High resolution comparative palynostratigraphy and palaeoecology of Oligocene sequences in the terrestrial basins of the Western British Isles and the marine North Sea Basin.

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Volume II

SYSTEMATICAL PALYNOLOGY

A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

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Submitted March 1996

CHAPTER 11

SAMPLE PREPARATION AND LABORATORY PROCESSING TECHNIQUES

SAFETY

Protective measures for all laboratory work discussed in the following text was adhered to at all times. A laboratory coat, safety goggles, protective barrier hand cream, inner latex gloves and outer rubber gloves were worn at all times when handling samples. All work with acids was undertaken in fume cupboards.

SAMPLES

A variety of lithologies from the British Oligocene deposits including clays, silty sandy clays, silts, lignites and conglomerates were prepared for palynological study. Out of 168 samples processed 167 were productive and yielded palynological assemblages of varying degrees. The samples more likely to yield palynomorphs, such as silts, lignites and the darker organic rich rocks, were chosen to be processed, in preference to other lithologies. While at the same time it was important to try to keep a relatively close sample spacing of 50 cm to 100 cm, for the six terrestrial sections studied and 20 to 60 ft for the two marine sections studied.

A quantitative technique for preparation was used. A weighed amount of sample, either core or cuttings was crushed, the amount being dependant on lithology. For lignites (Lough Neagh) 2 to 5g gave sufficient material for mounting, for core material 10g was needed and for the North Sea ditch cuttings 1 to 20g was used depending on the quantity supplied.

Laboratory processing techniques

1) Before processing the North Sea Well section 21/28b-7, the washed and dried cuttings were sieved using a 170μm copper top sieve, the bottom fraction was kept, then crushed. For the core samples this initial sieving was not necessary and the samples were crushed in a clean metal pestle and mortar.

2) The crushed sediments were placed into 400ml plastic pots with perforated lids. Each sample was tested for the presence of calcium carbonate with dilute HCl (5%). If Carbonates were present the samples were treated with concentrated HCl (36%). This was added in 10ml increments to allow effervescing to cease between each application. This was then left until all carbonate minerals were removed. The HCL was decanted off and tap water added. This decanting process continued until the sample became neutral.

3) The samples then underwent HF maceration to remove the silicate minerals present. Here 40% HF was added slowly to the sample in case of any violent exothermic reactions, upto about 100ml in total. This is then stored in a fume cupboard and stirred daily with a glass rod until no 'grit' was felt under the stirring rod indicating that the breakdown of the sample was complete. The HF was decanted off and the sample then made neutral with tap water.

4) The residue was transferred to a perspex sieve with a quality controlled 7μm sieve mesh. A low pressure sieving technique was used for speed and efficiency to remove 'fines' from the sample. In this method the sieve is placed over a plastic buckner flask sealed at the top with a rubber ring, a side arm off this flask, connected by a rubber tube to a vacuum device, powered by the cold water tap, creates a vacuum. The vacuum produced reduces the pressure in the flask and sucks the water through the sieve at a much enhanced rate.

5) After this initial sieving an 8-10 minute 'Nitric wash' to remove pyrite staining and to lightly oxidise the residue was undertaken, using 100ml of concentrated Nitric Acid. The sample was then placed in a glass beaker and topped upto a volume of 1000ml with tap water. This was then sieved to neutral.

6) Heavy liquid separation, to separate the organics and palynomorphs from any remaining mineral material such as mica, was then undertaken. The heavy liquid used was ZnCl which has a specific gravity (S.G.) of 1.95. To this a drop of HCl was added to stop the ZnCl forming compounds with any residual HF present in the sample. The residue and heavy liquid were placed in centrifuge tubes, shaken and then spun in the centrifuge for 12 minutes at 2200 rpm. After this process the floating organic fraction at a S.G. of 1.40 was separated from the heavier silica material, at a S.G. of 2.65. The organic fraction concentrated on top of the heavy liquid was removed by pipette and placed into a 100ml beaker of tap water (with a drop of concentrated HCL in to dissolve any precipitates). The sample was then sieved to neutral.

7) For samples with abundant amorphous organic matter (AOM) such as the North Sea samples from 21/28b-7 and 16/16b-4, the residues were treated with 2% NaCl (bleach) and placed in an ultrasonic bath for 60 seconds in order to break up the AOM and dissolve it.

8) No alkali treatments were adopted as these can cause the pollen grains to swell in size, this is important because at the present time pollen speciation (in some cases) is based on size differences.

9) The final residue is put into a 7.5 ml phial, the residue was diluted quantitatively until thin enough concentrations to work with were obtained. A drop of PVA (Polyvinyl alcohol) dispersant was added, to avoid the palynomorphs clumping together when drying the residues onto the glass cover slips. Finally these strew

mounts were mounted onto glass slides with a petropoxy resin. Four slides were made for each sample processed.

At all stages of the processing great care was taken to assure none of the sample was lost, so that the quantitative results obtained were as accurate as physically possible. This quantitative method is very useful as it enables calculations of palynomorphs per gram for each sample and also direct comparison between different samples.

CHAPTER 12

SYSTEMATIC PALYNOLOGY

INTRODUCTION:

The geological interpretations and conclusions of this study are based on a deatiled palynological investigation of numerous Oligocene sediments from the western British Isles. In order to give validity to this palynological research and the interpreted results, a systematical approach to the palynological work is needed.

In developing such a pragmatic approach, the first major hurdle to overcome was the disorder in the literature regarding classification of Tertiary pollen and spores. This disorder has developed through time, as various Tertiary palynologists have adopted numerous different taxonomic procedures. No consistent method of systematic taxonomy has been adhered to, restricting the value of the results in the literature, making them incompatible.

The North American school of palynologists such as Traverse (1955) and Leopold & Macginite (1972) have used the generic names of living plants to describe fossil pollen and spores. Macko (1957), Simpson (1961), Sein (1961a) and Machin (1971) are some of the few European workers who have followed this approach. The majority of European Tertiary palynologsts follow the work of Thomson & Pflug (1953), who defined a large number of form genera and species based on the morphology of the fossil palynomorphs. This approach was accepted and taken further by the work of Krutzsch (1958 and 1970) with the introduction of 'Form Groups'.

A radically different taxonomic and systematic approach was devised by Hughes (1976 and 1986). He defined a system of 'biorecords'. These involved accurate descriptions and clear illustrations with large numbers of each specimen being described for a single biorecord. Under this system all specimens identified by workers other than the originator are described as *cf.* A, i.e. they are comparable to the original. Those with significant differences are referred to as *cf.* B.

Another recently used method was adopted by Wilkinson & Boulter (1980) who used a genusbased system of classification. This involved the use of morphological form genus groups previously published in the literature. A grid system of forms was used instead of defining species; this grid combined two morphological features, often those showing the most variation e.g. size and wall structure or ornamentation. Letters were used within the grid, giving generic names, suffixed with a letter.

As a result of these different aproaches, various conflicting and differing systems of naming fossil pollen and spores, the published literature can be confusing. This 'chaotic' state greatly restricts the value of comparing the published records, which in

turn contributes to the view that pollen and spores are an unsuitable stratigraphical tool. This was furthered by Wilkinson & Boulter (1980) who considered that pollen and spores, are in fact facies controlled, and therefore of little use stratigraphically. Although the stratigraphical use of pollen and spores has been proved by the work of Schroder (1992), Jolley & Spinner (1991) and Jolley (1992a).

This systematic chapter is aimed at presenting a rationalised and realistic approach to the palynological problems mentioned above. It was decided that the most realistic and repeatable method of study was to use the already vast number of genera and species that have been erected, in a systematic and most importantly, a reusable way.

In choosing a systematic approach, the work of Wilkinson & Boulter (1980) was taken as a starting point, but once into the study it was found that it did not provide enough detail. The reduction of the binomial names to genera only, is problematic. Firstly, in reducing the value of the results stratigraphically when compared to the binomial system, and secondly by leading to the duplication of many species already in the literature; Wilkinson & Boulter (1980) suffixed their form genera with a letter depending on various combinations of morphologies but then went on to compare these letters to published species! The system of using extant genera and species to name fossil pollen and spores (Traverse, 1955) is also not used here as it implies a botanical affinity based on morphology alone, which is dubious in itself. The easy to use morphological form genus and species and form groups of Thomson & Pflug (1953) and Krutzsch (1958 and 1970) respectively give good, simple, but detailed descriptions of genera and species giving a large range of illustrations. This study is based on Form Taxa, as they are well established in the literature and the range of specimens described and illustrated gives a reliable, tested and usable "standard" to work from. The aim of this work is not as a complete taxonomic and systematic 're-think', as this would probably only add to the current confusion.

This work was undertaken on an Olympus BH-2 biological microscope and all the samples were studied under phase contrast. Where possible each palynological slide or sample was logged until a count of 250 palynomorphs was reached. The slide was then scanned for any other taxa outside the count that had not previously been recorded in that sample. For sample where both dinoflagellates as well as pollen and spores were encountered, a count of 250 for both was separately undertaken, in order to be able to make direct and statistical comparisons between the sets of pollen data and dinoflagellate data from the different sections this is especially important when comparing the pollen data from the marine sequences directly with those from terrestrial sequences.

Layout

The layout of the following systematic chapter is devised so as to make it as easy as possible, to follow the reasoning behind each generic and species identification. The genera are described in alphabetical order with species also alphabetically arranged. Here the type species is given for each genus described. Generic remarks are given to establish the diagnostic and characteristic features critical for the identification of each genera described.

Species are arranged alphabetically and for each a 'reference' is given. This reference refers to details of illustrations in the literature which show representative specimens of the species in question, and give an idea of the range involved in particular, the writers concept of the taxon. This is thought the best way of "standardising" what is named, while at the same time giving a direct comparison to the published literature. Only one or two specimens of each species are usually represented in plates and figures; these are often the most photogenic, and as a result give only a limited idea of the range of morphologies occurring within each species. The direct cross referencing to the literature used in this study, helps to circumvent these difficulties, as the 'reference' choosen aims to give a clear idea of the range of morphologies and variation seen for each species, where possible. Comments for each species, detailing the features critical for identification, and any other interesting features seen within the study are discussed. Where appropriate relative abundances are compared with those stated in the published literature. The occurrences of the species in this study are not detailed here as they are shown graphically on Tilia Charts (see enclosures 1-10). An idea of the stratigraphical range of the taxa compiled from published records for NW Europe is included here. Possible botanical affinities have been suggested for each of the form genera or species so as to give an idea of the range of parent vegetation. These botanical affinities have been described further and discussed along with the palaeoenvironmental conclusions (Chapter 9).

Morphological and other descriptive terms used in the description of the pollen and spores in this study are detailed fully in the work of Kremp (1968) and Thomson & Pflug (1953). Some new species have been created in this study and they are treated informally here, for example Genus sp. A.

The large scale or supergeneric organisation of the chapter shows two major divisions:

Division I Sporites (Potonie, 1893)
Division II Pollenites (Potonie, 1931a)

The first division is for spores and is further subdivided based on gross morphology into three classes: Aletes (Ibrahim, 1933), Monoletes (Ibrahim, 1933) and Triletes

(Rheisch, 1881) Potonie & Kremp, 1954. A separate group at the end of this division describes fungal and algal spores.

The second division is for pollen, this is further subdivided based on gross morphology and pore structures into fourteen groups: Bisaccates, Monocolpates, Dicolpates, Monoporates, Inaperturates, Atriate, Complex wall structures, Vestibulate pores, Simple nonatriate pores, Short polar axis tricolporates, Syncolporates, Colpates, Tricolporates and Tetradites.

DIVISION I SPORITES (Potonie, 1893)

Class Aletes (Ibrahim, 1933)

Genus ***Corrusporis*** Krutzsch, 1967a

TYPE SPECIES: ***Corrusporis tuberculatus*** Krutzsch, 1967a; p. 30 & 226, pl. 89, figs 1-8.

GENERIC REMARKS: This genus describes medium sized alete forms with a circular amb. They are thick walled and display a heavy uniform ornament varying from granulate, verrucate, baculate to tuberculate. Krutzsch (1967a) described specimens from this form genus from the Middle Oligocene to Lower Miocene and Lower Pleistocene of E. Germany. In this study occurrences were seen in all sections except those in the North Sea.

BOTANICAL AFFINITY: Bryophyta; *Pohlia*, *Leptostomum*, *Meesea* and *Pottia* are suggestions given by Krutzsch, 1967a and Jansonius & Hills, 1976

Corrusporis granotuberculatus Krutzsch, 1967a

Plate 1, Figure 1

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 224, pl. 88, figs 12-17 and Wilkinson & Boulter, 1980; p. 46, pl. 2, figs 11-12 are regarded as typical specimens.

COMMENTS: This alete rounded spore is covered with a closely packed ornament of round topped conical to flat topped verrucae. This form is smaller (25-45μm) than *C. tuberculatus* which is 45-60μm in size.

STRATIGRAPHIC RECORD: Upper Oligocene of Germany Krutzsch, 1967a

BOTANICAL AFFINITY: See under Genus heading above

Corrusporis tuberculatus Krutzsch, 1967a

Plate 1, Figures 2 to 5

REFERENCE: Krutzsch, 1967a; p. 226, pl. 89, figs 1-8 are regarded as typical specimens.

COMMENTS: A large alete circular spore having a thick wall ornamented with very characteristic large tuberculate elements. These are polygonal in outline and straight sided with flat tops in profile, and they show variation to more bulbous forms. This species is differentiated from *C. granotuberculatus* due to its larger size and more tuberculate character of the ornament. Krutzsch (1967a) subdivided this species but the divisions are not used here as are thought an unnecessary complication with no significant advantage stratigraphically being gained from it.

STRATIGRAPHIC RECORD: Middle to Upper Oligocene (Krutzsch, 1967a); Upper Pliocene of S Bohemia (Pacltova, 1960).

BOTANICAL AFFINITY: See under Genus heading above

Class Monoletes (Ibrahim, 1933)

Genus ***Echinosporis*** Krutzsch; 1967a

TYPE SPECIES: ***Echinosporis echinatus*** Krutzsch, 1967a; p. 172, pl. 63, figs 10-13.

GENERIC REMARKS: Simple bean shaped monolete spore with echinate sculpture.

Echinosporis echinatus Krutzsch, 1967a

Plate 1, Figures 6 & 7

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 172, pl. 63, figs 10-13 are typical specimens.

COMMENTS: Easily recognisable small monolete spore, with the monolete mark not quite extending the full length of the spore body. The echinate sculpture is characteristic of this species with each element having pointed tips. This species is present in the Sea of the Hebrides and North Sea sections and has a peak occurrence of 1.5% in 78/1 and 21/28b-7.

STRATIGRAPHIC RECORD: Miocene of Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Arcto-Tertiary form (Krutzsch, 1967a); *Onoclea* (Polypodiaceae) in the British Palaeocene (Boulter & Kvacek, 1989)

Echinosporis sp. **1** sp. nov.

Plate 1, Figure 8

COMMENTS: This is a small monolete spore, the monolete mark not quite extending the full length of the spore body and is often indistinct due to the heavy ornament. The exine is thick, much thicker compared with *E. echinatus*. The sculptural elements are composed of large irregular echinae with rounded tips, which are irregularly spaced over the surface. This species often shows an orange spore colouration.

STRATIGRAPHIC RECORD: In this study rare to present occurrences are recorded in the Sea of the Hebrides and Rona Basin sections with a peak occurrence of 1.1% in 78/1.

BOTANICAL AFFINITY: Unknown

Genus ***Laevigatosporites*** Ibrahim, 1933

TYPE SPECIES: ***Laevigatosporites vulgaris*** Ibrahim, 1933; p. 13, pl. 1, fig. 13.

GENERIC REMARKS: Psilate bean shaped monolete spore, with the monolete mark greater than half the length of the spore body.

Laevigatosporites discordatus Thomson & Pflug, 1953

Plate 2, Figures 1 & 2

REFERENCE: Thomson & Pflug, 1953; p. 59, pl. 3, figs 40-43 and Krutzsch, 1967a; p. 152, pl. 54, figs 8-9 are regarded as typical specimens.

COMMENTS: Characteristically larger than *L. haardti* with a more rounded amb and thicker exine.

STRATIGRAPHIC RECORD: Late Palaeocene of S England (Graus-Cavagnetto, 1976); Palaeocene to Lower Oligocene of West Germany (Thomson & Pflug, 1953); Middle Eocene to Middle Oligocene of East Germany (Krutzsch, 1967a); Middle Eocene of France (Chateauneuf, 1980); British Oligocene (Wilkinson & Boulter, 1980) and the Miocene of Germany (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Polypodiaceae (Thomson & Pflug, 1953)

Laevigatosporites haardti (Potonie & Venitz, 1934) Thomson & Pflug, 1953

Plate 2, Figure 3

REFERENCE: Thomson & Pflug, 1953; p. 59, pl. 3, figs 27-38 and Krutzsch, 1967a; p. 146, pl. 52, figs 12-18 are regarded as typical specimens.

COMMENTS: Small in size and thin walled. These are the most abundant spores in the British Oligocene deposits.

STRATIGRAPHIC RECORD: Common in the Tertiary. Early Palaeocene to Oligocene in Germany (Thomson & Pflug, 1953); Palaeocene of Belgium (Roche, 1965 and Krutzsch & Vanhoorne, 1977); Late Palaeocene and Early Eocene of SE. England (Graus-Cavagnetto, 1970b; 1976)

BOTANICAL AFFINITY: Polypodiaceae (Chateauneuf, 1980)

Genus ***Microfoveolatosporis*** Krutzsch, 1959b

TYPE SPECIES: ***Microfoveolatosporis pseudodentatus*** Krutzsch, 1959b; p. 212, pl. 14, fig. 463.

GENERIC REMARKS: Bean shaped monolete spore having a thick wall with a foveolate sculpture which can form a weak pseudoreticulum. The monolete mark is distinct and straight.

Microfoveolatosporis pseudodentatus Krutzsch, 1959b

Plate 2, Figures 4 & 5

REFERENCE: Krutzsch & Vanhoorne, 1977; p. 20, pl. 9, figs 5-6 and Krutzsch, 1959b; p. 212, pl. 41, fig. 463 are regarded as typical specimens.

COMMENTS: Large monolete spore with scattered foveolate sculpture, easily differentiated from *M. pseudoreticulatus* which is more elongate its length, being two times as long as its width

compared with *M. pseudodentatus* which is 2/3rds as wide as it is long.

STRATIGRAPHIC RECORD: Middle Eocene of Germany (Krutzsch, 1959b)

BOTANICAL AFFINITY: Unknown

Genus ***Verrucatosporites*** Pflug & Thomson in Thomson & Pflug, 1953

TYPE SPECIES: ***Verrucatosporites alienus*** (Potonie, 1931a; p. 566, fig. 1) Pflug & Thomson, 1953; p. 59-60, pl. 3, figs 46-51.

GENERIC REMARKS: Bean shaped monolete spore, with the monolete mark being prominent but not extending the full length of the spore. Some species have slightly concave proximal surfaces. The diagnostic characteristic of this genus is the ornament which is composed of prominent verrucae. Speciation is determined on the size and distribution of the ornament. During logging some specimens could only be identified to genus level due to poor preservation, therefore could not be confidently ascribed to a species and are referred to here, and in the occurrence charts (80/14) as *Verrucatosporites* spp..

Verrucatosporites alienus (Potonie, 1931a) Thomson & Pflug, 1953

Plate 2, Figures 6 to 8

REFERENCE: Krutzsch, 1967a; p. 182, pl. 67, figs 3, 12-15 and Thomson & Pflug, 1953; p. 59-60, pl. 3, fig. 47 are regarded as typical specimens.

COMMENTS: Typically a medium sized spore with an ornament of verrucae with rounded outlines which are widely spaced and reduced towards the monolete mark. In profile the verrucae appear as individual round topped cones 2-4 μm in size. These sometimes grade into, or are similar to those of *V. histiopteroides* in profile as these verrucae have

characteristically wide flat tops. But the verrucae are more irregular in outline and can be easily distinguished from the rounded outline of the verrucae of *V. alienus*.

STRATIGRAPHIC RECORD: Oligocene to Miocene of E. Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Polypodiaceae (Thomson & Pflug, 1953)

Verrucatosporites balticus (Krutzsch, 1962) Krutzsch, 1966

Plate 3, Figure 1

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 177-178, pl. 65, figs 12-26 are regarded as typical specimens.

COMMENTS: A monolete spore usually with a concave proximal surface. The ornament is of prominent verrucae 2-4 μm in size, which are irregular, oval in outline and are very closely spaced, compared to *V. alienus*. In profile the verrucae appear as closely spaced, nearly overlapping, rounded bulbous lumps. Krutzsch (1967a) recognised two subspecies namely; *V. balticus* subsp. *balticus* and *V. balticus* subsp. *major* which he differentiated on size only. Specimens encountered in this study are only referred to at species level due to the infrequent occurrence of specimens as well as no justification being found by the author for this subdivision.

STRATIGRAPHIC RECORD: Middle Oligocene to Miocene (Krutzsch, 1962); Oligocene of British Isles (Wilkinson, 1979; Wilkinson & Boulter, 1980 and Evans *et al.*, 1991)

BOTANICAL AFFINITY: *Nephrolepis* (Erdtman, 1947); Polypodiaceae (Graus-Cavagnetto, 1978; Chateauneuf, 1980; Krutzsch, 1967a)

Verrucatosporites favus (Potonie, 1931a) Pflug & Thomson in Thomson & Pflug, 1953

Plate 3, Figure 2

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 184, pl. 68, figs 1-12 and Thomson & Pflug, 1953; p. 60, pl. 4, figs 1-4 are regarded as typical specimens.

COMMENTS: This medium sized monolete spore can be both concave and convex on the proximal surface. The ornamentation is its distinguishing feature as the verrucae are subrounded to polygonal in outline and closely spaced, but are much lower in profile than *V. balticus*. Also the ornament reduces in size and definition towards the monolete mark, this is more marked than in species such as *V. balticus*. *V. secundus* has similar verrucae with a low profile but in plan view they are more faint than in *V. favus*.

STRATIGRAPHIC RECORD: Miocene of Germany (Thomson & Pflug, 1953); Middle Oligocene to Lower Miocene of Germany (Krutzsch, 1967a); Oligocene of the Western British Isles (Evans *et al.*, 1991 and Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Polypodiaceae (Thomson & Pflug, 1953; Krutzsch, 1967a; Graus-Cavagnetto, 1978)

Verrucatosporites histiopteroides Krutzsch, 1962

Plate 3, Figure 3 and Plate 4, Figure 1

REFERENCE: Krutzsch, 1962; p. 269, pl. 11, figs 1-6 and Krutzsch, 1967a; Atlas IV & V, p. 200, pl. 76, figs 1-7 are regarded as typical specimens.

COMMENTS: This is the most distinctive species of this genus, it is medium to large in size, generally with a concave proximal surface. The verrucae are relatively widely spaced and protrude as large straight sided flat topped verrucae upto 8 µm wide. The main diagnostic feature along with this distinctive profile is the outline of the verrucae which are irregular to elongate with edges that are characteristically 'etched' or ragged. Krutzsch (1967a) recognised two subspecies differentiated on size namely; *V. histiopteroides* subsp. *histiopteroides* and *V.*

histiopteroides subsp. *minor* but these have not been utilised in this study due to the low abundances of this species and also no palaeoecological and stratigraphical necessity for such a split, therefore no justification could be found for this differentiation.

STRATIGRAPHIC RECORD: Middle Oligocene to Miocene of Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: *Histiopteris incisa*, Denistedaceae (Krutzsch, 1967a)

Verrucatosporites megabalticus Krutzsch, 1967a

Plate 4, Figures 2 & 3

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 180, pl. 66, figs 1-13 are regarded as typical specimens.

COMMENTS: This medium sized monolete spore with verrucate ornament is easily distinguished from other species. Firstly by its concave proximal surface and secondly by its very distinctive verrucae. The verrucae are subrounded in outline and large in size c. 5 μm. These are much larger than *V. balticus* and protrude more in profile being very rounded and bulbous in character. Often due to the size of the verrucae, as few as five individual verrucae can be counted along the long axis of the amb (see figure 2 & 3, plate 4). It is distinguished from *V. alienus* by having more closely spaced verrucae and by its bulbous rounded verrucae in profile when compared to the distinct cones or peaks of *V. alienus*.

STRATIGRAPHIC RECORD: Middle Oligocene to Lower Miocene of E. Germany (Krutzsch, 1967a); Middle Oligocene of Poland (Ziembinska-Tworzydlo, 1974); Oligocene of Western British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Polypodiaceae

Class Triletes (Rheisch, 1881) Potonie & Kremp, 1954

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

TYPE SPECIES: ***Baculatisporites primarius*** (Wolff, 1934; p. 66, pl. 5, fig. 8) Pflug & Thomson in Thomson & Pflug, 1953; p. 56, pl. 2, figs 49-53.

GENERIC REMARKS: The emended diagnosis of Krutzsch (1967a) is used as it broadens the original diagnosis to include all spores with an osmundoid (granular) character of ornamentation, as well as echinate and baculate sculpture. No significant palaeoecological or stratigraphical significance can be gained from having these as separate genera (Wilkinson & Boulter, 1980). The genus contains azonotrilete spores with a circular amb. The trilete mark extends over $^{2}/_{3}$rds of the spore radius, in length. The exine is relatively thin and two layered, the sculptural elements are densely packed and range from weakly echinate, baculate to rugulate and vary in size, sometimes even on a single grain.

Baculatisporites nanus (Wolff, 1934) Krutzsch, 1959b

Plate 5, Figure 1

REFERENCE: Krutzsch, 1967a; p. 60, pl. 13, figs 1-43 are regarded as typical specimens.

COMMENTS: As for *B. primarius*, but differentiated by its smaller size being less than 30 μm. Again Krutzsch (1967a) has described five subspecies, these are not used here due to the variation in ornamentation of the specimens which makes the identification of the subspecies impractical.

STRATIGRAPHIC RECORD: Upper Oligocene to Pliocene in Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Osmundaceae

Baculatisporites primarius (Wolff,1934) Pflug & Thomson, 1953

Plate 5, Figure 2

REFERENCE: Thomson & Pflug, 1953; p. 56, pl. 2, figs 49-53 and Krutzsch, 1967a; p. 54, pl. 9, figs 1-12 are regarded as typical specimens.

COMMENTS: This is a medium sized miospore with a rounded amb. The trilete mark extends $^{2}/_{3}$rds of the diameter of the spore and is sometimes gaping. The ornamentation of densely spaced baculae grades into rugulate and echinate sculptural elements. Krutzsch (1967a) recognised five subdivisions of this species. These subdivisions are not used here as are thought to be an unnecessary complication and the variation of ornamentation that occurs both, between specimens and within specimens makes the identification of the subspecies impractical.

STRATIGRAPHIC RECORD: British Oligocene (Wilkinson & Boulter, 1980); Pliocene of Germany (Thomson & Pflug, 1953); Palaeocene to Eocene of Germany (Krutzsch, 1966 and Takahaski & Jux, 1982); Eocene to Oligocene of France (Chateauneuf, 1980)

BOTANICAL AFFINITY: Osmundaceae, *Osmunda* (Thomson & Pflug, 1953)

Genus ***Camerozonosporites*** Pant ex. Potonie, 1956

TYPE SPECIES: ***Camerozonosporites cretaceus*** Wayland & Krieger; 1953; p. 12, pl. 3, fig. 12) Potonie, 1956; p. 65.

GENERIC REMARKS: This genus was first published by Pant but was validated later by Potonie (1956). The emended diagnosis of Klaus (1960) is used here as it details the ornamentation, which was missing from the original diagnosis. This genus describes a trilete miospore in which the trilete rays nearly reach the equator. The amb is rounded to subtriangular in shape with a cingulum developed around the spore body. The cingulum distinctively

narrows at the corners of the amb (the radial areas) and has a maximum thickness interradially.

Camerozonosporites heskemsis (Pflanzl in Murriger & Pflanzl, 1955) Krutzsch, 1959b

Plate 5, Figures 3 & 4

REFERENCE: Krutzsch, 1963a, Atlas II, p. 122, pl. 42, figs 1-4 are regarded as typical specimens.

COMMENTS: This small to medium sized, subtriangular to rounded trilete miospore, has a characteristic psilate cingulum developed around the spore body. This cingulum varies in thickness, being thinnest in the radial areas and thickest in the interradial areas. The proximal surface is smooth to finely granulate showing a trilete mark which extends nearly to the equator. The distal surface is strongly ornamented with irregular shaped verrucae upto 4 μm long. There is only a fine distinction between this and *C. semilevis* Krutzsch (1963) which has finer verrucate or hamulate ornamentation in which the verrucae are often more joined or fused together.

STRATIGRAPHIC RECORD: Palaeocene of Germany (Krutzsch, 1959b); Upper Eocene to Oligocene of Europe, especially characteristic of Lower to Middle Oligocene (Krutzsch, 1963a); Palaeocene of England (Jolley, 1992b); Palaeocene of Belgium (Roche, 1965); Eocene of S England (Graus-Cavagnetto, 1976); Early Palaeocene of Denmark (Kedves, 1979); Early Oligocene of Bovey Tracy, British Isles (Wilkinson & Boulter, 1980).

BOTANICAL AFFINITY: Pteridaceae, *Pteris*

Genus ***Cicatricosisporites*** Potonie & Gelletich, 1933

TYPE SPECIES: ***Cicatricosisporites dorogensis*** Potonie & Gelletich, 1933; p. 522, pl. 1, fig. 1.

GENERIC REMARKS: The emendation of the original diagnosis by Potonie (1966) is used here. This describes medium to large subrounded trilete miospores with the trilete rays reaching the equator. They are characterised by an ornament of striae, which vary in size, shape and distribution. The ornamentation along with amb shape and size are used for the speciation of this genus.

Cicatricosisporites chattensis Krutzsch, 1961a

Plate 5, Figures 5 to 8

REFERENCE: Krutzsch, 1967a; p. 82, pl. 23, figs 1-7 are regarded as typical specimens.

COMMENTS: A medium to large sized trilete spore with a triangular amb with straight to convex sides. Both proximal and distal surfaces are strongly ornamented with a very distinct coarse ribbing or striae c. 2-3 μm wide. This ribbing is characterised by wavy edges. On the proximal surface the ribbing is concentric about the centre of the trilete mark but is arranged as parallel ribbing on the distal surface. In the centre of the proximal surface the striae pattern forms a closed triangular shape, this is very characteristic of *C. chattensis*. This species is considered characteristic of the Middle and especially Upper Oligocene (Wilkinson & Boulter, 1980).

STRATIGRAPHIC RECORD: Middle to Upper Oligocene in Western British Isles (Wilkinson & Boulter, 1980); Middle to Upper Oligocene (Krutzsch, 1967a).

BOTANICAL AFFINITY: Schizaceae (Chateauneuf, 1980 and Krutzsch, 1967a)

Cicatricosisporites dorogensis (Potonie & Gelletich, 1933) ex. Potonie, 1956

Plate 6, Figure 1

REFERENCE: Krutzsch, 1967a; p. 80, pl. 22, figs 1-5 and Krutzsch & Vanhoorne, 1977; p. 17, pl. 6, figs 11-14 are regarded as typical specimens.

COMMENTS: A thick walled rounded triangular trilete spore, medium to large in size, with the trilete mark extending to the equator. The ornamentation consists of parallel striae even in width (1-1.5µm) and relatively straight sided. This can be differentiated from *C. chattensis* which has much fewer and thicker striae which show a characteristically wavy irregular edge or outline. The ornament forms a concentric pattern around the proximal pole and meets in a triangle of striae about the distal pole. These are similar in morphology to, but differentiated from *C. rousei* (Rouse, 1962) Davies, 1985 which has broader thicker striae.

STRATIGRAPHIC RECORD: Upper Palaeocene to Middle Oligocene of Germany (Krutzsch, 1967a); Late Cretaceous to Late Oligocene of Europe (Krutzsch, 1966)

BOTANICAL AFFINITY: Schizaceae (Thomson & Pflug, 1953; Graus-Cavagnetto, 1976; 1978). Parent macrofossil plant is *Anema colwellensis* (Thomson & Pflug, 1953 and Chandler, 1955)

Cicatricosisporites paradorogensis Krutzsch, 1959b

Plate 6, Figure 2

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 80, pl. 22, figs 7-12; Krutzsch & Vanhoorne, 1977; p. 17, pl. 7, figs 1-2 and Krutzsch, 1959b; p. 172, pl. 32, figs 351-353, pl. 35, figs 366-371, pl. 36, figs 372-373 are regarded as typical specimens.

COMMENTS: A medium sized round to triangular trilete miospore, having a thick wall with an ornament of parallel regularly arranged striae, 1-1.5 µm wide. This species is recognised by the distinctive character of the striae which show numerous thin spots (resembling punctae) within the ribbing. This ribbing is

arranged radially about the proximal pole and concentrically around the distal pole. This pattern of ornamentation can sometimes appear obscured by the disruption of the striae by these thin spots. This species is easily differentiated from *C. dorogensis* which does not have the characteristic thin spots within the striae. Also *C. chattensis* and *C. rousei* have much fewer and thicker striae, the former having an irregular wavy outline to the ribbing.

STRATIGRAPHIC RECORD: Palaeogene of Germany (Krutzsch, 1959b); Middle Eocene of Germany (Krutzsch, 1959b); Oligocene of the Western British Isles (Wilkinson & Boulter, 1980); Middle Oligocene (Krutzsch, 1967a)

BOTANICAL AFFINITY: Schizaceae (Graus-Cavagnetto, 1978 and Krutzsch & Vanhoorne, 1977)

Genus ***Deltoidospora*** Miner, 1955

TYPE SPECIES: ***Deltoidospora hallii*** Miner, 1955; p. 618, p. 24, fig. 7

GENERIC REMARKS: The emended diagnosis of Danze-Corsin & Laveine (1963) is accepted here due to the short and poor nature of the original description. A type species was later designated by Potonie (1956). This broadly defined form genus includes all small to large simple trilete spores. The amb is concavely triangular to subcircular, with the trilete mark extending more than $^{2}/_{3}$rds the radius of the spore. The exine is two layered and psilate to infrapunctate. This genus incorporates *Leiotriletes* (Naumova, 1939) Potonie & Kremp (1955) and *Cyathidites*, Couper (1953). The specimens of *Deltoidospora* occur in all the sections of this study and reach a peak occurrence of 16.6% (78/1, 128.2m). This is more abundant than seen in the Bovey sections of Wilkinson & Boulter (1980) in which *Deltoidospora* were seen never to reach abundances greater than 1%. In practice the differentiation between Tertiary and reworked Mesozoic *Deltoidospora* was found problematic by

the author due to the very similar morphology of the taxa within this genus and the low spore colouration of the reworked material.

Deltoidospora apheles Hunger, 1952 comb. nov.

Plate 6, Figures 3 & 4

REFERENCE: Krutzsch, 1962; Atlas I, p. 22, pl. 4, figs 1-10 are regarded as typical specimens.

COMMENTS: A small to medium sized trilete spore which is thick walled, with a distinctively circular amb. The trilete mark has rays reaching over $^{2}/_{3}$rds of the radius of the spore. It is differentiated from *Undulatisporites* Pflug, 1953 which has a similar morphology of a round circular amb, but has undulating trilete rays.

STRATIGRAPHIC RECORD: Miocene of Germany (Hunger, 1952); Early Eocene of Germany (Krutzsch, 1966)

BOTANICAL AFFINITY: *Ophioglossum vulgatum* (Krutzsch, 1962)

Deltoidospora maxoides Krutzsch, 1962 comb. nov.

Plate 6, Figure 5

REFERENCE: Krutzsch, 1962, Atlas I, p. 18, pl. 12, figs 1-5 are regarded as typical specimens.

COMMENTS: This describes simple trilete spores, characteristically large in size with a circular to triangular amb which is psilate. The trilete mark extends over $^{2}/_{3}$rds of the spore radius and most specimens show a distinct tori developed at the edges of the trilete rays. Krutzsch (1962) has described two subspecies namely; *D. maxoides* subsp. *maxoides* and *D maxoides* subsp. *maximus*, but these subdivisions are not used here as are thought an artificial and unnecessary division. This taxon is

characteristic of floodplain terrestrial palynofloras (D. Jolley pers. comm., 1994).

STRATIGRAPHIC RECORD: Oligocene of Germany (Krutzsch, 1962)

BOTANICAL AFFINITY: Schizaceae (*Lygodium*) (Krutzsch, 1962 and Chateauneuf, 1980). This type of spore was described by Chandler (1955) from Schizaceae ferns of *Anemia poolensis* in S. England.

Deltoidospora wolffi Krutzsch, 1962 comb. nov.

Plate 6, Figure 6

REFERENCE: Krutzsch, 1962, Atlas I, p. 26, pl. 6, figs 1-14 are regarded as typical specimens.

COMMENTS: A medium sized simple trilete spore, rounded to triangular in shape with the trilete rays reaching over $^{2}/_{3}$rds of the spore radius. The walls are thin and psilate. The main differentiation from other *Deltoidosporas* being on size.

STRATIGRAPHIC RECORD: Early Eocene of N. Germany (Krutzsch, 1962); Oligocene to Pliocene of Germany (Krutzsch, 1962)

BOTANICAL AFFINITY: *Cyathaceae* (Gruas-Cavagnetto, 1976)

Genus ***Echinatisporis*** Krutzsch, 1959b

TYPE SPECIES: ***Echinatisporis longechinus*** Krutzsch, 1959b; p. 133, pl. 20, figs 217-219.

GENERIC REMARKS: This is a medium sized triangular to subcircular azonotrilete miospore. The trilete rays extend over $^{2}/_{3}$rds of the spore radius. The spore wall is simple with an ornamentation of spines, both distally and proximally that tend to be reduced towards the proximal pole. The character of this echinate ornament is important for speciation. This genus describes

spores that are morphologically similar to Recent *Selaginella* (Krutzsch, 1959b)

Echinatisporis echinoides Krutzsch, 1963a

Plate 7, Figure 1

REFERENCE: Krutzsch, 1963a; pl. 38, figs 1-5 are regarded as typical specimens.

COMMENTS: Krutzsch subdivided this species into three subspecies. These subgeneric taxa were seen to have biostratigraphic significance in Germany, but were not found significant elsewhere in Europe (Wilkinson & Boulter, 1980) and therefore this taxa has not been subdivided here.

STRATIGRAPHIC RECORD: Oligocene of the British Isles (Wilkinson & Boulter, 1980); Oligocene to Miocene of Germany (Krutzsch, 1963a)

BOTANICAL AFFINITY: Selaginellaceae, *Selaginella*

Echinatisporis miocenicus Krutzsch, 1963a

Plate 7, Figure 2

REFERENCE: Krutzsch, 1963a; pl. 36 figs 6-13 are regarded as typical specimens.

COMMENTS: This miospore is medium in size and subcircular in shape. This species is characterised by a distal and proximal ornamentation of spines. These spines are longer than those of *E. echinatus* although shorter than those of *E. longechinus*. The spines are also slightly different in character being less conical in shape (as in *E. echinatus*) and more elongate, tapering and flexuous.

STRATIGRAPHIC RECORD: Middle Miocene of Germany (Krutzsch, 1963a)

BOTANICAL AFFINITY: Selaginellaceae, *Sellaginella*

Genus ***Gleicheniidites*** Ross, 1949

TYPE SPECIES: ***Gleicheniidites senonicus*** Ross, 1949; pl. 1, fig. 3.

GENERIC REMARKS: These are small trilete miospores in which the amb is triangular with rounded radial areas and straight to concave sides. The trilete mark extends to the equator at the radial regions. The exine is single layered and shows strong thickenings or tori in the proximal interradial areas. This genus can be distinguished from *Toroisporis* (Krutzsch, 1959) which has an exine of two or more layers and shows tori present in many different positions. Differentiation between *in situ Gleicheniidites* and reworked Mesozoic specimens was aided by the difference in spore colouration, the darker orange specimens being characteristically Mesozoic.

Gleicheniidites senonicus Ross, 1948

Plate 7, Figures 3 & 4

REFERENCE: Kemp, 1970; p. 103, pl. 18, figs 3-7 are regarded as typical specimens.

COMMENTS: This describes a small trilete miospore, with an amb that is triangular often having concave sides. The exine is psilate to finely ornamented and shows distinct interradial thickenings or tori. *G. simplex* (Palctova) Simoncsics (1970) is distinguished from this species by its larger size.

STRATIGRAPHIC RECORD: Jurassic to Pliocene (Wilkinson & Boulter, 1980); Cretaceous of Sweden (Ross, 1949); Cretaceous of S England (Kemp, 1970)

BOTANICAL AFFINITY: Gleicheniaceae

Genus ***Kekryphalospora*** Fenton & Riding, 1987

TYPE SPECIES: ***Kekryphalospora distincta*** Fenton & Riding, 1987; p. 428, pl. 1, figs 1-6.

GENERIC REMARKS: This is a camerate trilete spore, the amb is subcircular to subtriangualar in shape. The laesurae are straight and extend to or almost to the equator. The intexine is laevigate to verrucate. The exoexine is separated from the intexine over the equatorial parts of the proximal surface and over the entire distal surface as a coarse reticulate net, the luminae of which form an irregular polygonal pattern. This genus is similar to the Palaeozoic genus *Retispora* Staplin (1960) which can be differentiated by its thin exoexine that is more closely adpressed to the distal intexine compared to *Kekryphalospora* and the genus *Spelaeotriletes* Neves & Owens (1966) which is differentiated due to its laevigate and infrapunctate exoexine only and the lack of any positive ornament. As specimens were very rare in this study, details were not sufficient to assign a species therefore specimens are recorded as *Kekryphalospora* spp. in the count. Due to the very delicate nature of the floating reticulum that is attached only in the most proximal areas, it is unlikely that the specimens encountered in this study were reworked. This extends the original stratigraphical range recognised by Fenton & Riding (1987) of Lower Jurassic to Middle Jurassic into the Palaeogene, Lower Tertiary.

Plate 7, Figure 5

STRATIGRAPHIC RECORD: Lower to Middle Jurassic of Britain (Fenton & Riding, 1987)

BOTANICAL AFFINITY: Unknown

Genus ***Lycopodiumsporites*** Thiergart, 1938 ex Delcourt & Sprumont, 1955

TYPE SPECIES: ***Lycopodiumsporites agathoecus*** (Potonie, 1934; p. 4 pl. 1, fig. 25) designated by Delcourt & Sprumont, 1955; p. 31

GENERIC REMARKS: This genus describes a trilete miospore with a rounded triangular amb. Ornamentation is of a distinct reticulum of broad, solid muri that overlap proximally. On the proximal surface the ornamentation is of a reticulum concentrated towards the equatorial regions and reduced towards the trilete area where the exine is psilate. It is differentiated from *Microreticulatus* (Krutzsch, 1959b) which has a smaller, lower reticulum and *Reticulatisporites* (Ibrahim, 1933) which has a coarser and less regular reticulum as well as a bizonate cingulum. Many specimens from this genus were found in sections from the Sea of the Hebrides, Stanley Bank Basin and the North Sea. Difficulties arise due to the uncertainty whether these specimens are *in situ* or reworked Mesozoic species. Spore colouration alone was not enough to determine reworking. A few specimens could be positively assigned to the Tertiary but the were not enough to speciate adequately. Therefore in the counts all specimens encountered are treated as *Lycopodiumsporites* spp..

Plate 7, Figure 6

Genus ***Microfoveolatisporis*** Krutzsch, 1962

TYPE SPECIES: ***Microfoveolatisporis tuemmlitzensis*** Krutzsch, 1962, Atlas I, p. 58, pl. 22, figs 1-3.

GENERIC REMARKS: A medium sized subcircular shaped trilete spore in which the trilete rays extend greater than $^{2}/_{3}$rds the radius of the spore. The relatively thick wall is ornamented with a regular network of small foveolae less than 1 μm in size and not too closely spaced. This genus differs from *Foveotriletes* (Van der Hammen, 1954) ex Potonie, 1956 which is subtriangular in shape and has a larger foveolae ornament.

Microfoveolatisporis tuemmlitzensis Krutzsch, 1962

Plate 8, Figure 1

REFERENCE: Krutzsch, 1962, Atlas I, p. 58, pl. 22, figs 1-3 are regarded as typical specimens.

COMMENTS: This species describes a medium sized trilete miospore with a subcircular amb and a thick microfoveolate wall which is possibly two layered. The distinctive ornament of small foveolae less than 1 μm in size is relatively closely spaced and forms a regular network which is occasionally fused in places forming a negative reticulum. This differs from *M. apheloides* Krutzsch (1962) which is similar in size but has much [illegible] and less distinct microfoveolae and *M. foveolatus* Krutzsch (1962) which is smaller with a strong ornament which is fused and resembles a foveolate, rugulate pattern.

STRATIGRAPHIC RECORD: Miocene of Germany (Krutzsch, 1962); Oligocene of Western British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Psilotaceae (Gruas-Cavagnetto, 1978)

Genus ***Polypodiaceoisporites*** Potonie, 1951 ex Potonie 1956

TYPE SPECIES: ***Polypodiaceoisporites speciosus*** Potonie, 1951 ex Potonie 1956; p. 63.

GENERIC REMARKS: This is a distinctive easily recognisable trilete miospore. The amb is subtriangular in shape and has rounded corners and straight sides. A continuous cingulum around the equator is characteristic and shows no variation in width. The trilete mark on the central body extends over $^{2}/_{3}$rds of the distance to the cingulum and can be paralleled by tori. The ornamentation of the central body varies from verrucae/rugulae to smooth/granular. Three species are described in the following section.

Polypodiaceoisporites gracillimus Nagy, 1963

Plate 8, Figure 2

REFERENCE: Krutzsch, 1967a, Atlas IV & V, p. 106-108, pl. 35, figs 5-20, pl. 36, figs 1-13 are regarded as typical specimens.

COMMENTS: Krutzsch differentiated this species into three subspecies. These are not used here as are thought an unnecessary division. It is subtriangular in shape and small to medium in size with a continuous cingulum surrounding the central body. The distinguishing features are the ornament of small verrucae on the proximal surface which distally appear as large protruding irregular verrucae, this is different to the ornament of *P. marxheimensis* which is smooth to granular proximally and rugulate to verrucate distally.

STRATIGRAPHIC RECORD: Upper Oligocene to Miocene of Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Pteridaceae, *Pteris*

Polypodiaceoisporites marxheimensis (Murriger & Pflug, 1953 ex Thomson & Pflug, 1953).Krutzsch, 1959b

Plate 8, Figure 3

REFERENCE: Krutzsch, 1967a, Atlas IV & V, p. 102, pl. 33, figs 1-5 are regarded as typical specimens.

COMMENTS: This describes subtriangular medium sized spores, characteristic in shape with straight sides and rounded corners. The cingulum is psilate and continuous around the spore body and shows no variation in width. The distinctive ornamentation of the spore body varies from verrucate and rugulate on the proximal surface to smooth and granular on the distal surface.

STRATIGRAPHIC RECORD: Palaeocene of Germany (Krutzsch & Vanhoorne, 1977); Late Palaeocene to Early Eocene of France (Kedves, 1963); London Basin (Allen, 1982) and Upper Eocene to Middle and Upper Oligocene Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Pteridaceae, *Pteris*

Polypodaceoisporites sp. **1**

Plate 8, Figure 4

REFERENCE: Kedves, 1980; p. 361, pl. 4, figs 5-8 are regarded as typical specimens.

COMMENTS: This zonotrilete spore has a triangular to slightly concave amb. The trilete mark extends to, or nearly to, the equator and sometimes shows tori developed around the laesurae. The equator is surrounded with a distinct continuous cingulum which is psilate and shows no variation in width. The central body is smooth both proximally and distally. Kedves (1980) assigned these spores to a new genus *Croxtonaesporites* Kedves (1980) on the ornamentation of the central body being psilate alone. But this assignation is not followed here and this distinctive species is placed under the genus *Polypodaceoisporites* which includes trilete spores which have a smooth cingulum of equal width around the spores central body.

STRATIGRAPHIC RECORD: Tertiary, Lower Danian of Denmark (Kedves, 1980)

BOTANICAL AFFINITY: Unknown

Genus ***Stereisporites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Stereisporites stereoides*** (Potonie & Venitz, 1934; p. 11, pl. 1, figs 4-5) Pflug, 1953; p. 53, pl. 1, figs 64-73.

GENERIC REMARKS: This describes trilete miospores, triangular in shape with convex sides and rounded corners. The trilete mark is simple and extends to the equator without tori being developed. The exine is distinctly two layered and generally psilate but sculpture can vary from granulate to verrucate and is important

for speciation along with the sculpture of the cingulum. This broadly defined, simple genus was split by the work of Krutzsch (1962, 1963a and 1966) into several subgeneric divisions based on identifiable morphological groups defined from exine structure and ornamentation features.

Subgenus ***Stereisporites (Cingulitriletes)*** Pierce, 1961

Stereisporites (Cingulitriletes) spp.

Plate 8, Figures 5

COMMENTS: Only one specimen of this subgenus was recorded throughtout this study, from the Sea of the Hebrides Basin (78/1). The rare occurrence of this only allows identification to the level of subgenera and is recorded as *Stereisporites (Cingulitriletes)* spp. in this study. This is a small trilete miospore with a distinct trilete mark whose rays extend to the equator over a psilate spore body. It is characterised by a well developed, psilate cingulum around the equator which shows no variation in width.

STRATIGRAPHIC RECORD: Oligocene of the Sea of the Hebrides 78/1

BOTANICAL AFFINITY: Sphagnaceae (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1978)

Subgenus ***Stereisporites (Stereisporites)*** Krutzsch, 1963a

Stereisporites (Stereisporites) stereoides (Potonie & Venitz, 1934) Krutzsch, 1963a

Plate 8, Figures 6 & 7

REFERENCE: Thomson & Pflug, 1953; p. 53, pl. 1, figs 64-73 and Krutzsch, 1963a; Atlas III, p. 42, pl. 3, figs 1-3 are regarded as typical specimens.

COMMENTS: This describes simple small trilete miospores, with a distinct trilete mark that extends to the equator. No distal or proximal

ornamentation is apparent and no cingulum is developed. These are easily distinguished due to there lack of ornamentation and other structures. This species has a peak occurrence of 3.1% (21/28b-7) in this study.

STRATIGRAPHIC RECORD: Miocene of Germany (Meyer, 1955 and Krutzsch, 1959b)

BOTANICAL AFFINITY: Sphagnaceae (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1978)

Subgenus ***Stereisporites (Structisporis)*** Krutzsch, 1963a

Stereisporites (Structisporis) intrareticulatus Krutzsch, 1963a

Plate 9, Figures 1 & 2

REFERENCE: Krutzsch, 1963a; Atlas III, p. 96, pl. 29, figs 1-13.

COMMENTS: This is a medium to large sized miospore. The amb is subcircular to subtriangular in shape, the trilete rays extend nearly to the equator. The cingulum around the equator is thin, continuous and psilate. The exine is smooth but proximally and distally shows a distinctive irregular wide reticulate pattern. The specimens seen in this study differ slightly in the fact that the ornament is concentrated around the centre of the trilete mark on the proximal surface.

STRATIGRAPHIC RECORD: Middle to Lower Tertiary and Pliocene of Germany (Krutzsch, 1963a)

BOTANICAL AFFINITY: Sphagnaceae (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1978)

Subgenus ***Stereisporites (Distgranisporis)*** Krutzsch, 1963a

Stereisporites (Distgranisporis) spp.

Plate 9, Figure 3

COMMENTS: This subgenera describes trilete miospores which are rounded to triangular in shape. The cingulum around the equator is thin, continuous and psilate. The exine is smooth but distally has a flat verrucate sculpture or granular ornamentation which varies in prominance and density. This subgenera is differentiated from *S. (Stereigranisporis)* which lacks ornamentation on the distal pole and from *S. (Distverrusporis)* where the verrucate ornament occurs only on the distal pole. In this study the rarity of this subgenera makes further speciation difficult and therefore specimens encountered are recorded as *S. (Distgranisporis)* spp.

STRATIGRAPHIC RECORD: Middle to Late Tertiary (Krutzsch, 1963a; Jansonius & Hills, 1976)

BOTANICAL AFFINITY: Sphagnaceae (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1978)

Stereisporites sp. 1

Plate 9, Figures 4 & 5

COMMENTS: This is a small to medium sized trilete miospore triangular in shape with slightly convex sides and rounded corners. The trilete mark is distinct and extends to the equator. This species is characterised by an ornamentation of protruding verrucae which are irregularly distributed over the exine and are widely spaced. They form an irregular pseudocingulum around the equator, which is very variable in width as it is composed of long verrucae. The ornamentation occurs on both the proximal and distal surfaces. This very distinctive species was only present in 77/7, 78/1 and 21/28b-7 (poss 73, 16) having rare to present relative abundances, generally less than 1%.

BOTANICAL AFFINITY: Sphagnaceae

Genus ***Toroisporis*** Krutzsch, 1959b

TYPE SPECIES: ***Toroisporis torus*** (Pflug, 1953; p. 54, pl. 2, fig. 14) Krutzsch, 1959b; p. 90, pl. 5.

GENERIC REMARKS: This genus describes an azonotrilete miospore, having a triangular to subcircular amb with a smooth exine. The exine is composed of a thick, two layered wall structure with proximal tori always present, in different manifestations and in a number of different places. This characteristic of the tori, differentiates this genus from *Gleichenidiites*. Subgenera have been defined according to the placement of the tori in *Toroisporis*. Differentiation between species has proved difficult due to the rarity of the specimens in the material of this study and poor preservation of what is present. Great difficulty in distinguishing between *insitu* and reworked specimens was a problem, therefore in the counts all specimens of this form genus are recorded as *Toroisporis* spp.. Despite the views of Kedves (1962) and Potonie (1966) who considered *Toroisporis* an unnecessary genus, European Tertiary palynologists have continued its usage, for example Wilkinson & Boulter, 1980 recorded occurrences of *Toroisporis* in Bovey with [illegible] specimens elsewhere in the British Oligocene.

Plate 9, Figure 6

Genus ***Trilites*** Cookson ex Couper, 1953

TYPE SPECIES: ***Trilites tuberculiformis*** Cookson ex. Couper, 1953; p. 136, pl. 18, fig. 61.

GENERIC REMARKS: The emended diagnosis of Dettman (1963) after her re-examination of the type species, is used here as it gives details of the ornamentation, not provided by the vague original diagnosis. This describes a medium sized trilete miospore, the amb is subtriangular in shape with the trilete rays nearly reaching the equator. The ornamentation is formed of closely spaced, irregular shaped verrucate to rugulate elements which have a random distribution, occurring on both distal and

proximal surfaces. Species of this genus were found in all the sections studied and reached a maximum relative occurrence of c. 2%, which is much less than occurrences published by Wilkinson & Boulter (1980) from Mochras and Bovey of up to 11%.

Trilites corruvallatus Krutzsch, 1967a

Plate 10, Figure 1

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 74, pl. 19, figs 1-6 are regarded as typical specimens.

COMMENTS: Small to medium sized trilete spores with trilete rays reaching to the equator. The ornamentation is of small verrucae which appear fused together forming an irregular corrugate pattern.

STRATIGRAPHIC RECORD: Lower Miocene of Germany (Krutzsch, 1967a)

BOTANICAL AFFINITY: Lygodiaceae (Krutzsch, 1967a)

Trilites multivallatus (Pflug, 1953) Krutzsch, 1959b

Plate 10, Figure 2

REFERENCE: Krutzsch, 1967a; Atlas IV & V, p. 72, pl. 18, figs 1-14 are regarded as typical specimens.

COMMENTS: This describes a small to medium sized trilete miospore. The amb is subtriangular in shape with straight to concave sides. This is characterised by an ornament of strong elongate verrucae somewhat vermiculate in character, which appear fused towards the trilete mark. This differs from *T. corruvallatus* in which the verrucae are smaller, less densely packed and often fused all over to form an irregular corrugate pattern.

STRATIGRAPHIC RECORD: Middle Oligocene of Germany (Krutzsch, 1967a); Middle Oligocene of Poland (Ziembinska-Tworzydlo, 1974); Upper

Oligocene to Miocene of E Germany (Krutzsch, 1967a); Middle and Upper Oligocene of Germany (Thomson, 1949 and Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Lygodiaceae (Krutzsch, 1967a) and *Lygodium*, Schizaceae (Chateauneuf, 1980)

Trilites sp. **1**

Plate 10, Figure 3

COMMENTS: This is a very distinctive trilete miospore. The trilete rays extend $^{2}/_{3}$rds of the radius of the spore body and are often gaping. The amb is subtriangular in shape with rounded corners and straight to slightly concave sides. The distinctive feature of this species is that of its reduced verrucate ornament, which occurs both proximally and distally. The verrucae are relatively small, widely spaced and have a polygonal outline. It shows similarity to the verrucate ornamentation of *Verrucatosporites favus*. The verrucae are not fused to the trilete mark unlike *T. multivallatus*. This species was found in the Sea of the Hebrides Oligocene deposits of this study but in rare numbers (< 1%). It seems this species is characteristic of British Oligocene sediments and has been found by other workers (D. Jolley, pers. comm., 1994).

STRATIGRAPHIC RECORD: None previously published

Genus ***Triplanosporites*** (Pflug, 1952) Thomson & Pflug, 1953

TYPE SPECIES: ***Triplanosporites sinuosus*** Thomson & Pflug, 1953; p. 58-59, pl. 3, figs 9-13.

GENERIC REMARKS: This genus is used to describe psilate trilete spores which are preserved in an equatorial position. These vary in size from small to large. The trilete mark is indistinct and one ray is folded over the top of one of the others, this leads to the

appearance of having a single axis through the pole. The distinguishing feature of this genus from such psilate trilete spores as *Deltoidospora* specimens is that preservation is in equatorial orientation as the polar axis is greater in length than the equatorial axis for *Triplanosporites*. Specimens from this genus have been recorded as *Triplanosporites* spp. in this study. No speciation was attempted, due to the poor preservation. It is probable that this genus is a preservational feature depending on the orientation of the specimen at that time. Therefore if this is the case speciation would be inappropriate and misleading.

Plate 10, Figure 4

Genus ***Undulatisporites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Undulatisporites microcutis*** Thomson & Pflug, 1953; p. 52, pl. 1, fig. 81.

GENERIC REMARKS: This is a medium sized trilete miospore rounded to convexly triangular in shape with raised laesurae. The trilete rays are distinct and extend over $^{2}/_{3}$rds of the radius of the spore body. The trilete rays are characteristically finely sinuous. The exine is smooth to scabrate, being thickened at the poles and showing no development of tori. The data of Wilkinson & Boulter (1980) suggests only rare occurrences of species from this genus in the British Oligocene.

Undulatisporites sculpturis Krutzsch, 1962

Plate 10, Figures 5 & 6

REFERENCE: Krutzsch, 1962; p. 76, pl. 31, figs 1-5 are regarded as typical specimens.

COMMENTS: This is a small to medium sized subtriangular miospore with slightly flattened radial areas. The trilete mark is distinct with

the rays reaching over 2/3rds of the spore body radius and appear to branch or split towards the radial areas of the spore. The trilete rays are characteristically very wavy and undulose, over an exine that is psilate to infrapunctate. This very distinctive species was very rare, only one specimen was recorded in this study from the Rona Basin section (77/7).

STRATIGRAPHIC RECORD: Miocene to Pliocene (Krutzsch, 1962); Oligocene of the British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Unknown

Genus *Verrucingulatisporites* Kedves, 1961

TYPE SPECIES: ***Verrucingulatisporites verrucatus*** Kedves, 1961; p. 140, pl. 8, fig. 10.

GENERIC REMARKS: This genus describes zonotrilete spores with rounded to triangular ambs. The trilete rays are distinct and extend to the equator. Both proximal and distal surfaces are ornamented with a 'remarkable' sculpture of large verrucae. And an irregular cingulum around the equator is a characteristic feature of this genus.

Verrucingulatisporites treplinensis Krutzsch, 1961a

Plate 11, Figures 1 & 2

REFERENCE: Krutzsch, 1967a; p. 120, pl. 41, figs 5-17 are regarded as typical specimens.

COMMENTS: A small to medium sized trilete miospore with rounded corners and straight to slightly concave sides. The psilate cingulum surrounding the central body is undulating and varies in width. The proximal ornament on the spore body varies from granulate to finely verrucate, distally this changes to more prominent pointed verrucae which protrude and are

'silhouetted' against the cingulum, forming a very distinctive denticulate pattern.

STRATIGRAPHIC RECORD: Upper Oligocene of Germany (Krutzsch, 1967a); British Oligocene (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Unknown

Spore sp. **88**

Plate 11, Figures 3 & 4

COMMENTS: This large trilete spore is very distinctive. It has a thick wall which gives a characteristic orange spore colour. The overall amb shape is triangular concave with the trilete rays reaching over $^{2}/_{3}$rds of the radius of the spore body. The exine is slightly granular with a heavy ornamentation of low irregular verrucae both proximally and distally.

BOTANICAL AFFINITY: Unknown

Fungal and Algal Spores

Genus ***Diporicellaesporites*** Elsik, 1968

TYPE SPECIES: ***Diporicellaesporites stacyi*** Elsik, 1968; p. 279, pl. 3, fig. 11.

REFERENCE: Elsik, 1968; p. 279, pl. 3, fig. 11 is regarded as a typical specimen.

GENERIC REMARKS: This describes elongate multicellate psilate fungal and spores which are diporate. One pore is situated at each end of the spore. The shape is variable but always elongate and never coiled. These were also described by Wilkinson & Boulter (1980) from the Mochras borehole. Specimens of this species are recorded as *Diporicellaesporites* sp.

Plate 11, Figure 5

STRATIGRAPHIC RECORD: Palaeocene of N. America (Elsik, 1968); Early Oligocene of Britain (Wilkinson & Boulter, 1980)

Genus ***Fusiformisporites*** Rouse, 1962 emend. Elsik, 1968

TYPE SPECIES: ***Fusiformisporites crabbi*** Rouse, 1962; p. 210, pl. 4, figs 28-29.

REFERENCE: Elsik, 1968; p. 272, pl. 2, fig. 11 is regarded as a typical specimen.

GENERIC REMARKS: The emendation of Elsik (1968) is accepted here. These are inaperturate, dicellate spores which are distinctly fusiform in outline, and are split in half by an equatorial wall. This partition gives the appearance of a constriction, which may or may not be present. The wall is two layered or more and has distinctive elongate striae, ribs, ridges or costae which run

parallel to the long axis of the spore and converge at the poles. No species were recognised and specimens are referred to in this work as *Fusiformisporites* spp.

Plate 11, Figure 6 and Plate 12, Figure 4

STRATIGRAPHIC RECORD: Upper Cretaceous to Eocene of N America (Rouse, 1962); Palaeocene to Pleistocene of N America (Elsik, 1968); Eocene to Oligocene (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Extant fungus *Cookeina* (in Wolf & Cavaliere, 1966)

Hyphae

REFERENCE: Elsik, 1968; p. 280, pl. 3, figs 13-15 are regarded as typical specimens.

COMMENTS: This describes elongate chains of spherical to subspherical cells. The outer walls are generally parallel and the walls between cells, septae, may have a single pore or may be split open, and point in one direction. The walls are psilate. Although Elsik (1968) recognised several types of hyphae they are all described together here as not enough were recorded in this study to confidently subdivide this group.

Plate 11, Figure 7

Genus ***Microthallites*** Dilcher, 1965

TYPE SPECIES: ***Microthallites lutosus*** Dilcher, 1965; pl. 10, figs 84-85.

REFERENCE: Dilcher, 1965; pl. 10, figs 84-85 are regarded as typical specimens.

GENERIC REMARKS: These are generally round in shape and lack any free hyphae. The stroma are radiate and dichotomising and formed of square to rectangular cells. These cells generally do not have any pores differentiating this from *Callimothallus* (author) which is characterised by a pore in each cell. This genus is quite common and often occur as broken fragments.

Plate 12, Figure 1

STRATIGRAPHIC RECORD: Eocene of N. America (Dilcher, 1965)

BOTANICAL AFFINITY: Unknown

Genus ***Pesavis*** Elsik & Jansonius, 1974

TYPE SPECIES: ***Pesavis tagluensis*** Elsik & Jansonius, 1974; p. 956, pl. 1, fig. 5.

GENERIC REMARKS: This is a multicellular fungal fruiting body. Composed of a central stem which is branched. The end of this central stalk shows a thickening, suggesting that at one time it was attached to another structure. The two lateral arms are generally curved and consist of a number of cells. The cells of this primary structure may or may not have secondary hyphae like filaments growing in towards each other from opposite arms.

Pesavis tagluensis Elsik & Jansonius, 1974

Plate 12, Figures 2 & 3

REFERENCE: Elsik & Jansonius, 1974; p. 956, pl. 1, fig. 5 is regarded as a typical specimen.

COMMENTS: This has a distinct multicellular body. A central stem or axis is branched into two lateral arms that are generally curved with their tips meeting or overlapping, enclosing a circular area. From each lateral cell thin hyphae like projections stretch

towards the centre of the enclosed area. A thickened darker membrane separates the primary cells from these secondary hyphae like projections.

STRATIGRAPHIC RECORD: Palaeocene to Eocene (Elsik, 1974); Bellbrook, Northern Ireland (Wilkinson & Boulter, 1980)

Genus ***Pluricellaesporites*** Van der Hammen, 1954

TYPE SPECIES: ***Pluricellaesporites typicus*** Van der Hammen, 1954, p. 104, 21.

REFERENCE: Elsik, 1968; p. 276, pl. 3, fig. 6 is regarded as a typical specimen.

GENERIC REMARKS: The emendation of Elsik & Jansonius (1974) is accepted here. These are multicellate fungal spores which are lenticular, oval or cylindrical in outline and symmetrical about the long axis. A single aperture or pore occurs at one end and the aporate end is often rounded but can be bulbous or pointed. It is multicellate with three or more cells, these cells are connected by septa. The exine is generally psilate but can be faintly scabrate.

Plate 12, Figure 6

STRATIGRAPHIC RECORD: Cretaceous of S America (Van der Hammen, 1954); Isolated specimens from Bovey and Mochras Britain (Wilkinson & Boulter, 1980)

Genus ***Scolecosporites*** Lange & Smith 1971

TYPE SPECIES: ***Scolecosporites maslinensis*** Lange & Smith, 1971; p. 76, pl. 6, fig. E.

GENERIC REMARKS: These are described as scoleco-phragmospores which have a length breadth index of 15:1 or more. They can occur in lengths up to 300μm and are simply elongate chains of many cells.

Plate 12, Figures 4 & 5

STRATIGRAPHIC RECORD: Middle Eocene of Australia (Lange & Smith, 1971); Eocene to Oligocene of Mochras, Britain (Wilkinson & Boulter, 1980)

DIVISION II POLLENITES Potonie, 1931a

Saccates Erdtman 1947

Class Bisaccates

Genus ***Abiespollenites*** Thiergart in Raatz, 1937

TYPE SPECIES: ***Abiespollenites absolutus*** Thiergart, 1937, p. 16, pl. 11.

GENERIC REMARKS: This bisaccate pollen grain is large in size. The two sacci are the same size or smaller than the central body or corpus and show constriction at their contact with the corpus. They are thick walled and have a distinct cappa over the corpus. Wilkinson & Boulter (1980) did not report a complete specimen, but recognised broken fragments from their thick exine. In contrast, Krutzsch (1971) recognised seven species, but in this study all specimens are recorded as *Abiespollenites* spp. due to poor preservation.

Plate 13, Figure 1

STRATIGRAPHIC RECORD: Rare; Miocene of Germany (Thiergart, 1937); Middle to Upper Tertiary of Germany (Krutzsch, 1971).

BOTANICAL AFFINITY: *Abies* (Thiergart, 1937)

Genus ***Piceapollis*** Krutzsch, 1971

TYPE SPECIES: ***Piceapollis tobolicus*** (Panova, 1966; pl. 105, fig. 4) Krutzsch 1971; p 104, pl. 22, figs 1-5.

GENERIC REMARKS: This bisaccate pollen grain is large in size. Characteristically the two sacci are not constricted at their junction with the corpus, which differentiates this genus from *Abiespollenites* which do show these constrictions. A distinct cappa or thickening is seen over the corpus and the wall structure of the corpus is infrareticulate. Specimens of this genus in this are referred to as *Piceapollis* spp. due to their low abundances which makes consistent and reliable species assignation difficult. Wilkinson & Boulter (1980) also found rare specimens of *Piceapollis* with a peak occurrence of 3% in Northern Ireland.

Plate 13, Figure 2

STRATIGRAPHIC RECORD: Late Mesozoic, Tertiary to Recent in Europe, Tertiary in Germany (Krutzsch, 1971)

BOTANICAL AFFINITY: Piniaceae, *Picea* (Thomson & Pflug, 1953 and Krutzsch, 1971)

Genus ***Pityosporites*** Seward, 1914

TYPE SPECIES: ***Pityosporites antarcticus*** Seward, 1914; p. 23, pl. 8, fig. 45.

GENERIC REMARKS: These are small to medium sized bisaccate pollens, composed of a central body or corpus and two sacci. Forms with more sacci can be seen and are abherent. Two divisions were proposed by Rudolph (1935) and were based on the degree of constriction of the sacci at the contact with the corpus. The diploxylon group described specimens with small sacci constricted at their contact with the corpus and the haploxylon group, in which the small sacci are not constricted at their

junction with the corpus. The diploxylon group and haploxylon group are subsequently referred to in the literature as *P. labdacus* (Potonie, 1934) Thomson & Pflug, 1953 and *P. microalatus* (Potonie, 1934) Thomson & Pflug, 1953 respectively. As this definition was originally based on fossil pollen of the modern genus *Pinus* it implies a relationship of the fossil pollen, in which this terminology is used, to the extant genus which could give misleading impressions of the botanical relationships here. *Pityosporites* are common, but speciation has proved difficult due to poor and differing preservation combined with difficulties in distinguishing between reworked and *in situ* specimens, this has meant that specimens are recorded as *Pityosporites* spp. Also little biostratigraphical or palaeoecological significance has been gained from subdividing this genus (Wilkinson & Boulter, 1980).

Plate 13, Figure 3

STRATIGRAPHIC RECORD: Common and wide occurrence; Jurassic to Recent, NW Europe. Oligocene of British Isles (Wilkinson & Boulter, 1980).

BOTANICAL AFFINITY: Pinaceae, *Pinus*

Genus ***Podocarpidites*** Cookson, 1947 ex Couper, 1953

TYPE SPECIES: ***Podocarpidites ellipticus*** Cookson, 1947; p. 131, pl. 13, fig. 6 ex. Couper, 1953.

GENERIC REMARKS: This genus describes bisaccate pollen grains whos sacci are distinctly larger in size than the corpus. The sacci also show constriction at the point of attatchment to the corpus. Size varies from medium to large but the much larger size of the sacci make this genus very easily recognisible. This genus was recorded in rare numbers in this study. Wilkinson & Boulter (1980) also found this genus to be rare in their Oligocene study. Some doubt as to whether this genus is *in situ* or reworked must be noted. The colour of the darker specimens would

suggest possible reworking, but this cannot be certain. All such specimens encountered are recorded as *Podocarpidites* spp.

STRATIGRAPHIC RECORD: Common and wide occurrence; Jurassic to Recent, NW Europe. Eocene to Miocene of Germany (Krutzsch, 1970); Oligocene of British Isles (Wilkinson & Boulter, 1980) and of France (Chateauneuf, 1980).

Plate 13, Figure 4

BOTANICAL AFFINITY: *Pinus* or *Podocarpus*

Class Monocolpates Iversen & Troels-Smith 1950

Genus ***Arecipites*** (Wodehouse, 1933) Krutzsch, 1970

TYPE SPECIES: ***Arecipites punctatus*** Wodehouse, 1933; p. 497, fig. 22.

GENERIC REMARKS: Wodehouse (1933) did not nominate a holotype for this genus, this was resolved by Potonie (1958) who designated *A. punctatus* the genotype, but it is the emended diagnosis of Krutzsch (1970) that is used here. This describes ellipsoidal monocolpate pollen grains, in which the colpus is tapered and not expanded at the ends. A fine to medium reticulate ornament differentiates this genus from *Liliacidites* which is larger with a coarser reticulum. The reticulum is sometimes supported by columellae.

Arecipites spp.

Plate 14, Figures 1 to 4

COMMENTS: Species have been identified on amb size, form of the colpus and reticulum character and shape. The work of Krutzsch (1970) on the genus gives a comprehensive study. It was found *Arecipites* shows a wide range of morphological variation and due to the differing preservation state of the material, speciation

is unreliable and would give inconsistent results therefore no speciation was attempted for this study. *Arecipites* is present in most of the sections studied and has a peak occurrence of 6% in Well 28, Northern Ireland. This is comparable with the occurrences recorded by Wilkinson & Boulter (1980) of 22% from the Bovey Basin and 12% from Bellbrook, Northern Ireland.

STRATIGRAPHIC RECORD: Widely recorded in the European Tertiary (Krutzsch, 1970 and Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Arecaceae (Palmae) c.f. *Sabal*, *Trachycarpus*, *Chamaedorea*, *Phoenix*.

Genus ***Monocolpopollenites*** Thomson & Pflug, 1953

TYPE SPECIES: ***Monocolpopollenites tranquillus*** (Potonie, 1934; p.51, pl. 2, fig. 8) Thomson & Pflug, 1953; p. 62-62, pl. 4, figs 24-37.

GENERIC REMARKS: The emended diagnosis of Krutzsch 1970 is accepted here. It describes distinct psilate monocolpate pollen grains. The colpus extends over $^{2}/_{3}$rds of the grains length and the exine is infrapunctate in character. This genus is easily differentiated from other monocolpate pollen, such as *Arecipites* which is distinguished by a fine to medium reticulate ornament and *Cycadopites* which is much larger in size, has a slightly coarser scabrate ornament and is more elongate in shape.

Monocolpopollenites tranquillus (Potonie, 1934) Thomson & Pflug, 1953

Plate 14, Figures 5 to 8

REFERENCE: Thomson & Pflug, 1953; p. 62-63, pl. 4, figs 24-37 and Krutzsch, 1970; Atlas VII, p. 98, pl. 19, figs 1-32 are regarded as typical specimens.

COMMENTS: This small elongate monocolpate pollen grain has a distinct colpus along the long axis but does not quite extend to the

poles. The colpus has rounded ends that are often flared. The exine is psilate to finely scabrate with a distinct infrareticulate structure.

STRATIGRAPHIC RECORD: Late Palaeocene of the Paris Basin (Gruas-Cavagnetto, 1968; Kedves, 1968); Middle Eocene to Miocene of Germany (Krutzsch, 1970)

BOTANICAL AFFINITY: *Palmae* (Areaceae)

Class Dicolpates Erdtman 1947

Genus ***Dicolpopollis*** Pflanzl 1956

TYPE SPECIES: ***Dicolpopollis kockeli*** Pflanzl, 1956, p. 241, pl. 16, figs 9-12.

GENERIC REMARKS: This is a very distinct small pollen grain, the amb is triangular to rounded (axe shaped) in prolate view and bilobed in polar view. Two colpi are present, often in a meridonal position, and they converge at one pole. The exine is reticulate to granulate

Dicolpopollis kockeli Pflanzl, 1956

Plate 15, Figures 1 & 2

REFERENCE: Krutzsch 1970, Atlas VII, p.152-153, pl. 42, figs 1-54 are regarded as typical specimens.

COMMENTS: This species is small in size. The exine is composed of short columellae supporting a fine reticulum, giving a luminate pattern less than c. 0.5μm in size.

STRATIGRAPHIC RECORD: Eocene to Miocene in Central Europe (Krutzsch, 1970); Eocene and Lower Oligocene in Paris Basin (Chateauneuf, 1980); Middle Tertiary from Bovey Tracey (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: *Daemonorps* and *Calamus* (Palmae) (Chandler, 1957 and Chateauneuf, 1980)

Class Monoporates Iversen & Troels-Smith 1950

Genus ***Graminidites*** Cookson, 1947 ex. Potonie, 1960

TYPE SPECIES: ***Graminidites medius*** Cookson 1947; p. 134, pl. 15, fig. 41.

GENERIC REMARKS: These are subspherical pollen grains with one small pore surrounded by a very distinct annulus. The smooth to finely scabrate exine is thin and commonly shows secondary folding.

Graminidites annulatus (Van der Hammen, 1954) Potonie, 1960.

Plate 15, Figures 3 & 4

REFERENCE: Wilkinson & Boulter, 1980; pl. 2, fig. 25 is regarded as a typical specimen.

COMMENTS: Specimens encountered were as above, subspherical pollen grains with a thin exine and a distinct annulus. Although only psilate forms were seen here. In this study graminiods were found not to occur in frequencies greater than 7% (73/36) and were generally rare, present in abundances of 1-5%. This compares to the peak occurrence of 3% in the Washing Bay section, Northern Ireland of Wilkinson & Boulter (1980).

STRATIGRAPHIC RECORD: Middle and Upper Oligocene to recent in Germany (Krutzsch, 1966).

BOTANICAL AFFINITY: Gramineae

Genus ***Milfordia*** Erdtman, 1960 emend. Krutzsch, 1970

TYPE SPECIES: ***Milfordia incerta*** (Thomson & Pflug, 1953) Krutzsch, 1961a; p. 325.

GENERIC REMARKS: Originally described as distinct punctate subspherical monocolpate pollen grains by Erdtman (1960). The type species has an elongate degraded area originally interpreted as a colpus. But all other species are monoporate. This genus describes pollen with a single pore, this pore having a distinct annulus. Ornamentation is composed of distinctive closely spaced punctae. Speciation is on grain and pore size and ornamentation.

Milfordia incerta (Thomson & Pflug, 1953) Krutzsch, 1961a

Plate 15, Figures 5 & 6

REFERENCE: Thomson & Pflug 1953; p. 66, pl. 5, fig. 31-35 and Krutzsch 1970; p. 73, pl. 9, figs 1-26 are regarded as typical specimens.

COMMENTS: This is a subspherical pollen grain with a distinctly punctate exine. All other species in this genus have a single pore but *M. incerta* has an germinal area which appears degraded and has ragged edges. This has been interpreted as a colpus by some authors (e.g. Erdtman, 1960 and Elsik, 1968) but this view was not followed here.

STRATIGRAPHIC RECORD: Early Palaeocene of Central Europe (Krutzsch, 1970); Late Palaeocene of southern England (Allen, 1982).

BOTANICAL AFFINITY: Restionaceae (Erdtman 1960 and Elsik 1968) and Centrolepidaceae (Erdtman 1960)

Genus ***Sparganiaceaepollenites*** Thiergart 1937

TYPE SPECIES: ***Sparganiaceaepollenites polygonalis*** Thiergart, 1937; p. 307, pl. 24, fig. 11.

GENERIC REMARKS: These monoporate pollen grains are distinguished from *Graminidites* as they have a rather indistinct pore which has no annulus. The exine is composed of a distinct columellate reticulum with varying sized luminae. Speciation is defined on size and shape of luminae and the number of columellae per muri. However many authors have not been able to recognise this to a species level (Allen, 1982 and Wilkinson & Boulter, 1980) due poor and differing preservations.

Sparganiaceaepollenites polygonalis Thiergart, 1937.

Plate 15, Figures 7 & 8

REFERENCE: Krutzsch, 1970; Atlas VII, p. 78, pl. 11, figs 1-34 are regarded as typical specimens.

COMMENTS: The specimens recorded are small with a single distinct pore, and no annulus. The exine structure is of a reticulum supported by a single muri. The resulting luminate pattern is smaller in size towards the pore and on the proximal areas being less than 1μm, but larger towards the distal poles being about 1μm. These have only been recorded in the Stanley Bank section studied and are rare having a peak occurrence of less than 1%.

STRATIGRAPHIC RECORD: Middle Oligocene to Pliocene of Germany (Krutzsch, 1970).

BOTANICAL AFFINITY: Typhaceae (Krutzsch, 1970).

Class Inaperturates Iversen & Troels-Smith 1950

Genus ***Inaperturopollenites*** Pflug & Thomson, 1953

TYPE SPECIES: ***Inaperturopollenites dubius*** Potonie & Venitz, 1934; p. 17, pl. 2, fig. 21.

GENERIC REMARKS: This genus describes small, once spherical pollen grains. The exine is thin, infrapunctate to smooth and shows strong secondary folds. The exine may or may not be split along a symmetry plane through the equator.

Inaperturopollenites distichiforme (Simpson, 1961) Jolley & Morton, 1992

Plate 16, Figure 1

REFERENCE: Jolley & Morton, 1992; p. 126, fig. 4.5 is regarded as a typical specimen.

COMMENTS: A very distinctive small inaperturate pollen grain. An equatorial split is present on which a distinct ligule protrudes from one edge or often the corner of the equatorial split. This is common throughout all the sections studied, except Well 28, Northern Ireland, and has a peak occurrence of 2.9% in 78/1, the Sea of the Hebrides.

STRATIGRAPHIC RECORD: Late Palaeocene of British Isles (Simpson, 1961; Jolley & Morton, 1992 and Srivastava, 1975) and Late Paleaocene to Early Eocene of NW Europe (Boulter & Manum, 1989)

BOTANICAL AFFINITY: Taxodiaceae; *Glyptostobus* (Boulter & Kvacek, 1989 and Jolley & Morton, 1992)

Inaperturopollenites dubius (Potonie & Venitz, 1934) Thomson & Pflug, 1953

Plate 16, Figure 2

REFERENCE: Thomson & Pflug, 1953; p. 65, pl. 4, fig. 89 and pl. 5, figs 1-13 and Wilkinson & Boulter, 1980; 45, pl. 1, figs 1-6 are regarded as typical specimens.

COMMENTS: These are small alete, spherical to subspherical pollen grains. The exine is thin and psilate to scabrate in ornamentation. The secondary folding of the exine and compression of the amb is the characteristic feature of this species. This species is rare to

present in all the sections examined and has a peak occurrence of 3.7% in 88/12, the Sea of the Hebrides.

STRATIGRAPHIC RECORD: Oligocene to Miocene of Germany (Potonie & Venitz, 1934); Cretaceous to Lower Tertiary of Germany (Thomson & Pflug, 1953).

BOTANICAL AFFINITY: Taxodiaceae, Cupressiceae, *Juniperus*, *Libocedrus*, *Tsuga*, *Chamaecyparis* (Thomson & Pflug, 1953)

Inaperturopollenites hiatus (Potonie, 1931a) Thomson & Pflug, 1953

Plate 16, Figure 3

REFERENCE: Thomson & Pflug, 1953; p. 65, pl. 5, figs 14-20 and Wilkinson & Boulter, 1980; p. 45, pl. 1, figs 18-22 and pl. 2, figs 1-10 are regarded as typical specimens.

COMMENTS: This is a small circular to elongate pollen grain. The exine is psilate and often shows secondary folding resulting from compression. *I. hiatus* is more rigid when compared to *I. dubius*. This is a very distinctive pollen grain and is characterised by an equatorial split, a gaping germinal. This ranges in length from slight to the full length of the pollen grain, but is generally about $^{4}/_{5}$ths of the diameter. Varying compression leads to many different appearances, the two halves most often appear wide and gaping, they are sometimes at 90° to each other or can even slide over each other. In this study *I. hiatus* is present as one of the most abundant species in the majority of the sections with a peak occurrence of about 68.1% in the Stanley Bank Basin.

STRATIGRAPHIC RECORD: Palaeogene of Paris Basin (Kedves, 1969), of Germany (Krutzsch, 1966); of Britain (Boulter, 1987; Jolley & Spinner, 1991 and Jolley, 1992a) and of Svalbard (Manum, 1962).

BOTANICAL AFFINITY: *Taxodium, Glyptostrobus* (Thomson & Pflug, 1953)

Inaperturopollenites magnus (Potonie, 1934) Thomson & Pflug, 1953

Plate 16, Figure 4

REFERENCE: Thomson & Pflug, 1953; p. 64-65, pl. 4, fig 83-88 are regarded as typical specimens.

COMMENTS: This describes larger inaperturate pollen grains with a psliate exine that is relatively thick and has secondary folds. Sometimes a germinal aperture can be seen. This species can be distinguished from *I. dubius* on size only but also has a thicker exine. This was rare in the study only recognised in 88/12, the Sea of the Hebrides.

STRATIGRAPHIC RECORD: Lower Tertiary of Germany (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Magnoliaceae, *Larix, Pseudotsuga* (Thomson & Pflug, 1953)

Genus ***Sequoiapollenites*** Thiergart, 1938

TYPE SPECIES: ***Sequoiapollenites polyformosus*** Thiergart, 1938; p. 301, pl. 23, fig. 6.

GENERIC REMARKS: This is a small spherical to subspherical pollen grain. The exine is thick and psilate, with a characteristically thin germinal area developed. No germinal split is present. A very distinctive and prominent ligule protrudes from this area of thinner exine. These are easily differentiated from *Inaperturopollenites* which have no ligule and associated thinned exine or germinal area and often show a germinal split which is never present in *Sequoiapollenites*.

Sequoiapollenites polyformosus Thiergart, 1937

Plate 16, Figure 5

REFERENCE: Krutzsch, 1971; Atlas VI, p. 212, pl. 68, figs 1-40 and Thomson & Pflug, 1953; p. 65, pl. 5, figs 21-25 are regarded as typical specimens.

COMMENTS: This is a very distinctive small to medium sized subspherical grain, with a relatively thick wall. No germinal split or aperture is present. A distinctive ligule is present and protrudes from an area of thinned exine, a germinal thinning.

STRATIGRAPHIC RECORD: Palaeogene of Germany (Thomson & Pflug, 1953); Late Palaeocene of S England (Allen, 1982); Middle Oligocene to Pliocene of Germany (Krutzsch, 1971)

BOTANICAL AFFINITY: Taxodiaceae; *Sequoia*, *Metasequoia*, *Cryptomeria* (Thomson & Pflug, 1953)

Genus ***Sciadopityspollenites*** Raatz, 1937 ex. Potonie, 1958

TYPE SPECIES: ***Sciadopityspollenites serratus*** (Potonie & Venitz, 1934; p. 15, pl. 1, fig. 6) Potonie, 1958; p. 81.

GENERIC REMARKS: This species was not validated until 1958 when Potonie formulated a generic diagnosis. This genus contains subrounded grains, with a very distinct, strong and densely packed ornamentation of verrucae or scabrae, often these sculptural elements can appear fused. A poorly defined subcircular to elongate germinal area is characteristic. The work of Wilkinson & Boulter (1980) recorded only one specimen of this genus throughout their study of the British Oligocene. Also Krutzsch (1967c) saw this form genus as only isolated specimens below the Upper Palaeocene and did not become more abundant until the Lower Miocene. In this study *Sciadopityspollenites* was present in all of the sections and had a peak occurrence of 3.3% in 88/12 (the Sea of the Hebrides) and 3.2% in 21/28b-7 (the North Sea). *Sciadopityspollenites* was found to be much more abundant than those recorded in the published literature. This genus is similar to the Mesozoic pollen *Cerebropollenites* which is differentiated by its darker maturation colour and its larger more fused verrucae elements compared to the smaller individual verrucae of *Sciadopityspollenites*.

Sciadopityspollenites serratus (Potonie & Venitz, 1934) ex. Potonie, 1958

Plate 16, Figures 6 & 7

REFERENCE: Krutzsch, 1971; Atlas VI, p. 176, pl. 53, figs 1-16 are regarded as typical specimens.

COMMENTS: These medium sized subspherical grains have an indistinct germinal area which is subtriangular to subcircular in shape and is often gaping. The ornamentation is composed of small irregular to rounded verrucae which are closely spaced.

STRATIGRAPHIC RECORD: Miocene of Germany (Raatz, 1937); Palaeogene of Germany (Krutzsch, 1971); Lower to Middle Eocene of the Paris Basin (Chateauneuf, 1980; Gruas-Cavagnetto, 1978)

BOTANICAL AFFINITY: Taxodiaceae; *Sciadopitys* (Gruas-Cavagnetto, 1976)

Atriate

Genus ***Caryapollenites*** Raatz, 1938 ex. Potonie, 1960 emend. Krutzsch, 1961a

TYPE SPECIES: ***Caryapollenites simplex*** Raatz, 1938; p. 19, fig. 6.

GENERIC REMARKS: This genus describes a very distinct medium sized well rounded, almost triangular, triporate pollen grain in which one or more of the pores are positioned subequatorially. The pores are weakly atriate and never tumescent, anulate or vestibulate. They are distinctly thick walled with two layers present. The exine is characteristically thinned. These wall modifications are often used for speciation along with shape and pore position. Wilkinson & Boulter (1980) stated that specimens from this genus are rare in Oligocene deposits in the Western British Isles. This was confirmed in this study with rare occurrences of different species of *Caryapollenites* being present in the majority of the sections studied, except 78/1 and 88/12.

Caryapollenites circulus (Pflug, 1953) Krutzsch, 1961a

Plate 17, Figure 1

REFERENCE: Thomson & Pflug, 1953; p. 86, pl. 9, fig. 56 (as *Subtriporopollenites simplex* subsp. *circulus*) is regarded as a typical specimen.

COMMENTS: These are medium sized triporate pollen grains. The amb is rounded triangular in shape. One or more of the pores are positioned off the equator and are weakly atriate. The wall is two layered and is characterised by a thinned exine area in the polar region which extends over half of the width of the grain and is circular in shape.

STRATIGRAPHIC RECORD: Late Palaeocene to Middle Eocene of NW Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Juglandaceae, *Carya* (Thomson & Pflug, 1953)

Caryapollenites imparalis Nichols & Ott, 1978

Plate 17, Figure 2

REFERENCE: Nichols & Ott, 1978; p. 105, pl. 2, figs 5-6 are regarded as typical specimens.

COMMENTS: These are medium sized triporate grains. The amb is rounded triangular in shape with straight to convex sides. Nichols & Ott (1978) described *C. imparalis* as having two or more pores off the equator and *C. inelegans* with all the pores in the same hemisphere. But this differentiation is not followed here, *C. imparalis* is used to describe specimens which have no exine modifications and have one or more pores positioned off the equator. Atria are present behind the exopores due to the endexine finishing at the endopores. The exine in this species is finely granulate.

STRATIGRAPHIC RECORD: Palaeocene of N. America (Nichols & Ott, 1978)

BOTANICAL AFFINITY: Juglandaceae, *Carya* (Nichols & Ott, 1978)

Caryapollenites simplex (Pflug, 1953) Krutzsch, 1961a

Plate 17, Figure 3

REFERENCE: Thomson & Pflug, 1953; p. 86, pl. 9, figs 64-73 are regarded as typical specimens.

COMMENTS: This is one of a group of *Caryapollenites* species that have a distinctive area of thinned exine at the poles. It is differentiated from *C. circulus* and *C. triangulus* which also possess thinned exine at the poles by its much larger size.

STRATIGRAPHIC RECORD: Tertiary of NW Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Juglandaceae; *Carya* Type (Thomson & Pflug, 1953)

Caryapollenites triangulus (Pflug in Thomson & Pflug, 1953) Krutzsch, 1961a

Plate 17, Figure 4

REFERENCE: Thomson & Pflug, 1953; p. 86, pl. 9, fig. 58 is regarded as a typical specimen.

COMMENTS: These are medium sized triporate pollen grains, rounded triangular in shape with one of the pores positioned off the equator. The two layered exine is characterised by a thinned area in the polar region which is triangular in shape with the corners pointing to the radial corners of the grain (see figure 4, plate 17). This is differentiated from *C. circulus* on the shape of the triangular thinned polar exine field and from *C. simplex* on size. This can be subjective but is clear on well preserved specimens.

STRATIGRAPHIC RECORD: British Oligocene (Wilkinson & Boulter, 1980); Late Palaeocene to Middle Eocene of NW Europe (Meyer, 1988)

BOTANICAL AFFINITY: Juglandaceae *Carya* (Thomson & Pflug, 1953)

Caryapollenites veripites (Wilson & Webster, 1946) Nichols & Ott, 1978

Plate 17, Figure 5

REFERENCE: Nichols & Ott, 1978; p. 106, pl. 2, figs 12-13 are regarded as typical specimens.

COMMENTS: This is a triporate grain with a rounded triangular amb. The pores are atriate and are located at the amb corners with at least one being positioned subequatorially. The polar thinning is developed as a circumpolar ring surrounding a polar island of normal thickness.

STRATIGRAPHIC RECORD: Palaeocene of N America (Nichols & Ott, 1978)

BOTANICAL AFFINITY: Juglandaceae, *Carya* (Nichols & Ott, 1978)

Genus ***Momipites*** Wodehouse, 1933

TYPE SPECIES: ***Momipites coryloides*** Wodehouse, 1933; p. 511, fig. 43.

GENERIC REMARKS: The original diagnosis of Wodehouse (1933) describes simple small triangular triporate pollen grains. The pores are atriate and the exine shows no modifications. Two emendations have been proposed to differentiate *Momipites* from other similar triporate pollen grains. Nichols (1973) did extensive work on N American and European *Momipites* species and related genera, in conclusion he added taxa with polar thinnings and triradiate thickenings and thin spots to the original diagnosis. This genus includes small pollen grains that are triangular in outline. They are triporate with all the pores in an equatorial position. The pores are non aspidate and have distinct semicircular atria. The exine is relatively thin and psilate to granular and may or may not show various structural

modifications. Thinnings or triradiate thickenings can occur at the poles and random folding due to compression is often seen.

Wilkinson & Boulter (1980), in their work on the British Oligocene, recorded *Momipites* with a maximum frequency of 13% in Bovey Tracey but they had also differentiated *Engelhardtioipollenites* (Potonie ex. Potonie, 1960) which is considered here a junior synonym of *Momipites* and moreover is named after the extant plant. Therefore these figures cannot be correlated to the numbers found in this study.

Momipites anellus Nichols & Ott, 1978

Plate 17, Figure 6

REFERENCE: Nichols & Ott, 1978; p. 103, pl. 1, figs 22-25 are regarded as typical specimens.

COMMENTS: This species describes triporate pollen grains, triangular in outline with slightly convex sides. Pores are equatorial in position, atriate in structure and circular in shape. The exine is smooth to finely granulate with the ektexine thickening towards the pores. A distinct thinning of the exine in a narrow circumpolar ring surrounding a polar island of exine of normal thickness characterises *M. anellus* as well as its convex grain outline. This differs from *M. tenuipolus* Anderson (1960) which has a polar thinning but a polar island is never present.

STRATIGRAPHIC RECORD: Palaeocene of North America (Nichols & Ott, 1978)

BOTANICAL AFFINITY: Juglandaceae; *Engelhardtia, Alfaroa* (Nichols & Ott, 1978)

Momipites coryloides Wodehouse, 1933

Plate 18, Figure 1

REFERENCE: Nichols & Ott, 1978; p. 100-101, pl. 1, figs 1-4 (as *M. wyomingensis*) and Frederiksen & Christopher, 1978; p. 12, pl. 1, fig. 1 (as *M. strictus*) are regarded as typical specimens.

COMMENTS: These are small simple subtriangular shaped pollen grains, with straight to convex sides. They are triporate in character with the pores positioned at the equator. The exine thickens slightly towards the pores which are only slightly tumescent. The exine is smooth to faintly granular and shows no modifications. This species is characterised by its lack of exine modifications and is one of the simplest morphologies within the genus *Momipites*. This species is widespread, occurring in all the sections studied except 78/1 and has a peak occurrence of 3.9% in 73/36.

STRATIGRAPHIC RECORD: Palaeocene of N. America (Nichols & Ott, 1978); Eocene to Oligocene of N. America (Frederiksen, 1980).

BOTANICAL AFFINITY: Juglandaceae; *Engelhardtia, Alforoa* (Wodehouse, 1933; Nichols & Ott, 1978)

Momipites tenuipolus Anderson, 1960

Plate 18, Figures 2 & 3

REFERENCE: Anderson, 1960; p. 25, pl. 7, fig. 14, Nichols, 1973; p. 110-111, pl. 1, figs 16-17 and Frederiksen & Christopher, 1978; pl. 1, figs 26-31 are regarded as typical specimens.

COMMENTS: These are small subtriangular shaped triporate pollen. The pores are in an equatorial position and circular to oval in shape with an atriate structure. The exine is psilate to weakly granulate and has a distinct area of thinned exine at the poles. This distinct thinned exine field is simple and circular to subtriangular in shape. *M. quietus* (Potonie) Krutzsch (1972) has the same area of thinned exine at the poles but is differentiated by its distinct angular amb shape and general smaller size.

STRATIGRAPHIC RECORD: Juglandaceae; *Engelhardtia, Alforoa*

BOTANICAL AFFINITY: Late Eocene to Early Oligocene of Central Europe (Thomson & Pflug, 1953 as *Triatriopollenites coryphaeus* subsp. *microcoryphaeus*)

Momipites triradiatus Nichols, 1973

Plate 18, Figure 4

REFERENCE: Nichols, 1973; p. 108, pl. 1, figs 10-15 are regarded as typical specimens.

COMMENTS: This is a small triporate pollen grain, with a subtriangular amb. The equatorially located pores are distinctly atriate and non aspidate. The pores are circular to meridonally elongate. The exine is psilate to finely scabrate and is characterised by a triradiate thickening that radiates from the apertures and is centred at one pole. The interporial areas between these thickenings are of normal thickness. This is differentiated from *M. triorbicularis* (Leffingwell, 1971) which has this spots of exine but no obvious thickenings.

STRATIGRAPHIC RECORD: Late Palaeocene of N. America (Nichols, 1973)

BOTANICAL AFFINITY: Juglandaceae; *Engelhardtia, Alfaroa* (Nichols, 1973)

Genus ***Platycaryapollenites*** Nagy, 1969 emend. Frederiksen & Christopher, 1978

TYPE SPECIES: ***Platycaryapollenites miocaenicus*** Nagy, 1969; pl. 53, figs 25-26.

GENERIC REMARKS: This form genus is similar to *Momipites* in shape and size, but the exine modifications in *Platycaryapollenites* are asymmetrical compared to the symmetrical organisation of exine modifications in *Momipites*. The emended description of Frederiksen & Christopher (1978) is used here due to the poor original description of Nagy (1969). This genus describes subtriangular pollen grains which possess three equatorial pores positioned at the amb corners, these pores are atriate. It is characterised by one or more elongate or arcuate areas of thin exine or pseudocolpi, which are organised asymmetrically on the polar surface of the grain. The arrangement of the

pseudocolpi is used for the determination of species. In this study *Platycaryapollenites* are rare only being present in three sections, the Sea of the Hebrides, Stanley Bank and Northern Ireland, therefore have not been identified to species level and are recorded as *Platycaryapollenites* spp. These superficially look similar in morphology, but are different in detail to the modern genus of *Platycarya*.

BOTANICAL AFFINITY: Juglandaceae, *Platycarya*

Plate 18, Figure 5

Genus ***Triatriopollenites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Triatriopollenites rurensis*** Pflug & Thomson, 1953; p. 79, pl. 7, fig. 94.

GENERIC REMARKS: These are small to medium sized triporate pollen grains in which the pores are equatorial and positioned at the corners of the amb. The pores are atriate and often have an associated anulus and can be tumescent but are never vestibulate. The exine is often two layered and is psilate to finely granulate. Species from this genus occur throughout the sections in this study but are generally rare, this is much less common than suggested by Wilkinson & Boulter (1980) who recorded abundances of up to 19% in Bovey Tracey.

Triatriopollenites aroboratus Pflug in Thomson & Pflug, 1953

Plate 18, Figure 6

REFERENCE: Thomson & Pflug, 1953; p. 80, pl. 7, figs 139-147 and Krutzsch & Vanhoorne, 1977; pl. 19, figs 8-10 are regarded as typical specimens.

COMMENTS: A medium sized subtriangular grain with weakly convex sides. The three pores are equatorial and positioned at the corners of the amb, they are aspidate with a thickening of the exine

towards them. The pores have a distinct, large atrium, which is surrounded by a flat anulus like thickening, but are not tumescent. The exine is two layered and infrareticulate in structure with a smooth to scabrate ornamentation. These species are rare in this study with a peak occurrence of 1.5% in Well 28, Northern Ireland.

STRATIGRAPHIC RECORD: Late Palaeocene to Early Eocene of Central Europe (Krutzsch, 1966); Middle Eocene of the North Sea (Condon *et al.*, 1992)

BOTANICAL AFFINITY: Myricaceae (Thomson & Pflug, 1953)

Triatriopollenites bituitus (Potonie, 1931a) Thomson & Pflug, 1953

Plate 18, Figure 7

REFERENCE: Thomson & Pflug, 1953; pl. 7, figs 118-120, 122, 128-130 and Ollivier-Pierre, 1980; pl. 16, fig. 6 are regarded as typical specimens.

COMMENTS: This species was very rare in this study, only one specimen was found in the Canna Basin. It is described as a small subtriangular triporate grain. The pores are equatorial and atriate. The exine thickens towards the pores, forming an anulus and giving a slightly tumescent structure. The exine is two layered and psilate. This specimen is easily distinguished from *T. aroboratus* and *T. roboratus* (Pflug, 1953) due to its small size and lack of pore structure, and from *Triporopollenites coryloides* (Thomson & Pflug, 1953) as it is atriate.

STRATIGRAPHIC RECORD: Eocene to Miocene of Central Europe (Thomson & Pflug, 1953); Oligocene of the British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Myricaceae (Thomson & Pflug, 1953)

Triatriopollenites confusus Zaklinskaya, 1963

Plate 18, Figure 8

REFERENCE: Zaklinskaya, 1963; pl. 1 fig. F is regarded as a typical specimen.

COMMENTS: These are small triporate pollen grains, which are rounded triangular in shape and have convex sides. The pores are equatorially positioned and are tumescent with weak anuli occasionally present. The atriate pores have distinct nozzle-shaped labra. The exine is smooth to scabrate often showing secondary folding and has a circumpolar ring of thin exine around an island of normal thickness exine. These are similar to *T. subtriangulus* (Stanley, 1965; Frederiksen, 1979) but are differentiated by the thinner folded exine and more distinctive polar exine modifications of *T. confusus*. This species was rare, only being present in the Stanley Bank section 73/36.

STRATIGRAPHIC RECORD: Palaeocene of USSR (Zaklinskaya, 1963) and S. England (Allen, 1982)

BOTANICAL AFFINITY: Myricaceae; Betulaceae (Allen, 1982)

Triatriopollenites roboratus Pflug in Thomson & Pflug, 1953

Plate 19, Figure 1

REFERENCE: Thomson & Pflug, 1953; pl. 7, figs 71-74 and Krutzsch & Vanhoorne, 1977; pl. 19, figs 3-7 are regarded as typical specimens.

COMMENTS: Again a very rare species only recognised as single specimens from Well 28, Northern Ireland and 77/7, the Rona Basin. This is a medium to large sized triporate pollen grain. The amb is subtriangular in shape with convex sides. The pores are equatorial and possess a large atrium, they are strongly tumescent with an anulus that is 'club' shaped in cross section. The exine is generally smooth to weakly granular. The weakly convex sides differentiates this species from *T. subtriangulus*

(Stanley, 1965) Frederiksen, 1980 and the tumescent 'club' shaped anuli differentiate this species from *T. aroboratus*.

STRATIGRAPHIC RECORD: Palaeocene of S England (Gruas-Cavagnetto, 1976) and France (Gruas-Cavagnetto, 1978)

BOTANICAL AFFINITY: Myricaceae (Gruas-Cavagnetto, 1978)

Triatriopollenites rurensis Thomson & Pflug, 1953

Plate 19, Figures 2 & 3

REFERENCE: Ollivier-Pierre, 1980; pl. 16, fig. 8 is regarded as a typical specimen.

COMMENTS: This is a medium sized triporate pollen grain. The pores are atriate and positioned equatorially at the corners of the amb. The pores are only slightly tumescent. This species was often present as single specimens but had a peak occurrence of 2.3% in well 28, Northern Ireland.

STRATIGRAPHIC RECORD: Middle to Lower Tertiary of Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Myricaceae, *Myrica* (Thomson & Pflug, 1953 and Ollivier-Pierre, 1980)

Triatriopollenites subtriangulus (Stanley 1965) Frederiksen, 1979

Plate 19, Figure 4

REFERENCE: Stanley, 1965; p. 291, pl. 43, figs 13-16 (as *Carpinus subtriangulus*) and Frederiksen, 1979; p. 151, pl. 2, figs 19-22 are regarded as typical specimens.

COMMENTS: These are medium sized oblate rounded triangular grains, with strongly convex sides. The equatorial pores are strongly atriate and appear as distinct 'doughnuts'. The exine is two layered and smooth to finely granular, increasing in granularity towards the atrium. Folding is common, and an irregular area of

thinned exine at the pole can be seen. The distinct rounded outline and characteristic 'doughnut' shaped anulus make this species easily distinguishable. Specimens from this species are rare, generally occurring singly.

STRATIGRAPHIC RECORD: Late Palaeocene of S. England (Allen, 1982); Early Eocene of S. England (Jolley & Spinner,1991)

BOTANICAL AFFINITY: Carpinaceae, *Carpinus* (Stanley, 1965); *Comptonia* (Gladkova, 1965; Frederiksen, 1979) which is of the Myricaceae.

Genus ***Juglanspollenites*** Raatz, 1938

TYPE SPECIES: ***Juglanspollenites verus*** Raatz, 1938, p. 18, pl. 1, fig. 19.

GENERIC REMARKS: This is a multipantaporate pollen grain characteristically oval, subcircular to polygonal in shape. The exine is thin, often folded and smooth to weakly infrapunctate with irregular distributed pores over it. The pores vary in number from 6 to 10 and are weakly atriate. The exine often thickens slightly towards the pores. Only one specimen of this genus was recorded in this study from 77/7, the Rona Basin. The number of specimens here was not sufficient to assign a species so this specimen is recorded as *Juglanspollenites* spp.

Plate 19, Figures 5 & 6

Genus ***Polyatriopollenites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Polyatriopollenites stellatus*** Potonie, 1931a; p. 28, pl. 2 ex. Pflug, 1953; p. 91, pl. 10, figs 84-95.

GENERIC REMARKS: This describes zonoporate pollen grains, which have a distinctly irregular and polygonal outline in their oblate compression. The number of pores varies from 3 to 7, these are equatorial with a distinct atrium and small anulus. The exine is smooth and often shows secondary folds. Evans *et al.* (1979) on the Oligocene sediments of the Canna Basin described pollen and

spore assemblages partly dominated by *Polyatriopollenites* but considered these to represent the influence of local floras. This view was influenced by Krutzsch (1967c) who believed that this form genus does not become significant until the Chattian (Upper Oligocene). Wilkinson & Boulter (1980) on their work on the British Oligocene refer their specimens of *Polyatriopollenites* to the form species *P. stellatus* and found them to be rare in most sections, reaching a maximum frequency of 6% in Northern Ireland. In this study very few specimens of *Polyatriopollenites* have been assigned to *P. stellatus* which is regarded as having an angular amb shape and is more typical of Eocene sediments.

Polyatriopollenites carpinoides Pflug in Thomson & Pflug, 1953

Plate 19, Figures 7 & 8

REFERENCE: Thomson & Pflug, 1953; p. 92, pl. 10, figs 79-84 are regarded as typical specimens.

COMMENTS: This species describes zonoporate pollen grains with 4 to 7 pores positioned equatorially. The polygonal amb is medium sized and rounded subangular in outline with convex edges between the pores. The pores are distinct and atriate with an anulus, a labrum is often present on each pore, but is faint. The exine is psilate. This species is differentiated from *P. stellatus* as it is larger, more rounded and less rigid. *P. stellatus* is also similar to the more angular *Alnipollenites verus* (Potonie 1931a) Potonie 1931b but does not possess its characteristic vestibulum and arci. The form species *P. carpinoides* has a wide distribution throughout the sections examined in this study. It is recorded from all the localities and is one of the dominant taxa in 78/1, the Canna Basin where one assemblage has a maximum frequency of 26%.

STRATIGRAPHIC RECORD: Middle to Lower Tertiary of Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Betulaceae, *Carpinus*

Polyatriopollenites stellatus Potonie 1931a ex. Pflug in Thomson & Pflug, 1953

Plate 20, Figure 1

REFERENCE: Thomson & Pflug, 1953; pl. 10, figs 84-95 and Wilkinson & Boulter, 1980; pl. 11, fig. 4 are regarded as typical specimens.

COMMENTS: This species describes zonoporate pollen grains which are distinctly rigid and polygonal in outline. It is the angular shape of this grain that differentiates this species from *P. carpinoides*. Pores occur equatorially positioned and vary in number from 4 to 7. These pores are atriate with a small anulus present. The exine is smooth and often folded.

STRATIGRAPHIC RECORD: Middle to Lower Tertiary of Europe (Thomson & Pflug, 1953; Krutzsch, 1967c and Kedves, 1974) Oligocene of Britain (Wilkinson & Boulter, 1980; Evans *et al.*, 1979).

BOTANICAL AFFINITY: Betulaceae, *Carpinus*

Genus ***Pterocarya*** Type

COMMENTS: Only a few specimens of this type are recorded throughout this study. Although recognised as *Pterocarya*-Type (Rose & Broome) they are not assigned to the genus *Pterocaryapollenites* (Raatz, 1938 ex. Potonie, 1960) as this is regarded as a junior synonym of *Polyatriopollenites*. The specimens examined are generally multiporate with 4 to 5 pores. They are smooth oval pollen grains with small weakly atriate pores, differentiating them from the more rigid polygonal and angular amb of *Polyatriopollenites*.

Plate 20, Figures 2 & 3

Complex wall structures

Genus ***Plicatopollis*** Krutzsch, 1962

TYPE SPECIES: ***Plicatopollis plicatus*** Potonie, 1934; p. 55, pl. 2, fig. 19.

GENERIC REMARKS: This describes convex triangular triporate pollen grains with the pores positioned at the amb corners. The pores have well developed anuli and are tumescent. Its distinguishing features are the symmetrically arranged exine thickenings or folds. Wilkinson & Boulter (1980) saw one specimen of this form genus. Although in the present study, specimens are widespread throughout the sections examined but are rare. Due to the low abundances recorded specimens have not been assigned to species level and are recorded as *Plicatopollis* spp.

Plate 20, Figures 4 to 6

BOTANICAL AFFINITY: Proto Juglandaceae (Fris, 1983)

Genus ***Pompeckjoidaepollenites*** Pflug, 1953

TYPE SPECIES: ***Pompeckjoidaepollenites subhercynicus*** (Krutzsch, 1954) Krutzsch, 1967a in Goczan *et al.*, 1967.

GENERIC REMARKS: These are very distinctive triporate subtriangular grains. The exine is distinctive and often has an ornament of verrucae to baculae. The pores are equatorial and are slightly anulate. This genus is characterised by a distinctive area of single thickness exine that connects each pore over the pole, a platae forming a thin radial Y-shape. The interradial areas are characterised by a area of double thickness exine which gives them a characteristic darker thicker appearance.

Pompeckjoidaepollenites subhercynicus (Krutzsch, 1954) Krutzsch, 1967a

Plate 20, Figures 7 & 8

REFERENCE: Thomson & Pflug, 1953; p. 69, pl. 6, figs 124-144 and Wilkinson & Boulter, 1980; p. 76, pl. 5, fig. 29 are regarded as typical specimens.

COMMENTS: This is a very distinctive small sized subtriangular triporate pollen grain. The equatorial pores protrude slightly and are anulate. The exine is ornamented with weak granulae. A thin area of exine over the poles connects the anuli that are present behind each pore and separate an arcuate shaped interradial area of thicker exine. Specimens of this species are rare in this study, only single specimens from 77/7 and 21/28b-7 are recorded.

STRATIGRAPHIC RECORD: Cretaceous (Maastrictian) to Upper Eocene of Central Europe (Krutzsch, 1967a); Oligocene of the British Isles (Wilkinson & Boulter, 1980); Late Palaeocene of southern England (Allen, 1982); Early to Middle Eocene of NW Europe (Meyer, 1988)

BOTANICAL AFFINITY: Normapolles, unknown

Vestibulate pores

Genus ***Alnipollenites*** Potonie, 1931a

TYPE SPECIES: ***Alnipollenites verus*** (Potonie 1931a; p. 332, pl. 2, fig. 40) Potonie 1931b; p. 4.

GENERIC REMARKS: These are polygonal to rounded multiporate pollen grains with a smooth exine. The vestibulate pores are positioned on the equator and at the amb corners, they vary in number from 3 to 7. The equator is the plane of symmetry through the grain. The distinguishing feature of this genus is the arched folds of exine that join the pores together, called arci.

Alnipollenites verus (Potonie 1931a) Potonie 1931b

Plate 21, Figures 1 & 2

REFERENCE: Thomson & Pflug, 1953; pl. 10, fig 62-76 and Wilkinson & Boulter, 1980; pl. 11, figs 11-13.

COMMENTS: These are small to medium sized polygonal multiporate pollen grains which have a smooth exine and weak infrareticulate structure. The pores are equatorial and range in number from 4 to 7. A clear vestibulum is present at each pore and a distinct arci connects the adjacent pores. The arci ranges from being very distinct to faint. In this study, specimens of *A. verus* are well dispersed, occurring in all the sections with widely varying abundances from single specimens per sample to frequencies of 57% in an assemblage from Well 28, Northern Ireland.

STRATIGRAPHIC RECORD: Widely recorded from Late Palaeocene to Recent (Thomson & Pflug, 1953; Krutzsch & Vanhoorne, 1977 and Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Betulaceae, *Alnus* (Thomson & Pflug, 1953)

Genus ***Corsinipollenites*** Nakoman, 1965

TYPE SPECIES: ***Corsinipollenites oculusnoctis*** (Thiergart, 1940; p. 47, pl. 7, fig. 1) Nakoman, 1965.

GENERIC REMARKS: These are very distinctive large triporate grains with a subtriangular outline. They are thick walled with structured layers. The pores are characteristic and variably positioned due to compression which leaves pores positioned at the corners of the amb but often displaced on to one hemisphere. The large, strongly tumescent and vestibulate pores have an annular thickening, pseudoculoid, these are the distinctive feature of this pollen.

Corsinipollenites oculusnoctis (Thiergart, 1940) Nakoman, 1965

Plate 21, Figures 3 to 5

REFERENCE: Wilkinson & Boulter, 1980; p. 55, pl. 6, figs 21-23 and pl. 7, figs 1-4 are regarded as typical specimens.

COMMENTS: These are large sized subtriangular shaped grains, with thick walls and very distinctive pores. The pores at each corner of the amb are large, tumescent and vestibulate, they are characteristically strongly anulate with large complex germinals. Specimens from this form species were recorded from Well 28, Northern Ireland and 73/36, Stanley Bank in low relative abundances. Two size populations were recorded the majority being large sized, 30-50μm in diameter, these correspond to the description of *C. oculusnoctis*, but some much smaller specimens 15-30μm in diameter were recorded and these are referred to as *C. oculusnoctis* forma *minor*.

STRATIGRAPHIC RECORD: Lower Eocene to Upper Miocene of Europe (Krutzsch, 1968); Oligocene-Miocene boundary of Czechoslovakia (Pacltova, 1960); Oligocene of Belgium (Roche & Schuler, 1976)

BOTANICAL AFFINITY: Oenotheraceae pollen (Krutzsch, 1968); Onagraceae

Genus ***Trivestibulopollenites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Trivestibulopollenites betuloides*** Pflug in Thomson & Pflug, 1953; p. 84, pl. 9, fig. 34.

GENERIC REMARKS: Small triporate pollen grains, subtriangular in shape with convex sides. The pores are equatorial and show a prominent labrum and distinct vestibulum, occasionally with an anulus present.

Trivestibulopollenites betuloiodes Pflug in Thomson & Pflug, 1953

Plate 21, Figures 6 & 7

REFERENCE: Thomson & Pflug, 1953; p. 85, pl. 9, figs 25-34 are regarded as typical specimens.

COMMENTS: These distinctive small triporate subtriangular pollen grains are thin walled and show no other ornamentation. The pores are equatorial and positioned at the corner of the amb. They are slightly tumescent with a small vestibulum. An anulus may also be developed. This species is similar in morphology to *Triporopollenites coryloides* (Pflug, 1953) but is distinguished by its vestibulate and tumescent pores.

STRATIGRAPHIC RECORD: Pliocene of Germany (Thomson & Pflug, 1953); Oligocene of the British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Betulaceae; *Betula* type (Thomson & Pflug, 1953)

Simple pores, non atriate

Genus ***Compositoipollenites*** Potonie 1951 ex. Potonie 1960

TYPE SPECIES: ***Compositoipollenites rhizophorous*** (Potonie, 1934; p. 94, pl. 5 fig. 25) Potonie, 1960, p. 105.

GENERIC REMARKS: These are very distinctive triporate spherical grains. The pores are subequatorial with a distinct anulus. The exine is thick and covered with characteristic spines.

Compositoipollenites rhizophorous subsp. ***burghasungensis*** (Murriger & Pflug, 1951) Thomson & Pflug, 1953

Plate 22, Figure 1

REFERENCE: Thomson & Pflug, 1953; p. 88, pl. 9, figs 126-132 and Krutzsch & Vanhoorne, 1977; pl. 26, figs 4-7 are regarded as typical specimens.

COMMENTS: Rare in this study with only one specimen being recorded. They are small subspherical triporate pollen grains. The exine is thin and smooth with an infrareticulate ornament. The surface is sculptured with closely spaced short slender spines.

STRATIGRAPHIC RECORD: Palaeocene of S. England (Gruas-Cavagnetto, 1970a) and Belgium (Krutzsch & Vanhoorne, 1977; Roche, 1965)

BOTANICAL AFFINITY: Icacinaceae, *Iodes*.

Compositoipollenites rhizophorous (Potonie, 1934) Potonie 1960 subsp. ***rhizophorous*** Krutzsch & Vanhoorne, 1977

Plate 22, Figure 2

REFERENCE: Thomson & Pflug, 1953; p. 88, pl. 10, figs 1-6 are regarded as typical specimens.

COMMENTS: Again rare, only seen as single specimens within this study. This describes medium sized robust triporate pollen grains with rounded ambs. The pores are subequatorially positioned, in one hemisphere and possess a large post vestibulum. The exine appears granulate and is covered with an ornamentation of regularly spaced distinct broad sharp conical spines, which appear solid. This is differentiated from *C. rhizophorous* subsp. *burghasungensis* which has more delicate slender spines.

STRATIGRAPHIC RECORD: Late Eocene to Early Oligocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene of Belgium (Krutzsch & Vanhoorne, 1977)

BOTANICAL AFFINITY: Icacinaceae, *Iodes*

Genus ***Echitriporites*** Van der Hammen, 1956 ex. Van Hoeken-Klinkenberg, 1964

TYPE SPECIES: ***Echitriporites trianguliformis*** Van Hoeken-Klinkenberg, 1964; p. 218, pl. 3', fig. 7.

GENERIC REMARKS: These are medium sized triporate grains with an echinate ornament. The amb is convexly triangular in shape. The sculpture is microscabrate with echinate elements.

Echitriporites sp. 1

Plate 22, Figures 3 & 4

COMMENTS: These are medium sized triporate grains. The amb is subtriangular to rounded with three pores positioned equatorially and at the amb corners. The pores are very distinct and have a pronounced anulus. The ornamentation is microscabrate with small echinate elements distributed over the surface. This species resembles *Compositoipollenites rhizophorous* subsp. *burghasungensis* in pore structure and ornamentation but is differentiated by the equatorial position of the pores in *Echitriporites*. This species was only recorded

from Stanley Bank where it was present in low numbers or as single specimens.

Genus ***Liquidambarpollenites*** Raatz, 1937

TYPE SPECIES: ***Liquidambarpollenites stigmosus*** (Potonie, 1931a; p. 332, pl. 2, fig. 1) Raatz, 1937; p. 17.

GENERIC REMARKS: These are medium sized oval to circular shaped periporate pollen grains. The simple pores vary in number from 8 to 12 and are regularly spaced over the surface. No atriate or anulate structures are present. The wall is two layered and thick, the outer layer is reticulate supported by columellae underneath. This genus is regarded as a senior synonym of *Periporopollenites* (Thomson & Pflug, 1953).

Liquidambarpollenites stigmosus (Potonie, 1931a) Raatz, 1937

Plate 22, Figures 5 to 7

REFERENCE: Thomson & Pflug, 1953; p. 11, pl. 15, fig. 58 and Wilkinson & Boulter, 1980; p. 66, pl. 11, figs 17-18 (as *Periporopollenites stigmosus*) are regarded as typical specimens.

COMMENTS: This describes medium sized periporate pollen grains with a rounded amb. Seven to twelve pores are regularly distributed over a thick exine which is covered in a fine positive reticulum. An anulus is developed and forms small anular rings around the otherwise simple pores. This is an easily distinguishable and unique appearing pollen grain.

STRATIGRAPHIC RECORD: Miocene of Central Europe (Thomson & Pflug, 1953); Middle and Upper Oligocene of Europe (Thomson & Pflug, 1953; Pacltova, 1960; Grabowska, 1965 and Kedves, 1974) and Middle Oligocene of Europe (Krutzsch, 1967c and Wilkinson & Boulter, 1980); Palaeocene of England (Jolley, 1992a)

BOTANICAL AFFINITY: Hammamelidaceae; *Liquidambar* (Thomson & Pflug, 1953)

Genus ***Triporopollenites*** Thomson & Pflug, 1953

TYPE SPECIES: ***Triporopollenites coryloides*** Pflug in Thomson & Pflug, 1953; p. 84, pl. 19, fig. 20.

GENERIC REMARKS: These are triporate subtriangular pollen grains with equatorial pores positioned at the amb corners. The pores are simple with the endopore being smaller than the exopore. No atrium or vestibulum is present, although some species possess an annulus. The exine is smooth to granulate.

Triporopollenites coryloides Pflug in Thomson & Pflug, 1953

Plate 23, Figures 1 & 2

REFERENCE: Thomson & Pflug, 1953; p. 84, pl. 9, figs 20-21 are regarded as typical specimens.

COMMENTS: This is a small to medium sized subtriangular grain with convex sides. The large pores at the amb corners are equatorial and are non atriate and non vestibulate. The endopore is larger than the exopore as a result of the endexine stopping short of the pore. The exine is thin, often folded and smooth to weakly granulate. It shows slight thickening towards the pores which forms a low slight labrum. This species is similar to *T. robustus* (Pflug, 1953) but is differentiated by its thinner, smoother wall structure and slight thickenings towards the pores.

STRATIGRAPHIC RECORD: Middle Tertiary to Pliocene (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Corylaceae or Myricaceae (Thomson & Pflug, 1953)

Triporopollenites cf. ***plectosus***

Plate 23, Figures 3 & 4

COMMENTS: Grains of this type in this study are rare occurring only as single specimens and have been assigned to *T.* cf. *plectosus* as they differ from the species description regarding the equatorial pores. The amb is rounded triangular in shape. The wall thickens slightly towards the pores to give a weak anulus. At least one pore is subequatorial, this conflicts with the genus diagnosis but is kept here for easy comparison to the published literature.

BOTANICAL AFFINITY: Ulmaceae, *Celtis*

Triporopollenites robustus Pflug in Thomson & Pflug, 1953

Plate 23, Figures 5 & 6

REFERENCE: Thomson & Pflug, 1953; p. 82, pl. 8, figs 109-135 and Krutzsch & Vanhoorne, 1977; p. 39, pl. 18, figs 9-14 are regarded as typical specimens.

COMMENTS: This species shows wide morphological variations but is generally medium sized and subtriangular in outline with convex sides. They are triporate with the equatorial pores located at the corners of the grains. no vestibulum is present. The exine is thick and psilate to granulate, characteristically being more granulate around the pores. Also the exine thickens towards the pores. In some cases an atrium was reported as being present e.g. Allen (1982) but following the original diagnosis of Pflug (1953) *Triporopollenites* are non atriate therefore cannot include such atriate forms. Despite this, the appearance of *T. robustus* is similar to that of *Triatriopollenites aroboratus*, but is differentiated by the latter possessing distinct atria.

STRATIGRAPHIC RECORD: Late Palaeocene to Oligocene of Central Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: *T. robustus* has been assigned to the extant S. Hemisphere genus *Casuarina*, Casuarinaceae (Frederiksen, 1979) but with no macrofossil evidence to support this. The European view

e.g. Thomson & Pflug (1953) is that due to its similar morphology and association with *T. coryloides*, affinities to the Myricaceae are suggested.

Genus ***Ulmipollenites*** Wolff, 1934

TYPE SPECIES: ***Ulmipollenites undulosus*** Wolff, 1934; p. 75, pl. 5, fig. 25.

GENERIC REMARKS: In outline these grains are rounded with 3 to 5 pores positioned equatorially or subequatorially. These simple pores are slightly tumescent with a low anulus. The exine is thin and has a distinct ornamentation of low weakly undulating verrucae, rugulae or granulae.

Ulmipollenites undulosus Wolff, 1934

Plate 23, Figures 7 & 8

REFERENCE: Wolff, 1934; p. 75, pl. 5, fig. 25 and Thomson & Pflug, 1953; p. 91, pl. 10, figs 52-58 are regarded as typical specimens.

COMMENTS: This is a medium sized multiporate pollen grain. The pores are simple, vary in number from 3 to 5 and are positioned equatorially or subequatorially. A low anulus is developed over the pores which are slightly tumescent. The thin exine is ornamented with low undulating verrucae. The multipore varieties are similar in shape and general appearance to *Polyatriopollenites* but are differentiated by the simple, non atriate pores and distinct undulose ornamentation. Specimens are recorded in low numbers or as single specimens in 73/36, 77/7 and 80/14.

STRATIGRAPHIC RECORD: Middle to Lower Tertiary of Central Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Ulmaceae, *Ulmus*

Tricolporates with short polar axis

Genus ***Intratriporopollenites*** Pflug & Thomson, 1953

TYPE SPECIES: ***Intratriporopollenites instructus*** (Potonie & Venitz) Pflug & Thomson, 1953; p. 87, pl. 10, fig. 21.

GENERIC REMARKS: These are lenticular pollen grains with circular to rounded triangular ambs. The position of the equatorial pores is not at the corners of the amb but on the centre of the sides, this is the distinctive feature of this genus. The pores have a distinct vestibulum and anulus and possess short colpi. The exine is smooth with columellae giving an infrareticulate appearance.

Intratriporopollenites ceciliensis Krutzsch, 1961a

Plate 24, Figures 1 & 2

REFERENCE: Krutzsch & Vanhoorne, 1977; p. 62, pl. 25, figs 20-23 and Wilkinson & Boulter, 1980; p. 55, pl. 6, figs 16-20 are regarded as typical specimens.

COMMENTS: These are characteristically small in size, lenticular in shape with a subrounded amb. The circular pores are positioned equatorially in the middle of the grain sides, they are vestibulate with a small anulus developed around the pore and have a weak short colpi. The exine is ornamented with a fine infrareticulate structure. Specimens of this species were widely recorded from the majority of the sections studied and range in number from single specimens to 1.1% in 73/36.

STRATIGRAPHIC RECORD: Lower to Middle Eocene of Germany (Mai, 1961) Central Europe (Krutzsch, 1961a) Southern England (Gruas-Cavagnetto, 1976)

BOTANICAL AFFINITY: Tiliaceae, *Tilia* (Krutzsch, 1961a; Mai, 1961)

Intratriporopollenites instructus (Potonie, 1931a) Thomson & Pflug, 1953

Plate 24, Figure 3

REFERENCE: Thomson & Pflug, 1953; p. 89, pl. 10, figs 14-23 and Wilkinson & Boulter, 1980; p. 54, pl. 5, figs 36-39 are regarded as typical specimens.

COMMENTS: Just a single specimen was recorded in this study from 73/36. This rarity was also suggested by Wilkinson & Boulter (1980) and Krutzsch (1967c) for Middle and Upper Oligocene sediments in Europe. This form species describes medium sized oblate rounded triangular grains. The pores are located in the middle of the sides and are distinctly anulate with only remnants of a post vestibulum. A short distinct colpus is present. The ornamentation is composed of a course reticulum formed from a columellate exine structure. The luminate pattern produced reduces in size away from the pole and although not seen here a polar thinning can be developed (Wilkinson & Boulter, 1980).

STRATIGRAPHIC RECORD: Widely recorded from Early Oligocene to Miocene in Europe (Thomson & Pflug, 1953; Pacltova, 1960, Roche & Schuler, 1976); (Rare in Middle and Upper Oligocene (Mai, 1961; Krutzsch, 1967c)

BOTANICAL AFFINITY: Tiliaceae (Thomson & Pflug, 1953)

Intratriporopollenites microreticulatus Mai, 1961

Plate 24, Figures 4 & 5

REFERENCE: Krutzsch & Vanhoorne, 1977; p.61, pl. 25, figs 13-19 and Wilkinson & Boulter, 1980; p. 54, pl. 5, figs 32-35 are regarded as typical specimens.

COMMENTS: This is an oblate rounded triangular pollen grain. It is triporate, the germinals are equatorial and located on the middle of the sides, never the corners. They are large semicircular with a distinctive dark area of thickened exine immediately behind the

pore. A post vestibulum is not seen. The exine shows a reticulate pattern. Abherent four pore forms of this species have been recorded. This species is differentiated from *T. ceciliensis* which is smaller, has a thinner exine and no dark thickened area in the pore region and from *T. pseudoinstructus* (Mai, 1961) which is of a similar size but has a much larger reticulate pattern. In this study *T. microreticulatus* was the most common of the *Intratriporopollenites* species and was present in all the sections examined and showed a maximum abundance of 5.8%, whereas the work of Wilkinson & Boulter (1980) recorded this species as being very rare.

STRATIGRAPHIC RECORD: Palaeocene to Eocene of Central Europe (Krutzsch, 1970; Mai, 1961) Eocene of England (Gruas-Cavagnetto, 1976) Oligocene of the British Isles (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Tiliaceae, *Tilia* (Mai, 1961)

Intratriporopollenites pseudoinstructus Mai, 1961

Plate 24, Figure 6

REFERENCE: Mai, 1961; pl. 10, figs 19-23 and Ollivier-Pierre, 1980; pl. 17, fig. 22 are regarded as typical specimens.

COMMENTS: These are distinctive oblate, rounded triangular triporate grains. The germinals are equatorial and in the centre of the sides. The pores are oval with a distinct anulus and clear short colpi. The apertures protrude slightly at the equator and occasionally show a separation of the exine layers forming a vestibulum. The ornamentation is composed of a clear reticulum forming a coarse luminate pattern. This species was recorded from only one section in this study, 78/1 and had a maximum relative abundance of 0.7%.

STRATIGRAPHIC RECORD: Lower Palaeozoic to Lower Oligocene of Germany (Mai, 1961)

BOTANICAL AFFINITY: Tiliaceae; *Tilia*

Genus ***Porocolpopollenites*** Pflug in Thomson & Pflug, 1953

TYPE SPECIES: ***Porocolpopollenites vestibuloformis*** Pflug in Thomson & Pflug, 1953; p. 92-93, pl. 10, fig. 122.

GENERIC REMARKS: Distinct pollen grains with a triangular shaped amb on which strong pores occur at the amb corners. Generally they are triporate but sometimes more pores can be seen. Each pore has a distinct short colpus. The ornamentation varies from psilate to verrucate.

Porocolpopollenites vestibulum (Potonie, 1931a) Pflug in Thomson & Pflug, 1953

Plate 25, Figures 1 to 5

REFERENCE: Thomson & Pflug, 1953, p. 94, pl. 11, figs 3-23 are regarded as typical specimens.

COMMENTS: These are medium sized oblate tricolporate pollen grains with a strongly triangular amb. Short colpi occur which are often parallel sided. The pores are vestibulate and have a large post vestibulum. The exine is thick with a characteristic coarse scabrate to verrucate ornamentation. Originally in this work it was decided to split this species in to two groups depending on ornamentation, into scabrate forms and heavy verrucate forms. But it was found that these sculptural elements grade into each other therefore this division could not consistently be differentiated between and is not used here, but this differing ornamentation should be noted and is illustrated in plate 25, figures 1 to 5. Specimens of this species occur commonly throughout the sections studied and reach a maximum abundance of 2.7% in 73/36.

STRATIGRAPHIC RECORD: European Tertiary (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: These were originally suggested as being related to the Symplocaceae (Thomson & Pflug, 1953), *symplocus*

Genus ***Reevesiapollis*** Krutzsch, 1970

TYPE SPECIES: ***Reevesiapollis triangulus*** (Mamczar, 1960; p. 220, pl. 14, fig. 202) Krutzsch, 1970; p. 314, pl. 5, figs 21-22, pl. 6, figs 4-6.

GENERIC REMARKS: These are distinctive small to large flat lenticular pollen grains with 3 to 6 equatorial pores. The amb is rounded to angular in shape with convex interaperture areas (depending on the number of apertures). The apertures consist of short colpi and are atriate.

Reevesiapollis triangulus (Mamczar, 1960) Krutzsch, 1970

Plate 25, Figures 6 & 7

REFERENCE: Allen, 1982; p. 167-168, pl. 16, figs 4-5 are regarded as typical specimens.

COMMENTS: These are very small oblate pollen grains, less than 18μm in size, with 3 or more apertures, commonly 4 or 5 in the material from this study are seen. The apertures are colporate, with short colpi being present. The endexine thickens slightly towards the pores. Some grains show the endexine and ektexine separating to form a vestibulum. The ornamentation is characteristically reticulate with luminae less than 1.5μm in size which become finer towards the equator.

STRATIGRAPHIC RECORD: Miocene of Poland (Mamczar, 1960); Palaeocene to Pliocene of Central Europe (Krutzsch, 1970)

BOTANICAL AFFINITY: Symplocaceae (Krutzsch & Vanhoorne, 1977); Sterculiaceae, *Reevsia* (Krutzsch, 1970)

Syncolporates

Genus ***Boehlensipollis*** Krutzsch, 1962

TYPE SPECIES: ***Boehlensipollis hohli*** Krutzsch, 1962; p. 272, pl. 3, figs 23-26.

GENERIC REMARKS: This describes medium sized syncolporate pollen grains. Concavely triangular in shape with a complex multilayered wall structure which is micropunctate. The germinals are equatorial and radially located, they are atriate and can be gapping. The exocolpi are sinuous and extend to the pole at least on one hemisphere.

Boehlensipollis hohli Krutzsch, 1962

Plate 26, Figures 1 to 6

REFERENCE: Boulter & Craig, 1979; pl. 2, figs 1-12 and Wilkinson & Boulter, 1980; p. 65-66, pl. 10, figs 21-25 are regarded as typical specimens.

COMMENTS: This species describes syncolporate pollen grains. They range in shape from triangular with slightly concave sides to ambs with deeply concave 'collapsed' sides. These variations are possibly only compressional features but have been described by authors such as Wilkinson & Boulter (1980) as two separate form species A and B respectively. But here these two morphologies are described as variations within this one form species. Other features include sinuous exocolpi which extends to the poles. Also a slight splitting along the germinals generally occurs, these germinals are located equatorially, at the radial corners of the amb. The exine is smooth to punctate in sculpture and infrareticulate in structure. The exine is characteristically thickened in the germinal areas which is pronounced when seen on the deeply concave sided variety grains giving the appearence of 'pouting lips'. This species is recorded from 73/36 and 80/14. Numbers up to 1.9% from 73/36 where enough to show the different morphological types described above. *B. hohli* was also seen by Boulter & Craig (1979) on their work on the Stanley Bank Basin.

STRATIGRAPHIC RECORD: Lower to Middle Oligocene of Germany (Krutzsch, 1962); of Europe (Krutzsch, 1967c); Oligocene of the Isle of Wight (Gruas-Cavagnetto, 1970a, 1976); Oligocene of France (Gorin, 1975 and Sittler & Schuler, 1975)

BOTANICAL AFFINITY: Elaeagnaceae, *Elaeagnus* (Gruas-Cavagnetto, 1978)

Genus ***Cupanieidites*** (Cookson & Pike) Krutzsch, 1969

TYPE SPECIES: ***Cupanieidites eucalyptoides*** Krutzsch, 1962; p. 271, pl. 3, figs 11-17.

GENERIC REMARKS: This genus describes syncolporate pollen with a triangular amb which has rounded corners. The colpi are narrow and have no bordering thickenings crossing the poles. The surface is smooth, punctate to granulate. The three germinals are located on the equator, at the radial corners of the amb and are well developed with an occasional operculum being present.

Cupanieidites eucalyptoides Krutzsch, 1962

Plate 27, Figures 1 to 4

REFERENCE: Krutzsch & Vanhoorne, 1977; p. 38, pl. 17, figs 13-15 and Ollivier-Pierre, 1980; p. 71, pl. 28, figs 12-13 are regarded as typical specimens.

COMMENTS: These are very small sized syncolporate pollen grains. Triangular in shape with weakly convex sides and a psilate exine. The pores can be distinct or indistinct. Varieties with a much wider and distinctly angular pores were also seen. These have been described as *C.* cf. *eucalyptoides* by Ollivier-Pierre (1980; pl. 28, fig. 13) but are only regarded as variations in this study.

STRATIGRAPHIC RECORD: Palaeocene to Oligocene of Europe (Krutzsch & Vanhoorne, 1977); Lower to Middle Oligocene Germany and Europe (Krutzsch, 1966)

BOTANICAL AFFINITY: Myrtaceae (Gruas-Cavagnetto, 1978) including *Eucalyptus*, Sapinidaceae

Genus ***Gothanipollis*** Krutzsch, 1959b

TYPE SPECIES: ***Gothanipollis gothanii*** Krutzsch, 1959b; p. 237, pl. 47, fig. 564.

GENERIC REMARKS: These are very distinct pollen grains, which are small to medium in size. The amb is concavely triangular with rounded corners with equatorial invaginations. The exine is thin with a smooth to distinctive punctae sculpture and is infrareticulate in structure. Distinct arci or 'cushions' are developed connecting adjacent pores together. They form a distinctive triangular area centred around the poles and are due to fractures along lines of weakness caused by the parting of the exocolpi in the germinal areas. Characteristic natural arci are formed at 90° to these lines of weakness and give a thicker area of exine centred on the poles and radiating into the interradial areas forming characteristic small thickened Y-shapes over the poles.

Gothanipollis gothanii Krutzsch, 1959b

Plate 27, Figures 5 & 6

REFERENCE: Boulter & Craig, 1979; pl. 2, figs 13-18, Ollivier-Pierre, 1980; p. 71, pl. 28, fig. 16 and Wilkinson & Boulter, 1980; p. 64-65, pl. 10 , figs 18-20 are regarded as typical specimens.

COMMENTS: This is a small distinctive syncolporate pollen with a concavely triangular amb and weakly developed germinals. The exine is smooth to punctate in sculpture. The generally gaping exocolpi form deep invaginations over half of the radius of the amb, but extend with no gape to the pole. Three lines of

weakness are developed between each germinal as a continuation of the exocolpi. The surface is smooth to punctate with an infrareticulate structure. Arci development occurs behind and parallel to the germinals and leads to the formation of a characteristic small thickened Y-shape over the polar region with the rays of the thickening extending into the interradial areas of the amb. This form species is recognised in the majority of sections studied, as single specimens or low numbers reaching a maximum frequency of 1.6% in 77/7.

STRATIGRAPHIC RECORD: British Oligocene (Wilkinson & Boulter, 1980); Eocene to Miocene (Krutzsch, 1966 and 1970)

BOTANICAL AFFINITY: Myrtaceae

Colpates

Genus ***Cupuliferoidaepollenites*** Potonie, Thomson & Thiergart, 1950 ex. Potonie, 1960

TYPE SPECIES: ***Cupuliferoidaepollenites liblarensis*** (Thomson in Potonie, Thomson & Thiergart, 1950 p. 55-56) ex. Potonie, 1960; p. 92. comb. nov.

GENERIC REMARKS: These are small simple ellipsoidal psilate tricolpate pollen grains, orientated in a prolate compression. The colpi run the full length of the slender grains and are not gapping and do not converge towards the poles. They are psilate with no wall infrastructure. The genera *Tricolpites* Cookson, 1947 ex. Couper, 1953 and *Tricolpopollenites* Thomson & Pflug, 1953 are differentiated from *Cupuliferoidaepollenites* as they can be prolate or oblate in orientation with variable exine structures.

Cupuliferoidaepollenites liblarensis (Thomson in Potonie, Thomson & Thiergart, 1950 p. 55-56) ex. Potonie, 1960 comb. nov.

COMMENTS: Two subspecies of these smooth tricolpate pollen grains have been described by Thomson & Pflug (1953) defined on the basis of size. These divisions have been followed in this study and are described in more detail below.

Cupuliferoidaepollenites liblarensis subsp. ***liblarensis*** (Thiergart, 1950) Thomson & Pflug, 1953

Plate 28, Figure 1

REFERENCE: Thomson & Pflug, 1953; p. 96-97, pl. 11, figs 115-125, 127, 133 are regarded as typical specimens.

COMMENTS: Small sized tricolpate elongate pollen grains ranging from 18-25µm in length. These are differentiated from *C. liblarensis* subsp. *fallax* (Potonie, 1934) Thomson & Pflug, 1953 on size alone. The grains are prolate in orientation. The colpi extend the full length of the grain and can show a marked geniculus at the equator. The wall structure is psilate and simple. These are differentiated from *Quercoidites microhenrici* (Potonie, 1931) Roche & Schuler, 1976 comb. nov. which is larger and has a scabrate to granulate ornament.

STRATIGRAPHIC RECORD: Palaeocene to Neogene (Thomson & Pflug, 1953; Krutzsch & Vanhoorne, 1977 and Allen, 1982)

BOTANICAL AFFINITY: Cupulifereae (Thomson & Pflug, 1953) Fagaceae, *Castanea* (Thomson & Pflug, 1953)

Cupuliferoidaepollenites liblarensis subsp. ***fallax*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 28, Figures 2 & 3

REFERENCE: Thomson & Pflug, 1953; p. 96-97, pl. 11, figs 133-151 and Krutzsch & Vanhoorne, 1977; pl. 29, figs 36-40 are regarded as typical specimens.

COMMENTS: These are very small in size, 10-18μm, elongate tricolpate grains generally seen in a prolate compression. The colpi extend the full length of the grain and can show a geniculus. The wall structure is simple and psilate. These are differentiated from *C. liblarensis* subsp. *liblarensis* which is slightly larger in size, 18-25μm.

STRATIGRAPHIC RECORD: Palaeocene to Neogene (Thomson & Pflug, 1953; Krutzsch & Vanhoorne, 1977 and Allen, 1982)

BOTANICAL AFFINITY: As above

Genus ***Quercoidites*** Potonie, Thomson & Thiergart, 1950 ex. Potonie, 1960

TYPE SPECIES: ***Quercoidites henrici*** Potonie, 1931a; p. 332, pl. 2, fig. 19.

GENERIC REMARKS: This genus describes tricolpate grains which are weakly crenulate in outline. In oblate view they are circular to trilobed and oval to fusiform in prolate view. The colpi almost reach the poles and often have a geniculus. The sculpture is granulate to scabrate and the structure is infrabaculate. This genus is differentiated from *Cupuliferoidaepollenites* by its granulate sculpture.

Quercoidites microhenrici (Potonie, 1931a) Roche & Schuler, 1976

Plate 28, Figures 4 to 6

REFERENCE: Thomson & Pflug, 1953; p. 96, pl. 11 figs 66-68, 84, 100 and Ollivier-Pierre, 1980; p. 57, pl. 21, fig. 10 (as *Scabratricolpites microhenrici*) are regarded as typical specimens.

COMMENTS: This describes small to medium sized pollen grains which are elongate, oval to fusiform in shape when in prolate compression. The colpi almost reach the poles and often have a geniculus. The exine is infrabaculate to intragranulate. This is differentiated from *Q. henrici* which is larger in size.

STRATIGRAPHIC RECORD: Palaeocene to Miocene of Germany (Thomson & Pflug, 1953); Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Fagaceae, *Quercus, Castaneopsis* (Thomson & Pflug, 1953)

Genus ***Retitricolpites*** (Van der Hammen, 1956) Pierce, 1961

TYPE SPECIES: ***Retitricolpites ornatus*** (Van der Hammen, 1956; p. 90, fig. 26) Pierce, 1961.

GENERIC REMARKS: This form genus describes distinct tricolpate pollen grains which have a reticulate wall structure. They are elliptical in prolate compression and have long colpi that extend the full length of the grain. In oblate compression the colpi are widely splayed and give a 'propeller' like appearance. Colpal membranes can be evident in some specimens (see figure 10, plate 28). The genus *Retitricolpites* is used here dispite it being an illegitimate junior synonym of the genus *Neea*, for which the holotype is a recent pollen grain and is such against the rules of the ICBN (Jansonius & Hills, 1976). Even so, *Retitricolpites* is a clear, useful and descriptive name, it has widespread use in the literature by palynologists who have ignored its illegitimacy over its usefulness. It is this view that is followed here keeping the name *Retitricolpites* despite its illegitimacy for its clear and understood definition, but also at the same time not leading to the proliferation of *nomem nudum* in the literature by defining new genera.

Retitricolpites angululuminosus Anderson, 1960 comb. nov.

Plate 28, Figures 7 & 8

REFERENCE: Ollivier-Pierre, 1980, p. 56-57, pl. 21, fig. 8 is regarded as a typical specimen.

COMMENTS: These are small to medium sized tricolpate pollen grains. Oblate preservations are especially common. The distinctive ornamentation is implied from its name, a reticulate pattern

composed of thin narrow muri which surround large polygonal luminae. This reticulum is larger in size and irregular to angular in outline compared with the smaller, rounded reticulum of *R. retiformis* (Thomson & Pflug, 1953).

STRATIGRAPHIC RECORD: Eocene of France (Ollivier-Pierre, 1980)

BOTANICAL AFFINITY: Hamamelidaceae (Simpson, 1961)

Retitricolpites retiformis Thomson & Pflug, 1953 comb. nov.

Plate 28, Figures 9 & 10

REFERENCE: Thomson & Pflug, 1953; p. 97, pl. 11, figs 59-61 and Ollivier-Pierre, 1980; p. 55, pl. 21, fig. 15 are regarded as typical specimens.

COMMENTS: This describes small to medium sized tricolpate pollen grains. Both prolate and oblate compressions are seen to occur. The characteristic feature of this pollen is the reticulate surface pattern, the muri are supported by an intrabaculate wall structure and the luminae produced are rounded and small in size. This is differentiated from *R. anguloluminosus* which has larger more angular luminae.

STRATIGRAPHIC RECORD: Late Palaeocene to Middle Oligocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene to Middle Eocene of S. England (Gruas-Cavagnetto, 1976)

BOTANICAL AFFINITY: *Platanus* (Thomson & Pflug, 1953 and Ollivier-Pierre, 1980); *Salix* type, Saliceae-Platanaceae (Gruas-Cavagnetto, 1976)

Genus ***Tricolpopollenites*** Pflug & Thomson, 1953

TYPE SPECIES: ***Tricolpopollenites parmularius*** (Potonie, 1934; p. 52, pl. 2, fig. 7) Thomson & Pflug, 1953; p. 97, pl. 11, fig 158.

GENERIC REMARKS: This genus describes tricolpate pollen grains. The amb is oval shaped in a prolate position and has rounded poles. Ornamentation varies from granulate, baculate to spinose. Here *Tricolpopollenites* is used to describe form species which cannot be assigned to any of the previous tricolpate genera.

Tricolpopollenites cf. ***discus***

Plate 29, Figures 1 & 2

COMMENTS: These are small to medium sized tricolpate pollen grains. Preservation is generally in an oblate position. The exine is thin and shows a smooth to granular ornamentation with three distinct colpi developed. This species is characterised by its very circular disc-like shape in an oblate view.

Tricolpopollenites hians Stanley, 1965 comb. nov.

Plate 29, Figures 3 to 5

REFERENCE: Stanley, 1965; p. 321, pl. 47, figs 24-27 are regarded as typical specimens.

COMMENTS: This describes small to medium sized tricolpate pollen grains which are commonly preserved in oblate positions, although prolate preservations were recorded. The colpi extend the full length of the grain and are wide. In oblate view the wide colpi give a 'propeller' like appearance with colpal membranes forming ragged edges to the colpi. The exine is two layered and the surface is ornamented with a very fine reticulum, composed of rounded luminae, less than 0.5μm in size, separated by wide muri. This reticulum is only visible at high magnifications and appears micropunctate. This is differentiated from *T. parvus* (Stanley, 1965) which has larger luminae and a very thick endexine.

STRATIGRAPHIC RECORD: Palaeocene of N. America (Stanley, 1965)

BOTANICAL AFFINITY: Variably as Plataginaceae, Nyctaginaceae, Oleaceae but most probably Platanaceae from *in situ* anther evidence.

Tricolpopollenites* cf. *hians

Plate 29, Figures 6 to 8

REFERENCE: Jolley, 1991; pl. 42, fig. 3 is regarded as a typical specimen.

COMMENTS: This tricolpate pollen grain is similar in shape, size and ornamentation to *R. hians* but can be differentiated on wall structure. In *T.* cf. *hians* the exine is two layered composed of inter connecting rows of baculae. Also colpal membrane are not present. This is also differentiated from *Fraxinoipollenites variabilis* (Stanley, 1965) which is distinctly barrel shaped in prolate view and the wall structure is composed of clavae rather than baculae and has a larger reticulate pattern.

STRATIGRAPHIC RECORD: Palaeocene of S. England (Jolley, 1991)

BOTANICAL AFFINITY: Variably as Plantaginaceae, Nyctaginaceae, Oleaceae but probably Plantanaceae from *in situ* anther evidence.

Genus ***Tetracolpites*** Vimal, 1952 ex. Srivastava, 1966

TYPE SPECIES: ***Tetracolpites reticulatus*** Srivastava, 1966; p. 546, pl. 7, fig. 27.

GENERIC REMARKS: This is a tetracolpate pollen grain. Only specimens preserved in oblate orientations are recorded. They are medium sized and have wide splayed colpi. Ornamentation varies from granulate to reticulate.

Plate 30, figure 1

Tetracolpites reticulatus Srivastava, 1966

Plate 30, Figure 2

REFERENCE: Srivastava, 1966; p. 546, pl. 7, fig. 27 is regarded as a typical specimen.

COMMENTS: Oblate tetracolpate pollen grains characteristically flattened to give an oblate view showing widely splayed colpi, no colpal membranes are apparent. The ornamentation is composed of a small reticulum. The luminae are 0.5-1μm (2 specimens) in size and are subrounded in shape and enclosed by a thick muri. This species is similar to *R. retiformis* which has the similar characteristic reticulate ornament but is differentiated by being tetracolpate. Specimens of this species are relatively rare, only recorded from 77/7, 78/1 and 16/16b-4 as single specimens.

STRATIGRAPHIC RECORD: Maastrictian of N. America (Srivastava, 1966)

BOTANICAL AFFINITY: Compared to *Fraxinus americanus* by Vimal (1952)

Tricolporates

Genus ***Cupuliferoipollenites*** Potonie, 1951 ex. Potonie, 1960

TYPE SPECIES: ***Cupuliferoipollenites cingulum*** Potonie, 1931b, p. 26, pl. 1, 45a-46a, b, 48, 60a, d, 61c and 62c.

GENERIC REMARKS: These are small tricolporate pollen grains, elongate in shape due to there prolate compression. The colpi are long and do not converge at the poles. The exine is smooth, although some intra wall structure may be evident. This is differentiated from *Tricolporopollenites* Thomson & Pflug (1953) which includes tricolporate grains with exine ornamentation.

Cupuliferoipollenites cingulum (Potonie, 1931b) Thomson & Pflug, 1953 comb. nov.

COMMENTS: Thomson & Pflug (1953) recognised three subspecies differentiated on the basis of size, these have also been distinguished in this study and are described separately below.

STRATIGRAPHIC RECORD: Palaeocene to Miocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene to Middle Eocene of S England (Gruas-Cavagnetto, 1976); Early Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Fagaceae; *Castea* (Potonie, 1960); *Castanopsis* (Gruas-Cavagnetto, 1976); *Leguminosae* (Paplionoideae)

Cupuliferoipollenites cingulum (Potonie, 1931b) Thomson & Pflug, 1953; subsp. ***fusus*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 30, Figures 3 & 4

REFERENCE: Thomson & Pflug, 1953; p. 100, pl. 12, figs 15-27 are regarded as typical specimens.

COMMENTS: This describes elongate tricolporate pollen grains which occur in prolate preservations. The exine is smooth in sculpture and intrarugulate in structure. The diagnostic feature is its size which is small, 22-28μm in length.

STRATIGRAPHIC RECORD: See above

BOTANICAL AFFINITY: See above

Cupuliferoipollenites cingulum (Potonie, 1931b) Thomson & Pflug, 1953; subsp. ***oviformis*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 30, Figure 5

REFERENCE: Thomson & Pflug, 1953; p. 100, pl. 12, figs 42-49 are regarded as typical specimens.

COMMENTS: A small psilate tricolporate pollen grain preserved in a prolate compression. The colpi extend the full length of the grain and

do not converge at the poles. The diagnostic feature of this subspecies is its very small size, 10-18µm in length.

STRATIGRAPHIC RECORD: See above

BOTANICAL AFFINITY: See above

Cupuliferoipollenites cingulum (Potonie, 1931b) Thomson & Pflug, 1953; subsp. ***pusillus*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 30, Figures 6 & 7

REFERENCE: Thomson & Pflug, 1953; p. 100, pl. 12, figs 18-24 are regarded as typical specimens.

COMMENTS: These are the medium sized subspecies of *C. cingulum* being 18-22µm in length. They are psilate tricolporate pollen grains preserved in a prolate compression, giving an elongate 'cigar' shaped amb, the amb can sometimes be pointed in shape at the polar regions. The exine is infrarugulate in structure.

STRATIGRAPHIC RECORD: See above

BOTANICAL AFFINITY: See above

Genus ***Cyrillaceaepollenites*** Murringer & Pflug, 1951 ex. Potonie, 1960

TYPE SPECIES: ***Cyrillaceaepollenites megaexactus*** (Potonie, 1931a; p. 26, pl. 1, fig. V42b) Potonie, 1960; p. 102.

GENERIC REMARKS: This genus describes psilate tricolporate grains which have a distinct rounded oval amb. Potonie (1960) proposed the genus *Cyrillaceaepollenites* to subdivide the large 'bag' genus of *Tricolporopollenites* Thomson & Pflug (1953). It is differentiated from the other psilate tricolporate genus *Cupuliferoipollenites* by its more rounded amb shape.

Cyrillaceaepollenites megaexactus (Potonie, 1931a) Potonie, 1960

Plate 30, Figure 8 & 9

REFERENCE: Thomson & Pflug, 1953; p. 100-101, pl. 12, figs 50-57, 65-80 and 87-92 (as *Tricolporopollenites megaexactus)* are regarded as typical specimens.

COMMENTS: This is a small tricolporate pollen grain with a distinctly spherical amb. The pores are clear and the colpi converge polewards. The exine is psilate and shows no other structures. This is differentiated from other psilate tricolporate species such as *Cupuliferoipollenites cingulum* by its distinctly spherical amb shape.

STRATIGRAPHIC RECORD: Miocene of Germany (Potonie, 1931a); Palaeogene of Germany (Thomson & Pflug, 1953); Eocene of S. England (Gruas-Cavagnetto, 1976) and Palaeocene of S. England (Allen, 1982)

BOTANICAL AFFINITY: Cyrillaceae; Clethraceae (Potonie, 1931a; Thomson & Pflug, 1953)

Genus ***Echitricolporites*** Van der Hammen ex. Germeraad, Hopping & Muller, 1968

TYPE SPECIES: ***Echitricolporites spinosus*** (Van der Hammen) Germeraad, Hopping & Muller, 1968; Van der Hammen, 1956; p. 92, fig. 30.

GENERIC REMARKS: This genus describes medium to small sized tricolporate pollen grains. In shape they are spherical to rounded oval, in prolate compression. The colpi are long, extending to the poles and the pores are circular. The exine is covered with a short echinate ornamentation. This genus is very distinctive although is similar in shape and ornamentation character to the triportae genus *Compositoipollenites*.

Echitricolporites spinosus

Plate 31, Figures 1 & 2

REFERENCE: Germeraad, Hopping & Muller, 1968; pl. XVI, figs 11-12 are regarded as typical specimens.

COMMENTS: This small spherical tricolporate pollen grain is very distinctive. The long colpi show the developement of slight margoes (figure 2, plate 31) and the circular pores vary from distinct to indistinct. The exine is ornamented with distinct short, broad based echinae, which are thick at the base and sharply pointed at the tip. These echinae occur evenly spaced over the grain making this species easily recognisible.

STRATIGRAPHIC RECORD: Tertiary in the Tropics (Germeraad, Hopping & Muller, 1968)

BOTANICAL AFFINITY: *Baccharis tricuneata*, Compositae Jansonius & Hills (1976) Asteraceae, *compositae* (Germeraad, Hopping & Muller, 1968)

Genus ***Favitricolporites*** Sah, 1967 emend. Srivastava, 1972

TYPE SPECIES: ***Favitricolporites eminens*** Sah, 1967, p. 85, pl. 6, fig. 17.

GENERIC REMARKS: The emendation proposed by Srivastava (1972) restricts the original genus diagnosis of reticulate tricolporate grains to include only baculoreticulate tricolporate grains. So much confusion in the literature is apparent for reticulate and other related forms. This genus has been split off from *Tricolporopollenites* and describes specimens with baculoreticulate structures only. As yet no satisfactory genus to describe reticulate forms has been proposed. *Rhoipites* (Wodehouse, 1933) is not satisfactory as it includes reticulate and pitted forms but not baculoreticulate forms as suggested by Takahashi & Jux (1982).

Favitricolporites microreticulatus (Pflug & Thomson, 1953) Takahashi & Jux, 1982 comb. nov.

Plate 31, Figures 3 & 4

REFERENCE: Thomson & Pflug, 1953; p. 106, pl. 14, figs 27-40 are regarded as typical specimens.

COMMENTS: These are small to medium sized tricolporate pollen grains, oval in shape with long colpi. The pores are equatorial and the exopore is meridonally stretched. This group has a faint reticulate ornament which is made up of closely spaced baculae, a baculoreticulum, forming luminae less than 0.5μm in size. This was assigned to *Rhoipites* by Takahashi & Jux (1982) but this only describes truly reticulate and pitted morphologies, therefore the baculoreticulate structure here is not truly reticulate as so is not assigned to *Rhoipites* here. *Favitricolporites* is a much more appropriated genus to assign this species to as it is restricted to include only baculoreticulate tricolporate forms, therefore is ideal to describe this species. Thomson & Pflug (1953) described two formas of this species on amb shape. Although these are not distinguished here in this study. Wilkinson & Boulter (1980) recognised this species but found specimens very rare. This was also seen in this study occurrences are rare although recorded from all the sections. Abundances range from single specimens up to 1.1% per sample.

STRATIGRAPHIC RECORD: Oligocene to Miocene of Central Europe (Thomson & Pflug, 1953); Eocene to Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Sambucaceae (Thomson & Pflug, 1953) or Caprifoliaceae

Genus ***Ilexpollenites*** Thiergart, 1937 ex. Potonie, 1960

TYPE SPECIES: ***Ilexpollenites iliacus*** (Potonie, 1931a; p. 556, fig. 5) ex. Potonie, 1960; p. 99.

GENERIC REMARKS: A distinctive genus describing medium sized tricolporate pollen grains, which can be oblate or prolate in preservation. The

colpi and equatorial pores are often faint or indistinct. The ornamentation is very distinctive and composed of individual clavae which are unconnected and may be of differing sizes.

Ilexpollenites iliacus (Potonie, 1931a) ex. Potonie, 1960

Plate 31, Figures 5 to 8

REFERENCE: Thomson & Pflug, 1953; p. 106, pl. 14, figs 43-60 (as *Tricolporopollenites iliacus*) and Wilkinson & Boulter, 1980; p. 61, pl. 9, figs 13-14 are regarded as typical specimens.

COMMENTS: These are small to medium sized tricolpate grains. They are usually compressed into a prolate position but can be in oblate preservations. When prolate they are oval to elongate in shape, with indistinct colpi and pores. The ornamentation is of clavae greater than 2µm in height which are larger and swollen towards the polar regions. Wilkinson & Boulter (1980) in their work on the British Oligocene saw a maximum frequency of 5% of this species. Although in this study specimens were widespread, being present in all the sections examined, they were never seen to reach abundances greater than 1.1%. This species is easily differentiated from *I. margaritatus* (Potonie, 1931a) Raatz, 1937 which has smaller clavae that are of even height over the grain.

STRATIGRAPHIC RECORD: Miocene of Germany (Potonie, 1960); Upper Oligocene to Lower Miocene of Germany (Thomson & Pflug, 1953); Eocene of S. England (Gruas-Cavagnetto, 1976); Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Aquifoliacea, *Ilex* (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1976)

Ilexpollenites margaritatus (Potonie, 1931a) Raatz, 1937

Plate 32, Figures 1 & 2

REFERENCE: Thomson & Pflug, 1953; p. 107, pl. 14, figs 64-80 are regarded as typical specimens.

COMMENTS: This describes small to large sized tricolporate grains generally preserved in a prolate position. The colpi and pores are indistinct. The ornamentation is composed of closely spaced clavae which are of an even size over the grain surface, this is the diagnostic feature of this species, differentiating it from *I. Iliacus* which has larger , swollen clavae towards the polar regions.

STRATIGRAPHIC RECORD: Eocene of Central Europe (Thomson & Pflug, 1953); Early Eocene of Belgium (Krutzsch & Vanhoorne, 1977)

BOTANICAL AFFINITY: Aquifoliaceae, *Ilex* (Thomson & Pflug, 1953 and Gruas-Cavagnetto, 1976)

Ilexpollenites microiliacus (Thomson & Pflug, 1953) n. comb.

Plate 32, Figures 3 & 4

REFERENCE: Thomson & Pflug, 1953; p. 107, pl. 14, figs 61-63 are regarded as typical specimens.

COMMENTS: This describes small sized (15-25μm) tricolporate pollen grains, preserved in a generally prolate position. The colpi and pores are indistinct. Ornamentation is composed of the distinct clavae characteristic of this genus. This species is differentiated from other *Ilexpollenites* species due to its small size.

STRATIGRAPHIC RECORD: Tertiary of Central Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Aquifoliaceae, *Ilex* (Thomson & Pflug, 1953)

Genus ***Mediocolpopollis*** Krutzsch, 1959b

TYPE SPECIES: ***Mediocolpopollis compactus*** Krutzsch, 1959b; p. 150, pl. 35, figs 22-27.

GENERIC REMARKS: Tricolporate pollen grains which have an elongate amb and long colpi. The colpi have thickened margins and are distinct. The exopores are large and equatorial, they are elongate in shape and together give the appearance of a thin belt around the equator. A small vertical colpoid feature is situated between the wall layers at each pore (a mediocolpus). Few specimens of this species are recorded therefore they are not speciated and are recorded as *Mediocolpopollis* spp.

Plate 32, Figures 5 & 6

STRATIGRAPHIC RECORD: Oligocene of E. Germany (Krutzsch, 1959b, 1961a) Middle Eocene to Lower Oligocene of Germany (Krutzsch, 1967c)

Genus ***Nyssapollenites*** Thiergart, 1937 ex. Potonie, 1960

TYPE SPECIES: ***Nyssapollenites pseudocruciatus*** (Potonie, 1931b; p. 328, pl 1, fig. 10) Thiergart, 1938; p.328.

GENERIC REMARKS: This genus describes tricolporate pollen grains that are found to be common throughout all the sections studied. In prolate compression they are ellipsoidal in shape and are trilobed in oblate compression. The pores and colpi are distinct, the colpal edges have a slight thickening forming a margo and the exopores are large and meridonally stretched. The exine is psilate and unornamented but is distinctly infrapunctate with the punctae being densely packed. This infrapunctate exine structure differentiates *Nyssapollenites* from the smooth simple tricolporates *Cupuliferoipollenites* and *Cyrillaceaepollenites* and from other ornamented tricolporate genera such as *Tricolporopollenites* (Thomson & Pflug, 1953 emend.).

Nyssapollenites kruschi (Potonie, 1931b) comb. nov.

COMMENTS: This describes small to large oval shaped pollen grains. The pores and colpi are well developed and the exine is infrapunctate in structure. Thomson & Pflug (1953) recognised three subspecies. In this study 2 subspecies have been recorded, these are differentiated on size. The largest subspecies *rodderensis* where not recorded here. *N. kruschi* subsp. *pseudolaesus* (Potonie, 1931b) Thomson & Pflug, 1953 is used for oblate specimens of *N. kruschi*. This was also used by Wilkinson & Boulter (1980) but is not followed here as different orientations of preservation are not thought relevant characteristics for subspeciating taxon.

Nyssapollenites kruschi (Potonie, 1931b) subsp. ***analepticus*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 32, Figures 7 to 9

REFERENCE: Thomson & Pflug, 1953; p. 103-104, pl. 13, figs 14-24, Krutzsch & Vanhoorne; p. 81, pl. 34, figs 20-22 and Wilkinson & Boulter, 1980; p. 62, pl. 9, fig. 19 are regarded as typical specimens.

COMMENTS: These are small sized, 15-30μm, tricolporate pollen grains. The amb is ellipsoidal in prolate compression, often oval to a rounded diamond shape and is trilobed in oblate compressions. The colpi are clear and have distinct margoes at their edges. The pores are circular and clearly positioned at the equator. The exine is lacking in sculpture but has a fine infrapunctate structure. In the literature these are mostly recorded as *N. kruschi*. These are common to abundant in all the sections studied. Individual samples contain up to 36.4% of this species making it the most common tricolporate pollen recorded in this study.

STRATIGRAPHIC RECORD: Palaeocene to Miocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene to Early Eocene of Belgium (Krutzsch & Vanhoorne, 1977); Late Palaeocene to Late Eocene of S. England (Allen, 1982)

BOTANICAL AFFINITY: Nyssaceae, *Nyssa* (Thomson & Pflug, 1953)

Nyssapollenites kruschi (Potonie, 1931b) subsp. ***accessorius*** (Potonie, 1934) Thomson & Pflug, 1953

Plate 33, Figures 1 & 2

REFERENCE: Thomson & Pflug, 1953; p. 104, pl. 13, figs 27-38 are regarded as typical specimens.

COMMENTS: This is similar to *N. kruschi* subsp. *analepticus* it is an infrapunctate tricolporate grain with distinct pores and colpi that have associated margoes This subspecies is differentiated by its larger in size being 30-40µm in length.

STRATIGRAPHIC RECORD: Palaeocene to Miocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene to Early Eocene of Belgium (Krutzsch & Vanhoorne, 1977); Late Palaeocene to Late Eocene of S. England (Allen, 1982)

BOTANICAL AFFINITY: Nyssaceae, *Nyssa* (Thomson & Pflug, 1953)

Nyssapollenites satzveyensis Pflug in Thomson & Pflug, 1953 comb. nov.

Plate 33, Figures 3 & 4

REFERENCE: Thomson & Pflug, 1953; p. 103, pl. 13, figs 10-13 are regarded as typical specimens.

COMMENTS: Large sized tricolporate pollen grains. They are very rounded with splayed colpi in oblate compression and elongate and oval in prolate compression. The colpi are very clear and have distinct thickened margoes at their edges. The pores are clear and large, 5-8µm in diameter. The exine is psilate with an obvious and characteristic infrapunctate structure. This is easily differentiated from other *N. kruschi* grains which are much smaller in size with smaller sized pores.

STRATIGRAPHIC RECORD: Late Palaeocene to Early Eocene of Belgium (Krutzsch & Vanhoorne, 1977)

BOTANICAL AFFINITY: Nyssaceae, *Nyssa* (Thomson & Pflug, 1953)

Genus ***Tricolporopollenites*** Thomson & Pflug, 1953 emend.

TYPE SPECIES: ***Tricolporopollenites dolium*** Potonie, 1950; pl. 12, figs 114-117.

GENERIC REMARKS: This genus originally defined by Thomson & Pflug (1953) was more of a 'super genus' becoming a bag to all tricolporate pollens irrespective of their size, shape and ornamentation. This study has attempted to use clearer more specific or definite generic names where possible. Here psilate forms have been assigned to the genus *Cupuliferoipollenites,* psilate, rounded forms to *Cyrillaceaepollenites* and *Nyssapollenites* describes forms with a distinct infrapunctae exine structure. Tricolporates with a clavate ornament have been assigned to *Ilexpollenites* and *Favitricolporites* describes tricolporates with a baculoreticulate ornamentation. Many other genera have been proposed but are misused in the literature. Reticulate species vary greatly in structure and have been assigned in the past to genera such as *Retitricolporites* (Van der Hammen) an illegitimate name and *Rhoipites* (Wodehouse, 1933) for reticulate and pitted forms, these are not adequate as they are not clear and can lead to confusion. Therefore the continued use of these in this study is thought inappropriate. Also it is unnecessary to erect another new genus to the already immense numbers published. Therefore species with a reticulate sculpture are included in *Tricolporopollenites* along with other ornamented forms that have not as yet been assigned to a more appropriate genus. These taxonomic problems are beyond the scope of this study but will be undertaken in any future work done by the author. The emended diagnosis of *Tricolporopollenites* to include only tricolporate pollen grains with scabrate, granulate, baculate, reticulate and spinose forms is suggested, until more suitable genera can be assigned to

these forms meanwhile they are 'bagged' together for clarity and simplicity.

Tricolporopollenites baculoferus Pflug in Thomson & Pflug, 1953

Plate 33, Figures 5 & 6

REFERENCE: Thomson & Pflug, 1953; p. 105, pl. 14, figs 4-8 are regarded as typical specimens.

COMMENTS: These are small to medium sized tricolporate pollen grain, commonly preserved in prolate positions and are oval to rounded in shape. The colpi and pores are indistinct with the endopores being meridonally stretched. The distinct ornamentation of baculae is supported by a columellate exine structure. The baculae are generally small and not connected. The baculate ornament has been seen to grade into clavae (Wilkinson & Boulter, 1980) but is never developed enough to be referred to as *Ilexpollenites*. This species is differentiated from *F. microreticulatus* in which the baculae are closely spaced forming a reticulate pattern. Wilkinson & Boulter (1980) only found 10 specimens of this species throughout their study. This species was also rare in the sections examined during this project.

STRATIGRAPHIC RECORD: Palaeocene to Oligocene of Central Europe (Thomson & Pflug, 1953); Late Palaeocene of S. England (Gruas-Cavagnetto, 1976; Allen, 1982); Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Unknown

Tricolporopollenites edmundi (Potonie, 1931b) Thomson & Pflug, 1953

Plate 34, Figures 1 to 4

REFERENCE: Thomson & Pflug, 1953; p. 101, pl. 12, figs 125-132 and Gruas-Cavagnetto, 1976; p. 76, pl. 2, figs 7-9 are regarded as typical specimens.

COMMENTS: This describes medium to large sized tricolporate pollen grains. They are generally in prolate compression and have a distinctly 'rhomb' shaped amb. The colpi and pores are distinct. The colpi are long with characteristic margoes. The endopores are circular and indistinct but the exopores are large and meridonally stretched and form a distinct '*Nyssapollenites*' type pore. Ornamentation is composed of a reticulum supported by a simlpibaculate or duplibaculate exine structure. The reticulum formed is very characteristic often with oval shaped luminae. The luminae appear bigger in intercolpal areas but are less than 1µm in size. In this study there is a gradation between *T. edmundi* and *N. satzveyensis* which appear similar. Krutzsch (1960) also recognised this gradation and described a *'satzveyensis-edmundi'* group in his work on the German Tertiary. Within the species of *T. edmundi* variations have been recognised which have a much larger reticulum, the luminae being up to 2µm in size and larger rounded pores up to 4-5µm in size, while still having the distinct large 'rhomb' shaped amb and characteristic reticulate pattern. Specimens from this species occur in the majority of the sections examined and reach a maximum abundance of 2.6% in 80/14.

STRATIGRAPHIC RECORD: Palaeocene to Oligocene of Europe (Thomson & Pflug, 1953)

BOTANICAL AFFINITY: Araliaceae, Cornaceae

Tricolporopollenites pseudocingulum (Potonie, 1931b) Thomson & Pflug, 1953

Plate 34, Figures 5 & 6

REFERENCE: Thomson & Pflug, 1953; p. 99, pl. 12, figs 96-111 and Wilkinson & Boulter, 1980; p.59, pl. 8, figs 8-26 are regarded as typical specimens.

COMMENTS: This describes medium sized prolate tricolporate grains. The colpi are distinct and converge polewards. The equatorial pores are clear and characteristically meridonally stretched. The outline of the amb is crenulate with a rugulate structure

and the ornamentation varies from scabrate to granulate. These have been described by Roche & Schuler (1976) as *Scabratricolporites* (Van der Hammen, 1956) Roche & Schuler, 1976. Wilkinson & Boulter (1980) describe these as the most abundant *Tricolporopollenites* species in their work on the British Oligocene. This is disputed here as *T. pseudocingulum* occurs from single specimens up to abundances of 3.6%.

STRATIGRAPHIC RECORD: Palaeocene to Pliocene of Central Germany (Thomson & Pflug, 1953); Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: Anacardiaceae, *Rhus* (Thomson & Pflug, 1953)

Tricolporopollenites spinus Krutzsch, 1962a

Plate 34, Figures 7 to 9

REFERENCE: Wilkinson & Boulter, 1980; p. 60, pl. 9, fig. 67 is regarded as a typical specimen.

COMMENTS: These are small to medium sized tricolporate pollen grains, they are generally seen in prolate orientations and are oval to elongate in shape. The colpi and pores are very distinct, the colpi have well developed margoes at their edges and the pores have the distinct *'Nyssapollenites'* type appearance but can be indistinct in some orientations and can appear as tricolpate grains. The spinose ornamentation is distinctive and distinguishes this species from other tricolporates. They can be sparse or densely packed and are parallel sided and give a very characteristic 'woolly' appearance. Specimens of this species were quite rare in this study, this rarity was also noted by Wilkinson & Boulter (1980).

STRATIGRAPHIC RECORD: Middle Oligocene of Central Europe (Krutzsch, 1967c); Middle Oligocene of Poland (Grabowska, 1965 and Ziembinska-Tworzydlo, 1974); Oligocene of Britain (Wilkinson & Boulter, 1980)

BOTANICAL AFFINITY: unknown

Tricolporopollenites viburnoides Gruas-Cavagnetto, 1978 comb. nov.

Plate 35, Figures 1 to 6

REFERENCE: Gruas-Cavagnetto, 1978; p. 36, pl. 14, figs 16-19 are regarded as typical specimens.

COMMENTS: These are medium sized prolate tricolporate pollen grains. They are elongate in shape. The colpi are long and have distinct margoes developed. The large equatorial pores are distinct with the exopore being meridonally stretched. The ornamentation is distinctly reticulate and composed of thin pale muri enclosing large irregular angular polygonal luminae. These luminae are of a similar size and sometimes appear slightly larger in intercolpal areas. This is easily distinguished from species such as *T. megareticulatus* (Krutzsch & Vanhoorne, 1977) which has a similar reticulate structure, but its amb is much more rounded in shape and from *T. edmundi* which has a much smaller reticulum giving smaller more rounded luminae. Specimens of this species were generally rare occurring with abundances less than 2%.

STRATIGRAPHIC RECORD: Early Eocene of France (Gruas-Cavagnetto, 1978)

BOTANICAL AFFINITY: Caprifoliaceae, *viburnum* (Gruas-Cavagnetto, 1978)

Tricolporopollenites sp. 1

Plate 35, Figures 7 to 9 and Plate 36, Figures 1 to 3

COMMENTS: This species describes small to medium sized tricolporate pollen grains, preserved in both prolate and oblate orientations. The amb is elongate to oval in shape, in a prolate view. The colpi and pores are often indistinct. The exine sculpture is very characteristic and composed of large granulate to verrucate elements.

Class Tetradites Cookson, 1947

Genus ***Ericipites*** Wodehouse, 1933

TYPE SPECIES: ***Ericipites longisulcatus*** Wodehouse, 1933; p. 516, fig 52.

GENERIC REMARKS: These are small to medium sized psilate pollen grains occurring in tetrahedral tetrads that are closely adpressed. Sometimes colpi are visible and the pollen resemble tricolporate grains. Wilkinson & Boulter (1980) recorded numbers of less than 2%. This was also found in this study with samples being rare. As specimens were rare they have been recorded as *Ericipites* spp.

Plate 36, Figure 4 & 5

BOTANICAL AFFINITY: Ericaceae (Potonie, 1931)

Others

Incertae sedis A

Plate 36, Figure 6

COMMENTS: This is medium in size with a distinctly spherical body. The wall is thick and granulae and has a distinct ornamentation of short wide based granular cone structures. These are closely arranged and concentric around the body.

REWORKING

The following taxa, listed alphabetically, were recognised during this study but are regarded as reworked or caved. Approximate age ranges of these taxa have been suggested along side each taxon where appropriate:-

SPORES

Anapiculatisporites spp. Palaeozoic to Jurassic

Auritulinasporites spp. Late Jurassic to Cretaceous

Caliallisporites damperi (Balme, 1957) Sukh Dev 1961 Middle/Late Jurassic to Early Cretaceous

Caliallisporites trilobatus (Balme, 1957) Sukh Dev 1961 Middle/Late Jurassic to Early Cretaceous

Caliallisporites turbatus (Balme, 1957) Middle/Late Jurassic to Early Cretaceous

Cerebropollenites mesozoicus (Couper, 1958) Nilsson 1958 Early to Middle Jurassic

Chasmatosporites spp Early to Middle Jurassic

Classopollis spp Triassic to Late Cretaceous (probably Purbeck)

Classopollis 'norissi' Late Jurassic

Classopollis tetrad Triassic to Late Cretaceous (probably Purbeck)

Cycadopites Jurassic to Cretaceous

Densoisporites velatus (Weyland & Krieger) Krasnova, 1961 (in Samorlovitch *et al.* 1961) Late Jurassic

Dichyophylidites harrisii (Couper, 1958) Jurassic to Cretaceous

Echinatosporis miocenicus Krutzsch, 1963a

Exesipollenites spp. Jurassic to Cretaceous

Klukisporites spp Jurassic to Cretaceous

Klukisporites variegatus (Couper, 1958) Jurassic

Krauselisporites reisingeri Jurassic to

Lycospora pusilla (Ibrahim) Somers 1971 Dinnantian to Westphalian

Murospora spp Jurassic to Cretaceous

Neoraistrikia spp. Jurassic

Parvisaccites enigmatus Triassic to Jurassic

Perinopollenites elatoides (Couper 1958) Jurassic

Pilosisporites spp Jurassic

Podocarpidites spp Jurassic to Cretaceous

Triporoletes reticulatus Cretaceous to Palaeocene

Triquitrites spp.

POLLEN

Fenestrites spinosus (Van der Hammen, 1956) Miocene. Plate 36, figure 7

DINOFLAGELLATES, ACRITARCHS AND ALGAE

INTRODUCTION

In this study dinoflagellate cysts were obtained from the marine sediments sampled from North Sea well sections, 21/28b-7 and 16/16b-4 and from the Solan Bank High section 77/7. These dinoflagellate cysts enable a stratigraphical and time framework to be developed, with the use of the various published dinoflagellate zonation schemes such as Costa & Manum (1988), and Powell (1992). From this, characteristic pollen events for the time period in question can be directly correlated to the dinoflagellate cyst zonations, so as to enable an age to be interpreted for the pollen events in the marine section, from which parallels can be drawn to the terrestrial, pollen and spore sequences. The dinoflagellate cysts encountered in this study form the basis of the following systematic chapter.

SYSTEMATICAL ORGANISATION

The analysis of dinoflagellate genera has developed significantly since the early days of limited numbers of genera and species. Now there are hundreds of genera and thousands of species. Therefore with these large numbers of taxa it is important that the systematic palynology is well defined and clearly organised.

Many authors in the past have used various methods to group dinoflagellate cy Stover & Evitt (1978) utilised a system of grouping dinoflagellates on archeopyle type, this was a good starting point but is too crude and simplified a system to use here. Later Evitt (1985) developed a complex system based on dinoflagellate paratabulation, in which 17 morphological categories were devised. In practice this system is too complex to use with the morphological categories being too detailed, impractical and difficult to remember and relate to each other.

In this chapter the dinoflagellate cyst genera are grouped based on simple morphology. Two main subdivisions are distinguished under the Class Dinophyceae (Fritsch, 1929) and Order Peridiniales (Haekel, 1894) namely; the Family Peridiniaceae (Ehrenberg, 1832) and the Family Gonyaulacaceae (Lindemann, 1928). Further subdivisions within the above categories are listed below:

Peridinioid cysts
- Wetzeliella Group
- Other Peridinioids

Gonyaulacoid cysts
- proximate cysts
- chorate cysts

proximochorate cysts

Unknown affinity

Other acritarcha and algae genera are described in this section and are subdivide as follows:

Class Chlorophyta (Kutzing, 1843)
Class Zygnemataceae
Class Prasinophyceae
Group Acritarcha (Evitt, 1963)

Within each subdivision the taxa are listed alphabetically and utilising the linnean approach to nomenclature. The subdivisions are based on morphological, not biological features, i.e. they are 'form taxa'. This approach is consistent with the pollen and spore approach in the use of form taxa, dividing genera into groups of simple morphological similarities. The terminology used to describe dinoflagellate taxa is summarised by Evitt *et al.* (1977), Stover & Evitt (1978) and Evitt (1985). The paratabulation descriptions used within the diagnoses utilise the kofoidian system of description (Kofoid, 1909), which is ideal for the objective analysis of individual plates which are described according to their position relative to the cingulum. This is in contrast to the Taylor-Evitt system (Evitt, 1985) which is used to compare paratabulation patterns when plates that are considered homologous occupy different positions, which can cause confusion in the nomenclature around the sulcal area.

The description of each genus and species follow a similar line to that of the previous section on pollen and spore systematics. For each of the genera recorded in this study, the type species and author is cited. Generic remarks are given and include an idea of the key morphological features of the genus. For each species a 'reference' is given, this reference refers the reader to details and illustrations in the published literature perceived by this author to give a representative idea of the species in question. Also giving the range and variation involved within each species to clarify the authors concept of the taxa, which can be difficult to do well, with a description and one figure for illustration. This is followed by comments on distinctive morphological features of the species and differences to other taxa where appropriate. The occurrences of each taxon recorded in this study, are not detailed here as they are graphically displayed on 'Tilia graph' charts (enclosures 1-10). A stratigraphical record is given for each species, this includes selected occurrences of the taxon from the published literature, focusing on the NW European area. Finally taxa encountered in this study that are regarded as being reworked or caved are listed alphabetically, with the approximate age ranges of these taxa also suggested.

PERIDINIOID CYSTS

This group of cysts is thought to originate in the Triassic and continues to Recent times. They originate from photosynthesising animals which are parasitic in habit. The cysts have a characteristic morphology, in general they show dorsoventral flattening and have a peridinioid outline, they are cavate to various extents and this often results in the development of horns. They generally possess a simple intercalary archeopyle, type I. The tabulation is peridinioid 4', 2-3a, 7", Xc, 5"', 2"" with the 7" plate characterising this group. As paratabulation features are infrequent it can be difficult to work out a tabulation formula in some cases. This group is subdivided into:

> Wetzeliella group, this contains cysts which are typically circumcavate, characterised by an oval to diamond shaped endocyst, with a pericoel that extends into horns, one apical, two antapical and two laterally. Also various types and distributions of surface ornamentation is important.
>
> Other Peridinioids

Wetzelliela group

Genus ***Rhombodinium*** Gocht, 1955

TYPE SPECIES: ***Rhombodinium draco*** Gocht, 1955; p. 85, fig. 1.

REMARKS: These are large proximate, circumcavate peridinioid cysts which have one apical, two lateral and two antapical horns. The periphragm is smooth with low relief ornamentation sometimes occurring. The paratabulation is quadra style and indicated by the archeopyle only. The archeopyle is intercalary type I/I (2a only). The paracingulum is generally faint and is emphasised by the lateral horns.

Rhombodinium draco Gocht, 1955

Plate 37, Figure 1

REFERENCE: Bujak, 1979; p. 314, pl. 1, figs 1-2, 4 and Bujak *et al.*, 1980; p. 78, pl. 20, fig. 6 are regarded as typical specimens.

COMMENTS: These are characterised by a rounded rhomboid outline. They are large, cornucavate peridinioid cysts. One apical, two lateral and two antapical horns are present. The periphragm has a low relief ornament of irregularly spaced granules or tubercles. Another distinctive feature of this species is a soleiform periarcheopyle and endarcheopyle, which are of the same size. A paracingulum is sometimes visible.

STRATIGRAPHIC RECORD: Upper Eocene of S England (Bujak, 1979, 1980) of Germany (Alberti, 1961); Upper to Middle Oligocene of NW Europe (Costa & Manum, 1988); Middle Oligocene of Germany (Gocht, 1952, 1955, 1967, 1969; Benedek, 1972); Upper Oligocene of Germany (Brosius, 1963; Benedek, 1972)

Genus ***Wetzeliella*** Eisenack, 1938 emend Lentin & Williams, 1976

TYPE SPECIES: ***Wetzeliella articulata*** Eisenack, 1938,p. 186, text fig. 4.

REMARKS: These are very distinctive large proximochorate peridinioid cysts, which are cornucavate to circumcavate. The endocyst is circular to subcircular in shape. The endophragm and periphragm are separated by a pericoel. The periphragm extends to form one apical, two lateral and two antapical horns, the positions of which can be taxonomically important. The periphragm has an ornamentation of short tubular processes. The process distribution is generally non tabular but can be as intratabular clusters. A paracingulum is picked out by a lack of tabulation or a traverse alignment of ornamentation. The reflected paratabulation from the archeopyle and intratabular features indicates a peridinioid, quadra style tabulation, 4', 3a, 7", Xc, 5"', 2"", with an intercalary archeopyle of the type I/I (2a only) which is stenodeltaform in shape (Bujak & Davies, 1983). *Wetzeliella* is easily distinguished from similar genera such as *Rhombodinium* (Gocht, 1955) which has no process

development, *Charlesdowniea* (Vozzehennikova, 1963) Lentin & Vozzhennikova, 1989 in which the processes are connected and linked distally, *Wilsonidinium* (Lentin & Williams, 1977) in which the parasutural features are clearly marked by ornamentation, which is not the case for *Wetzeliella* and *Apectodinium* (Costa & Downie, 1976) Lentin & Williams, 1977 in which the endocyst and paratabulation are much less distinct than in *Wetzeliella*. Much work has been done on this group of peridinioid cysts, which ranges from the Palaeocene to the Oligocene. Many authors such as Costa & Downie (1976, 1979), Costa *et al.* (1978) and Powell (1992) in proposed zonal schemes for the NW European Tertiary use this group making it of some stratigraphical importance. For this study it should be noted the ranges of *W. gochti* (Costa & Downie, 1976) and *W. symmetrica* (Weiler, 1956) are restricted to the Oligocene of NW Europe in the work of the authors mentioned above.

Wetzeliella gochti Costa & Downie, 1976

Plate 37, Figures 2&3

REFERENCE: Costa & Downie, 1976; p. 610, pl. 92, figs 2-3 and Chateauneuf, 1980; p. 151, pl. 28, figs 12-13 are regarded as typical specimens.

COMMENTS: Subpentagonal to subrhombic and rounded in outline. The endophragm lies close to the periphragm leaving only a narrow well defined pericoel. The horns if present are reduced to being short and blunt with the right antapical horn being shorter than the left, when present. The processes are abundant and of variable shape and characteristic. They are flexible and thin walled and can be open or closed distally with aculeate or entire to simple, acumate or capitate distal tips respectively and give this species a scruffy appearance. This species is similar to *W. symmetrica* (Weiler, 1956) with thin flexible processes but is differentiated by the characteristic four well developed horns of *W. symmetrica*.

STRATIGRAPHIC RECORD: Eocene to Oligocene of France (Chateauneuf, 1980); Early to Middle Oligocene of NW Europe (Costa & Manum, 1988); Middle Oligocene of Belgium (Costa & Downie, 1976)

Wetzeliella symmetrica Weiler, 1956

Plate 38, Figures 1 to 4

REFERENCE: Broisius, 1963; p. 35, pl. 2, fig. 7 and Davey *et al.*, 1966; p. 196, pl. 20, fig. 6 are regarded as typical specimens.

COMMENTS: In this species the periphragm has a very distinctive rhombic shaped outline, the angles of this are elongated to form long but equal horns. Although five horns are present the left antapical is greatly reduced, often being almost absent. The position of the single apical horn is critical, it is centred over a midventral line. The processes are relatively thin walled, flexible and slender with aculeate to bifurcate distal margins (shown in plate 38, figure 4). The distinct rhombic shape and four pronounced, long horns and position of the apical horn differentiate this species from *W. gochti*.

STRATIGRAPHIC RECORD: Eocene of England (Davey *et al.*, 1966); Early to Middle Oligocene of NW Europe (Costa & Manum, 1988); Oligocene to Miocene of NW Europe (Costa & Downie, 1976); Middle Oligocene to Middle Miocene of Germany (Brosius, 1963)

Other peridinioids

Genus ***Deflandrea*** Eisenack, 1938 emend Williams & Downie, 1966 emend Lentin & Williams, 1976

TYPE SPECIES: ***Deflandrea phosphoritica*** Eisenack, 1938; p. 187, fig. 6.

REMARKS: A very distinctive bicavate or circumcavate cyst, medium to large in size and elongate to pentagonal in shape with one apical and two antapical horns. Tabulation when seen is

peridinioid. The periphragm is smooth to granular and shows a circular cingulum. The longitudinal furrow is restricted to the hypotract. The inner body, the endophragm, is circular, of variable thickness and is generally smooth. The archeopyle is intercalary, type I/I (2a only) and eurydeltaform. This genus is distinguished from *Cerodinium* (Vozzhennikova, 1963 emend Lentin & Williams, 1987) which has a type I, isodeltaform archeopyle.

Deflandrea heterophlycta Deflandre & Cookson, 1955

Plate 39, Figures 1 to 4

REFERENCE: Deflandre & Cookson, 1955; p. 249, pl. 5, fig. 6, text fig. 5 and Chateauneuf, 1980; p. 137, pl. 22, figs 7-8 are regarded as typical specimens.

COMMENTS: A medium to large sized circumcavate peridinioid cyst with a subspherical endocyst. The periphragm is elongated and forms one apical and two antapical horns. A paracingular trace can be seen in the form of two parallel ridges of the pericyst at the equator. The archeopyle is type I. This species is easily distinguished from other species of *Deflandrea* as its endocyst is characteristically ornamented with irregularly dispersed tubercles, becoming more numerous and coarser towards the poles. Specimens examined in this study also had an ornamentation of organised linear, fine spines running lengthways along the apical horn (shown in plate 39, figure 1). This species is similar to *Dracodnium condylos* (Williams & Downie, 1966b) but is differentiated by the distinct lateral horns present in Wetzelielloid species.

STRATIGRAPHIC RECORD: Late Eocene to Early Oligocene of NW Europe (Deflandre & Cookson, 1955 and Costa & Manum, 1988); Oligocene of France (Chateauneuf, 1980)

Deflandrea phosphoritica Eisenack, 1938

Plate 39, Figures 5 & 6

REFERENCE: Deflandre & Cookson, 1955; p. 249, pl. 4, fig. 5; Davey *et al.*, 1966; p. 231-232, pl. 26, figs 2, 3, 6 and 9; Eaton, 1976; p. 290-291, pl. 17, fig. 1 are regarded as typical specimens.

COMMENTS: These are medium to large sized circumcavate peridinioid cysts. The periphragm extends into one apical and two antapical horns and shows no ornamentation. The interhorn area is distinctly indented. The endophragm is subspherical and generally smooth. A paracingulum trace is seen by two parallel ridges of the pericyst at the equator, a gap in this paracingulum represents a sulcal area. The archeopyle is type I, eurydeltaform and is located at a high position in the pericyst and endocyst, differentiating this species from *D. oebisfeldensis* (Alberti, 1959) in which the position of the archeopyle is lower in the pericyst and the antapical pericoel which is more box-like in shape.

STRATIGRAPHIC RECORD: Late Palaeocene to Early Eocene of France (Gruas-Cavagnetto, 1968); Early Eocene of Belgium (Morgenroth, 1966a and Gruas-Cavagnetto, 1968); Late Eocene to Early Oligocene of Germany (Eisenack, 1938; Chateauneuf, 1980); Upper Oligocene of Germany (Gerlach, 1961; Benedek, 1972). The Late Palaeocene records here are regarded as doubtful.

Genus ***Lentinia*** Bujak, 1980

TYPE SPECIES: ***Lentinia serrata*** Bujak, 1980; p. 71-72, pl. 18, fig. 7, text figs 18-19.

REMARKS: This genus describes small peridinioid cysts, in which the periphragm is extended to form one apical and two antapical horns. The periphragm and endophragm are closely adpressed generally restricting cavation to the horns. The ornamentation of the periphragm varies from smooth to spinose and always develops denticulate crests along its paracingulum margins. Paratabulation can be worked out from the distribution of the

ornamentation in some species, 4', 3a, 7", 5"', 2"". A paracingulum is present, it is indented and planar to helicoidal. A parasulcus is also indented and delimited with rows of denticles. The archeopyle is an intercalary hexa type I/I (2a only). This genus is differentiated from *Deflandrea* by its restricted pericoel and denticular ornament.

Lentinia wetzelii Morgenroth, 1966a

Plate 40, Figures 1 & 2

REFERENCE: Morgenroth, 1966a; pl. 1, figs 4 and 5 are regarded as typical specimens.

COMMENTS: This species was transferred from the genus *Deflandrea* by Bujak (1980). It describes a small peridinioid cyst, the periphragm is extended to form three short horns, one apical and two antapical. Due to the closely adpressed periphragm and endophragm cavation is cornucavate, restricted to the position of the horns. The periphragm ornamentation is intratabular and composed of short spines. The archeopyle is a type I (2a only) and is stenodeltaform. The archeopyle is smaller compared to *L. serrata* and the epicyst and hypocyst are of equal sizes.

STRATIGRAPHIC RECORD: Early Eocene of Germany (Morgenroth, 1966a), of the Rockall Trough (Costa & Downie, 1979); Middle Eocene of S England (Bujak *et al.*, 1980)

Genus ***Palaeocystodinium*** Alberti, 1961

TYPE SPECIES: ***Palaeocystodinium golzowense*** Alberti, 1961; p. 20, pl. 7, figs 10-12, pl. 12, fig. 16.

REMARKS: This is a very distinctive proximate cyst which is bicavate, the endocyst is subspherical to elongate and has a single slender pointed apical and antapical horn. The periphragm is smooth to faintly ornamented and shows no indication of

paratabulation except at the archeopyle, which is intercalary type I (2a only). This genus is differentiated from the similar bicavate genera *Svalbardella* (Manum, 1960) which has wider blunt, round ended horns and has some indication of paratabulation other than the archeopyle.

Palaeocystodinium golzowense Alberti, 1961

Plate 40, Figure 3

REFERENCE: Eaton, 1976; p. 294, pl. 16, fig. 7 is regarded as a typical specimen.

COMMENTS: This is a bicavate proximate peridinioid cyst which has two pointed slender horns, one apically and one antapically positioned. The endophragm is elongate and oval and the periphragm is smooth and extends to form the distinctive horns. As the horns are long, thin and slender they often appear folded and twisted. The only indication of paratabulation is seen at the archeopyle which is an intercalary 2a only type I.

STRATIGRAPHIC RECORD: Lower Eocene of France (Gruas-Cavagnetto, 1970b) of Belgium (De Coninck, 1968, 1972) of England (Eaton, 1976); Upper Eocene of Germany (Alberti, 1961) of England (Eaton, 1976); Middle Oligocene of Germany (Alberti, 1961; Benedek, 1972); Upper Oligocene of Germany (Alberti, 1961; Brosius, 1963)

Palaeocystodinium sp. **A** of Costa & Downie, 1979

Plate 40, Figures 4, 5 & 6

REFERENCE: Manum *et al.*, 1989; pl. 13, fig. 15 is regarded as a typical specimen.

COMMENTS: Distinctively a *Palaeocystodinium* species, this cyst is bicavate, the endocyst is spherical and the periphragm extends into two horns, at the poles, one apical and one antapical. The horns are

very broad based and relatively short but have the characteristic pointed tips. The periphragm over the horns has a faint granular ornament and distinct longitudinal folds or striae that run the length of the horn, converging at the tip. The only indication of paratabulation is again the archeopyle which is an intercalary type I (2a only). This species is differentiated from *P. golzowense* by its spherical endocyst and broad based short pointed horns which possess longitudinal folds.

STRATIGRAPHIC RECORD: Early Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Phthanoperidinium*** Drugg & Loeblich, 1967

TYPE SPECIES: ***Phthanoperidinium ameonum*** Drugg & Loeblich, 1967; p. 182, pl. 1, figs 1-5.

REMARKS: This describes small to medium sized proximate ovoid cysts. The periphragm and endophragm are thin and closely adpressed. The periphragm forms a short apical horn with an antapical horn occurring occasionally. The characteristic feature of this genus is the very distinctive parasutural ridges which show varying ornamentation from smooth to spinose. The intratabular areas may also be ornamented. The archeopyle is 2I or 3I and can include precingular plates. Variations of archeopyle types within this genus have been fully discussed in the work of Islam (1982). Both parasutural ridges and archeopyle have enabled the formula for paratabulation to be deduced, 4', 2a or 3a, 7", 5‴, 2⁗, 0-5s.

Phthanoperidinium alectrolophum Eaton, 1976

Plate 41, Figure 1

REFERENCE: Eaton, 1976; pl. 17, figs 10-11, text-fig 23A and Bujak *et al.*, 1980; pl. 5, fig. 9, pl. 19, figs 3-4 are regarded as typical specimens.

COMMENTS: These are medium sized subcircular proximate cysts, which possess only a short blunt apical horn. The endophragm and periphragm are closely adpressed and the periphragm is smooth. Thin smooth sutural crests of variable height occ over the cyst. The margins of the crests are thickened and densily ornamented with short spines. The sutural crests and intercalary archeopyle indicate a peridinioid paratabulation. This species differs from *P. multispinum* (Bujak *et al.*, 1980) which has longer spines and from *P. eocenicum* (Cookson & Eisenack, 1965) which shows no distal thickenings and lac margins of granules or tubercles, this species also possesses a well developed apical horn.

STRATIGRAPHIC RECORD: Middle Eocene of S England (Bujak *et al.*, 1980) Upper Eocene of S England (Eaton, 1976)

Phthanoperidinium amoenum Drugg & Loeblich, 1967

Plate 41, Figures 2 & 3

REFERENCE: Drugg & Loeblich, 1967; p. 182, pl. 1, figs 1-5, text figs 1a-c Chateauneuf, 1980; pl. 144, pl. 27, fig. 1 are regarded as typical specimens.

COMMENTS: These are small oval peridinioid cysts with the endophragm and periphragm not clearly differentiated. A short apical horn is usual, but with no antapical horns being present. The paracingulum is slightly helicoidal and the archeopyle is a hexa intercalary type I (2a only). The tabulation is clear and marked by low and faintly denticulate sutures. The wall varies from smooth, granulate to vermiculate. Two size populations of this species have been recorded, very small specimens (<40μm) from 16/16 and small (>40μm) in both 16/16 and 21/28. This species is similar to *P. eocenicum* (Cookson & Eisenack, 1965) but is differentiated as this species possesses an antapical horn and *P. resistente* (Morgenroth, 1966a) which is larger with non granular sutural margins.

STRATIGRAPHIC RECORD: Oligocene of USA (Drugg & Loeblich, 1967); Lower Oligocene of France (Chateauneuf, 1980)

Phthanoperidinium comatum (Morgenroth, 1966b) Eisenack & Kjellstrom, 1971

Plate 41, Figures 4 & 5

REFERENCE: Bujak *et al.*, 1980; p. 72, pl. 19, figs 5-6, text figs 20b and 21 are regarded as typical specimens.

COMMENTS: Small proximate oval peridinioid cysts which have a short apical projection. The periphragm and endophragm are very closely adpressed making the endocyst rarely visible. The periphragm is ornamented with distinct parasutural ridges which pick out the peridinioid paratabulation clearly. This species is easily distinguished from others in this genus by the long slender spines that project from the parasutural ridges. *P. tritonum* (Eaton, 1976) is synonymous with this species.

STRATIGRAPHIC RECORD: Eocene of S England (Eaton, 1976; Bujak *et al.*, 1980); Lower Oligocene of N Germany (Morgenroth, 1966b) of France (Chateauneuf, 1980)

Phthanoperidinium echinatum Eaton, 1976

Plate 41, Figure 6

REFERENCE: Eaton, 1976; p. 298-299, pl. 17, fig. 8-9, 12 and text fig. 23B are regarded as typical specimens.

COMMENTS: Small proximate, rounded to polygonal cysts with a short blunt apical horn. The periphragm is smooth to granular and ornamented with short hair-like projections along the plate boundaries which pick out the peridinioid tabulation. The paracingulum is clearly defined. The distinctive ornamentation differentiates this from other *Phthanoperidinium* species.

STRATIGRAPHIC RECORD: Early to Late Eocene (Eaton, 1976)

Phthanoperidinium filigranum Benedek, 1972 emend Benedek & Sargeant, 1981

Plate 41, Figure 7

REFERENCE: Benedek & Sargeant, 1981; p. 325-327, text fig 4, pl. 8, figs 1-8 are regarded as typical specimens.

COMMENTS: This species has formally being assigned to genera such as *Deflandrea* and *Vozzhennikova* (Lentin & Williams, 1976). They are peridinioid cysts, the endophragm and periphragm are closely adpressed and the periphragm is developed into three short horns, one apical and two antapical and is cornucavate. The parasutural areas are delimited by low crests which indicate a peridinioid paratabulation. The periphragm is ornamented with a net like fine mesh, characterising this form any other *Phthanoperidinium* species. It is similar to *P. eocenicum* (Cookson & Eisenack, 1965) Lentin & Williams (1973) which is more elongate and has coarse dot like thickenings on paraplate surfaces instead of the net like ornament in *P. filigranum*. The archeopyle is intercalary, type I (2a only).

STRATIGRAPHIC RECORD: Middle Oligocene of Germany (Benedek, 1972, Benedek & Sargeant, 1981)

Phthanoperidinium geminatum Bujak *et al.*, 1980

Plate 42, Figures 1, 2 & 3

REFERENCE: Bujak *et al.*, 1980; p. 72-74, pl. 19, fig. 8-12, text figs 20d and 22a are regarded as typical specimens.

COMMENTS: These are small to medium sized oval peridinioid cysts. A short apical horn is usual and two short antapical horns are possible. The endocyst is rarely visible due to the periphragm and endophragm being closely adpressed. The ornamentation of the periphragm varies from chagrinate to granulate, with

parasutural rows of granules, short spines or low crests. Simulate rows, or zones of a similar ornament (often greater in height and obscuring the parasutural ornament) are always present and occur 1-3µm inside the parasutures except where the plates border the paracingulum. Although other *Phthanoperidinium* species have this similate, double row of ornament, *P. geminatum* is differentiated from *P. comatum* which has distinctive long spines and *P. levimurum* (Bujak *et al.*, 1980) which has clear parasutural crests.

STRATIGRAPHIC RECORD: Late Eocene of S England (Bujak *et al.*, 1980)

Phthanoperidinium levimurum Bujak *et al.*, 1980

Plate 42, Figures 4,5 & 6

REFERENCE: Bujak *et al.*, 1980; p. 74, pl. 19, figs 13-16, text figs 20e and 22b are regarded as typical specimens.

COMMENTS: These oval shaped peridinioid cysts are small to medium in size. One small apical horn and one or two small antapical horns are typical. The endocyst is rarely seen but the thin periphragm shows a granulate to vermiculate ornament Distinctive parasutural crests characterise this species differentiating it from the spinose or smooth *Phthanoperidinium* species. The paracingulum is relatively deep and helicoidal. The archeopyle is a type I/I (2a only).

STRATIGRAPHIC RECORD: Late Eocene of S England (Bujak *et al.*, 1980)

STRATIGRAPHIC RECORD: Middle Eocene of S England (Bujak *et al.*, 1980) Upper Eocene of S England (Eaton, 1976)

Genus ***Selenopemphix*** (Benedek, 1972 emend Lentin & Williams, 1976) Bujak *et al.*, 1980

TYPE SPECIES: ***Selenopemphix nephroides*** Benedek, 1972; p. 47, pl. 11, fig. 13, pl. 16, figs 1-4.

REMARKS: Lentin & Williams (1976) emended the original diagnosis, distinguishing it from *Lejeunia* (Gerlach, 1961) by the type of compression, with *Selenopemphix* having a polar compressi[illegible] Bujak *et al.* (1980) distinguished the two on archeopyle, in *Selenopemphix* the archeopyle is laterally offset. This genus describes medium to large cysts, circular to oval in polar view and peridinioid in outline dorsoventrally being pentagonally shaped with one apical and two antapical horns. The endophragm and periphragm are closely adpressed and often cannot be distinguished. The autophragm commonly shows folding and is smooth, granulate to spinate in sculpture. When present the spines are solid and generally restricted to the paracingulum and horns. Paratabulation is only seen from the archeopyle and paracingulum. The paracingulum is slightly helicoidal. The parasulcus is indicated by an indentation on the ventral surface. The archeopyle is intercalary I/I (2a only), hexa type. It is asymmetrical relative to the middorsal line distinguishing this genus from *Lejeunia*.

Selenopemphix nephroides Benedek, 1972 emend Bujak *et al.*, 1980

Plate 42, Figures 7 to 10

REFERENCE: Benedek, 1972; p. 47, pl. 11, fig. 13, pl. 16, figs 1-4 and Bujak *et al.*, 1980; p. 84-85, pl. 21, fig. 6, text fig. 23a are regarded as typical specimens.

COMMENTS: A polar compression gives this cyst its characteristic appearance. The apex is elongated slightly to form a rounded horn and the antapex extends to form two antapical horns of approximately equal sizes. This species is differentiated from other *Selenopemphix* species by being smooth, having no ornamentation or spines on the autophragm. A paracingulum is defined by equal raised ridges. A parasulcus is inferred from a shallow indentation. The archeopyle is intercalary, type I/I (2a only) and its position is asymmetrical relative to a middorsal line.

STRATIGRAPHIC RECORD: Upper Eocene of S England (Bujak *et al.*, 1980); Oligocene of Germany (Benedek, 1972); Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Svalbardella*** Manum, 1960

TYPE SPECIES: ***Svalbardella cooksoniae*** Manum, 1960; p. 21-22, pl. 1, figs 1-3 and text fig. 2 are regarded as typical specimens.

REMARKS: This genus describes peridinioid cysts which are bicavate. The endocyst is subspherical to elongate and the periphragm is elongate and forms a single bluntly rounded apical and antapical horn at each pole. The paratabulation is indicated by the archeopyle and other parasutural features. The archeopyle is intercalary type I (2a only). The parasutural features are picked out by a faint or low relief ornamentation which is generally limited to precingular and postcingular areas of the cyst especially the paracingulum, described by Manum (1960) as an "equatorial girdle". This genus is differentiated from *Palaeocystodinium* which has long slender pointed horns and paratabulation only indicated by the archeopyle.

Svalbardella cooksoniae Manum, 1960

Plate 43, Figures 1 to 3

REFERENCE: Manum *et al.*, 1989; pl. 19, fig. 6 is regarded as a typical specimen.

COMMENTS: This species is very distinctive, it describes a bicavate peridinioid cyst. A single bluntly rounded apical and antapical horn is present at each pole. The paratabulation is indicated by the archeopyle and faint paracingulum. The archeopyle is intercalary type I (2a only). The periphragm shows an ornamentation of granulae that form a finely undulate appearance and is concentrated on the polar regions of the cyst.

especially the horns, giving this species a characteristic appearance and making it unlike any other species.

STRATIGRAPHIC RECORD: Palaeocene to Eocene of Spitzbergen (Manum, 1960); *Early Eocene to Early Oligocene** of the Norwegian Sea (Manum *et al.*, 1989)

Svalbardella sp. **1**

Plate 43, Figures 4 & 5

COMMENTS: This is a very distinctive species, it is a bicavate peridinioid cyst, with the cavation restricted to single, very small apical and antapical horns. They are short with a narrow base and taper to a rounded distal tip. The archeopyle is intercalary, type I (2a only) and is the only indication of paratabulation other than for a faint cingulum. The endocyst is closely adpressed to the pericyst and is ovoid in shape. The ornamentation is concentrated over the horns and is finely granulate. The granulae appear to be arranged to form pseudostriae. This species is present in 21/28b-7 and 16/16b-4 and is similar to *Svalbardella* cf. *granulata* of Wilson, 1967 (p. 226-227, figs 7-9). This species has very short ornamented horns but they are slightly pointed at their ends compared to *S.* sp. 1 which have very short round ended 'nipple like' horns.

Svalbardella sp. 2

Plate 43, Figures 6 & 7

COMMENTS: Only a few specimens of this species were recorded in this study. It is a bicavate peridinioid cyst. The endocyst is oval and elongate. The periphragm extends to form two small cavations or horns at the poles. These horns are short, broad based, bluntly rounded and tend to run close to, but parallel with the end of the endocyst, mirroring it. The periphragm is smooth showing no ornamentation. An intercalary, hexa type I (2a only) archeopyle is present and a faint paracingulum is occasionally indicated.

GONYAULACOID CYSTS

Gonyaulacoid cyst types originated in the Middle Jurassic and range through to the Recent. The motile stages of these cyst types are thought to be photosynthetic only and not parasitic as in peridinioids. The characteristic paratabulation formula is 0p.r., 4', 0a, 6", 6c, 6‴, 1p, 1⁗, with the 6" plate distinguishing this group from peridinioid cysts. This group is subdivided as below:

Proximate cysts
Chorate cysts
Proximochorate cysts

Proximate cysts

Genus ***Amiculosphaera*** Harland, 1979b

TYPE SPECIES: ***Amiculosphaera umbracula*** Harland, 1979b; p. 535, pl. 1, figs 11-14, 22-23, pl. 2, figs 1-3.

REMARKS: These are cavate cysts in which a pericoel separates the endophragm and periphragm. The periphragm forms a 'cloak like' covering to the endophragm. The periphragm is supported at the apex by an apical process that is a continuation of the periphragm and is attached to the hypocyst in the postcingular plate series. The tabulation is gonyaulacoid and can be indicated on the periphragm. The archeopyle is precingular (3" only).

Amiculosphaera umbracula Harland, 1979b

Plate 44, Figure 1

REFERENCE: Manum *et al.*, 1989; pl. 1, figs 6-7 are regarded as typical specimens.

COMMENTS: This describes cavate gonyaulacoid cysts which are medium to large in size. The endocyst is spherical to oval in shape and the periphragm is inflated to ovoid, with the epicystal part of the periphragm being larger and more expanded compared with the hypocystal part in which the wall layers tend to be closely adpressed except at the paracingulum. The endophragm and periphragm are separated by a epicystal pericoel which is supported apically by a single flaring apical process. This is the characteristic feature in distinguishing this species, as this flaring process is expanded almost from the base. One large apical process and four gonal processes at the antapical plate boundaries occur.

STRATIGRAPHIC RECORD: Middle Miocene to Pleistocene of the Bay of Biscay (Harland, 1979b); Late Miocene to Early Pleistocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Apteodinium*** Eisenack, 1958

TYPE SPECIES: ***Apteodinium granulatum*** Eisenack, 1958; p. 386, pl. 23, figs 8-14; emend. Sarjeant, 1985, p. 79-81, 83; emend Lucas-Clark, 1987; p. 70, 172.

REMARKS: This genus describes medium to large sized proximate cysts which are oval to subspherical in shape. The autophragm forms one short pointed apical horn, generally no tabulation or ornamentation is present although some low relief features can be discernable with faint parasutural areas being indicated at the cingulum. Wall structure may be smooth or ornamented, spongy or cavenous. The archeopyle is precingular, type P and the operculum is free. This genus is similar to *Millioudodinium* Stover & Evitt, 1978 but is differentiated by the clearer indication of paratabulation in *Millioudodinium.* Sarjeant (1981, 1985) had differentiated the genera of *Emslandia* Gerlach, 1961 and *Apteodinium* using wall structure, but due to the later emendation of Lucas-Clark 1987 describing *Apteodinium* as possessing an autophragm only, *Emslandia* is now thought to be synonymous with *Apteodinium*.

Apteodinium spiridoides Benedek, 1972

Plate 44, Figures 2 to 4

REFERENCE: Benedek, 1972; p. 5, pl. 2, fig. 1 and pl. 15, figs 1-6 and Benedek & Sarjeant, 1981; p. 318-320, pl. 2, figs 1-3 are regarded as typical specimens.

COMMENTS: These are medium sized proximate cysts. They are subspherical and possess one short pointed horn, apically. The wall is thick and spongy. Under transmitted light its appearance is very distinctive, as an irregular pattern of cavities and canals running through the wall, sometimes opening to the exterior, giving this cyst an appearance like no other. The surface ornamentation is granular to finely scabrate. The paracingulum is clearly defined by an indentation in the periphragm and equatorial ridges. The archeopyle is precingular, type P.

STRATIGRAPHIC RECORD: Middle Oligocene of Germany (Benedek, 1972; Benedek & Sarjeant, 1981); Middle Oligocene to Miocene of NW Europe (Manum *et al.*, 1989)

Apteodinium trinovantium Jolley, 1991

Plate 44, Figure 5

REFERENCE: Jolley, 1991; pl. 21, figs 10-12 are regarded as typical specimens.

COMMENTS: A medium sized proximate cyst which is spherical to subspherical in shape. The autophragm is thin and a prominent horn is developed apically. It is simple and shows no ornamentation. The archeopyle is precingular, type P (3" only) and is free. Raised ridges of the paracingulum are laevorotory and indicate a gonyaulacoid tabulation pattern. This species is easily differentiated from *A. spiridoides* which has a much thicker spongy wall that is distinctively cavate.

STRATIGRAPHIC RECORD: Late Palaeocene to Early Eocene of Britain (Jolley, 1991)

Genus ***Corrudinium*** Stover & Evitt, 1978

TYPE SPECIES: ***Corrudinium incompositum*** (Drugg, 1970; p. 810-811, fig 1E-O, 2A) Stover & Evitt, 1978; p. 149a.

REMARKS: This genus describes small to medium sized proximate to proximochorate cysts. They are subspherical in shape with no apical horn or protrusion. The paratabulation is gonyaulacoid and is indicated by parasutural ridges or septa of uniform height. The tabulation formula is 3-4, 6", 6c, 5-6‴, 0-1p, 1⁗, 2-7s. Characteristic accessory ridges or septa occur over the paraplates and can obscure paratabulation and are as discontinuous, straight or curved features. The archeopyle is precingular, type P (3" only) and is free. This genus is differentiated from *Impagidinium* Stover & Evitt, 1978 which has no accessory ridges and from *Cribroperidinium* (Neale & Sarjeant, 1962 emend. Davey, 1969) which has an apical horn and is larger in size.

Corrudinium incompositum Drugg, 1970

Plate 44, Figures 6 & 7

REFERENCE: Drugg, 1970; p. 810-811, figs 1E-1O, 2A and De Coninck, 1986; p. 12, pl. 2, figs 1-2 are regarded as typical specimens.

COMMENTS: These are small sized oval cysts with no apical horn. The periphragm is ornamented with slightly raised parasutural ridges or crests. These crests reflect a gonyaulacoid paratabulation pattern. The paraplates are occupied with discontinuous septa between the parasutural ridges. A precingular archeopyle is characteristic.

STRATIGRAPHIC RECORD: Middle Eocene of NW Europe (Manum *et al.*, 1989); Oligocene of N America (Drugg, 1970); Lower Oligocene of France (Chateauneuf, 1980)

Genus ***Cribroperidinium*** Neale & Sarjeant, 1962 emend Helenes, 1984

TYPE SPECIES: ***Cribroperidinium septatum*** Neale & Sarjeant, 1962; p. 442 pl. 19, fig. 4, text fig. 3.

REMARKS: This genus describes medium to large sized proximate gonyaulacoid cysts. They are spherical to subspherical in shape and the autophragm is elongated forming a prominent apical horn. The parasutures are picked out by ridges or raised septa and enable paratabulation to be deduced. From the work of Davey (1969) a paratabulation formula was suggested, ?6', (1-5a), 8-9", 0c, 9"', 1p, 1-3p.v. (5-7p.c.), 0"" (-?2""). Intratabular ornamentation commonly occurs. The archeopyle is precingular and is free (3" only). The cingulum is clearly defined and is laevorotatory. This genus is differentiated from *Corrudinium* which is small and is lacking in apical horn development. Stover & Evitt (1978) suggested *Millioudodinium* (Stover & Evitt, 1978 emend Sarjeant, 1982b) as a junior synonym of *Cribroperidinium*.

Cribroperidinium giuseppei (Morgenroth, 1966a) Helenes, 1984

Plate 45, Figures 1 & 2

REFERENCE: Morgenroth, 1966a; p. 5-6, pl. 2, figs 4-6 are regarded as typical specimens.

COMMENTS: This species is characteristically a medium sized proximate gonyaulacoid cyst. Its overall shape is subspherical to elongate, with a well developed apical horn. The archeopyle is precingular (3" only) and free. The wall is thick often appearing spongy with a granular ornament, some low intratabular ornamentation is possible. The cyst is divided by

low parasutural ridges. In this study specimens of this species were easily recognised due to their preservation which indicated a thick wall and relatively long apical horn with parasutural ridges delimiting paratabulation.

STRATIGRAPHIC RECORD: Early Eocene of Germany (Morgenroth, 1966a); Middle Eocene of British Isles (Eaton, 1976; Bujak *et al.*, 1980 and Condon *et al.*, 1992)

Genus ***Fromea*** Cookson & Eisenack, 1958 emend Yun, 1981

TYPE SPECIES: ***Fromea amphora*** Cookson & Eisenack, 1958; p. 56, pl. 5, figs 10-11.

REMARKS: These small to medium sized cysts are ellipsoidal in shape and are smooth with a faint ornamentation. No paratabulation features are present, with the exception of a paracingulum which can be apparent sometimes. An archeopyle at the apex is present but is of uncertain type. The emendation to the brief original description by Yun (1981) is accepted here.

Fromea fragilis (Cookson & Eisenack, 1962) Stover & Evitt, 1978

Plate 45, Figure 3

REFERENCE: Cookson & Eisenack, 1962; pl. 7, figs 10-11 and Jolley, 1991; pl. 31, figure 3 are regarded as typical specimens.

COMMENTS: This species was transferred by Stover & Evitt (1978) from *Paleostomocystis* (Deflandre, 1937 emend Deflandre, 1966) which remained to only include cysts with a reticulate ornamentation. This species is very characteristic, the cyst is small to medium sized, and elongate in shape with an unknown archeopyle type at the apex. A distinctive fold runs down the smooth cyst surface from the apex to antapex.

STRATIGRAPHIC RECORD: Late Palaeocene of Denmark (Heilmann-Clausen, 1985)

Genus ***Kallosphaeridium*** De Coninck, 1969

TYPE SPECIES: ***Kallosphaeridium brevibarbatum*** De Coninck, 1969; p. 44-45, pl. 13, figs 14-15 emend Jan du Chene *et al.*, 1985; p. 10.

REMARKS: This genus describes a small to medium sized, proximate cyst, with no ridges, septa or processes. The autophragm is smooth or displays low relief ornamentation often with fine hairs ornamenting the shell. The archeopyle is apical with an attached operculum, tAa. Although some differences were encountered i.e. one psilate specimen was recorded (*Kallosphaeridium* sp. 1, plate 45, figure 5), the majority seen were as hairy cysts (*K. brevibarbatum:* plate 45, figure 4). Only low number of this genus were recorded from both the North Sea sections from single specimens up to 1.18%.. This along with preservation and fragmentation made speciation difficult therefore all specimens are referred to as *Kallosphaeridium* spp. This genus differs from *Batiacasphaera* Drugg, 1970 in having an attached rather than free operculum.

Genus ***Membranosphaera*** Samoilovich in Samoilovich & Mtchedlishvili, 1961 ex. Norris & Sarjaent, 1965 emend Drugg, 1967

TYPE SPECIES: ***Membranosphaera maastrichtica*** Samoilovich in Samoilovich & Mtchedlishvili, 1961; p. 251, pl. 83, figs 1a-d, 2a-d, 3 and 4a-d ex. Norris & Sarjaent, 1965; p. 40.

REMARKS: This describes subspherical cysts that are small to medium in size. The autophragm shows a number of projections as non tabular fine spines. The cyst is composed of one layer which is often folded and is without indications of paratabulation. The archeopyle is apical and the operculum is free. Insufficient numbers of this taxa were recorded to allow speciation

therefore specimens encountered are recorded as *Membranosphaera* spp.

Plate 45, Figure 6

Genus ***Microdinium*** Cookson & Eisenack, 1960
emend Sarjeant, 1966a emend Stover & Evitt, 1978

TYPE SPECIES: ***Microdinium ornatum*** Cookson & Eisenack, 1960; p. 6-7, pl. 2, figs 3-8, text figs 2-4.

REMARKS: This genus describes proximate small spherical to subspherical cysts in which a broad paracingulum is present and separates the smaller epicyst from the larger hypocyst. This genus has been emended by Sarjeant (1966a) who added a paratabulation formula based on paraseptal ornament and Stover & Evitt (1978) whose emendation was concerned with archeopyle type (tA or tAtI) and the numbers of precingular paraplates. They deduced the following paratabulation formula 1-4', 0-3a, 6", 6c, 5-6‴, 1p, 1⁗, 0-5s. The paratabulation is marked by parasutural low crests or ridges. The surface ornamentation ranges from smooth, granular, punctate to tuberculate. The archeopyle types are 2A, 4A, P or 2P and E and are important in distinguishing this genera from *Cladopyxium* (Mclean, 1972) whose archeopyle is formed by the loss of two apical paraplates only.

***Microdinium* sp 1** of Chateauneuf 1980

Plate 46, Figures 1 & 2

REFERENCE: Chateauneuf, 1980; p. 143, pl. 26, figs 5-7 are regarded as typical specimens.

COMMENTS: This is a very distinctive species of *Microdinium*. It is a small to medium sized proximate cyst, which is spherical to oval in shape. The paracingulum is broad and the parasutures are

ornamented with continuous low crests or low ridges. The cyst is composed of two layers which are usually adpressed. The periphragm is broken up by these crests which indicate a gonyaulacoid paratabulation. The archeopyle is apical. The intraplate areas are smooth to granular with an ornamentation of small irregular clusters or zones of spines or anastomosing irregular crests. This species is differentiated from other *Microdinium* species by the presence of the distinctive zones of short pointed spines in the intraplate areas. It is also differentiated from other similarly ornamented species such as *Corrudinium incompositum* which has a precingular archeopyle rather than an apical archeopyle. The latter distinction is difficult when fragmented specimens are encountered.

STRATIGRAPHIC RECORD: Late Eocene of France (Chateauneuf, 1980)

Microdinium sp. **A**

Plate 46, Figure 4

COMMENTS: A rare species of *Microdinium* only recorded in low numbers from one assemblage in the section, 21/28b-7. These are small in size and are smooth with only faint traces of the parasutural ridges over the cyst. The lack of ornamentation differentiates this species from *M.* sp. 1 (Chateauneuf, 1980) and *M.* sp. 2.

Microdinium sp. **2**

Plate 46, Figure 3

COMMENTS: This species was rare in this study, only recorded as single specimens from the 16/16b-4 section. They are small in size and spherical to subspherical in shape. Parasutural ridges occur over the cyst and are unornamented. The surface ornamentation between these crests appears punctate to fenestrate, making this species easily distinguishable from all others.

Genus ***Tectatodinium*** Wall, 1967

TYPE SPECIES: ***Tectatodinium pellitum*** Wall, 1967; p. 113, pl. 16, figs 11-12.

REMARKS: This genus describes proximate gonyaulacoid cysts. They are subspherical in shape. The periphragm and endophragm wall layers are closely adpressed. The cyst surface varies from smooth to ornamented, with paratabulation only expressed from the precingular archeopyle (3" only). Other indications such as a paracingulum are rarely present and vague. In this study this genera was only encountered in low numbers from single specimens to 1%. This rarity of specimens and the varying preservations, often fragmented, was not enough to allow the accurate assignation of species to this genera, they are therefore referred to here as *Tectatodinium* spp. Although variations ranging from specimens with a spongy wall to numerous fine spines covering the cyst were encountered.

Plate 46, Figure 5

Genus ***Thalassiphora*** Eisenack & Gocht, 1960

TYPE SPECIES: ***Thalassiphora pelagica*** (Eisenack, 1954) Eisenack & Gocht, 1960 emend. Benedek & Gocht, 1981; p. 58-61.

REMARKS: This genus describes very distinctive medium to large sized proximate cysts. They have a distinct pericoel, the endocyst is subspherical and is surrounded by a much larger pericyst that is subspherical to lenticular, and may have a short apical projection. The endophragm and periphragm are separated by a distinct pericoel except in the mid-dorsal region where the layers meet. The paratabulation is gonyaulacaceaen and is indicated by the archeopyle and faint low parasutural ridges depending on the species. The archeopyle is precingular, type P (3" only) and the operculum is free.

Thalassiphora fenestrata Liengjarern, Costa & Downie, 1980

Plate 46, Figures 6 & 7

REFERENCE: Liengjarern *et al.*, 1980; p. 489, pl. 54, fig. 1 is regarded as a typical specimen.

COMMENTS: This is a very distinctive species of *Thalassiphora* having a distinct pericoel separating the subspherical endocyst from the larger subspherical to lenticular pericyst. The paratabulation is gonyaulacoid and is indicated by the precingular archeopyle only. Parasutural features are obscured by the ornamentation on the periphragm. The characteristic feature of this species is the fenestrate ornamentation over the periphragm. This fenestration occurs especially in lateral and ventral areas of the cyst and is reduced towards the mid-dorsal area. The fenestration occurs as large perforations, circular to oval in shape, with smaller circular perforations occurring between. This species is similar to *T. pelagica* (Eisenack, 1954) Eisenack & Gocht emend. Benedek & Gocht, 1981 in shape and wall structure but is distinguished by the fenestrate periphragm of *T. fenestrata*.

STRATIGRAPHIC RECORD: Late Eocene of the Norwegian Sea (Manum *et al.*, 1989); Late Eocene to Early Oligocene of S England (Liengjarern *et al.*, 1980)

Thalassiphora pelagica (Eisenack, 1954) Eisenack & Gocht, 1960
emend Benedek & Gocht, 1981

Plate 47, Figure 1

REFERENCE: Davey & Williams, 1966b; p. 234, pl. 26, fig. 7 is regarded as a typical specimen.

COMMENTS: This species is large in size. The endophragm is subspherical and thick, its ornamentation is slightly fibrous to granular. The periphragm is also relatively thick and granular to fibrous. A characteristic short spine is sometimes developed on the 1"" paraplate, this has previously been described as a keel. A

distinct pericoel separates the endocyst from the pericyst except in the mid-dorsal area where the two wall layers meet. Here a precingular archeopyle occurs, type P (3" only). This species is similar to *T. fenestrata* which is differentiated by its fenestrate perforations of the periphragm. *T. delicata* (Williams & Downie, 1966b) is differentiated by its smaller size, general absence of a short antapical horn, thin, hyaline endophragm and periphragm and raised parasutures.

STRATIGRAPHIC RECORD: Late Palaeocene to Early Eocene of Denmark (Heilmann-Clausen, 1985, 1988); Eocene of S England (Davey *et al.*, 1969); Early Eocene of Belgium (Morgenroth, 1966a) of S England (Eaton, 1976); Eocene to Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Lower Oligocene to Middle Miocene of Germany (Brosius, 1963)

Genus ***Tuberculodinium*** Wall, 1967 emend Wall & Dale, 1971

TYPE SPECIES: ***Tuberculodinium vancampoae*** (Rossignol, 1962; p. 134, pl. 2, fig. 1) Wall, 1967; p. 114-115.

GENERIC REMARKS: This genus describes medium to large sized oblate to subspherical cysts. The autophragm is ornamented with numerous intratabular tubercles which are pillar-like or barrel shaped and which support an enclosing ectophragm. This intratabular ornament is arranged in latitudinal rows and is absent in the paracingular area. Tabulation can be inferred as 5-8', 8-13", 6-13‴, 3-11⁗. The compound antapical archeopyle is a very distinctive feature of this genera.

Tuberculodinium vancampoae (Rossignol, 1962) Wall, 1967

Plate 47, Figure 2

REFERENCE: Manum *et al.*, 1989; pl. 20, fig.11 and Powell, 1992; pl. 4.10, fig. 11 are regarded as typical specimens.

COMMENTS: This describes a medium to large sized subspherical cyst. Numerous intratabular short wide pillar like, large tubercles ornament the autophragm and support an enclosing ectophragm (not visible on Plate 47, figure 2). The ornamentation varies in size over the cyst and is generally larger in apical areas. An antapical archeopyle is clear.

STRATIGRAPHIC RECORD: Late Oligocene to Holocene (Powell, 1992)

Chorate cysts

Genus ***Achilleodinium*** Eaton, 1976

TYPE SPECIES: ***Achilleodinium biformoides*** (Eisenack, 1954; p. 68, pl. 11, figs 16-20) Eaton, 1976; p. 234.

REMARKS: These are medium sized cysts. They are subspherical in shape. The endophragm and periphragm are adpressed between the processes. Two types of intratabular and penitabular processes occur. They are tubular, hollow processes which can be distally open or closed and of variable size. Slender processes occur at the paracingulum and parasulcal areas. Paratabulation is gonyaulacoid, 4', 6", 6c, 5"', 1p, 1"", 3-5s. The periphragm is smooth to finely granular and has no parasutural features. The archeopyle is precingular, type P (3" only) and the operculum is free. This genus is differentiated from *Hystrichokolpoma* (Klumpp, 1953 emend Williams & Downie, 1966a) which also has two different process types but is distinguished by the presence of an apical archeopyle rather than a precingular archeopyle.

Achilleodinium biformoides (Eisenack, 1954) Eaton, 1976

Plate 47, Figure 3

REFERENCE: Eaton, 1976; p. 235, pl. 1, figs 1-6, text fig. 4 are regarded as typical specimens.

COMMENTS: Only one specimen of this species was encountered in this study, from the North Sea section, 16/16b-4. It is medium in size and subspherical in shape. The periphragm is smooth to finely granulate. The processes are intratabular and vary in size and shape, while showing a characteristic striated and fibrous appearance with the larger processes showing longitudinal folds. The apical processes are relatively narrow and open distally. The precingular and postcingular processes are large with a broad cross section and are distally expanded and

closed. The antapical processes are as above but generally longer. The paracingular and parasulcal processes are slender, hollow and open distally.

STRATIGRAPHIC RECORD: Lower Eocene of Belgium and Germany (Morgenroth, 1966a); Middle Eocene of France (Gruas-Cavagnetto, 1971); Upper Eocene of Belgium (Rozen, 1965) and of Prussia (Eisenack, 1954, 1965); Lower Eocene to Early Oligocene of Prussia (Eisenack, 1954); Middle to Upper Oligocene of N Germany (Benedek, 1972)

Genus ***Adnatosphaeridium*** Williams & Downie, 1966c

TYPE SPECIES: ***Adnatosphaeridium vittatum*** Williams & Downie, 1966c; p. 215, pl. 24, figs 3, 7, text fig. 56.

REMARKS: These are medium sized skolochorate subspherical gonyaulacoid cysts. The intratabular processes are solid or hollow and tubular to funnel form. The adjacent processes are connected by a distal ribbon like, sometimes fenestrate, trabeculae which is very distinct. The archeopyle is apical, tA and free. *Glaphyrocysta* (Stover & Evitt, 1978) is similar to the genus in question but is differentiated by its lenticular body and process free middorsal area.

Adnatosphaeridium vittatum Williams & Downie, 1966c

Plate 47, Figure 4

REFERENCE: Williams & Downie, 1966c; p. 215, pl. 24, figs 3, 7 and Eaton, 1976; p. 238, pl. 2, fig. 1 are regarded as typical specimens.

COMMENTS: This species was very rare in this study. With only a single specimen being recorded from the North Sea well, 16/16b-4. It is small in size and the central body is elliptical with a thin granular wall. The processes are the characteristic feature of this species. They show variation in breadth and can be very broad. Generally they are hollow and expanded distally. In

shape the processes are taeniate and occur in linear, soleate or annulate complexes. The processes can be free or united, if distally united they are interconnected by trabeculae which can be broad and membranous. Sometimes the outer margins of the branches are finely serrate. This serration feature can give this species a similar appearance to *Areosphaeridium arcuatum* (Eaton, 1971) but it is easily distinguished by the broad processes and membranous trabeculae seen on closer examination.

STRATIGRAPHIC RECORD: Early Eocene of S England (Williams & Downie, 1966c); Early to Late Eocene of S England (Eaton, 1976)

Genus ***Aiora*** Cookson & Eisenack, 1960
Wilson & Clowes, 1980 Stover & Evitt, 1978

TYPE SPECIES: ***Aiora fenestrata*** (Deflandre & Cookson, 1955; p. 283, pl. 3, fig. 2, text fig. 43) Cookson & Eisenack, 1960, p. 9.

REMARKS: This genus describes elliptical cysts, with a smooth central body from which a number of solid processes are developed. These processes are connected distally to form a thin membrane. The type species was originally assigned to *Cannosphaeropsis fenestrata* (Deflandre & Cookson, 1955) but is now differentiated from *Cannosphaeropsis* due to the localised points of the trabeculae that are thin, strongly flattened and perforated by rounded openings of variable size. Only one specimen of this genus was recorded in this study therefore specimens encountered are noted as *Aiora* spp.

Plate 47, Figure 5

Genus ***Areoligera*** Lejeune-Carpentier, 1938 emend Williams & Downie, 1966c

TYPE SPECIES: ***Areoligera senonensis*** Lejeune-Carpentier, 1938; p. 164-166, text figs 1-3.

REMARKS: These are very distinctive lenticular cysts with a circular to bilobed central body. They are medium to large in size and skolochorate. The cyst is composed of an autophragm only which is smooth to faintly ornamented. Penitabular processes occur as groups forming arcuate or linear complexes, one per paraplate in the apical, precingular, postcingular and antapical series. The 1"" plate is characterised by an annular complex and the cingulum is ornamented with reduced linear complexes The tips of adjacent process groups can be connected by trabeculae. Characteristically the mid-dorsal and mid-ventral areas of the cysts are free of processes or the processes are reduced. The reflected paratabulation is 4', 6", 2-4c, 5"', 1p, 1"". The archeopyle is apical and free, with a zig zag principle archeopyle suture. An offset sulcal notch is also apparent on the ventral surface. This genus is differentiated from *Systematophora* (Klement, 1960) which has normal mid-dorsal and midventral processes and its overall shape is subspherical rather than the reduced ornamentation on the middorsal and midventral areas and the lenticular cyst shape of *Areoligera*. Also *Glaphyrocysta* (Stover & Evitt, 1978) is differentiated by its intricate network of distal trabeculae, with few adjacent complexes being joined.

Areoligera medussettiformis (O. Wetzel, 1933a) Lejeune-Carpentier, 1938

Plate 47, Figure 6

REFERENCE: Williams & Downie, 1966c; pl. 25, fig. 4 and Eaton, 1976; pl. 3, figs 3 and 7 are regarded as typical specimens.

COMMENTS: This species was rare, only recorded from one of the North Sea wells studied, 21/28b-7, generally as single specimens or in relatively low numbers. They are medium sized lenticular gonyaulacoid cysts which are circular to bilobed in shape. The processes are intratabular and occur in arcuate to linear complexes. They occur as slender processes which distally show fenestrate trabeculae and simple distal spines, giving this cyst a general 'scruffy' appearance. The archeopyle is apical,

tA and free, and has a zig zag margin. A sulcal notch is visible on the ventral surface and is offset. This species is differentiated from *A. semicirculata* (Morgenroth, 1966b) Stover & Evitt, 1978 by having fine processes with only a fi distal trabeculae that are also fenestrate rather than the varying process breadth and more numerous trabeculae between the adjacent process complexes of *A. semicirculata*.

STRATIGRAPHIC RECORD: Upper Cretaceous of N Germany (Wetzel, 1933a) of Belgium (Lejeune-Carpentier, 1938); Lower Palaeocene of Denmark (Morgenroth, 1968); Middle Eocene of France (Gruas Cavagnetto, 1971); Eocene of S England (Williams & Downie, 1966c)

Areoligera semicirculata (Morgenroth, 1966b) Stover & Evitt, 1978

Plate 48, Figures 1 to 6

REFERENCE: Morgenroth, 1966b; pl. 2, figs 3-4 and Brinkhuis, 1994; pl. 1, figs 4-7 are regarded as typical specimens.

COMMENTS: In this study this species was found to be significant in some assemblages and had a maximum occurrence of 27.8% in 16/16b-4. This species describes lenticular cysts which are circular to bilobed in shape and medium to large in size. The central body is smooth to faintly ornamented and is covered with penitabular process groups that are connected by a proximal membrane. The processes are arranged in arcuate, soleate and linear complexes, one per plate. These processes can be connected by distal trabeculae to varing extents. The specimens encountered in this study showed great variation of process character. They vary from process groups which are joined by membranes proximally and distally or are deeply incised to form seperate spines distally with acumate, T-shaped or sometimes joined tips.

STRATIGRAPHIC RECORD: Middle Oligocene of Germany (Morgenroth, 1966b); Middle to Late Oligocene of Italy (Brinkhuis, 1994)

Genus ***Areosphaeridium*** Eaton, 1971

TYPE SPECIES: ***Areosphaeridium diktyoplokus*** (Klumpp, 1953; p. 392, pl. 18, figs 3-7) Eaton, 1971; p.358-359.

REMARKS: This genus describes skolochorate gonyaulacoid cysts in which the central body is subspherical to lenticular in shape and is intermediate in size. Generally, 17 to 24 solid intratabular processes occur. These have characteristic distal terminations which range from platform like to perforate or arcuate to denticulate. The archeopyle is apical, type tA and has a zig zag principle archeopyle suture. This genus is differentiated from *Hystrichosphaeridium* (Deflandre, 1937) and *Oligosphaeridium* (Davey & Williams, 1966b) which have tabular, non fibrous and hollow processes unlike the solid processes of *Areosphaeridium*. *Cordosphaeridium* (Eisenack 1963b emend Morgenroth, 1968) has fibrous processes that are less distally complex than *Areosphaeridium* with a precingular archeopyle and paracingular processes. *Cyclonephelium* (Deflandre & Cookson, 1955 emend Williams & Downie, 1966c) generally has more than one process per paraplate and these processes are frequently distally united.

Areosphaeridium arcuatum Eaton, 1971

Plate 49, Figure 1

REFERENCE: Eaton, 1971; p. 360, pl. 3, figs 1-9 and Bujak *et al.*, 1980; pl. 2 fig. 6 are regarded as typical specimens.

COMMENTS: These are relatively small sized cysts. The central body is subcircular, finely granulated in ornamentation and is frequently dorsoventrally flattened with the antapex typically offset to the right of the mid-ventral line. The processes are intratabular, solid and fibrous each is distally expanded and bifurcate. The bifurcations vary from patulate to recurved. The majority of the processes are slender with a denticulate distal margin but

occasional broad processes with a fenestrate irregular distal margin have been seen. One process per paraplate is usual with no paracingular processes occurring leaving the cyst with a characteristic 'bald' equatorial ring. *A. arcuatum* differs fr[om] *A. diktyoplokus* whose processes are all in the form of fenestrate platform like distal margins rather than bifurcate and denticulate distal margins. It differs from *A. multicornutum* (Eaton, 1971) which has paracingular processes but no processes on the 6" and 6"' paraplates.

STRATIGRAPHIC RECORD: Middle to Upper Eocene of S England (Eaton, 1971, 1976); Eocene to Oligocene of France (Chateauneuf, 1980); Late Eocene to Early Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Middle Oligocene of Germany (Gerlach, 1961)

Areosphaeridium? actinocoronatum (Benedek, 1972) Stover & Evitt, 1978

Plate 49, Figures 2 to 4

REFERENCE: Benedek, 1972; p. 34, pl. 12, fig. 13 and Manum *et al.*, 1989; pl. 3, fig. 2 are regarded as typical specimens.

COMMENTS: This species was tentatively assigned to *Areosphaeridium* by Stover & Evitt (1978) despite the lack of knowledge of the archeopyle character of this species. This species describes a small sized cyst which is ornamented with numerous solid processes. These processes display a very distinctive distal termination of flaring fenestrate platforms, which appear very irregular and almost seem to form an entire mesh over the processes.

STRATIGRAPHIC RECORD: Middle to Late Oligocene of Germany (Benedek, 1972); Middle Oligocene to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Areosphaeridium dktyoplokus (Klumpp, 1953) Eaton, 1971

Plate 49, Figure 5

REFERENCE: Eaton, 1976; pl. 6, fig.2, Bujak, 1984; pl. 1, fig. 1 and Manum *et al.*, 1989; pl. 3, fig 3 are regarded as typical specimens.

COMMENTS: This species describes a circular to subcircular gonyaulacoid cyst with 15 to 20 intratabular solid fibrous processes occurring. The characteristic feature of this species is the distinctive process terminations which distally form a broad net-like perforate platform which is circular to polygonal in shape and has an irregular to entire margin. These process endings make this species easily distinguishable from all others. Only single specimens of this species was seen to occur in this study.

STRATIGRAPHIC RECORD: Eocene of the Norwegian Sea (Manum *et al.*, 1989) of Belgium (De Coninck, 1972) of Germany (Morgenroth, 1966a) and S England (Eaton, 1971); Oligocene of Germany (Maier, 1959).

Genus ***Callaiosphaeridium*** Davey & Williams, 1966a

TYPE SPECIES: ***Callaiosphaeridium asymmetricum*** (Deflandre and Courteville, 1939; p. 100, pl. 4, figs 1-2) Davey & Williams, 1966b; p. 104.

REMARKS: This genus describes intermediate to large sized skolochorate subspherical cysts. Two types of processes occur. Firstly the paracingular processes which are intratabular, tubular and tunnel shaped. Secondly slender but solid gonal processes which have furcate tips. Characteristical parasutural ridges over the wall extend between the gonal processes. The lack of an anatpical process is a distinctive feature of this genus. The archeopyle is a combination epicystal type, tAtP. This genus differs from *Spiniferites* (Mantell, 1850 emend Sarjeant, 1970) in having paracingular intratabular processes and an epicystal archeopyle. Only rare single specimens of this genus were encountered in the North Sea section, 16/16b-4, in this study. Due to the low numbers encountered indentification to species level would not be accurate therefore all specimens of this genus are referred to as *Callaiosphaeridium* spp. Although

this genus is documented as a Late Cretaceous genus (Wilson & Clowes, 1980) it is suggested here that the specimens recorded are in situ due to there good preservations and lack of other reworking of that age.

Plate 49, Figure 6 & 7

Genus ***Cannosphaeropsis*** (O. Wetzel, 1933b)
emend Williams & Downie, 1966c

TYPE SPECIES: ***Cannosphaeropsis utinensis*** O. Wetzel, 1933b; p. 6, pl. 3, figs 9-17, text fig. 12.

REMARKS: These are very distinctive skolochorate cysts. They are medium sized. The central body is surrounded by a network of trabeculae nearly concentric to the central body. This network of single parasutural trabeculae is supported by a varying number of gonal processes. Triradiate accessory branches of the trabeculae can be present at the gonal positions. Paratabulation is gonyaulacacean but it is difficult to determine due to the distortion of the parasutural trabeculae and varying number of processes. The archeopyle is precingular (3" only). This genus is differentiated from *Nematosphaeropsis* (Deflandre & Cookson, 1955) emend Williams & Downie, 1966c which has a double trabeculae i.e. two trabeculae connecting adjacent processes.

Cannosphaeropsis utinensis O.Wetzel, 1933b

Plate 50, Figure 1

REFERENCE: Manum *et al.*, 1989; pl. 4, fig. 5 is regarded as a typical specimen.

COMMENTS: This species is characterised by a subspherical central body from which a number of processes extend, branch and join together forming a loose external network. Short branches are developed near some of the points of branching.

STRATIGRAPHIC RECORD: Upper Cretaceous of the Baltic (Wetzel, 1933b); Middle Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Chiropteridium*** Gocht, 1960

TYPE SPECIES: ***Chiropteridium lobospinosum*** (Gocht & Weiler, 1956; p. 138, pl. 12, figs 1-3) Gocht, 1960; p. 222.

REMARKS: These are medium to large sized, very distinctive skolochorate cysts. The body is lenticular in shape with two distinctive antapical lobes but the outline of the cysts is irregular due to the 'wingy' processes. The periphragm is smooth to faintly ornamented. The processes are isolated or connected proximally and are predominant on the margins of the dorsal and ventral surfaces. They are absent or reduced on the midventral surfaces. The archeopyle is apical tA and the principle archeopyle suture is zig zag. The parasutural notch is offset. Paratabulation is poorly indicated by the archeopyle and occasional alignment of processes, the paratabulation formula is unknown. This genus is differentiated from *Membranophoridium* (Gerlach, 1961) which has processes that are both proximally and distally connected and give an even, smooth edge to the cyst compared to the proximally connected processes of *Chiropteridium* which give a jagged, incised and irregular cyst outline. Also in *Membranophoridium* no isolated processes are present unlike *Chiropteridium*. Although in both genera a lenticular body and concentration of processes in a marginal area is characteristic.

Chiropteridium lobospinosum (Gocht & Weiler, 1956) Gocht, 1960

Plate 50, Figures 2 & 3

REFERENCE: Gocht, 1960; p. 222-227, pl. 17, figs 1-16, pl. 18, figs 17-18 and Brosius, 1963; p.48, pl. 1, fig. 2 are regarded as typical specimens.

COMMENTS: This species describes dorsoventrally flattened, bilobed cysts. The periphragm and endophragm are adpressed in the middorsal and midventral areas, with the periphragm being separated in the marginal areas to form large 'wingy-like' processes. The distal margins vary, being deeply incised with their terminations being secate to acuminate. This species is differentiated form *C. mespilanium* (Maier, 1959) Lentin & Williams, 1973 which has no large 'wingy-like' processes, instead their processes are formed from the incision of the membranous margins with the rest of the membranous processes having a uniform ambitus relaively close to the body, rather than the large 'wingy' processes of *C. lobospinosum* in which the membranous processes vary in length and have large incised divisions between the processes.

STRATIGRAPHIC RECORD: Lower Oligocene of France (Chateauneuf, 1980); Early to Middle Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Middle Oligocene of Germany (Gocht, 1960); Middle to Upper Oligocene of Netherlands (Brosius, 1963); Oligocene to Miocene of the Bering Sea (Bujak, 1984)

Chiropteridium mespilanum (Maier, 1959) Lentin & Williams, 1973

Plate 51, Figures 1 & 2

REFERENCE: Gocht, 1960; pl. 18 figs 1-16 are regarded as typical specimens.

COMMENTS: These cysts are dorsoventrally flattened with two antapical protrusions characteristic. The endophragm possesses a faintly granular surface and the periphragm forms membranenous processes on the ventral and dorsal surfaces, of variable width. The distal margins vary from being entire to deeply incised and their terminations are digitate, secate or acumate. The processes are concentrated on the edge of the cyst and are sparse in the midventral and middorsal areas. The archeopyle is apical. In this species the membanous attatchment between the processes remains close to the central body of the cyst compared to the larger membranous prosesses of *C.*

lobospinosum and *C. partispinosum* (Gerlach, 1961) Brosius, 1963.

STRATIGRAPHIC RECORD: Lower Eocene to Middle Eocene of S England (Eaton, 1976); Middle Oligocene of Germany (Gocht, 1960); Late Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Oligocene to Lower Miocene of the Bering Sea (Bujak, 1984); Middle Oligocene to Middle Miocene of Spain (Maier, 1959)

Chiropteridium partispinatum (Gerlach, 1961) Brosius, 1963

Plate 51 Figure 3

REFERENCE: Gerlach, 1961; p. 201, pl. 29, figs 3, 6 and Brosius, 1963; p. 48, pl. 12, figs 3, 4 are regarded as typical specimens.

COMMENTS: These skolochorate cysts are lenticular in shape and are characterised by two distinct antapical lobes. The cyst outline is very irregular due to the processes. The processes are concentrated proximally on the marginal areas of the cyst. The processes are characteristic and occur as more interupted processes when compared with the large 'wingy' processes of *C. lobospinosum* and *C. mespilanum*. Long, often isolated processes occur with varing branched, acumate or secate terminations.

STRATIGRAPHIC RECORD: Lower Oligocene of France (Chateauneuf, 1980); Middle to Late Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Middle to Late Oligocene of Germany (Gerlach, 1961); Upper Oligocene of Netherlands (Brosius, 1963)

Genus ***Cleistosphaeridium*** Davey *et al.*, 1966

TYPE SPECIES: ***Cleistosphaeridium diversispinosum*** Davey *et al.*, 1966; p. 167, pl. 10, fig. 7.

REMARKS: This genus describes medium to large sized skolochorate cysts. They are subspherical in shape with the autophragm being

smooth to finely ornamented between the processes. The processes generally number less than 50, they are non tabular, closed distally and of similar size. The tips of the processes are acuminate, bifurcate or branched. The principle archeopyle suture is zig zag and the archeopyle is apical, tA. This genus is differentiated from *Operculodinium* (Wall, 1967) which has a precingular archeopyle rather than an apical archeopyle and from *Polysphaeridium* (Davey & Williams, 1966b) which possess processes which are generally open distally.

***Cleistosphaeridium* sp. 1** of Manum *et al.*, 1989

Plate 51, Figures 4 & 5

REFERENCE: Manum *et al.*, 1989; pl. 3, figs 10, 11 are regarded as typical specimens.

COMMENTS: A single specimen of this species was recorded in this study. It is medium in size and subspherical in shape. The cyst surface is smooth to faintly ornamented. Parallel sided short processes occur over the cyst, these are open distally and end with a flat entire margin which has very short fine bifurcations or secae at the tips. The archeopyle is apical. Overall the cyst is hyaline in character. This is similar to Miocene specimens from Denmark of *Cleistosphaeridium* cf. *ancoriferum* of Piasecki (1980).

STRATIGRAPHIC RECORD: Early to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Cordosphaeridium*** Eisenack, 1963b

TYPE SPECIES: ***Cordosphaeridium inodes*** (Klumpp, 1953; p. 391, pl. 18, figs 1-2) emend Morgenroth, 1968; p. 549-550.

REMARKS: These are skolochorate, gonyaulacoid cysts, which are subspherical in shape. The archeopyle is precingular (3" only) and is free. Generally 22 to 30 intratabular processes are present. The processes are fibrous, solid or hollow and

commonly occur as one process per plate. The periphragm between the processes is fine to coarsely ornamented and is commonly fibrous. The paratabulation as indicated from the archeopyle is 3-4', 6", 6c, 5-6‴, 0-1p, 1⁗, 0-3s, +?s. This geneus is distinguished from others by its distinctive fibrous processes and subcircular body.

Cordosphaeridium cantharellum (Brosius, 1963) Gocht, 1969

Plate 52, Figures 1 & 2

REFERENCE: Benedek, 1972; pl. 8, fig. 6 and Bujak *et al.*, 1980; pl. 13, fig. 5 are regarded as typical specimens.

COMMENTS: These are large fibrous walled cysts similar to *C. inodes*. They possess numerous fibrous, broad and long processes. The distal terminations of which are characteristically 'cauliflower-like', they are widely flared and undulose. In the specimens examined in this study the fibrous, trumpet shaped distal tips are often recurved, hanging downwards parallel to the process stalk or were often flared so widely, they appeared to distally join together adjacent processes. This is a very characteristic species due to its large size and large fibrous processes with the flared, undulose distal terminations. This species has been seen to be abundant within some of the North Sea assemblages and reaches a maximum abundance of 11.5% in well 21/28b-7 in this study. *C. cantharellum* along with *C. minimum* (Morgenroth, 1966a) Benedek, 1972 are the two most common species of *Cordosphaeridium* recorded in this study.

STRATIGRAPHIC RECORD: Middle Eocene of S England (Bujak *et al.*, 1980); Late Eocene to Lower Oligocene of France (Chateauneuf, 1980); Lower Oligocene of England (Liengjarern, 1973)

Cordosphaeridium fibrospinosum Davey & Williams, 1966b

Plate 52, Figure 3

REFERENCE: Davey & Williams, 1966b; p. 86, pl. 5, fig. 5 and Eaton, 1976; pl. 6, fig. 6 are regarded as typical specimens.

COMMENTS: This species is characterised by a fibrous periphragm and very broad but short fibrous processes which have perforate walls forming fine frills running over the surface. The processes are open distally, with entire or undulose margins which can be slightly expanded. The processes are arranged one per paraplate and the archeopyle is precingular (3" only), these features reflect the tabulation typical of this genus. Overall this species is medium to large in size.

STRATIGRAPHIC RECORD: Palaeocene to Upper Eocene of Germany (Gocht, 1969); Early Eocene of S England (Davey & Williams, 1966b); Middle Eocene of France (Gruas-Cavagnetto, 1971) Lower Oligocene of France (Chateauneuf, 1980); Middle to Upper Oligocene of Germany (Benedek, 1972)

Cordosphaeridium funiculatum Morgenroth, 1966a

Plate 52, Figures 4 to 7

REFERENCE: Bujak *et al.*, 1980; pl. 13, figs 16-17 and Brinkhuis, 1994; pl. 4, figs 1-3 are regarded as typical specimens.

COMMENTS: This species is intermediate in size and subspherical in shape. The periphragm is thick and forms a coarse reticulum or network of fibrous cords. The reticulum varies both in size (3-6μm in diameter; Liengjarern, 1973) and in shape from elongate to pentagonal in outline. The proximal ends of each process comprise of numerous oval areas which seem to be elongate towards the processes they are delimited by a reticulum or by fibrous cords. This reticulum runs together to form the solid processes of various lengths. The processes can be distally branched. The distinct reticulate ornamentation distinguishes this species from any other *Cordosphaeridium* species

STRATIGRAPHIC RECORD: Lower Eocene of NW Europe (Morgenroth, 1966b); Upper Eocene of Germany (Gocht, 1969); Upper Eocene of S England (Bujak *et al.*, 1980); Late Eocene to Lower Oligocene of France (Chateauneuf, 1980); Lower Oligocene of Prussia (Eisenack, 1954)

Cordosphaeridium minimum (Morgenroth, 1966a) Benedek, 1972

Plate 53, Figures 1 to 4

REFERENCE: Eaton, 1976; pl. 7, figs 1-3 are regarded as typical specimens.

COMMENTS: This is a small sized species of *Cordosphaeridium*. It is relatively thin walled with only a slightly ornamented to fibrous periphragm. The solid processes are fibrous, distally expanded and trumpet shaped. This species differs from *C. inodes minus* (Morgenroth, 1966b) by its smaller size, upto half the size. In this study the expanded distal tips of the processes often appeared to join or connect the adjacent processes together due to the width of the distal expansion. The small size of this species differentiates it from other *Cordosphaeridium* species. It is similar to *Hystrichosphaeridium latirictum* (Davey & Williams, 1966b) and *H. patulum* (Davey & Williams, 1966b) which are also small in size with expanded distal margins on their processes but they lack the fibrous central body and fibrous processes of *Cordosphaeridium minimum*. This species is less common than *Cordosphaeridium cantharellum* throughout the sections in this study and reaches a maximum frequency of 3.98% in 21/28b-7.

STRATIGRAPHIC RECORD: Lower Eocene of Germany (Morgenroth, 1966a); Late Eocene to Early Miocene of the Norwegian Sea (Manum *et al.*, 1989); Middle to Upper Oligocene of Germany (Benedek, 1972)

Genus ***Dapsilidinium*** Bujak, Downie, Eaton & Williams, 1980

TYPE SPECIES: ***Dapsilidinium pastielsii*** (Davey & Williams, 1966b; p. 92-93, pl. 4, fig. 10) Bujak *et al.*, 1980; p. 28.

REMARKS: This genus describes skolochorate gonyaulacoid cysts which are subspherical to oval in shape. The periphragm ornamentation ranges from smooth, chagrinate to granulate and is extended to form intratabular processes. More than one process per paraplate is common and they are of a uniform length. The processes are hollow, tubiform and open distally. The archeopyle is apical, tA and is the only indication of paratabulation. Species of *Dapsilidinium* are differentiated on the variability of process types. This genus is similar to *Diphyes* (Cookson, 1965 emend Davey & Williams, 1966b) but is differentiated by the absence of a prominent antapical process and from *Polysphaeridium* Davey & Williams, 1966b which has as epicystal archeopyle rather than an apical archeopyle.

Dapsilidinium pastielsii (Davey & Williams, 1966b) Bujak *et al.*, 1980

Plate 53, Figures 5 & 6

REFERENCE: Bujak *et al.*, 1980; pl. 6, figs 6 and 9 are regarded as typical specimens.

COMMENTS: The subspherical body is smooth to granular in ornamentation with a number of long tubular processes developed over it. These processes are flared proximally, then taper distally to a constriction before flaring slightly to a secate or serrate termination. The archeopyle is apical, tA with a zig zag suture. This species is differentiated from *D. simplex* (White, 1842) Bujak *et al.*, 1980 which has short parallel sided processes and from *D. pseudocolligerium* (Stover, 1977) Bujak *et al.*, 1980 which has shorter more gently tapering processes.

STRATIGRAPHIC RECORD: Early Eocene of S England (Davey & Williams, 1966b)

Dapsilidinium simplex (White, 1842) Bujak *et al.*, 1980

Plate 53, Figures 7 & 8

REFERENCE: Bujak *et al.*, 1980; pl. 14, figs 11-12 are regarded as typical specimens.

COMMENTS: These are smooth to faintly ornamented spherical cysts. The periphragm is extended into tubular parallel sided processes. These processes are short and do not taper throughout their length but do show a slight flaring at their distal termination. The archeopyle is apical, tA with a zig zag suture. For discussion see *D. pastielsii*.

STRATIGRAPHIC RECORD: Late Cretaceous of S England (White, 1842); Middle to Upper Eocene of S England (Bujak *et al.*, 1980)

Genus ***Diphyes*** Cookson, 1965 emend Davey & Williams, 1966b

TYPE SPECIES: ***Diphyes colligerum*** (Deflandre & Cookson, 1955) Cookson, 1965; p. 86-87, pl. 9, figs 1-12.

REMARKS: These are skolochorate cysts with a subspherical central body composed of two wall layers. This genus is small to medium in size. The archeopyle is apical. The processes are hollow, either open or closed distally and occur in numbers from 1 to 4 per paraplate. This genus is restricted to forms which possess two types of processes, numerous fine intratabular processes and one single large antapical process.

Diphyes colligerum (Deflandre & Cookson, 1955) Cookson, 1965

Plate 54, Figures 1 & 2

REFERENCE: Davey & Williams, 1966b; pl. 4, figs 2, 3 and Eaton, 1976; pl. 8, fig. 7 are regarded as typical specimens.

COMMENTS: This species is subspherical in shape. The periphragm shows a faint ornamentation and possesses a number of simple, tubular processes. These processes taper distally to a neck then flare slightly at their terminations to give an entire distal margin.

The processes are arranged, four on each precingular paraplate, two to four on each postcingular paraplate and two on the cingular paraplates. The large tubular antapical process is parallel sided and may be distally tapering or ragged and possibly secate. Although this species is very distinct due to the single large antapical process. It can be confused with *Dapsilidinium pseudocolligerum* (Stover, 1977) Bujak *et al.*, 1980 and *D. pastielsii* (Davey & Williams, 1966b) Bujak *et al.*, 1980 which have the same archeopyle structure and similar form of processes as *Diphyes colligerum* except for the large swollen antapical process. Low numbers to single specimens of this species were recorded from the two North Sea well sections in this study.

STRATIGRAPHIC RECORD: Widely recorded from the Late Palaeocene to Late Oligocene. Eocene to Oligocene of S England (Liengjarern, 1973); Late Eocene to Late Oligocene of N Italy (Brinkhuis, 1994)

Genus ***Distatodinium*** Eaton, 1976

TYPE SPECIES: ***Distatodinium craterium*** Eaton, 1976; p. 263-264, pl. 9, figs 1-5.

REMARKS: This genus describes medium to large elongate, ellipsoidal cysts. They are skolochorate with an apical archeopyle which shows a zig zag principle archeopyle suture. The processes are simple or branched, blade-like in cross section and vary in number from few to many. The processes are characteristically expanded distally and have multiple bifurcations with adjacent processes occasionally connected by trabeculae. The paracingular area is generally process free. Eaton (1976) suggested parasutural positions for the processes except for species such as *D. ellipticum* (Cookson, 1965) Eaton, 1976 where the processes are not sutural as they have been seen to occur in arcuate complexes. This genera is similar to the elliptical genera of *Tanyosphaeridium* (Davey & Williams, 1966b) except that the processes are distally less complex and are intratabular.

Distatodinium craterium Eaton, 1976

Plate 54, Figure 3

REFERENCE: Eaton, 1976; pl. 9, figs 1-5 and Bujak *et al.*, 1980; pl. 2, figs 10-11 are regarded as typical specimens.

COMMENTS: This species is elongate to oval in outline. The periphragm is smooth to finely granular. The processes are parasutural in arrangement. The number of processes varies from 13 to 17, they are simple or branched and flattened to blade-like. The processes are characteristically broad and both proximally and especially distally expanded. Distally the expanded trumpet shaped processes have very complex terminations as bifurcations and trifurcations plus complex secondary branchlets giving a 'twig-like' appearance. One process per plate is usual although the paracingulum is free of processes and the antapical plate has two processes developed on it. Adjacent processes within the separate tabulation zones may be proximally connected. See *D. ellipticum* for comparisons.

STRATIGRAPHIC RECORD: Middle to Late Eocene of S England (Bujak *et al.*, 1980); Middle Eocene to Early Miocene of the Norwegian Sea (Manum *et al.*, 1989); Upper Eocene of S England (Eaton, 1976); Late Eocene to Late Oligocene of N Italy (Brinkhuis, 1994); Middle Oligocene of Switzerland (Scherer, 1961)

Distatodinium ellipticum (Cookson, 1965) Eaton, 1976

Plate 54, Figures 4 & 5

REFERENCE: Eaton, 1976; pl. 9, figs 7-9 are regarded as typical specimens.

COMMENTS: In this species the cysts are oval to elongate in shape. The ornamentation varies from smooth to finely granulate. The number of processes varies from 40 to 60, they are simple or branched and flattened to blade-like. These solid processes vary in breadth and are expanded both proximally and distally with complex terminations as bifurcations and trifurcations

with complex secondary branchlets giving the characteristic 'twig-like' appearance. The processes occur over all the cyst zones and tend to be concentrated at the apex and antapex. This species differs from *Distatodinium craterium* which has fewer processes, which are broader and stronger. Also the paracingulum is free of processes and the overall shape of *D. craterium* is less elongated than *D. ellipitcum.*

STRATIGRAPHIC RECORD: Upper Eocene of Australia (Cookson, 1965); Upper Eocene of S England (Eaton, 1976); Eocene to Late Oligocene of Italy (Brinkhuis, 1994); Early Oligocene of the Norwegian Sea (Manum *et al.*, 1989); Middle to Upper Oligocene of Germany (Benedek, 1972)

Distatodinium paradoxum (Brosius, 1963) Eaton, 1976

Plate 55, Figures 1 & 2

REFERENCE: Eaton, 1976; pl. 9, fig.6 and Chateauneuf, 1980; pl. 22, fig.3 are regarded as typical specimens.

COMMENTS: These are oval to elonagte gonyaulacoid cysts. The surface is smooth to faintly granular. About 20 processes occur over the cyst. These processes are slender, simple or branched and are flattened to blade like in cross section. They are both proximally and distally expanded with the distal tips showing bifurcations and trifurcations with complex and irregular secondary branchlets at their tips. The distribution of the processes around the cyst body is as aligned rings except for the paracingular areas which are devoid of processes. The archeopyle is apical. The characteristic feature of this species is the appearance of the processes which are concentrated in the precingular, postcingular and antapical plate series, as clusters of processes at opposite ends of the oval cyst. This dsitribution of processes lead to this species, in the past, being assigned to *Bipolaribucina* (Jiabo, 1975 ex Lentin & Williams, 1981 which is now regarded as a junior synonym of *Distatodinium* according to Chen *et al.* (1988).

STRATIGRAPHIC RECORD: Upper Eocene of S England (Eaton, 1976; Bujak *et al.*, 1980); Late Eocene to Early Oligocene of France (Chateauneuf, 1980); Middle Oligocene to Middle Miocene of the Norwegian Sea (Manum *et al.*, 1989); Late Oligocene of Germany (Brosius, 1963); Oligocene of Italy (Brinkhuis, 1994)

Genus ***Homotryblium*** Davey & Williams, 1966b

TYPE SPECIES: ***Homotryblium tenuispinosum*** Davey & Williams, 1966b; p. 100-101, pl. 4, fig. 11, pl. 12, fig. 1, 5, 7, text fig. 21.

REMARKS: This genus describes skolochorate gonyaulacoid cysts. The periphragm between the processes is smooth to granular and is thin. About 25 plate centred processes are present. They are all hollow, tubular and open distally. Species are differentiated on the morphology of the processes. The combination archeopyle is type A+3A+6p. This genus is represented throughout both of the North Sea sections in this study.

Homotryblium floripes Deflandre & Cookson, 1955 (Stover, 1975)

Plate 55, Figures 3 to 5

REFERENCE: Deflandre & Cookson, 1955; p. 276, pl. 7, figs 1, 2 and 7 are regarded as typical specimens.

COMMENTS: This species describes medium sized skolochorate cysts which are subspherical in shape. The wall layers are thin, often giving the cyst a faint overall appearance. About 25 intratabular, plate centred processes occur over the smooth cyst body. These processes are composed of what appears to be 2 or more hollow tubes arranged into cylindrical groups, this gives a rosette outline at the proximal ends of the processes. Distally the tubular hollow processes are branched and widened. The processes separate distally to give a digitate distal margin. The characteristics of the processes make this species similar to *H. vallum* (Stover, 1977) which is easily differentiated as its processes are much shorter. This species occurs within

assemblages from both the North Sea sections studied, generally in abundances up to 10-13% but with a maximum frequency of 34.5% in 16/16b-4 where it forms a dominant part of one particular assemblage.

STRATIGRAPHIC RECORD: Lower Tertiary of Denmark (Deflandre & Cookson, 1955); Middle to Late Eocene of Italy (Brinkhuis, 1994); Late Oligocene to Early Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Homotryblium oceanicum Eaton, 1976

Plate 55, Figure 6

REFERENCE: Eaton, 1976; p. 268, pl. 10, figs 5-8 are regarded as typical specimens.

COMMENTS: These are subspherical to spherical, medium sized skolochorate cysts. The periphragm has a granular ornamentation and is extended into 25 plate centred long, broad cylindrical processes. These processes are of a constant width and show little distal expansion. The distal margin is denticulate, secate or aculeate and the proximal margin has a circular outline. The archeopyle is a combination type. This species is differentiated from *H. tenuispinosum* (Davey & Williams, 1966b) which has shorter narrower processes.

STRATIGRAPHIC RECORD: Middle to Upper Eocene of S England (Eaton, 1976)

Homotryblium tenuispinosum Davey & Williams, 1966b

Plate 56, Figure 1

REFERENCE: Davey & Williams, 1966b; p. 101, pl. 4, fig. 11, pl. 12, figs 1, 5, 7, text fig. 21 are regarded as typical specimens.

COMMENTS: These are medium sized skolochorate cysts. The central body is spherical and is composed of two thin layers. The endophragm is smooth and the periphragm is granular. Up to

25 plate centred processes occur over the periphragm and indicate a gonyaulacoid paratabulation, 3', 6", 6c, 5"', 1p, 1"", 1-5s. The processes are very distinctive simple, hollow and tubiform. They are open distally with aculeate or secate margins which are often recurved. The processes can be of variable width and are restricted to one per paraplate with the paracingular and parasulcal processes being more slender. The proximal ends of the processes show a circular outline at their junction with the central body. The combination archeopyle is type 1-3A and 1-6P. This species differs from *H. pallidum* (Davey & Williams, 1966b) which has thinner, less ornamented walls and broader processes with more variable distal margins, and from *H. oceanicum* which is characterised by its larger, broader processes. *H. tenuispinosum* occurs throughout both of the North Sea sections in this study and has a maximum occurrence of 11.9% in 21/28b-7.

STRATIGRAPHIC RECORD: Early to Late Eocene of S England (Davey & Williams, 1966b; Eaton, 1976; Bujak *et al.*, 1980); Middle Eocene to Oligocene of the East Shetland Platform (Condon *et al.*, 1992)

Homotryblium vallum Stover, 1977

Plate 56, Figure 2

REFERENCE: Stover, 1977; p. 79-80, pl. 3, figs 45-53 are regarded as typical specimens.

COMMENTS: This is a medium sized skolochorate cyst. The endophragm and periphragm are adpressed between the processes and the ornamentation of the periphragm is smooth to granular. Upto 25 intratabular processes occur over the cyst, one per paraplate. These processes are very distinctive, they are short and composed of 2 or more slender tubes arranged in cylindrical groups. These processes have a rosette outline at their proximal ends against the central body. The distal ends are branched, digitate and slightly expanded. The paracingular processes are often taeniate. This species is transitional with *H. plectilum* (Drugg & Leoblich, 1967) but can be

distinguished by its taeniate processes, it is also differentiated from *H. floripes* which is similar but with larger processes and a smoother periphragm.

STRATIGRAPHIC RECORD: Early Oligocene to Early Miocene (Stover, 1977); Late Oligocene of N Italy (Brinkhuis, 1994); Early to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Hystrichokolpoma*** Klumpp, 1953 emend Williams & Downie, 1966b

TYPE SPECIES: ***Hystrichokolpoma cinctum*** Klumpp, 1953; p. 389, pl. 17, figs 3-5.

REMARKS: This genus describes medium to large sized skolochorate cysts. They are subspherical in shape with the endophragm and periphragm being adpressed between the processes. The archeopyle is apical, tA, with a smooth principle archeopyle suture. Two types of intratabular hollow processes characterise this genus. Firstly large processes with an expanded base which can be constricted distally but are always open. Proximally these large processes are quadrate in cross section and reflect the paraplate outline. Secondly slender hollow processes occur, these delimit the paracingular and parasulcal areas. The paratabulation is gonyaulacoid and the formula is 4', 6", 6-12c, 5-6‴, 1p, 1⁗, 2-5s, and is indicated from the processes and archeopyle.

Hystrichokolpoma cinctum Klumpp, 1953

Plate 56, Figure 5

REFERENCE: Eaton, 1976; pl. 10, fig. 9 is regarded as a typical specimen.

COMMENTS: These are subspherical cysts with the endophragm and periphragm adpressed between the processes. Two types of processes are characteristic of this genus. Large intratabular processes occur on the apical, precingular, postcingular and antapical plates with the antapical process being much larger.

These hollow processes are wide proximally and follow the plate boundaries but they taper distally towards a narrower opening. Thinner, elongate, tubular processes occur on the paracingulum, these flare proximally. This species is synonymous with *H. eisenacki* (Williams & Downie, 1966b).

STRATIGRAPHIC RECORD: Early Eocene of Belgium (De Coninck, 1971) of France (Graus-Cavagnetto, 1970a) of S England (Williams & Downie, 1966b); Early to Upper Eocene of S England (Eaton, 1976; Bujak *et al.*, 1980); Early Eocene to Middle Oligocene of N Germany (Gocht, 1969); Middle Eocene to Late Oligocene of Italy (Brinkhuis, 1994); Upper Eocene of Prussia (Eisenack, 1954); Lower Oligocene of France (Chateauneuf, 1980); Early Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Hystrichokolpoma rigaudiae Deflandre & Cookson, 1955

Plate 56, Figures 3 & 4

REFERENCE: Eaton, 1976, pl. 10, fig. 10 is regarded as a typical specimen.

COMMENTS: This describes subspherical medium to large sized cysts. The processes are the distinguishing feature of this species. Two types of plate centred processes occur. The paracingular processes are hollow, tubular and parallel sided. The precingular and postcingular processes are flared at both their proximal and distal terminations, with a constriction midway along their length. The distal margins of these larger processes are irregular, although the proximal process endings follow the plate boundaries. The presence of a very large broad process at the antapex is very characteristic. This process is constricted midway along its length, then flares distally before constricting to terminate in an open pointed tip. A number of thorny to tuberculae type protrusions occur distally on this antapical process. The archeopyle is apical, type tA. This species is easily distinguished from *H. cinctum* by the flared large processes and the thorn like projections on the large antapical process.

STRATIGRAPHIC RECORD: Palaeocene of S England (Gruas-Cavagnetto, 1970a); Early Eocene of Belgium (De Coninck, 1965, 1967, 1976) of France (Gruas-Cavagnetto, 1968, 1970a) of Germany (Morgenroth, 1966a); Early to Middle Eocene of S England (Eaton, 1976); Middle Eocene to Late Oligocene of Italy (Brinkhuis, 1994); Upper Eocene of S England (Liengjarern *et al.*, 1980); Upper Eocene to Lower Oligocene of France (Chateauneuf, 1980); Oligocene of France (Chateauneuf, 1980) of Germany (Gerlach, 1961) of the North Sea (Manum, 1976); Middle to Upper Oligocene of Germany (Benedek, 1972); Late Oligocene to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989); Miocene of Germany (Gerlach, 1961)

Genus ***Hystrichosphaeridium*** Deflandre, 1937 emend Davey & Williams, 1966b

TYPE SPECIES: ***Hystrichosphaeridium tubiferum*** (Ehrenberg, 1838; pl. 1, fig. 16) Deflandre, 1937; p. 68 emend Davey & Williams, 1966a; p. 56-58.

REMARKS: This genus describes small to large sized skolochorate cysts. They are subspherical in shape and possess 25 to 30, hollow, cylindrical, intratabular processes. These processes are open and expanded distally and are of a similar shape. The presence of six paracingular processes is characteristic of this genus distinguishing it from *Oligosphaeridium* (Davey & Williams, 1966b emend Davey, 1982). The tabulation is gonyaulacoid, 0-1pr, 4', 6", 6c, 5-6‴, 1p, 1⁗, 2-5s, as indicated from the processes and archeopyle. The archeopyle is apical, tA and the principle archeopyle suture is zig zag. This genus is differentiated from *Areosphaeridium* which has solid processes, from *Cordosphaeridium* which has fibrous processes, from *Homotryblium* which has a combination archeopyle and from *Hystrichokolpoma* which has processes of two different sizes.

Hystrichosphaeridium latirictum Davey & Williams, 1966b

Plate 56, Figure 6

REFERENCE: Davey & Williams, 1966b; pl. 10, fig. 8 and Bujak *et al.*, 1980; pl. 8, figs 4-5 are regarded as typical specimens.

COMMENTS: Small in size, this species is elliptical in shape. The periphragm is smooth to faintly granular. The archeopyle is apical, type tA. The intratabular processes are tubiform and slender. The processes are characteristically widely expanded or flared distally and are open. Variations along the distal margin occur from circular to oval, serate and undulate to aculeate. Smaller processes which are shorter and closed distally occur on the parasulcal plates.

STRATIGRAPHIC RECORD: Early Eocene of S England (Davey & Williams, 1966b); Late Oligocene to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Hystrichosphaeridium patulum Davey & Williams, 1966b

Plate 56, Figure 7

REFERENCE: Davey & Williams, 1966b; pl. 10, fig. 5 and Eaton, 1976; pl. 11, fig. 5 are regarded as typical specimens.

COMMENTS: These are small sized cysts. They are subspherical in shape and are thin walled with a smooth periphragm. This species is characterised by its small size and varying width of processes over the body. The broad to fine open processes are intratabular, tubiform and of a similar length. The processes are greatly expanded or flared distally. Distal ramifications can be strongly developed. This species is differentiated from *H. tubiferum* (Ehrenberg, 1838) Davey & Williams, 1966a which has longer and more slender processes but these two species are thought to be transitional.

STRATIGRAPHIC RECORD: Early Eocene of S England (Eaton, 1976; Davey & Williams, 1966b) of Belgium (De Coninck, 1968); Lower to Upper Eocene of S England (Eaton, 1976)

Genus ***Hystrichostrogylon*** Agelopoulos, 1964 emend Stover & Evitt, 1978

TYPE SPECIES: ***Hystrichostrogylon membraniphorum*** Agelopoulos, 1964; p. 674, text figs 1-2.

REMARKS: This is a very distinctive genus. The emendation of Stover & Evitt (1978) is accepted here as it gives clearer detail regarding archeopyle type and paratabulation. These are medium sized skolochorate cysts which are subspherical in shape. The endocyst and pericyst are closely adpressed over most of the cyst body. Elsewhere, especially in the hypocystal areas, the pericyst and endocyst are separated by a wide pericoel. The processes can be both gonal and intergonal. This along with the weak parasutural ridges defines a gonyaulacoid paratabulation, 3-4', 6",6c, 5-6‴, 0-1p, 1⁗. All the processes reach to a uniform ambitus, with those developed on the adpressed pericyst being longer than those on the pericoel. The archeopyle is precingular, type P (3" only).

Hystrichostrogylon membraniphorum Agelopoulos, 1964

Plate 57, Figures 1 & 2

REFERENCE: Eaton, 1976; pl. 1, figs 8-10 and Manum *et al.*, 1989; pl. 10, fig. 11 are regarded as typical specimens.

COMMENTS: This species was transferred to *Achomosphaera* (Evitt, 1963) by Eaton (1976) on evidence of a lack of parasutural septa, although this is not accepted here, because of the development of the pericoel. These are small to medium sized subspherical skolochorate cysts. Faint parasutural septa are developed over the periphragm and a pericoel over the ventral part of the cyst is very characteristic. The processes are gonal with trifurcate then bifurcate distal endings. The processes are shorter on the pericoel and longer on the adpressed body, so they reach a uniform ambitus. Both the parasutural septa and the gonal processes indicate the typical gonyaulacoid paratabulation. The archeopyle is precingular, type P (3" only). This species is

differentiated from *Spiniferites* (Mantell, 1850 emend Sarjeant, 1970 and *Achomosphaera* species by its smaller size and large but partial pericoel development.

STRATIGRAPHIC RECORD: Middle Eocene of S England (Eaton, 1976); Middle to Late Eocene of N Germany (Agelopoulos, 1964); Late Eocene of S England (Bujak *et al.*, 1980)

Hystrichostrogylon sp. **1** of Manum *et al.*, 1989

Plate 57, Figure 3

REFERENCE: Manum *et al.*, 1989; pl. 13, figs 11-13 are regarded as typical specimens.

COMMENTS: These are small to medium sized skolochorate cysts. This species is distinguished by a fenestrate periphragm from which the processes are developed. The processes are typically trifurcate then bifurcate at their distal terminations. In places the endocyst and pericyst are adpressed but elsewhere an often large pericoel is developed. The pericoel development is distinctive of this genus and the fenstrate nature of the periphragm is the characteristic feature of this species making it easy to differentiate from others.

STRATIGRAPHIC RECORD: Early to Middle Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Lingulodinium*** Wall, 1967 emend Wall *et al.*, 1973

TYPE SPECIES: ***Lingulodinium machaerophorum*** (Deflandre & Cookson, 1955) Wall, 1967; p. 109..

REMARKS: This genus describes skolochorate cysts which are subspherical in shape. The processes are very distinctive, they are non-tabular hollow and blade-like with circular proximal attachments to the cyst body and are closed distally. The archeopyle is epicystal and varies from simple, compound or

combination, P to 5P or AP (Stover & Evitt, 1978). The multiple archeopyle and blade-like processes that are closed distally distinguishing this genus from others. It is differentiated from the similar *Operculodinium* (Wall, 1967) by the presence of non-tabular processes and the different archeopyle type.

Lingulodinium machaerophorum (Deflandre & Cookson, 1955) Wall, 1967

Plate 57, Figures 4 to 6

REFERENCE: Eaton, 1976; pl. 8, fig. 10 is regarded as a typical specimen.

COMMENTS: These are medium to large sized cysts, the periphragm of which is granular and expanded in places to form non-tabular, hollow processes. In this study the cysts often appear thick walled and hyaline in character. The processes are generally circular to oval at their proximal junction with the cyst body. Distally the processes vary from being parallel sided to tapering, but with all of them tapering to a point distally. Processes do vary in type and length on each cyst. Harland (1983) described this species as being typical of esturine and low salinity environments. This species is easily distinguished from all others due to the hollow, non-tabular and blade-like processes.

STRATIGRAPHIC RECORD: Early Eocene of Belgium (De Coninck, 1968) of France (Gruas-Cavagnetto, 1968) of Germany (Morgenroth, 1966a); Early to Late Eocene of S England (Eaton, 1976; Gruas-Cavagnetto, 1970a); Middle to Upper Oligocene of Germany (Gerlach, 1961; Liengjarern *et al.*, 1980); Upper Oligocene of Germany (Benedek, 1972); Middle Miocene of Germany (Maier, 1959; Gerlach, 1961); Pliocene to Pleistocene of the North Sea (Harland, 1983)

Genus ***Melitasphaeridium*** Harland & Hill, 1979

TYPE SPECIES: ***Melitasphaeridium choanophorum*** (Deflandre & Cookson, 1955) Harland & Hill, 1979; p. 39-40.

REMARKS: This genus describes skolochorate gonyaulacoid cysts. They are subspherical in shape with a smooth to faintly ornamented periphragm. A number of intratabular processes are developed from the periphragm. These hollow processes have expanded distal tips with a smooth to denticulate margin. The paratabulation is indicated from the processes and the archeopyle, the formula is 0-1pr, 4', 6", 0-6c, 6‴, 1p, 1⁗. The archeopyle is precingular (3" only) and the operculum is free.

Melitasphaeridium asterium (Eaton, 1976) Bujak *et al.*, 1980

Plate 58, Figures 1 & 2

REFERENCE: Eaton, 1976; pl. 11, figs 7-8 and Bujak *et al.*, 1980; pl. 2, fig. 3 are regarded as typical specimens.

COMMENTS: These are small in size and subspherical to rounded in shape. The periphragm is smooth with a number of tubular slender processes developed over it. About 20 processes are present probably one per paraplate. They are characteristically expanded distally to form funnel shaped wide platforms from which a number of spines occur on the distal margin and these spines are typically recurved. Some processes can be slightly expanded proximally. The archeopyle is apical. This species is similar to *M. choanophorum* (Deflandre & Cookson, 1955) Harland & Hill, 1979 but is distinguished by the length of distal spines or process tips. Bujak *et al.* (1980) suggested that *M. pseudorecurvatum* (Morgenroth, 1966a) Bujak *et al.*, 1980, *M. asterium* and *M. choanophorum* (Deflandre & Cookson, 1955) Harland & Hill, 1979 formed a stratigraphical sequence of morphologies. This finding is disregarded here as specimens of these species are found to occur together in this study. This species was recorded from both of the North Sea sections.

STRATIGRAPHIC RECORD: Late Eocene of S England (Eaton, 1976)

Melitasphaeridium choanophorum (Deflandre & Cookson, 1955) Harland & Hill, 1979

Plate 58, Figure 3

REFERENCE: Manum *et al.*, 1989; pl. 12, fig. 11 is regarded as a typical specimen.

COMMENTS: These are small gonyaulacoid cysts. They are spherical to subspherical in shape. The periphragm is smooth to faintly ornamented with intratabular processes developed from it. The processes are parallel sided and hollow with slightly flared proximal bases. Distally they are expanded into funnel shaped endings which have short distal spines around their margins. The archeopyle is precingular (3" only) and the operculum is free. For discussion see *M. asterium*. This species was rare in this study, recorded from one of the North Sea sections, 16/16b-4, as single specimens only.

STRATIGRAPHIC RECORD: Middle to Late Oligocene of Germany (Benedek, 1972); Early to Middle Miocene of the Norwegian Sea (Manum, 1976; Manum *et al.*, 1989)

Melitasphaeridium pseudorecurvatum (Morgenroth, 1966a)
Bujak, Downie, Eaton & Williams, 1980

Plate 58, Figures 4 & 5

REFERENCE: Eaton, 1976; pl. 11, fig. 6 and Bujak *et al.*, 1980; pl. 2, figs 1-2 are regarded as typical specimens.

COMMENTS: This is a small sized cyst which is subspherical to spherical in shape. The periphragm is hyaline and develops into a number of processes, generally less than 60. The processes are intratabular, tubular and parallel sided. Distally they are expanded into a funnel or platform shaped tip on which narrow spines occur as terminations. The distal tips are recurved in this species. The archeopyle is precingular (3" only) and the operculum is free. This species was recorded from both of the North Sea sections and was the most common species of this genus encountered. It attained a maximum frequency of 3.7% in 16/16b-4.

STRATIGRAPHIC RECORD: Lower Eocene of Belgium (Morgenroth, 1966a; Gruas-Cavagnetto, 1968; De Coninck, 1968) of France (Gruas-Cavagnetto, 1970b) of Germany (Morgenroth, 1966a) of S England (Davey & Williams, 1966b); Middle Eocene of France (Gruas-Cavagnetto, 1971); Lower to Upper Eocene of S England (Eaton, 1976)

Genus ***Paucisphaeridium*** Bujak, Downie, Eaton & Williams, 1980

TYPE SPECIES: ***Paucisphaeridium inversibuccinum*** (Davey & Williams, 1966b; p. 82, pl. 12, fig. 3) Bujak *et al.*, 1980; p.32.

REMARKS: This genus describes spherical to subspherical chorate cysts. They are characteristically small in size. Processes in this genus are distinctly proximally expanded. they are hollow and are constricted towards their distal ends. Sulcal processes if present are slender. The archeopyle is apical.

Pausicsphaeridium cf. ***inversibuccinum***

Plate 58, Figures 6 & 7

COMMENTS: This describes small chorate cysts which are spherical to subspherical in shape. The processes are hollow and expanded proximally although are constricted distally. The specimens recorded differ from *P. inversibuccinum* sensu Bujak *et al.* (1980) as the distal ends are flat and not slightly flared with an aculeate or denticulate margin. Also the expansion at the proximal ends of the processes are not as marked in these specimens.

Genus ***Polysphaeridium*** Davey & Williams, 1966b

TYPE SPECIES: ***Polysphaeridium subtile*** Davey & Williams, 1966b; p. 92, pl. 11, fig. 1 emend Bujak *et al.*, 1980; p. 34.

REMARKS: These are skolochorate cysts which range from small to large in size. The cysts are subspherical in shape and are thin walled. The processes are of similar size and shape and occur over the cyst in an intratabular arrangement. The processes are typically parallel sided and expanded slightly at their distal terminations. The archeopyle was originally described as apical, but the work of Bujak *et al.* (1980) and Eaton (1976) has illustrated specimens demonstrating a combination archeopyle, A+3A+6P. The paratabulation is gonyaulacoid with a formula 4', 6", 6c, 5-6", 1p, 1"", x5 (Bujak *et al.*, 1980). This genus is differentiated from *Cleistosphaeridium* which has distally closed processes and *Diphyes* which has similar process types but also has a distinctive antapical process.

Polysphaeridium subtile Davey & Williams, 1966b
emend Bujak, Downie, Eaton & Williams, 1980

Plate 58, Figures 8 & 9

REFERENCE: Bujak *et al.*, 1980; pl. 3, figs 9, 12 are regarded as typical specimens.

COMMENTS: In this species the endophragm and periphragm are thin. The periphragm is ornamented with granulae. Intratabular processes occur extending from the periphragm they are hollow, parallel sided and open distally. The distal margins of the processes are expanded and have a serrate termination. The processes in the material from this study are shorter than those illustrated in the holotype of Davey & Williams (1966a; p. 72, pl. 11, fig. 1). This species is similar to *Diphyes colligerum* especially in processes form, but is distinguished by the presence of a large antapical horn in *D. colligerum*.

STRATIGRAPHIC RECORD: Lower Eocene of S England (Davey & Williams, 1966b; Gruas-Cavagnetto, 1970a); Lower to Upper Eocene of S England (Eaton, 1976); Middle Eocene of France (Chateauneuf, 1980)

Polysphaeridium cf. ***subtile***

Plate 58, Figure 10

COMMENTS: These specimens were recorded from one of the North Sea sections, 16/16b-7. This species was distinguished from *P. subtile* by its process size. The periphragm is faintly granular and extends to form numerous intratabular processes. These are hollow parallel sided and open. Distally they are slightly expanded with serrate tips. Overall this is similar to *P. subtile* except in that the processes are substantially longer but of the same character to *P.*cf. *subtile.*

Genus ***Systematophora*** Klement, 1960

TYPE SPECIES: ***Systematophora areolata*** Klement, 1960; p. 62-65, pl. 9, figs 1-8, text figs 32-35.

REMARKS: These are skolochorate subspherical cysts. Upto 26 penitabular process complexes occur over the generally smooth cyst body. These groups of processes arise from annular, arcuate or rectilinear ridges as lengthy processes. The processes may have distal linkages but are typically without. Each complex of processes tend to occupy the majority of the area of the paraplate and occur over all parts of the cyst. Isolated or rectilinear processes occur on the paracingular areas. The archeopyle is apical, tA with a zig zag principle archeopyle suture. The paratabulation deduced from the archeopyle and process complexes is gonyaulacoid, 3-4', 6", 5-6a, 5-6‴, 0-1p, 1⁗, 0-2s. This genus is differentiated from *Areoligera* which has a lenticular body and a process free or reduced area of processes middorsally and midventrally, and from *Emmetrocysta* (Stover, 1975) which has a clear distal ring of trabeculae developed.

Systematophora ancyrea Cookson & Eisenack, 1965

Plate 59, Figure 1

REFERENCE: Cookson & Eisenack, 1965; p. 126, pl. 14, figs 1-3 are regarded as typical specimens.

COMMENTS: This species describes subspherical cysts. The cyst body is relatively thick and smooth, it is ornamented with numerous paratabular processes arising from annular ring complexes. The processes are long, flexuous, branching distally and occasionally show distal linkages between adjacent processes of the same complex. The apical operculum seen in figure 1, plate 59 is still attached. This species is differentiated from *Systematophora placacantha* which has no interconnections between processes and characteristic T-shaped or flaring distal process tips.

STRATIGRAPHIC RECORD: Late Eocene of Australia (Cookson & Eisenack, 1965)

Systematophora placacantha (Deflandre & Cookson, 1955)
Davey *et al.*, 1969 emend May, 1980

Plate 59, Figures 2 to 4

REFERENCE: Deflandre & Cookson, 1955; pl. 9, figs 1-3, Bujak *et al.*, 1980; pl. 21, figs 11-12 and Manum *et al.*, 1989; pl. 18, figs 9-10 are regarded as typical specimens.

COMMENTS: A medium sized subspherical gonyaulacoid cyst. A number of intratabular processes arise from ring complexes developed on the periphragm. These process complexes are generally annular or arcuate. The processes are solid while remaining slender and flexuous. Proximally they can be slightly expanded and membranous. Along their length they taper before flaring to form a T-shaped distal endings which are not interconnected distally. The archeopyle is apical, type tA.

STRATIGRAPHIC RECORD: Early to Middle Eocene of S England (Bujak *et al.*, 1980; Islam, 1983a); Late Eocene to Early Oligocene of France (Chateauneuf, 1980); Middle Eocene to Late Miocene of the

Norwegian Sea (Manum *et al.*, 1989); Miocene of Australia (Deflandre & Cookson, 1955)

Genus ***Tanyosphaeridium*** Davey & Williams, 1966b

TYPE SPECIES: ***Tanyosphaeridium variecalamum*** Davey & Williams, 1966b; p. 98-99, pl. 6, fig. 7, text fig. 20.

REMARKS: These are small to large sized skolochorate cysts. The cyst is characteristically elongate to ellipsoidal in shape with a number of non-tabular or intratabular processes over the periphragm. The periphragm and endophragm are adpressed between the processes and the periphragm is smooth to faintly ornamented. The processes are simple, tubular, open and generally not interconnected distally. The archeopyle is apical, type tA. This genus is differentiated from *Distatodinium* which has complexly branched processes distally.

Tanyosphaeridium sp. **1** Manum, 1976

Plate 59, Figure 5

REFERENCE: Manum, 1976; pl. 4, figure 3 and 4 are regarded as typical specimens.

COMMENTS: Only one specimen of this species was recorded in this study. The cyst body is elongate to ellipsoidal. The endophragm and periphragm are adpressed between the processes and numerous processes are developed over the periphragm. These are tubular, hollow, parallel sided processes that are expanded only slightly distally and are open. The archeopyle is type tA.

STRATIGRAPHIC RECORD: Early Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Dinocyst sp. 4 of Manum, 1976

Plate 59, Figures 6 & 7

REFERENCE: Manum, 1976; pl. 4, figs 6-7 are regarded as typical specimens.

COMMENTS: These are small sized gonyaulacoid cysts which are spherical to subspherical in shape. The endophragm is smooth to faintly granular in ornamentation. The periphragm and endophragm are closely adpressed except where the periphragm is expanded to form processes. The relatively wide processes are parallel sided to slightly constricted in the middle and flared slightly at the proximal and distal ends. The distal terminations of the processes are entire, flat and open. The small size and characteristic cylindrical to tubiform shape of the processes make this a distinctive dinoflagellate cyst. The archeopyle is probably apical but this is still uncertain so it is problematic in assigning a suitable genus.

STRATIGRAPHIC RECORD: Late Eocene to Middle Miocne of the Norwegian to Greenland Sea (Manum, 1976); Early Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Proximochorate cysts

Genus ***Achomosphaera*** Evitt, 1963

TYPE SPECIES: ***Achomosphaera ramulifera*** (Deflandre, 1937; p. 74, pl. 11, figs 5-6, pl. 14, fig. 10) Evitt, 1963; p. 163.

REMARKS: This genus describes proximochorate to skolochorate cysts which occur within the *Spiniferites* group of cysts which encompass cysts with similar types of morphologies. They range from small to large in size and are subspherical in shape. Numerous isolated processes are developed over the cyst between which the endophragm and periphragm is adpressed. The cyst wall between the processes is relatively thick and is smooth to variously ornamented. The processes are solid or hollow, gonal only or gonal and intergonal. The distal tips of the gonal processes are trifurcate and the tips of the intergonal processes are bifurcate, then these primary furcations are additionally bifurcate as in *Spiniferites* Mantell, 1850 emend Sarjeant, 1970. Adjacent processes are not connected distally and parasutural feature between the processes are absent (or faint). The paratabulation is gonyaulacoid but its formula is unknown due to the lack of parasutural features. The archeopyle is precingular (3" only) and the operculum is free. This genus is differentiated from the similar genus *Spiniferites* which has clear parasutural features visible. For further discussion see *Spiniferites*.

Achomosphaera alcicornu (Eisenack, 1954) Davey & Williams, 1966a

Plate 60, Figure 1

REFERENCE: Davey & Williams, 1966a; pl. 5, fig. 3 and Eaton, 1976, pl. 1, fig. 11 are regarded as typical specimens.

COMMENTS: These are proximochorate to skolochorate gonyaulacoid cysts, with a precingular archeopyle. The processes are the

characteristic trifurcate then bifurcate *Spiniferites* type of processes. This species is characterised by the large hollow gonal processes on which longitudinal ridges or septa occur along the length of the processes. The processes are buccinate distally with primary trifurcated and secondary bifurcated distal tips. This species is morphological similar to *Spiniferites pseudofurcatus* (Klumpp, 1953) Sarjeant, 1970 emend Sarjeant, 1981 and is distinguished by the absence of parasutural features. Some intergradation between these two species occurs when the parasutural septa are faint.

STRATIGRAPHIC RECORD: Widely recorded from the Palaeocene to Miocene of NW Europe; Oligocene of E Prussia (Eisenack, 1954); Middle Oligocene of N Germany (Gerlach, 1961; Gocht, 1969; Benedek, 1972); Upper Oligocene of N Germany (Benedek, 1972); Middle Miocene of N Germany (Gerlach, 1961)

Achomosphaera crassipellis (Deflandre & Cookson, 1955) Stover & Evitt, 1978

Plate 60, Figure 2

REFERENCE: Davey & Williams, 1966a; pl. 1, fig. 7 and Gerlach, 1961; pl. 27, fig. 5 are regarded as typical specimens.

COMMENTS: This describes subspherical gonyaulacoid cysts. Gonal processes are developed from the periphragm, these are hollow with trifurcate tips that have additional bifurcations distally. The archeopyle is precingular and the operculum is free. This species is characterised by the thick nature of the central body. The periphragm is coarsely reticulate to granular in ornamentation. No parasutural features are present over the periphragm, distinguishing this from *Spiniferites ramosus* subsp. *granosus* (Davey & Williams. 1966a) Lentin & Williams, 1973.

STRATIGRAPHIC RECORD: Early Eocene of Australia (Deflandre & Cookson, 1955); Middle Oligocene to Middle Miocene of Germany (Gerlach, 1961)

Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963

Plate 60, Figures 3 & 4

REFERENCE: Eaton, 1976; pl. 1, fig. 7 is regarded as a typical specimen.

COMMENTS: This species describes subspherical, proximochorate to skolochorate gonyaulacoid cysts. The endophragm and periphragm are closely adpressed between the processes, and the periphragm ornamentation is smooth to faintly granular. The processes are characteristic of the *Spiniferites* type, primary trifurcations or bifurcations with additional bifurcated distal tips. This species resembles *Spiniferites ramosus* subsp. *ramosus* (Ehrenberg, 1838) Loeblich & Loeblich, 1966 with the exception of the parasutural septa that run between the processes which are absent in *Achomosphaera ramulifera*. This is the most common species of all the *Achomosphaera* species in this study. It occurred throughout both of the North Sea sections studied and had a maximum frequency of 17.4% in 16/16b-4.

STRATIGRAPHIC RECORD: Late Cretaceous of Australia (Deflandre, 1937); Widely recorded from the Cretaceous to Pliocene of NW Europe.

Genus ***Dinopterygium*** Deflandre, 1935 emend Stover & Evitt, 1978

TYPE SPECIES: ***Dinopterygium cladoides*** Deflandre, 1935; p. 231, pl. 8, fig. 6.

REMARKS: This genus contains medium sized, proximochorate cysts which are subspherical in shape. The periphragm is ornamented with raised parasutural septa with groups of tubercles occurring in the intratabular areas. The parasutural septa and the intratabular structures indicate a gonyaulacoid paratabulation, 4', 6", xc, 6‴, 1p, 1⁗, 1ps. The archeopyle is a combination epicystal archeopyle, tAtP and the principle archeopyle suture is straight and within the paracingulum. The paracingulum is defined by parallel rows of septa. This genus is differentiated from *Heteraulacysta* (Drugg & Loeblich, 1967 emend Bujak *et*

al., 1980) in which the ornamentation is uniformly distributed over the periphragm rather than the intratabular clusters of structures.

Dinopterygium fehmarnense (Lentin & Williams, 1973) Stover & Evitt, 1978

Plate 60, Figures 5 & 6

REFERENCE: Morgenroth, 1966a; pl. 12, figs 7-8 are regarded as typical specimens.

COMMENTS: This species includes subspherical cysts which have a circular outline in an apical and antapical view. Raised parasutural crests are developed over the surface. The periphragm is smooth except for the characteristic strong ornamentation of regular tubercles which occur in clusters in the centre of each paraplate. Parallel crests of parasutures mark the position of the paracingulum. This species is differentiated from other species of *Dinopterygium* as the clusters of tubercles are irregularly distributed, whereas in other species these tubercles occur in regular patterns.

STRATIGRAPHIC RECORD: Early Eocene of Germany (Morgenroth, 1966a)

Genus ***Impagidinium*** Stover & Evitt, 1978

TYPE SPECIES: ***Impagidinium dispertitum*** (Cookson & Eisenack, 1965; p. 123-124, pl. 12, figs 5-7) Stover & Evitt, 1978; p. 165.

REMARKS: These are small to large sized proximochorate cysts. They are subspherical in shape and lacking in an apical projection or horn. The paratabulation is gonyaulacoid and clearly defined by raised parasutural septa which are smooth to imperforate. Between the septa the autophragm is generally smooth or with low relief features. The archeopyle is precingular, type P (3" only) with the operculum being free. It differs from *Leptodinium* (Klement, 1960) which is more elongate to subpolygonal, possesses an apical horn and rarely shows

reduced paratabulation. Also paraplate differences are apparent i.e. in *Leptodinium* the paraplate 1a is longer than the 4a paraplate rather than being equal and the 6' paraplate is quadrangular rather than subtriangular.

Impagidinium patulum (Wall, 1967) Stover & Evitt, 1978

Plate 61, Figures 1 to 4

REFERENCE: Wall, 1967; p. 105-106, pl. 14, fig. 20, pl. 15, fig 1-4, text fig. 4 and Harland, 1983; pl. 46, figure 6 & 7 are regarded as typical specimens.

COMMENTS: This is a large sized proximochorate cyst. It is subspherical in shape and is thick walled. Tabulation is clearly picked out by distinct smooth parasutural septa. This species is characterised by size and paratabulation, especially in the parasutural area.

STRATIGRAPHIC RECORD: Middle Miocene to Holocene (Wall, 1967)

Genus ***Impletosphaeridium*** Morgenroth, 1966a

TYPE SPECIES: ***Impletosphaeridium transfodum*** Morgenroth, 1966a; p. 32, pl. 10, figs 4 and 5.

REMARKS: This genus describes rounded to subspherical gonyaulacoid cysts. Numerous solid processes occur over the cyst. The processes vary greatly in form, they can be distally acuminate, expanded, spatulate or branched and are non-tabular or penitabular. This genus was originally designed by Morgenroth (1966a) as a 'bag' genus used for species which could not be assigned to *Baltisphaeridium* or other more suitable genera. The species that remain assigned to *Impletosphaeridium* until a more suitable genera is found have varying archeopyle types from apical to precingular and varying process types.

Impletosphaeridium implicatum Morgenroth, 1966a

Plate 61, Figure 5

REFERENCE: Eaton, 1976; pl. 21, fig. 10, text fig. 25A is regarded as a typical specimen.

COMMENTS: These are subspherical cysts. The periphragm is smooth to faintly ornamented and is expanded to form a dense coverage of processes. The solid processes are simple or branched with long flexuous distal terminations. In cross section the processes are circular to subcircular. The archeopyle type is unknown. This species is differentiated from others by its long flexuous distal branching processes. In this study this species was recorded from one of the North Sea wells, 16/16b-4, as single specimens only.

STRATIGRAPHIC RECORD: Early to Middle Eocene of S England (Bujak *et al.*, 1980); Lower Eocene of Belgium (De Coninck, 1968) of Germany (Morgenroth, 1966a) of France (Gruas-Cavagnetto, 1976); Lower to Middle Eocene of S England (Eaton, 1976)

Impletosphaeridium insolitum Eaton, 1976

Plate 61, Figure 6

REFERENCE: Eaton, 1976; pl. 21, figs 5 and 8 and Bujak *et al.*, 1980; pl. 5, fig. 5 are regarded as typical specimens.

COMMENTS: These are subspherical gonyaulacoid cysts in which the periphragm ornamentation varies from smooth to finely granular. Processes are developed from the periphragm, they are numerous, solid and slender. This species is characterised by the processes which are simple or distally bifurcate with small bulbous spherical distal terminations. A proximal membrane joining the processes at the point of bifurcation often occurs. A polygonal opening is described in the cyst body (Eaton, 1976) but an archeopyle type is unknown. This species was recorded from both of the North Sea sections and was the most abundant species of *Impletosphaeridium* with a maximum occurrence of 5.9% in 16/16b-4.

STRATIGRAPHIC RECORD: Lower to Upper Eocene of S England (Eaton, 1976); Upper Eocene to Lower Oligocene of S England (Liengjarern *et al.*, 1980)

Impletosphaeridium ligospinosum (De Coninck, 1969) Islam, 1983a

Plate 61, Figures 7 & 8

REFERENCE: De Coninck, 1969; pl. 15, fig. 19 is regarded as a typical specimen.

COMMENTS: These are characteristically small, rounded to subspherical cysts with a number of solid but fine processes covering the central body. The periphragm is generally smooth between these processes. The processes are also smooth and have uneven distal bifurcations. Membranes can connect the processes proximally although they are not common in this study. This species was recorded from both of the North Sea sections studied in this work and had a maximum abundance of 3.6% in 16/16b-4.

STRATIGRAPHIC RECORD: Palaeocene of S England (Jolley, 1992) and Early Eocene of Belgium (De Coninck, 1969) and of S England (Islam, 1983a)

Genus ***Membranophoridium*** Gerlach, 1961
emend Stover & Evitt, 1978

TYPE SPECIES: ***Membranophoridium aspinatum*** Gerlach, 1961; p. 199-201, pl. 29, figs 7-8.

REMARKS: This genus includes medium to large sized proximochorate gonyaulacoid cysts. The body is lenticular with processes concentrated at the margins of the cyst and lacking in the middorsal and midventral areas. These processes are joined both proximally and distally, forming lateral lobes and antapical lobes. These lobes give the cyst a relatively smooth outline.

The archeopyle is apical, tA, with a zig zag principle archeopyle suture.

Membranophoridium aspinatum (Gerlach, 1961) Stover & Evitt, 1978

Plate 62, Figures 1 to 3

REFERENCE: Gerlach, 1961; pl. 29, figs 7-8, Chateauneuf, 1980; pl. 26, fig. 1 and De Coninck, 1986; pl. 7, figs 8-13 are regarded as typical specimens.

COMMENTS: This describes medium to large sized proximochorate cysts. They are very distinctive with a lenticular body. The endophragm and periphragm are smooth to faintly ornamented. Processes are absent in the middorsal and midventral areas but are concentrated on the lateral areas of the cysts. A continuous periphragm covers the processes which are joined both proximally and distally forming lateral marginal and antapical lobes. The continuous covering gives this cyst a smooth outline. This species is differentiated from *Chiropteridium* (Gocht, 1960) species in which the processes are concentrated in the marginal areas but are only connected proximally and as so have a resulting jagged irregular outline to the cysts and can have isolated processes present. Whereas in *M. aspinatum* the cysts has a smooth outline and no isolated processes. In this study specimens of this species occurred throughout both the North Sea sections and had a maximum abundance of 1.02% in 16/16b-4. Stratigraphical importance has been placed on this species as it has a suggested last occurrence at the Oligocene-Miocene boundary.

STRATIGRAPHIC RECORD: Late Eocene of S England (Liengjarern *et al.*, 1980); Late Eocene to Early Oligocene of France (Chateauneuf, 1980); Middle to Upper Oligocene of Germany (Gerlach, 1961)

Genus ***Nematosphaeropsis*** Deflandre & Cookson, 1955
emend Wrenn, 1988

TYPE SPECIES: ***Nematosphaeropsis labrinthea*** (Ostenfeld, 1903; p. 578, fig. 12) Reid, 1974; p. 592.

REMARKS: This genus describes small to medium sized proximochorate subspherical cysts which are commonly folded. Processes are similar to those of *Spiniferites* and *Achomosphaera* with the gonal processes having trifurcate distal tips which then bifurcate and intergonal processes which bifurcate then bifurcate again distally. But this genus is differentiated from *Spiniferites* and *Achomosphaera* as the distal tips of adjacent processes are joined together by paired trabeculae. This trabeculae mirrors the paratabulation although in this study the specimens of this genus were commonly folded, making the determination of paratabulation difficult. The archeopyle is precingular, type P (3" only) and the operculum is free. The paratabulation is gonyaulacoid, 3-4', 5-6", 6c, 5-6"', 1p, 1"" and this is indicated by the trabeculae and poorly defined low parasutural features between the bases of the processes. The paracingulum is delimited by parasutural crests, if visible. This genus differs from other genera with trabeculae such as *Cannosphaeropsis* which has only single trabeculae joining adjacent processes.

Nematosphaeropsis labrinthea (Ostenfeld, 1903) Reid, 1974

Plate 62, Figures 4 to 7

REFERENCE: Deflandre & Cookson, 1955; pl. 8, fig 5 and Manum *et al.*, 1989; pl. 15, fig 12-14 are regarded as typical specimens.

COMMENTS: This species describes small to medium sized proximochorate cysts. The central body is oval to subspherical in shape, it is thin walled and generally smooth. The cyst is commonly folded. Numerous gonal and intergonal processes are developed over the cyst. The distal endings of the gonal processes are trifurcate with secondary bifurcate tips and the intergonal processes are bifurcate with secondary bifurcate tips. The processes appear long, thin and hollow. The archeopyle is precingular (3" only). For discussion see *N. lemniscata.*

STRATIGRAPHIC RECORD: Recent (Ostenfeld, 1903); Middle Eocene to Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Nematosphaeropsis lemniscata Bujak, 1984

Plate 63, Figures 1 to 3

REFERENCE: Bujak *et al.*, 1980; pl. 3, figs 5-7 and Manum *et al.*, 1989; pl 14, fig. 3 are regarded as typical specimens.

COMMENTS: The central body is spherical to oval in shape. It is thin walled, smooth to chagrinate and is commonly folded. The processes are relatively long and smooth, thin and hollow. The gonal processes have ribbon-like distal trifurcations with secondary bifurcations and the intergonal processes are distally bifurcate with secondary bifurcate tips. The bifurcate distal tips of the adjacent processes are joined by pairs of wide 'ribbon-like' trabeculae. These trabeculae replicate the paratabulation patterns of the cyst. The archeopyle is precingular (3" only). This species is differentiated from *N. labrinthea* which has slender trabeculae rather than the wider ribbon-like trabeculae of *N. lemniscata*. Bujak (1984) described *N. lemniscata* as characterising cold water environments and Reid (1974) described *N. labrinthea* as characterising warm water environments.

STRATIGRAPHIC RECORD: Late Oligocene to Early Pleistocene of the Bering Sea (Bujak, 1984); Early to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989)

Genus ***Operculodinium*** Wall, 1967

TYPE SPECIES: ***Operculodinium centrocarpum*** (Deflandre & Cookson, 1955; p. 272-273, pl. 8, fig. 3-4) Wall, 1967;p. 111.

REMARKS: These are proximochorate to skolochorate subspherical cysts. Numerous processes occur over the central body. These

processes or spines are slender, identical and non-tabular. The processes typically show capitate distal terminations. The archeopyle is precingular, type P (3" only). This genus shows great variation between species they vary from small to large in size and the processes also vary greatly in type from short and acuminate to long with T-shaped distal endings. It differs from *Lingulodinium* which has a simple, compound or combination archeopyle and *Cleistosphaeridium* which has an apical archeopyle.

Operculodinium bellulum Islam, 1983a

Plate 63, Figure 4

REFERENCE: Islam, 1983a; pl. 2, fig. 6 is regarded as a typical specimen.

COMMENTS: This is a distinctive species. It describes cysts which are ellipsoidal in shape with a precingular archeopyle. The cyst is small to medium in size and the wall is thick with a minute reticulate to granular ornamentation. Processes are developed over the cyst, they are non-tabular and smooth with circular flared proximal endings and tapering acuminate distal endings.

STRATIGRAPHIC RECORD: Early Eocene of S England (Islam, 1983a)

Operculodinium centrocarpum (Deflandre & Cookson, 1955) Wall, 1967

Plate 63, Figures 5 & 6

REFERENCE: Deflandre & Cookson, 1955; pl. 8, figs 3-4 and Manum *et al.*, 1989; pl. 13, fig. 9 are regarded as typical specimens.

COMMENTS: This species describes subspherical cysts. The central body is smooth with a number of intratabular solid processes which have taeniate distal terminations. The archeopyle is precingular (3" only).

STRATIGRAPHIC RECORD: Widely recorded from the Palaeocene to Recent of NW Europe

Operculodinium microtriana Klumpp, 1953

Plate 63, Figure 7

REFERENCE: Islam, 1983a; pl. 4, fig. 1 is regarded as a typical specimen.

COMMENTS: They are proximochorate to skolochorate gonyaulacoid cysts. The central body is subspherical with a fibrous periphragm from which numerous non-tabular processes arise. These processes are fine, smooth and distally flared with T-shaped endings. The archeopyle is precingular (3" only).

STRATIGRAPHIC RECORD: Late Eocene of Germany (Klumpp, 1953)

Operculodinium sp. of Piasecki, 1980 or sp. 2 of Manum, 1976

Plate 64, Figures 5 to 8

REFERENCE: Manum, 1976; pl. 1, fig. 21 and Piasecki, 1980; pl. 3, fig. 6 are regarded as typical specimens.

COMMENTS: This species of *Operculodinium* is small in size and is oval to subspherical in shape. The periphragm is smooth and appears hyaline in the specimens recorded in this study. The periphragm is extended to form short parallel sided to subconical processes which are intratabular. The archeopyle is precingular. The hyaline cyst nature and distinct process shape make this species easily distinguishable from others.

STRATIGRAPHIC RECORD: Miocene of Denmark (Piasecki, 1980)

Operculodinium sp. 1

Plate 64, Figure 2

COMMENTS: This species is subspherical in shape with the periphragm showing a faintly granular surface and the development of numerous non-tabular processes. These processes are relatively long, tubular and smooth. Proximally the process endings have a circular outline, then they taper distally until reaching a distinct T-shaped termination. The archeopyle is

precingular. This species is easily differentiated from other *Operculodinium* species as it has long tubular processes with T-shaped terminations rather than the shorter processes of *Operculodinium* sp. 2 or the flexurous nature of the processes of *Operculodinium* sp. 3.

Operculodinium sp. 2

Plate 64, Figures 3 & 4

COMMENTS: This species describes medium sized proximochorate to skolochorate cysts. The cyst is subspherical in shape and its surface is faintly granular. A number of short, tubular processes are developed over the cyst surface. These processes have a circular proximal outline, then are constricted midway before expanding distally to form a T-shaped termination. The archeopyle is precingular.

Operculodinium sp. 3

Plate 64, Figure 1

COMMENTS: These are medium sized cysts in which the central body is smooth to faintly ornamented. Numerous non-tabular processes occur over the periphragm. The processes are identical, long and slender to fine and flexuous in character. Distally they show fine capitate or T-shaped tips. The archeopyle is precingular. This species is differentiated from other *Operculodinium* species by its fine, slender and flexuous processes.

Genus ***Pentadinium*** Gerlach, 1961

TYPE SPECIES: ***Pentadinium laticinctum*** Gerlach, 1961; p. 165, pl. 26, figs 5-6, text figs 6-7.

REMARKS: This genus describes proximochorate cavate cysts, which are subspherical in shape. The gonyaulacoid paratabulation is

expressed by folds or thickenings forming crests in the periphragm. They have a precingular archeopyle (3" only). They are differentiated from *Stephodinium* (Deflandre, 1936 emend Davey, 1970) as the periphragm and endophragm are adpressed between the parasutural features. Whereas in *Pentadinium* the periphragm and endophragm are widely separated dorsally.

Pentadinium laticinctum Gerlach, 1961

Plate 65, Figures 1 & 2

REFERENCE: Benedek, 1972; p. 43-46, pl. 6, figs 8-10 and Eaton, 1976; p. 279-280, pl. 13, figs 6-11, text fig. 17 are regarded as typical specimens.

COMMENTS: Overall these are rounded, subspherical to polygonal gonyaulacoid cysts which has a short apical horn sometimes developed. The endophragm is thick and subspherical with an irregular granular surface ornamentation. The periphragm is thin and generally smooth, sometimes becoming granular. The parasutural areas are marked by linear folds in the periphragm or linear thickenings forming sutural crests with undulating and irregular dorsal margins. The archeopyle is precingular (3" only) and the paracingulum, picked out by the crests, enables the tabulation formula to be deduced, 1-3', 5", 5"', 1''''. Many subspecies have been described by Gerlach (1961), Gocht (1969) and Benedek (1972) on ornamentation, but due to the preservation and few numbers of specimens encountered, subspecies could not be confidently assigned in this study.

STRATIGRAPHIC RECORD: Eocene of British Isles (Eaton, 1976; Bujak *et al.*, 1980); Middle to Upper Oligocene of Germany (Gerlach, 1961; Benedek, 1972); Middle Miocene of Germany (Gerlach, 1961)

Genus ***Spiniferites*** Mantell, 1850 emend Sarjeant, 1970

TYPE SPECIES: ***Spiniferites ramosus*** (Ehrenberg, 1838; pl. 1, figs 1, 2, 5) Loeblich & Loeblich, 1966; p. 56-57.

REMARKS: This genus describes proximochorate to skolochorate subspherical cysts which range from small to large in size. The wall is composed of two layers, the endophragm and periphragm, these are variably adpressed between the processes. Ornamentation of the periphragm between the processes is smooth to ornamented, but is rarely thick or structured. Parasutural septa or crests are developed as raised ridges of the periphragm. Gonal and intergonal processes arise from the parasutural septa. The processes are solid or rarely hollow and typically closed distally with variability of process length common. These processes can contain vacuoles. The nature of branching of the processes and the septa make this genus very distinctive. The gonal processes branch distally into trifurcations which in turn bifurcate. The intergonal processes are distally bifurcated then bifurcated again. No interconnections at the process tips occur. Paratabulation is defined by the parasutural septa as, 3-4', 5-6", 6c, 5-6'", 1p, 1''''. The paracingulum is defined by parasutural features and is laevorotatory, with the sulcal area being smooth. The archeopyle is precingular, type P (3" only). In this study this genus is differentiated by the presence of septa from *Achomosphaera* (Evitt, 1963). Although this is doubted in the literature as some authors do not agree that septa is a feature for the recognition of genera. Duxbury (1983) described *Achomosphaera* as a junior synonym of *Spiniferites* but failed to transfer the type species to *Spiniferites* therefore Lentin & Williams (1985) rejected this. Although other workers (Evitt, 1985) have suggested that *Achomosphaera* should be included in *Spiniferites*.

Spiniferites pseudofurcatus (Klumpp, 1953) Sarjeant, 1970
emend Sarjeant, 1981

Plate 65, Figures 3 & 4

REFERENCE: Eaton, 1976; pl. 14, figs 12-13 are regarded as typical specimens.

COMMENTS: These are large subspherical cysts. They are distinguished by large hollow gonal processes, in which the parasutural septa appear to continue up the length of the processes. Distally these processes show the characteristic trifurcate with secondary bifurcate endings. The distal tips are buccinate and the length of the processes vary greatly within individual specimens. Parasutural septa are present and indicate the *Spiniferites* type paratabulation. The periphragm between the processes is smooth to faintly ornamented. The archeopyle is precingular (3" only). This species is similar to *Achomosphaera alcicornu* (Eisenack, 1954) Davey & Williams, 1966a but is differentiated on the presence or absence of septa. This species is differentiated from other *Spiniferites* species by its large size and large hollow buccinate gonal processes that show longitudinal ridges of the septa running along their length.

STRATIGRAPHIC RECORD: Palaeocene of N Germany (Gocht, 1969) of Denmark (Heilmann-Clausen, 1985); Early Eocene to Late Miocene of the Norwegian Sea (Manum *et al.*, 1989); Late Eocene to Early Oligocene of France (Chateauneuf, 1980); Late Oligocene of Germany (Benedek, 1972)

Spiniferites multibrevis (Davey & Williams, 1966a) Below, 1982

Plate 65, Figure 5

REFERENCE: Davey & Williams, 1966a; pl. 1 fig. 4, pl. 4, fig. 6 and Eaton, 1976; pl. 14, fig. 6 are regarded as typical specimens.

COMMENTS: These are subspherical cysts, intermediate in size but characterised by relatively short gonal and intergonal processes. These processes can vary slightly in length between specimens. Parasutural septa of raised ridges arising from the periphragm, connect the processes proximally. The processes show the trifurcations and bifurcations that are characteristic of this genus. The cyst surface between the processes is smooth

to faintly ornamented. The archeopyle is precingular, type P (3" only) and is free. This species is differentiated from *Spiniferites ramosus* subsp. *ramosus* (Ehrenberg, 1838) Loeblich & Loeblich, 1966 which has longer processes. This differentiation can be difficult and subjective when examining specimens of *S. multibrevis* with longer processes as the two species tend to intergrade, where any uncertainty occurred specimens were assigned to *Spiniferites ramosus* subsp. *ramosus*.

STRATIGRAPHIC RECORD: Widely recorded from the Early Cretaceous to Oligocene of NW Europe (see Eaton, 1976)

Spiniferites ramosus subsp. ***ramosus*** (Ehrenberg, 1838)
Loeblich & Loeblich, 1966

Plate 65, Figure 6

REFERENCE: Eaton, 1976; pl. 14, fig. 3 is regarded as a typical specimen.

COMMENTS: These are gonyaulacoid cysts with the typical *Spiniferites* tabulation. They are elongate to subspherical in shape and the cyst is relatively thin walled. The cyst surface is divided up by parasutural septa which are variably developed as raised ridges of the periphragm. The septa connect the gonal processes proximally, often with the septa continuing up the length of the process. The gonal processes trifurcate and the intergonal processes bifurcate with both types terminating in further small bifurcations. The paracingulum is clearly defined by the parasepta and is laevorotatory. The archeopyle is precingular, type P (3" only). This species has upto 17 subspecies described by such workers as Davey & Williams (1966a), Lentin & Williams (1973) and others. *S. ramosus* subsp. *ramosus* is differentiated from *S. ramosus* subsp. *gracilis* (Davey & Williams, 1966a) Lentin & Williams, 1973 which is similar but is lacking in the parasutural processes. The lack of a granular ornamentation differentiates *S. ramosus* subsp. *ramosus* from *S. ramosus* subsp. *granomembranaceus* (Davey & Williams, 1966a) Lentin & Williams, 1973 and *S. ramosus* subsp.

granosus. *S. multibrevis* is distinguished from *S. ramosus* subsp. *ramosus* by its distinctly shorter processes.

STRATIGRAPHIC RECORD: Widely recorded from Early Cretaceous to Recent.

Spiniferites ramosus subsp. ***granomembranaceus*** (Davey & Williams, 1966a) Lentin & Williams, 1973

Plate 66, Figures 3 & 4

REFERENCE: Eaton, 1976; pl. 14, fig. 5 and Bujak *et al.*, 1980; pl. 4, figs 10-11 are regarded as typical specimens.

COMMENTS: These are gonyaulacoid cysts which are subspherical in shape. The periphragm surface is ornamented with granules. The parasutural septa which proximally connect the gonal and intergonal processes are well developed and form membranes especially in the paracingular and polar regions. This species is differentiated from other membranous forms such as *S. membranaceus* (Rossignol, 1964) Davey & Williams, 1966a which lacks the granular ornamentation over the periphragm.

STRATIGRAPHIC RECORD: Late Eocene to Early Oligocene of France (Chateauneuf, 1980)

Spiniferites ramosus subsp. ***granosus*** (Davey & Williams, 1966a) Lentin & Williams, 1973

Plate 66, Figures 1 & 2

REFERENCE: Eaton, 1976; pl. 14, fig. 4 and Bujak *et al.*, 1980; pl. 4, figs 4-5 are regarded as typical specimens.

COMMENTS: These are subspherical gonyaulacoid cysts, the surface is divided up by the raised parasutural septa made of raised ridges of the periphragm. The surface of the periphragm is heavily ornamented with granules. Both gonal and intergonal processes are present and connected proximally by only slightly raised parasutural septa. The gonal processes are trifurcate and bifurcate and the intergonal processes are bifurcate then

bifurcate. The lack of well developed membranes or parasutural septa distinguish this species from the other granular ornamented species such as *S. ramosus* subsp. *granomembranaceus*.

STRATIGRAPHIC RECORD: Early Eocene of S England (Davey & Williams, 1966a); Early Oligocene of France (Chateauneuf, 1980)

Spiniferites sp. **1** of Manum *et al.*, 1989

Plate 66, Figures 5 & 6

REFERENCE: Manum *et al.*, 1989; pl. 17, fig. 5 is regarded as a typical specimen.

COMMENTS: A great stratigraphical importance has been placed on this species in the literature by Manum *et al.* (1989) who has suggested a restricted age of Lower Oligocene. This species is very distinctive, it is a large gonyaulacoid cyst that is subspherical in shape. The surface is characterised by a strong rugulate ornamentation. Smooth slightly raised septa are developed over the periphragm with large simple processes arising from the septa. The processes are parallel sided and can appear hyaline in the specimens encountered in this study. Distally they show the typical trifurcate and bifurcate tips with both types again bifurcating at their terminations. This is a very distinctive species of *Spiniferites*, the large size, strong rugulate ornamentation, smooth septa and simple processes differentiate it from all others. In this study specimens were recorded from both the North Sea sections with a maximum abundance of 1.17% in 16/16b-4.

STRATIGRAPHIC RECORD: Early Oligocene of the Norwegian Sea (Manum *et al.*, 1989)

Spiniferites sp. A

Plate 67, Figure 1

COMMENTS: Only one specimen of this species was recorded in this study, from 21/28b-7. They are gonyaulacoid cysts, generally

subspherical to elongated in shape. The cyst surface is divided by parasutural septa which join the processes proximally. These septa are typically membranous connecting the processes together for a greater part of there length. The processes are trifurcate with shorter bifurcate distal tips, the terminations show very exaggerated recurved seceate bifurcate tips. The membranous development of the parasutural septa and exaggerated recurved distal tips make this a very distinctive species of *Spiniferites*.

Unknown affinity

Genus ***Cyclopsiella*** Drugg & Loeblich, 1967

TYPE SPECIES: ***Cyclopsiella elliptica*** Drugg & Loeblich, 1967; p. 190, pl. 3, figs 1-6, text fig. 7.

REMARKS: These are small rounded cysts. Their wall is two layered, the periphragm is thin and can be smooth to ornamented in structure. The periphragm is separated from the endophragm by a pericoel. A small circular apperture is present on one side of the cyst. The distinct aperture and two layered structure of the cyst make this genus clearly distinguishable.

Cyclopsiella vieta Drugg & Loeblich, 1967

Plate 67, Figure 2

REFERENCE: Drugg & Loeblich, 1967; p. 192, pl. 3, figs 7-9 are regarded as typical specimens.

COMMENTS: This species describes a two layered cyst which is relatively small in size. A circular aperture is present and is bordered by a low rim. The endophragm is thick and smooth to granular. The periphragm is thin and forms a flange around the inner body. The characteristic feature of this cyst is the overall shrivelled wrinkled to reticulate pattern of the periphragm. A strong equatorial fold can be seen. The shrivelled, wrinkled periphragm differs from the smooth *C.* sp. A and the granular *C.* sp. B. This species was rare in this study only one specimen was recorded from 16/16b-4.

STRATIGRAPHIC RECORD: Oligocene of N America (Drugg & Loeblich, 1967)

Cyclopsiella sp. ***A***

Plate 67, Figure 3

COMMENTS: These small ellipsoidal cysts occured throughout the two North Sea sections studied and had a maximum abundance of 2.39% in 21/28b-7. The cysts are characteristically smooth and thin walled. The periphragm is separated from the endophragm by a pericoel. A circular aperture is present. The smooth periphragm and endophragm differentiate this from *C.* sp. B which has an ornamentation of granules and from *C. vieta* which has a wrinkled outer layer to the cyst.

Cyclopsiella sp. ***B***

Plate 67, Figure 4

COMMENTS: This describes small ellipsoidal cysts, which have a two layered with the endophragm and periphragm separated by a pericoel. The periphragm is smooth and the endophragm is ornamented with large, clear, widely spaced granules. This ornamentation along with the circular aperture opening make this species very distinctive. This species was recorded from both the North Sea sections studied and had a maximum abundance of 1.59% in 21/28b-7.

Class Chlorophyceae (Kutzing, 1843)

Genus ***Tasmanites*** Newton, 1875

TYPE SPECIES: ***Tasmanites punctatus*** Newton, 1875; p. 337, pl. 10, figs 2-9.

REMARKS: Several types of *Tasmanites* were encountered within this study. They are thick walled in structure with characteristic punctae developed in it. Overall they are medium to large in size and their shape is circular. Individual species are not distinguished within this study and specimens are recorded as *Tasmanites* spp.

Plate 68, Figure 1

Genus ***Pediastrum*** Meyer, 1829

REMARKS: The coenobia of the planktonic freshwater green algea, *Pediastrum* has been recorded from the Cretaceous to Recent from marine and freshwater environments (Evitt, 1963). In this study specimens encountered are recorded as *Pediastrum* spp.

REFERENCE: Piasecki, 1980; pl. 4, fig.4 is regarded as a typical specimen.

Plate 69, Figure 1

Genus ***Botryococcus*** Kutzing, 1843

TYPE SPECIES: ***Botryococcus braunii*** Kutzing, 1843, p. 892.

REMARKS: Specimens of this type encountered in this study are recorded as *Botryococcus* spp. and have been recorded from 16/16b-4 and 73/36. They are small in size with a complex structure giving rise to a cauliflower appearence. These are thought to be brackish water algae.

Plate 69, Figures 2 & 3

Class Zygnemataceae

Genus ***Ovoidites*** Potonie, 1951 ex Krutzsch, 1959b

TYPE SPECIES: ***Ovoidites ligneolus*** Potonie, 1951 ex Krutzsh, 1959b p. 249.

REFERENCE: Wilkinson & Boulter, 1980; pl. 11, fig. 30 and Krutzsch & Vanhoorne, 1977; pl. 2 are regarded as typical specimens.

REMARKS: These are large to medium in size and oval to pointed oval in outline. Sometimes a split along an equatorial zone is apparent. The surface of this internal cyst varies from smooth to reticulate but has a characteristic hyaline appearance. This fossil algea is thought to represent freshwater environments (Krutzsch, 1961d; Wilkinson & Boulter, 1980; Jolley & Morton, 1992).

STRATIGRAPHIC RECORD: Upper Cretaceous to Pleistocene of Germany (Krutzsch, 1959b)

Plate 69, Figures 4 & 5

Genus ***Schizosporis*** Cookson & Dettman, 1959

TYPE SPECIES: ***Schizosporis reticulatus*** (Cookson & Dettman, 1959; p. 213-214, pl. 1, fig. 1-4) emend Pierce, 1976; p. 27-30.

REMARKS: These are elongate cysts, they characteristically occur in two parts with a long split running upto 2/3rds of the way around the body. The ornamentation varies from psilate to reticulate.

Schizosporis reticulatus Cookson & Dettman, 1959 emend Pierce, 1976

Plate 69, Figure 6

REFERENCE: Wilkinson & Boulter, 1980; pl. 4, fig. 15 and Wilkinson, 1979, pl. 19, fig. 15 are regarded as typical specimens.

COMMENTS: This describes medium to large sized elongate cysts characterised by a rugulate to reticulate hyaline wall structure giving this cyst a very characteristic appearance. These are recorded from 77/7, 73/36, 88/12 and 80/14 in low numbers, generally as single specimens.

STRATIGRAPHIC RECORD: Oligocene of the UK (Wilkinson, 1979; Wilkinson & Boulter, 1980)

Algal sp. 1

Plate 69, Figure 7

COMMENTS: This algal cyst was consistently recognised throughout the sections in this study. Its origin is tentatively suggested as freshwater. The cyst is spherical to subspherical in shape and small to medium in size. The cyst is hyaline in character with a short widely spaced echinate ornamentation. This ornamentation occurs in a non-tabular arrangement.

GROUP ACRITARCHA (Evitt, 1963)

Family Herkomorphitae (Downie *et al.*, 1963)

Genus ***Cymatiosphaeria*** O.Wetzel, 1933b

TYPE SPECIES: ***Cymatiosphaeria radiata*** O.Wetzel, 1933b; p. 27, pl. 4, fig.8 emend Sarjeant, 1985; p. 161-162.

REMARKS: Specimens from this genus are recorded as *Cymatiosphaeria* spp. This describes small spherical psilate cysts. These cysts are characterised by numerous membranes or raised septa which divide the cyst surface into a number of polygonal fields.

Plate 67, Figure 6

Family Sphaeromorphitae (Downie, *et al.*, 1963)

Genus ***Ascostomocystis*** (Drugg & Loeblich, 1967) Stover & Evitt, 1978

TYPE SPECIES: ***Ascostomocystis hydria*** Drugg & Leoblich, 1967; p. 187, pl. 3, figs 13-15, text fig. 5.

REMARKS: This genus describes flask shaped elliptical cysts. They are two layered with a thin endophragm which is rigid and a thin periphragm separted by a pericoel which is free around the edges. An aperture is present at the apex but is of unkown type. This genus is differentiated from the similar genus *Cyclopsiella* (Drugg & Loeblich, 1967) which has a distinct circular opening formed at the apex.

Ascostomocystis granulata Chateauneuf, 1980

Plate 68, Figure 7

REFERENCE: Chateauneuf, 1980; p. 133, pl. 19, figs 8 and 11 are regarded as typical specimens.

COMMENTS: This species is elliptical in shape with a thick endophragm and thin periphragm separated by a pericoel. A small circular apical aperture is present. This species is distinguished by the thick ornamented endophragm which is covered with closely spaced small granules.

STRATIGRAPHIC RECORD: Late Eocene to Early Oligocene of France (Chateauneuf, 1980)

Genus ***Paralecaniella*** Cookson & Eisenack, 1970b

TYPE SPECIES: ***Paralecaniella indenta*** (Deflandre & Cookson, 1955; p. 292, pl. 9, figs 5-7, text fig. 56) Cookson & Eisenack, 1970; p. 323 emend Elsik, 1977; p. 96.

REMARKS: This is simple genus. The endophragm and periphragm are smooth and are separated by a distinct narrow pericoel. The archeopyle is small but of an unknown type. Two raised parallel ridges or rows of ornamentation indicate the presence of a paracingulum or parasulcus. The ovreall size of the cysts is small to medium. It is the emendation of Elsik (1977) which is used here as it adds detail to the original description of Cookson & Eisenack (1970).

Paracaniella indentata (Deflandre & Cookson, 1955)
Cookson & Eisenack, 1970 emend Elsik, 1977

Plate 67, Figure 5

REFERENCE: Deflandre & Cookson, 1955; pl. 9, figs 5-7 are regarded as typical specimens.

COMMENTS: These are small sized, circumcavate cysts in which the two wall layers are separated by a distinct but small pericoel. The endophragm is smooth and mirrored by an elliptical periphragm which often displays a faintly granular ornamentation. Parallel folds running equatorially aroud the cyst delimit the paracingulum. The archeopyle is sometimes present but the type is unknown.

STRATIGRAPHIC RECORD: Palaeocene to Miocene of Australia (Deflandre & Cookson, 1955)

Genus ***Leiosphaeridia*** Eisenack, 1958 emend Downie & Sarjeant, 1963

TYPE SPECIES: ***Leiosphaeridia baltica*** Eisenack, 1958; p. 8, pl. 2, fig. 5.

REMARKS: Specimens encountered within this group are recorded as *Leiosphaera* spp.. They vary in size from small to large and are 'sack like' spheres of algal bodies. They are characteristically structureless with no apertures. In this study these algal bodies did not form a major constituent of any assemblage.

Plate 68, Figure 6

Family Acanthamorphitae (Downie *et al.*, 1963)

Genus ***Micrhystridium*** Deflandre, 1937

TYPE SPECIES: ***Micrhystridium inconspicuum*** (Deflandre, 1935; p. 233, pl. 8, figs 11-12) Deflandre, 1937; p. 80 emend Deflandre & Sarjeant, 1970.

REMARKS: This genera describes subspherical to subpolygonal cysts which possess a moderately thick wall. This wall is smooth and is ornamented with numerous solid spines which vary in number, size and distribution. The spines are generally wider at the base, they taper and close distally.

Micrhystridium fragile Deflandre, 1947a

Plate 68, Figure 3

REFERENCE: Deflandre, 1947a; p. 8, figs 13-18 are regarded as typical specimens.

COMMENTS: This species describes small sized cysts in which the central body is spherical; smooth and thick walled. A number of widely spaced flexuous spines are developed over the cyst. These spines are long, solid and taper distally. They vary in number and length, although are never greater than the diameter of the test. A circular opening or pylome is clearly visible (plate 68, figure 3).

STRATIGRAPHIC RECORD: Jurassic of Britain (Wall, 1965); Late Palaeocene to Early Eocene of S England (Hussain, 1967) of Belgium (De Coninck, 1968)

Micrhystridium lymense Wall, 1965

Plate 68, Figure 4

REFERENCE: Wall, 1965; pl. 2, figs 10-17 are regarded as typical specimens.

COMMENTS: These are small sized cysts in which the central body is spherical to subspherical and is thick walled. Numerous small solid spines are developed over the cyst. These are less in

number and more rigid than those of *M. fragile*. This species is easily differentiated from others by its thicker wall structure.

STRATIGRAPHIC RECORD: Jurassic of S. England (Wall, 1965); Early Eocene of S. England (Hussain, 1967)

Micrhystridium stellatum Deflandre, 1945

Plate 68, Figure 5

REFERENCE: Deflandre, 1945; pl. 3, figs 16-19 are regarded as typical specimens.

COMMENTS: This describes a small spherical to subpolygonal test. The test wall is relatively thick and ornamented with erect to flexuous spines. In this speices an opening or pylome is rarely seen. The spine are generally greater in length than the radius of the cyst.

STRATIGRAPHIC RECORD: Ordovician to Eocene (Wall, 1963); Eocene of the Isle of Wight (Eaton, 1971; 1976)

Family Polygonomorphitae Downie *et al.*, 1963

Genus ***Veryhacium*** Deunff, 1954
emend Downie & Sarjeant, 1963 emend Turner, 1984

TYPE SPECIES: ***Veryhacium trisulcum*** Deunff, 1951 ex Deunff, 1959; p. 27-28, pl. 1, fig. 1-4,8, 10, 12-14, 16-17, 20, 22-23 Tynni, 1982; p. 85.

REMARKS: This genus is characterised by a distinctive polygonal test outline on which a limited number of spines are developed. Deunff suggested a limit of 3 to 10 spines are characteristic although a generic diagnosis on number of spines alone seems rather unsatisfactory. In this study specimens from this genera are described as *Veryhacium* spp., no differentiation of species was made to the low numbers encountered. The number of

spines of the specimens recorded in this study ranged from 3 to 4 on a subpolygonal to triangular test. The shape of the cyst is more or less determined by the number of spines it possesses.

Plate 68, figure 2

REWORKING AND CAVING

The following taxa, listed alphabetically, were recognised during this study as reworked or caved material. The approximate age ranges of these taxa have been suggested along side each were known or appropriate:

Aptea (now Pseudoceratium) anaphrissa (Sarjeant, 1966b) Sarjeant & Stover, 1978 emend Bint, 1986
Areoligera medusettiformis (Wetzel, 1933b) Lejeune-Carpentier, 1938 Senonian to Miocene
Amiculosphaera umbracula (Harland, 1979) Late Miocene to Early Pleistocene
Batiacasphaera spp. Aalenian to Palaeogene
Canningia spp.
Cibotiumspora jurenensis (Balme) Filatoff, 1955 Jurassic to Cretaceous
Circulodinium hystrix Cretaceous
Circulodinium spp.
Cleistosphaeridium disjunctum Davey *et al*, 1966
Cleistosphaeridium spp.
Cribroperidinium granulatum (Klement, 1960) Stover & Evitt, 1978 Lower Jurassic
Cribroperidinium spp.
Ctenidodinium sellwoodii (Sarjeant, 1975) Stover & Evitt, 1978 Middle Jurassic
Cyclonephelum spp.
Gonyaulacysta jurassica (Deflandre, 1938) Norris & Sarjeant, 1965 emend Sarjeant, 1982 Callovian to Oxfordian
Kallosphaeridium cf. *brevibarbatum* Palaeocene
Liasidinium variabile (Drugg, 1978) Sinemurian
Nannoceratopsis pellucida Deflandre, 1938 emend Evitt, 1961 Callovian to Kimmeridgian
Nannoceratopsis senex Van Helden, 1977 lt Pleinsbachian to ely Bathonian
Oligosphaeridium pulcherrimum (Deflandre & Cookson, 1955) Davey & Williams, 1966a

Palaeoperidinium pyrophorum (Ehrenberg, 1938) Sarjeant, 1967 Palaeocene
Pareodinia ceratophora Deflandre, 1947b emend Gocht, 1970 Bathonian to Kimmeridgian
Mendicodinium groenlandicum (Pocock, 1972) Davey, 1979
Mudrongia tetracantha (Gocht, 1957) Alberti, 1961 late Hetterivian
Rhynchodiniopsis cladophora (Deflandre, 1938) Below, 1981 early Oxfordian
Sentusidinium spp.
Stephanelytron redcliffense Sarjeant, 1961 emend Stover *et al.*, 1977 Callovian to Oxfordian
Subtilispaera spp.
Systematophora fasciculigera Klement, 1960 mid Oxfordian to ely Kimmeridgian
Systematophora spp.

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APPENDIX 1

Details of samples collected from BGS Borehole 80/14, location 57 deg 45.88'N 6 deg 54.58'W
20th April 1993, BGS Edinburgh

Sample Depth (m)		Lithology
63.97 - 64.00	**	lignite, black hard with clayey band with carbonaceous spots
64.26 - 64.28	**	lignite with dark green silty clay layers with carb. spots and wood fragments
64.52 - 64.53	*	lignite with grey/green silty clay layers with orange/red patches
64.95 - 65.00	**	base of lignite with green/brown clay layers and wood laths
66.19 - 66.22	**	pale grey/brown clay, slightly coarser quartz, feldspar and mica fragments, with wood and plant fragments
66.88 - 66.92	**	green/brown clay with slickensides quartz, feldspar, plant and carbonaceous frags
67.21 - 67.23	**	grey/green clay with fragments of wood, mica, quartz and feldspar
67.63 - 67.64	*	hard brittle black lignite, highly folded
67.75 - 67.77	**	bleached grey/green/brown clay with lignite/wood fragments
67.81	*	lignite, brown/black bands hard brittle and crumbly with clayey and very carbonaceous patches
67.82	*	lignite black/brown colour bands hard and brittle
67.98 - 68.00	*	lignite black/brown colour bands hard and brittle
68.17 - 68.19	*	black laminated lignite and siltstone
68.24 - 68.25	**	base of lignite, pale grey clay with lignite wood fragments and mica
68.96 - 68.98	**	grey clay with mica and wood fragments also orange weathered feldspars
70.75 - 70.77	**	grey clay with carbonaceous and woody fragments
71.28 - 71.30	**	dark grey/brown/green siltstone with mica, wood quartz and feldspar frags
71.35 - 71.36	*	dark grey sandy siltstone with mica carbonaceous spots and plant/wood fragments
72.95 - 72.98	**	pale grey clay with larger woody bits and areas of brown slickensides
73.77 - 73.80	**	grey clay with large slickensides, brown carbonacous patches
74.47 - 74.50	**	grey clay with slickensides
75.20 - 75.24	**	pale grey/green, very gritty quartz and feldspar frags <4mm and sub angular
76.73 - 76.74	**	pale grey silty clay with lignite quartz and feldspar fragments
77.00	**	grey/brown clay very smooth with slickensides and plant/wood fragments
77.96 - 78.00	**	pale grey clay with lignite quartz and feldspar fragments
78.49 - 78.53	*	brown.black carbonaceous silty claystone
78.93 - 78.94	**	dark brown/purple carbonaceous siltstone with mica

* denotes samples processed for palynological study
** denotes samples processed and studied for palynology

Table 1.1 The depth and description of the samples taken from section 80/14

Detail of samples collected from BGS Borehole 88/12, (57deg 37.599'N, 7deg 00.036'W)
21st April 1993 from BGS Edinburgh

Sample Depth (m)		Lithology
31.8		conglomerate with rounded pebbles and slickensides
32.58 - 32.61		conglomerate with rounded pebbles and slickensides
32.78 - 32.81	**	dark green fine grained silty claystone
33.01 - 33.04		dark green fine grained silty claystone
33.20 - 33.23		dark green fine grained silty claystone
33.5	**	dark green fine grained silty claystone with slickensides and mica
33.75 - 33.74		conglomerate

34.07 - 34.08		conglomerate, large clasts with smaller clasts and quartz frags in the matrix
34.60 - 34.64	**	conglomerate, large clasts with smaller clasts and quartz frags in the matrix
37.50 - 37.56		conglomerate with matrix of smaller sized and wider variety of clasts
37.98 - 38.00		conglomerate with matrix of smaller sized and wider variety of clasts
38.33 - 38.35		conglomerate with matrix of smaller sized and wider variety of clasts
39.25 - 39.30		conglomerate, well lithified
39.85 - 39.89		black c grained siltstone/f-m grained sand
40.02 - 40.03	**	black c grained siltstone/f-m grained sand
40.10 - 40.14		black lignite with sandy layers
40.50 - 40.52		conglomerate with very dark matrix
40.93 - 40.96		conglomerate with very dark matrix
41.25 - 41.35	**	conglomerate with 1 cm frags of pink/orange feldspar and quartz frags and lignite patches
41.60 - 41.62		conglomerate
41.70 - 41.74	**	black sand with lignite layers, black/brown streaks
41.95 - 41.99		conglomerate
42.48 - 42.51		conglomerate
44.43 - 44.45		conglomerate
44.75 - 44.85	**	conglomerate
45.18 - 45.21		conglomerate
45.97 - 45.99		conglomerate
46.54 - 46.57		conglomerate
47.40 - 47.43		conglomerate
47.95 - 47.99		conglomerate
48.50 - 48.53	**	dark brown/black carbonaceous rich sand layer within the conglomerate

** denotes samples processed and logged for detailed palynological study

conglomerate:
conglomerate consists of large clasts greater than 7 cm in size with smaller clasts in the matrix, grey/green in colour and is clast supported. clasts are well rounded often with a weathered rim. cement is slightly calcereous and cavities are filled with quartz

Table 1.2 The depth and description of the samples taken from section 88/12

Details of samples collected from Borehole 78/1A
20 April 1993 from BGS Edinburgh

Sample Depth (m)		Lithology
122.29		green/red mottled claystone in core rubble
123.04	**	green/red pebbly silty clay with lignite/carbonaceous fragments
123.90	*	green/brown clay (micaceous + feldspar frags) with red carbonaceous/lignite fragments
124.37	**	green/brown clay with lignite, carbonaceous and feldspar fragments
126.45	*	clay with carbonaceous and lignite fragments
126.90	**	brown/grey clay with lignite fragments
127.49 - 128.14		green/red coarse grained sandy gritty layer
128.20	**	c. grained sandy gritty beds with green/brown clay interval(clay layer is sampled here)
128.30		f/m grained green/red sand with fragments of feldspar
130.10	**	brown clay with clay pebbles
130.41	*	darker green/brown clay with clay pebbles + carbonaceous fragments
131.50 - 131.59	**	green/grey clay
133.00 - 133.18	**	brown clay with black steaks
134.92 - 135.10	**	finer grained brown/green clay with slickensides, carbonaceous spots + plant frags
136.43 - 136.60		green clay with pebbles upto 5 mm
136.60 - 136.90	**	green/brown clay, crumbly texture
139.57 - 139.70	**	green/brown clay, more clayey with carbonaceous frags

141.20 - 141.40	**	green/brown clay with carbonaceous frags

* denotes samples which were selected for palynological processing

** denotes samples selected for detailed palynological analysis(Logging)

Table 1.3 The depth and description of the samples taken from section 78/1

Details of samples collected from Borehole 77/7 A (59 deg 20.6'N and 4 deg 57.8'W)
21 April 1993 from BGS Edinburgh

Sample Depth (m)		Lithology
96		dark green mud/clay with shell fragments and quartz fragments
99.7 - 99.9		green/white carbonate sandstone with numerous bivalve shell fragments
104	**	green glauconitic sandst. non calcareous with quartz frags
110.6	**	buff/brown siltst. shelly frags, freshwater
110.82 - 110.83		fine black and grey laminated siltstone with carbonaceous spots and plant fragments within a brown/buff siltstone
111.00 - 111.01	**	brown/black siltst with fine buff siltst laminations
111.30 - 111.32	**	grey brown laminated siltst with plant frags and carbonaceous spots
111.63 - 111.65		grey/brown siltstone with plant fragments
111.82 - 111.85	**	base of the laminated siltstone unit is a dark brown carbonaceous clayst with plant frags
112.00 - 115.70	**	chocolate brown mudst with some sandy patches
115.70 - 115.78	**	black lignite
115.84 - 115.85		laminated with sandy layers between the lignite, lignite dirty/silty in places
115.93 - 115.95	*	laminated brown/black lignite
119.3		top of c. 1m black lignite band. sandy at the top
119.38	**	black lignite
119.52	*	black lignite with plant fragments and yellow spots of sulphur staining
119.62		black lignite showing yellow (sulphur/limonite?) staining and plant fragments
119.72	*	brown/black lignite with plant fragments, sandy at the base
119.80 - 120.00	*	base of lig (seat earth) black sandstone stained black from the lignite above
120.13 - 120.14	**	sandstone with excellent rootlets, paler in colour away from the lignite
124.00 - 126.00	**	white/grey highly altered kaolin rich clay with carb spots and quartz grains (sub angular/sub rounded)
126.5		white/grey clay with quartz fragments and black carbonaceous spots
127.55	*	grey/buff clay with quartz frags, carbonaceous spots and flakes of white mica
128.55		white/buff clay with quartz frags, carbonaceous spots and flakes of white mica
130.00 - 132.00	*	buff clay with quartz and feldspar frags

* denotes samples which were selected for palynological processing

** denotes samples selected for detailed palynological analysis(Logging)

Table 1.4 The depth and description of the samples taken from section 77/7

Details of samples collected from BGS Borehole 73/36 (51 deg 17.30'N and 4 deg 39.03'W)

13 January 1994 from BGS
Keyworth

Sample Depth (m)		Lithologies
5.0 - 6.0		black hard mudstone with plant fragments
6.0 - 8.0		black hard mudstone with plant fragments
8.0 - 10.0	**	middle of lignite
10.35	**	mid brown grey mudstone with lignite and plant fragments
10.86	**	silty lignite, black dirty lignite
11.17	**	dark brown mudstone with plant fragments
12.22	**	black lignitic claystone, very organic rich
12.65	**	black lignitic claystone, more organic rich
12.85		clastic lignite, black lignitic gritty mudstone with orientated clay blebs
13.2		lignite, whole laths of wood
13.4		dirty lignite with yellow staining
13.6		black rubbley clastic rich dirty lignite with pebbles and grey clay clasts or lenses
14		middle of lignite, lignite
14.1		basal lignite with yellow sulphur staining
14.15	**	below lignite, mid/dark grey claystone with large plant fragments
16.74	**	grey claystone with large plant and lignitic fragments
17.22	**	pale grey claystone with few plant fragments
17.7		pale grey claystone with few plant fragments
18.03	**	grey sandstone with red orange grains included
18.75	**	pale grey claystone with few plant fragments below a sandstone band
19.31	**	pale grey claystone with few plant fragments
19.8	**	grey laminated claystone with sand lenses
20.3	**	waxy mid grey claystone with mica and few plant fragments
20.9	**	dark grey waxy laminated claystone
21.38	**	black very carbonaceous/lignitic mudstone
22.15	**	pale claystone with plant fragments and rootlets
22.5		pale grey claystone with clastic and plant and carbonaceous fragments
23.03		claystone with plant fragments and mottling contorted by drilling
23.83		paler grey claystone laminated with lignite and carbonaceous fragments
24.42	**	mid grey mudstone with plant and lignite fragments and rootlets
24.82		grey siltstone
25.65		grey claystone with plant and lignite fragments
26.12		buff unconsolidated sandstone with plant fragments
26.79	**	grey claystone with red bands
27.3		hard red sandstone
27.52		mid grey claystone
27.63		orange red siltstone
27.78	**	laminated dark and darker brown and red claystone
28.9		pale claystone with rootlets (possibly a ganister)
29.75		pale claystone mottled with brown patches
30.2	**	dark and darker brown siltstone
30.55		pale claystone with plant fragments
32.4		chocolate brown/grey laminated claystone with large lignite frags and silty patches
33.1	**	dark grey mudstone with plant fragments
33.37		grey laminated claystone with silty patches
33.6		pale grey sandstone with some plant fragments

** denotes samples selected for detailed palynological analysis(logging)

Table 1.5 The depth and description of the samples taken from section 73/36

Details of cutting samples given by UNOCAL

Well 16/16b-4, drilled
1991
Location 58 deg 24'50.570"N and 01 deg 07'53.600"E

Sample Depth (m)	Lithology
3440	claystone above lignite bands
3460	claystone above lignite bands
3500	grey brown siltstone
3580	base of glauconitic, micaceous, carbonaceous, f/m sandstone within a claystone
3600	siltstone
3640	claystone with bivalve fragments
3720	claystone with calcareous and silty patches
3800	claystone micaceous
3840	calcareous patch in a grey brown siltstone
3880	grey brown siltstone
3920	grey brown siltstone
3960	limestone band within a claystone
4000	calcareous claystone above a limestone mudst layer
4020	siltstone within a claystone
4100	claystone with silty and calcareous patches siltst
4140	claystone siltst
4180	claystone siltst
4220	siltstone
4260	siltstone
4300	siltstone with pyrite
4320	claystone with silty patches

Table 1.6 The depth and description of the samples taken from section 16/16b-4

Details of cutting samples given by UNOCAL

Well 21/28b-7, drilled 1991

Location 57 deg 01'44.067" N, 00 deg 26'25.480" E

Sample Depth (m)	Lithology
2880	m. grained grey/green slightly calc. claystone, soft with loose qrtz grains common
2910	m. grained grey/green slightly calc. claystone, soft with loose qrtz grains common
2940	claysyone
2970	claystone
3000	brown siltstone, slightly sandy
3060	claystone within a brown siltstone
3090	brown siltstone , slightly sandy and calcareous with mica
3150	limestone, brown tan angular and crystalline
3180	m grained grey/green claystone with loose quartz and sand grains
3210	m grained grey/green claystone with loose quartz and sand grains
3270	m grained grey/green claystone with loose quartz and sand grains

Table 1.7 The depth and description of the samples taken from section 21/28b-7