microvelatus* (al.*Tsugaepollenites lucidus* in the present study). The cone was considered of doubtful Ginkgoalean affinity.

[29] Van Konijnenburg-Van Cittert (1971) identified *Alisporites* from the fertile parts of *Pteroma thomasii.*

[30] *Podocarpidites* is considered to be of podocarpaceous affinity (eg. Filatoff 1975, Dettmann 1986).

[31] Forms assignable to.the dispersed taxa *Araucariacites* and *Callialasporites* have been isolated from modern *Araucaria* cones (Courtinat 1987). In addition Couper (1958) and Archangelsky and Gamerro (1967) have obtained *Araucariacites* (and *Inaperturopollenites*) type pollen from the fossil conifer Brachyphyllum (from Jurassic and Lower Cretaceous strata respectively). On the other hand forms similar to *Callialasporites* have been recorded from Lower Cretaceous podocarps (eg. Gamerro 1965, Townrow 1962).

[32] Couper (1958) and Harris (1973) have identified *Perinopollenites* type pollen from cone preparations of *Elatides*, a Jurassic Taxodiaceous conifer. Filatoff (1975) considered the genera *Exesipollenites*, *Spheripollenites*, *Cupressacites* and *Perinopollenites* similar to pollen produced by the Cupressaceae, Taxaceae and Taxodiaceae.

[33] Filatoff (1975) compared the genera *Exesipollenites* and *Spheripollenites* (herein considered synonymous with *Exesipollenites*) to pollen produced by the Cupressaceae, Taxaceae and Taxodiaceae.

[34] *Corollina* type pollen appears to be primarily associated with Cheirolepidacean pollen (Francis 1983, 1984).

[35] Couper (1958) considered *Cerebropollenites* to be of coniferous origin, possibly from plants with affinities to extant *Tsuga* . Hughes (in Tschudy and Scott 1965) also regarded *Cerebropollenites* as a form of proto-Tsuga pollen. Van Konnijnenburg-Van

continued...

Cittert and Van Der Burgh (1989), however, recovered *Cerebropollenites* type pollen from *Masculostrobus* sp. from Upper Jurassic strata of Scotland. The affinities of *Masculostrobus* are unknown, but the authors suggest a possible Taxodiacean relationship.

Appendix 2.2. Catalogue of species documented in Harris (1961, 1964, 1969, 1979) and Harris *et al.* (1974) (V1, V2, V3, V4 and V5 respectively in the text) with suggestions for morphogeneric assignations of spores and pollen grains where possible.

Pteridophyta

Equisetales

Equisetum columnare Brogniart (Saltwick Fm), no spore remains.

Equisetum laterale Phillips (Saltwick and Cloughton Fms), no spore remains.

Equisetum beani (Bunbury) Harris (locally common in the Scalby Fm, found also in the Saltwick and Cloughton Fms), no spore remains.

Equisetum sp. A, no spore remains.

Neocalamites nathorsti Erdtman (Saltwick Fm), no spore remains.

Neocalamites hoerensis (Schimper) Halle (Saltwick and Cloughton Fms), no spore remains.

Schizoneura stenophylla Harris (Saltwick Fm), no spore remains.

Annulariopsis simpsoni (Phillips) Harris (Saltwick Fm), no spore remains.

Calamites(?) *rotifer* Harris (Saltwick Fm), no spore remains.

Lycopodiales

Lycopodites falcatus Lindley & Hutton (Saltwick and Cloughton Fms), "Spores of one kind are particularly numerous round two of the cones and some are figured sticking to the sporangia walls but they are very likely fern spores"(V1 p. 42).

Filicales

Marattiaceae

Marattia anglica (Thomas) Harris (Saltwick Fm), "Spores oval, mean size 30μx24μ (range noted 37μ-26μ long and 33μ-19μ broad), wall fairly thin, faintly tuberculate, showing one groove"(V1 p. 73); spores comparable with *Marattisporites scabratus* .

Osmundaceae

Todites thomasi Harris (Gristhorpe Mbr, Cloughton Fm), "Spores round, with rather thin, finely granular walls, mean diameter about 44μ (range noted 40μ-50μ)."(V1 p.77); spores comparable with *Osmundacidites wellmanii* .

Todites denticulatus (Brogniart) Krasser (all Fms), "Spores round, mean diameter about 37μ (range noted 25μ-48μ) with a thin, minutely punctate (almost smooth) wall. Triradiate cracks fine, nearly as long as the spore radius, without thickened margins"(V1 p. 82); spores comparable with *Puctatisporites minor* .

Todites williamsoni (Brogniart) Seward (all Fms), "Spores rounded, mean diameter 55μ, range noted 45μ-75μ; wall fairly thick and almost perfectly smooth. Triradiate crack nearly as long as spore radius, margins unspecialised. Number of spores per sporangium about 100."(V1 p. 90); spores comparable with *Puctatisporites major* .

Todites princeps (Presl) Gothan (all Fms), "Spores round, about 32µ wide (20µ-40µ) with a thin smooth wall. Triradiate cracks finely marked, rather shorter than the spore radius"(V1 p. 96); spores comparable with *Puctatisporites minor* .

Osmundopsis sturi (Raciborski) Harris (Gristhorpe Mbr, Cloughton Fm), "Spores numerous, round, about 40µ wide, with tuberculate walls and well-marked triradiate cracks; margins of cracks scarcely thickened"(V1 p. 99); spores comparable with *Verrucosisporites varians* .

Matoniaceae

Phlebopteris polypodioides Brogniart (Cloughton Fm), "Spores rounded-tetrahedral, 34µ wide, walls smooth, not very thick, triradiate cracks about 75 per cent of the spore radius, with conspicuously thickened borders."(V1 p.104); spores comparable with *Concavisporites toralis.*

Phlebopteris woodwardi Leckenby (all Fms), no spores recovered.

Phlebopteris dunkeri (Schenk) Schenk (Saltwick Fm), "Spores rounded tetrahedral, size unknown" (p.110).

Selenocarpus muensterianus (Prestl) Schenk (Saltwick Fm), "Spores numerous, rounded triangular about 34µ-47µ wide; wall fairly thick, smooth; triradiate scar well developed probably with a conspicuous margin."(V1 p. 112); spores assignable to the genus *Biretisporites.*

Matonidium goepperti (Ettingshausen)Schenk (Saltwick and Cloughton Fms), "Spores 44µ wide, rounded-tetrahedral, with rather thick, smooth walls; triradiate cracks up to about three-quarters of the spore radius with broad and strongly thickened borders"(V1 p.115); spores comparable with *Concavisporites toralis.*

Dipteridaceae

Dictyophyllum rugosum Lindley & Hutton (Saltwick and Cloughton Fms) "Spores tetrahedral, walls fairly thick, smooth; when vertically compressed, sides usually concave or flat. Triradiate scars well marked, bordered by strongly thickened cuticle; mean diameter about 40µ"(V1 p.119); spores comparable with *Dictyophyllidites harrisi*

Clathropteris obovata Oishi (Saltwick Fm), spores not recovered.

Hausmannia dichotoma Dunker (Saltwick Fm), spores not recovered.

Schizeaceae

Kluki exilis (Philips) Raciborski (Saltwick and Cloughton Fms), "Spores...typically 60µ wide (extremes 35µ and 80µ). Dorsal surface rounded, ventral with long triradiate cracks and flat facets. Margins of triradiate cracks often raised, no arcuate ridges present. Dorsal surface very thickly cutinised, marked with deep pits, walls separating three pits often raised to form a rounded lump; walls separating two pits often broken by a low channel connecting the pits. Facets less thickly cutinised, surface bearing many small warts, separate or united in groups."(V1 p.129-130); spores comparable with the genus *Ischyosporites* .

Stachypteris spicans Pomel (Saltwick Fm), "Spores 40µ-80µ wide (typically about 50µ). Dorsal side very thick walled, rounded, ventral thinner, flattened, with three flat facets. Dorsal side marked with deep pits separated by ridges which anastomose irregularly, neighbouring pits often connected by a narrow channel. Facets bearing small tubercles. Triradiate ridges about 80 per cent of the spore radius, rather prominent"(V1 p. 137); spores comparable with the genus *Ischyosporites* .

Dicksoniaceae

Coniopteris simplex (Lin. & Hutt.)Harris (Saltwick and Cloughton Fms), "Spores rounded triangular, cuticle fairly thin, smooth; mean diameter 53µ (range noted 37µ-60µ). Triradiate marks clear but not prominent, bordered by a slightly thickened margin."(V1 p. 144); spores assignable to the genus *Deltoidospora* .

Coniopteris burejensis (Zalessky) Seward (Saltwick Fm), "Spore rounded triangular, about 40µ wide, walls moderately thick, almost smooth (or very finely granular). Triradiate crack with an ill-defined but slightly thickened margin."(V1 p. 147); spores comparable with the genus *Deltoidospora* .

Coniopteris bella Harris (all Fms), "Spores rounded triangular, mean size about 40µ (range noted 32µ-50µ), walls moderately thick, nearly smooth. Triradiate crack well-marked, margin slightly thickened but ill-defined"(V1 p.151); spores comparable with the genus *Deltoidospora* .

Coniopteris hymenophylloides (Brogniart) Seward (all Fms), "Spores rounded-triangular with moderately thick, very slightly mottled (almost smooth) walls. Mean width 40µ, range noted in one sporangium 32µ-55µ. Triradiate cracks with a slight, ill-defined border. Side of spores most often slightly concave, occasionally flat or slightly convex."(V1 p. 154); spores can be accomodated in the genus *Deltoidospora* .

Coniopteris murrayana (Brogniart) Brogniart (Saltwick and Cloughton Fms), "Spores rounded-tetrahedral, mean diameter 45µ; walls of medium thickness, slightly mottled or almost perfectly smooth. Margins of triradiate crack only slightly thickened, margo undeveloped."(V1 p.160); spores comparable with the genus *Deltoidospora* .

Coniopteris margaretae Harris (Cloughton Fm), "Spores very large, rounded-tetrahedral; mean diameter 74μ(smallest and largest noted...65μ and 88μ); wall thick, smooth. Triradiate crack with a distinctly thickened margo; triradiate crest sometimes rather prominent and projecting as a delicate ridge 2μ high"(V1 p. 164); spores comparable with the genus *Biretisporites* .

Kylikipteris arguta Harris (Saltwick and Cloughton Fms), "Spores rounded; mean diameter about 44μ; walls moderately thick, almost smooth. Margo scarcely thickened"(V1 p.168); spores referred to the genus *Deltoidospora* .

Eboracia lobifolia (Phillips)Thomas (all Fms), "Spores rounded tetrahedral, sometimes with hollow sides, mean diameter 32μ. Triradiate crack long, with a strongly marked, thick border. Spore wall rather thick, smooth."(V1 p.174); spores comparable with the genus *Biretisporites* .

Dicksonia mariopteris Wilson & Yates (Saltwick and Cloughton Fms), "Spores rounded triangular to triangular, mean width 39μ, range noted 24μ-56μ. Triradiate cracks rather long with a slightly thickened margo. Wall fairly thick, smooth."(V1 p. 178); spores comparable with the genus *Deltoidospora.*

Dicksonia kendalli Harris (Saltwick Fm), "Spores rounded-triangular (sides more often convex than concave), mean diameter 67μ, range noted 58μ-78μ. Triradiate crest rather prominent, margo broad but very ill-marked. Spore wall not very thick, almost smooth."(V1 p.181); spores assignable to the genus *Deltoidospora* .

Aspideae?

Aspidites thomasi Harris (Cloughton Fm), "Spores triangular, mean diameter 35μ (widest and narrowest observed 45μ and 29μ); triradiate crack rather long, often slightly sinuous, border thickened. Spore wall rather thick, smooth."(V1 p. 184); spores comparable with the genus *Deltoidospora* .

Unclassified filicales

Cladophlebis haiburnensis (L. &H.) Brogniart (Saltwick Fm), no spores recovered.

Cladophlebis aktashensis Turutanova-Ketova (Saltwick Fm), no spores recovered.

Sphenopteris metzgerioides Harris (?Cloughton Fm), no spores recovered.

Caytoniales

Sagenopteris spp. (leaf fossil only).

Caytonanthus arberi (Thomas) Harris (Gristhorpe Member, Cloughton Fm), "Pollen grains typically 22µ from wing to wing (extremes 18-28µ), central cell about 15µ long; wings seldom bulging but often slightly constricted; mean width of wing 13.5µ (extremes 9-18µ), surface of wings pitted, but pitting not very conspicuous"(V2 p. 15); pollen grains comparable with *Vitreisporites pallidus* .

Caytonanthus oncodes (Thomas) Harris (Gristhorpe Member, Cloughton Fm), "Pollen grains typically 31µ from wing to wing (extremes 25-35µ), central cell about 17µ from end to end, wings bulging slightly, seldom contracted, mean width 16.5µ (extremes 10-22µ). Surface of wings clearly and regularly pitted." (V2 p.17); pollen grains comparable with *Vitreisporites pallidus* .

Caytonia spp. (fossilised fruiting bodies only).

Amphorispermum pullum Harris (seed fossil only).

Cycadales and Pteridospermales

Nilssonia spp. (fossilised leaf fragments only).

Deltolepis spp. (fossilised scale leaves).

Paracycas cteis (Harris) Harris (fossilised leaf fragments only).

Pseudoctenis spp. (fossilised leaf fragments only).

Ctenozamites spp. (fossilised leaf fragments only).

Ctenis spp. (fossilised leaf fragments only).

Pachypteris spp. (fossilised leaf fragments only).

Stenopteris spp. (fossilised leaf fragments only).

Unnamed Pteridosperms or Cycads

Androstrobus manis Harris (Gristhorpe Member, Cloughton Fm), "Pollen grains monosulcate, oval, typically 36x26µ (extremes of length 40µ and 26µ); wall almost perfectly smooth but appearing faintly and very finely mottled."(V2 p.157); pollen grains comparable with *Cycadopites minimus* .

Androstrobus wonnacotti Harris (Saltwick and Cloughton Fms), "Pollen grains monosulcate, oval, typically 29x21µ, occasionally rather smaller. Wall smooth, or very obscurely mottled."(V2 p. 159); pollen grains comparable with *Cycadopites minimus* .

Androstrobus prisma Thomas & Harris (Saltwick Fm), "Pollen grains very uniform, round; about 35µ wide, surface minutely granular with granules 1µ apart. Walls 1µ thick, but sometimes showing an ill-defined thinner area on one side. Grain probably originally almost spherical."(V2 p.161); pollen grains comparable with the genus *Chasmatosporites* .

Appendix 2.2

Androsrobus sp. A. (Hasty Bank and Rosemary Topping), "Pollen grains monosulcate, oval, smooth, about 30x24µ."(V2 p.163); pollen grains comparable with *Cycadopites minimus* .

Beania gracilis Carruthers (Cloughton Fm), "Pollen was found in certain ovules of 10mm. or more and in one of these the pollen had penetrated deeply into the nucellus and had there burst widely."(V2 p. 166); pollen grains presumed to be of *Cycadopites* type.

Beania mamayi Thomas and Harris (Cloughton Fm), no spores recovered.

Pteridosperm-like reproductive organ

Pteroma thomasi Harris (Hasty Bank), "Pollen grains averaging 88µ wide and 55µ high.(In the sample of 22 measured, extremes were width 107µ and 53µ, height 61µ and 46µ.). Sacci marked with minute pits, pits often rather distant, size ranging from less than 1µ to 2µ. Boundary between sacci and corpus obscurely marked"(V2 p.171); pollen grains comparable with the genus *Alisporites* .

Bennettitales

Zamites spp. (fossilised leaf fragments only).

Otozamites spp. (fossilised leaf fragments only).

Ptilophyllum spp. (fossilised leaf fragments only).

Nilssoniopteris spp. (fossilised leaf fragments only).

Anomozamites spp. (fossilised leaf fragments only).

Dictyozamites spp. (fossilised leaf fragments only).

Pterophyllum spp. (fossilised leaf fragments only).

Cycadolepis spp. (fossilised scale leaves only).

Williamsonia spp. (fossilised female flowers only).

Williamsonia himas Harris (Saltwick Fm), "Associated pollen grains oval, averaging 50µx30µ, monosulcate, often split logitudinally, wall fairly thick, almost smooth." (V3 p.141); pollen grains comparable with the genus *Cycadopites* .

Williamsoniella coronata Thomas (Saltwick & Cloughton Fms), "The pollen grains are 30µx20µ and have fairly thin, smooth walls" (V3 p.144); pollen grains comparable with the genus *Cycadopites* .

Williamsoniella papillosa Cridland (Saltwick and Cloughton Fms), "The grains are oval, with thin smooth walls and typically 27µ long." (V3 p.148); pollen grains comparable with the genus *Cycadopites* .

Bennetticarpus spp. (fossilised gynoecia).

Weltrichia setosa (Nathorst) Harris (Saltwick Fm), "Pollen grains oval, 37µx20µ, with a thin, finely granular wall"(V3 p. 161); pollen grains comparable with the genus *Cycadopites* .

Weltrichia sol Harris (Saltwick Fm), "Pollen grains oval with a longitudinal sulcus; length of grain 44-50µ, width 20-30µ (means 46µ long and 24µ wide); wall smooth"(V3 p.165); pollen grains comparable with the genus *Cycadopites* .

Weltrichia spectabilis (Nathorst) Harris (Saltwick Fm), "Pollen grains oval, monocolpate, about 60µx36µ, walls thin, smooth. (Grains often split and appearing narrow.)"(V3 p. 167); pollen grains comparable with the genus *Cycadopites* .

Weltrichia pecten (Leckenby) Harris (Saltwick and Cloughton Fms), "The present ones had shed their pollen"(V3 p. 169); pollen grains presumed to be of *Cycadopites* type as suggested on p.170.

Weltrichia whitbiensis (Nathorst) Harris (Saltwick Fm), no pollen grains described.

Bucklandia spp. (fossilised stems).

Ginkgoales

Ginkgo spp. (fossilised leaf fragments).

Baiera spp. (fossilised leaf fragments).

Sphenobaiera spp. (fossilised leaf fragments).

Eretmophyllum spp. (fossilised leaf fragments).

Pseudotorellia spp. (fossilised leaf fragments).

Male cone attributed to *Ginkgo huttoni* (Sternb.) (Scalby Fm), "Pollen grains monocolpate, outline elongate-elliptical with acute ends; longest axis 35µ(extremes 29µ-42µ); colpus (in distal surface) extending about whole length of pollen grain, slit-like to broad; wall (exine) 1µ-1.5µ thick, consisting of two layers; nexine and sexine; nexine smooth, 0.5µ thick; sexine 0.5µ-1.0µ thick, not completely smooth, but structure rather vague."(V4 p.76); pollen grains comparable with the genus *Cycadopites* .

Czekanowskiales

Solenites spp. (fossilised leaf fragments).

Czekanowskia spp. (fossilised leaf fragments).

Sphenarion spp. (fossilised leaf fragments).

Leptostrobus cancer Harris (Saltwick and Cloughton Fms), pollen grains recovered on and in the seed capsules include forms comparable with *Araucariacites australis* and *Cerebropollenites mesozoicus* .

Ixostrobus whitbiensis Harris (Saltwick Fm), "Adherent pollen grains 35µ-40µ long, broadly oval, with broad and conspicuous colpus extending almost whole length. Wall of grain thin (nearly 1µ thick), consisting almost entirely of sexine, nexine (if recognised) merely smooth basal layer. Surface of sexine minutely verrucose, apparently composed of rounded capita united with one another and separating pits. Capita and pits each about 1μ wide." (V4 p. 131); pollen grains comparable with the genus *Cycadopites* .

Desniophyllum gramineum Harris (Saltwick Fm), (fossilised leaf fragments only).

Coniferales

Brachyphyllum mamillare Lindley & Hutton (all Fms), "Compressed pollen grains rounded, diameter typically about 70μ, extremes noted in about 100 grains 56-84μ, wall inaperturate. Exine 1-2μ thick, consisting of a nexine which may be separated by shrinkage of the sexine; nexine smooth, up to 1μ thick, sexine about 1μ thick and finely marked with granules about 1μ wide."(V5 p. 8); pollen grains comparable with *Araucariacites australis* and *Callialasporites* spp..

Brachyphyllum crucis Kendall (all Fms) description quoted from Van Konijnenburg-Van Cittert (1971,1972), " Pollen grains spherical with somewhat flattened poles, equatorial diameter 35μ (extremes 30-40μ); exine divided into two caps by an indistinct equatorial belt, 5μ wide; exine of the caps 1-2μ thick, baculate, striae of the equatorial belt not very distinct, usually 8 striae, sometimes upto 12; distal cap separated from the equatorial belt by a distinct thin region (rimula) 1-2μ wide; distal pole with a circular thin area about 9μ in diameter, proximal pole with a triangular thin area extending over the largest part of the pollen grain (in polar view)" (V5 p. 20); pollen grains comparable with *Corollina* .

Brachyphyllum ardenicum Harris (Saltwick and Cloughton Fms), (fossilised shoots only).

Pagiophyllum kurri (Schimper) Harris, male cone (of Kendall), "The pollen sacs have shed their pollen though one preparation believed to be a pollen sac tapetum shows many similar-looking round pollen grains. Kendall noted their size and thick walls but no other features. Couper (1958) however, who re-examined the preparations, was able to recognise the characteristic features of *Classopollis* (al. *Corollina*) and I concur, though the preservation is poor"(V5 p. 36).

Pagiophyllum ordinatum Kendall (fossilised leaf compressions).

Pagiophyllum maculosum Kendall (fossilised leaf compressions).

Hirmerella kendalliae Harris (Cloughton Fm) (Female cone with associated pollen grains), "Pollen grains of *Classopollis* adhere to this (megaspore) membrane."

Pagiophyllum fragilis (Bose) Harris (fossilised leaf compressions).

Geinitzia rigida (Phillips) Harris (fossilised leaf compressions).

Geinitzia divaricata (Bunbury) Harris (fossilised leaf compressions).

Elatides williamsonii (Lindley & Hutton) Nathorst (male cone and pollen), "Pollen grains round, not remaining in tetrads. Diameter about 45-50μ (grains smaller than 45μ presumed to be immature). Exine double, sexine separated fron nexine by a gap of 5μ. Sexine very delicate, finely granular (often torn and missing or found separately; usually absent from small pollen grains). Nexine about 1μ thick, almost smooth. Pore possibly on a slight elevation and appearing as a ring when compressed vertically (but not often seen).(Walls especially sexine, forming small irregular folds in compression.)" (V5 p. 69-70); pollen grains comparable with *Perinopollenites elatoides*.

Elatides thomasii Harris (all Fms), "Pollen sacs 0.8mm x 0.4mm, containing rounded pollen grains 45-55μ wide, pollen probably with delicate sexine around the nexine." (V5 p. 75); no comparison attempted

Cyparissidium rudlandicum Harris (fossilised leaf compressions).

Cyparissidium blackii (Harris) Harris with *Pityanthus scalbiensis* van Konijnenburg-van Cittert and *Scarburgia hillii* Harris (Scalby Fm), "Pollen grains disaccate, sacci offset distally. In equatorial or lateral longitudinal view, corpus rounded and distinctly broader than high (but if contracted to form a sulcus height appearing reduced and sacci drawn together). Sacci nearly semicircular. Proximal surface of corpus thickened to form a cappus but thinning gradually towards equator and then thinning sharply to join distal surface (a fold commonly present near junction of two parts). In polar view and in end or lateral transverse view of grain, corpus thickness (depth) nearly same as its height, but saccus length much increased and sacci showing angular roots, inner margins of sacci bounding the corpus. Wall of corpus just over 1μ thick in cappus, composed of thin sexine, then short columellae and at outside rounded capita 1μ wide which make the outer surface rough and form a reticulum enclosing the lumina 1μ wide. Wall of distal part much thinner and only faintly granular, no definite aperture apparent. Wall of saccus just over 1μ thick, reticulate, muri formed by rows of granules 1μ wide enclosing lumina upto 2μ wide, but at root of saccus meshes wider and considerably elongated"(V5 p. 83-85); no comparison attempted.

Scarburgia hillii Harris (seed-bearing cone) (Scalby Fm), "Both (pollen) grains agree in their fine details with *Pityanthus scalbiensis* pollen and similarly distorted dispersed grains are frequent in the Upper Deltaic black shales"; no comparison attempted.

Pityocladus scarburgensis Harris (fossilised stems).

Appendix 2.2

Schizolepis liasokeuperianus C.F.W. Braun (detached cone scales).

Marskea jurassica (Florin) Harris (Saltwick Fm), "Pollen grains 20µ wide, showing thin area up to 8µ wide. Wall thin, in surface view showing minute granules and gaps, in optical section showing probable columellae. Plaques 2µ wide frequent on tapetal membrane."(V5 p. 107-109); pollen grains comparable with the genus *Exesipollenites* .

Torreya spp. (Small fossilised shoots).

Elatocladus spp. (fossilised lateral branch system).

Poteridion spp. (fossilised ovuliferous dwarf shoot).

Bilsdalea spp. (fossilised ultimate shoots).

Trulla spp. (fossilised female cones).

Lindleyocladus spp. (fossilised ultimate shoots).

Carpolithes spp. (fossilised seed).

Appendix 2.3

List of species recorded from the Cleveland Basin in the palaeobotanical work of Van Konijnenburg-Van Cittert.

Van Konijnenburg-Van Cittert (1971)

	Macroplant species	Equivalent dispersed species
Caytoniales		
	Caytonanthus arberi	*Vitreisporites pallidus*
	Caytonanthus oncodes	*Vitreisporites pallidus*
	Caytonanthus sp. A	*Vitreisporites pallidus*
Lyginopteridales		
	Pteroma thomasii	*Alisporites* sp. B Muir (MS)
Cycadales		
Nilssonia-type		
	Androstrobus manis	*Monosulcites minimus*
	Androstrobus wonnacotti	''
	Androstrobus szei	''
	Androstrobus major	''
	Androstrobus sp. A Harris 1964	''
Pseudoctenis-Ctenis Group		
	Androstrobus prisma	*Chasmatosporites apertus*
Probable *Cycadales*		
	Hastystrobus muirii	*Eucommiidites troedssonii*
Bennittitales		
Williamsoniella-type		
	Williamsoniella spp	*Monosulcites minimus*
Weltrichia-type		
	Weltrichia spp	*Monosulcites carpentieri, M. subgranulosus*
Ginkgoales		
	Ginkgo huttoni	*Monosulcites minimus*
Doubtful *Ginkgoales*		
	Leptostrobus cancer	*Tsugaepollenites lucidus* (*al. Callialasporites microvelatus* in the present study)
Coniferospermae		
Araucariaceae		
	Brachyphyllum mamillare	*Araucariacites australis* and *Callialasporites dampieri*, *C. segmentatus* (*C. minus* in this work), *C. trilobatus*;the present author would also like to suggest *C. turbatus* on the basis of pl. XI, fig. 6.

Appendix 2.3

Taxodiaceae	
Elatides williamsoni	*Perinopollenites elatoides*
Hirmerella-group	
Brachyphyllum crucis	*Circulina* sp., after prolonged maceration, *Classopollis multistriatus* (*al. C. torosus*).
Coniferospermae incertae sedis	
Masculostrobis harrisii	*Inaperturopollenites* sp.
Pityanthus scalbiensis	Indeterminate bisaccate grains.

van Konijnenburg-van Cittert 1981

Filicales	
Schizaeaceae	
Klukia exilis	*Ischyosporites variegatus*
Stachypteris hallei	''

van Konijnenburg-van Cittert 1989

Filicales	
Dicksoniaceae	
Coniopteris simplex	*Cyathidites (Deltoidospora) minor*
Coniopteris margaretae	*Cyathidites (Deltoidospora) australis*
Coniopteris concinna	*Cyathidites (Deltoidospora) minor*
Coniopteris bella	''
Coniopteris hymenophylloides	''
Coniopteris murrayana	''
Kylikipteris arguata	''
Eboracia lobifolia	''
Dicksonia mariopteris	''
Dicksonia kendalliae	*Cyathidites (Deltoidospora) australis*

Plate 1

Figure 1. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.1, grid ref. 137.2 13.7, X860.

Figure 2. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.1, grid ref. 137.2 13.7, phase contrast, X860.

Figure 3. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.1, grid ref. 158.3 6.3, X860.

Figure 4. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.1, grid ref. 137.7 14.0, X860.

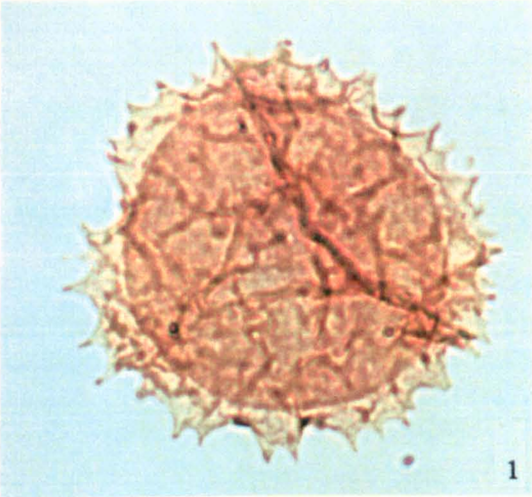
Figure 5. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.5, grid ref. 151 6.7, X860.

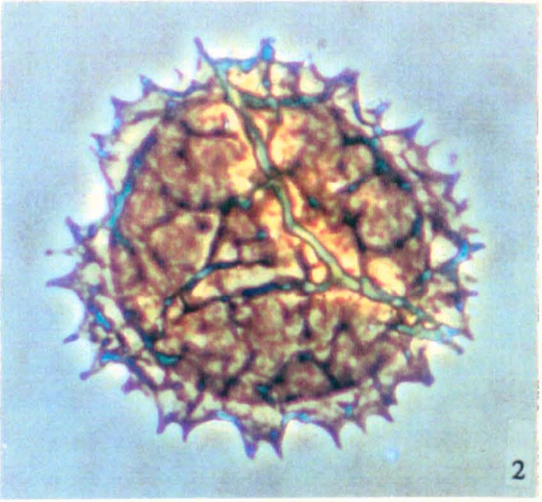
Figure 6. *Kraeuselisporites whitfordensis* Backhouse 1988, slide 89302.1, grid ref. 160 10.1, X860.

Figure 7. *Varivaginaspora spinoreticulata* n. Gen. and sp., slide 89302.1, grid ref. 157.7 14.0, holotype, X860.

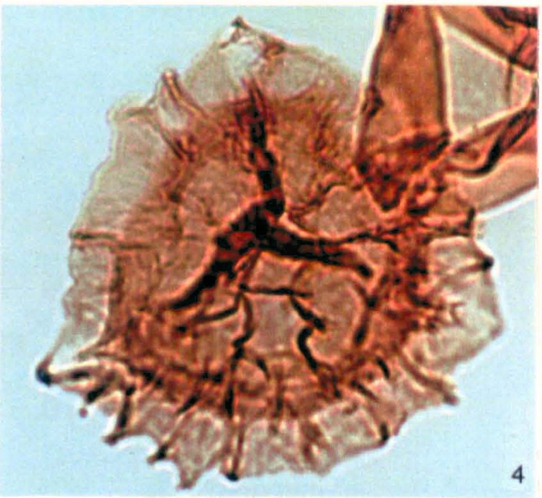
Figure 8. *Varivaginaspora spinoreticulata* n. Gen. and sp., slide 89302.1, grid ref. 135.8 7.8, paratype, X860.

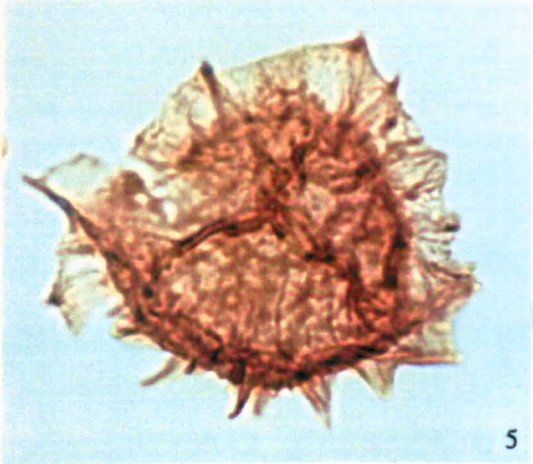
Plate 1


1


2


3


4


5


6


7


8

Plate 2

Figure 1. *Kraeuselisporites whitfordensis* n. sp., slide 89302.1, grid ref. 133.5 3.4, tetrad, X860.

Figure 2. *Pararetispora jurassica* n. Gen. and sp., slide 89026.1, grid ref. 129.8 10.8, holotype, X500.

Figure 3. *Varivaginaspora reticulata* n. Gen and sp., slide 89026.1, grid ref. 149.5 6.9, holotype, X500.

Figure 4. *Varivaginaspora reticulata* n. Gen and sp., slide 89026.1, grid ref. 142.2 16.0, paratype, X500.

Figure 5. *Varivaginaspora reticulata* n. Gen and sp., slide 89026.1, grid ref. 145.3 7.8, paratype, X500.

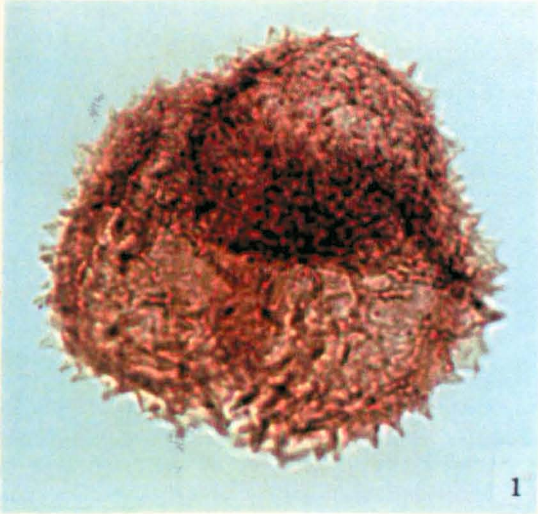
Figure 6. *Kraeuselisporites scalbiensis* n. sp., slide 89302.1, grid ref. 141.9 11.8, holotype, proximal view, X860.

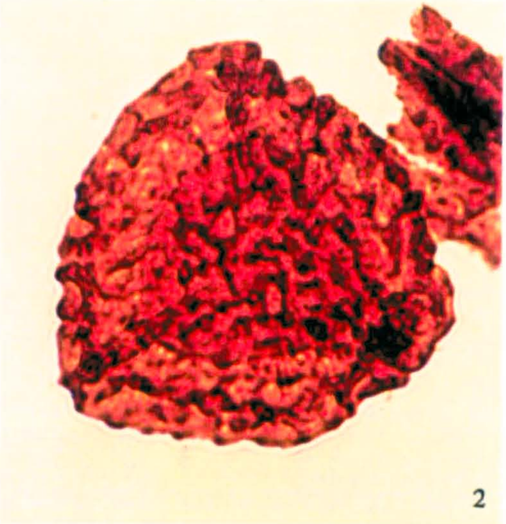
Figure 7. *Kraeuselisporites scalbiensis* n. sp., slide 89302.1, grid ref.141.9 11.8, holotype, distal view, X860.

Figure 8. *Paxillitriletes phyllicus* (Murray) Hall & Nicholson 1973, slide 89301.1, grid ref. 158.2 12.7, X250.

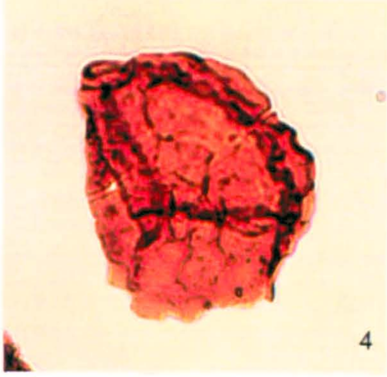
Figure 9. *Kraeuselisporites scalbiensis* n. sp., slide 89302.1, grid ref., 151.6 12.1, X860.

Plate 2

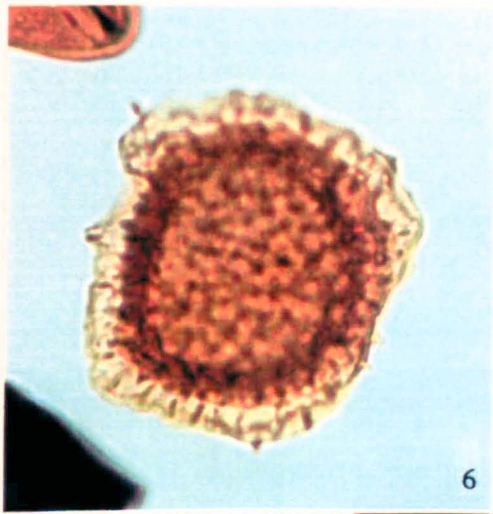

1

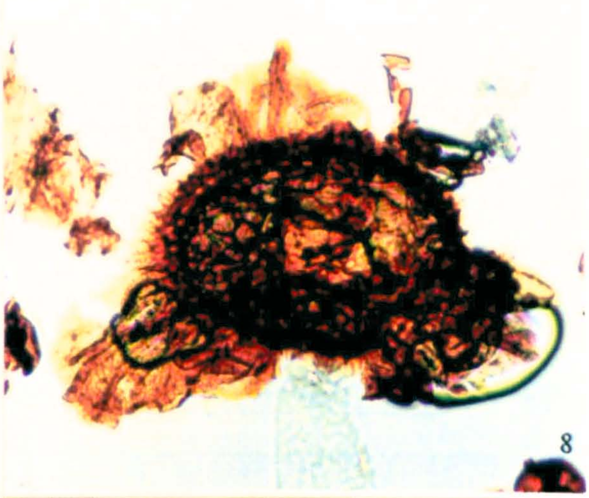

2


3


4


5


6


8


7

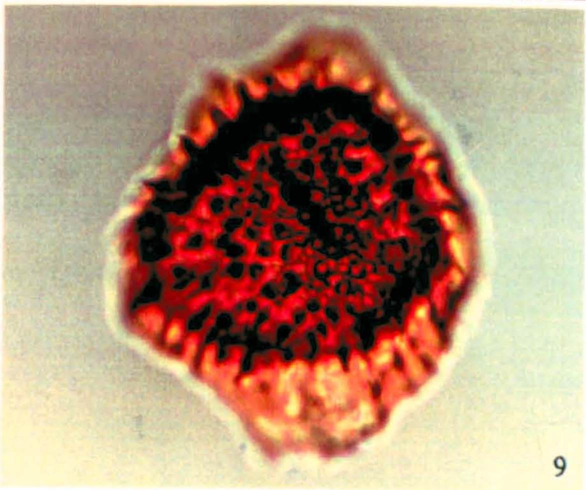

9

Plate 3

Figure 1. *Calamospora mesozoica* Couper 1958, slide 89015.1, grid ref. 148.3 19.3, X860.

Figure 2. *Deltoidospora minor* (Couper 1953) Pocock 1970, slide 89302.1, grid ref. 129.5 13.8, X860.

Figure 3 *Deltoidospora minor* (Couper 1953) Pocock 1970, slide 89305.1, grid ref. 133.5 19.0, exhibiting a well defined contact area, X860.

Figure 4. *Deltoidospora australis* (Couper 1953) Pocock 1970, slide 89302.1, grid ref. 155.5 3.2, X860.

Figure 5. *Cibotiumspora jurienensis* (Balme) Filatoff 1975, slide 89302.1, grid ref. 158.9 3.2, X860.

Figure 6. *Concavisporites toralis* (Leschik) Nilsson 1958, slide 89002.1, grid ref. 140.2 19.1, X500.

Figure 7. *Cibotiumspora* sp. SC1, slide 89305.1, grid ref. 145.3 22.6, proximal view, X860.

Figure 8. *Cibotiumspora* sp. SC1, slide89305.1, grid ref. 145.3 22.6, distal view, X860.

Figure 9. *Obtusisporis convexus* Pocock 1970, slide 89015.1, grid ref. 143 11.2, X860.

Figure 10. *Gleicheniidites senonicus* Ross 1949, slide 89305.1, grid ref. 157.2 22.0, X860.

Figure 11. *Waltzispora concava* (Bolkhovitina) n. comb., slide 89012.1, grid ref. 138.7 16.1, X860.

Figure 12. *Dictyophyllidites* sp. SD1, slide 89002.1, grid ref. 156.2 16.4, X500.

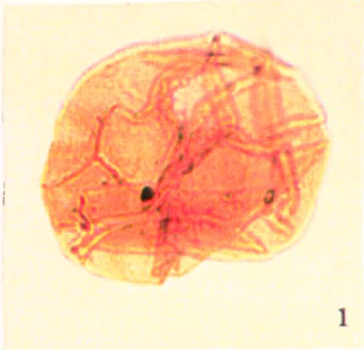
Figure 13. *Murospora florida* (Balme) Pocock 1961, slide 89301.1, grid ref. 150.8 23, X860.

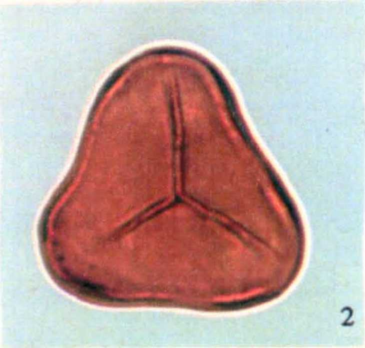
Figure 14. *Punctatisporites major* (Couper 1958) Kedves & Simoncsics 1964, slide 89009.5.1, grid ref. 143.1 16.9, X500

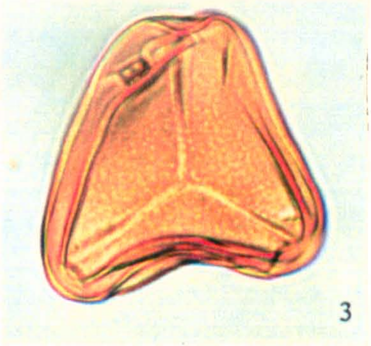
Figure 15. *Punctatisporites minor* (Couper 1958) Brenner 1986, slide 89302.1, grid ref. 139 2.8, X860.

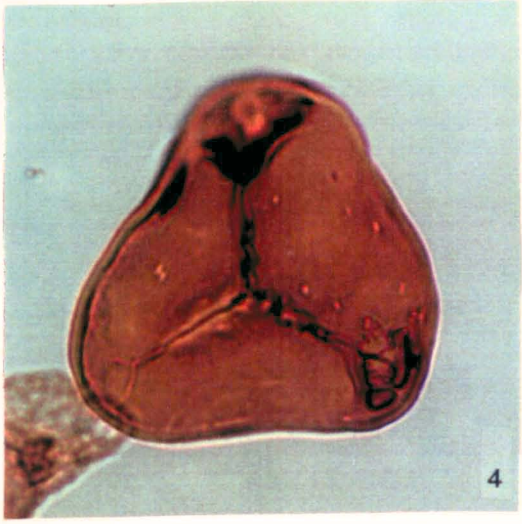
Figure 16. *Biretisporites potoniaei* (Delcourt & Sprumont) Delcourt, Dettmann & Hughes 1963, slide 89301.1, grid ref. 138 5.0, X860.

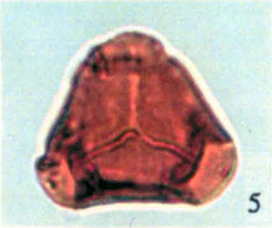
Plate 3

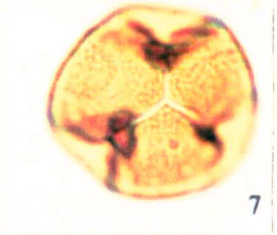

1

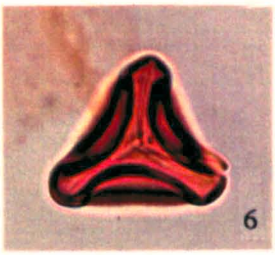

2


3


4

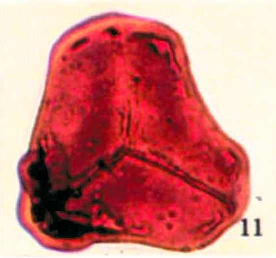

5

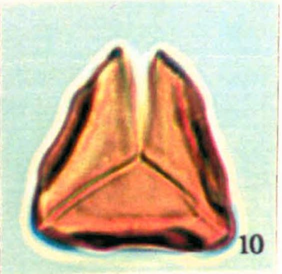

7


6

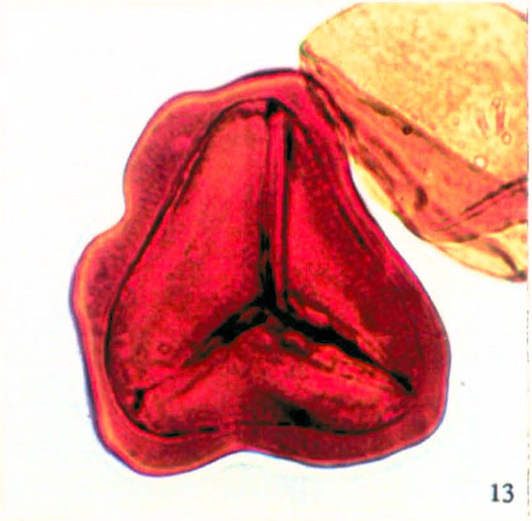

8

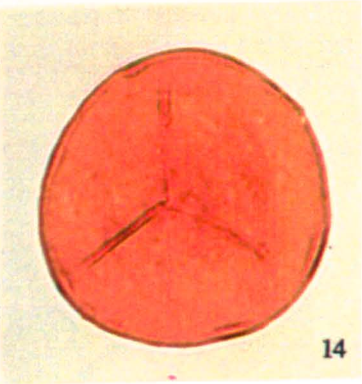

9

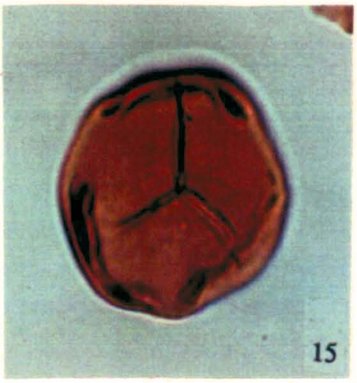

11


10


12


13


14


15


16

Plate 4.

Figure 1. *Dictyophyllidites equiexinus* (Couper 1958) Dettmann 1963, slide 89302.1, grid ref. 131.0 4.0, X860.

Figure 2. *Dictyophyllidites harrisii* Couper 1958 slide 89003.1, grid ref. 126.5 19.5, X860.

Figure 3. *Matonisporites phlebopteroides* Couper 1958, slide 89002.1, grid ref. 141.8 19.0, X500.

Figure 4. *Dictyophyllidites spectabilis* (Dettmann 1963) n. comb. and emend., slide BMGMCW2, grid ref. 133.6 3.2, X860.

Figure 5. *Dictyophyllidites spectabilis* (Dettmann 1963) n. comb. and emend., slide BMGMCW2, grid ref. 139 19.4, side view, X860.

Figure 6. *Dictyophyllidites spectabilis* (Dettmann 1963) n. comb. and emend., slide 89302.1, grid ref. 136.7 6.3, X860.

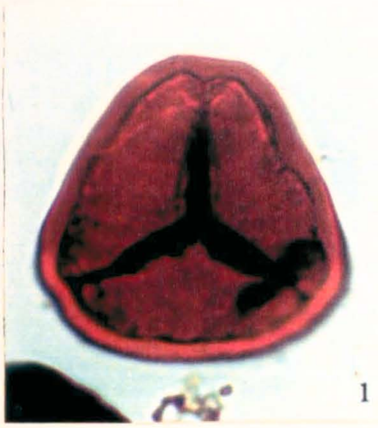
Figure 7. *Iraqispora speciosa* (Mädler) Lund 1977, slide 89301.1, grid ref. 145.6 9.8, X860.

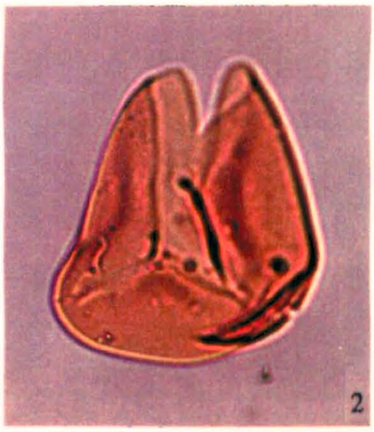
Figure 8. *Stereisporites psilatus* (Ross) Pflug *in* Thomson & Pflug 1953, slide 89301.1, grid ref. 155.5 3.2, X860.

Figure 9. *Foveosporites moretonensis* de Jersey 1964, slide 89007.1, grid ref. 152 4.2, X500.

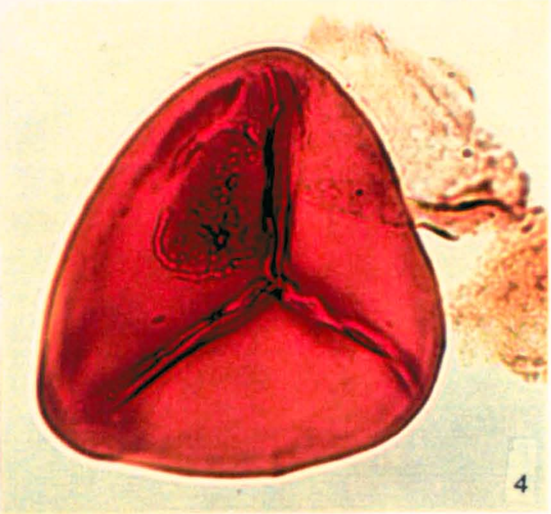
Figure 10. *Foveosporites* sp. SF1, slide 89213.2, grid ref. 140.3 13.6, X860.

Plate 4


1


2


3

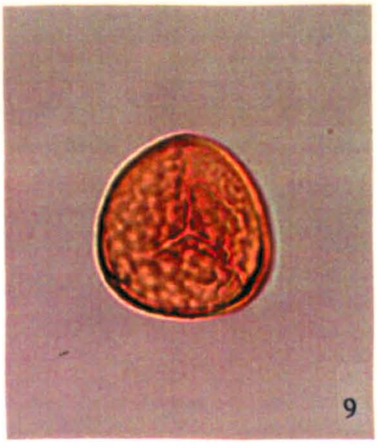

4


5


6


7


8


9

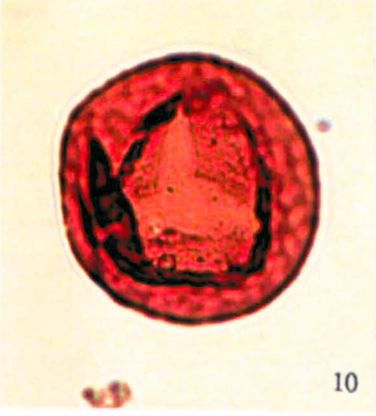

10

Plate 5.

Figure 1. *Stereisporites antiquasporites* (Wilson & Webster) Dettmann 1963, slide 89328.1, grid ref. 152.3 23, X860.

Figure 2. *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963, slide 89302.1, grid ref. 136.8 2, degraded specimen, X860.

Figure 3. *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963, slide 89027.1, grid ref. 144.1 22.5, X860.

Figure 4. *Sestrosporites pseudoalveolatus* (Couper) Dettmann 1963, slide 89302.1, grid ref. 132 13.2, X860.

Figure 5. *Densoisporites circumundulatus* (Brenner) Playford 1971, slide 89401.1, grid ref. 149.3 15.0, X860.

Figure 6. *Densoisporites velatus* Weyland & Krieger 1953, slide 89302.1, grid ref. 135.8 11.0, showing well developed outer wall layer, X860.

Figure 7. *Densoisporites velatus* Weyland & Krieger 1953, slide 89302.1, grid ref. 133.2 2.5, showing a poorly developed outer wall layer, X860.

Figure 8. *Densoisporites crassus* Tralau 1968, slide 89002.1, grid ref. 144.8 21.2 X500.

Figure 9. *Striatella balmei* Filatoff and Price 1988, slide 89008.1, grid ref. 155 1.9 X500.

Figure 10. *Striatella balmei* Filatoff and Price 1988, slide 89010.1, grid ref. 138.3 14.8 X500.

Figure 11. *Striatella scanica* (Nilsson) Filatoff and Price 1988, slide 89302.1, grid ref. 143.7 13.1, X860.

Figure 12. *Striatella patenii* Filatoff and Price 1988, slide 89008.1, grid ref. 136.8 3.2, X500.

Figure 13. *Striatella jurassica* Mädler 1964, slide 89302.1, grid ref. 145.2 12.5, X860.

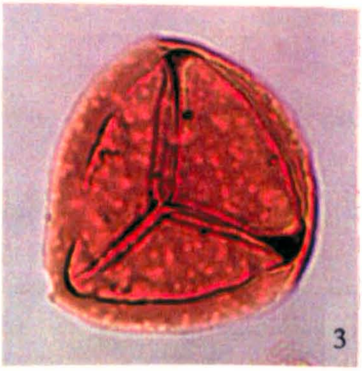
Figure 14. *Striatella seebergensis* Mädler 1964, slide 89302.1, grid ref. 129.6 10.3, X860.

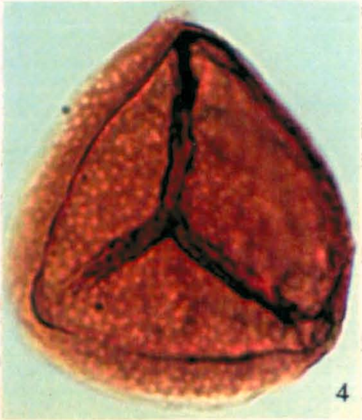
Figure 15. *Striatella* sp. SS2, slide 89306.1, grid ref. 144.610.0, X860.

Plate 5


1


2

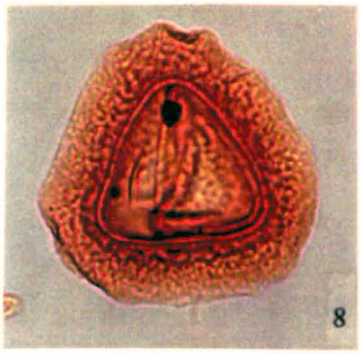

3


4

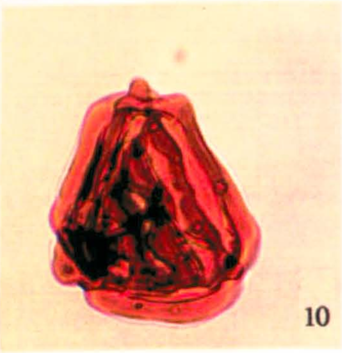

5

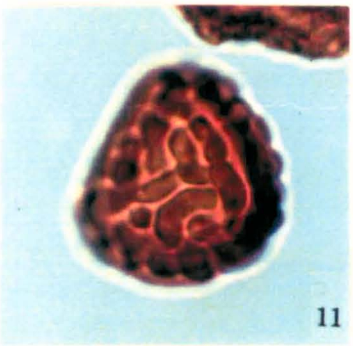

6


7


8


9


10


11


12


13


14

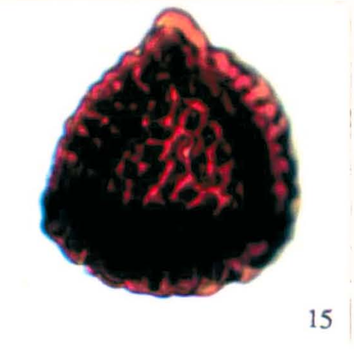

15

Plate 6.

Figure 1. *Striatella* sp. SS1, slide 89302.1, grid ref. 134 7.9, X860.

Figure 2. *Contignisporites cooksoniae* (Balme) Dettmann 1963, slide 89401.1, grid ref. 149.3 15.0, X860.

Figure 3. *Retitriletes annotinoides* (Tralau 1968) n. comb., slide 89014.1, grid ref. 152.6 8.4, X500.

Figure 4. *Retitriletes austroclavitidites* (Cookson) Potonié 1956, slide 89301.1, grid ref. 138.9 13.9, X860.

Figure 5. *Retitriletes clavatoides* (Couper) Döring et al. 1963, slide 89004.1, grid ref. 141.8 18.2, proximal view, X500.

Figure 6. *Retitriletes clavatoides* (Couper) Döring et al. 1963, slide 89004.1, grid ref. 141.8 18.2, distal view, X500.

Figure 7. *Retitriletes eminulus* (Dettmann) Srivastava 1977, slide 89002.1, grid ref. 158.8 17.9, proximal view, X500.

Figure 8. *Retitriletes eminulus* (Dettmann) Srivastava 1977, slide 89002.1, grid ref. 158.8 17.9, distal view, X500.

Figure 9. *Retitriletes semimuris* (Danzé-Corsin & Laveine 1963) McKellar 1974, slide 89305.1, grid ref. 147.3 16.2, X860.

Figure 10. *Retitriletes semimuris* (Danzé-Corsin & Laveine 1963) McKellar 1974, slide 89013.1, grid ref. 140.7 20.7, extreme specimen with a strongly interrupted distal sculpture, right distal view, X500.

Figure 11. *Retitriletes semimuris* (Danzé-Corsin & Laveine 1963) McKellar 1974, slide 89013.1, grid ref. 140.7 20.7, same specimen as Fig 10, left distal view X500.

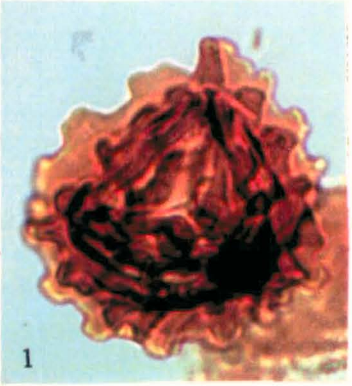
Figure 12. *Kekryphalospora distincta* Fenton & Riding 1988, slide 89013.1, grid ref. 142.1 16.5, oblique view showing the distal sculptural elements, X500.

Figure 13. *Kekryphalospora distincta* Fenton & Riding 1988, slide 89009.5.1, grid ref. 156.7 20.2, equatorial focus showing the mesh-like nature of the sculptural elements, X500.

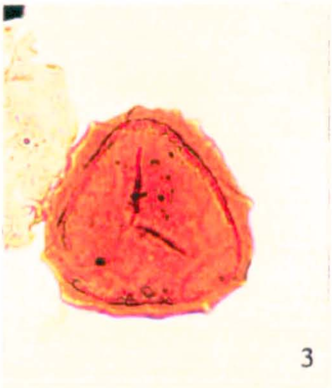
Figure 14. *Kekryphalospora distincta* Fenton & Riding 1988, slide 89009.5.1, grid ref. 156.7 20.2, same specimens as Fig 13, distal focus, X500.

Figure 15. *Ischyosporites variegatus* (Couper) Schulz 1967, slide 89009.5.1, grid ref. 156.4 7.2, X500.

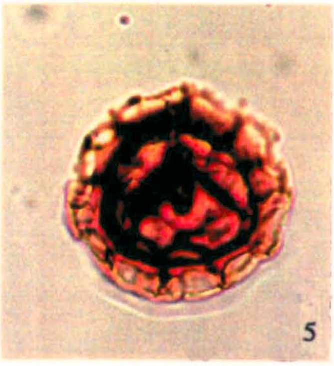
Plate 6

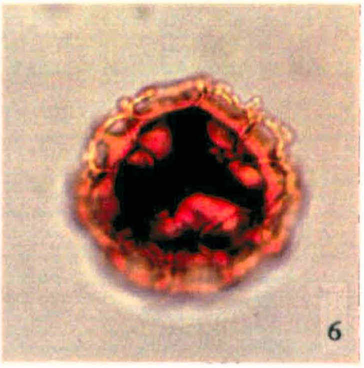

1

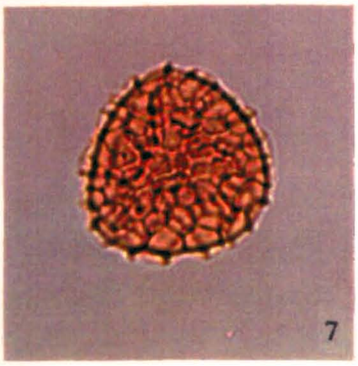

2

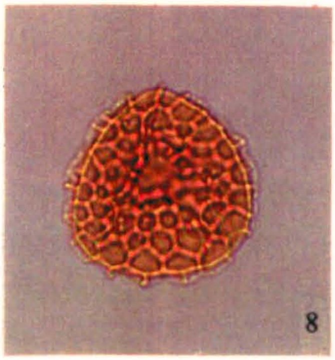

3

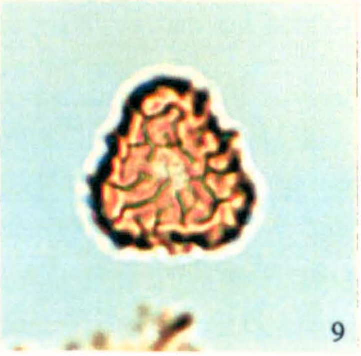

4


5

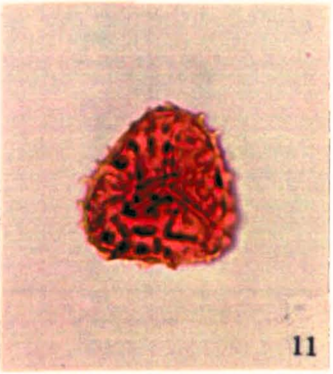

6


7

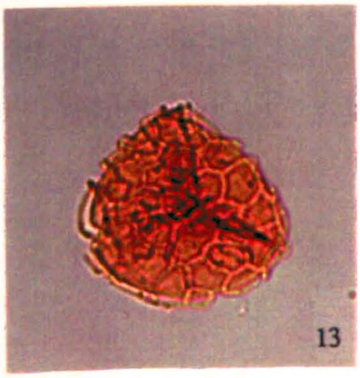

8

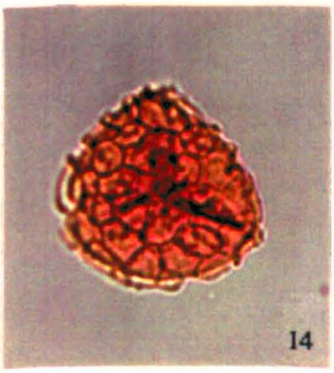

9


10


11


12


13


14


15

Plate 7.

Figure 1. *Ischyosporites variegatus* (Couper) Schulz 1967, slide 89009.5.1, grid ref. 156.7 20.2, X500.

Figure 2. *Trilobosporites antiquus* Reiser and Williams 1969, slide 89010.1, grid ref. 151.3 16.3, X500.

Figure 3. *Staplinisporites caminus* (Balme) Pocock 1962, slide 89302.1, grid ref. 142.9 8.1, X860.

Figure 4. *Staplinisporites telatus* (Balme) Döring 1965, slide 89002.1, grid ref. 132 14.1, showing well developed ornament and inter-radial crassitudes, X860.

Figure 5. *Staplinisporites telatus* (Balme) Döring 1965, slide 89305.1, grid ref. 148.2 17.2, X860.

Figure 6. *Staplinisporites telatus* (Balme) Döring 1965, slide 89002.1, grid ref. 132 14.1, extreme specimen close to *Lycopodiacidites rugulatus* but showing a poorly developed distal circular sculptural element, X860.

Figure 7. *Lycopodiacidites rugulatus* (Couper) Schulz 1967, slide 89002.1, grid ref. 131.8 10.0, X500.

Figure 8. *Lycopodiacidites rugulatus* (Couper) Schulz 1967, slide 89012.1, grid ref. 139.2 9.6, X500.

Figure 9. *Trachysporites fuscus* Nilsson 1958, slide 89029.1, grid ref. 142.6 19.7

Figure 10. *Trachysporites brevipapillosus* (Couper 1958) n. comb. and emend., slide 8989003.1, grid ref. 137.2 6.6, X500.

Figure 11. *Trachysporites brevipapillosus* (Couper 1958) n. comb. and emend., slide 89302.1, grid ref. 158 19.7, X860.

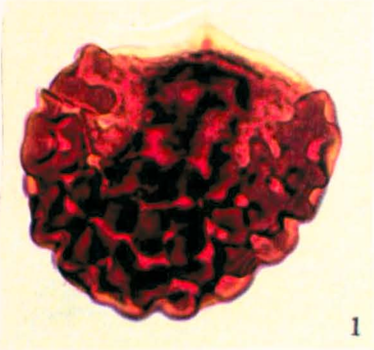
Figure 12. *Ornametifera distalgranulata* (Couper) Burden & Hills 1989, slide 89027.1, grid 138.3 20.0, X500.

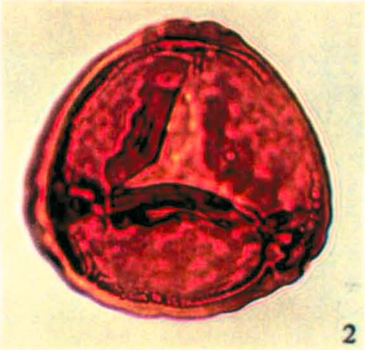
Figure 13. *Nevesisporites bigranulatus* (Levette-Carette) Morbey 1975, slide 89302.1, grid ref. 158.3 19.4, proximal view, X860.

Figure 14. *Nevesisporites bigranulatus* (Levette-Carette) Morbey 1975, slide 89302.1, grid ref. 158.3 19.4, distal view, X860.

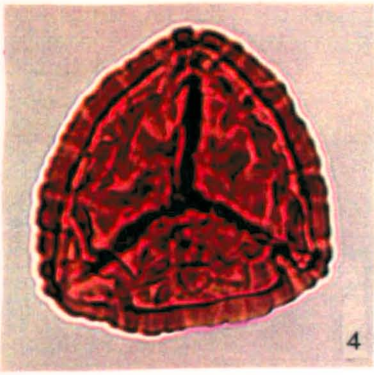
Figure 15. *Granulatisporites subgranulosus* (Couper 1958) n. comb., slide 89301.1, grid ref. 142.7 14.8, X860.

Plate 7

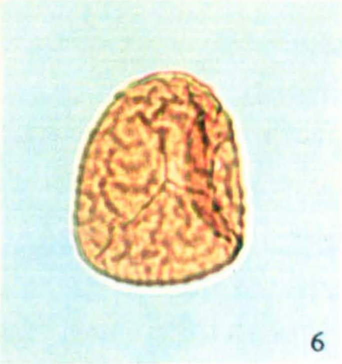

1


2

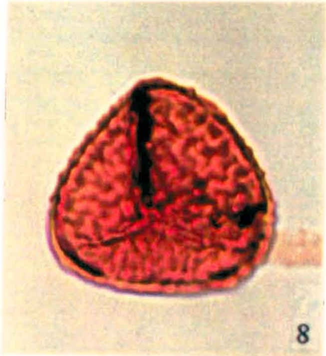

3


4


5

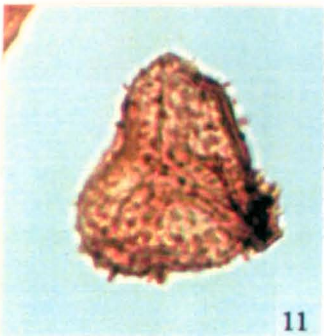

6


7


8


9


10


11


12


13


14


15

Plate 8.

Figure 1. *Tuberosistriletes aequiverrucatus* n. sp., slide 89411.1, grid ref. 143.5 18.2, holotype, X860.

Figure 2. *Tuberosistriletes horridus* n. sp., slide 89411.1, grid ref. 145.1 22.9, holotype, proximal view, X860.

Figure 3. *Tuberosistriletes horridus* n. sp., slide 89411.1, grid ref. 145.1 22.9, holotype, distal view, X860.

Figure 4. *Tuberosistriletes horridus* n. sp., slide 89411.1, grid ref. 130.8 21.4, paratype, X860.

Figure 5. *Tuberosistriletes horridus* n. sp., slide 89411.1, grid ref. 145.5 21.5, paratype, X860.

Figure 6. *Tuberosistriletes horridus* n. sp., slide 89411.1, grid ref. 126.2 21.6, paratype, X860.

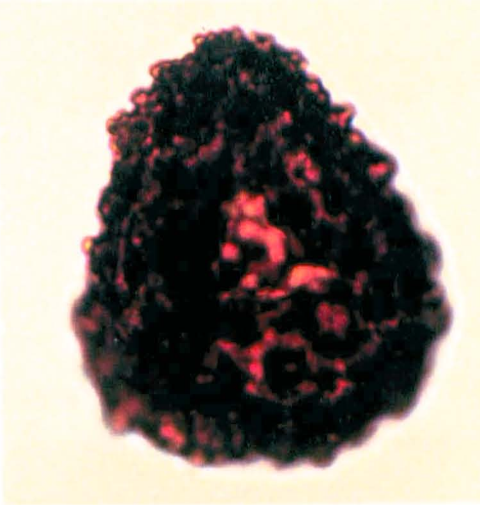
Figure 7. *Tuberositriletes variverrucatus* (Couper 1958) Döring 1964., slide 89027.1, grid ref. 129.6 23.2, X500.

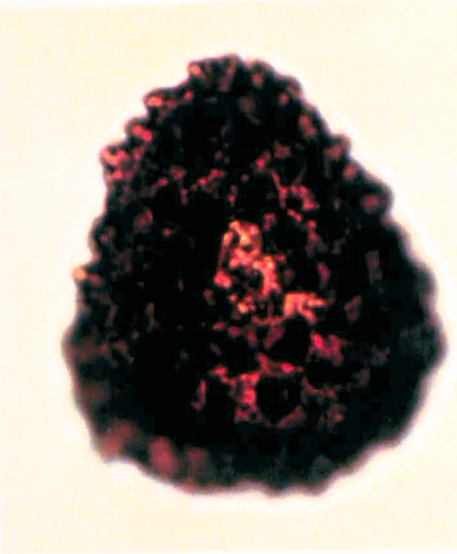
Figure 8. *Leptolepidites argenteaeformis* (Bolkhovitina) Morbey 1975, slide 89411.1, grid ref. 148.5 19.8, X860.

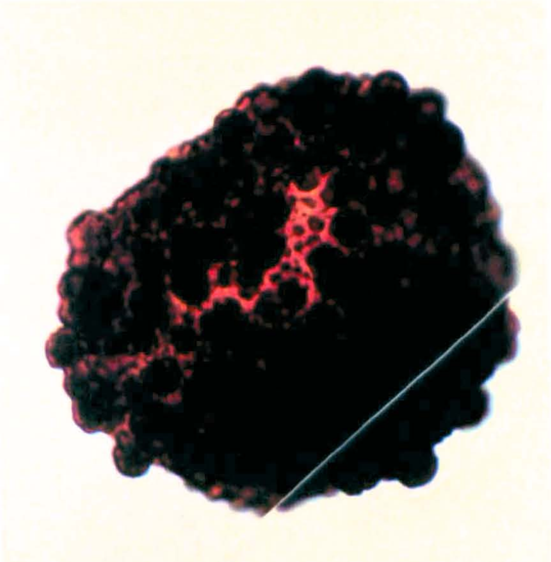
Figure 9. *Leptolepidites argenteaeformis* (Bolkhovitina) Morbey 1975, slide 89302.1, grid ref. 158.3 3.8, X860.

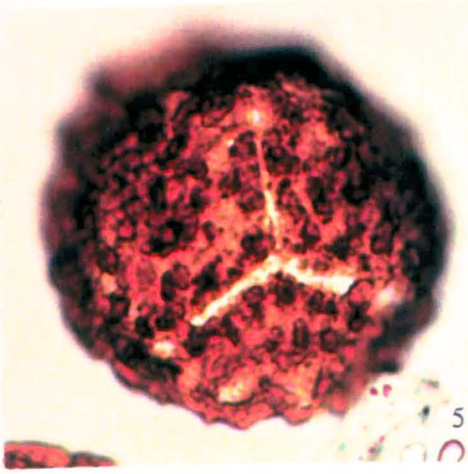
Plate 8


1


2


3


4


5


6


7


8


9

Plate 9.

Figure 1. *Tuberositriletes perverrucatus* (Couper 1958) n. comb., slide 89411.1, grid ref. 141.9 22.9, X860.

Figure 2. *Tuberositriletes perverrucatus* (Couper 1958) n. comb., slide 89411.1, grid ref. 136.8 20.4, X860.

Figure 3. *Leptolepidites bossus* (Couper) Schulz 1967, slide 89010.1, grid ref. 149.7 8.6, X500.

Figure 4. *Leptolepidites bossus* (Couper) Schulz 1967, slide 89007.1, grid ref. 141.3 18.3, X500.

Figure 5. *Leptolepidites equatibossus* (Couper) Tralau 1968, slide 89002.1, 134.3 13.8, X860.

Figure 6. *Leptolepidites macroverrucosus* Schulz 1967, slide 89002.1, grid ref. 152 23.2, X500.

Figure 7. *Leptolepidites obscuriverrucatus* n. sp., slide 89001.1, England finder ref. L38, X500.

Figure 8. *Leptolepidites major* Couper 1958, slide 89002.1, grid ref. 132.3 8.2, X500.

Figure 9. *Leptolepidites* sp. SL1, slide 89013.1, grid ref. 134.2 15.8, proximal view, X500.

Figure 10. *Leptolepidites* sp. SL1, slide 89013.1, grid ref. 134.2 15.8, distal view, X500.

Figure 11. *Leptolepidites* sp. SL1, slide 89009.4.1, grid ref. 125.9 6.2, proximal view, X500.

Figure 12. *Leptolepidites* sp. SL1, slide 89009.4.1, grid ref. 125.9 6.2, distal view, X500.

Figure 13. *Antulsporites saevus* (Balme) Archangelsky & Gamerro 1966, slide 89009.5.1, grid ref. 143.1 16.9, X500.

Figure 14. *Antulsporites varigranulatus* (Levette-Carette) Reiser & Williams 1969, slide 89010.1, grid ref. 139.1 12.5, X500.

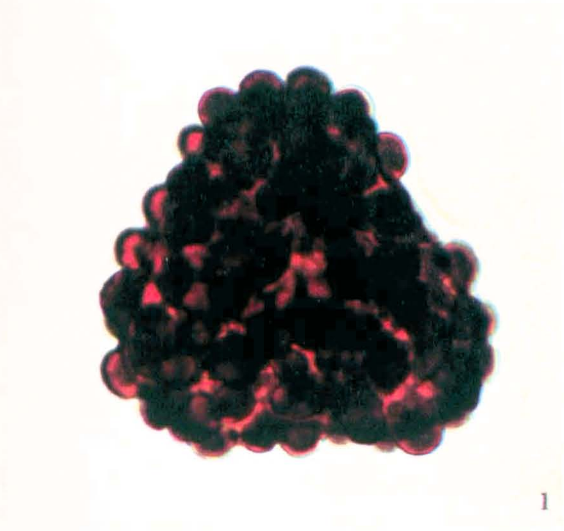
Figure 15. *Antulsporites varigranulatus* (Levette-Carette) Reiser & Williams 1969, slide 89002.1, grid ref. 139.4 6.5, X500.

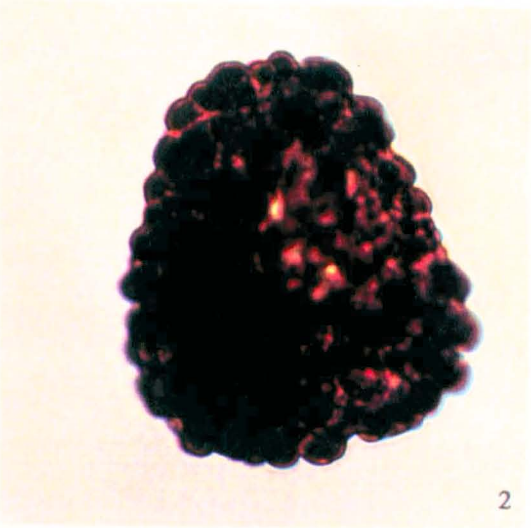
Figure 16. Spore form 1, slide 89307.1, grid ref., 162.9 3.3, distal view, X860.

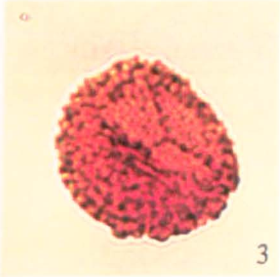
Figure 17. Spore form 1, slide 89307.1, grid ref., 162.9 3.3, proximal view, X860.

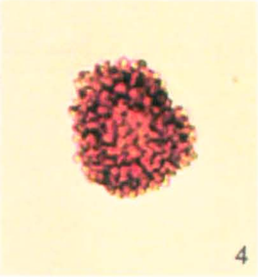
Figure 18. *Neoraistrickia truncata* (Cookson) Potonié 1956, slide 89027.1, grid ref. 135 23, X860.

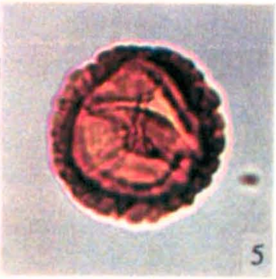
Plate 9


1


2


3


4


5

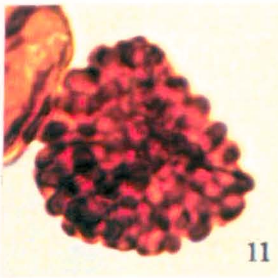

6


7


8


9

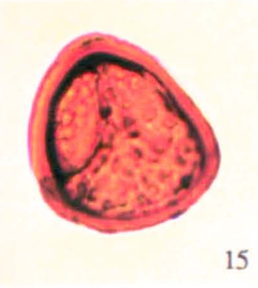

10

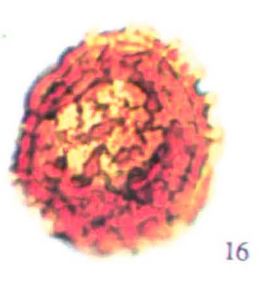

11

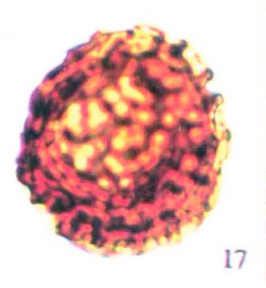

12


13


14


15


16


17


18

Plate 10.

Figure 1. *Neoraistrickia truncata* (Cookson) Potonié 1956, slide 89027.1, grid ref. 156.4 17.4, X860.

Figure 2. *Neoraistrickia truncata* (Cookson) Potonié 1956, slide 89027.1, grid ref. 130.9 16.9, X860.

Figure 3. *Neoraistrikia* sp. SN1, slide 89302.1, grid ref. 151.2 18.9, X860.

Figure 4. *Neoraistrikia* sp. SN1, slide 89302.1, grid ref. 154.8 16.2, X860.

Figure 5. *Anapiculatisporites dawsonensis* Reiser & Williams 1969, slide 89302.1, grid ref. 132.8 16, X860.

Figure 6. *Echinatisporis baculatus* n. comb. and emend., v89302.1, grid ref. 143.2 3.2, X860.

Figure 7. *Echinatisporis baculatus* n. comb. and emend., slide 89302.1, grid ref. 159.1 20.3, X860.

Figure 8. *Echinatisporis baculatus* n. comb. and emend., slide 89302.1, grid ref. 141.8 13.3, X860.

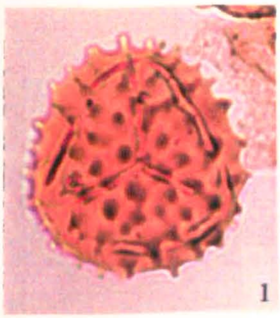
Figure 9. *Echinatisporis baculatus* n. comb. and emend., slide 89302.1, grid ref. 158.9 12.2, X860.

Figure 10. *Baculatisporites comaumensis* Cookson ex Potonié 1956, slide 89302.1, grid ref. 132.8 6.2, X860.

Figure 11. *Osmundacidites wellmanii* Couper 1953, slide 89302.1, grid ref. 145.5 3.0, X860.

Figure 12. *Rugulatisporites nequenensis* Volkheimer 1972, slide 89009.4.1, grid ref. 123.9 23.2, X500.

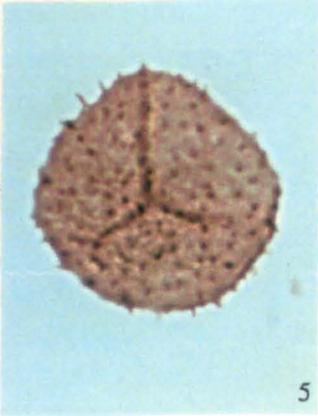
Plate 10

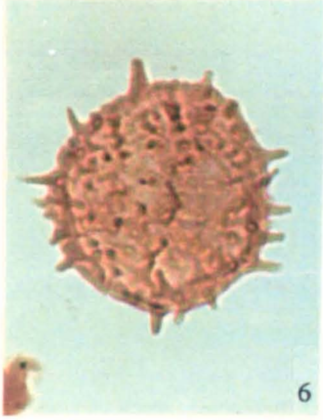

1

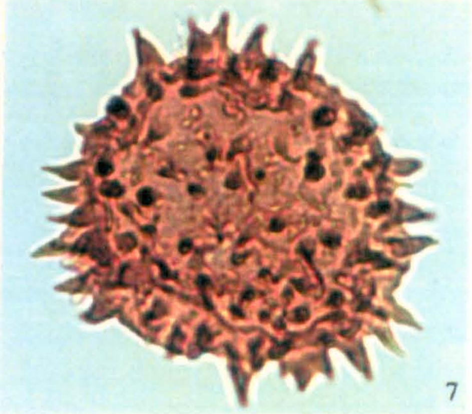

2


3

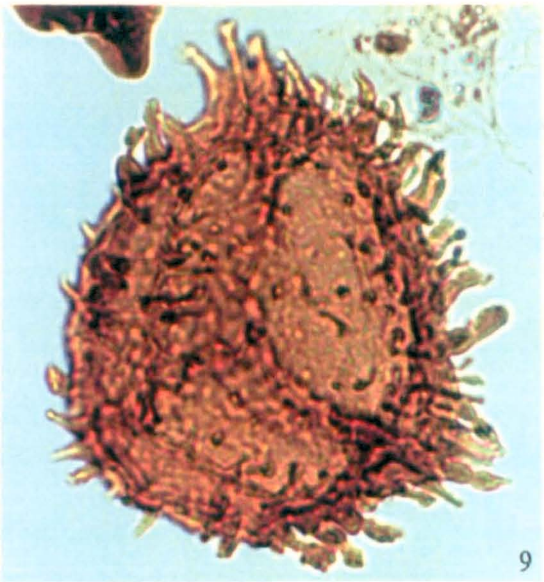

4


5


6


7


8


9


10


11


12

Plate 11.

Figure 1. *Verrucosisporites varians* Volkheimer 1972, slide 89302.1, grid ref. 155.5 3.8, X860.

Figure 2. *Marattisporites scabratus* Couper 1958, slide 89001.1, England finder ref. N32/4, X500.

Figure 3. *Monolites couperi* Tralau 1968, slide 89302.1, grid ref. 140.3 9.2, X860.

Figure 4. *Callialasporites dampieri* (Balme) Norris 1969, slide 89302.1, grid ref. 141.8 2.2, X860.

Figure 5. *Callialasporites microvelatus* Schulz 1966, slide 89302.1, grid ref. 151.7 23.2, X860.

Figure 6. *Callialasporites minus* (Tralau) Guy 1971, slide 89302.1, grid ref. 136.9 7.8, X860.

Figure 7. *Callialasporites trilobatus* (Balme) Sukh Dev 1961, slide 89019.1, grid ref. 129.4 20.4, X860.

Figure 8. *Callialasporites turbatus* (Balme) Schulz 1967, slide 89302.1, grid ref. 136.1 8.1, X860.

Figure 9. *Araucariacites australis* Cookson 1947, slide 89302.1, grid ref. 132.6 6.2, X860.

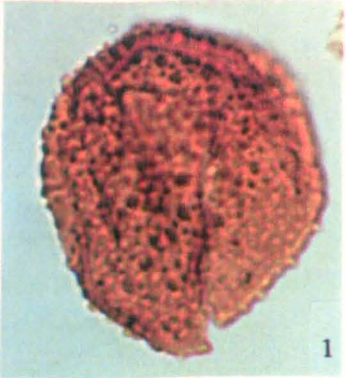
Figure 10. *Leiosphaeridia hyalina* (Deflandre) Eisenack 1958, slide 89016a, grid ref. 153.9 21.2, X860.

Figure 11. *Hemisphaerium simplex* n. sp., slide 89020.1, grid ref. 140.2 9.8, holotype, X860.

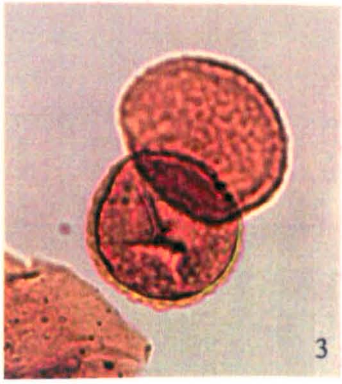
Figure 12. *Hemisphaerium parvum* (Cookson & Dettmann) n. comb., slide 89215.1, grid ref. 152.5 22.8, X860.

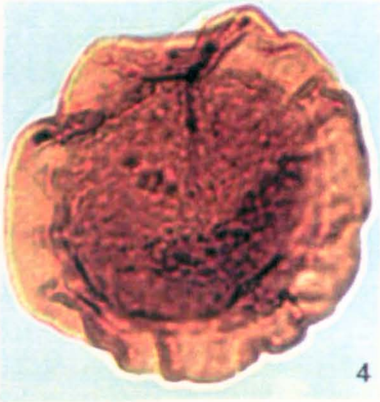
Figure 13. *Hemisphaerium parvum* (Cookson & Dettmann) n. comb., slide 89215.1, grid ref. 139.1 19.1, X860.

Plate 11


1

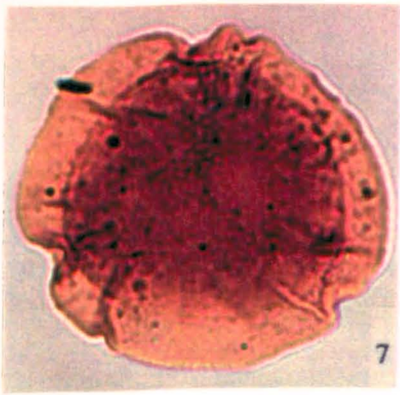

2


3

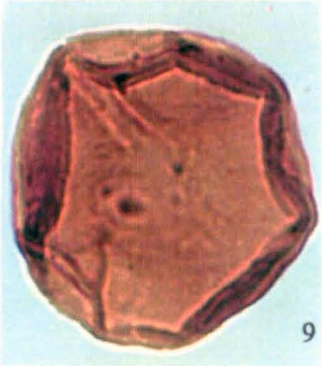

4

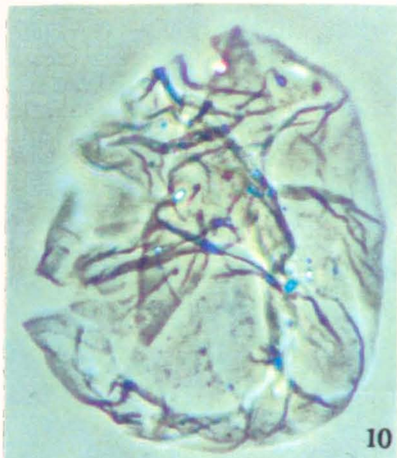

5


6


7


8


9


10


11


12


13

Plate 12.

Figure 1. *Hemisphaerium giganteum* n. sp., slide 89220.1, grid ref. 140.6 9.8, holotype, X860.

Figure 2. *Hemisphaerium giganteum* n. sp., slide 89220.1, grid ref. 159.5 10.5, paratype, X860.

Figure 3. *Hemisphaerium giganteum* n. sp., slide 89220.1, grid ref. 141 3.8, paratype, X860.

Figure 4. *Hemisphaerium simplex* n. sp., slide 89220.1, grid ref. 159.4 15.6, paratype, X860.

Figure 5. *Hemisphaerium simplex* n. sp., slide 89220.1, grid ref. 146.1 18.9, paratype, X860.

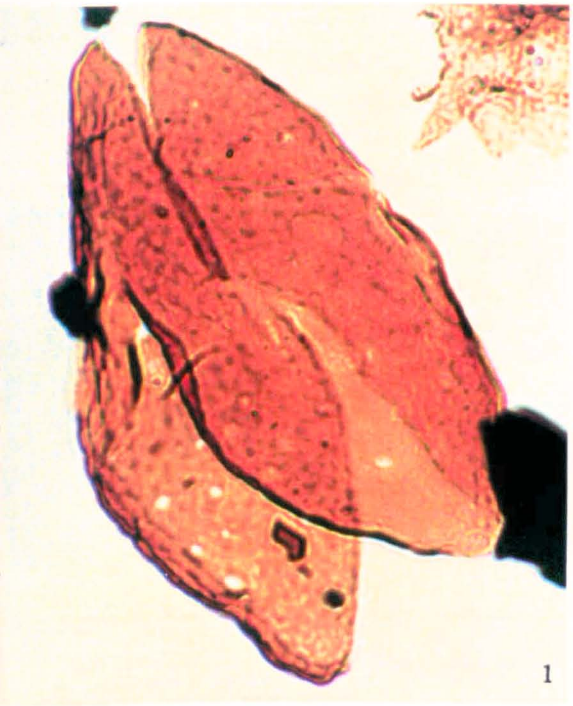
Figure 6. *Microsporonites cacheutensis* Jain 1968, slide 89302.1, grid ref. 142.8 6.5, X860.

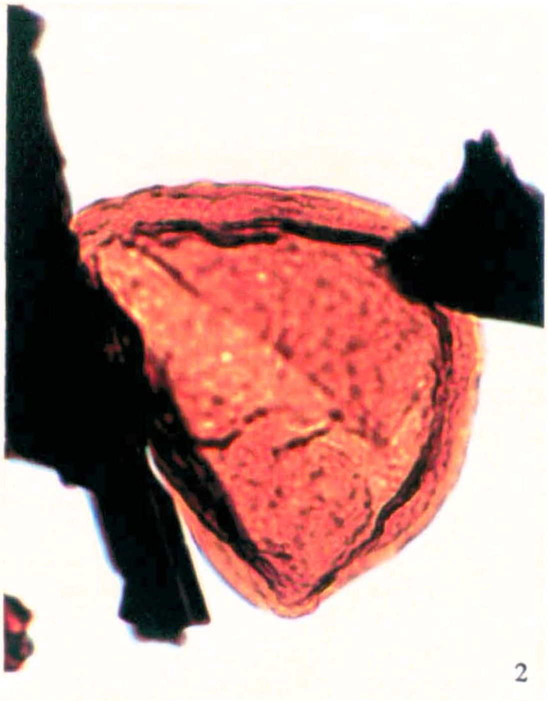
Figure 7. *Tetraporina rara* (Playford & Dettmann 1965) n. comb., slide 89215.2, grid ref. 149.3 19.5,

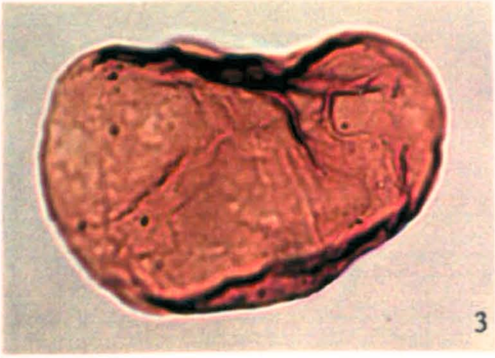
Figure 8. *Micrhystridium fragile* Deflandre 1937, slide 89013.1, grid ref. 156.8 5.0, X500.

Figure 9. *Micrhystridium stellatum* Deflandre 1945, slide SALT 16.1, grid ref. 157.2 15.3, X860.

Figure 10. *Solisphaeridium lymense* Wall var. *lymense* (Wall) n. comb., slide 89029.1, grid ref. 139.8 22.1, X500.

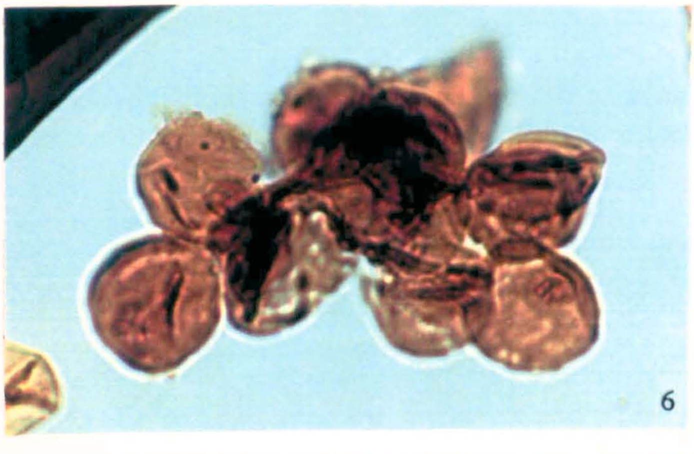

1


2

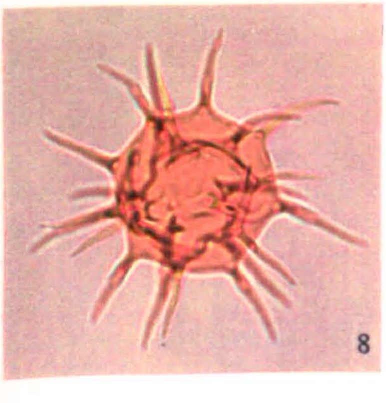

3


4


5


6


7


8


9


10

Plate 13.

Figure 1. *Crassosphaera hexagonalis* Wall 1965, slide 89218.1, grid ref. 147.3 6.0, X860.

Figure 2. *Lecaniella foveolatus* Filatoff 1975, slide SALT 21.1, grid ref. 143.6 15.4, X860.

Figure 3. *Chomotriletes minor* (Kedves) Pocock 1970, slide 89302.1, grid ref. 149 19, X860.

Figure 4. *Scalbiella reticulata* n. sp., slide 89302.5, grid ref. 157.1 13.4, holotype X2150

Figure 5. *Lecaniella varireticulata* n. sp., slide 89220.1, grid ref. 135.9 16.1, holotype, X860.

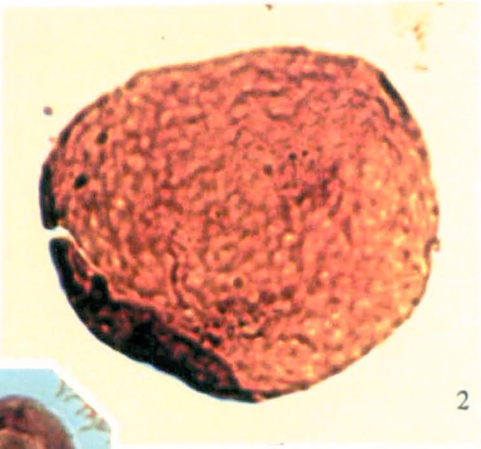
Figure 6. *Lecaniella varireticulata* n. sp., slide 89220.1, grid ref. 140.1 12.4, paratype, X860.

Figure 7. *Lecaniella varireticulata* n. sp., slide 89220.1, grid ref. 154.5 15.9, paratype, X860.

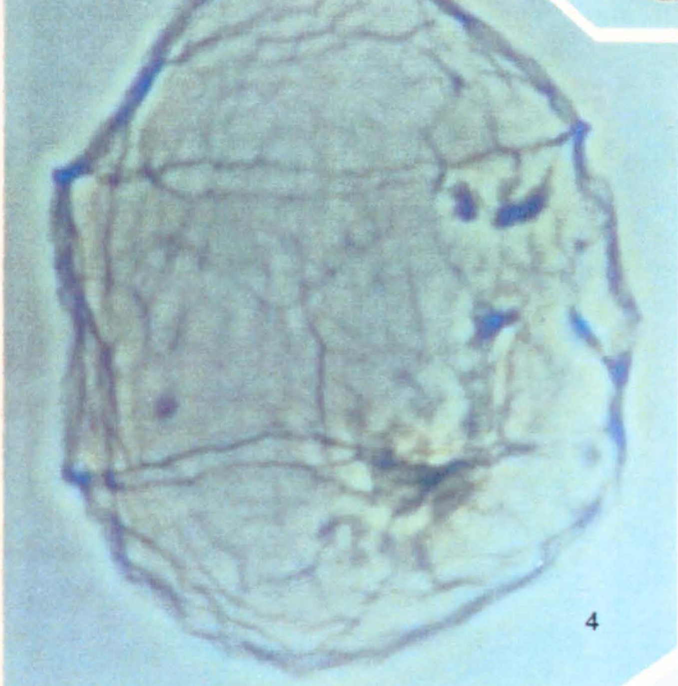
Figure 8. *Lecaniella varireticulata* n. sp., slide 89220.1, grid ref. 145.3 15.8, paratype, X860.

Figure 9. *Tasmanites newtonii* Wall 1965, slide 89302.1, grid ref. 154.2 5.3, X860.


1


2


3


4


5


6


8


7

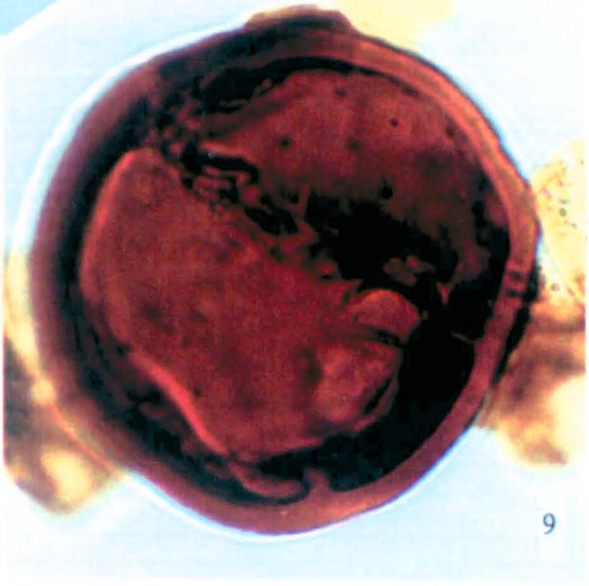

9

Plate 14.

Figure 1. *Enigmaspora bella* n. Gen. and sp., slide 89302.1, grid ref. 148.8 18.5, holotype, X860.

Figure 2. *Enigmaspora bella* n. Gen. and sp., slide 89302.1, grid ref. 148.8 18.5, holotype, X860.

Figure 3. *Enigmaspora bella* n. Gen. and sp., slide 89302.1, grid ref. 135.6 21.6, X860.

Figure 4. *Enigmaspora bella* n. Gen. and sp., slide 89302.5, grid ref. 136.3 8.3, X860.

Figure 5. *Enigmaspora bella* n. Gen. and sp., slide 89302.5, grid ref. 138.2 11.8, X860.

Figure 6. *Enigmaspora bella* n. Gen. and sp., slide 89302.1, grid ref. 156.5 11.1, X860.

Figure 7. *Enigmaspora bella* n. Gen. and sp., slide 89302.1, grid ref. 136.2 16.0, X860.

Figure 8. *Corollina simplex* (Danzé-Corsin & Laveine) Cornet & Traverse 1975, slide 89010.1, grid ref. 142.4 5.8, X500.

Figure 9. *Corollina torosus* (Reissinger) Cornet & Traverse 1975, slide 89302.1, grid ref. 142.6 8.1, X860.

Figure 10. *Exesipollenites scabratus* (Couper) Pocock 1970, slide 89001.1, England finder ref.P26/3, X500.

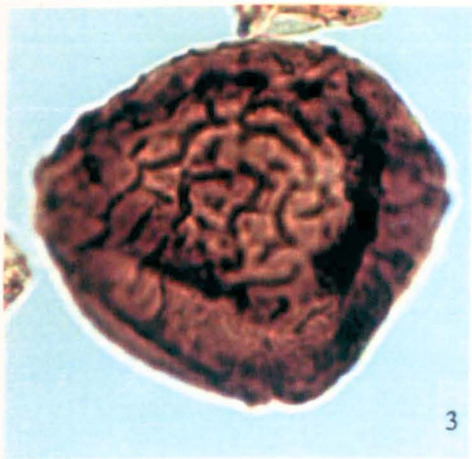
Figure 11. *Exesipollenites laevigatus* Pocock 1970, slide 89001.1, England finder ref. M26, X500.

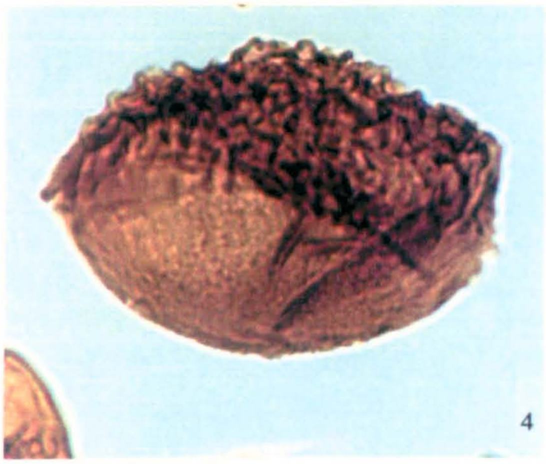
Figure 12. *Exesipollenites tumulus* Balme 1957, slide 89302.1, grid ref. 136.8 19.1, X860.

Plate 14

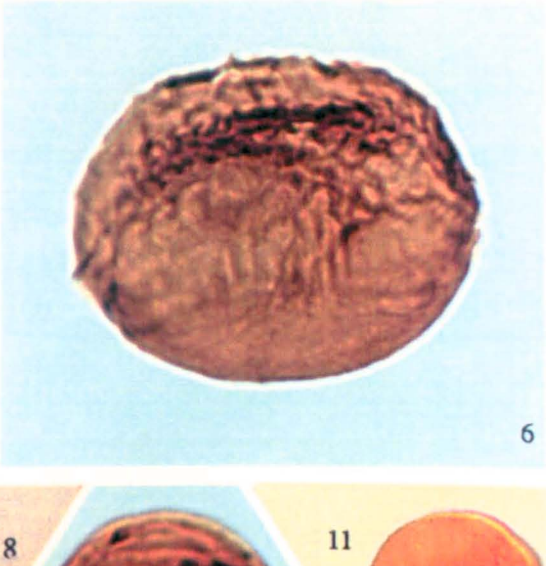

1


2


3

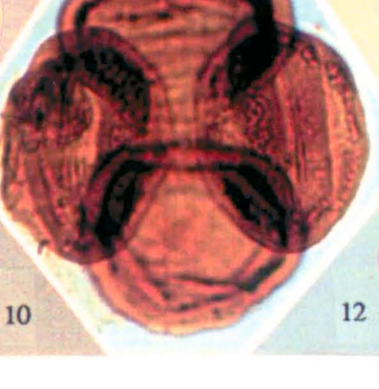

4


5


6


7


8


9


10


11


12

Plate 15.

Figure 1. *Perinopollenites elatoides* Couper 1958, slide 89302.1, grid ref. 129.2 15.3, X860.

Figure 2. *Cycadopites carpentieri* (Delcourt & Sprumont) Singh 1964, slide 89201.1, grid ref. 148.6 4.2, X860.

Figure 3. *Cycadopites minimus* (Cookson) Pocock 1970, slide 89002.1, grid ref. 137.8 3.5, X500.

Figure 4. *Chasmatosporites apertus* (Rogalska) Nilsson 1958, slide 89201.1, grid ref. 155.6 18.7, X500.

Figure 5. *Chasmatosporites apertus* (Rogalska) Nilsson 1958, slide 89302.1, grid ref. 158.8 18, X860.

Figure 6. *Chasmatosporites hians* Nilsson 1958, slide 89027.1, grid ref. 144.1 22.5, X860.

Figure 7. *Chasmatosporites* sp. PC1, slide 89302.1, grid ref. 133.5 4.8, X860.

Figure 8. *Eucommiidites troedssonii* Erdtman *ex* Couper 1958, slide 89004.1, grid ref. 141.2 21.3, X500.

Figure 9. *Cerebropollenites mesozoicus* (Couper) Nilsson 1958., slide 89302.1, grid ref. 158.8 7.3, X860.

Figure 10. *Cerebropollenites mesozoicus* (Couper) Nilsson 1958., slide 89302.1, grid ref. 154.3 23.3, X860.

Figure 11. *Botryococcus braunii* Kützing 1849, slide BMGMCW2, grid ref. 141.7 20.5, X860.

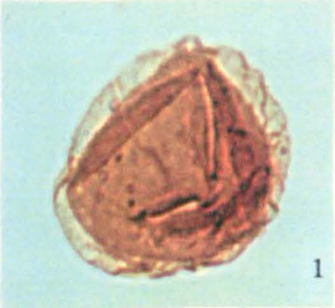
Figure 12. *Pterospermella helios* (Sarjeant) de Coninck 1975, slide 89029.1, grid ref. 127.2 19.6, X500.

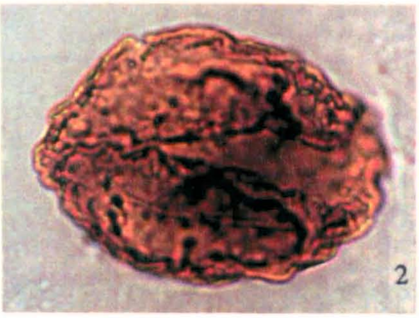
Figure 13. *Cymatiosphaera eupeplos* (Valensi) Deflandre 1954, slide 89002.1, grid ref. 155.8 21.9, X500.

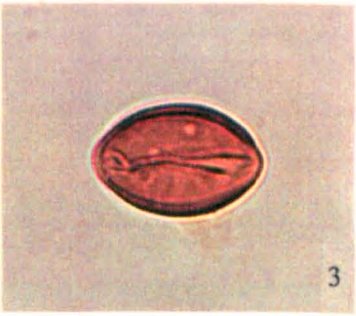
Figure 14. Palynomorph form 1, slide 89002.1, grid ref. 131.8 10.0, X500.

Figure 15. *Abietinaepollenites dunrobinensis* Couper 1958, slide 89302.5, grid ref. 141.3 9.4, X860.

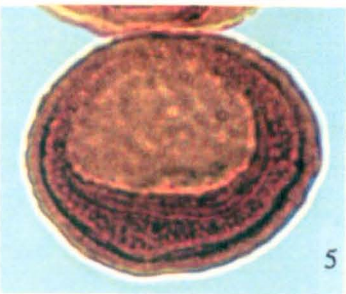
Plate 15


1


2


3


4

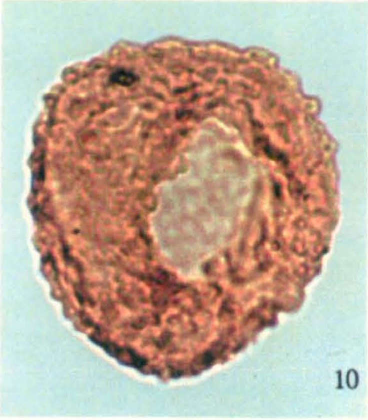

5


6

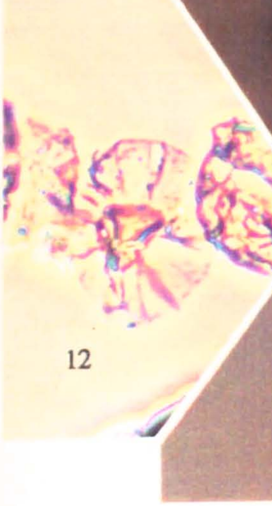

7


8


9


10


11


12


13


14


15

Plate 16.

Figure 1. *Alisporites grandis* (Cookson) Dettmann 1963, slide 89302.1, grid ref. 158.8 10.6, X860.

Figure 2. *Podocarpidites ellipticus* Cookon ex Couper 1953, slide 89302.1, grid ref. 142.6 16.5, X860.

Figure 3. *Alisporites microsaccus* (Couper) Pocock 1962, slide 89302.1, grid ref. 159.4 3.2, X860.

Figure 4. *Alisporites similis* (Balme) Dettmann 1963, slide 89305.1, grid ref. 142 .2 20.2, X860.

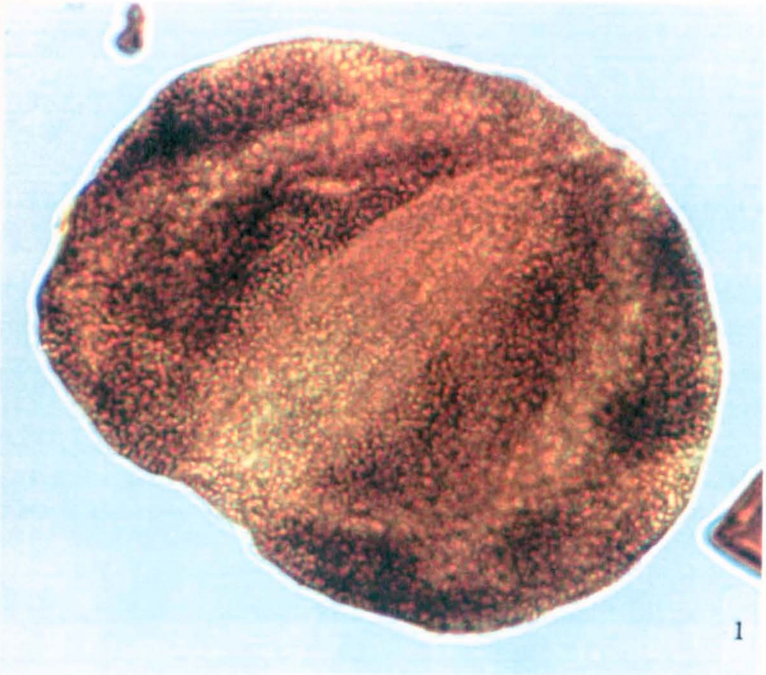
Figure 5. *Pinuspollenites* spp., slide 89303.1, grid ref. 137.8 20.2, X860.

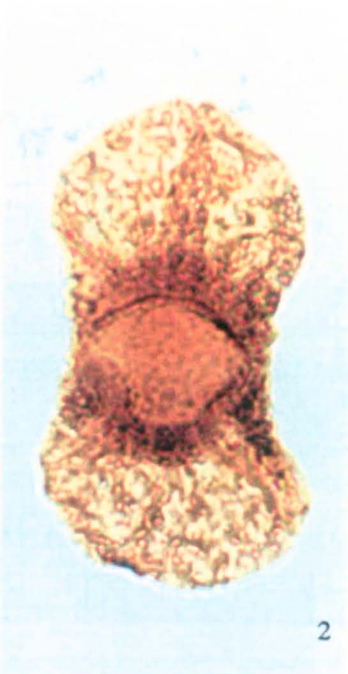
Figure 6. *Vitreisporites pallidus* (Reissinger) Nilsson 1958, slide SALT 39.2, grid ref. 144.1 11.0, X860.

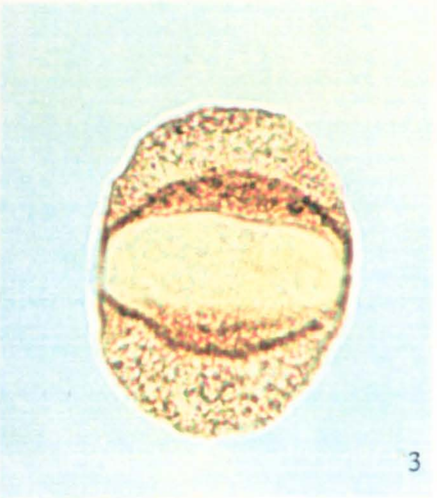
Figure 7. *Ovalipollis ovalis* (Krutzsch) Pocock and Jansonius 1968, slide 89001.1, grid ref. 142.1 22, X860..

Figure 8. *Ovalipollis limbata* (Maljavkina) Pocock and Jansonius 1968, slide 89302.1, grid ref. 159.1 8.2, X860.

Plate 16


1

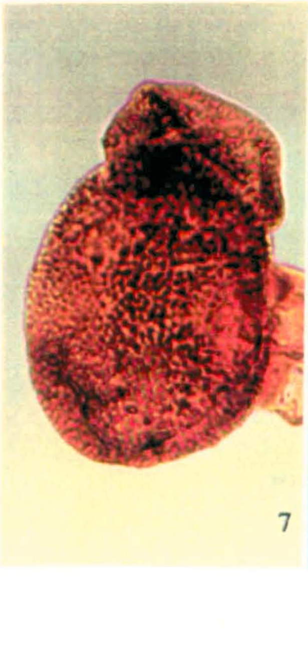

2


3


4


5


6


7


8

Plate 17.

Figure 1. *Batiacasphaera* sp. DB1, slide 89013.1, grid ref. 156.5 18.8, X500.

Figure 2. *Baticacsphaera* sp. DB2, slide 89201.1, grid ref. 146.9 7.8, phase contrast, X860.

Figure 3. *Baticacsphaera* sp. DB2, slide 89201.1, grid ref. 146.9 7.8, phase contrast, X860.

Figure 4. *Orobodinium automobile* Gocht & Wille 1990, slide 89027.1, grid ref. 138.3 20.0, phase contrast, X500.

Figure 5. *Orobodinium automobile* Gocht & Wille 1990, slide 89027.1, grid ref. 138.3 20.0, phase contrast, X500.

Figure 6. *Batiacasphaera* sp. DB3, slide 89208.1, grid ref. 147.3 6.0, X860.

Figure 7. *Valensiella* sp., slide 89027.1, grid ref. 133.7 14.5, phase contrast, X500.

Figure 8. *Jansonia jurassica* Pocock 1972, slide 89201.1, grid ref. 142.9 4.6, X860.

Figure 9. *Kallosphaeridium* sp. DK1, slide 89016a, grid ref. 152.1 11.2, X860.

Figure 10. *Kallosphaeridium coniferum* n. sp., slide BMGMCW2, grid ref. 129.6 20.2, holotype, X860.

Figure 11. *Kallosphaeridium coniferum* n. sp., slide BMGMCW2, grid ref. 129.6 20.2, holotype, phase contrast, X860.

Figure 12. *Sentusidinium rioultii* (Sarjeant) Sarjeant & Stover 1978, 89027.1, 133.3 23.4, X860.

Figure 13. *Kallosphaeridium coniferum* n. sp., slide BMGMCW2, grid ref. 129.6 20.2, holotype, phase contrast, operculum detail, X2150.

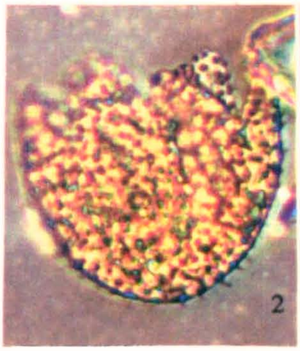
Figure 14. *Kallosphaeridium coniferum* n. sp., slide BMGMCW2, grid ref. 129.6 20.2, holotype, phase contrast, operculum detail, X2150.

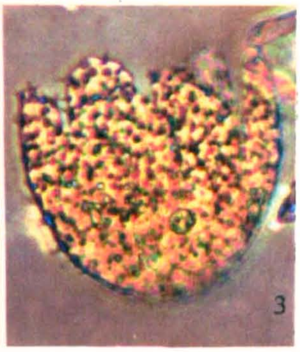
Figure 15. *Lithodinia caytonensis* (Sarjeant) Gocht 1976, slide SALT 16.1, grid ref. 148 11.3, typical form, X860.

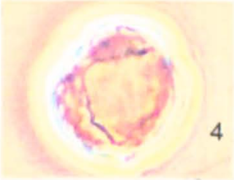
Figure 16. *Lithodinia caytonensis* (Sarjeant) Gocht 1976, slide SALT 16.1, grid ref. 152.2 15.3, squat form, X860.

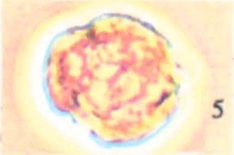
Plate 17

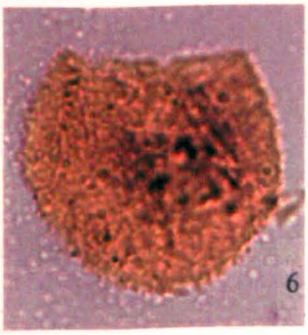

1

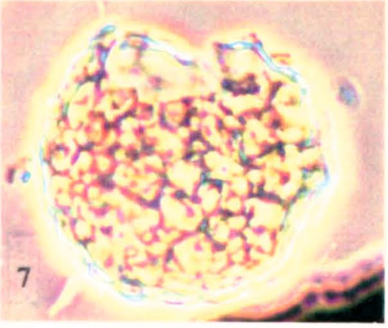

2

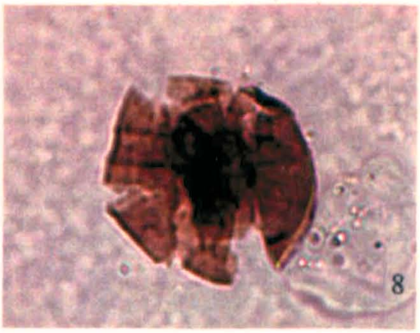

3

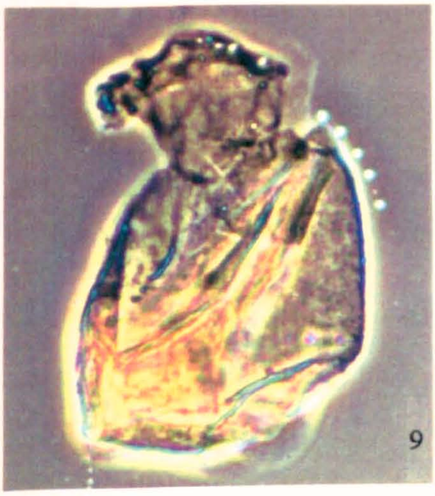

4


5

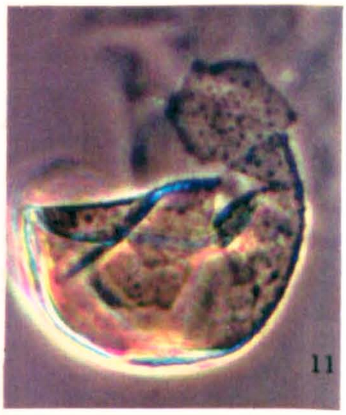

6


7

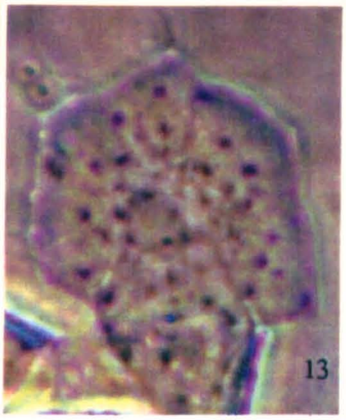

8

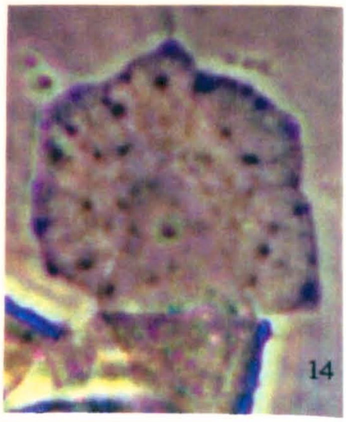

9

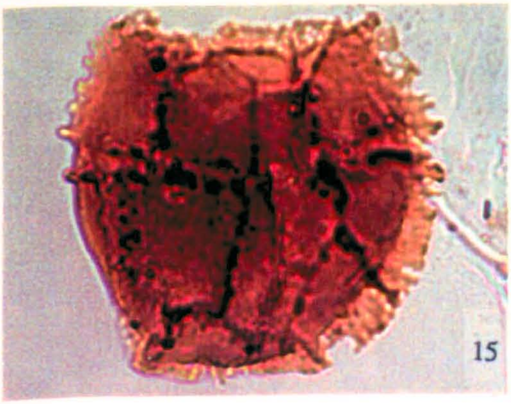

10


11


12


13


14


15


16

Plate 18.

Figure 1. *Kallosphaeridium tenuum* n. sp., slide 89016a, grid ref. 147.9 21.5, holotype, X860.

Figure 2. *Kallosphaeridium tenuum* n. sp., slide 89016a, grid ref. 150.5 1.2, paratype, X860.

Figure 3. *Kallosphaeridium tenuum* n. sp., slide 89016a, grid ref. 141.3 22.1, paratype, X860.

Figure 4. *Ambonosphaera calloviana* Fensome 1979, slide 89203.1, grid ref. 147.3 18.6, X860.

Figure 5. *Sirmiodinium grossii* Alberti 1961, slide 89213.2, grid ref. 139.7 21.0, X860.

Figure 6. *Prolixosphaeridium anasillum* Erkmen & Sarjeant 1980, slide 89214.4, grid ref. 158.7 16.0, X860.

Figure 7. *Stephanelytron* sp. DS1, slide SALT 16.1, grid ref. 157.2 19.8, X860.

Figure 8. *Stephanelytron* sp. DS1, slide SALT 16.1, grid ref. 143.8 22.2, X860.

Figure 9. *Ambonosphaera calloviana* Fensome 1979, slide 89203.1, grid ref. 147.3 18.6, phase contrast, X860.

Figure 10. *Prolixosphaeridium anasillum* Erkmen & Sarjeant 1980, slide 89207.3, grid ref. 152.2 10.7, X860.

Plate 18

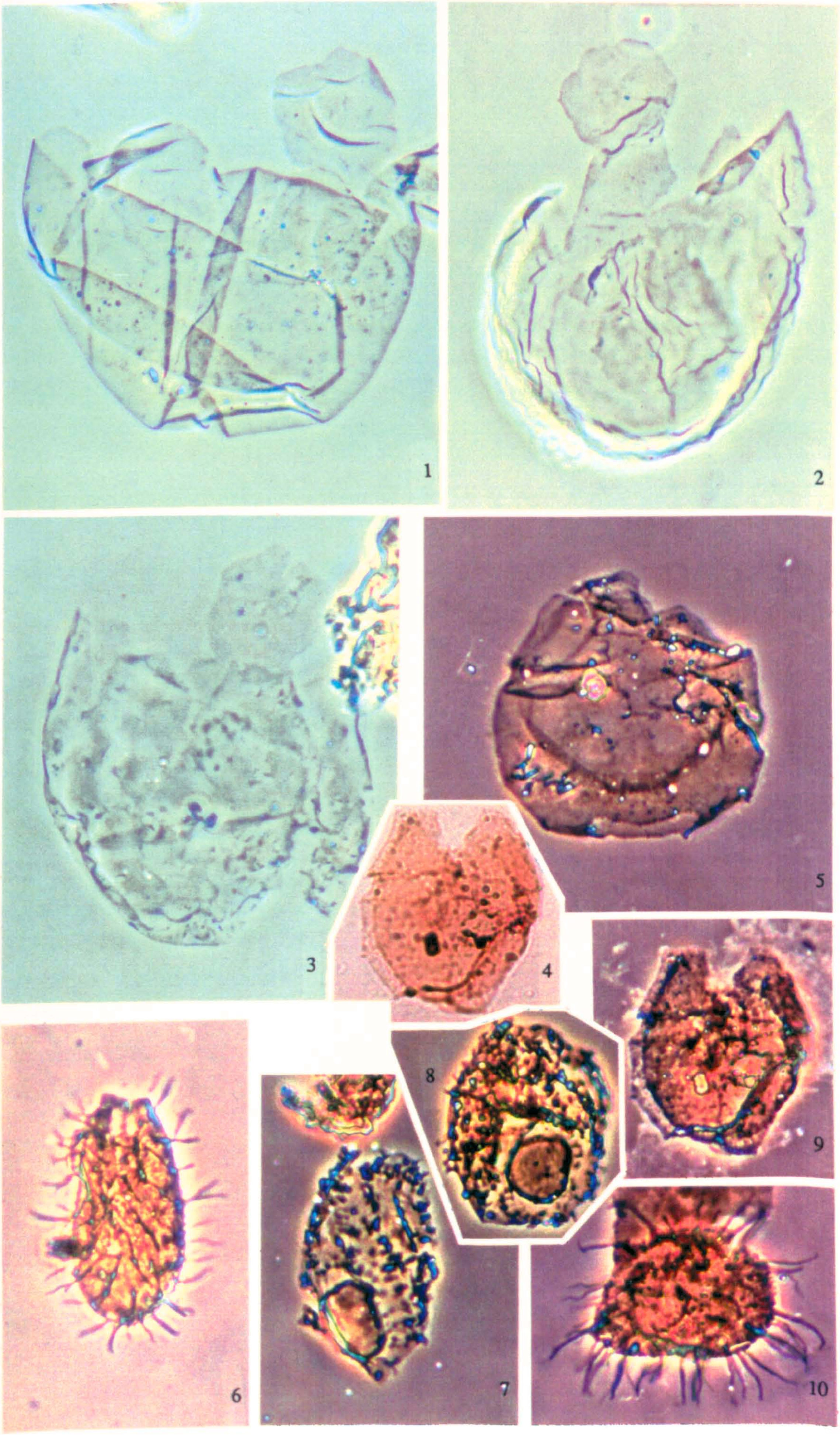


Plate 19.

Figure 1. *Compositosphaeridium polonicum* (Gorka) Erkman & Sarjeant 1980, slide 89323.2, grid ref. 152.6 20.8, upper focus, X860.

Figure 2. cf.*Compositosphaeridium polonicum* (Gorka) Erkman & Sarjeant 1980, slide 89323.2, grid ref. 152.6 20.8, lower focus, X860.

Figure 3. Chorate cyst indeterminate, slide 89323.1, grid ref. 128.6 10.0, X860.

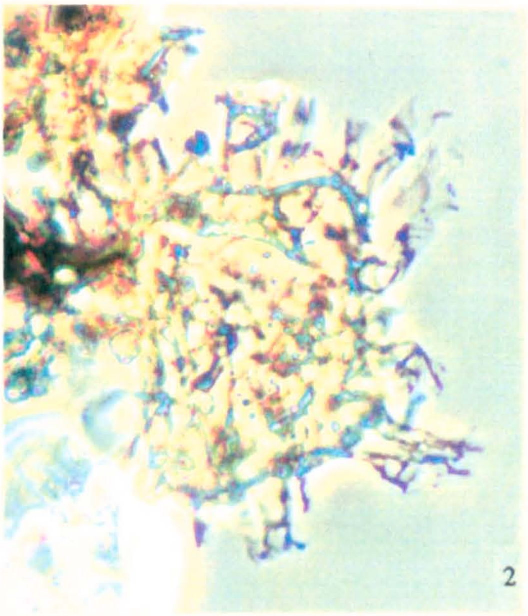
Figure 4. *Cleistosphaeridium varispinosum* (Sarjeant) Woollam & Riding 1983, slide 89201.1, grid ref. 161.8 7.5, X860.

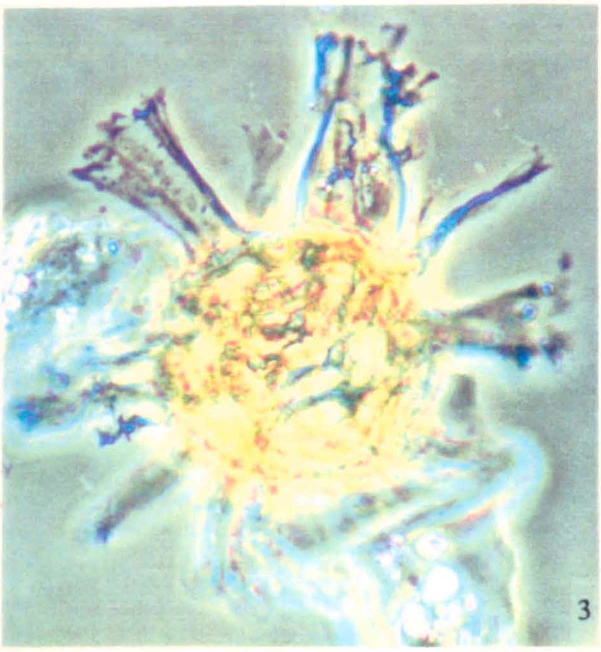
Figure 5. *Adnatosphaeridium caullyeri* (Deflandre) Williams & Downie 1966, slide 89323.1, grid ref. 136 20.5, X860.

Figure 6. *Aldorfia aldorfensis* (Gocht) Stover & Evitt 1978, slide SALT 16.1, grid ref. 136.7 21.1, X860.

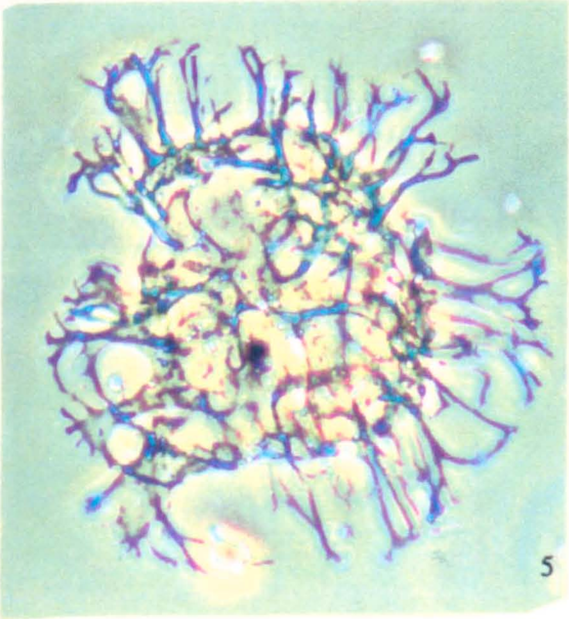
Plate 19


1


2


3


4


5

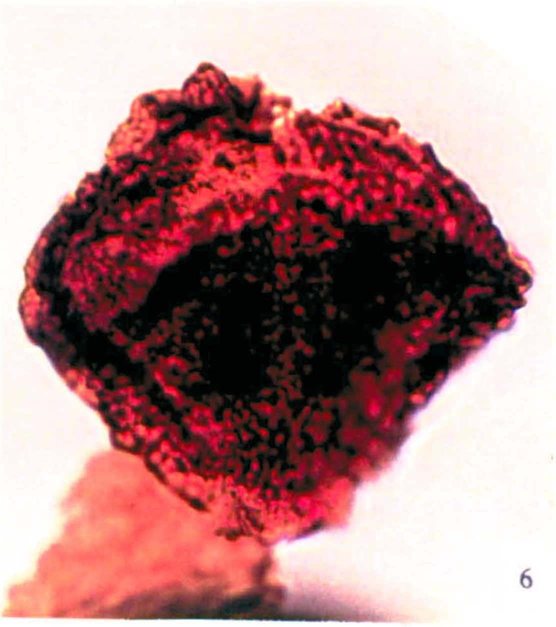

6

Plate 20.

Figure 1. *Rigaudella aemula* (Deflandre) Below 1982, slide SALT 16.1, grid ref. 147 10.1, X860.

Figure 2. *Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* Sarjeant 1982, slide 89201.1, grid ref. 149.2 12.8, X860.

Figure 3. *Gonyaulacysta jurassica* subsp. *adecta* var. *adecta* Sarjeant 1982, slide 89201.1, grid ref. 149.2 12.8, X860.

Figure 4. *Tubotuberella dangeardii* (Sarjeant 1968) Jan du Chêne *et al.* 1986, slide 89201.1, grid ref. 161.3 18.0, X860.

Figure 5. *Tubotuberella dangeardii* (Sarjeant 1968) Jan du Chêne *et al.* 1986, slide 89201.1, grid ref. 161.3 18.0, X860.

Figure 6. *Durotrigia daveyi* Bailey 1987, slide 89013.1, grid ref. 148.4 9.2, X500.

Figure 7. *Durotrigia daveyi* Bailey 1987, slide 89013.1, grid ref. 148.4 9.2, X500.

Figure 8. *Durotrigia daveyi* Bailey 1987, slide 89013.1, grid ref. 147.3 15.3, X500.

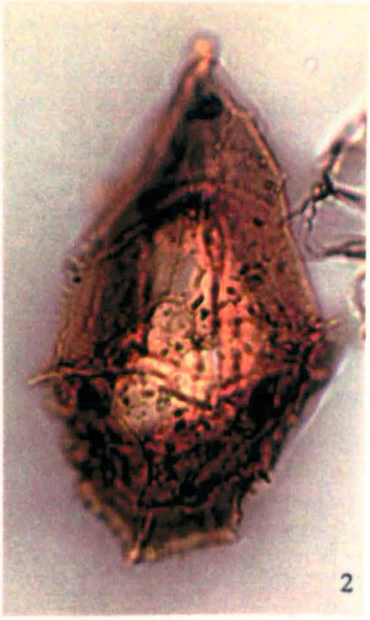
Figure 9. *Durotrigia daveyi* Bailey 1987, slide 89013.1, grid ref. 147.3 15.3, X500.

Figure 10. *Phallocysta* cf. *eumekes* Dörhöfer & Davies 1980, slide 89016a, grid ref. 140.3 17.9, X860.

Figure 11. *Phallocysta* cf. *eumekes* Dörhöfer & Davies 1980, slide 89016a, grid ref. 141.2 16, X860.

Plate 20

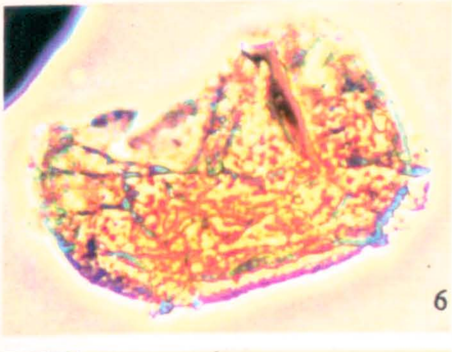

1

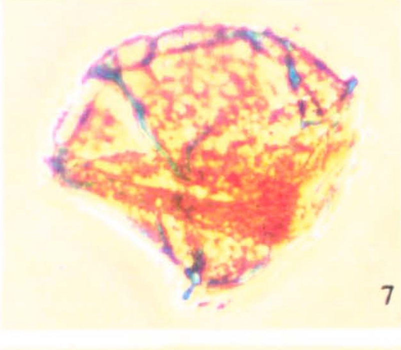

2

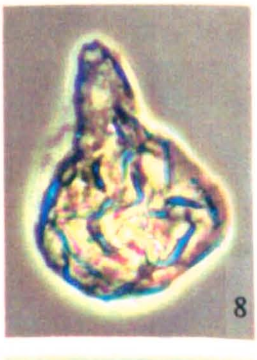

3

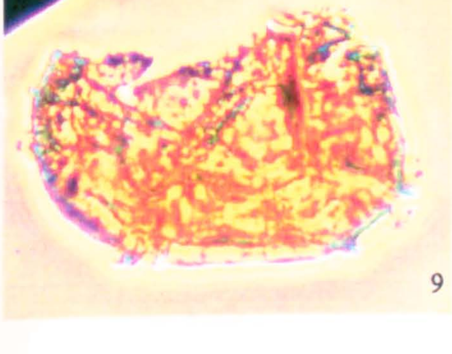

4

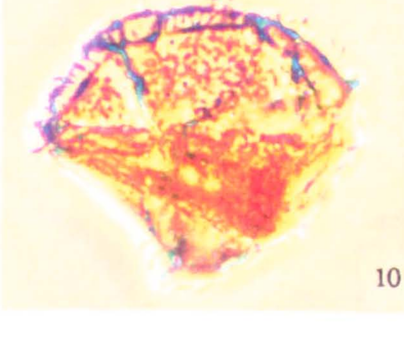

5


6


7


8


9


10


11

Plate 21.

Figure 1. *Durotrigia filapicata* (Gocht) Riding & Bailey 1991, slide 89027.1, grid ref. 148.9 12.0, oblique ventral view, X860.

Figure 2. *Dissiliodinium* cf. *willei* Bailey & Partington 1991, slide 89002.1, grid ref. 131.2 23.7, ventral view, X860.

Figure 3. *Durotrigia filapicata* (Gocht) Riding & Bailey 1991, slide 89027.1, grid ref. 148.9 12.0, left dorsal view, X860.

Figure 4. *Dissiliodinium* cf. *willei* Bailey & Partington 1991, slide 89002.1, grid ref. 131.2 23.7, dorsal view, X860.

Figure 5. *Ctenidodinium combazii* Dupin 1968, slide 89201.2, grid ref. 146.1 17.8, complete specimen, X860.

Figure 6. *Ctenidodinium sellwoodii* (Sarjeant) Stover & Evitt 1978, slide 89201.1, grid ref. 156.4 9.4, hypocyst, X860.

Figure 7. *Ctenidodinium sellwoodii* (Sarjeant) Stover & Evitt 1978, slide 89201.1, grid ref. 155.8 15.5, X860.

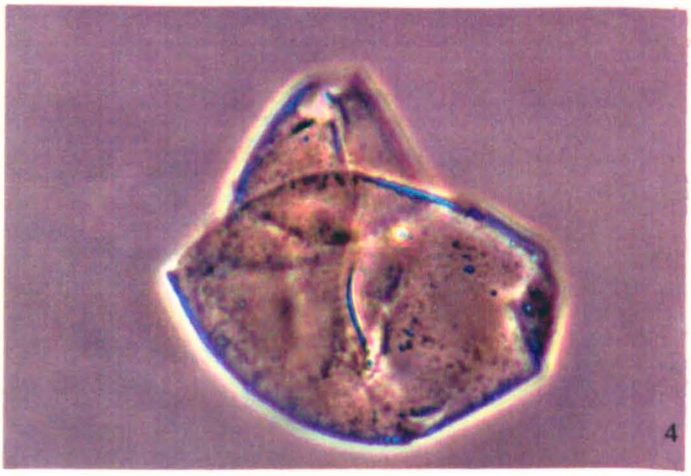
Figure 8. *Korystocysta* sp. indet., slide SALT 16.1, grid ref. 151.9 10.1, X860.

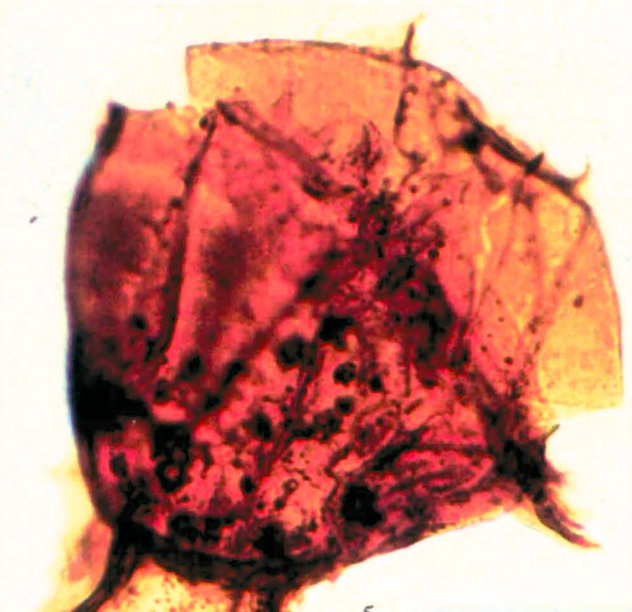
Plate 21

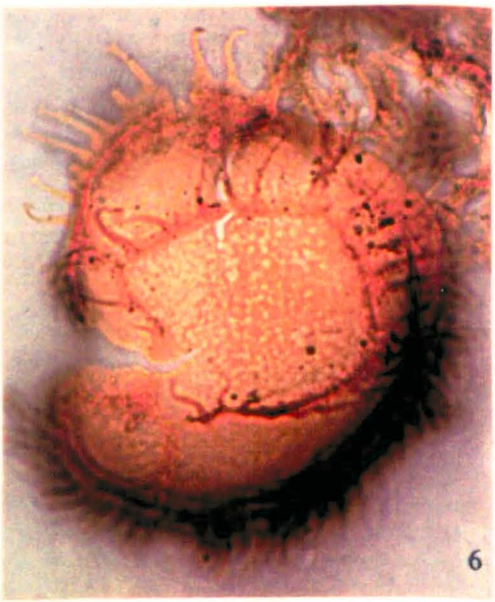

1

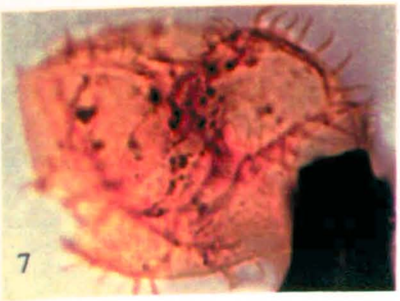

2


3


4


5


6


7


8

Plate 22.

Figure 1. *Pareodinia ceratophora* subsp. *scopaea* (Sarjeant) Lentin & Williams 1973, slide 89201.1, grid ref. 158.2 12.3, X860.

Figure 2. *Pareodinia ceratophora* (Deflandre) Gocht 1970, slide 89029.1, grid ref. 139.9 22.7, X500.

Figure 3. *Pareodinia prolongata* Sarjeant 1959, slide SALT 1.1, grid ref. 159.1 18.6, note lack of archaeopyle, X860.

Figure 4. *Pareodinia prolongata* Sarjeant 1959, slide SALT 17.2, grid ref. 157.7 21.4, X860.

Figure 5. *Tabulodinium senarium* Dodekova 1990, slide 89213.3, grid ref. 140.6 12.2, X860.

Figure 6. *Susadinium scrofoides* Döfhöfer & Davies 1980, slide 89016a, grid ref. 155.8 18.2, X860.

Figure 7. *Caddasphaera halosa* (Filatoff) Fenton *et al.* 1980, slide 89027.1, grid ref. 139.3 22.9, X500.

Figure 8. *Nummus velumiferus* n. sp., slide SALT 17.2, slide grid ref. 150.7 15.2, holotype, X860.

Figure 9. *Mancodinium semitabulatum* (Morgenroth) Below 1987, slide 89027.1, 156.2 7.0, X500.

Figure 10. *Moesiodinium raileanui* Antonesçu 1974, slide 89016a, grid ref. 145.8 17.9, X860.

Figure 11. *Nummus velumiferus* n. sp., slide SALT 17.2, grid ref. 165 14.3, paratype, showing folded wall, X860.

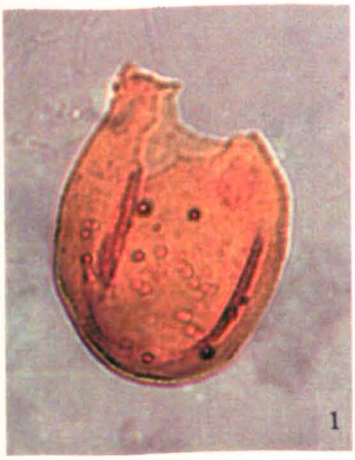
Figure 12. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 147.2 20.0, holotype, X860.

Figure 13. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 145.7 20.5, paratype, ventral view, X860.

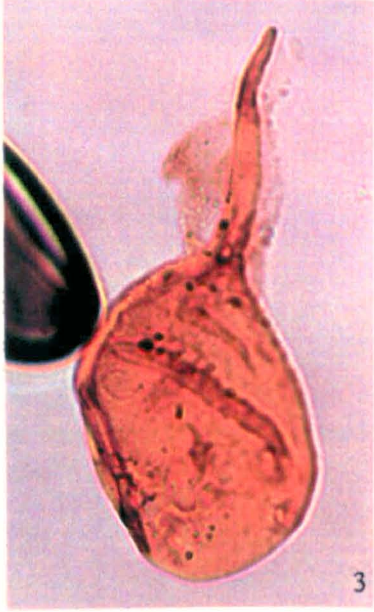
Figure 14. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 145.7 20.5, paratype, dorsal view, X860.

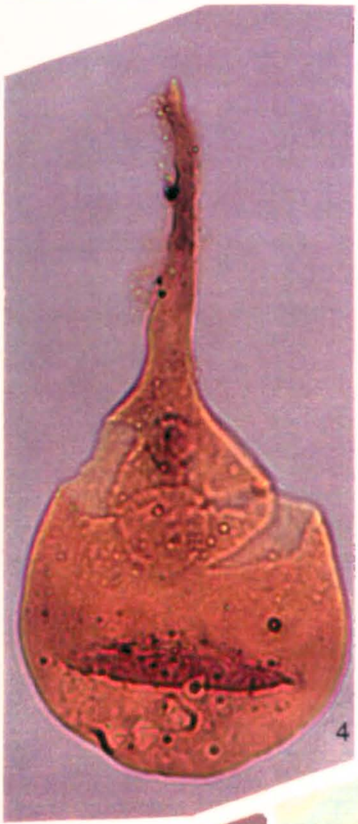
Figure 15. *Nummus velumiferus* n. sp., slide SALT 17.2, grid ref. 158.5 4.6, paratype, heavily degraded, X860.

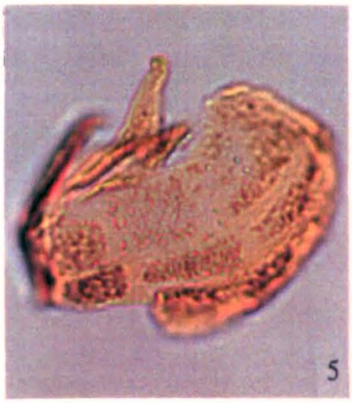
Plate 22

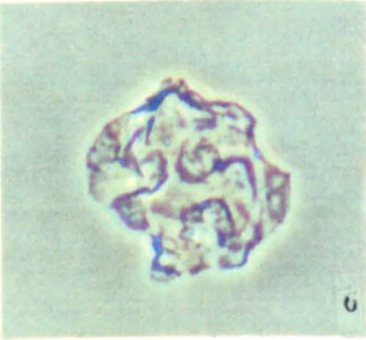

1


2

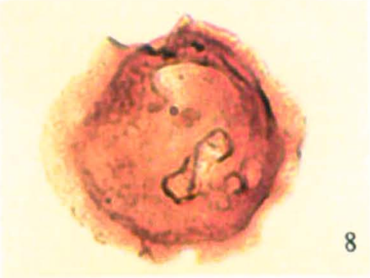

3

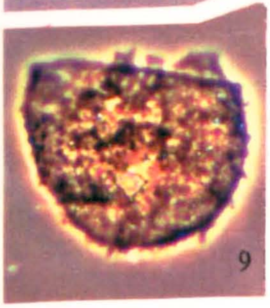

4

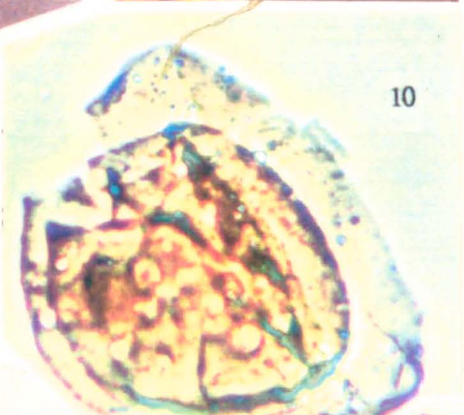

5


6


7


8


9


10


11


12


13


14

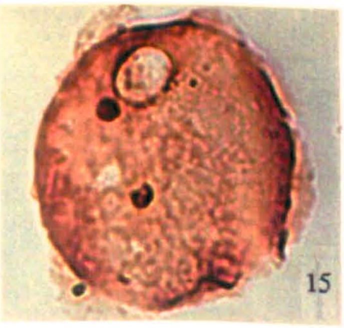

15

Plate 23.

Figure 1. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 132.1 17.9, paratype displaying cingular notch, X860.

Figure 2. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 155.3 21.8, paratype showing accessory archaeopyle fissures,

Figure 3. *Phallocysta spinosa* n. sp., slide 89016a, grid ref. 156.2 11.1, paratype showing alignment of the ectophragm ornament. The optical foveolate ornament is clearly visible on the hypocyst, X500.

Figure 4. *Nannoceratopsis gracilis* (Alberti) Evitt 1962, slide 89213.3, grid ref. 142.6 21.3, X860.

Figure 5. *Nannoceratopsis pellucida* (Deflandre) Evitt 1961, slide SALT 16.1, grid ref. 133.6 9.8, X860.

Figure 6. *Nannoceratopsis ambonis* (Drugg) Riding 1984, slide 89007.1, grid ref. 128.8 15.0, X860.

Figure 7. *Scalbiella reticulata* n. Gen and sp., slide 89302.1, grid ref. 157.2 15.4.

Figure 8. *Scalbiella reticulata* n. Gen and sp., slide 89302.1, grid ref. 134.5 10.2.

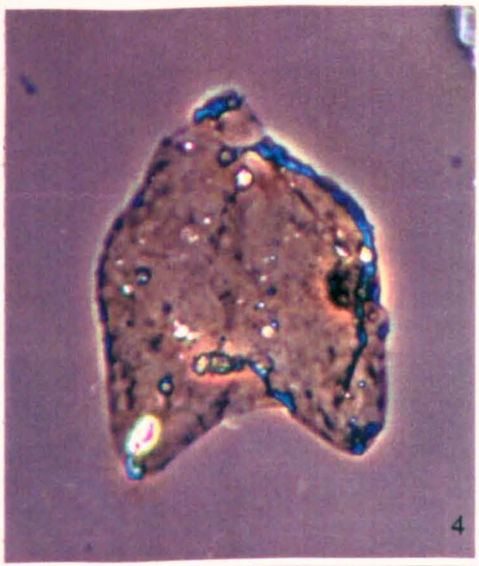
Figure 9. *Scalbiella reticulata* n. Gen and sp., slide 89302.5, grid ref. 133.7 14.8.

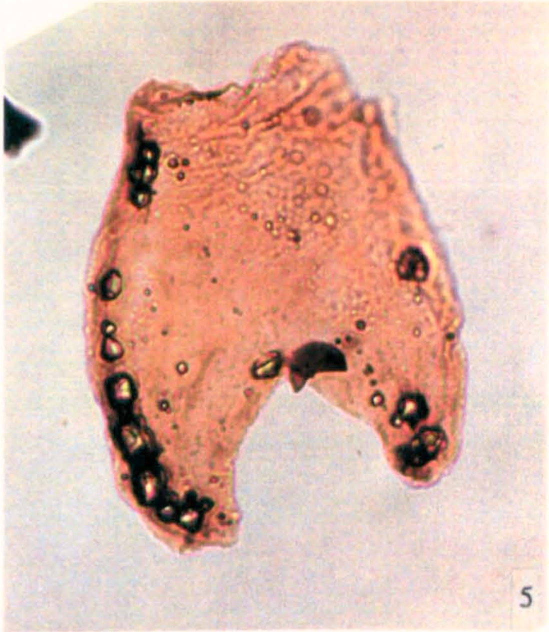
Plate 23

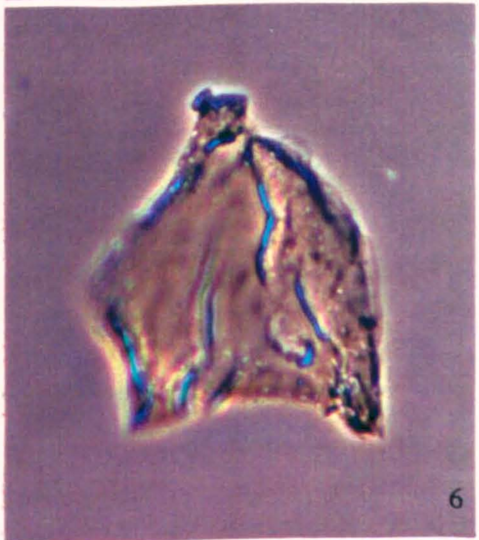

1


2


3

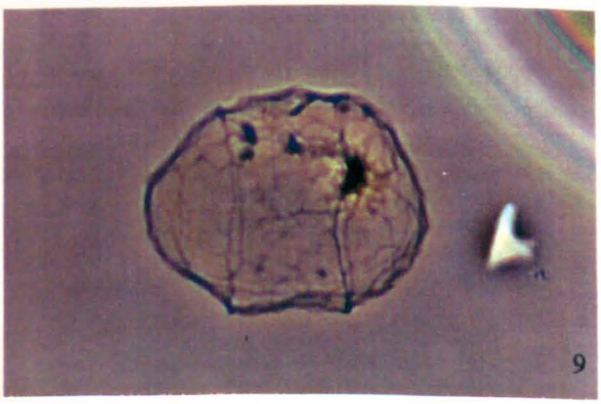

4


5


6


7


8


9

Enclosure 1. Cunstone Nab raw data and standardised data

Enclosure 2. Gristhorpe Bay raw data and standardised data

Enclosure 3. Yons Nab raw data and standardised data

Enclosure 4. Crook Ness raw data and standardised data

Enclosure 5. Saltergate raw data and standardised data

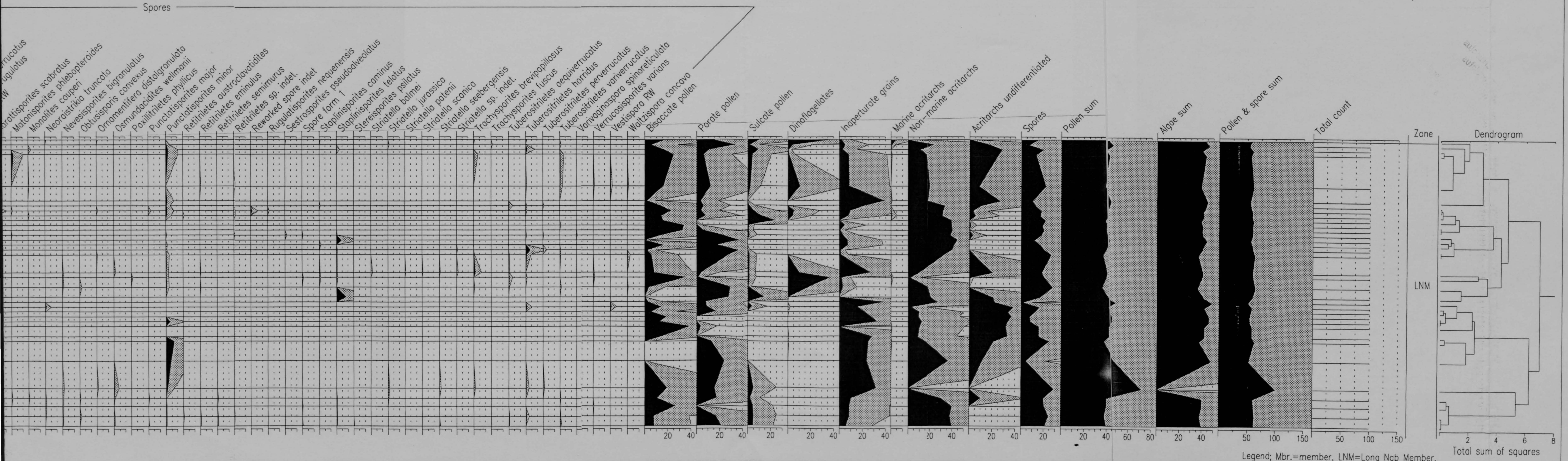
Enclosure 6. Talbot Wood raw data and standardised data

Enclosure 1. Cunstone Nab raw data and standardised data

Enclosure 2. Gristhorpe Bay raw data and standardised data

Gristhorpe Bay section, standardised (percentage) data.
Legend; M.=marine, U.=undifferentiated, RW=reworked.

Enclosure 2. Gristhorpe Bay raw data and standardised data



Legend; Mbr.=member, LNM=Long Nab Member.

Enclosure 2. Gristhorpe Bay raw data and standardised data

Gristhorpe Bay section, raw data.
Grouping and species legend; M.=marine, U.=undifferentiated,
RW=reworked.

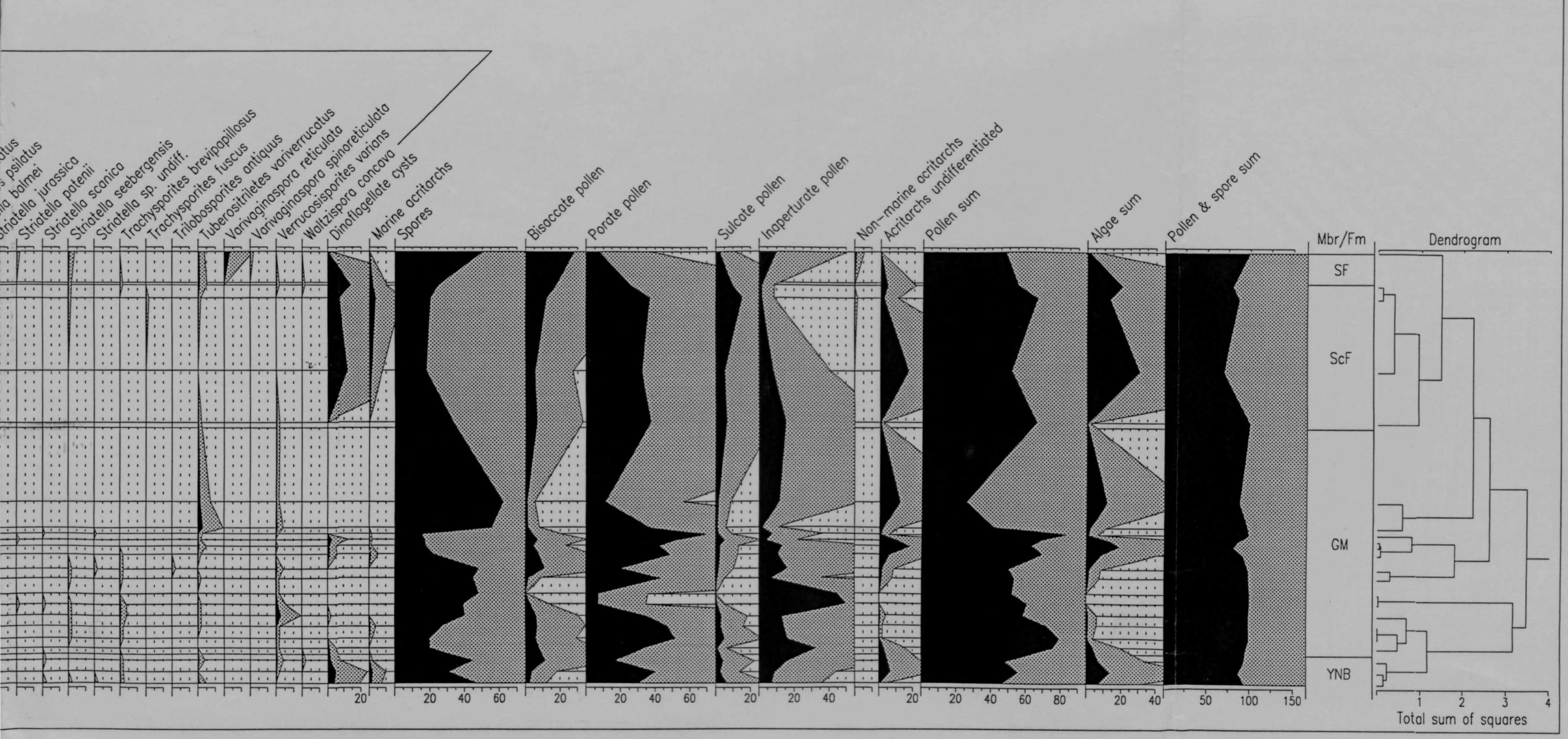
Enclosure 2. Gristhorpe Bay raw data and standardised data

Legend; Mbr.=Member, LNM=Long Nab Member.

Enclosure 3. Yons Nab raw data and standardised data

Yons nab section, standardised (percentage) data.
Legend;M.=marine,N.M.A.=non-marine acritarchs,U.=undifferentiated,
Mbr/Fm=member/formation,YNB=Yons Nab Beds,GM=Gristhorpe Member,
ScF=Scarborough Formation,SF=Scalby Formation.

Enclosure 3. Yons Nab raw data and standardised data



Enclosure 3. Yons Nab raw data and standardised data

Yons Nab section, raw data.
Legend;M.=marine,N.M.A.=non-marine acritarchs,U.=undifferentiated,
Mbr/Fm=member/formation,YNB=Yons Nab Beds,GM=Gristhorpe Member,
ScF=Scarborough Formation,SF=Scalby Formation.

Enclosure 3. Yons Nab raw data and standardised data

Enclosure 4. Crook Ness raw data and standardised data

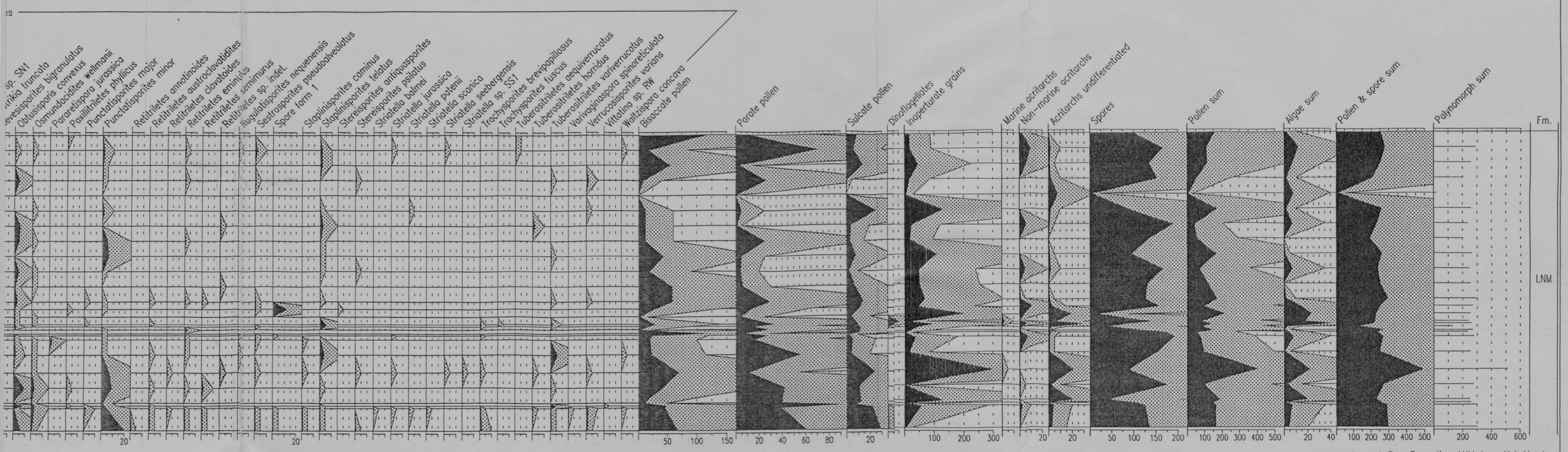
Crook Ness section, standardised (percentage) data.
Grouping legend; A.=marine acritarchs, N.M.A.=non-marine acritarchs,
A.U.=acritarchs undifferentiated.

Legend; Mbr.=member, LNM=Long Nab Member.

Enclosure 4. Crook Ness raw data and standardised data

Crook Ness section, raw data.
Grouping legend; A=marine acritarchs, N.M.A.=non-marine acritarchs,
A.U.=acritarchs undifferentiated.

Enclosure 4. Crook Ness raw data and standardised data



Legend; Fm.=Formation, LNM=Long Nab Member.

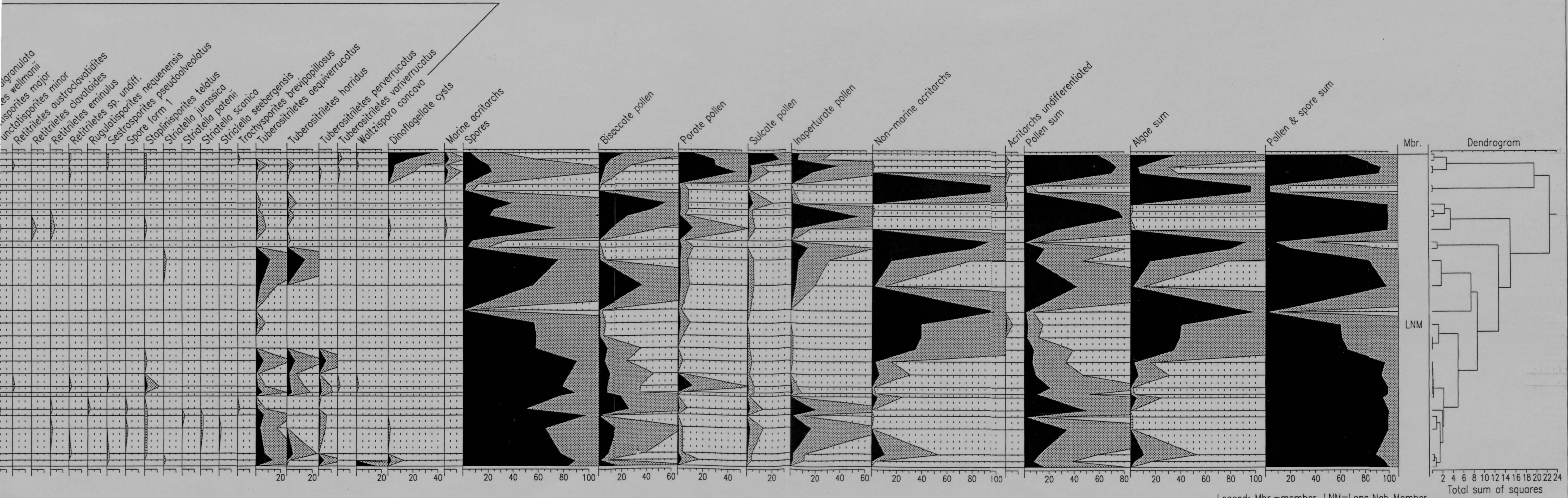
Enclosure 5. Saltergate raw data and standardised data

Enclosure 5. Saltergate raw data and standardised data

Enclosure 5. Saltergate raw data and standardised data

Saltergate section, standardised (percentage) data.
Grouping legend;M.=marine, U.=undifferentiated.

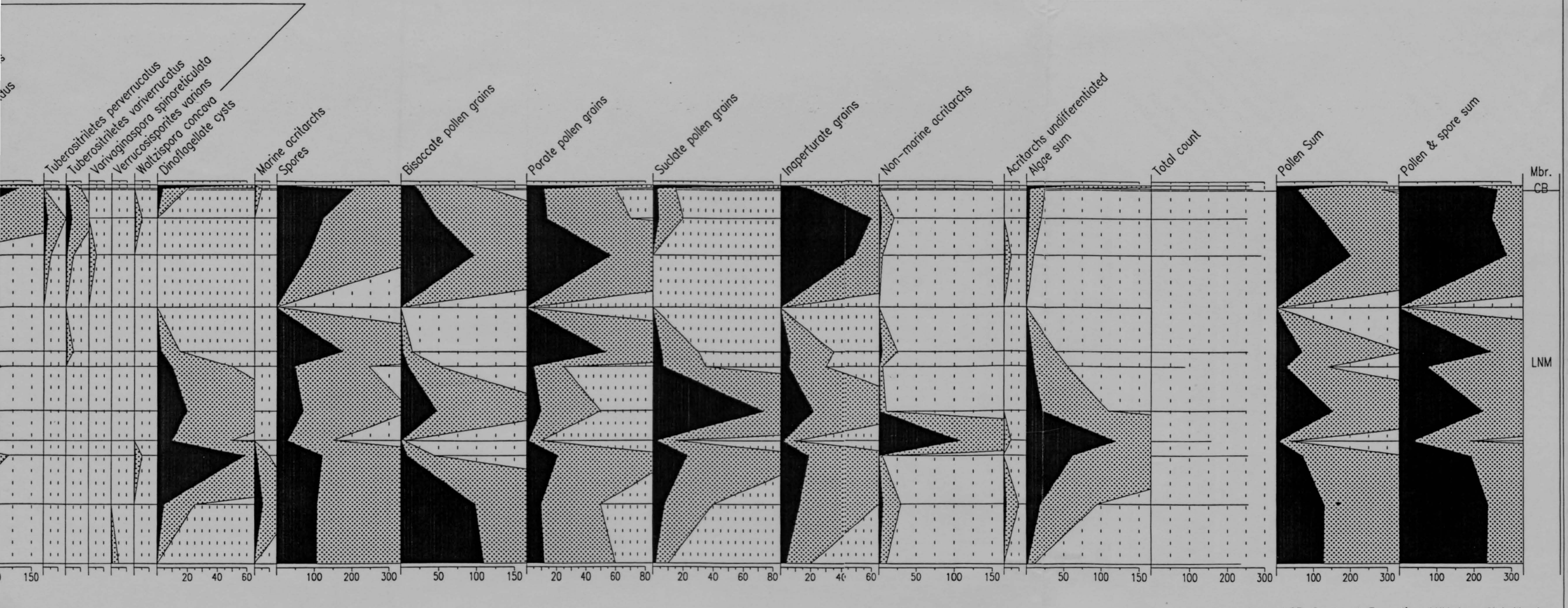
Enclosure 5. Saltergate raw data and standardised data



Legend; Mbr.=member, LNM=Long Nab Member.

Enclosure 6. Talbot Wood raw data and standardised data

Enclosure 6. Talbot Wood raw data and standardised data



Legend;CB=Cornbrash Formation. LNM=Long Nab Member.

Enclosure 6. Talbot Wood raw data and standardised data

Talbot Wood section, standardised (percentage) data.
Grouping legend; Por.=porate, Inap.=inaperturate, A.=marine acritarchs
N.M.A.=non–marine acritarchs, A.U.=acritarchs undifferentiated.

Legend; CB=Cornbrash Formation, LNM=Long Nab Member.