# Pollen and Spore Assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland

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## SUMMARY

**Pollen and spore assemblages from the Oligocene Lough Neagh Group and Dunaghy Formation, Northern Ireland**

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This study was initiated to solve a stratigraphic problem for the Geological Survey of Northern Ireland prior to the revision in 1997 of the 1:250 000 map of the solid geology of Northern Ireland.

An exploratory drilling programme carried out by the Survey in 1983/1984 revealed the existence of previously unknown Tertiary sediments north west of the Tow Valley Fault. The boreholes revealed a sequence of clays and lignites that were attributed to the Lough Neagh Group. These lay above an interbedded sequence of lithomarge, pyroclastics and lacustrine deposits termed the Dunaghy Formation.

The Geological Survey required an age to be assigned to this formation and it was proposed that the use of the preserved pollen and spore assemblages offered the best means for dating the sequence. In order to achieve this four boreholes were analysed. Boreholes 13/611, 13/603, 36/4680 and 27/415 contain the Lough Neagh Group. In addition 13/611 and 13/603 contain the Dunaghy Formation.

From the pollen and spore assemblages recovered an Oligocene age is confirmed for the Lough Neagh Group and proposed for the Dunaghy Formation. This information led to the attribution of an Oligocene age to the Dunaghy Formation in the 1997 revised 1:250 000 Geological Map of Northern Ireland.

The palaeovegetation deduced from the recovered pollen and spore assemblages is in accordance with an Oligocene cooling. The climax angiosperm vegetation, predominantly consisting of temperate forms with some megatherm taxa, grew in a raised bog forest ecosystem within a fluvial-lacustrine environment.

All pollen and spore taxa recovered are described including new forms identified. A correlation of the four sections is proposed.

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# 1. INTRODUCTION

In 1983/1984, the Geological Survey of Northern Ireland undertook an exploratory drilling programme that revealed the presence of previously unknown Tertiary sediments north west of the Tow Valley Fault. These sediments extended from Stranocum through Ballymoney to Agivey in Counties Antrim and Londonderry, Northern Ireland.

The boreholes revealed a sequence of clays and lignites that were attributed to the Lough Neagh Group, well known from its extensive occurrence around Lough Neagh to the south. These sediments rested not upon fresh basalt but an interbedded sequence of lithomarge, volcanic acid tuffs, ashes, agglomerates and lacustrine sediments (comprising clay with Fe bands, occasional conglomerates, palaeosol horizons and beds of lignites and lignitic clays).

This interbedded sequence of lithomarge (a multicoloured, clay–based weathering product of the lavas), pyroclastics and lacustrine deposits was named the Dunaghy Formation. It was postulated that this sequence might have accumulated during the late Eocene. The problem facing the Geological Survey was to assign an age to these sediments for inclusion in the 1997 second edition 1:250 000 Geological Map of Northern Ireland. As no other means of biostratigraphically dating the sequence was thought possible, it was suggested that an analysis of the preserved pollen and spore assemblages might help to achieve this aim.

This research was undertaken in a response to the problem of dating the Dunaghy Formation. All pollen and spores identified from core samples have been described. For the purposes of classification within this study five new genera, six new species and three new sub-species have been informally erected. Nine new combinations are proposed. Seven pollen and six spore informal types are described.

The palynological assemblages obtained from the Lough Neagh Group and the Dunagy Formation, within boreholes 13/611 and 13/603 of the Ballymoney deposit, are compared with the Lough Neagh Group, from boreholes 27/415 from the Coagh region on the west shore of Lough Neagh, and 36/4680, from the Lough Beg area on the south east shore of Lough Neagh.

A palaeovegetation, palaeoenvironment and palaeoclimate are proposed for the deposits from these areas based upon the pollen and spore assemblages identified. Correlation of the sections based upon the pollen and spore assemblages obtained has been attempted.

All established sample preparation techniques used are fully described, as are newer methods that were investigated during the course of this work.

## 2. GEOLOGY OF THE LOUGH NEAGH GROUP

In Northern Ireland the dawn of the Tertiary saw subaerial vulcanism in the Palaeocene producing an extensive lava plateau. The north east of the province of Northern Ireland is dominated by basaltic lava flows which cover an area of approximately 400km$^2$. The basalts are separated into a Lower Basalt Formation of olivine basalt with associated fine banded andesite, overlain by the Interbasaltic Formation comprising laterite, bauxite, lithomarge and associated rhyolitic intrusives and pyroclastics. The overlying Upper Basalt Formation again comprises olivine basalt lava. The whole lava succession of Palaeocene volcanic episode has been dated by $^{40}Ar$-$^{39}Ar$ stepwise degassing method as 61-58 Ma. Thompson (1986).

After the Palaeocene volcanic episode the resultant lava plateau portrayed a synclinal form due to warping of the cooling crust. Subsequent large-scale fault-related subsidence (synclinal folding and block faulting) around the region of Lough Neagh produced a tectonic basin. The weathering of surrounding higher ground provided large quantities of siliciclastic sediment that provided the basin infill and this now constitutes the Lough Neagh Clays. Lignite horizons interbedded with the clays in the basin are perceived as fluvio-lacustrine in origin, deposited in marginal swamps and reworked into a lacustrine environment.

The Lough Neagh Group was once thought to only occur in the areas around the shores and beneath the waters of Lough Neagh, extending over an area of 500km$^2$ of which 300km$^2$ lie beneath the Lough. From cored sections in boreholes, it is now known that the Group extends over an area of approximately 25km from near Garvagh Co. Londonderry, through Ballymoney, to Stranocum Co. Antrim (see fig. 2.1).

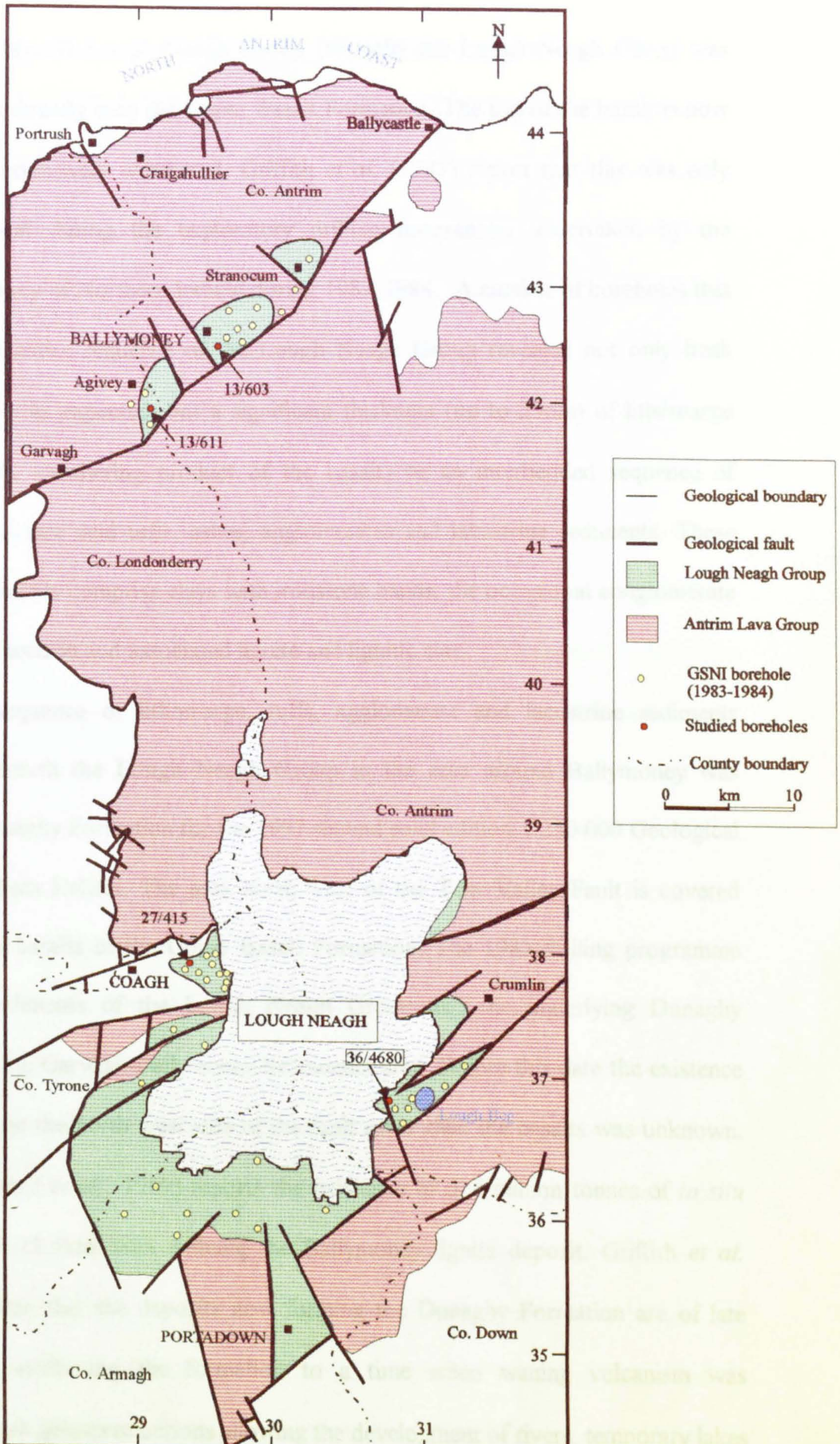



Fig. 2.1 Distribution of the Lough Neagh Group (after Griffith *et al.* 1987)

Previously the Lough Neagh Group (formally the Lough Neagh Clays) was thought to rest directly atop the Upper Basalt Formation. The top of the basalt is now known to be extensively weathered. Griffith *et al.* (1987) report that this was only brought to light during the exploratory drilling programme undertaken by the Geological Survey of Northern Ireland during 1983-1984. A number of boreholes that penetrated the entire sequence of the Lough Neagh Group revealed not only fresh basalt lava, as was expected, but a significant thickness (up to 296m) of lithomarge (the clay based weathering product of the basalt) or an interbedded sequence of lithomarge, volcanic acid tuffs, ashes, agglomerates and lacustrine sediments. These lacustrine sediments comprise clays with ironstone bands, the occasional conglomerate and palaeosol horizon and associated lignite and lignitic clay.

This sequence of lithomarge, tuffs, agglomerate and lacustrine sediments discovered beneath the Lough Neagh Group in the area around Ballymoney was named the Dunaghy Formation for the 1997 second solid edition 1:250 000 Geological Map of Northern Ireland. The area north west of the Tow Valley Fault is covered extensively by basalts of the Upper Basalt Formation. The 1983 drilling programme discovered sediments of the Lough Neagh Group and the underlying Dunaghy Formation in the Garvagh-Ballymoney-Stranocum area. Before this date the existence of any strata on the north west side of the fault other than the basalts was unknown. Quigg (in Parnell *et al.*, 1989) reports the existence of 628 million tonnes of *in situ* lignite over a 12.5km$^2$ area defining the Ballymoney lignite deposit. Griffith *et al.* (1987) postulate that the deposits now forming the Dunaghy Formation are of late Eocene age, attributing the formation to a time when waning vulcanism was interspaced with quiescent periods allowing the development of rivers, temporary lakes and vegetation. The climate and accumulation of vegetative matter was sufficient to allow the formation of peat beds that are now preserved as lignite seams.

## 2.1 The Lough Neagh Group, an historical review

There has been a long history of study of the sediments of the Lough Neagh Group. The existence of clay deposits and associated lignite around the shores of Lough Neagh has been known for many centuries. The clays have been utilised in the manufacture of a type of coarse pottery, through extraction from open or bell shaped pits, and the lignites as a fuel. More recently the clays have been mixed with fireclay to manufacture brown glazed sanitary pipes. The English writer Nennius, at some time between the seventh and ninth centuries, referred to the petrifying powers of the water of Lough Neagh, reporting that the lake called Lough Neagh has the property of changing wood into stone. This thought probably arose from the discovery of silicified wood around the margins of the Lough.

The first mention of lignites and fossil wood was by Barton (1751) who described clays and black wood from a section near the mouth of the Glenavy River. The significance of the recording of black wood prompted the Marquis of Hartford to drill for coal at Sandy Bay on the east shore of the Lough in 1799 (Stewart, 1800).

Griffith (1837-1838) observed lignite seams in blue clay to a depth of 76 ft 6 in (23.3m) and noted that boreholes, drilled 2 miles (3.2km) south east of Coalisland at Annaghmore, penetrated 292 ft (89m) of Tertiary clay. He concluded that the basin of deposition must have been more extensive and deeper than the present day Lough.

In a paper on the mode and formation of Lough Neagh, Hardman (1875) reports sections of clay and lignite used for the manufacture of pottery and for fuel respectively. He regarded the clays of the Lough Neagh Group as of a considerably later date than the basalts considering them to be of Pliocene age, based upon the mistaken belief that the basalt was of Miocene age. In an appendix to his 1875 paper, and again in Hardman (1876), a Pliocene age is attributed to the clays noted as lying on basalt and covered by drift in a section by the Crumlin River near Crumlin on the eastern shore of Lough Neagh. Evidence for this age assignment was based upon the occurrence of a species of *Unio*, the clays having been found to be barren of any diatoms.

Swanston (1879) effectively disparages Hardman's (1875) and (1876) evidence as when he collected samples of the supposed *Unio* he had them identified as the common mussel *Mytilus edulis*. The discovery of four species of foraminifera in the shell beds, which were noted as common in coastal sediments and in drift beds further disputed Hardman's assignation of the clays as belonging to the Lough Neagh Group and Pliocene in age. After examination of the stratigraphic position of the clay beds, Swanson concluded that the clays described by Hardman were a deposit of boulder clay and a glacial or post-glacial deposit. Regarding the age of the Lough Neagh Clays and associated lignite, Swanston notes that they may repose upon the basalt but may be of any age between that of the basalt and the clays of the glacial epoch, in all probability spanning the entire period.

Gardner (1885) records the views of Hull (1878) and Kinahan (1878) with regard to the Lough Neagh beds being of Pliocene age, but notes:

"... older writers agree with members of the Belfast Field Club, especially Messieurs Grey and Swanson in considering their age to be contemporaneous with the basalt; and this view I do not hesitate to uphold." (p. 84)

Gardner notes the composition of the Lough Neagh Formation to be similar to the Tertiary formation at Bovey. He regards it as having a stratigraphical position above the Chalk, beneath the Boulder Clay and believes it to rest upon basalt.

Cole *et al.* (1912) agreed that Hardman's view of the Lough Neagh Clays being of Pliocene age was a possibility, however, they did not ascribe a definite age to the sediments other than to say that they were post Eocene.

In 1918-1919 the Department for the Development of Mineral Resources sank a borehole at Washing Bay off the south-west shore of the Lough reaching a depth of 1969ft 4 in (600.25m) which penetrated the Lower Basalt Lavas. Plant specimens, which were recovered from the bore, were examined by Johnson and Gilmore (1921a, 1921b). They described the presence of *Sequoia couttsiae* and three new species of *Dewalquea*: *D. hibernica*, *D. fraxinifolia*, and *D. denticulata*. These authors noted that *S. couttsiae* was identical in every detail to that described by Heer (1862) from sediments at Bovey Tracey and that, as such, it indicated an Oligocene age for the Lough Neagh Beds. Johnson and Gilmore (1921b) noted that the most prevailing type of *Sequoia* they recorded had adpressed foliage of squamiform leaves as occurs in *S. sempervirens*. They report that this is the prevailing type of *Sequoia* noted by Heer in the Bovey Tracy deposits and note that Gardner (1885) reports that *S. sempervirens* develop more of this type of leaf when introduced to a warmer climate. This was taken as evidence that adpressed foliage was more adapted to a warmer climate than spreading foliage.

Wright (1924) described three zones within the Lough Neagh Clays from the Washing Bay borehole: the Upper Clays and Sands, 833ft (254m) of alternating sand and clay; the Middle shales, 127ft 7in (39m) of a brown and distinctly shaley lithology containing the first well preserved plants in the bore; the Lower Clays and Sands, a unit 187ft 5in (57m) thick resting upon lithomarge marking the base of the Lough Neagh Series. Wright referred to the zone of grey and red lithomarge, 71ft (21.5m) in thickness, which lay beneath the Lough Neagh Series and atop the Upper Basalts as the Postbasaltic Zone of Weathering. He noted that from this evidence the suggestion that the Lough Neagh Clays were of Interbasaltic age could be regarded as totally disproved. The Clays were reported to be certainly not of Pliocene age, but belonging to the older Tertiary as evidence indicated that they were deposited previous to Miocene folding and faulting. Cole and Hallissy (1924) were of a similar opinion to Wright in believing that the Lough Neagh Clays were probably pre-Miocene in age.

Between 1923-1925, under instruction from a Mr. H. D. M. Barton of Antrim, a borehole was sunk at Aughrimderg, Clonoe, 2½ miles (4km) north-west of Washing Bay borehole, reaching a depth of 1663ft (507m) and penetrating the full extent of the Lower Basalt Series to reach chalk. Hartley (1948) describes the lithological succession noted within the Aughrimderg borehole and a correlation between it and the Washing Bay borehole, noting the disappearance of the Post Basaltic Zone of the Upper Basalt Series between the two. From this he concluded that a considerable time interval must have elapsed during which much denudation must have occurred. No fossil material was described from this borehole and Wilkinson *et al.* (1980) note that the core samples were not retained.

Hartley (1951) presented a note on the age of the Lough Neagh Clays by giving a very brief summary of some of the previous literature on the subject. He concluded that it was apparent that no undisputed or precise determination of the age of the clays had been possible either by palaeontological or purely geological methods up to 1924.

In 1949 Dernagh No. 1 borehole was drilled east north east of Coalisland Railway station. This was followed by Dernach No.2 in 1954, 70 yd (64m) west of No. 1, and the Mire House borehole, 1½ miles (2.4km) east of Coalisland Railway Station. Fowler and Robbie (1961) describe the section recovered from the boreholes and present a correlation of the Dernagh No.1, Mire House and Washing Bay boreholes. In Dernagh No. 1 Fowler and Robbie note that some difficulty was experienced in determining the Lough Neagh Clay/Basalt junction as basalt fragments were found in the basal bed of the Lough Neagh Clays. The Interbasaltic bed was not found in this borehole, or the Mire House, so the basalts were considered to belong to the Lower Basalt Series.

Watts (1962) presents brief results of some studies of the Pollen assemblages of the Irish Tertiary deposits. Pollen assemblages from the Lough Neagh Clays of the Washing Bay and Mire House boreholes were believed to indicate an early or middle Oligocene age. From a boring in the Lough Neagh Clays, to test for a new bridge foundation at Verner's Bridge near Dungannon, County Tyrone, Watts (1963) records the presence of pyritised but well-preserved seeds of *Eurya stigmosa*. He reports that this discovery does not contradict the age of the Lough Neagh Clays as presented in his 1962 paper, but in his 1963 paper he attributes a late Eocene or early Oligocene age to the deposits.

In order to investigate the economic potential of the clay and lignite of the Lough Neagh Group a series of boreholes was drilled. In 1964 the Geological Survey initiated a borehole programme to investigate the lignite potential of the Crumlin area. The investigation of the ceramic clay characteristics of the Lough Neagh Clays led to a series of shallow boreholes being sunk by English Clays Lovering Pochin and Co. Ltd. In 1975-1976 shallow boreholes were drilled by the Geological Survey to further investigate the potential of the lignite as an economic deposit (Bazley, 1978). The real importance of the lignite deposits was not discovered until the drilling programme of Mossbrook Colliery Ltd. and Shirland Fireclay Ltd. in 1978 whilst drilling for shallow Carboniferous coal deposits at Ballycastle, East Tyrone.

Wilkinson and Boulter (1980) present an Upper Oligocene age for the Lough Neagh Clays based upon the pollen and spore assemblages recovered from cuttings from the old boreholes at Washing Bay, Mire House and Dernagh No. 1, in the Coalisland region to the south west of Lough Neagh, and from core samples from more recent boreholes drilled in the 1970s at Bellbrook and Ballynakilly. Wilkinson *et al.* (1980) report investigations of the pollen and spore assemblages of the Lough Neagh Group undertaken as part of a detailed study of Tertiary deposits in the western part of the British Isles (Wilkinson and Boulter, 1980). In this study they report that the pollen and spore investigations from the Mire House and Washing Bay boreholes were based upon core samples. The conclusion of this work was that the Lough Neagh clays were of Chattian age.

Parnell *et al.* (1989) and Parnell and Meighan (in Parnell *et al.*, 1989) provide valuable recent data on the lignite and associated sediments of the Lough Neagh Basin.

## 2.2 Lithology of the Lough Neagh Group

The following is a brief summary of the lithological characteristics of the Lough Neagh Group principally after Parnell *et al.* (1989).

The group consists of clays, sandy clays and sands with thin bands and irregular nodules of siderite as well as beds of lignite and lignitic clay. Conglomerates occur near to the base of the sequence and towards the top associated with beds of sand.

### Conglomerates

Being mostly matrix supported and consisting of basalt and chalk fragments, the conglomerates or pebble beds pass downward into brecciated *in situ* regolithic basalt. Higher in the sequence thin layers of conglomerate occur containing a variety of pebbles derived from basement basalt, dolerite, quartzite and Carboniferous limestone.

### Sandstones

Sandstones occur at numerous levels in the sequence and exhibit low-angle cross-lamination. They can broadly be divided into well sorted, containing rounded quartzose grains, and poorly sorted, containing fine to coarse angular sand grains within a clayey matrix.

### Clays

The clays that are often sandy and occasionally micaceous are pale coloured over the top of the formation and generally darken in the lower half. Their colouration is variable from black through shades of grey and brown to green. Beds are in general massive, lamination and bedding being rare. Many are organically rich and include plant material in various states of preservation. In some beds roots, and occasionally stems, may be noted in growth position while in others plant material is finely disseminated.

The fauna of the sequence consists of gastropods and freshwater bivalves. Parnell *et al.* (1989) extracted ostracod carapaces of indeterminate genus and diatom fragments. He reports that a borehole in Coagh containing a bed several centimetres thick was composed mostly of diatom frustules. He also reports the occurrence of fragments of salamander teeth in a mudstone from the Coagh district.

**Lignite**

The Lignites comprise woody, non-woody and clayey forms of varying composition containing up to 75% organic carbon. Black, woody lignites may be almost pure and plant fragments and cell structure may have been preserved by silicification. Non-woody forms tend to be more massive and not display any recognisable plant structure. Clayey lignites are variable in colour and composition depending upon the amount of clay mixed with the woody material. The lignite may occur interbedded with all the lithologies outlined above, but is more particularly noted grading into darker clays.

Parnell *et al.* (1989) state that the low vitrinite reflectance of the lignite indicates that is has been buried to a depth of less than 1km and subjected to temperatures of no more than 50°C. N.M.R spectra taken by Fawcett and Grimshaw (1989) indicate that the organic compounds within the lignite have an affinity with lignin and peat and not brown coal.

## 2.3 Mineralogy and Provenance of the Lough Neagh Group

Seymour (in Cole *et al.*, 1912) reported that the clays were derived from the denudation of lithomarge of the Interbasaltic Zone between the Upper and Lower Basaltic groups. He then concluded that, if this were the case, the Upper Basalt must have had a limited distribution as it was improbable that it was entirely removed to expose the Lithomarge beneath.

Wright (1924) expresses the opinion that, given the evidence at that time from boreholes, the clays appear to have been derived from destruction of a zone of lithomarge weathering of post-Basaltic age being partially derived from the destruction of the Upper Basalt lavas. As previously stated, the Washing Bay borehole revealed the Postbasaltic Zone of Weathering comprising grey and red lithomarge, 71ft (21.5m) thick, lying beneath the Lough Neagh Series and above the Upper Basalts.

Fowler and Robbie (1961) proposed that Upper Carboniferous sediments, probably Millstone Grit, were responsible for the provenance of the Lough Neagh Clays. Quartz pebbles and sand were derived from granite and sandstone whilst clay minerals, principally illite and kaolinite, originated from shales and fireclays in the Carboniferous formation or from kaolinized Newery and Mourne Granites.

In order to determine the provenance of the sediments of the Lough Neagh Group, Shukla (in Parnell *et al.*, 1989) carried out a detailed petrographic analysis of heavy minerals in the Group and on their possible source rocks. The results identified several sources:

1. Acid igneous rock
2. Basic and ultrabasic rock
3. Pegmatitic
4. High grade metamorphic rock
5. Sedimentary sources

Out of the five sources four can be matched to heavy minerals in the Dalradian metasediments, the Ordovician Tyrone Igneous Complex and Tertiary basalt Lavas.

Shukla noted that the occurrence or non-occurrence of zoning within inclusions in zircon grains, as well as shape, colour and chemical composition, was particular to certain members of the Tyrone Igneous complex. Provenance may also be determined by variations in elemental composition of zircons and opaque minerals.

The Clay was found to predominantly source from Tertiary basaltic lava, whilst sandstones and silts principally sourced from the Tyrone Igneous Complex and pre-Tertiary sediments.

## 2.4 Structural setting

Parnell *et al.* (1989) state that the Lough Neagh Basin was probably a group of sub-basins and that the existence of a continual depositional system covering the entire region from the Ballymoney deposits in the north to the main Lough Neagh Group deposits around the present day Lough was unlikely. The sediments are thought to have accumulated with contemporaneous faulting in a syndepositional extensional regime (Parnell *et al.*, 1989; Fowler and Robbie, 1961). The NE-SW and NNW-SSE trend of the faults and of many Palaeocene dykes is suggestive of E-W extensional activity. Tertiary strike-slip reactivation of Mesozoic NE-SW faults may have occurred (Parnell *et al.*, 1989).

The Ballymoney basins distributed along the Tow Valley Fault may be related to transtentional (sinistral) movement along the fault zone.

## 2.5 Clay Mineralogy

In the Dungannon Memoir, Fowler and Robbie (1961) record that the main clay type in the Lough Neagh Clays is a pale grey and bluish grey sandy clay, predominantly composed of illite, and kaolinite. Stuart and Gallagher in Parnell *et al.* (1989) used X-ray Diffraction and Differential Thermal Analysis and X-ray Fluorescence Spectroscopy to analyse the clay. Their results show kaolinite to be the commonest clay mineral occurring with small quantities of micas and illite. They did not record any montmorillonite. These results are thought to indicate a non-marine sedimentary environment.

Stuart and Gallagher report that the Lough Neagh Clays depict many similarities with the Barton Clay but not the Early Eocene London Clay. The Lough Neagh Clays share some common features with clays in the Bovey Tracy and Petrockstow Beds of Devon, the Gault, Wealden and Wadhurst Clays and the Lias and Oxford Clays.

**2.6 Lignite geochemistry**

Meighan and Dewison (in Parnell *et al.,* 1989) present a brief summary of the geochemistry of a small sample of lignites from the Crumlin deposit, Coagh and Ballymoney. They conclude that the lignites from the three areas are all geochemically very similar. They contain higher concentrations (that may be of an order of magnitude) of the 'more basaltic' trace elements V, Cr, Ni, and Cu than their counterparts from West Germany and New Zealand.

Meighan and Dewison conclude that geochemical data suggests that the weathering products of the Tertiary basalts exerted a major control in the inorganic geochemistry of the lignites.

**2.7 The Coagh deposit**

The existence of a lignite deposit in the Coagh region was discovered in 1984 by the Geological Survey drilling programme. Seismic surveys of the area run in 1981-1982 and 1984 identified a shallow basin-like structure. This was interpreted as the top of the Antrim Lava Group, and the overlying low velocity layer was thought to be indicative of the existence of deposits of the Lough Neagh Group (Griffith *et al.*, 1987).

The Lough Neagh Group of the Coagh deposit comprises four distinct lithological units (Griffith *et al.*, 1987).

1. Blue-grey to brown, clay and sandy clay containing ironstone bands. Thin beds of lignitic clay and lignite are rare (<2m thick). Conglomerates may occur near the base of the Group. The junction with the underlying Antrim Lava Group is often imprecise due to the deep weathering of the basalt.

2. Overlying the basal clay unit is a series of clayey lignite and lignitic clay passing into lignite with thicknesses varying from 19-49m. The lignite occurs in single seams in the western part of the deposit and comprises multiple seams towards the shores of Lough Neagh.

3. Olive green clays with thicknesses varying from 18-65m overlie the lignite usually with a sharp contact.

4. The uppermost sequence of the Lough Neagh Group comprises a sequence of brown-grey and blue-grey sand and sandy clay and clay often containing ironstone bands and nodules. Thin layers of lignite and lignitic clay (<1.5m thick) may occur.

**2.8 The Ballymoney deposit**

Also discovered by the Geological Survey drilling programme of the early 1980s was the existence of sediments of the Lough Neagh Group north of the Tow Valley Fault.

The 1967 gravity map of Northern Ireland portrays a steep gravity gradient running NE-SW from Ballycastle through Ballymoney and further SW. This zone correlates with the Tow Valley Fault, Caledonoid in origin, undergoing reactivation in the Mesozoic and in the early and late Tertiary. Bouguer anomalies dominated by a low gravity field are recorded between the Tow Valley Fault and the North Antrim coast. These gravity anomalies were attributed to a thick basin of Mesozoic and Carboniferous rocks underlying the Basalt as Permo-Trias strata had been identified in a borehole at Port More (Bennet in Wilson and Manning, 1978). The discovery of clay with wood and lignite in a water borehole drilled in the SW of Ballymoney in 1983 came as something of a surprise as basalt was expected (Griffith *et al.*, 1987).

The drilling of boreholes by the Geological Survey confirmed the existence of the strata identified from the water borehloe. Griffith *et al.* (1987) report that review of the gravity data by Bennett (pers. comm. Griffith *et al.*, 1987) identified the existence of two separate closures around the area of low Bouger anomalies at Agivey, Country Londonderry and Ballymoney-Stranocum, Country Antrim. A SE deflection of isogals representing the Tow Valley Fault at Ballymoney and Stranocum was interpreted as having been caused by a SE thickening wedge of Tertiary sediments on top of the Tow Valley Fault Zone (see fig. 2.2).

Ground based magnetometer surveys in the Agivey-Ballymoney-Stranocum areas established the extent of the deposit. Results from these surveys indicate that the southern edge of the sedimentary basin lies 1.5 km south of Ballymoney Railway Station and that both the southern and western margins of the basin may be faulted.

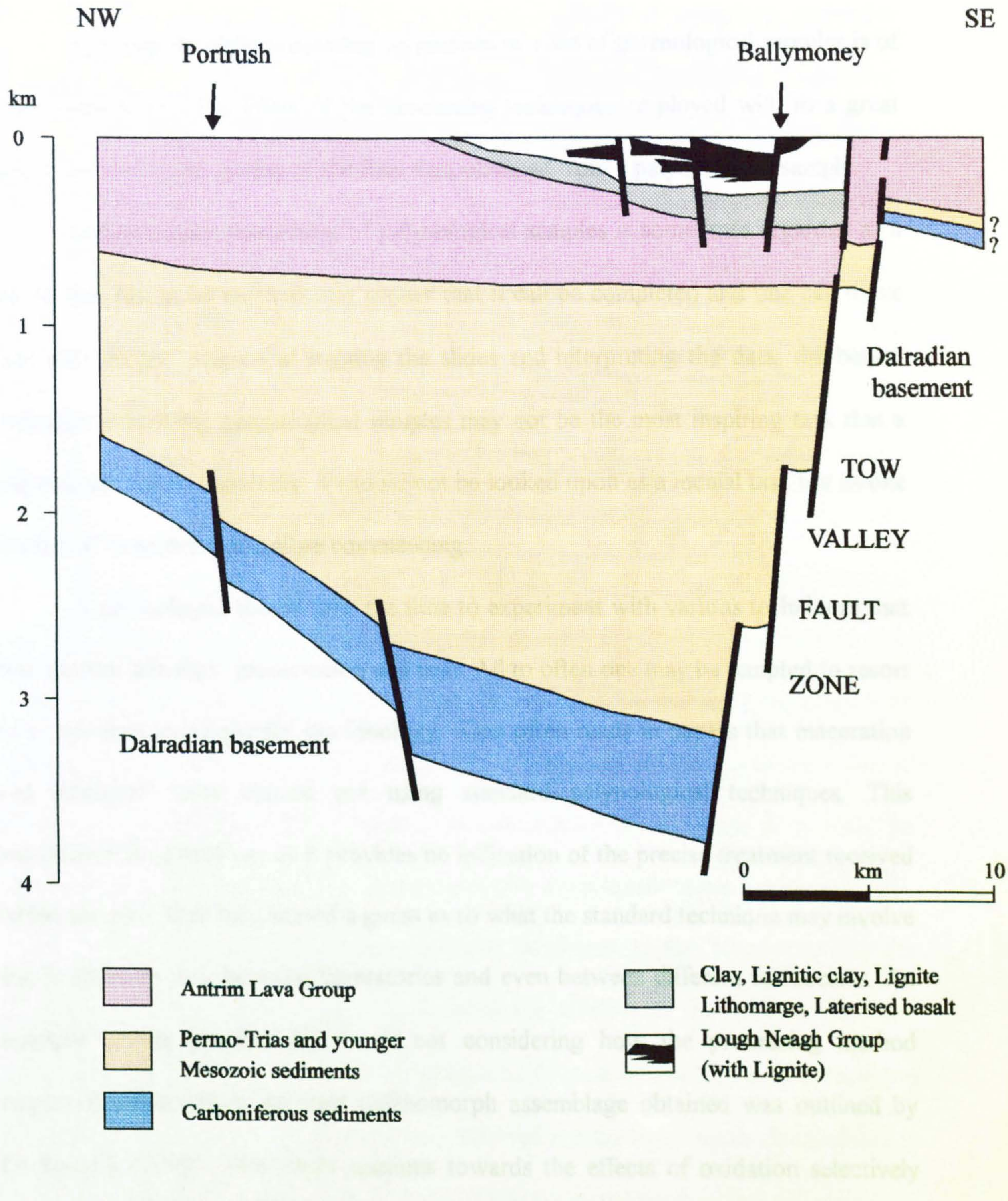



Fig. 2.2 Cross section of the north Antrim Basin, Ballymoney deposit. (after Griffith *et al.*, 1978)

# 3. SAMPLE PREPARATION

Applying the right processing techniques to a set of palynological samples is of prime importance. The effect of the processing techniques employed will, to a great extent, determine the quality of the final data obtained from a palynological sample.

Unfortunately, processing of palynological samples is sometimes regarded as a labour that has to be endured: the sooner that it can be completed and one can move onto the 'proper' science of logging the slides and interpreting the data, the better. Although processing palynological samples may not be the most inspiring task that a palynologist has to undertake, it should not be looked upon as a menial task but as one worthy of consideration before commencing.

A palynologist should take the time to experiment with various techniques that best suit the lithology, preservation and task. All to often one may be tempted to resort to a 'standard technique for the lithology.' One often reads in papers that maceration and oxidation were carried out using standard palynological techniques. This information is of little use as it provides no indication of the precise treatment received by the samples. One may hazard a guess as to what the standard technique may involve but procedures vary between laboratories and even between different technicians. An example of the possible pitfalls of not considering how the processing method employed might affect the final palynomorph assemblage obtained was outlined by Dodsworth (1995). This paper cautions towards the effects of oxidation selectively removing the Gonyaulacineae assemblage resulting in assemblages dominated by Peridiniineae in mid-Cretaceous 'black shales'. Harland (pers. comm. in Dodsworth, 1995) reports of the selective removal of peridiniineaen dinocysts during oxidation of Quaternary kerogen.

The examples of selective removal quoted relate to dinoflagellate assemblages, however, Jolley (pers. comm.) has warned of the effects of potassium hydroxide (KOH) solution on the exine of pollen producing degradation and swelling of grains.

When embarking on this piece of research one of the aims was to explore the possibility of applying certain techniques to the various lithologies encountered. Consequently much time was spent in the laboratory experimenting with various procedures and techniques, not all of which were successful. Practicality was a prime concern as one has to produce results within a finite time. The methods finally employed were a compromise between achieving acceptable results and finishing processing the samples within time limits.

An initial aim was to try to produce a truly quantitative unsieved palynological slide, i.e. one that would contain as many palynomorphs from the original rock sample as was experimentally possible. If this could be completed satisfactorily the amount of pollen preserved in a specific lithology could be calculated. If this could be achieved for an autochthanous deposit of lignite, the pollen productivity of the flora could be estimated to a greater degree of accuracy than with a non-quantitative sample.

Processing methods that are routinely employed in the laboratory for the preparation of palynological samples involve the sieving of the residue after the different stages of acid maceration and oxidation to neutralise, clean and concentrate the residue. The process of sieving employed uses a nylon sieve mesh clamped into a PTFE sieve frame. The residue is poured into the sieve and washed through with a jet of water via a rubber hose from a tap. This method becomes increasingly difficult if a sieve mesh smaller than 20$\mu$m is used. While this size of mesh may be satisfactory for the collection of larger marine microplankton, it is far too large for the collection of small pollen. In this study mesh sizes of 5$\mu$m and 7$\mu$m were initially used in an attempt to collect any very small pollen that might exist in a sample. The time and patience required to sieve a fine grained sediment through such small mesh sizes was exhaustive and somewhat trying. The problems increase if a large mass of sediment is being processed or the lithology is of a particularly fine-grained nature, e.g. clay. The results of using a $5\mu m$ and $7\mu m$ mesh produced preparations that did not appear to have a pollen assemblage of different composition from that of a $10\mu m$ sieve. As a result of this the effort spent for no apparent gain was not judged to be worthwhile.

The sieving stages of preparation were identified as a source of pollen loss. Sediment became trapped in between the sieve mesh and the sieve holder. The use of a new, tight fitting sieve holder over that of an old, well used looser fitting improved this, however, an increase in the incidence of small tears in the mesh as it was clamped into the sieve was noted. These tears may often go unnoticed and then increase in size as the bottom of the mesh is rubbed with the fingers to loosen sediment in the sieve to aid its throughput. The same problem was noticed when suction was used to aid the sieving process.

In order to provide suction to aid the washing of residue through a sieve mesh, the following apparatus was set up. A suction valve was attached to a tap and to the side arm of a plastic Buchner flask, via lengths of rubber hose. A rubber flange was attached to the top of the flask to provide a seal upon which the sieve holder was placed. This process was found invaluable when processing fine-grained clays especially when experimenting with $5\mu m$ and $7\mu m$ sieve meshes. The method is not flawless. Suction must not be too great or applied for too long a period of time as clogging of the mesh occurs and consequently the mesh may be sucked out of the holder with the loss of the sample. There was concern as to whether pollen could be sucked through the mesh. The drawing of residue into spaces between the mesh and holder also occurs.

As residue was washed through the sieve with the water jet, pollen was unavoidably lost throughout splashing out of the sieve and in the fine aerosol that resulted, even when care was taken to keep the pressure of the water jet low.

As the sieving stage of preparation was seen to be a source of residue and hence pollen loss, a method to remove this stage from the preparation procedure was attempted.

In order to obtain a quantitative unsieved preparation the following method was experimented with.

To prevent sample loss and contamination it was decided to carry out all the procedures in one centrifuge tube. Whilst this method has proved successful for the preparation of a small mass of a pollen rich lithology and has been routinely employed in Quaternary palynological studies, it was found to be unsuccessful for preparation where larger quantities of rock needed to be macerated.

The sample was mechanically disaggregated using a pestle and mortar. A known mass of rock, up to 20g, occasionally larger, depending on the lithology, was placed in a polyethene beaker into which approximately 40ml of 40% hydrofluoric acid was added. The rock was left to macerate with daily stirrings until complete breakdown was achieved. The process of diluting a sample in a beaker and allowing sufficient time for the residue to settle before successive decants and dilutions could take place to eventually neutralise the residue was time consuming. It was therefore decided to employ centrifugation as a method to quickly draw down the residue and so eliminate the lengthy settling period that would otherwise be required.

The hydrofluoric acid was decanted and the residue was washed into a 100ml capped polyethene centrifuge tube. This was then topped up with water, capped and centrifuged at a speed between 2000 and 3000rpm for 4 minutes. Four samples could be centrifuged at any one time. Despite the perceived time saving advantages of this method, it was found to be rather labour intensive as many centrifugations were required to fully neutralise the residue. Other tasks in the laboratory could not be satisfactorily performed while centrifugation was taking place as time was too short.

Once neutrality was achieved a sample of the residue was inspected under a microscope to assess the oxidation time required and then returned to the centrifuge tube where oxidation occurred. Upon completion the tube was topped up with water to terminate, or at least lessen the reaction, then centrifuged and decanted as many times as necessary until neutrality was achieved. As with the dilution of the hydrofluoric acid, this process was found to be lengthy and required many centrifugations to reach neutrality. The problem was compounded when a solution of KOH was used to remove the humic acids released after the initial oxidation. The removal of the KOH residue by dilution, centrifugation and decanting the supernatant took an excessive amount of time compared to washing through a sieve, as many centrifugations and dilutions had to be employed to remove the reaction residue. The termination of the reaction could not be guaranteed to have occurred at the desired time. Topping the centrifuge tube up with water and following this with numerous centrifugations meant that the reaction could not be lessened or stopped as effectively as it had been when diluted in a litre of water and immediately sieved.

One of the main problems identified with the centrifugation method was its ability to cope with the quantity of rock needing to be macerated for presumed low yielding lithologies. The 100ml centrifuge tube (the largest size that the laboratory equipment could use) was not a very large reaction vessel when quantities of rock up to or in excess of 20g were used. As a consequence of this, maceration in hydrofluoric acid was a lengthy process. In some cases complete maceration could not be achieved at all or in an experimentally acceptable time.

Another problem associated with this method was the decanting and centrifugation of the sample itself. Various centrifugation times and speeds were experimented with. Speeds above 3000 rpm were thought ill advised for fear of causing mechanical damage to palynomorphs. Incomplete compaction of the residue into the bottom of the tube resulted in the loss of palynomorphs when the supernatant was decanted, thus rendering the method as obsolete since the prevention of palynomorph loss was its aim. Lengthy centrifugation times to ensure the removal of more palynomorphs from the supernatant were not conducive to experimental time and the smooth running of the laboratory as the apparatus was not free for the use of others and the overall time spent per sample was prohibitive. Total removal of palynomorphs from the supernatant was not achieved.

It became apparent that this method was not producing the desired aim and that retention of all palynomorphs would not be possible. It was decided that whichever processing method was employed, it should be applied to all similar lithologies so that a consistent loss of palynomorphs could be assumed and results of pollen abundance in the lithologies be compared.

The method resorted to was one of 'traditional sieving.' The procedures followed for the differing lithologies are outlined below. Throughout the processing of samples single use, disposable polyethene pots and plastic pipettes were used to prevent sample contamination from unclean glassware wherever possible.

### 3.1 Non-lignitic samples

#### Disaggregation and acid maceration

1. The sample was mechanically disaggregated using a pestle and mortar into pieces approximately the size of small peas.

2. A known mass of rock was placed in a 250ml polyethene pot to which approximately 40ml of concentrated hydrochloric acid (35%) was added to remove any calcareous material. The sample was stirred at regular intervals. Upon the cessation of any effervescence, or after a period of an hour if no effervescence was evident and the disseminated sample had settled, the acid was decanted and the pot topped up with water. This process was repeated until neutrality was reached.

3. Approximately 40ml of 40% hydrofluoric acid or sufficient to cover the sample was added. The acid was added carefully by degrees as a vigorous exothermic reaction is sometimes noted when adding HF to clays. The residue was stirred daily until maceration was complete and no grittiness was felt with the stirring rod.

4. The acid was carefully decanted and the pot topped up with water and left to settle overnight or for a minimum of six hours. This allowed two decants to be completed during one laboratory day. This process was continued until neutrality was reached.

5. When neutrality was achieved the sample was washed through a 10$\mu$m sieve and a small sample was pipetted onto a clean microscope slide for examination under a laboratory microscope to assess the oxidation time required. The inspected residue was then returned to the sample.

**Oxidation and removal of humic acids**

Due to the nature of pollen exine and its use in identification, excessive oxidation should be avoided. All lithologies within this study required only mild oxidation to liberate the palynomorph assemblages. In some cases pollen could be clearly recognised in the kerogen post maceration in hydrofluoric acid. Experimentation and experience showed that a short oxidation with concentrated $HNO_3$ (70%) was all that was required to liberate a palynomorph assemblage. Oxidation times varied between 30 seconds - 5 minutes.

After oxidation was complete the sample was washed into a litre beaker full of water to dilute the acid and stop any further reaction and then washed through a 10$\mu$m sieve mesh. The neutralised residue was rinsed with a 1% solution of KOH, to remove humic acids liberated by the oxidation. The residue was then washed through a 10$\mu$m sieve until the water ran clear, signifying the removal of the KOH reaction products.

If at this stage of preparation a large amount of mineral remained in the sample and obscured the pollen and spore assemblage, it was removed by heavy liquid separation as follows.

**Mineral removal**

1. The residue was pipetted, with as little water as possible, into a 55ml plastic screw topped centrifuge tube to a level not exceeding the top of the tapering base.

2. A zinc chloride solution with a specific gravity of 2.7 was added to the 50ml mark. In order to prevent the formation of a precipitate a few drops of conc. HCl were added. The lid was replaced and the tube agitated to ensure a thorough dispersal of the residue and acid throughout the heavy liquid medium.

3. The sample was placed in a centrifuge, balanced, and spun at 2200rpm for 12 minutes.

4. Upon completion of centrifugation the tube was carefully removed from the centrifuge ensuring that no agitation took place. The mineral matter had separated and collected at the base of the tube whilst the organic matter floated atop the zinc chloride solution.

5. The organic fraction was pipetted from the tube into a litre beaker of water. The tube was then gently agitated to dislodge any remaining residue seen to be adhering to its sides. The top fraction of the zinc chloride solution was then decanted into the litre of water to ensure that all the organic residue had been recovered.

6. A few drops of conc. HCl were added to the beaker to further ensure no precipitation occurred and hence aid the process of sieving the mixture.

7. The mixture was washed through a 10$\mu$m sieve.

If the sample did not contain significant amounts of large organic debris it was pipetted into a sample tube ready for slide preparation.

**Removal of organic debris**

During the preparation of samples it became evident that in many preparations a large amount of organic debris, plant cuticle, fungal hyphae, and particles of uncertain origin were present. During the preparation of slides the residue had to be strewn thinly to avoid obscuring the pollen and spores. A common technique used to remove such matter is to swirl the sample and top sieve it with a mesh of 125$\mu$m or smaller. Swirling a sample is effective to some extent but there is often much organic debris left in the preparation. There is also the disadvantage of removing some of the pollen and spore assemblage. A method to effectively remove the organic debris by a qualitative separation of the pollen and spores was sought.

### 3.2 Alcohol separation of organic debris

Hansen and Gudmundsson (1979) describe a technique to achieve such a quantitative separation of palynomorphs from unwanted organic debris. The technique is based on the theory that palynomorphs, unlike most organic debris, are hollow particles. If a residue is suspended in alcohol, the alcohol fills the cavity and dilutes the water, reducing the density of the hollow particles (palynomorphs), whilst the density of the organic debris remains unchanged. The density of the palynomorphs is reduced to less than $1 g/cm^3$ as the cavity comprises the greatest part of the volume. As a result of this, in a layered column of water and alcohol palynomorphs will remain on an alcohol/water interface.

As Hansen and Gudmundsson (1979) give no indication of the dimensions of their separation column, a column was designed, based upon their line drawing, and specially constructed using common sense with regard to the volume of residue requiring separation. The column consisted of a graduated glass burette tube 75cm in length with a bore of 1.5cm, see fig. 3.1. A series of 3 taps projected from the side of the tube positioned approximately 21cm, 33cm and 65cm from the top of the column. The tap mechanisms were of standard plastic burette design to facilitate easy dismantling for cleaning. There was a tap of the same construction at the base of the tube.

The following method based upon that outlined by Hansen and Gudmundsson (1979) was employed. Separation in the column was run after the oxidation stage in the processing of samples. The sieved residue was washed from the sieve into a

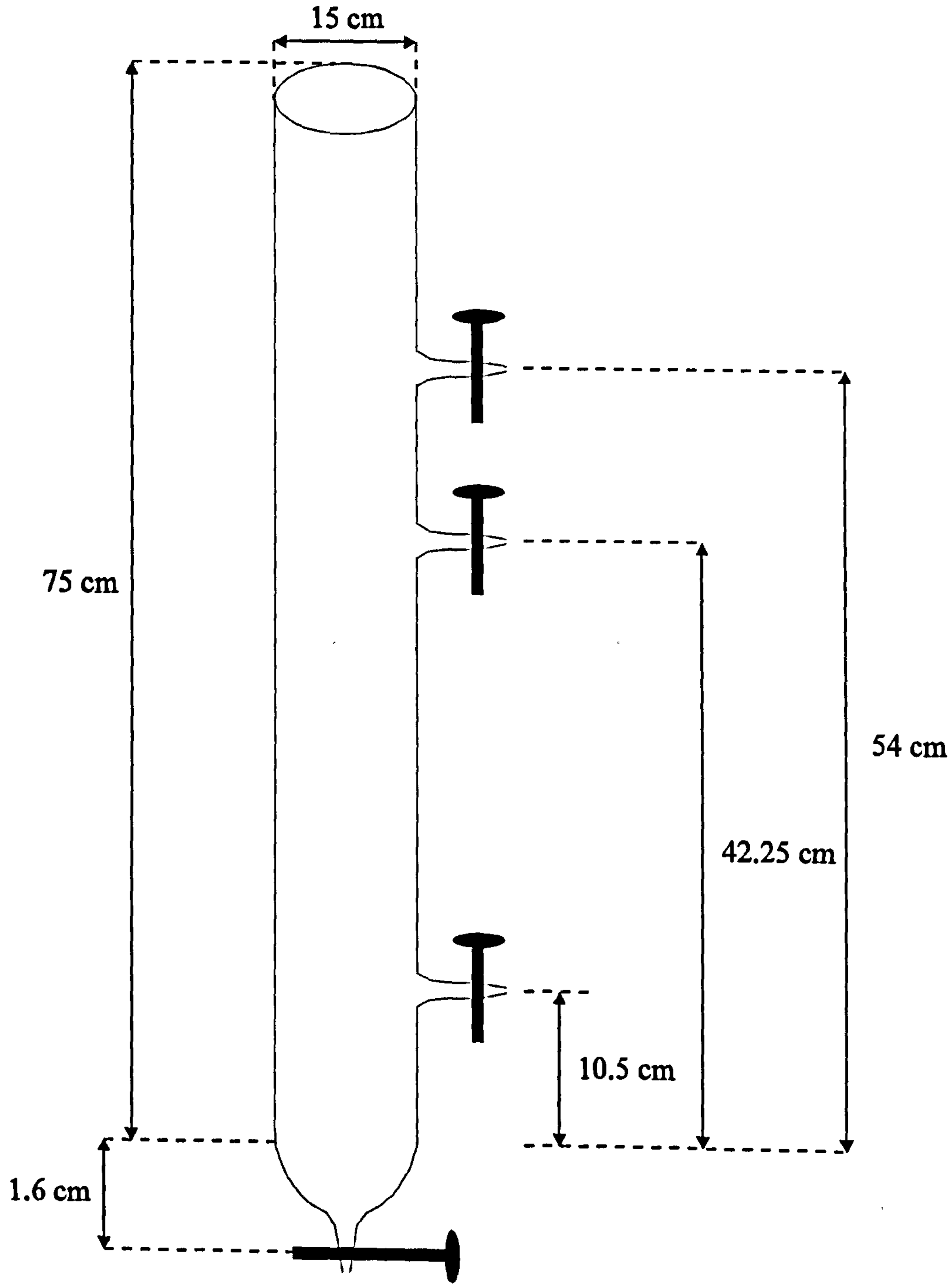



Fig. 3.1 Diagramatic representation of the alcohol separation column.

centrifuge tube and spun to concentrate the residue at the bottom. If complete compaction of the residue had not been achieved the tube was left to settle until this occurred. The top liquid was carefully pipetted off and approximately 40ml of pure ethanol (99.8%) added. The residue was stirred to ensure thorough dispersal in the alcohol. The residue was left to soak in the ethanol for a minimum period of 40 minutes. As settling of the residue occurred the tube was agitated at intervals to ensure an even soak of all particles.

The separating column was placed on a sturdy bench, free from vibration and out of direct sunlight or heat, where it would not be disturbed. The column was filled with water to a level positioned above the top tap allowing room for the volume of ethanol to be added. The next stages of the procedure required great care to avoid disturbing the column as water and alcohol are miscible. Hansen and Gudmundsson (1979) recommend carefully pouring the suspension of alcohol and residue onto the water surface and note that after a few seconds the water and alcohol separate into two distinct layers. Due to the miscibility of water and alcohol it was found that if the residue was poured onto the water surface, a mixing of the water and the ethanol suspended residue occurred, resulting in the loss of palynomophs as they dropped into the water and fell through the column. Careful pipetting of the residue onto the water surface produced less mixing of alcohol and water but it did not solve the problem. The solution was to pipette a small quantity of ethanol onto the water surface to initiate the mixing of ethanol and water. The addition of ethanol was continued until a stable layer (between 1-2cm in height) resulted. The residue could then be pipetted onto the ethanol layer/water interface.

Separation was observed to begin immediately with the larger, denser particles falling through the column. Hansen and Gudmundsson note that after 15-30 minutes most massive particles (organic debris and insoluble minerals) have passed the alcohol/water interface and that after 45-60 minutes this interface has become indistinct, so the microfossil containing fraction should be removed before this has happened. It was noted that the 30 minutes cut off point appeared to be approximately correct for the visual separation of the majority of large particles from the residue.

To remove the top palynomorph containing fraction the ethanol/water interface was slowly brought to a level a few mm above the upper tap by opening the bottom tap. The bottom residue was collected for inspection to determine if any significant palynomorph loss had occurred. The top fraction was collected via the side arm and inspected for the content of palynomorphs and organic debris.

The results of the experiments were somewhat disappointing. Despite the obvious separation that could be seen, the top fraction collected still contained much organic debris and the bottom fraction contained large amounts of pollen.

Exhaustive attempts utilising a large number of experiments were repeated with the different lithologies encountered in the studied sections. Experiments were run removing the top fraction at intervals of 10, 15, 20, 25, 30, 35, 40, 50 and 60 minutes. The initial soaking of the residue in ethanol was increased in stages up to 1 hour. In all cases the top fraction collected always contained much organic debris and the bottom fraction always contained significantly large amounts of pollen.

It is thought that the most likely explanation for this is that the ethanol did not penetrate the pollen exine. If the cavities in the pollen were not being filled, or sufficiently filled with alcohol, then their density would not be reduced, they would not be retained on the alcohol/water interface and would fall through the separating column. This was noted to have occurred.

Hansen and Gudmundsson (1979) developed this separation technique using Cretaceous-Tertiary sediments from central West Greenland. The marine sediments were mostly dark and black shales having extremely high contents of carbonised organic debris. They report repeated short oxidations (10 minutes duration) of their sediments using fuming $HNO_3$ and occasionally Schultze's solution. They note that the removal of humic acid and the swelling of the microfossils by washing with dilute alkali (10% KOH or 5% $NH_3OH$) is of importance. Absorption of the alcohol is the key to the process (Hansen and Gudmundsson note that totally carbonised or compressed microfossils are not suitable). It is thought that the apparent non-absorption of the ethanol by the pollen, in the experiments run in this study, might be the result of the mild oxidation not making the exine permeable enough to the ethanol, rather than an insufficiency of time soaking in the ethanol.

The persistent occurrence of organic debris in the upper fraction may be explained by the fact that its density was not great enough to cause it to drop through the column. The easy separation of the organic debris, reported by Hansen and Gudmundsson (1979), might be a result of a greater density of their organic debris as it is reported to have been carbonised. This was not the case for the organic debris occurring in samples in this study.

Despite the method appearing sound in theory, it did not achieve the desired aim, which was the selective removal of unwanted organic debris from samples studied. As a result of this the method was abandoned.

In a further attempt to selectively remove the unwanted organic debris, a method utilising the differing densities of pollen and debris but not relying upon attempting to change the density of the pollen was tested.

### 3.3 Density separation of pollen

The principle of this technique is the same as that applied to the removal of mineral matter from a palynological sample. Dispersing the residue in a heavy liquid with a specific gravity greater than that of the pollen, but less than that of the particles that need to be separated, and employing centrifugation will cause the pollen to rise and remain on top of the liquid. The particles of greater density will collect at the bottom of the column. This technique has proved successful in the separation of large amounts of black, woody material from Carboniferous miospore assemblages in coal samples from Karoo sediments (Bakrin pers. comm.).

A standard lab solution of zinc chloride (SG 2.7) was taken and diluted with water until a SG of 1.45 was attained (measured with a hydrometer). As the specific gravity of pollen exine is about 1.4 (Traverse, 1988), zinc chloride solution with an SG of 1.45 was used as a starting point. The oxidised residue was dispersed in the zinc bromide solution and centrifuged at a speed of 2500 rpm for 10 minutes. Upon inspection of the residue collected at the top of the tube, it was noted that large amounts of organic debris persisted. Pollen was noted in the residue at the bottom of the tube.

Further experiments were conducted increasing the SG of the zinc chloride up to 1.52. Further increases were not recommended based upon previous experiments (Bakrin pers. comm.). In all samples an adequate separation of the organic debris did not occur: this may be due to the specific gravity of the organic debris being very close to that of the pollen so a distinct separation could not be achieved.

Failure of the two experimental methods to selectively remove unwanted organic debris led to the decision to utilise the traditional method of swirling and top sieving. Despite disadvantages of some pollen loss and the incomplete removal of organic debris, swirling and top sieving is commonly used for the removal of unwanted mineral and organic matter. It is not recognised to significantly bias an assemblage by selective removal of pollen.

**Swirling and top sieving**

The residue was washed into a white porcelain swirling basin of approximately 20cm diameter. A gentle jet of water from a narrow rubber hose attached to a tap was used to disperse the organic residue through the water. The jet was then directed around the side of the dish to set up a swirling motion causing the larger, denser organic debris to collect at the bottom of the dish whilst the less dense pollen and spores remained on the surface. The jet of water was removed and the swirling motion was allowed to subside for a few seconds before the top fraction, predominantly pollen and spore bearing, was decanted. Care was taken not to upset and re-disperse the denser organic fraction in the bottom of the basin. The decanted fraction was poured through a 106$\mu$m sieve resting over a 10$\mu$m sieve mesh to remove any remaining large organic or mineral matter.

The sub 106$\mu$m residue was collected in the 10$\mu$m sieve and pipetted into a sample tube ready for mounting on slides.

**3.4 Lignite samples**

The lignitic samples were treated slightly differently from the clays. Initially, acting upon cautioning about the effects of potassium hydroxide solution upon pollen, and following a previously reported method of oxidation utilising just $HNO_3$, lignite samples were simply oxidised with conc. $HNO_3$. Originally up to 10g of lignite, broken into small pieces no more than a few millimetres in size, was oxidised in concentrated

$HNO_3$ for up to 5 minutes. Pollen yields from all samples treated in this way were very low, much lower than one would have expected from such a lithology. Upon the addition of KOH solution, post $HNO_3$ oxidation, an intense brown colouration was noted and further breakdown of the lignite was seen to occur. The resulting pollen yield in most lignite samples was hugely increased compared to the yield resulting from not utilising KOH.

Wilkinson and Boulter (1980) noted that lignites from their deposits yielded poor assemblages. The processing method employed by them for lignite preparation involved the oxidation of 2-3g of lignite with concentrated $HNO_3$. Lignite breakdown was reported to have occurred within 5 minutes. At no stage do Wilkinson and Boulter mention the use of KOH solution within the preparation of their lignite samples.

As the pollen yield when utilising KOH had been so prolific and incomplete breakdown of some of the small piece of lignite was noted, it was decided to grind the lignite to a fine grade. This is common with the preparation of coal samples and uses a smaller mass of sample. The lignite samples were ground with an agate pestle and mortar and passed through a 500$\mu$m sieve. The sub 500$\mu$m fraction was collected and 0.5g was weighed into a polyethene beaker. Conc. $HNO_3$ was added and the sample was left to oxidise for 5 minutes. After dilution and sieving at 10$\mu$m the sample was washed into a beaker with a 1% solution of KOH, to which more 1% KOH was added. The reaction was left to run for 5 minutes during which time the residue was stirred occasionally. Upon completion the residue was washed into a litre beaker of water and sieved at 10$\mu$m until the wash ran clear. If large pieces of organic matter were present in the preparation they were removed by the method outlined previously. The residue was then pipetted into a sample tube ready for slide preparation.

### 3.5 The action of KOH upon a pollen assemblage

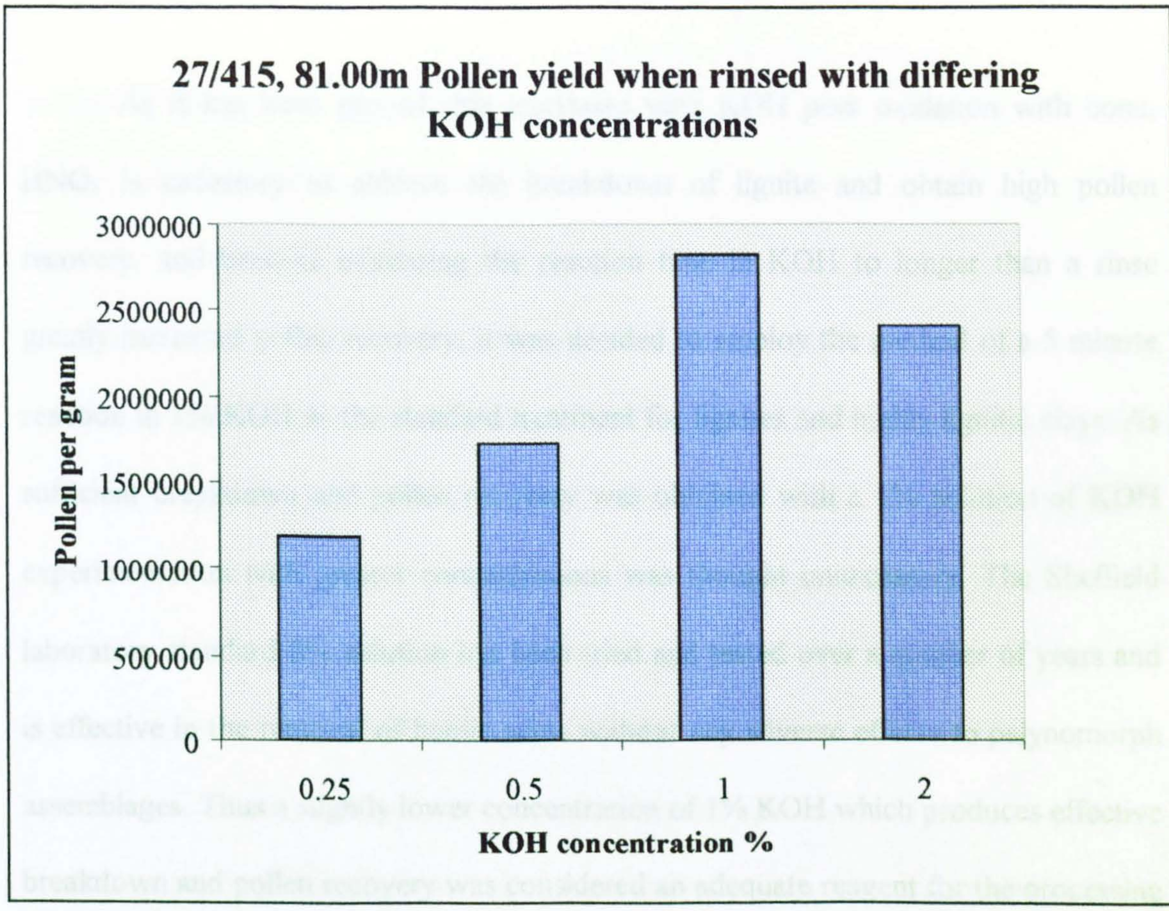
Within the Sheffield palynological laboratory the standard concentration of KOH utilised is a 2% solution. To remove humic acids an oxidised preparation is 'rinsed' with the solution, that is the solution is poured into the sieve and swirled around for a few seconds then washed through. Previous experience by departmental laboratory technicians has found this concentration to be effective at removing humic acids without having a detrimental effect upon a palynomorph assemblage. In the processing of peats numerous authors have used boiling solutions of up to 10% KOH as part of acetolysis treatments (Walton, 1940; Fageri and Iversen, 1950). This would therefore seem to indicate that pollen is somewhat resistant to the action of KOH.

KOH is known to be quite destructive to cellulose, in nature cellulose is easily broken down into sugars e.g. glucose, by micro-organisms, by enzymic action, hydrolysis and oxidation. Chitin, present in the structure of fungal spores and mycelia may be regarded as a close relative of cellulose. Its structure differs only in the replacement of an H atom on a side branch of the structure by an acetamide group ($HNCOCH_3$). Chitin is much more resistant to degradation than cellulose. Sporopollenin, regarded as probably the most inert organic compound known, forms the basic structure of the highly resistant wall in pollen, spores, dinoflagellates and acritarchs. Traverse (1988) reports that in a series of experiments into the structure of sporopollenin, *Betula vulgaris* pollen was prepared by prolonged KOH lyzing. The utilisation of KOH within preparations in this study was not noted to have a detrimental effect upon the pollen. It was, however, used in low concentration and not heated. Within some laboratories it is standard practice to use KOH in a concentration of 5% or 10% and to heat the sample to accelerate the reaction with no reported detrimental effect to the pollen assemblage. Cases where KOH has been noted as detrimental to the pollen assemblage, or reported to cause excessive swelling of the grains might, perhaps, be location or lithology/preservation specific. These considerations aside and acting upon cautioning about the possible effects of KOH, it was decided to run some experiments with concentrations of KOH lower than the Sheffield standard 2% to see if a low concentration could be used to recover high pollen concentration from lignites.

To test the effects of varying concentrations of KOH lower than 2% upon pollen yield from lignites a series of experiments were run.

KOH pellets (85% min) were dissolved to prepare solutions in the following concentrations; 0.25%, 0.5%, 1%, 2%. Samples of lignite were taken, ground using a small agate pestle and mortar and passed through a 500$\mu$m sieve. 0.5g of the sub 500$\mu$m fraction was taken and oxidised with conc. $HNO_3$ (70%) for 5 minutes, neutralised and sieved through a 7$\mu$m sieve mesh. The residues were then treated with the varying concentrations of KOH. One set of samples was rinsed with the KOH, the other was left in the solution for 5 minutes. After the reaction times were complete the samples were washed clear and quantitative slides were prepared and counted (as outlined later in this chapter) to estimate the pollen yield.

The results are shown fig. 3.2. When rinsed with KOH the pollen recovery was greater with increasing concentration of KOH up to 1% solution concentration. A drop in recovery was noted for the 2% concentration. This decrease was not great and may possibly be attributed to the nature of the method used to determine the amount of pollen per gram (see discussion of this method later in this chapter).When left to react for 5 minutes in a 0.25% KOH solution an increase in recovery over 2.5 times greater than that obtained from rinsing in this solution was noted. A similar magnitude of increased recovery was noted with 5 minutes reaction with the 1% solution.



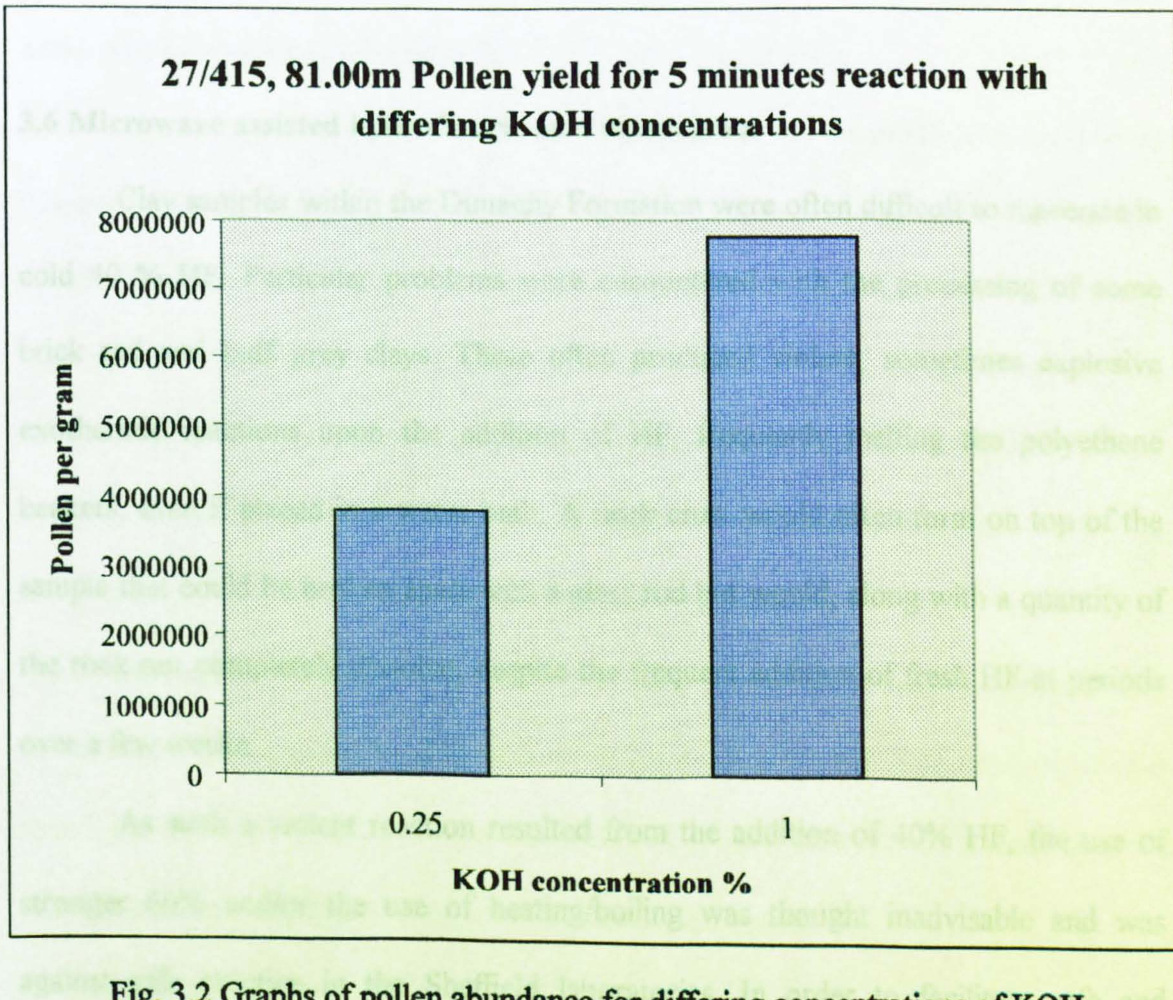




**Fig. 3.2 Graphs of pollen abundance for differing concentrations of KOH and reaction times**

As it has been proved that treatment with KOH post oxidation with conc. $HNO_3$ is necessary to achieve the breakdown of lignite and obtain high pollen recovery, and because increasing the reaction time in KOH to longer than a rinse greatly increased pollen recovery, it was decided to employ the method of a 5 minute reaction in 1% KOH as the standard treatment for lignites and highly lignitic clays. As sufficient breakdown and pollen recovery was obtained with a 1% solution of KOH experimentation with greater concentrations was thought unnecessary. The Sheffield laboratory standard 2% solution has been tried and tested over a number of years and is effective in the removal of humic acids without any adverse effects to palynomorph assemblages. Thus a slightly lower concentration of 1% KOH which produces effective breakdown and pollen recovery was considered an adequate reagent for the processing of the lignites in the studied sections.

### 3.6 Microwave assisted hydrofluoric acid maceration

Clay samples within the Dunaghy Formation were often difficult to macerate in cold 40 % HF. Particular problems were encountered with the processing of some brick red and buff grey clays. These often produced violent, sometimes explosive exothermic reactions upon the addition of HF, frequently melting the polyethene beakers, even if placed in a water bath. A thick crust would often form on top of the sample that could be broken apart with a glass rod but would, along with a quantity of the rock not completely dissolve, despite the frequent addition of fresh HF at periods over a few weeks.

As such a violent reaction resulted from the addition of 40% HF, the use of stronger 60% and/or the use of heating/boiling was thought inadvisable and was against safe practice in the Sheffield laboratories. In order to facilitate safe and complete breakdown of such lithologies, it was decided to experiment with microwave heating of the HF and sample to achieve rapid and complete breakdown.

A method pioneered at Sheffield using microwaves in hydrofluoric digestion of rock is described by Ellin and McLean (1994). The method utilises the heating of samples in CEM Corporation MDS-81 630w microwave. This system has been proved to enable rapid digestion with HF in sealed reaction vessels, however, it suffers a number of disadvantages, principally the limit of 2.5g of sample for digestion. Concerns over the safety of using HF under pressure and the possible dangers of contamination with acid vented during a pressure build up have been voiced. The system operates on a pulsed power principal, that is, when operating at 50% power it actually operates at 100% power for 50% of the time. It is not as controllable and is less efficient at digestion than a more recent focused microwave digestion method developed by Jones and Ellin (1998).

The main differences between the two systems may be briefly summarised as follows. In the unfocused pressurised system the microwave energy is delivered to the sample, contained in a closed PTFE reaction vessel, by dispersal throughout the entire oven space. This necessitates sample rotation to ensure an even energy distribution in much the same way as in a domestic microwave oven. Upon leaving the magnetron the microwaves in the focused system pass through a waveguide to be focused onto the lower portion of a tall PTFE reaction vessel (Jones and Ellin,1998). This allows the top of the reaction vessel and the reflux head atop the vessel to remain cool, enabling the arrangement to function akin to heating on a hot plate but with much increased heat input and without the need for a pressurised system. The system is thus regarded to be inherently safer than the unfocused, pressurised system.

The apparatus utilised was a Microdigest 401 manufactured by Prolabo. This was a relatively new piece of equipment in Sheffield undergoing trials, but essentially the same as the A301 Microdigester outlined in Jones and Ellin (1998). The whole system may be automated as different power levels and heating times may be pre-programmed. Reagents may be added automatically to the reaction vessel via a system of pumps and tubing thus eliminating the need for continual technician contact with chemicals.

Prior to digestion the rock was ground, using a pestle and mortar, to small pea sized pieces. A known mass of rock was added to the vessel and 40% HF was added in an approximate ratio of HF:rock of 3:1. An initial programme of 40% power was run for five minutes . If a complete breakdown did not occur a second programme of 25% power for 5 minutes was run which resulted in complete digestion of the sample. Table 3.1 lists the samples processed and the power setting and reaction times for each sample.

The reaction vessels were cleaned between each sample digestion by rinsing them out and then returning them to the machine. The small tube protruding from the top of the reaction vessel to form part of the reflux head was placed in the vessel before a cleaning programme was run to ensure removal of palynomorphs that may have become deposited in it during the HF reflux or a venting. 20 ml of fuming nitric acid was added and a pre-programmed cleaning cycle was run to ensure that any palynomorphs which remained as contaminants were destroyed through oxidation by heated fuming nitric acid. The acid was decanted and the vessels washed with detergent and a stiff bottle-brush.

The system proved effective at the rapid and complete breakdown of some samples that would not undergo breakdown with cold HF treatment. The speed, ease

## 13/611 Landagivey No. 1

| Depth (metres) | Lithology | Mass macerated (g) | Power % | Reaction time (minutes) | Sample utilised | Sample productivity |
|---|---|---|---|---|---|---|
| 155.00 | Sandy clay + lignite | 10 | 40 | 5 | × | |
| | | | 25 | 5 | | |
| 157.00 | Blue grey clay | 10 | 40 | 5 | × | |
| | | | 25 | 5 | | |
| 157.41 | Blue green clay | 10 | 40 | 5 | ✓ | Productive |
| 164.80 | Green grey clay | 10 | 40 | 5 | ✓ | Productive |
| 166.00 | Pale blue grey clay | 10 | 40 | 5 | ✓ | Barren |
| 170.00 | Khaki clay | 10 | 40 | 5 | ✓ | Barren |
| 174.00 | Grey khaki clay | 10 | 40 | 5 | ✓ | Productive |
| 190.00 | Khaki clay | 10 | 25 | 5 | ✓ | Barren |
| 206.00 | Khaki clay | 10 | 40 | 5 | ✓ | Productive |
| 208.00 | Khaki clay | 10 | 40 | 5 | ✓ | Productive |
| 212.00 | Blue grey clay | 10 | 40 | 5 | × | |
| 218.00 | Khaki clay | 10 | 40 | 5 | ✓ | Barren |
| | | | 25 | 5 | | |
| 220.00 | Brick red clay | 10 | 40 | 5 | × | |
| | | | 25 | 5 | | |
| 230.00 | Buff grey clay + lignite wafers | 10 | 40 | 5 | ✓ | Productive |
| | | | 25 | 5 | | |
| 230.45 | Dark grey clay +sand + lignite wafers | 10 | 40 | 5 | × | |
| 231.50 | Sandy lignite | 10 | 40 | 5 | × | |
| | | | 25 | 5 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 232.00 | Sandy lignite | 10 | 25 | 5 | ✗ | |
| | | | | | | |
| 250.00 | Brick red clay | 10 | 40 | 5 | ✓ | Barren |
| | | | 25 | 5 | | |
| | | | | | | |
| 259.58 | Tuff? pale grey pink and white grains | 10 | 40 | 5 | ✗ | |
| | | | 25 | 5 | | |
| | | | | | | |
| 261.00 | Grey sandy clay + lignite | 5 | 40 | 5 | ✓ | Productive |
| | | | 25 | 5 | | |
| | | | | | | |
| | | | | | | |
| 264.00 | Tuff? grey clay sandy pink bands | 10 | 40 | 5 | ✓ | Barren |
| | | | 25 | 5 | | |
| | | | | | | |
| 265.65 | Conglom., blue green clay matrix, pink clasts | 10 | 40 | 5 | ✗ | |
| | | | 25 | 5 | | |

Table 3.1 Data for microwave digestion of samples.

of use and safety advantages of enabling heated HF treatment, without the need for open heating of HF on a hot plate, are all advantages that the application of focused microwave digestion appears to offer. The limited use of the system within this study was found to be highly advantageous. Further work ongoing at Sheffield will attest to the applicability of the system to other lithologies and the use of the system for oxidation of digested residue.

## 3.7 Slide preparation and pollen abundance calculation

### Slide preparation

The residue for each sample was pipetted into a small sample tube and left to settle overnight. Each sample tube had a series of gradations on the side, the volume marked by each of these was measured and noted. The excess water was carefully removed with a pipette so that a known volume of water remained in the tube. The residue was then thoroughly dispersed throughout the water and a known volume of water and residue was removed from the tube using a small bore 1ml syringe. This volume of residue was placed into another sample tube with a known volume of warm P.V.A. to assist in the dispersal of the pollen across the coverslip. The residue was dispersed throughout the P.V.A. and pipetted equally over 4, 22mm x 22mm no. 0 coverslips. These were left to dry on a covered warm plate before mounting with a permanent petro-poxy adhesive.

### Calculation of approximate pollen abundance

As the mass of rock (prior to HF maceration) was known and as the residue (post all the processing steps) was placed in a known volume of water from which a known aliquot was taken for coverslip preparation, the approximate mass of residue (rock) on each slide may be calculated. The approximate number of pollen grains (pollen and miospores) on each slide was calculated. With this data the approximate number of pollen grains per gram of rock/sediment could be calculated.

**Calculation of the approximate number of pollen on a slide**

To obtain the approximate number of pollen grains on a slide, the number of pollen in one traverse across the centre of the coverslip was counted using a x40 lens. The diameter of the field of view using a x40 lens was measured with a graduated slide as 0.5mm. The coverslip is 22mm wide therefore there are 22/0.5 = 44 fields of view across the coverslip with a x40 lens. The number of pollen in one traverse on the other slides in the batch was counted and the mean calculated. The mean number of pollen in one traverse x 44 = the approximate number of pollen on one coverslip.

In samples where the pollen recovery was very low the number of pollen grains on the whole slide was counted as often no grains were recorded over a number of traverses.

**Calculation of the approximate mass of rock on a coverslip**

With the known masses of rock and volumes of residue used in coverslip preparation the approximate mass of rock on each coverslip was calculated as follows:

volume of residue in sample tube (ml) / aliquot taken for dispersal (ml) = X

Mass of rock macerated (g) / X = Y

Y = Mass of rock (g) in aliquot taken for dispersal (ml)

Y/4 = Z

Z = Mass of rock on each coverslip.

No. of pollen grains on one coverslip / Z = Approximate no. of pollen grains per gram of sediment

It should be noted that the word approximate has been used throughout as the method is by no means to be taken as an accurate measurement of the amount of rock on each slide, the number of grains on each slide or the amount of pollen per gram of sediment. The inaccuracies present in the processes of preparation and calculation are considered to be too great to provide anything more than an approximate guide to the general pollen yielding productivity of a sediment type. The method is intended to be one that can be easily employed during the routine processing of palynological samples without the need for the addition of exotic pollen (e.g. *Locopodium* tablets). The method used follows the basic principle of more accurate and time-consuming methods for the calculation of absolute pollen frequencies (Erdtman, 1943; Muller, 1959 and Davis, 1965). The approximate pollen per gram for samples in the studied sections is presented in Appendix 1.

**3.8 Counting Technique**

Pollen and spores were counted under phase contrast microscopy at x400 magnification using a Leitz Labrolux K binocular microscope.

During initial studies 100 pollen and spores were counted on each of the four slides prepared. Percentages of the dominant pollen or spore species were not found to differ greatly when the total count of 400 specimens was compared with the count of 100 from each coverslip. This is thought to be due to the assemblages representing a relatively stable low diversity flora.

Data recorded and presented within this study was generated from a count of 200 specimens of pollen and spores for each sample (where recovery allowed), 100 on each of two slides.

A 200 count is generally regarded as statistically sufficient to obtain a picture of vegetational composition and character. It is a standard number for routine analyses of palynological samples within the petroleum industry and has personally been found to produce effective assemblage representation for stratigraphic and palynological analyses in a variety of terrestrial environments.

Counts were made by starting a traverse across the middle of a coverslip and proceeding in a single direction, always left to right, to ensure that no area was inadvertently recounted if counting was stopped before a traverse was completed. After the count had been made the remainder of each coverslip was scanned to record the presence of any rarely occurring taxa that were not recorded in the initial 200 count. The taxa recorded outside the initial count were not generally found to have been recorded in a 400 count thus supporting the view that they are taxa of rare occurrence and that a 400 count for the assemblages recorded in the sections was giving no greater data refinement than a count of 200. An assessment of the preservation and general character of the assemblages was made to aid interpetation of the data.

# 4. RELATIONSHIP OF POLLEN ABUNDANCE TO PARENT FLORA

If the amount of pollen per gram of a sediment is taken as representative of the amount of pollen rain and that pollen rain considered representative of the diversity and abundance of the parent flora, deduced from botanical affinity of the dispersed pollen, the following assumptions have to be made:

1. That the pollen in the deposit is a representative random sample of the pollen rain occurring during the period of deposition,
2. That no bias has been introduced by differential preservation,
3. That the field sample of sediment used is a representative random sample of the sediment at the time of deposition,
4. That the laboratory sample used is a representative random sample of the field sample,
5. During the preparation of the sample prior to mounting on slides, no differential bias of loss of pollen has occurred due to the procedures employed,
6. That the sample strewn on the coverslip is a representative random sample from the laboratory sample,
7. That the area of the coverslip counted to calculate the total pollen is representative of the pollen assemblage on the whole coverslip.

Points 1-4 have to a great extent, to be assumed to be valid, especially if one is working from borehole material. Points 5 and 6 may be safeguarded against by laboratory procedure and careful employment of reagents and oxidation. However, as highlighted by the techniques employed during the preparation of samples used in this study, the elimination of inaccuracies in these steps can prove extremely difficult and it is doubted if they can ever be totally overcome.

Point 7 has been proved to be an invalid assumption by Brooks and Thomas (1967) in a study on the non-randomness of pollen distribution on microscope slides. A degree of 'clumping' of grains in the centre of a coverslip may often be noted even on a coverslip that looks to the eye to contain an even distribution of residue. The areas around the margins of a coverslip are frequently observed to contain less pollen than the areas in the centre of a traverse.

With all the problems and potentially invalid assumptions, the chances of determining a precise value for the number of pollen per unit mass of sediment, and the potential for determining the pollen rain and from it the relative abundance of elements of the parent flora appear to be slim. The important point to note is that a consistent approach should be adopted in all calculations and estimations.

### 4.1 Differing pollen productivity and representation

It one wishes to determine the relative abundance of constituents of the parent flora from the recovered dispersed pollen, the problem of differing relative pollen productivity of taxa arises. The recording of pollen assemblages and numerical abundance from sediments has little direct relation to the palaoeflora unless the data is interpreted with regard to the pollen productivity. Von Post (1916, 1918) noted that the ability of fossil pollen assemblages to record vegetational composition truthfully may be influenced by the effect of disproportionate pollen productivity and dispersal capacity of the plant species, particularly the important trees.

Hesselman (in Von Post, 1916) noted that the changes in species abundance may be recorded more truthfully if pollen diagrams depicted absolute pollen abundance rather than percentage diagrams (as used by Von Post). Von Post reported that the absolute data would prove misleading without sufficient knowledge of sedimentation rates. Davis (1967) produced absolute pollen diagrams corrected for the effects of sedimentation rate by utilising C-14 dating. The changes demonstrated by the diagrams are almost identical to those appearing in the percentage diagrams for the period of forest vegetation (Andersen, 1970). Absolute pollen diagrams provide a useful check upon the truthfulness of changes in pollen percentages but they tell one little about the vegetational composition. The evaluation of this must involve corrections for disproportionate species representation (Andersen, 1970).

To provide a guide to pollen productivity of an element of a palaeoflora, it is necessary to refer to extant species of similar botanical affinity to that proposed for the fossil taxon and extrapolate the data back in time. Problems of applicability of proposed botanical affinities to fossil pollen again become apparent. Validity of the botanical assignment is of prime importance to the application of correcting factors for the differing pollen productivity of a taxon.

Factors affecting the applicability of the assessment of different pollen productivity include consideration of pollen preservation and dispersal.

Pollen preservation: The corrosion of pollen where the unification of perforations in the exine cause the greater part of it to be removed (Havinga, 1964, 1967; Elsik, 1966 and Cushing, 1967) has been thought to be connected to the degradational activity of phycomycetes in soil of high biological activity. Havinga (1964, 1967) records a type of degradation in which the pollen exine is gradually thinned, having observed this in sandy soils and artificially oxidised sediments. In 1967 he produced a list showing that the susceptibility to erosion of pollen types by artificial oxidation corresponded to that noted during pollen analysis of sandy soil where corrosion involved the thinning of the exine. The list of common tree genera in ascending order of corrosion susceptibility is as follows:

*Tilia, Alnus, Corylus, Betula, Carpinus, Ulmus, Quercus, Fagus, Fraxinus.*

Experiments by Havinga (1967) where pollen grains were subjected to destruction in biologically active soils produced a type of corrosion where the exine displayed perforations. The list of increasing corrosion susceptibility noted in this case was:

*Quercus, Fraxinus, Tilia, Betula, Fagus, Carpinus, Ulmus, Alnus, Corylus.*

The effects of the differential susceptibility to degradation, and therefore preservation, should perhaps be borne in mind when interpreting pollen diagrams.

Pollen dispersal: The method of pollen dispersal employed by a plant i.e. whether it is anemophilous (wind dispersed) or entomophilous (insect dispersed) may have a profound effect upon the amount of pollen produced, the efficiency and range of its dispersion and subsequent chance of fossilisation. Pollen of large size or ornate sculpture is usually entomophilous: pollen of small size and a lesser or smooth sculpture is generally anemophilous. This is a general rule and exceptions occur. Bisaccate pollen e.g. *Pinus* and *Picea* is often of large size and is anemophilous. Small Cretaceous pollen, approximately 8$\mu$m in size, was reported by Bassinger and Dilcher (1984) as likely not to be wind pollinated as its diminutive size would mean that it would not have the impact velocity to adhere to a stigma.

Wind direction and velocity, in relation to the size and structural composition of a forest, are factors involved in effective pollen dispersal and distribution. These may be tested and applied to the pollen dispersal and distribution of a modern vegetation type but they are of little concern to the construction of a palaeoflora for they cannot be tested. With regard to the aerial transportability of different sized pollen grains Rempe (1937), while collecting airborne pollen, noted that a strong mixing of pollen due to air turbulence takes place. He recorded high pollen concentration up to 500-1000m altitude and noted that heavy pollen grains were carried aloft as effectively as lighter ones. Factors such as dry deposition and wet (rain) deposition will similarly be untestable in relation to a palaeoflora.

Tauber (1965) demonstrated that the transport distance of pollen was greatly dependent upon the height above the ground of the source vegetation. He also outlined a method of local pollen deposition, whereby pollen caught on leaves and twigs is deposited in the vicinity of the parent flora when washed off by rain.

Aerial transport can result in the deposition of pollen thousands of kilometres from its source, however, only a small number of grains travel the distance (Farley, 1990 and references therein).

It becomes clear that the openness of vegetation produces an important constraint on pollen distribution. Studies on aerial transport of pollen demonstrate that most pollen is deposited close to the parent plant and that transport over a greater distance only occurs in open settings e.g. grassland or if the crown of a parent plant protrudes into the wind (Farley, 1990).

Andersen (1970) provides a succinct summary of the way pollen is deposited within a forest from his studies on modern forests in Denmark:

1. Pollen falling from trees may be carried several hundred metres from the parent before reaching the ground, but large amounts may be deposited at or very near the parent tree.

2. Falling pollen lumps may be deposited near the parent source or a few hundred metres away.

3. Pollen collected in the crown layer of the tree by filtration is washed to the ground by rain falling nearly vertically. The deposited pollen originates from trees up to a few tens of metres away.

4. Pollen in immature inflorescences and that collected on catkins may fall to the ground with them.

5. Pollen of herbaceous forest plants is deposited only a few metres from its source.

6. Pollen grains carried into the forest by wind, 'foreign pollen' is deposited a few tens of metres from the forest edge. It may be carried over the canopy, mixed into the canopy by air turbulence, caught by filtration and washed to the ground. A large proportion of foreign pollen is thought to be transported and deposited in this way.

Farley (1990) and references therein outline the potential for pollen distribution over large distances by water noting that large quantities of pollen can be transported by quite small streams. The pollen content of a stream reflects removal of pollen from soils by runoff. A large percentage of the pollen brought into a lake may be via water transport, up to 50% (Tauber, 1967) increasing to as much as 90% (Peck, 1973; Bonny, 1976, 1978).

Farley (1990) concludes that the transport mode of pollen in a terrestrial non-marine setting will be controlled by the local dominance of either pollen fall from the local vegetation or waterborne pollen which in turn is controlled by the degree of water access to the depositional environment. The degree of difference between environments is therefore evidence of either a difference in the mode of pollen deposition or a difference in the vegetation.

Consideration of the effects of pollen dispersal will have a more direct bearing on the interpretation of a palaeo-pollen assemblage originating from an autochthonous deposit, where the effects of sediment deposition and reworking will be at a minimum.

## 4.2 Absolute and differing relative pollen productivity

The absolute pollen productivity may be defined as the number of pollen grains produced per unit crown per unit of time. It may differ in a single species due to differing flowering intensities attributable to a variety of ecological factors. Single trees will flower to a greater extent and with greater frequency than those in close proximity. The ratio of the absolute pollen productivity to that of another species may be termed the relative pollen productivity. It is this relative pollen productivity compared to the chosen reference species *Fagus silvatica* that has resulted in the following list of pollen productivity produced by Andersen (1970) from measurements of surface samples derived from two forests in Denmark.

The list of North European trees is presented in order of decreasing pollen productivity:

*Pinus, Betula, Quercus, Alnus*

*Carpinus*

*Ulmus, Picea*

*Fagus, Abies*

*Tilia, Fraxinus, Acer.*

This list compares closely with that produced from surface samples by Hesmer (1933):

*Pinus, Betula, Alnus, Carpinus*

*Picea*

*Fagus, Quercus, Tilia.*

Results of other investigations for trees in northern Europe with comments on their potential accuracy are presented by Andersen (1970). The lists of pollen productivity differ in detail but do display some agreement with Andersen's list.

Andersen also presented correction factors for the North European trees as follows:

| | |
|---|---|
| *Pinus, Betula, Quercus, Alnus* | 1:4 |
| *Carpinus* | 1:3 |
| *Ulmus, Picea* | 1:2 |
| *Fagus, Abies* | 1x1 |
| *Tilia, Fraxinus, Acer.* | 1x1 |

Andersen (1970) reports that as the data from which he produced his results was derived from pollen assemblages within humus deposits from the forest floor, the material could therefore be regarded as originating from within the forest. It is worthy of note that pollen from open areas within forests e.g. lakes or bogs would contain pollen reflecting the vegetation of a larger area. In such cases light pollen e.g. *Pinus, Betula, Quercus* and *Alnus* may be over represented in a corrected assemblage as their source area would be greater than for other trees. The pollen from shrubs and herbs may be poorly dispersed into lake or bog deposits.

# 5. LITHOLOGICAL DESCRIPTIONS OF SAMPLES

This chapter contains brief descriptions of the lithologies of the samples analysed and listed in enclosures 1-12. Descriptions of the core sections taken from each well may be found in Appendix 2.

The colour terminology (denoted by a preceding capital letter to the colour description) used for the description of the specimens analysed is taken from the Munsell colours in the Rock Colour Chart (The Geological Society of America, 1995). The colours were described in bright daylight from fresh surfaces of the samples where they were broken from the core. The colours described in the core descriptions from the exterior of the core (Appendix 2) are often darker to that from the fresh exposed surface. The relationship of these colours to the Munsell colours used in the sample descriptions may be determined by comparing descriptions for the samples used to those of the cored sections.

## 5.1 13/611 Landagivey No. 1

| | |
|---|---|
| 47.00m | Dusky brown to Brownish black lignite, hard and compact with a good woody structure. |
| 60.00m | Pale brown to Brownish grey, clayey sand, fine-grained, containing white flecks in the matrix and the occasional lignite fragment. |
| 69.95m | Brownish black lignite, hard and compact. |

| | |
|---|---|
| 82.00m | Medium light grey to pale Light olive grey stiff clay. |
| 89.00m | Greyish black to Black hard lignite with large patches of Light brownish grey, stiff to hard clay containing abundant fine lignite fragments. |
| 100.00m | Light grey clay with a slight sandy content, some small patches of Fe staining evident. |
| 110.00m | Light grey to Medium light grey clay. |
| 121.00m | Brownish grey to Brownish black clayey lignite. |
| 131.00m | Light grey to pale Light olive grey clay. |
| 149.12m | Brownish grey to Brownish black/Black lignite. Some Medium light grey clay patches containing small <1mm diameter White clasts and occasional Moderate orange to Light brown clasts. |
| 154.00m | Light olive grey to Medium light grey clay, fine grained texture containing small <1mm diameter White clasts. |
| 155.19m | Brownish black to Black lignite. |

| | |
|---|---|
| 157.41m | Light bluish grey to Greenish grey stiff clay. |
| 160.00m | Light olive grey stiff to hard clay, some Pale red to Pale red purple mottling. |
| 164.80m | Light olive grey to pale Greenish grey very stiff to hard clay, with rare, small Light brown to Moderate brown patches. |
| 166.00m | Light bluish grey stiff clay. |
| 170.00m | Light olive grey to Pale olive stiff clay. |
| 174.00m | Light olive grey stiff clay with rare small Moderate brown patches. |
| 190.00m | Dark yellowish orange stiff clay. |
| 206.00m | Light grey olive to Pale olive stiff clay. |
| 208.00m | Dusky yellow to Pale olive clay. |
| 209.00m | Dark yellowish brown to Brownish grey stiff clay containing common thin Brownish black to Black lignite and organic fragments. |

| | |
|---|---|
| 218.00m | Dark yellowish orange very stiff clay with rare, small Light Brown patches. |
| 230.00m | Light grey to Light olive grey clay containing traces of organic detritus and a leaf fragment. |
| 250.00m | Moderate reddish brown stiff to hard clay. |
| 259.58m | Pale greenish yellow matrix supporting very abundant closely spaced, small 1-2mm diameter, White, Greyish orange pink, Greyish orange, Light brown, Moderate reddish brown, Dark grey and Black clasts, rounded and rounded angular to angular. A tuff? |
| 260.00m | Very light grey to Light grey stiff clay with the occasional thin band of Dark yellowish orange staining. |
| 261.00m | Light olive grey to Greenish grey clay with Black lignite laminae. |
| 262.00m | Medium light grey clayey matrix containing small, 2-3 mm diameter Moderate orange pink clasts. Some traces of Black lignite are evident. |

| | |
|---|---|
| 264.00m | Light Greenish grey to Light grey fine grained hard clay (tuff?) with Greyish orange pink to Pale red banding. |
| 265.65m | Greenish grey hard clay matrix supporting occasional Moderate orange pink and White rounded clasts 1-5mm long. Clay/?conglomerate. |

### 5.2 13/603 Ballymoney No. 1

| | |
|---|---|
| 48.00m | Light grey slightly sandy firm clay. |
| 60.00m | Light brownish grey to medium Brownish grey clay containing fine dark organic fragments and fine Black lignite fragments. |
| 80.10m | Medium Brownish grey clay with some and the occasional Brownish black lignite fragment. |
| 100.00m | Very light grey clay with a slight sandy texture containing very occasional very small lignite fragments. |
| 120.00m | Light olive grey to Medium light grey clay with a slight sandy content containing Moderate brown (sideritic?) patches and a leaf fragment. |
| 130.00m | Pale Light brownish grey to Light grey clay containing occasional lignite fragments. |
| 150.00m | Brownish black to Black hard lignite containing the very occasional small, 2-3mm diameter bright yellow resinous droplets. |
| 161.19m | Brownish black to Black hard lignite. |

| | |
|---|---|
| 180.00m | Brownish black to Black hard lignite with some woody texture. |
| 200.07m | Pale Brownish grey lignitic clay containing Brownish black to Black lignite fragments. |
| 218.60m | Yellowish grey to Very light grey clay containing very occasional Black organic/lignitic fragments. |
| 222.74m | Pale yellowish brown to Light olive grey lignitic clay. Predominantly clay with fine Black lignite fragments. |
| 240.00m | Light grey to Light olive grey stiff to hard clay with Dusky yellow patches. |
| 260.00m | Light grey to Light olive grey clay containing the occasional trace of lignite. |
| 280.00m | Yellowish grey to Light olive grey stiff clay containing Black lignite fragments. |
| 290.00m | Very light grey to Bluish white stiff to hard clay. |

**5.3 36/4680 Deerpark No. 2**

| | |
|---|---|
| 72.05m | Pale yellowish brown stiff clay. |
| 80.00m | Moderate yellowish brown fine sandy clay. |
| 90.00m | Greyish orange to Dark yellowish orange sandy clay, with Moderate yellowish brown patches of ?Fe staining. |
| 103.62m | Light olive grey very sandy lignitic clay containing abundant Black woody lignite fragments. |
| 110.00m | Yellowish grey to Dusky yellow soft and friable clayey sand. |
| 131.71m | Dark Yellowish grey to Light olive grey stiff lignitic clay, with a slight very fine sandy texture, containing small Black lignite fragments. |
| 140.67m | Dark greenish grey, very friable medium-grained quartz sandy clay, containing abundant Black lignite fragments. |
| 150.56m | Dusky yellow stiff fine sandy clay with occasional small patches of Moderate yellowish brown mottling. |

| | |
|---|---|
| 169.05m | Dusky yellow, stiff, fine sandy clay with small patches of Moderate yellowish brown mottling and containing occasional Black, soft lignite fragments. |
| 179.20m | Pale olive fine grained stiff sandy clay. |
| 190.00m | Dusky yellow to Light olive grey fine grained stiff sandy clay. |
| 200.33m | Light grey to Light bluish grey stiff, hard clay. |
| 223.18m | Brownish black hard lignite with a bright lustrous appearance containing small Black organic fragments. |
| 237.75m | Dusky yellow to Pale olive fine grained sandy clay. |
| 242.25m | Greyish black to Black hard lignite with a bright lustrous shine, containing very occasional, very small patches of pale yellowish brown stiff to very hard clay. |
| 245.30m | Greyish black to Black hard lignite with some patches of bright lustrous shine and occasional very small patches of Brownish grey very stiff clay. |
| 250.00m | Greenish grey fine grained hard fine sandy clay. |

| | |
|---|---|
| 259.77m | Pale olive to Light olive grey stiff clay. |
| 265.13m | Light grey to Light bluish grey very hard clay. |

**5.4 27/415 Upper Mullan No. 1**

| | |
|---|---|
| 37.30m | Greyish orange to Pale yellowish brown partly lithified sand with a fine grained sandy to clayey matrix containing quartz grains and unspecified grains generally up to 5mm, occasionally attaining 10mm along their longest axis. The occasional Black wood lignite fragment is noted. |
| 41.00m | Dark yellowish brown to Olive grey very stiff to hard clay. |
| 51.00m | Light grey to pale Yellowish grey stiff to hard clay with small patches of Moderate yellow mottling. |
| 61.00m | Greyish orange to Moderate yellowish brown very stiff to hard clay. |
| 71.00m | Medium grey/Medium dark grey to Brownish grey very stiff to hard clay with Brownish grey to Moderate yellowish brown patches. |
| 75.95m | Brownish black hard compacted lignite containing small Black fragments. |
| 85.00m | Brownish black hard compacted lignite containing Black slightly lustrous layers up to 2mm thick. |

| | |
|---|---|
| 102.00m | Pale yellowish brown to Pale brown lignitic clay. The clayey matrix contains abundant Brownish black to Black lignite fragments. |
| 115.00m | Pale yellowish brown to Dark yellowish brown lignitic clay. The stiff to hard clay matrix contains abundant Brownish black to Greyish black lignite fragments. |
| 125.00m | Very light grey to Bluish white stiff clay containing small, 1-5mm diameter ?Fe mineral deposits and some Dark yellowish orange stained patches. |
| 131.00m | Very light grey to Light grey friable sandy clay, containing some small, <1mm grains of ?Fe mineral and Greyish orange to Dark yellowish orange staining. |
| 137.00m | Olive grey to Olive black stiff clay containing Medium light grey to Light olive grey stiff clay patches and occasional hard Brownish black to Black lignite fragments. |
| 145.00m | Medium light grey stiff clay with a slightly, fine sandy texture containing common Dark yellowish orange to Moderate yellowish brown patches and common small, <1mm diameter ?Fe mineral grains. |

| | |
|---|---|
| 151.80m | Dusky yellow to Light olive grey friable medium grained sandy clay with common White and occasional Moderate reddish brown grains <1mm in diameter. Greyish black to Black lignite fragments are common. |
| 153.00m | Yellowish grey to Pale olive stiff clay with a fine sandy texture. Some dark faintly lustrous ?Fe mineral (sideritic?) grains approximately 1mm in diameter are dispersed throughout the clay. No significant Fe staining is noted only very small, up to 1mm diameter, Dark yellowish orange to Dark brown patches. |
| 165.00m | Pale olive stiff clay with common Dark yellowish orange to Dark brown stained patches. |
| 173.00m | Pale olive to Light olive grey stiff clay with a slightly friable sandy texture, mottled with Olive grey to Dark yellowish brown patches. Small grains of ?Fe mineral <1-1mm in diameter are common. |
| 175.00m | Pale olive to Light olive grey stiff clay with a fine, slightly sandy texture. Small patches of Moderate yellowish brown staining and common small, <1mm diameter, grains of ?Fe mineral occur. |

181.00m A coarse sand/mini conglomerate with a dark Dusky yellow to moderate olive brown matrix supporting abundant small, <1mm diameter White and Light brown to Moderate reddish brown grains. Larger Greyish pink grains up to 5mm diameter occur with a lesser abundance. Small,<1mm diameter, dark grains of ?Fe mineral are present with occasional Greyish black to Black lignite fragments.

183.34m A highly weathered basalt comprising, Pale olive to Light olive grey stiff clay containing occasional to rare small,<1mm diameter, Moderate yellowish brown stained patches and occasional < 0.5mm diameter white specks.

185.00m A highly weathered basalt comprising Light brown to Moderate brown stiff clay with Dark yellowish orange, Moderate yellowish orange and Pale yellowish brown mottling.

195.00m A highly weathered basalt comprising, Moderate brown stiff clay with some Moderate reddish brown patches. A harder more indurated Medium light grey to Greenish grey rock containing abundant small, approximately 0.5mm diameter ?Fe mineral grains and having a relic igneous texture occurs with the clay.

# 6. SYSTEMATICS, CLASSIFICATION AND NOMENCLATURE

In order to understand our environment in all its diversity and complexity the human brain needs to subdivide and organise vast quantities of information. To enable this we have developed systems of classification to delimit concepts and phenomena leading to a nomenclature to provide a vehicle of communication to convey these concepts. This need to classify, be it matter, biological systems, social class, indeed any number of things, is fundamental to the way our minds work in organising and hence making sense of the environment we live and function in.

Taxonomy, the study of the processes of classification, utilises the reasoning and judgement of the individual taxonomist to produce a classification, to which a nomenclature may then be applied. This nomenclature must be of a clear, well-defined and precise nature to enable it to convey the ideas and concepts of the taxonomist's classification.

The individual judgement of the taxonomist produces the concept of the classification and delimits the boundaries within which it is defined. This is the subjective part of the procedure and is therefore apt to cause much difference of opinion and discussion. In this respect taxonomy cannot be constrained by a rigid set of rules, as can nomenclature. The nomenclature, the attribution of names is independent of individual bias as it is governed by the International Code of Botanical Nomenclature (I.C.B.N.).

To make sense of the myriad of different forms of pollen and miospores an easily applied, clearly stated system of classification is needed. This is the crux of the classification problem in all aspects of taxonomic palynological study but, perhaps, this has its greatest manifestation in the taxonomic procedure applied to Tertiary palynology.

Traverse (1988) states that it is widely accepted that the problems of Tertiary taxonomy and nomenclature are probably amongst the worst in the geological column. This problem has its roots in the nature of the palynomorphs, especially the pollen to which a classification is to be applied and to a set of evolutionary circumstances pertaining to this group at the time. The problem is further exacerbated by the variety of different approaches that have been applied to the classification problem in the past.

### 6.1 Problems of Tertiary Pollen Classification

The structural nature of the pollen grains themselves provides the first problem to be overcome in establishing a classification. Amongst the most commonly occurring Tertiary pollen, particularly tricolpate and tricolporate groups, there are few morphological characters displaying little variation upon which to construct a classification (Boulter and Wilkinson, 1977). In a review of sixteen papers on European Tertiary palynology, that most commonly used the form-species described by Thomson and Pflug (1953), Boulter and Wilkinson (1977) made two important findings. Firstly, that the range of the taxa that had been recorded more than once since 1953 had been extended to cover most of the Tertiary. Secondly, that the taxa, originally having been described as of a restricted range, had rarely been referred to by subsequent authors. They believed this to be due to the limitations of the original descriptions, not that the stratigraphic or geographic ranges of the pollen are significantly restricted. This led to a conclusion that no single existing taxon of tricolpate or tricolporate Tertiary pollen contributes to the solution of stratigraphic problems. Kemp and Harris (1977) have a similar point of view regarding what they term form-species of common morphological type eg. tricolporate grains of reticulate exine pattern. They state that the erection of new form-species for these common types of pollen "... serves no useful purpose and only adds to the already unwieldy agglomeration of names." (p. 6)

This problem is compounded by controversy over pollen morphology, where the same morphological feature is interpreted in different ways. Size is an important limitation in the observation of pollen. The diminutive nature of many pollen grains means that the morphological aspects to be observed and interpreted may often lie at the limit of resolution using light microscopy.

The poor description of many taxa published in the latter part of the nineteenth century and up to the middle of the twentieth century, due to a lack of taxonomic detail and non-application of a clear descriptive nomenclature, has led to the ambiguous use of taxa. The lack of clear illustration of taxa is an important point that is often overlooked. The observation and interpretation of palynomorphs is, by its very nature, a visual procedure. All too often unclear photomicrographs have been produced to supposedly illustrate the defining aspects of the taxa. A clear description of the taxa is, without doubt, of great importance, however, aspects of the structural interpretation of taxa exist in most descriptions. A clear illustration of the taxa alludes to the morphological nature of the grain without introducing any interpretational bias of the morphology from the author.

Language is a barrier to communication to no lesser extent in the description of palynological taxa than it is in science and to people as a whole. The situation is aided to some extent in that the rules of the I.C.B.N. do not formally recognise taxa that are not published in English, French, German or Russian. This still leaves the problem that unless one fully comprehends the diagnosis and description of a taxon, incorrect assignation of species to published taxa may easily occur. Just 'getting the gist' of a description and matching to a possibly poor illustration is bound to cause problems, especially as these can be perpetuated through future publications.

To some extent these problems are well illustrated in the publication of Thomson and Pflug (1953). As a source of description and illustration of Tertiary fossil pollen and spores, it has seen widespread usage. The text has been the primary source material of many palynologists starting investigations into this field. Although a benchmark publication in its day, the poor illustrations and somewhat concise descriptions sometimes lack sufficient clarity to enable a true idea of the taxa to be gained. The fact that it is in German has, no doubt, caused much exasperation to the language skills of British palynologists.

**6.2 Systems of classification**

In the search for an ideal system of taxonony and nomenclature many ideas and variations have been put forward over the years. The following is a brief historical summary of some of the different systems proposed.

Wodehouse (1933) in his paper on the oil shales of the Green River formation, as follow up to Wodehouse (1932), a paper on the pollen of the living representatives of the Green River flora, used the names of extant pollen and suffixed them with *-pites*. Erdtman (1947) constructed what may be regarded as the first artificial form-genera by his system of 'sporomorphs' that describe the major morphological types of pollen. However, this system did not comply with the I.C.B.N. for Erdtman did not advocate the use of extant names for fossil pollen in pre-Pleistocene studies. Cookson (1947), however, used Erdtman's system in such a way so as to comply with the I.C.B.N.

Potonié, Thomson and Thiergart (1950) and Potonié (1952) were responsible for proposing three systems that depended upon the relationship of the dispersed pollen to the extant taxon. They named these systems the natural, half-natural and artificial systems.

Thomson and Pflug (1953) also did not advocate the use of extant names for fossil pollen and constructed a purely morphological system of classification. This has become a widely used and accepted system especially among European palynologists.

Traverse (1955) disregarded the morphological system of Thomson and Pflug (1953) instead proposing a four tier system in a similar manner to that of Potonié *et al.* (1950) and Potonié (1952). Traverse's system was based upon the ideas that pollen might be classified as: attributable to an extant genus or family, of uncertain botanical affinity, or not attributable to an extant taxon. Traverse (1988) states that where a generic reference is absolutely clear there is no reason to avoid using an extant generic name. He gives the example of *Nyssa* pollen in the Brandon Lignite (Traverse, 1955) which can only be such because of its association with other organs. His opinion is that the transfer of this pollen to *Nyssapollenites* would be a ridiculous exercise. He emphasises that this is a minority view. He does, however, have a valid point for many palynologists read the name *Nyssapollenites* and effectively make the concrete connection to *Nyssa* in their mind's eye. However, the name *Nyssapollenites* seems to effectively make the desired botanical connection and also to satisfy the purest in that an exact generic matching, with its associated biological implications, is not made. This being the case the half-natural name would seem to be the better choice as an exact biological match could probably not be proven.

Van der Hammen (1956) described pollen applying a nomenclature based upon its morphology. The names assigned were based upon extant taxa; this and his creation of illegitimate junior homonyms invalidated his system. These considerations aside, his system has seen extensive use within tropical pollen studies (Leidelmeyer, 1966; Guzman, 1967; Germeraad *et al.*, 1968; Roche and Schuler, 1976).

Since their conception the different schemes outlined above have been adopted by differing schools of palynological study and this has caused a regional bias. The works of Potonié and specifically that of Thomson and Pflug (1953) have principally influenced European workers. Within the Southern Hemisphere the ideas of Van der Hammen and his co-workers have been widely used. In Australasia the ideas of Cookson have been influential. In North America the views of Traverse have advocated the use of extant taxonomic names, whilst a mix of natural, extant taxa and artificial taxa have been used by workers such as Elsik and Rouse.

The scheme that departs significantly from the above is the 'biorecord, genusbox' system of Hughes. Through a variety of publications, Hughes (1963, 1969, 1970, 1971,1975) has developed a scheme to improve the recording of palynological data and its application to stratigraphic correlation. Hughes felt that the strict controls of the I.C.B.N. regarding binomial nomenclature and the priority, synonymy and illegitimacy of names constrained and prevented the realisation of the potential of pollen and spores for detailed stratigraphical correlation. The creation, by careless taxonomy, of what Hughes (1970) termed "balloon taxa" had caused the stratigraphic and evolutionary significance of pollen and spores to become overlooked or dismissed. The basis of his ideas and those of his co-workers, Hughes and Moody-Stuart (1969) and Hughes and Croxton (1973), call for the rejection of Linnéan taxonomic procedure and its replacement with his 'biorecord, genusbox' system. The details of this system are specified in the publications referred to earlier. They may be briefly summarised as follows.

The germination of ideas by Hughes stemmed from his failure to produce adequate stratigraphic refinement and correlation of the Cretaceous Wealden Group (Hughes, 1958). This was despite what he judged to be favourable circumstances of extensive outcrop, cored sections, a close sampling strategy and an abundant recovery of palynomorphs and taxa. Hughes advocated the setting up of "biorecords" as a reference taxon that would effectively replace the Linnéan form-species. This biorecord was to be based on a significant (but not fixed) number of species with any variations specified. The extent of the lithology/rock sample from which it came was to be stated. Once published a biorecord is unchangeable and not affected by any system of priority. It may be disregarded by subsequent authors who may freely errect others.

Hughes (1969) "genusbox" effectively replaces the Linnéan form-species. No type exists, instead morphographic limits are defined against other taxa. Stratigraphic limits for this genusbox are set.

"Comparison records" are made as all specimen records are placed in a formal graded comparison with a biorecord, having an individual significance lower than a biorecord. Hughes (1973) proposed three grades of comparison:

cf. A. indicating no qualitative character difference from the biorecord, ie. a positive interpretation of similarity to be used as a stratigraphic indicator,

cf. B. indicating minor qualitative differences of any kind which may be of minor stratigraphic significance,

cf. C. indicating greater differences that would call for the creation of a new biorecord when the need to do so arises.

The comparison record is seen as the crux of Hughes' stratigraphic procedure from which correlations can be constructed.

Traverse (1975) presents a reasoned, precise, if not a little acidic critique of Hughes (1975). Traverse succinctly outlines the pitfalls of the Hughesian methodology. They are not outlined again here as they are best and most amusingly read in the context of Traverse's vocabulary. It will suffice to say that his view point is that "Realistically it is very unlikely that Hughes' proposed system will be adopted formally." (p. 146) He adds that:

"The aims Hughes wishes to accomplish in paleopalynological systematics could more effectively be accomplished by a campaign on his part to get his colleagues to agree to exercise more care in the areas of size of populations studied, descriptions of taxa, geographic and geologic descriptors and the like. That is the guts of his proposal ... In the meantime those suggestions in his presentation that are of value are jeopardized by their being wedded to a Luddite-like attack on the formal machinery of botanical nomenclature." (p.146)

Kemp and Harris (1977) stated that in principle they agreed with the basic tenets of Hughes, but did not feel that the replacement of form-species with biorecords would serve their purpose better, as it would make the comparison with previously described microfloras extremely difficult. It should, however, be noted that the aim of their study was to provide basic descriptive data in support of previously published discussions of the palaeobiogeography and that their aim was not primarily stratigraphical.

Boulter and Wilkinson (1977) describe a system of group names for Tertiary pollen. The method involves the designation of a small number of groups that are very simply defined by polar length and surface sculpture. They are proposed as alternatives to the Linéan binomial nomenclature. The criteria used in definition are most often available in the published literature so enabling comparison to published taxa to be completed. Boulter and Wilkinson report that their groups have as much stratigraphical value as the original binomial taxa. The first phase of their analysis, the definition of the groups using polar length and surface sculpture, is effected by the identification of the groups within a grid. The grid has polar length along the horizontal axis and the surface sculpture lying along the vertical axis. The name of the taxa is constructed from existing form-generic names suffixed by a letter and number code denoting the morphospecies, this having been derived from the grid. The second phase proposed by Boulter and Wilkinson involves a very detailed level of study utilising the scanning electron microscope and comparison with other fossil material and equivalent extant pollen, other advanced techniques (unspecified) and computer analysis. They state that when it is necessary to create a new form-species or biorecord, as much information as possible must be provided so as to define the taxa precisely.

It is clear that when constructing this system Boulter and Wilkinson have been influenced by the ideas of Hughes. The first phase of their scheme produces a nomenclature that is not easily mnemonic and conveys little information without the grid from which it was defined. This in itself is enough to prevent it from being accepted into common usage. The second phase of detailed refinement is not one that can be carried out in routine palynological analysis.

Wilkinson and Boulter (1980) used a variation on the first phase of their scheme (Boulter and Wilkinson, 1977). Here pollen was assigned to a published genus and groups were defined on the grid system but denoted by a single letter. Many groups were described as similar, or very similar, to previously published form-species without actually assigning them to the published species.

The systems of classification generally in use may be broken down into the following four basic types.

1. The 'natural' system: this approach to classification makes reference to the relationship of the fossil taxa to extant taxa and names the taxa as such eg. *Nyssa.*

2. The 'half-natural' system: this is used if a relationship to extant taxa is suspected and a generic name is coined alluding to this eg. *Nyssapollenites.* The suffix *-pollenites* attests to the fossil nature of the taxa. Under the present I.C.B.N. regulations half-natural names are recognised in the same way as artificial form-generic names provided that they are validly published.

3. The 'artificial' system: this uses purely artificial names based upon a morphological feature of the taxa eg. *Tricolporopollenites.* A natural affinity might be suggested in the description of the taxa.

4. The 'biorecord, genusbox' system of Hughes.

The use of a 'natural' system of classification could be regarded as the ultimate goal of the taxonomist if the linkage to the extant taxon could be certain. This would enable definite ecological, botanical and climatological conclusions to be drawn from the occurrences and distributions of the taxa. This is probably an unrealistic aim and care should be exercised in the attributions that are drawn based upon a purely morphological comparison with no supporting palaeobotanical evidence. In numerous publications Potonié (1951, 1956a, 1956b, 1958a, 1975) warned of the problems of assigning Tertiary fossil pollen to extant genera if the holotype pollen was in dispersed form and not in situ in a parent plant organ.

During the Tertiary, angiosperm evolution was progressing rapidly and a great diversity of species existed. This in itself creates difficulties in the classification of Tertiary pollen. Traverse (1988) states that extant angiosperms may often only be identifiable to the generic level (sometimes only to the family level). Bearing this in mind we may sometimes be trying to disseminate taxa to a tier of meaningless ecological separation.

A point of disagreement between palynologists appears to be the quantity and detail of evidence required linking a fossil taxon to an extant taxon. Faegri (1956) and Potonié (1958b) believed that a part of a plant, an organ genus, is not representative of the whole when comparing fossil and extant plants, especially if one is investigating evolutionary change. Boulter (1979) believes that taxonomic problems in palynology may be resolved by reference to the whole megafossil record. This calls into question whether enough use is being made of palaeobotanical data by palynologists. It is not standard practice among many palynologists to make use of macrofossil evidence in conjunction with the pollen assemblage of a deposit. Studies which do are few and far between (Machin, 1971; Collinson, 1983). This may be partially because work is being carried out on deposits lacking, or of unsuitable environment for the preservation of macrofossils, but is also greatly influenced by the background of the palynologist and the type of study being carried out. Many palynologists having a geological but not a botanical training have approached a study from a stratigraphic rather than a palaeobotanical / palaeoecological viewpoint. In the defence of palynologists, Traverse (1988) points out that macrofossil palaeobotanists are not always particularly interested in the referability of *in situ* pollen and spores from inflorescences, to taxa of dispersed sporomorphs. He cites the example of Manchester and Crane (1983) who described in detail pollen from a fagaceous plant of Oligocene age and compared it with that of the extant beech-oak alliance. Traverse adds that they neglected to mention to which taxa (*Quercoidites* or *Cupuliferoipollenites* or some other taxon) the pollen would be attributed if dispersed.

The problems of mosaic evolution impinge upon the assignation of palaeotaxa to extant taxa. Different organs of angiosperms evolved at different rates, thus, pollen resembling that of an extant genus may have originated from a plant that was quite different. Wing (1981) and Hickey and Wing (1983) recorded Tertiary *Platycarya* pollen along with other organs as originating from plants with leaves that were not attributable to *Platycarya* or even to the family Juglandaceae. Conversely Crept (1979) recorded Eocene fossil flowers that yielded pollen not dissimilar to the extant relatives of the flower producing plants.

Some objection has been made to the attribution of fossil pollen to extant genera from the point of view that as the pollen grain is only a haploid organ, representing the short gametophytic part of a plant's life cycle, it is unsuitable as a basis of reference for attribution to an extant genera. This is a valid point, however considering that fossil leaf species have, and are still referred to extant genera, without great objection or controversy, it is one that may be regarded as being somewhat pedantic.

These considerations aside, the morphology of the pollen and spores may be the only clue one has to begin constructing the palaeoflora, palaeoecology and hence the palaeoclimate. By the nature of their size, the ability of pollen and spores to be preserved in great quantity and widely distributed makes their potential to provide information on the diversity of the palaeoflora much greater than that of botanical macrofossils. As such their usefulness should not be dismissed. A balance has to be struck between proceeding with too much caution so as to dismiss potentially useful information and becoming misled by erroneous botanical attributions.

### 6.3 Solution to the taxonomical and nomenclatorial problem?

It would appear that no easy, all encompassing solution exists to the problems of taxonomy and nomenclature within Tertiary pollen studies. None of the systems presently in use seem able to clearly and succinctly cater for all needs.

A complete abandonment of the use of all previous schemes and the installation of a universally accepted one, may seem an ideal, but one that is extremely unlikely to happen. Such a procedure would be fraught with difficulties, not least in the conversion of all previous data to the new scheme. So much previous data has been accumulated and systems are so ingrained into the science that complete abandonment of previous ideas would be a mistake and would undoubtedly cause many problems.

Various disciplines often have different requirements from a system of taxonomy and nomenclature. Whilst a palaeopalynologist might be more concerned with resolving a stratigraphic problem, a Quaternary palynologist might be more concerned with the ecological implications of the pollen asemblage. Systems of taxonomy and nomenclature used in Tertiary palaeopalynology often appear to attempt to bridge the gap between functioning in a stratigraphical and a botanical context. As such the system may be stretched too far in one or other direction and so not function adequately. For reasons identified previously the widely accepted artificial form-generic approach is not ideally suited to either purpose. This is unfortunate as both stratigraphic resolution and a better understanding of the ecological restrictions of taxa is the goal of many palaeopalynologists.

The recognition of a form taxon that is attributable to an extant genera is a major step forward. It provides a degree of specificity away from a broad ranging form generic name, to a possibly more stratigraphically restricted 'half natural' generic name that has an implied ecological attribution.

For the sake of consistency and to aid some comparison with previous studies and taxonomy, the system used in this thesis is a combination of the 'half natural' and artificial form taxa systems.

If a pollen grain or spore is regarded as referable to an extant taxon and is widely accepted as thus, the name of the taxa is used with the suffix *-pollenites*. This signifies the probable affinity to the extant genus and the ecological parameters that the affinity infers, whilst not actually stating that it is biologically the same genus, as this causes a series of problems in itself that can most probably not be proved or disproved. Where an affinity to an extant taxon is not universally accepted or is not known, the form generic taxon is used. This morphologically identifies the taxon and enables comparison to previous literature, providing some consistency to a data set. Whilst this may not solve any of the problems previously identified it does not create more.

The production of synonymy lists for each species has not been carried out in this thesis. Due to the vast array of published species, the concise nature and poor quality of many earlier descriptions and illustrations, the exercise is seen as futile. Its only purpose would be to present yet another lengthy list of personal opinions on the assignation of species that is based upon observations of data of sometimes-dubious quality. All the problems previously attested to, description, illustration, language, impinge upon the quality and meaningfulness of a synonymy list. Unless the list is completely exhaustive it is of selective limited use. Reference to published data has been made where it was deemed appropriate. The author is in agreement with Smith

(1986) when he states that: "Selective reference to published records is of course normal palaeontological practice, but tends to be overshadowed by concern over synonymy and priority." (p. 151)

A suprageneric system, in the sense of the turma, infraturma divisions of Thomson and Pflug (1953), and that of the classes of Naumova (1939), with the subsequent emendations that have resulted is not used. Genera are grouped informally according to their germinal structure. These groupings are obvious and are based upon the structure/s that one first identifies when observing a grain. It is felt that the morphological groups are just as effective in gathering pollen with a similar germinal morphology as the formalised groups of the aforementioned authors, however, they do not suffer from the encumbrance of the formality of published precedence and emendation.

# 7 POLLEN AND SPORE SYSTEMATICS

All the slides for the samples analysed from the four bore holes 13/611 Landagivey No. 1, 13/603 Ballymoney No. 1, 36/4680 Deerpark No. 2 and 27/415 Upper Mullan No. 1 are located in the Centre for Palynology, University of Sheffield. Core samples from which the analysed material was taken reside with the Geological Survey of Northern Ireland.

## 7.1 Monocolpate pollen

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

Type species: *Arecipites punctatus* Wodehouse, 1933, fig. 22 (designated by Potonié 1958, Synopsis II, p. 97.)

Generic remarks: Elliptical to elongate oval monocolpate pollen with a reticulate sculpture, cloumellae may be present beneath the reticulum. Lumina usually smaller on the distal surface than on the proximal surface particularly in the area immediately adjacent to the colpus. The distal extremities of the colpus may be slightly flared and rounded, tapering and pointed, or gaping.

The original diagnosis of Wodehouse is terse and lacks clarity regarding the generic concept of *Arecipites*. It does not allude to the widely accepted reticulate nature of the genus, only likening the structure of the type species to the extant taxon *Phoenix dactylifera*.

Nichols *et al.* (1973) emended the genus and stated that they would not regard *Arecipites* as reticulate in accordance with their description of that term. They also restricted *Arecipites* to forms with tapered extremities to the colpus, placing flared and rounded types into *Monocolpopollenites*. This emendation is rejected as the author agrees with Kemp and Harris (1977) and Wilkinson and Boulter (1980) that the form of the colpus and to some extent the structure of the exine are inconsistent and difficult to apply diagnostically. Nichols *et al.* (1973) rejected Anderson's (1960) emendation of the genus restricting it to only finely reticulate forms with lumina generally less than 0.5$\mu$m as they considered it to depart substantially from Wodehouse's generic concept and the description of the type species. Anderson's emendation is rejected here. The emendatation of Krutzsch (1970) is accepted as it places emphasis on the reticulum character and may be meaningfully applied to the grains recognised within this study.

*Arecipites* Group A Wilkinson and Boulter, 1980.

Pl. 1, figs. 1-3.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 3 figs. 10-21.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 49.

Description: Monocolpate pollen with an oval amb with rounded to pointed apices in prolate compression. The colpus is aligned along the long axis of the grain, its extremities may be tapered or gaping. The exine is reticulate comprising thin muri less than 0.5$\mu$m wide and lumina up to 1$\mu$m in diameter. Grains measured range in size from 19-28$\mu$m in length.

Discussion: This form of *Arecipites* is characterised by its thin muri and small lumina.

Wilkinson and Boulter (1980) state that their group includes the following species of Krutzsch (1970): *Arecipites butomoides*, *Arecipites gossmarensis*, *Arecipites longicolpatus*, *Arecipites lusaticus*.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980). The aforementioned species of Krutzsch (1970) have been reported from the Oligocene to Pliocene of Germany. Wilkinson and Boulter (1980) report that they are regarded as being recorded most commonly from the Oligocene.

Botanical affinity: Palmae.

*Arecipites* Group C Wilkinson and Boulter, 1980.

Pl. 1, figs. 4-6.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980. pl. 3, fig. 25-32.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 49.

Description: Monocolpate pollen with an oval amb with rounded apices in prolate compression. The colpus is aligned along the long axis of the grain, its extremities may be tapered or slightly flared. Exine structure is baculo-reticulate. The reticulation comprises relatively thick muri 0.5-<1$\mu$m wide and lumina up to 2$\mu$m in diameter on the proximal surface and 1$\mu$m on the distal surface. Adjacent to the colpal margins the lumina decrease in diameter to less than 0.5$\mu$m, to coalesce to form a distinct margo. Grains measured range in size from 23-31$\mu$m in length and 12-14$\mu$m in width.

Discussion: This species is characterized by its relatively thick muri and distinct colpus. Wilkinson and Boulter (1980) described the colpus as generally not seen in their specimens. The specimens described here appear similar in all other respects. The author is in agreement with Wilkinson and Boulter (1980) in that their *Arecipites* Group C incorporates the following species of Krutzsch. *Arecipites oligocaenicus* Krutzsch, 1970, *Arecipites brandisensis* Krutzsch, 1970, *Arecipites convexus*, (Thiergart, 1937) Krutzsch, 1970 and *Arecipites?* sp.6 Krutzsch, 1970.

It is the author's opinion that the number of species of seemingly very similar forms described by Krutzsch (1970) is not of practicable use in this study.

Occurrences: Present in all sections.

Stratigraphic record: Middle to Late Oligocene of the Western British Isles, Wilkinson and Boulter (1980). *Arecipites oligocaenicus* Krutzsch, 1970, Middle Oligocene of East Germany, *Arecipites brandisensis* Krutzsch, 1970, Lower Miocene East Germany *Arecipites convexus*, (Thiergart, 1937) Krutzsch, 1970, Middle Miocene of East Germany and *Arecipites?* sp.6 Krutzsch, 1970, Miocene of East Germany.

Botanical affinity: Palmae, Krutzsch (1970).

*Arecipites* Group D Wilkinson and Boulter, 1980

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 4, figs. 1-5.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 49.

Description: Monocolpate pollen with a rounded oval amb in prolate compression. A reticulate ornament covers the grain comprising relatively thin muri 0.2$\mu$m wide with polygonal lumina up to 3$\mu$m in diameter. Grains measured range in size from 28-30$\mu$m in length.

Discussion: This species occurs rarely, it is characterized by the delicate nature of the reticulum. No specimens suitable for illustration were recorded.

Occurrences: 13/603, 27/415.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Palmae.

*?Arecipites* Group E Wilkinson and Boulter, 1980.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 4, figs. 6-7.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 50.

Description: Monocolpate pollen with an elongate oval amb in prolate compression. A baculo-reticulate ornament covers the grain. The baculae are 1-1.5$\mu$m high and form lumina up to 2$\mu$m in diameter. The single grain recorded measured 25$\mu$m in length.

| | |
|---|---|
| Discussion: | The single specimen recorded was in a poor state of preservation and has been questionably assigned to the Group, it was unsuitable for illustration. |
| Occurrence: | 36/4680. |
| Stratigraphic record: | Oligocene of the Western British Isles, Wilkinson and Boulter (1980). |
| Botanical affinity: | ?Palmae. |

*Arecipites symmetricus* Krutzsch, 1970

Pl. 2, figs. 1-2.

| | |
|---|---|
| Holotype: | Krutzsch, 1970, pl. 23, figs. 11-14. |
| Diagnosis: | See Krutzsch, 1970, p. 108. |
| Description: | Monocolpate pollen with an oval to rounded oval amb. The colpus extends almost to the grain margins and is distinct with flared rounded extremities. The wall is 1$\mu$m thick. A baculo-reticulate structure can be discerned using x1000 oil immersion phase contrast microscopy. The bacula are observed to have small slightly swollen rounded heads. Lumina are small, 0.5$\mu$m in diameter and of similar size on the proximal and distal surfaces. A slight thickening is noted along the colpus margins. Grains measured range in size from 25-26$\mu$m in length and 18-19$\mu$m in width. |

Discussion: This species is characterized by the character of the reticulum and the distinct colpus type.

Occurrences: 13/611, 13/603.

Stratigraphic record: Throughout the 'middle and younger' Tertiary, Krutzsch (1970).

Botanical affinity: Palmae, Krutzsch (1970).

*Arecipites* cf. *papillosus* (Mürriger and Pflug, 1951) Krutzsch, 1970.

Pl. 2, figs. 3-4.

Holotype: Mürriger and Pflug, 1951, pl. 5, figs. 6-9.

Diagnosis: See Krutzsch, 1970, p. 100.

Description: Monocolpate pollen with an oval to rounded oval amb. The colpus is distinct and extends short of the grain margins having tapered extremities. The collumellate wall is 1$\mu$m thick and comprises small clavae with expanded swollen heads. These may be clearly discerned using L/O analysis. They comprise narrow muri approximately 0.5$\mu$m wide enclosing lumina of 2.5-3$\mu$m on the proximal surface and 0.5$\mu$m on the distal surface. Grains measured range in size from 25-27$\mu$m in length and 21-22$\mu$m in width.

Discussion: The grains have been referred to as cf. *papillosus* as they are smaller with a thinner wall and a more distinct colpus than those illustrated by Krutzsch, 1970.

The grains bear a superficial resemblance to *Arecipites* Group C Wilkinson and Boulter (1980) however *Arecipites* cf. *papillosus* has thinner muri relative to the lumina and the collumellate structure forming the reticulation is clearly discerned.

Occurrences: 13/611, 13/603.

Stratigraphic record: Eocene to Middle Oligocene of Germany, Krutzsch, 1970.

Botanical affinity: Palmae, Krutzsch, 1970.

Genus *Cycadopites* Wodehouse, 1933.

Type species: *Cycadopites follicularis* Wilson and Webster, 1946, pl.1, fig. 7.

Generic remarks: The type species is described in Wilson and Webster (1946) as Wodehouse (1933) did not assign any species to the genus. The emended diagnosis of Krutzsch (1970) is accepted here.

The type species is Monocolpate pollen with an elongate elliptical amb, the length is approximately twice the width. The colpus runs the full length of the grain and is usually observed gaping at the ends and constricted in the middle. The thin exine may display some folding especially around the colpus. A slight ornament may be observed but the exine is generally smooth.

*Cycadopites* is easily differentiated from the monocolpate pollen attributed to *Monocolpopollenites* because of its clear, thin, elongated form and characteristic gaping colpus.

*Cycadopites* sp. A.

Pl. 3, figs. 1-2.

Holotype: 36/4680, 265.13,slide 2, L46.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Monocolpate pollen with an elongated elliptical amb. The length of the grain is twice the width. The colpus is long reaching to the grain margins and often displays characteristic flaring ends. The exine is smooth and unornamentated. Grains measured range in size from 26-35$\mu$m in length and 10-16$\mu$m in width.

Discussion: The specimens identified bear a resemblance to *Cycadopites. gracilis* Krutzsch, 1970.

Occurrence: Present in all sections.

Stratigraphic record: Unknown.

Botanical affinity: Cycadaceae.

Genus *Magnolipollis* Krutzsch, 1970.

Type species: *Magnolipollis neogenicus* Krutzsch, 1970, p. 132, pl. 32, fig. 1-4.

Generic remarks: Thin walled monocolpate pollen with an elongate oval to ellipsoidal amb. The exine comprises a finely columellate wall with a smooth unornamented surface that may display a fine punctation.

*?Magnolipollis neogenicus* subsp. *minor* Krutzsch, 1970.

Pl. 3, fig. 3.

Holotype: Krutzsch, 1970, pl. 32 figs. 1-4.

Diagnosis: See Krutzsch, 1970. p. 132.

Description: Monocolpate pollen with an elongate oval amb. The wall is collumellate and up to 1$\mu$m thick. The surface of the grain displays an irregular punctation. Some folding of the wall is noted. The single grain recorded measures 32$\mu$m in length.

Discussion: The single grain encountered in the study is questionably attributed to the species.

Occurrence: 13/611.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1970).

Botanical affinity: Magnoliaceae, Krutzsch (1970).

Genus *Monocolpopollenites* Pflug and Thomson, 1953 (in Thomson and Pflug, 1953).

Type species: *Monocolpopollenites tranquillus* (Potonié, 1934, p. 51, pl. 2, fig. 8.) Pflug and Thomson, 1953, p. 62-63, pl. 4, figs. 24-27.

Generic remarks: Monocolpate pollen with an elliptical to elongate oval amb. The colpus reaches short of the grain margins, lying along the long axis of the grain and often displays a medial constriction and rounded, slightly flared ends. The exine is psilate but may display a weak granation.

The type species has had a history fraught with various attributions and emendations. Originally it was described under the genus *Pollenites* by Potonié (1934). Thomson and Pflug (1953) transferred the type species to their form genus *Monocolpopollenites*. Jansonius and Hills (1976) state that this transfer did not comply with I.C.B.N. Article 33 as a full and clear reference to the basionym was not made in the correct manner. Their opinion is the same as that proposed by Potonié (1966) recognising the seniority of *Monocolpopollenites* over his previous consideration of *Palmaepollenites* as having seniority (Potonié, 1958b). Potonié (1966) and Krutzsch

(1962a) speculated that *Arecipites* Wodehouse, 1933 may be the correct attribution.

It is clearly apparent from Thomson and Pflug (1953) p. 62-63, to which of Potonié's papers and figured specimens they refer when proposing the transfer, so it is accepted in this study.

Krutzsch (1970) provided an emended diagnosis to the original description of Thomson and Pflug (1953). That emendation is accepted here.

*Monocolpopollenites tranquilloides* Nichols, Ames and Traverse, 1973.

Pl. 3, fig. 4.

Holotype: Nichols, Ames and Traverse, 1973, pl. 2, figs. 2-5.

Diagnosis: See Nichols, Ames and Traverse, 1973, p. 252.

Description: Monocolpate pollen with an elongate oval amb. The colpus lies along the long axis of the grain, reaching short of the amb and displays a medial constriction and rounded flared ends. Distinct margo like thickenings occur around the colpus in the region of the medial constriction, up to 3$\mu$m wide. The exine is thin, less than 1$\mu$m in thickness and is psilate. The single grain recorded measures 35$\mu$m in length.

Discussion: This species is very similar to *Monocolpopollenites tranquillus*, (Potonié 1934) Thomson and Pflug, 1953. It is distinguished by the distinctive thickenings around the colpus margins.

Occurrence: 13/611.

Stratigraphic record: Late Palaeocene, Texas, U.S.A.

Botanical affinity: Palmae or Cycadales, Nichols, Ames and Traverse (1973).

*Monocolpopollenites tranquillus* (Potonié 1934) Thomson and Pflug, 1953.

Pl. 4, figs. 1-2.

Holotype: Potonié, 1934, pl. 2, fig. 8.

Diagnosis: See Potonié, 1934, p. 51

Description: Monocolpate pollen with an elongate oval amb. The colpus lies along the long axis of the grain, reaching short of the amb and displays a medial constriction and rounded flared ends. The exine is thin, less than 1$\mu$m and is psilate or it may display a weak granation. Grains measured range in size from 19-29$\mu$m.

Discussion: See remarks for *M. tranquilloides*.

Occurrence: 13/611, 13/603.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Palmae, Thomson and Pflug (1953).

## 7.2 Dicolpate pollen

Genus: *Dicolpopollenites* Pflanzl, 1956 ex Potonié 1966.

Type species: *Dicolpopollis kockelii* Pflanzl 1956, p. 241, pl. 16, fig. 9.

Generic remarks: Dicolpate pollen with an irregularly oval amb, best likened to the shape of an axe head. Two colpi are aligned approximately parallel to the equator. The exine is reticulate.

The genus was not validly published by Pflanzl (1956) as no diagnosis was given. Potonié (1966) provided a diagnosis, designated the type species and reinterpreted the exine as being reticulate and not granulate as Pflanzl (1956) had described.

*Dicolpopollis kockelii* Pflanzl, 1956 ex Potonié 1966.

Pl. 4, figs. 3-5.

Holotype: Pflanzl, 1956, pl. 16, fig. 9.

Diagnosis: See Potonié, 1966, p. 160.

Description: Dicolpate pollen with an amb the shape of an axe head/triangular. One pole is flattened, the other tapers to a point that may be blunted. The colpi run approximately parallel to the sides of the grain. A split may be observed running between the colpi causing the grain to gape open along the flattened pole. The exine is covered with a reticulate ornament with muri 0.5$\mu$m high enclosing irregular polygonal lumina 0.5-1.5$\mu$m wide. Grains measured range in size from 16-20$\mu$m.

Discussion: A form with larger lumina up to 2$\mu$m in diameter that decrease in size towards the amb has been noted. The lumina size is the only difference noted in these specimens from the description given above and is regarded as a feature of intraspecific variation. This decrease in lumina size towards the amb is a feature not mentioned by Krutzsch (1970) but one which may be noted in his illustrations of *Dicolpopollis kockelii* on pl. 42.

Occurrence: 13/603, 36/4680, 27/415.

Stratigraphic record: Lower Oligocene to Lower Miocene, Vinken (1988).

Botanical affinity: Palmae, Thanikaimoni *et al.* (1984).

*?Dicolpopollis* Group D Wilkinson and Boulter, 1980.

Pl. 4, fig. 6.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 4, fig. 23.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 51.

Description: Dicolpate pollen with a triangular shaped amb approximating to the shape of an axe head, one side straight the other two more gently convex. The colpi appear to run parallel to the grain sides. The exine is covered with a reticulate ornament comprising thick muri 0.75$\mu$m wide enclosing lumina 1-2$\mu$m in diameter. The single specimen recorded measured 20$\mu$m in length.

Discussion: The specimen recorded is in poor preservation but portrays a characteristic splitting noted in other forms of *Dicolpopollis* and broadly conforms to Wilkinson and Boulter's (1980) description of their *Dicolpopollis* Group D. Due to poor preservation and uncertainty of the attribution the specimen is questionably assigned to the group.

Occurrence: 36/4680.

Stratigraphic record: Oligocene of the Western British Isles (only noted in Bellbrook section western shores of Lough Neagh), Wilkinson and Boulter (1980).

Botanical affinity: Palmae.

### 7.3 Tricolpate pollen

Genus *Cupuliferoidaepollenites* Potonié, Thomson and Thiergart 1950, ex Potonié, 1960.

Type species: *Cupuliferoidaepollenites liblarensis* Thomson, 1950, (in Potonié, Thomson and Thiergart, 1950), p. 55-56 ex Potonié, 1960, p. 92.

Generic remarks: Tricolpate pollen with an elongate ovoidal amb, recorded in prolate compression. The poles display rounded caps which do not trend to pointed. The exine is unornamented and smooth.

The genus is useful as it enables subdivision of the all-encompassing genera *Tricolpopollenites,* Thomson and Pflug, 1953 and *Tricolpites,* Cookson, 1947, ex Couper, 1953. The aforementioned genera include pollen with a variety of exine structures and ornament and in prolate and oblate compressions.

Thomson and Pflug (1953) described two subspecies of *Cupuliferoidaepollenites liblarensis, C liblarensis fallax* for forms smaller than 18$\mu$m and *C. liblarensis liblarensis* for forms greater than 18$\mu$m but less than 25$\mu$m. The species *Cupuliferoidaepollenites parmularis* was erected for pollen of this morphology with a length greater than 25$\mu$m. The distinction between the three subspecies of *Cupuliferoidaepollenites* is based purely upon size. Despite the author's opinion that the splitting of the subspecies is somewhat artificial and that no botanical or stratigraphical value can be attributed to it within this study, a distinct size grouping has been observed enabling the subspecies split to be easily recognised. The majority of forms observed were in the size range of *C. liblarensis liblarensis*.

*Cupuliferoidaepollenites liblarensis* Thomson, 1950, (in Potonié, Thomson and Thiergart, 1950) ex Potonié 1960, subsp. *fallax* (Potonié, 1934) Thomson and Pflug, 1953.

Holotype: Potonié, 1934, pl. 3, fig. 10.

Diagnosis: See Potonié, 1934, p. 70.

Description: Tricolpate pollen with an elongate ovoidal amb, in prolate compression. The poles display rounded caps. The exine is thin walled, less than 1$\mu$m thick, unornamented and smooth. The colpi are long reaching just short of the poles. Grain measured range in size from 12-17$\mu$m.

Discussion: See generic remarks

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: Cupuliferae, Thomson and Pflug (1953), Fagaceae, Graus Cavagnetto (1968).

*Cupuliferoidaepollenites liblarensis* Thomson, 1950, (in Potonié, Thomson and Thiergart, 1950) ex Potonié 1960, subsp. *liblarensis* Thomson and Pflug, 1953.

Pl. 5, fig. 1.

Holotype: Thomson, 1950, (in Potonié, Thomson and Thiergart, 1950), pl. B, figs. 26-27.

Diagnosis: See Thomson, 1950, (in Potonié, Thomson and Thiergart, 1950), p. 55.

Description: Tricolpate pollen with an elongate ovoidal amb, in prolate compression. The poles display rounded caps. The exine is thin walled, less than 1$\mu$m thick, unornamented and smooth. The colpi are long, reaching just short of the poles. Grains measured range in size from 18-25$\mu$m in length.

Discussion: See generic remarks.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: Cupuliferae, Thomson and Pflug (1953), Fagaceae, Graus Cavagnetto (1968).

*Cupuliferoidaepollenites parmularis* (Potonié, 1934) Thomson and Pflug, 1953.

Holotype: Potonié, 1934, pl. 2, fig. 7

Diagnosis: See Potonié, 1934, p. 52.

Description: Tricolpate pollen with an elongate ovoidal amb, in prolate compression. The poles display rounded caps. The exine is thin walled, less than 1$\mu$m thick, unornamented and smooth. The colpi are long, reaching just short of the poles. Grains measured range in size from 27-29$\mu$m in length.

Discussion: This species resembles *Cupuliferoidaepollenites liblarensis* subsp. *liblarensis* and *Cupuliferoidaepollenites liblarensis* subsp. *fallax* in all respects except for its larger size.

Occurrence: 13/611, 27/415.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: Cupuliferae, Thomson and Pflug (1953), Fagaceae, Graus Cavagnetto (1968).

*Platanuspollenites* gen. nov. comb.nov.

Type species: *Platanuspollenites ipelensis* Pacltová, 1966, p. 61, pl. 19, figs. 14-16, comb. nov.

Generic diagnosis: Tricolpate pollen with a rounded oval amb in prolate compression. The exine is thick in relation to the size of the grain, 1-1.5$\mu$m, displaying a collumellate structure. The columellae comprise very small clavae. Careful focusing on the exine reveals a microreticulation so fine as to almost appear as a punctation. The colpi are relatively short, do not reach the grain margins and are parallel sided with obtuse ends. In oblate compression the colpi gape widely and due to their diminutive length are not deeply incised. The apocolpia is large.

Generic remarks: The new genus *Platanuspollenites* is erected here to contain pollen that bears a very close similarity to pollen of the extant genus *Platanus*. As a clear relationship to the extant genus appears to have been proved in the literature there seems no justification to retain this morphologically distinct group in the all encompassing form genus *Tricolporopollenites*, to which the author believes it was wrongly attributed by Pacltová (1966).

Potonié, (1931a) pl. 2, fig. 34, illustrated *Pollenites gertrudae* from the Miocene of Germany giving a description in the form of symbols. Jansonius and Hills (1976) translated this as: "subcircular in outline, granulose, tricolpate, colpi long; size ca. 17$\mu$m." (card 2024) Potonié, Thomson and Thiergart (1951) listed *Platanoidites gertrudae* but gave no generic diagnosis. *Platanoidites* Potonié, Thomson and Thiergart, 1951, ex Potonié, 1960, has the following diagnosis

"... spherical to broadly ovoid shape; equator slightly trilobate; tricolpate, the colpi +/- 2/3 of each meridian in length, with geniculus; exine granulate to finely reticulate, outline finely crenate." (Potonié, 1960, p. 94).

Whilst the generic name, decription and size of *Platanoidites gertrudae* seem to allude to a similarity to the type of pollen here attributed to *Platanuspollenites* gen. nov., the clarity of the diagnosis of Potonié (1960) is such that this cannot be ascertained with certainty, hence the erection of *Platanuspollenites*.

*Platanuspollenites ipelensis* Pacltová, 1966, comb. nov. emend.

Pl. 5, figs. 2-6.

1966, *Tricolporopollenites ipelensis* Pacltová, p. 61, pl. 19, fig. 14-16.

Holotype: Pacltová, 1966, pl. 19, figs. 14-16.

Diagnosis: Small tricolpate pollen with a rounded oval amb in prolate compression. The exine is up to 1-1.5$\mu$m thick. It displays a microreticulation and a collumellate structure comprising very small clavae less than 1$\mu$m in length. The colpi are parallel sided with obtuse ends, relatively short, ranging from 7-10$\mu$m, and reach short of the grain margins. The margins of the colpi display distinctive ragged edges. In oblate compression the colpi gape widely and are not deeply incised. The apocolpia is large. The holotype measures 20$\mu$m in length.

Description: Grains measured range in size from 15-26$\mu$m in length and 12-17$\mu$m in width in prolate compression. In oblate compression the diameter of the grain ranges from 20-23$\mu$m.

Discussion: Pacltová (1966) described *Trocolporopollenites ipelensis* as occurring quantitatively and characterising the pollen spectrum of Chattian-Aquitanian of the Ipel basin, Czechoslovakia. The English translation of the diagnosis given is as follows

> "Oval suboblate shape. Polar axis 20-23$\mu$m, equatorial 16-18$\mu$m (Holotype 20 x 16$\mu$m). Exoexine has a thick clavate sculpture. Colpi do not extend up to the poles. Almost indistinct pores are covered with the sculptural elements." (p.61)

The botanical relationship was given as cf. Salicaceae.

The illustrated specimens of the holotype of *Tricolporopollenites ipelensis*, Pacltová, 1966, pl. 19, figs. 14-16 and further illustrated specimens figs. 17-19 do not appear to have pori and do not illustrate the described clavate sculpture. The sculpturing illustrated appears to be indeterminate. The likening to Salicaceae would allude to a reticulation being present. The illustrated specimens have an overall appearance like specimens of the extant species *Platanus orientalis* as illustrated by Moore *et al.* (1991).

Pacltová (1978) in a paper on Evolutionary trends of platanaceoid pollen in Europe during the Cenophytic, reported finding a type of pollen in the Upper Oligocene (Egerian) marine deposits of the Panonian Basin in Southern Slovakia that represented "... a characteristic element of an upper Oligocene pollen assemblage abundant in the studied section." (p.71)

Pacltová notes that he originally described this pollen type as *Tricolporopollenites ipelensis.*

Upon systematic investigation as to the distribution of this pollen type in Europe, Pacltová (1978) reports that *T. ipelensis*

> "... occurs commonly in Middle Oligocene deposits, being particularly abundant in certain phases of the Upper Oligocene, evidently in low temperature zones." (p.71)

Pacltová (1978) p. 72 states that the biological assignment of *Platanus* species was supported through morphological analysis of pollen from the extant species *P. occidentalis, P. orientalis, P. acerifolia and P. wrightii,* and by comparison to *in situ* pollen from the inflorescences of *P. neptuni* from the Lower Miocene described by Buzek, Holy and Kvacek (1967). The distinctive features outlined are:

> "...endogerminal with irregularly sinuous outline without internal pores in the equator.
>
> exogerminal - the longitudinally oval colpus is closed with a smooth or variously conspicuously sculptured membrane. The exoporus

sculpture is an important generic and intrageneric feature. However, in some species no colpus membrane may probably be evidenced, the colpus of these species being very narrow.

Pollen wall structure - the exoexine/endoexine ratio varies distinctly within the Platanoid group, particularly in the following characters...

... Exoexine - reticulate, collumellate. Reticulum may be small or in extreme cases so minute that under the light microscope it appears as microfoveolate. The underlying columellae of the reticulum are observable under the light microscope with difficulty as their size approaches the enlargement power of the microscope. Sometimes in the optical section only the columellae may be evidenced as tiny bodies under the tectum.

Endoexine - double layered, one smooth, the internal layer is smooth and equally thick on the whole of the surface. The upper layer varies in thickness from the equator to the pole." (p. 73)

Pacltová (1978) concluded that *P. ipelensis* is most closely related to the extant species *P. occidentalis.*

Wilkinson and Boulter (1980) liken their *Tricolporopollenites* Group E, pl. 8 figs. 29 and 30 to *T. ipilensis* Pacltová 1966. The author is not in agreement with the suggested similarity as a *Tricolporopollenites* Group E is tricolporate and clearly of different affinity to *T. ipilensis* as now emended and assigned to an affinity with *Platanus.*

Occurrence: Present in all sections.

Stratigraphic record: Middle Oligocene to Upper Oligocene of Europe, Pacltová (1978).

Botanical affinity: *Platanus*, Platanaceae, Pacltová (1978).

Genus *Quercoidites* (Potonié, Thomson and Thiergart, 1950) Potonié, 1960.

Type species: *Quercoidites henrici* Potonié, 1931a, p. 329, pl. 2, fig. 19.

Generic remarks: Tricolpate pollen with an elongate ovoidal amb and a scabrate ornament.

*Quercoidites microhenrici* (Potonié, 1931b) Potonié, 1960.

Pl. 6, figs. 1-2.

Holotype: Potonié, 1931b, pl. 1, fig. 19c.

Diagnosis: See Potonié, 1960, p. 92.

Description: Tricolporate pollen with an elongate ovoidal amb. The exine has a collumellate structure and a scabrate ornament that gives the grain a crenate appearance. The colpi are long, reaching just short of the grain margins. Grains measured range in size from 20-28$\mu$m. in length. In oblate compression the colpi appear widely splayed and deeply incut, giving rise to a small apocolpia.

Discussion: The nature of the columellate structure is difficult to discern as it lies at the limits of resolution of the light microscope. It is described as intragranulate or intrabaculate by Thomson and Pflug (1953). This species is differentiated from *Q. henrici* (30-50$\mu$m) by its smaller size.

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Pliocene of Europe.

Botanical affinity: *Quercus*, Fagaceae, Thomson and Pflug (1953).

### 7.3.1 Reticulate Tricolpate Pollen

Reticulate tricolpate pollen has been assigned to a variety of different genera by numerous authors based upon different interpretation of the structure of the pollen. This morophological group of grains suffers from all of the nomenclatorial and taxonomic problems and confusion attested to in the previous chapters discussing the state of nomenclatorial and taxonomic problems of pollen within the Tertiary.

Commonly previously used genera for reticulate tricolpate pollen include:

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

This well-known and used genus is illegitimate and a synonym of the extant genus *Neea*. That aside, its diagnosis was simply given as "Reticulate tricolpate pollen". No mention as to how the reticulum is formed was given resulting in a genus that is poorly defined and all encompassing and so taxonomically not particularly specific.

*Fraxinoipollenites* Potonié, 1951 ex Potonié, 1960.

The diagnosis is as follows: "Shape elongate ovoid to fusiform; with three long colpi that show neither a geniculus nor a pore; exine granulate to reticulate; outline crenate." (p.94)

This diagnosis is felt to be vague and does not specify if the reticulation is an ornament or a result of the structure of the pollen.

*Salixipollenites* Srivastava, 1967.

The diagnosis is as follows:

"Tricolpate pollen, more or less deeply three lobed, isodiametric, slightly elongate or oblately flattened; colpi long and tapering; without internal marginal thickenings and without germ pores; exine thick and coarsely reticulate." (p.529)

The type species is described with the reticulum becoming finer towards the margins of the colpi and towards the pole. Srivastava intended this genus to accommodate fossil pollen comparable to that of *Salix*.

Reticulate tricolpate pollen encountered within this study have not been assigned to any of the aforementioned genera due to their unclear description. Two form genera are here proposed to which fossil reticulate tricolpate pollen may be assigned to provide a clear morphological distinction of reticulum structure upon which grains may be easily separated.

Of the reticulate, tricolpate grains identified within this study, two modes of reticulum formation have been observed. The first is where the reticulum is a structure that is formed by the columellae that comprise the wall of the grain. This structure has previously been commonly referred to as baculoreticulate. The second is where the reticulum appears as an ornament and no columellate structure has been readily observed.

Moore *et al.* (1991) clearly explain how a reticulation can result from very different structure. "One grain could be tectate with the reticulum walls on top of the tectum and the other could be intectate where the reticulum walls are formed by the columellae connected at their heads." (p.75) They suggest that these two forms may be distinguished by calling the former tectate, reticulate (*suprareticulate*) and the latter intectate, reticulate (*eureticulate*). The terms suprareticulate and eureticulate are clearly defined by Moore *et al.* (1991)as follows:

"**Eureticulate:** With a partially dissolved tectum, i.e. the heads of columellae joined in only one or two directions to form the muri of the reticulum. Distribution of columellae often corresponds to that of the muri although there may be free cloumellae in the lumina, eg. *Salix, Ligustrum*." (p. 164)

"**Suprareticulate:** With a reticulum on top of the tectum. Pattern is thus independent of the distribution of the columellae, e.g. *Galeopsis*. Columellae are not always visible, eg. in some members of the Leguminosae." (p. 166)

Wilkinson and Boulter (1980) identified four groups of reticulate, tricolpate pollen. The reticulate, tricolpate pollen identified in this study can be placed within these four groups as they are defined and illustrated. The author does not, however, agree with Wilkinson and Boulter's use of the form genus *Salixipollenites* as pollen attributed to their *Salixipollenites* Group B is described as having "... no tendency to baculo reticulate forms." (p.57) and forms included in their Group D appear as such.

Moore *et al.* (1991) define *Salix* as eureticulate:

"Lumina size and exine thickness markedly decreasing towards the edge of the colpus edge such that a clear margo is present. The immediate edge of the colpus is actually tectate without lumina..." (p. 124).

The eureticulate (baculoreticulate) tricolpate groups *Salixipollenites* Group A and Group C, as described and illustrated by Wilkinson and Boulter (1980), may be considered to conform to the diagnosis of *Salixipollenites*, Srivastava 1967, as literally defined. However, Srivastava intended his genus *Salixipollenites* to accommodate fossil pollen comparable to that of *Salix* and described the type species as having a reticulum generally finer towards the margins of the colpi and towards the poles. As the name *Salixipollenites* implies an attribution to *Salix*, and the pollen attributed to *Salixipollenites* Group A and Group C by Wilkinson and Boulter (1980) does not conform to the author's accepted definition of this type of pollen, namely that of Moore *et al.* (1991) as defined above, the attribution of Wilkinson and Boulter's (1980) specimens to *Salixipollenites* is rejected.

In this study reticulate tricolpate pollen assigned to *Salixipollenites* Group A and Group C of Wilkinson and Boulter (1980) is assigned to the morphological genus *Euretitricolpites* gen. nov. Pollen assigned to *Salixipollenites* Group B and Group D of Wilkinson and Boulter (1980) is here assigned to the morphological genus *Supraretitricolpites* gen. nov.

Genus *Euretitricolpites* gen. nov.

Type species: None designated, as the genus is informally erected for the purposes of this study.

Generic diagnosis: Tricolpate reticulate pollen in which the reticulum is formed as a structure of the tectate wall. The muri of the reticulum are formed by the close juxtaposition and/or joining of the heads of the columellae comprising the intectate/partially tectate wall of the grain.

Generic remarks: Upon careful focusing at x1000 magnification the heads of the columellae may be discerned and the structure thus ascertained. This genus has been created to provide a clearly defined morphological group into which pollen of this structure (some forms previously termed baculoreticulate) may be assigned.

*Euretitricolpites* Group A Wilkinson and Boulter, 1980.

Pl. 6, figs. 3-5.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 7, figs. 24-27, 35.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 57.

Description: Tricolpate, finely reticulate pollen with an ovoidal to elongate ovoidal amb in prolate compression. The muri of the reticulum are formed by small baculae up to < 0.5$\mu$m long. The lumina are very small, less than 0.5$\mu$m in diameter. The colpi are long, reaching just short of the poles. Grains measured range in size from 20-26$\mu$m in length. In oblate compression the colpi gape widely, the apocolpium is small. Grains measured range in size from 18-22$\mu$m in diameter.

Discussion: Wilkinson and Boulter (1980) state that specimens in this group are comparable to *Retitricolpites retiformis*, Pflug and Thomson, 1953, (in Thomson and Pflug 1953) and to forms attributed to that species by Roche and Schuler (1976).

The only other microreticulate tricolpate pollen identified in this study is *Platanuspollenites* gen. nov. This is easily differentiated from *Euretitricolpites* Group A Wilkinson and Boulter (1980) by its more rounded amb, shorter colpi with obtuse ends, a large apocolpium and cloumellae comprising small clavae.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: *Retitricolpites retiformis*, Pflug and Thomson, 1953, was thought to have an affinity to the Salicaceae-Platanaceae by Graus Cavagnetto (1968).

*Euretitricolpites* Group C Wilkinson and Boulter, 1980.

Pl. 6, fig. 6.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 7, figs. 32-34, 40.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 58.

Description: Tricolpate, reticulate pollen with an ovoidal to elongate ovoidal amb in prolate compression. The muri of the reticulum are formed by small baculae up to 1$\mu$m long. The lumina vary in size from 1-1.5$\mu$m in diameter. The muri are thick up to 0.75$\mu$m. The colpi are long, reaching just short of the poles.

Grains measured range in size from 18-24$\mu$m in length. In oblate compression the colpi gape widely, the apocolpium is small.

Discussion: This group occurs rarely and is differentiated from *Euretitricolpites* Group A Wilkinson and Boulter (1980) by its larger lumina and thicker muri.

Occurrence: 13/611, 27/415.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Unknown.

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

Type species: *Retitricolpites ornatus* (Van der Hammen 1956), Pierce 1961 p. 50 *Tricolpites (Retitricolpites) ornatus* Van der Hammen 1956, p. 90, fig. 26.

Generic remarks: Reticulate tricolpate pollen. Despite the genus being illegitimate under the rules of the I.C.B.N. (see previous discussion under Reticulate Tricolpate Pollen) and not being very specific in its all-encompassing diagnosis, the genus is widely used and is useful as a form genus for pollen of this morphology in much the same way as the form genera *Tricolporopollenites* and *Tricolpopollenites* of Thomson and Pflug (1953) are of use. Van der Hammen and Wijmstra

(1964), in an attempt to correct the illegitimacy of the name, proposed *Retitricolpites ovalis* as a lectogenotype. This did not resolve the situation, as it was contrary to article 7 of the 1966 code.

Despite the problems regarding the name, *Retitricolpites* is utilised for the type of reticulate tricolpate pollen in this study that has a reticulation whose structural composition is uncertain.

*Retitricolpites* sp. A

Pl. 7, fig. 1-6.

Holotype: 13/603, 280.00m, slide 1, K36/1.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Tricolpate pollen with an oval to elongate oval amb in prolate compression. The colpi are aligned along the long axis of the grain reaching just short of the grain margins. The grain surface is covered by a reticulate ornament that comprises polygonal lumina up to 2$\mu$m. The muri are very fine, approximately 0.1$\mu$m wide and 1$\mu$m high. Grains measured range in size from 17-19$\mu$m in length and 12-14$\mu$m in width.

Discussion: This is a very distinctive species, easily distinguished from other species by its characteristic very fine muri with relatively large luminae in relation to its small size. The structure comprising the muri is unclear. With LO analysis at x1000 magnification the heads of individual baculae that probably comprise the lumina appear to be evident, this would lead the reticulation to be classified as eureticulate. Due to the low numbers of specimens recorded and the uncertainty as to the structure of the reticulum, grains of this morphology are attributed to the form genus *Retitricolpites* to provide an overall indication of their morphology.

Occurrences: 13/611, 13/603.

Stratigraphic record: Unknown

Botanical affinity: Unknown.

Genus *Supraretitricolpites* gen. nov.

Type species: None designated as the genus is informally erected for the purposes of this study.

Generic diagnosis: Tricolpate reticulate pollen in which the reticulum is formed as an ornament surmounting the tectate wall. The reticulation is independent of the distribution of the columellae that may not be visible.

Generic remarks: Upon careful focusing at x1000 magnification no evidence of the heads of the columellae forming the reticulum may be discerned. This genus has been created to provide a clearly defined morphological group into which pollen of this structure may be assigned.

*Supraretitricolpites* Group B Wilkinson and Boulter, 1980.

Pl. 8, figs. 1-5.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 7, figs. 28-31, 36-38.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 57.

Description: Tricolpate, reticulate pollen with an ovoidal to rounded ovoidal amb in prolate compression. The muri of the reticulum are thin, up to 0.5$\mu$m thick and formed as an ornament surmounting the tectum. There is no evidence of a baculo-reticulation. The lumina vary in size from 0.5-1$\mu$m in diameter. The colpi are long, reaching just short of the poles. Grains measured range in size from 19-35$\mu$m in length. In oblate compression the colpi gape widely, the apocolpium is small, the grains measured range in size from 22-24$\mu$m in diameter.

Discussion: Wilkinson and Boulter (1980) liken prolate preservation of this group to *Tricolpopollenites indeterminates*, Romanowicz, 1961 and they liken oblate specimens to *Retitricolpites* fsp. as recorded by Roche and Schuler (1976).

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Unknown.

*Supraretitricolpites* Group D Wilkinson and Boulter, 1980.

Pl. 8, fig. 6.

Holotype: None specified as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 8, figs. 1-4.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 58.

Description: Tricolpate reticulate pollen preserved in oblate compression. The muri of the reticulum are formed as an ornament surmounting the tectum. There is no evidence of a baculo-reticulation. The lumina vary in size from 1-2.5$\mu$m in diameter. The muri are up to 1$\mu$m thick. The colpi gape widely and are deeply incut forming a small apocolpium. Grains measured range in size from 30-35$\mu$m in diameter.

Discussion: Pollen of this type has an infrequent occurrence, it is differentiated by its thick muri and the size of the lumina and compression.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Unknown

Genus *Tricolpopollenites* Pflug and Thomson, 1953 (in Thomson and Pflug, 1953).

Type species: *Trocolpopollenites parmularius* (Potonié, 1934) Thomson and Pflug, 1953, p. 97.

*Pollenties parmularis* Potonié, 1934, p. 52, pl. 2, fig. 7.

Generic remarks: Tricolpate pollen with the polar axis equal to or longer than the equatorial axis. Three colpi lie along the polar axis with a symmetrical distribution.

*Tricolpopollenites hastus* sp. nov.

Pl. 9, figs. 1-4.

Named after the Latin for spear, *hastus*, in reference to the ornament.

Holotype: 13/603, 218.60m, slide 2, N41.

Diagnosis: Tricolpate pollen with a polar axis greater than the equatorial axis, an elongate ovoidal amb with pointed poles in prolate compression. The colpi reach just short of the amb. The exine is psilate with a columellate wall 0.5$\mu$m thick. A distinct ornament of spines up to 3$\mu$m in length, spaced 2-3$\mu$m apart cover the exine, decreasing in size towards the poles. The spines often appear flexed. In specimens with a denser ornament, the spines may be ordered in such proximity to produce a weak reticulation, noted in certain optical sections. The thin weak muri, comprising of the tips of the spinose elements, may be discerned using LO analysis at x1000 magnification. Grains measured range in size from 18-22$\mu$m in length and 12-16$\mu$m in width.

Discussion: This species most closely resembles *Tricolporopollenites spinus* Krutzsch, 1962a, recorded from the Middle to Upper Oligocene. It differs in not possessing the short elements in-between the main spines illustrated by Krutzsch's species and by not displaying pori.

*T. hastus* appears to be very similar to *Tricolpopollenites* Group E, Wilkinson and Boulter (1980). They describe their group of pollen as having an ornament of spines with rounded tips, in combination with flat topped baculae. Their illustrated specimens appear very similar to *T. hastus*. Despite no mention of a weak reticulation being apparent on any of the specimens described by Wilkinson and

Boulter (1980), the specimen illustrated on their plate 7, fig. 21 appears to show such a feature.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Unknown.

*Tricolpopollenites verrucatus* sp. nov.

Pl. 9, figs. 5-6.

Holotype: 13/611, 47.00m, slide 1, H50/3.

Diagnosis: Tricolpate pollen with the polar axis longer than the equatorial axis. The exine comprises a fine columellate wall 0.5$\mu$m thick covered with a distinct ornament of irregular verrucae irregularly distributed over the surface of the grain. The verrucae measure 1.5-2$\mu$m in height. The colpi are long, reaching just short of the grain margins. In oblate compression the colpi appear deeply incised, the apocolpium is small and the grains measure approximately 20$\mu$m in diameter. In oblate compression the grain margins are straight to slightly convex but never strongly so.

Discussion: In prolate compression grains measured range in size from 20-26$\mu$m in length and 15-17$\mu$m in width.

The columellate nature of the wall may be difficult to discern in prolate compression. Careful L/O analysis at x1000 magnification with an oil immersion lens may facilitate this identification.

The strong verrucate ornament of this species easily differentiates it from *Quercoidites microhenrici*.

| | |
|---|---|
| Occurrence: | Present in all sections. |
| Stratigraphic record: | Unknown. |
| Botanical affinity: | Unknown. |

## 7.4 Tricolporate pollen

Genus *Cryillaceaepollenites* Mürriger and Pflug 1951, ex Potonié, 1960.

Type species: *Cryillaceaepollenites megaexactus* (Potonié, 1931b, p. 26, pl. 1. fig. 42b) Potonié, 1960, p. 102.

Generic remarks: Tricolporate pollen with a rounded to oval elongate amb and an unornamented smooth exine. The genus was erected by Potonié (1960) as a subdivision of Thomson and Pflug's (1953) large form genus *Tricolporopollenites*. *Cryillaceaepollenites* is differentiated from *Cupuliferoipollenites* by the more elongate amb of the latter genus.

*Cryillaceaepollenites megaexactus* (Potonié, 1931b) Potonié, 1960.

Pl. 10, figs. 1-2.

Holotype: Potonié, 1931b, pl. 1, fig. 42b.

Diagnosis: See Potonié, 1931b, p. 26.

Description: Small tricolporate pollen with a rounded to oval amb in prolate compression. A distinct convexity of the amb occurs round the equator of the grain. The colpi reach just short of the poles. The pores are strongly defined lying round the equator of the grain. The exine is unornamented and smooth. Grains measured range in size from 14-20$\mu$m in length.

Discussion: This small rounded tricolporate grain is easily distinguished from *Cupiliferoipollenites cingulum*, the species that it most closely resembles, by the clear convexity of the amb producing a distinctly rounded appearance.

Occurrence: 13/603, 36/4680, 27/415.

Stratigraphic record: Oligocene/Miocene of Germany, Potonié (1931b).

Botanical affinity: *Cryillaceae*, Clethracea, Potonié (1931).

Genus *Cupuliferoipollenites* Potonié, 1951 ex Potonié 1960.

Type species: *Cupuliferoipollenites cingulum* Potonié, 1931b, p. 26, pl. 1, fig. 45a, 46a, 46b, 48b, 60a, 60d, 61c, 62c.

Generic remarks: Tricolporate pollen with an elongate amb in prolate compression. The polar ends have a rounded aspect and the sides of the grain are subparallel. The exine is smooth and unornamented. The colpi are long, parallel and reach just short of the poles.

Thomson and Pflug (1953) in a new combination of Potonié's (1934) *Pollenites quisqualis pusillus* and *Pollenites oviformis* down graded the species to sub-species rank contained within their *Tricolporopollenites cingulum.* The author accepts the view of Jolley (1991) that *Cupuliferoipollenites pusillus,* Potonié, 1951, is identical with *Tricolpopollenites cingulum,* (Potonié, 1931b) Thomson and

Pflug, 1953, thereby making *C. pusillus* a junior synonym of *C. cingulum* (Potonié 1931b), Jolley, 1991 and accepts the changing of the type species from *C. pusillus to C. cingulum.*

The combination of Jolley (1991) placing the genus as *Cupuliferoipollenites* is accepted as it distinguishes this pollen from the all encompassing group *Tricolporopollenites* Thomson and Pflug, 1953.

*Cupuliferoipollenites cingulum* (Potonié 1931b) Jolley, 1991.

*Cupuliferoipollenites cingulum* (Potonié 1931b) Jolley, 1991. subsp. *pusillus* (Potonié 1931b), Thomson and Pflug, 1953).

Pl. 10, figs. 3-5.

Holotype: Potonié, 1934, pl. 3. fig. 21.

Diagnosis: See Potonié, 1934, p. 71.

Description: Tricolporate pollen with an elongate amb. The sides of the grain are subparallel but may display a slight convexity. The polar ends are rounded. The colpi are distinct and lie parallel to each other reaching just short of the poles. The pori are clearly defined lying round the equator of the grain. The grains are generally smooth and unornamented, however, a very weak granulation may be developed on some specimens. Grains measured range in size from 18-22$\mu$m in length.

Discussion: The distinction between *Cupuliferoipollenites cingulum pusillus* and *Cupuliferoipollenites cingulum oviformis* is based purely upon size. Despite the author's opinion that no botanical or stratigraphical value can be attributed to the splitting into the subspecies of Thomson and Pflug (1953), a distinct size grouping has been observed enabling the subspecies split to be easily recognised.

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Miocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Fagaceae, *Castanea*, Potonié (1960).

*Cupuliferoipollenites cingulum* (Potonié 1931b) Jolley, 1991. subsp. *oviformis* (Potonié 1934), Thomson and Pflug, 1953.

Pl. 10, fig. 6.

Holotype: Potonié, 1931a, pl. 1, fig. 20 (Potonié, 1934, pl. 5, figs. 23, 27.)

Diagnosis: See Potonié, 1934, p. 95.

Description: Small tricolporate pollen with an elongate amb. The sides of the grain are subparallel but may display a slight convexity. The polar ends are rounded. The colpi are distinct and lie parallel to each other reaching just short of the poles. The pori are clearly defined lying round the equator of the grain. The grains are smooth and unornamented. Grains measured range in size from 10-16$\mu$m.

Discussion: See discussion for *Cupuliferoipollenites cingulum pusillus.*

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Miocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Fagaceae, *Castanea*, Potonié (1960).

Genus *Holkopollenites* Fairchild, 1966, (in Stover, Elsik and Fairchild, 1966).

Type species: *Holkopollenites chemardensis* Fairchild, 1966, (in Stover, Elsik and Fairchild, 1966.) p. 6, pl. 2, fig. 8.

Generic remarks: Tricolporate pollen with a deltoid amb. Colpi are long and deeply incised displaying a strong margo extending the full length of the colpi. Exine incised by irregular channels approximately parallel to the equator.

?*Holkopollenites* spp.

Pl. 11, figs. 1-2.

Description: Tricol (porate?) pollen with a deltoid shaped amb, preserved in oblate compression. The margins of the grain are straight giving the deltoid appearance but may display a slight convexity. Margines surround the germinals. The colpi gape widely, up to 10$\mu$m. The colpal margins are ragged and display a slight out turning at their equatorial margins possibly indicating pori? The exine is 1-1.5$\mu$m thick and appears punctate, however, grains identified are poorly preserved. Grains measured range in size from 18-26$\mu$m in diameter.

Discussion: Elsik (1968) notes that specimens he recorded as *H. chemardensis* may be as described by Fairchild (1966), as colpate with no pore.

The specimens recorded in this study resemble those questionably attributed to *Holkopollis* by Elsik (1968), pl. 30, figs. 4-6, in that evidence of equatorial pores are lacking as are the striations on the exine, however, margines are noted in the grains described here.

In oblate compressions of Nyssapollenites the exine may be observed to be thicker near the equator and evidence of the pori is distinct. The colpi in *Nyssapollenites* tend to be less deeply incised and the colpal gape less pronounced.

Occurrence: 36/4680

Stratigraphic record: The monotypic type species was originally described from the Palaeocene of Texas, U.S.A.

Botanical affinity: Unknown

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

Type species: *Ilexpollenites iliacus* Potonié, 1931d, p. 556, fig. 5, ex Potonié, 1960, p. 99.

Generic remarks: Tricol(porate?) pollen with a oval to rounded oval amb in prolate compression. The exine is densely covered in a distinctive ornament of clavae/pilae with swollen rounded heads. The colpi and ?pori are indistinct.

Potonié's diagnosis states that pores are "more or less distinguishable" and so defines *Ilexpollenites* as tricolporate. The specimens assigned to this genus within this study display all the characteristics of *Ilexpollenites iliacus* and *Ilexpollenites margaritatus* respectively, however no clear pori have been observed.

Wilkinson and Boulter (1980) in their description of *Ilexpollenites* from the Oligocene of the western British Isles, describe the colpi and pori as always indistinct.

Moore *et al.* (1991) assign *Ilexpollenites* to the Trizonocolpate section of their pollen key and make no mention of pori in their description. Their illustrations on plate 38, figures e and f and the S.E.M. photograph, plate 69, figures a and c do not illustrate pori.

*Ilexpollenites iliacus* Potonié, 1931d, ex Potonié, 1960.

Pl. 11, figs. 3-4.

Holotype: Potonié, 1931d, fig. 5.

Diagnosis: See Potonié, 1960, p. 99.

Description: Tricol(porate?) pollen with an elongate oval to rounded oval amb. The germinals are indistinct as they are obscured by the tightly packed ornament of clavae/pilae. A variation in the size of the ornament occurs across the grain. The pilae are up to 3$\mu$m in height at the poles and have swollen rounded heads, they decrease in size to 2$\mu$m at the equator. The grains are most often preserved in prolate compression where the ornament can be seen to decrease in size towards the germinals. In oblate compression the amb is rounded with colpi up to 10$\mu$m long displaying a slight thickening round the edges. A decrease in the height of the pilae towards the colpal margin is clearly displayed, elements being 0.5-1.0$\mu$m in height. In prolate compression grains measured range from 19-26 $\mu$m in length and from 20-22$\mu$m diameter in oblate compression.

Discussion: *Ilexpollenites iliacus* is easily distinguished from *Ilexpollenites margaritatus* as in the latter species the clavae/pilae are smaller and there is no variation in the size of the ornament from the pole to the equator.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Aquifoliaceae, *Ilex*, Thomson and Pflug (1953).

*Ilexpollenites margaritatus* (Potonié, 1931d) Raatz, 1937.

Pl. 11, figs. 5-6.

Holotype: Potonié, 1931d, pl. 1 fig. 33.

Diagnosis: See Potonié, 1931d, p. 328.

Description: Tricol(porate?) pollen with an elongate oval to rounded oval amb. The germinals are indistinct as they are obscured by the tightly packed ornament of clavae/pilae. The colpi when discerned reach up to 12$\mu$m in length. The pilae are up to 2$\mu$m in height and have swollen rounded heads. The grains are most often preserved in prolate compression. Grains measured range from 20-24$\mu$m in length and 15-20$\mu$m in width.

Discussion: As noted for *Ilexpollenites iliacus* pori cannot be discerned on the specimens recorded.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Aquifoliaceae, *Ilex*, Thomson and Pflug (1953).

Genus *Mediocolpopollis* Krutzsch, 1959c.

Type species: *Mediocolpopollis compactus* Krutzsch, 1959c, p. 150, pl. 35. figs. 22-27.

Generic remarks: Tricolporate pollen with distinct mediocolpi, with thickened colpal margins, an elongate oval amb and a psilate exine.

*Mediocolpopollis compactus* Krutzsch, 1959c.

Pl. 12, figs. 1-2.

Holotype: Krutzsch, 1959c, pl. 35, figs. 22-27.

Diagnosis: See Krutzsch, 1959c, p. 150.

Description: Tricolporate pollen with a distinct colpal structure consisting of thickened colpal margins surrounding equatorially elongated exopores and endopores (usually difficult to discern) of similar size. The mediocolpoid structure consists of a small vertically elongated colpoid space between the exo and endopores, appearing as a small colpus in plan view. The amb is elongate oval and the exine is psilate. The colpi extend along the length of the grain. Grains measured range in size from 20-25$\mu$m in length.

Discussion: This species is easily distinguished from other tricolporate pollen by its distinctive colpal struture.

Occurrence: Present in all sections.

Stratigraphic record: Upper Oligocene of Germany, Krutzsch (1959c).

Botanical affinity: Unknown, pollen of this morphology has been likened to Sapotaceae pollen but differs in the form of the germinal structure.

### Genus *Nyssapollenites* Thiergart, 1938 ex Potonié, 1960.

Type species: *Nyssapollenites pseudocruciatus* (Potonié, 1931a, p. 328, pl. 1. fig. 10.) Thiergart, 1938, p. 328.

Generic remarks: Tricolporate pollen with a rounded to slightly elongate amb in prolate compression. The colpi display clear margines, the endopores are large and often display an equatorial elongation. In oblate compression the colpi are widely gaping and the amb displays a straight to slightly convex outline.

*Pollenites pseudocruicatus* Potonié, 1931a was assigned to *Nyssapollenites* by Thiergart (1938), this was not valid as no generic diagnosis was given. Potonié (1960) provided this, thus legalising the name.

### *Nyssapollenites kruschi* (Potonié, 1931d) Jolley, 1991, subsp. *analepticus* (Potonié, 1934) Thomson and Pflug, 1953.

Pl. 12, figs. 3-6.

Holotype: Potonié, 1934, pl. 2, figs. 36-38.

Diagnosis: See Potonié, 1934, p. 64.

Description: Tricolporate pollen with a rounded to slightly elongated amb in prolate compression. Each colpus displays a thickening forming a distinct margo at its margins. The colpi reach short of the margins of the amb. The exopores are large and circular.

The exine is up to 1.5$\mu$m thick and unornamented, having a intrapunctate structure, this may not always be discernable. Grains measured range in size from 19-30$\mu$m in length. In oblate compression the amb displays straight to slightly convex sides with deeply incised colpi and a measured diameter ranging from 20-24$\mu$m.

Discussion: Despite the probable artificial nature to the splitting of the species to the sub-species *Nyssapollenites kruschi analepticus* and *Nyssapollenites kruschi accessorius*, on the grounds of size, it has been carried out as observation has shown the two distinct size groups can be identified and so attribution to the two subspecies may be easily made.

The practice of Thomson and Pflug (1953) of assigning all oblate compressions of pollen in the *kruschi* group to Potonié's 1931a species *pseudolaesus*, and that of Wilkinson and Boulter (1980) to their *Nyssapollenites* Group C is not followed within this study. Oblate compressions are not common and when found have been assigned to the relevant subspecies.

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Miocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Nyssaceae, Thomson and Pflug (1953).

*Nyssapollenites kruschi* (Potonié 1931d) Jolley, 1991, subsp. *accessorius* (Potonié, 1934) Thomson and Pflug, 1953.

Pl. 13, fig. 1.

Holotype: Potonié, 1934, pl. 6, fig. 9.

Diagnosis: See Potonié, 1934, p. 64.

Description: Pollen assigned to this subspecies is identical to *Nyssapollenites kruschi* subsp. *analepticus* except in its larger size. Grains larger than 31$\mu$m in length are attributed to subsp. *accessorius*. Grains measured range in size from 31-34$\mu$m in length.

Discussion: See previous section on *Nyssapollenites kruschi* subsp. *analepticus*.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Palaeocene to Miocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Nyssaceae, Thomson and Pflug (1953).

*Nyssapollenites satzveyensis* Pflug, 1953, (in Thomson and Pflug, 1953).

Pl. 13, fig. 2.

Holotype: Pflug, 1953, (in Thomson and Pflug, 1953), pl. 13, figs. 10-13.

Diagnosis: See Pflug, 1953, (in Thomson and Pflug, 1953), p. 103.

Description: Tricolporate pollen with an elongate oval amb in prolate compression. The exine is up to 1-1.5$\mu$m thick, unornamented and displays a distinct intrapunctation. Each colpus displays a clear margo and a large equatorially elongated exopore up to 3$\mu$m wide and 2$\mu$m high. The endopores are difficult to discern. Grains measured range in size from 30-36$\mu$m in length.

Discussion: *Nyssapollenites satzveyensis* differs from *Nyssapollenites kruschi* by the more elliptical shape of its amb and the distinct intrapunctation and germinals. It is larger than *Nyssapollenites kruschi* subsp. *analepticus*.

Wilkinson and Boulter (1980) illustrate specimens on pl. 9. figs. 1-3. that they describe as having a microreticulate surface and attribute to their *Tricolporopollenites* Group F. These appear very similar to grains here attributed to *Nyssapollenites satzveyensis.*

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Nyssaceae, Thomson and Pflug (1953).

*Nyssapollenites incognitus* n.sp.

Pl. 13, figs. 3-4.

Named after the Latin, *incognitus*, unknown or unrecognised, in reference to the concealed nature of the central colpus in prolate compression.

Holotype: 36/4680, 265.13m, slide 1, Q45.

Diagnosis: Tricolporate pollen with a rhombohedral amb in prolate compression, less commonly more ovoidal in shape. The central colpus appears as a thickened bar up to 4$\mu$m wide, with flared ends, running along the length of the grain with no discernable pori. This thickening is formed by a fold in the exine and the margo of the colpus. The other colpi each display a margo and clear meridionally elongated pori. The exine is up to 1.5$\mu$m thick, unornamented and may display an infrapunctation. The holotype measures 22$\mu$m in length. Grains measured range in size from 20-25$\mu$m.

Discussion: With careful focusing at x1000 phase contrast magnification a pore may be discerned on some specimens with a less thickened central colpus. The central thickening/folding displays a constriction around the equator of the grain where the pore is located. A similar type of compression of the colpus has been noted in prolate compressions of other species of *Nyssapollenites* where the central colpus on the 'distal' surface of the grain appears as a split colpus. This form of preservation of the central colpus is thought to be a characteristic of *Nyssapollenites* that is displayed to its most prominent degree in this species.

*Nyssapollenites incognitus* has been recorded by Wilkinson and Boulter (1980) as *Nyssapollenites* Group B, as this is an informal name it has no standing under the I.C.B.N.

The characteristic central colpus structure serves to distinguish this species from other species of *Nyssapollenites.*

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Nyssaceae? Wilkinson and Boulter (1980). They warn of exercising caution regarding any firm conclusions as to the botanical affinity of this species in the absence of evidence from megafossil remains of plants from the Nyssaceae.

Genus *Porocolpopollenites* (Potonié 1931a) Pflug, 1953, (in Thomson and Pflug, 1953).

Type species: *Porocolpopollenites vestibulum* Potonié, 1931a, pl. 2, fig. 23.

Generic remarks: Tricolporate vestibulate pollen with a triangular amb in oblate compression. The colpi are small and indistinct, specimens may appear to be triporate under low magnification.

Potonié did not provide a diagnosis. Pflug, 1953, (in Thomson and Pflug, 1953) validated the genus by publishing a diagnosis.

*Porocolpopollenites calauensis* Krutzsch, 1961d.

Pl. 13, figs. 5-6.

Holotype: Krutzsch, 1961d, pl. 4, figs. 94-97.

Diagnosis: See Krutzsch, 1961d, p. 318.

Description: Tricolporate vestibulate pollen always noted in oblate compression. The amb is rounded triangular with three distinct strongly annulate pori, 3-4$\mu$m in width, positioned at the corners of the triangle and displaying a post vestibulum. The exine is 1-1.5$\mu$m thick in the inter amb areas thickening to 3$\mu$m around the pori forming the annuli. The exine is sparsely ornamented with expanded granate to low clavate/pilae elements, 1.5$\mu$m long, in some cases extending to form short baculate elements that may reach 3$\mu$m in length. The colpi are indistinct and rarely discernible. Grains measured range in size from 26-30$\mu$m in diameter.

Discussion: The distinct ornament and strongly annulate pori serve to distinguish this species.

Occurrence: Present in all sections.

Stratigraphic record: Middle Oligocene of Germany, Krutzsch (1961d). Upper Eocene to Oligocene-Miocene boundary, Krutzsch (1967c).

Botanical affinity: Symplocaceae, Krutzsch (1961d).

*Porocolpopollenites vestibulum*

Pl. 14, figs. 1-4.

Holotype: Potonié, 1931a, pl. 2, fig. 23.

Diagnosis: See Pflug, 1953, (in Thomson and Pflug, 1953), p. 93.

Description: Tricolporate vestibulate pollen always noted in oblate compression. The amb is triangular with three distinct pori positioned at the corners of the triangle, displaying thickenings along the pore margins. The colpi are short and straight sided, approximately 4$\mu$m long but may be up to 8$\mu$m on a large specimen. The colpi are often indistinct unless viewed under x 1000 magnification. The exine is up to 1$\mu$m thick, a scabrate ornament covers a collumellate structure producing a reticulation. Grains measured range in size from 20-36$\mu$m in diameter.

Discussion: The underlying structure may be more clearly observed in areas where the exine is thinner or particularly in partially degraded specimens where the surface ornament has been reduced/partially removed.

Pflug's diagnosis states that forms with three, four and rarely five pores are included in this genus. Forms with three pores predominate in this study. Only one specimen with four pores has been observed.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Symplocaceae, Thomson and Pflug (1953).

### 7.4.1 Reticulate Tricolporate Pollen

Reticulate tricolporate pollen has previously commonly been assigned to the genera *Rhoipites* Wodehouse, 1933 and *Favitricolporites* Sah emend Srivastava, 1972.

*Rhoipites*

Wodehouse's original diagnosis of *Rhoipites* is as follows: "Ellipsoidal tricolpate pollen with furrows long and pointed and pore thickenings conspicuous, projecting deeply inwards; exine rather finely reticulate-pitted." (p.513) Wodehouse stated that the type species *R. bradleyi* matches perfectly with the extant species *Rhus typhina*.

In the pollen key of Moore *et. al.* (1991) *Rhus typhina* keys out in the trizonocolpate rugulate striate section and is described as follows:

"Grain larger, >30$\mu$m. Strongly striate perforate in the mesocolpia with quite long parallel muri travelling meridionally or in swirling patterns. The perforations occur in single rows between the muri; this 'ladder' effect gradually becoming tectate-perforate in the small apocolpia. Endoaperture with diffuse of flaring ends (best-seen under phase contrast)." (p. 154)

If the description of *Rhus typhina* of Moore *et. al.* (1991) is accepted, this would seem to allude to Wodehouse possibly having a different type of pollen in mind for *Rhoipites* from the pollen frequently assigned to it since. Possibly intending it for very finely reticulate-pitted types or if the attribution to *Rhus* is followed, possibly a different type of pollen entirely.

Kemp and Harris (1977) clearly describe the specimens that they assigned to *Rhoipites* as having a columellate semitectate exine, the distal ends of the exine uniting to form the muri of the reticulum. *R. microluminus* is described with lumina of 0.4-0.5$\mu$m. Those of *R. grandis* are described as up to 2.5-3$\mu$m in length.

In the sense of the pollen described and attributed to *Rhoipites* by Kemp and Harris (1977) *Rhoipites* could be described as eureticulate-semitectate.

*Favitricolporites*

Sah (1967) originally described the genus but the diagnosis was such that it encompassed nearly all tricolporate pollen. Srivastava (1972) provided an emended diagnosis restricting the genus to include only "tricolporate retipillate pollen, thus distinguishing it from the tricolporate reticulate genus *Rhoipites* Wodehouse." (p. 256)

It seems uncertain as to what type of reticulum structure Srivastava thought *Rhoipites* was alluding. This may be because of the poor original description of the genus or because of Wodehouse likening it to *Rhus typhina*.

It is clear that later authors e.g. Kemp and Harris (1977) regarded *Rhoipites* as "... collumellate, semi-tectate ... distal ends of columellae unite to form muri of the reticulum ..." (p.38) This would seem to partly agree with Srivastava's description of the way the reticulum of *Favitricolpites* is produced. However, the S.E.M. illustrations in these two publication differ markedly with those of *Favitricolpites* distinctly appearing more baculate with the tips of the baculae appearing slightly independent and not fully fused together.

It is not inconceivable that many of the features of exine structure trend towards each other and the fusing of capitae of tightly packed baculae may eventually trend to a semitectate structure. The use of the S.E.M. in conjunction with light microscopy is the only way to accurately determine the structure/ornament of certain types of pollen. As the limit of resolution of the light microscope is approached it may be impossible to accurately and unequivocally determine the structure of a grain.

*Favitricolpites* is here understood to contain pollen with a tightly packed baculate ornament from which a reticulate pattern may result due to the close proximity of the baculate elements and the partial coalescence of their distal tips.

Since the original diagnosis of *Rhoipites* does not appear to match with later uses of the name, it is not utilised within this study to prevent the perpetuation of a possible misinterpretation. Tricolporate, collumellate, semi-tectate pollen in which the distal ends of the columellate unite forming the walls of the muri (in the sense that Kemp and Harris (1977) used *Rhoipites*) is here placed in the genus *Euretitricolporites* gen. nov. The term eureticulate is used in the same context as it was in the definition of the structure of reticulate tricolpate grains earlier in this study.

Srivastava (1972) gave a description of *Favitricolporites baculoferus* that stated the

"... sexine pilate, subtectate; baculate-layer 0.8$\mu$m thick, bacules distinct; tectate-layer about 0.8$\mu$m thick, capitate; capita partially fused with neighbouring ones, about 0.8$\mu$m in diameter, slightly smaller towards the colpi margins; sculpture retipilate; lumina less than 1$\mu$m in size, meshes formed by 5-7 capita surrounding a lumen."(p.256)

In the original diagnosis as *Tricolporopollenites baculoferus* Thomson and Pflug (1953) made no mention of a reticulation or of the swollen nature of the ends of the baculae to lend them to be described as pilae/capitate. The original illustration as *T. baculoferus* in Thomson and Pflug (1953) is inadequate to display such features.

Wilkinson and Boulter (1980) describe a group of pollen *Tricolporopollenites* Group G in which the baculae fuse to form a surface reticulation. They also describe a group of pollen *Tricolporopollenites* Group E that they note as having a reticulate ornament in which the reticulum is made up of closely spaced baculae but describe some specimens as having "... a more normal reticulation with thin muri."(p.60) *Tricolporopollenites* Group E may therefore encompass two slightly different structures that may be difficult to discern with light microscopy. They compare their pollen to *T. microreticulatus*, Thomson and Pflug, 1953, who described it as having a baculate sculpture so ordered that it appeared as a net (reticulate). Takahashi and Jux (1982) transferred this species to *Rhoipites*.

***Retitricolporites***

*Retitricolporites* (Van der Hammen, 1956) Van der Hammen and Wijmstra, 1964 has a simple diagnosis: "Tricolporate pollen grains with a reticulate sculpture." (p.92) The term sculpture as defined by Potonié (1934) and Faegri and Iversen (1950) refers to elements that stand out in relief on the surface of the exine without reference to the internal construction. If a reticulation were to be described as a sculpture (and the definitions of Potonié (1934) and Faegri and Iversen (1950) had been accepted) the reticulation would appear to be able to be termed suprareticulate, as defined earlier in this study. As the diagnosis does not clarify more precisely how the reticulation is constructed, i.e. if it is indeed suprareticulate or euretriculate, the genus is felt to be too vaguely defined to be of detailed taxonomic use.

Jansonius and Hills (1976) state that the genus is illegitimate. See generic discussion later in this chapter.

Genus *Euretitricolporites* gen. nov.

| | |
|---|---|
| Type species: | None designated as the genus is informally erected for the purposes of this study. |
| Generic diagnosis: | Tricolporate reticulate pollen in which the reticulum is formed as a structure of the tectate wall. The muri of the reticulum are formed by the close juxtaposition and/or joining of the heads of the columellae comprising the intectate/partially tectate wall of the grain. |

Generic remarks: Upon careful focusing at x1000 magnification the heads of the columellae may be discerned and the structure thus ascertained. This genus has been created to provide a clearly defined morphological group into which pollen of this structure (some forms previously termed baculoreticulate) may be assigned.

*Euretitricolporites microreticulatus* Pflug and Thomson, 1953, (in Thomson and Pflug 1953) comb. nov.

Pl. 14, fig. 5.

1953, *Tricolporopollenites microreticulatus* Pflug and Thomson, 1953, (in Thomson and Pflug 1953), p. 106, pl. 14, figs. 27-40.

Holotype: Thomson and Pflug, 1953, pl. 14, figs. 27-40.

Diagnosis: See Thomson and Pflug, 1953, p. 106.

Description: Tricolporate, microreticulate pollen with an ovoidal amb in prolate compression and flattened poles. The colpi are long, reaching just short of the poles, the pores comprise a small endopore and a larger meridionally stretched exopore. The reticulum is composed of closely spaced baculae with slightly swollen tips that coalesce to form the muri of the reticulum. Lumina are small, up to 0.5$\mu$m in diameter. Grains measured range in size from 19-30$\mu$m.

Discussion: The reticulation is very fine and may only be discerned at x 1000 magnification.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene to Miocene of Germany Thomson and Pflug (1953). Since, recorded throughout the Tertiary of Europe.

Botanical affinity: *Sambucus*, Caprifoliaceae, Thomson and Pflug (1953).

*Euretitricolporites* cf. *microreticulatus* sensu Takahashi and Jux, 1982, comb. nov.

Pl. 14, fig. 6, pl. 15, fig. 1-2.

1982, *Rhoipites* cf. *microreticulatus* Takahashi and Jux, p. 54, pl. 6, fig. 13.

Type: Takahashi and Jux, 1982, pl. 6, fig. 13.

Diagnosis: See Takahashi and Jux, 1982, p. 54,

Description: Very small tricolporate, microreticulate pollen with an ovoidal amb in prolate compression and flattened poles. The colpi are long, reaching just short of the poles, the pores comprise a small endopore and a larger meridionally stretched exopore. The reticulum is composed of fine, closely spaced baculae, 0.5-0.75$\mu$m long with slightly swollen tips that coalesce to form the muri of the reticulum. Lumina are very small, 0.2-0.5$\mu$m in diameter. Grains measured range in size from 11-13$\mu$m in length and 7-9$\mu$m in width.

Discussion: *Euretitricolporites* cf. *microreticulatus* sensu Takahashi and Jux, 1982, comb. nov. resembles *Euretitricolporites microreticulatus* Pflug and Thomson, 1953, comb. nov. in all respects except its size. This group is separated as the change in size is distinct and a clear division is discernible. The reticulation is very fine and may only be discerned at x 1000 magnification

Occurrence: Present in all sections.

Stratigraphic record: Palaeogene of Germany, Takahashi and Jux (1982).

Botanical affinity: Unknown.

Genus *Retioperculotricolporites* gen. nov.

Type species: None designated as the genus is informally erected for the purposes of this study.

Generic diagnosis: None is given as the genus is informally erected for the purposes of this study.

Generic remarks: The genus is informally erected as no published genus was found to satisfactorily house the pollen recorded. The morphologically closest genus *Psilatricolporites* Van der Hammen 1956 ex Pierce 1961, by its definition contains psilate, operculate pollen.

*Retioperculotricolporites* spp.

Pl. 15, fig. 3.

Holoype: 36/4680, 140.67m, slide 4, S48/3.

Diagnosis: Small tricolporate pollen with operculate pori and a reticulate ornamentation. Grains noted in oblate compression, the amb is circular with a diameter of 19$\mu$m. The colpi are deeply incised, 7$\mu$m long, the apocolpia is small. The colpal gape is 6$\mu$m and the operculum is 2.5-3$\mu$m wide. The exine is covered with a very fine reticulation, the lumina are less than 0.5$\mu$m wide the muri less than 0.25$\mu$m thick.

Discussion: A comparison may be drawn with *Psilatricolporites operculatus* Van der Hammen 1956 ex Pierce 1961 with regards to the germinal structure.

Moore *et al.* (1991) comment that the membrane around the edges of the apertures in operculate pollen is often very thin and as a result the opercula are frequently lost during fossilisation.

Occurrence: 36/4680, 27/415.

Stratigraphic record: None.

Botanical affinity: Unknown, (*Psilatricolporites operculatus* is noted by Van der Hammen (1956) as resembling *Alchornea*, Euphorbiaceae.

Genus *Retitricolporites* (Van der Hammen, 1956) Van der Hammen and Wijmstra, 1964.

Type species: *Retitricolporites normalis* (Van der Hammen, 1956) Van der Hammen and Wijmstra, 1964.

*Tricolporites (Retitricolporites) normalis* Van der Hammen, 1956, fig. 31.

Generic remarks: Van der Hammen and Wijmstra (1964), elevated the subgenus *Tricolporites (Retitricolporites)* to generic rank and stated *Retitricolporites normalis* Van der Hammen, 1956, as the genotype. To cover themselves in case the foundation on a recent species should be incorrect (which they did not believe) they stated *Retitricolporites guianensis*, Van der Hammen and Wijmstra, 1964, as the lectogenotype.

Jansonius and Hills (1976) state that this procedure is in conflict with Article 7 of the 1966 International Code of Botanical Nomenclature, which requires that a name is permanently attached to its nomenclatural type. This being the case the designation of the type species made *Retitricolporites* illegitimate and a later synonym of *Viburnum* (vide *Tricolporites* subgen. *Retitricolporites*).

Despite the illegitimacy of *Retitricolporites* it is a widely used and understood genus. As such, it is considered a useful form genus for pollen with a reticulation that is of unknown or uncertain structure.

Within this study *Retitricolporites* is utilised for reticulate tricolporate pollen that has not been attributed to any legitimately published genus and, due to the structure of the reticulation being uncertain, has not been described as eureticulate or suprareticulate.

*Retitricolporites* sp. A

Pl. 15, figs. 4-6.

Holotype: 13/603, 60.00m, slide 4, K44/1

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Small tricolporate pollen preserved in oblate compression. Amb circular to rounded triangular. The colpi are long, reaching just short of the poles, the apocolpia is small approximately 2$\mu$m in diameter. The exact pore structure is unclear. The pori bear a distinctive margo either side of an equatorially elongated endopore/colpal structure. The exine is microreticulate, the polygonal lumina are of variable size over the surface of the grain ranging from 0.25-0.5$\mu$m in diameter, the muri are 0.5$\mu$m high. Grains measured range in size from 15-18$\mu$m in diameter.

Discussion: This is a distinctive pollen type that has not been attributable to a published species. The precise morphology of its pori is uncertain and unlike any other pollen noted within this study.

Occurrence: 13/603.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.

*Retitricolporites gentianoides* sp. nov.

Pl. 16, figs. 1-4.

Named because of its similarity to *Gentianella* pollen.

Holotype: 36/4680, 265.13m, slide 3, W45/3.

Diagnosis: Large tricolporate pollen with an elongated oval amb. The colpi are long and reach to the poles. The exopores are large and distinct, 4$\mu$m in diameter, circular to slightly equatorially elongated they are surrounded by a strong margo. The exine displays a clear reticulation comprising meridionally elongated lumina up to 1-1.5$\mu$m long and 0.5$\mu$m wide. Grains measured range in size from 32-40$\mu$m in length.

Discussion: The characteristic elongated nature of the lumina is thought to be partially a result of compression, however, elongation of the lumina has been observed in specimens displaying less compression equatorially.

This is a very characteristic pollen type that is unlike any others recorded in this study. Preservation of specimens assigned to this species is never very good. The precise nature of the wall structure has not been discerned.

Occurrence: 13/603, 36/4680, 27/415.

Stratigraphic record: Unknown.

Botanical affinity: Gentianaceae.

Genus *Tiliaepollenites* Potonié, 1931b.

Type Species: *Tiliaepollenites indubitabilis* Potonié, 1931b, p. 4, fig. 14.

Generic remarks: Tricolporate pollen with a rounded triangular amb. The colpi are very short and may be hard to discern, consequently grains often appear to be triporate. The germinals are positioned in the middle of the sides of the grains and not at the corners. The vestibulate pori possess a distinct annulus. The columellae comprising the exine may give rise to a reticulation on the grain surface.

Krutzsch (1961d) states that the genus is a junior synonym of *Tilia*, as the holotype of the genus is a grain of Recent *Tilia cordata*, a contaminant in the original preparation. Whether this is the case or not is here regarded as irrelevant as the morphology of fossil specimens is clearly like that of the extant pollen *Tilia* and the name is widely used and understood. It is the author's opinion that common sense regarding the name and morphology of the genus should in certain cases rule over the sometimes over-encumbering pedantries of taxonomic procedure.

*Tiliaepollenites* sp. A

Pl. 17, figs. 1-2.

Holotype: 36/4680, 103.62, slide 1, F49/1.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Tricolporate pollen with a rounded triangular amb. The colpi are very short and may be hard to discern, consequently grains often appear to be triporate. The germinals are positioned in the middle of the sides of the grains and not at the corners. The exine is 1$\mu$m thick, the columellae comprising the exine give rise to a reticulation on the grain surface. The lumina are small, 0.5$\mu$m-0.75$\mu$m in diameter. The pori are of closed type having an external opening of 1-1.5$\mu$m diameter and an internal diameter of 3$\mu$m. A strong annulus surrounds the pori behind which lies a distinct area of thickened exine, approximately 5$\mu$m in diameter, which appears as a dark spot. Grains measured range in size from 28-33$\mu$m.

Discussion: Mai (1961) described and illustrated six new species and two subspecies of *Intratriporopollenites* that have since been recorded throughout the Tertiary of NW Europe. Mai's speciation, based upon the three types of structure described and illustrated diagramatically on p. 63 of his paper as simplibaculate muri e.g. *I. pseudinstructus*, duplibaculate muri e.g. *I. Insculptus* and scrobiculate muri e.g. *I. platyphyllos,* is thought to be too difficult to apply consistently and accurately to all but the very best preserved specimens. Even when this is the case, the limit of resolution of light microscopy is approached when using LO analysis to attempt to determine the structures he described as producing the differing microreticulations. For this reason, and due to the somewhat concise nature of Mai's descriptions which do not always contain information on the lumina size, a feature that is considered important in speciation as it is relatively easily discerned, taxa of Tiliaeaceous affinity recorded in this study, that resemble but cannot be definitely assigned to Mai's species, are assigned to informal species and any similarity to those published is noted.

*Tiliaepollenites* sp. A resembles *Intratriporopollenites cecialensis* Krutzsch, 1961d, in the fine structure of its reticulation but differs in its larger size and nature of the pori. A resemblance to the specimens illustrated by Mai (1961) as *Intratriporopollenites pseudinstructus* is noted, especially in relation to the dark, thickened spot of exine behind the pori, a feature cleary observable in some of Mai's illustration but not mentioned in any description.

A gradation in ornament type has been noted between *Tiliaepollenites* sp. A and *Tiliaepollenites* sp. B. Whilst at some levels of focus, coalescence of the fine reticulation may give the impression of a slight scabration, specimens assigned to *T.* sp. B display a more clearly defined scabration and the pore structure is of a different type.

*Tiliaepollenites* sp. A resembles the illustrated specimens Wilkinson and Boulter (1980) assigned to their *Tiliaepollenites* Group C (interpretated as scabrate with a fine infrareticulation). They noted their group as being similar to *Intratriporopollenites insculptus* Mai, 1961, previously recorded by Pacltova (1966) and Ziembinska-Tworzydlo (1974) and from the Oligocene at Bovey Tracey by Chandler, 1957.

Occurrence: Present in all sections.

Stratigraphic record: Unknown. See comparisons in discussion.

Botanical affinity: *Tilia*, Tiliaceae.

*Tiliaepollenites* sp. B

Pl. 17, fig. 3.

Holotype: 13/611, 60.00m, slide 2, L50/3.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Tricolporate pollen with a rounded triangular amb. The colpi are very short and may be hard to discern, consequently grains often appear to be triporate. The germinals are positioned in the middle of the sides of the grains and not at the corners. The exine is 0.5$\mu$m thick. The exine bears a fine scabrate ornament, however, with very careful focusing at x1000 magnification with an oil immersion lens, an infrareticulation can be discerned. The lumina are very fine, 0.25$\mu$m in diameter. The pori are of open type, having an external opening of 3-3.5$\mu$m in diameter and an internal diameter of approximately the same. A strong annulus, 1.5$\mu$m wide, surrounds the pori behind which lies a distinct area of thickened exine appearing as a dark spot. Grains measured range in size from 25-26$\mu$m in diameter.

Discussion: Wilkinson and Boulter (1980) briefly describe their *Tiliaepollenites* Group A as having a fine scabrate sculpture and the exine producing an infrareticulate appearance on the pollen surface. They liken their group to *Intratriporopollenites microreticulates*, Mai, 1961. Whilst the illustrations of *I. microreticulates*, pl. 10 figs 1-9, perhaps appear to possess this type of ornament, no mention of it is made in the original diagnosis. However, this is short and not descriptive of the structure or ornament of the exine. No darkening of the exine behind the pori is mentioned or illustrated by Wilkinson and Boulter (1980), and cannot be observed in Mai (1961) pl. 10, figs. 3-9.

Occurrence: Present in all sections.

Stratigraphic record: Unknown. See comparisons in discussion.

Botanical affinity: *Tilia*, Tiliaceae.

*Tiliaepollenites ceciliensis* Krutzsch, 1961d comb. nov.

Pl. 17, fig. 4.

1961, *Intratriporopollenites ceciliensis* Krutzsch, p. 313, pl. 3, figs. 58-67.

Holotype: Krutzsch, 1961d, pl. 10, figs. 58-62.

Diagnosis: See Krutzsch, 1961d, p. 313.

Description: Small tricolporate pollen with a rounded triangular amb. The colpi are very short and may be hard to discern, consequently grains often appear to be triporate. The germinals are positioned in the middle of the sides of the grains and not at the corners. The exine is 0.5$\mu$m thick and bears a fine reticulation. The lumina are fine, up to 0.5$\mu$m in diameter. A fine crenation occurs around the amb due to the protrusion of the muri. The pori are up to 2$\mu$m wide and 1.5$\mu$m deep and are of the open type. A slight darkening of the exine behind the pori may be noted. Grains measured range in size from 17-19$\mu$m in diameter.

Discussion: This species is easily distinguished from other forms of Tiliaceoid pollen encountered in this study by its small size and the almost smooth appearance of its exine. The reticulation may only just be discerned at x400 magnification.

*Tiliaepollenites ceciliensis* strongly resembles grains described by as *Intratriporopollenites minimus* by Mai (1961).

Occurrence: 13/611, 13/603, 27/415.

Stratigraphic record: Middle Eocene of Europe, Krutzsch (1961d).

Botanical affinity: *Tilia*, Tiliaceae, Krutzsch (1961d).

*Tiliaepollenites instructus* (Potonié and Venitz, 1934, Thomson and Pflug,1953) comb. nov.

Pl. 17, figs. 5-6.

1934 *Intratripollenites instructus* Potonié and Venitz, p. 37, pl. 4, figs. 109-110.

Holotype: Potonié and Venitz, 1934, p. 37, pl. 4, figs. 109-110.

Diagnosis: See Potonié and Venitz, 1934, p. 37.

Description: Tricolporate pollen with a rounded triangular amb. The colpi are very short and may be hard to discern consequently grains often appear to be triporate. The germinals are positioned in the middle of the sides of the grains and not at the corners. The exine is 1$\mu$m thick, the columellae comprising the exine give rise to an obvoius reticulation on the grain surface clearly observable at x400 magnification. The lumina, enclosed by thin muri, vary in size over the grain from 0.5$\mu$m at the grain margins to 2$\mu$m at the poles. The pori appear to be of closed type, the external opening of lesser diameter than the internal. Focusing through the pori the V shape of the short colpi, measuring 4$\mu$m in length and 2$\mu$m in gape, may be discerned. A strong annulus surrounds the pori. Grains measured range in size from 27-33$\mu$m in diameter.

Discussion: The larger lumina forming the reticulation and the decrease in size towards the margins of the grain, clearly differentiates this species from other forms of *Tiliaepollenites* recorded in this study.

Occurrence: 13/603, 36/4680.

Stratigraphic record: Upper Oligocene to Miocene of Germany, Mai (1961).

Botanical affinity: *Tilia*, Tiliaceae, Thomson and Pflug (1953).

Genus *Tricolporopollenites* Pflug and Thomson, 1953, (in Thomson and Pflug, 1953).

Type species: *Tricolporopollenites dolium* (Potonié 1931b) ex Thomson and Pflug (1953).

*Pollenites dolium* Potonié 1931b, p. 26, pl. 1, fig. 45d.

Generic remarks: Tricolporate pollen with the polar axis equal to or longer than the equatorial axis. Three germinals comprising colpi lie along the polar axis with a symmetrical distribution and pori lie along the equatorial axis with symmetrical distribution.

*Tricolporopollenites* sp. A

Pl. 18, figs. 1-5.

Holotype: 13/603, 80.10m, slide 3, W36/4.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Tricolporate pollen with an oval to rounded amb. The exine is columellate and covered with a loose arrangement of baculose-spinose elements, with slightly swollen tips, up to 2$\mu$m in length, becoming progressively reduced in height towards the poles. The baculae appear to support thin muri that form a reticulum with irregular polygonal lumina up to 2$\mu$m in diameter. The colpi reach just short of the grain margins. The pori are distinct with large circular exopores. Grains measured range in size from 20-27$\mu$m in length.

Discussion: See discussion for *Tricolporopollenites spinoreticulatus* sp. nov.

Occurrence: 13/611, 13/603.

Stratigraphic record: Unknown.

Botanical affinity: ?Euphorbiaceae, ?Caprifoliaceae.

*Tricolporopollenites* sp. B

Pl. 18, fig. 6.

Holotype: 13/611, 261.00, slide 1, 053/1.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Small tricolporate reticulate pollen most often seen in oblate compression. The germinals bearing strong margines, distinctly thickened round the pori, are deeply incised with a small apocolpia. The reticulation comprises an ornament of thin muri 0.1-0.2$\mu$m thick and up to 1$\mu$m high, enclosing polygonal luminae up to 1-1.5$\mu$m in diameter. Grains measured range in size from 12-20$\mu$m in polar diameter.

Discussion: The large size of the lumina relative to the size of the grain and the thickened colpi and pori serve to distinguish this grain from other reticulate tricolporate pollen in this study.

Occurrence: 13/611, 13/603, 36/4680.

Stratigraphic record: Unknown

Botanical affinity: Unknown

*Tricolporopollenites baculoferus* Pflug, 1953, (in Thomson and Pflug, 1953).

Pl. 19, figs. 1-3.

Holotype: Thomson and Pflug, 1953, pl. 14, figs. 4-8.

Diagnosis: See Thomson and Pflug, 1953, p. 105.

Description: Tricolporate pollen with an elongate oval to rounded amb. The exine is covered with tightly packed baculae up to 2$\mu$m in length and 0.5$\mu$m in width. The baculae decrease in length towards the poles. The tips of the baculae appear slightly swollen. The tight packing of the elements and some possible fusing of the tips of the elements may produce the trace of a reticulation at certain levels of focus. The colpi reach just short of the grain margins. Grains measured range in size from 20-30$\mu$m in length.

Discussion: See discussion under in Reticulate Tricolpate Pollen, *Favitricolporites*.

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Oligocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Unknown.

*Tricolporopollenites pseudocingulum* (Potonié, 1931a) Thomson and Pflug, 1953.

Pl. 19, fig. 4.

Holotype: Potonié, 1931a, pl. 1 figs. 3, 4.

Diagnosis: See Thomson and Pflug, 1953, p. 99.

Description: Tricolporate pollen with an elongate oval amb. The sides of the grain may appear subparallel in smaller specimens, however they usually display a convexity. The polar ends are rounded. Colpi are distinct and lie parallel to each other reaching just short of the poles. The pori are clearly defined lying around the equator of the grain. The grains are covered in a scabrate ornament. Grains measured range in size from 12-28$\mu$m in length.

Discussion: This pollen is abundantly recorded throughout the sections studied. It most closely resembles *Cupuliferoipollenites cingulum.* Distinction of the grains is clear due to the distinct ornament displayed on *Tricolporopollenites pseudocingulum*.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: Anacardiaceae, Thomson and Pflug (1953).

*Tricolporopollenites spinus* Krutzsch 1962a.

Pl. 19, figs. 5-6, pl. 20, fig. 1.

Holotype: Krutzsch 1962a, pl. 6, figs. 16-26.

Diagnosis: See Krutzsch 1962a, p. 278.

Description: Tricolporate pollen with an elongate oval amb and pointed poles. The exine is surface covered with a distinct ornament of long spines up to 3$\mu$m in length equatorially, becoming shorter towards the poles, spaced 2-3$\mu$m apart. In the intervening spaces between the spines small, closely packed, very fine pilate elements, 0.5$\mu$m wide and up to 1$\mu$m long, with slightly capitate tips may be observed. The colpi are distinct and reach just short of the poles. The endopores are larger than the exopores that measure approximately 2$\mu$m in diameter. Grains measured range in size from 20-30$\mu$m in length.

Discussion: This species closely resembles *Tricolpopollenites hastus* sp. nov. It differs in possessing the shorter elements in between the spines and by displaying pori. No expression of a reticulation is usually noted due to the density and arrangement of the spinose elements. Upon specimens with a denser ornament an expression of a reticulation may start to form.

A form of this pollen type with slightly shorter spines and a rounder/fatter amb was recorded in common abundance in 36/4680 223.18m. This has been regarded as intraspecific variation.

Occurrence: Present in all sections.

Stratigraphic record: Middle and Upper Oligocene of Germany, Krutzsch (1962a).

Botanical affinity: Unknown.

*Tricolporopollenites spinoreticulatus* sp. nov.

Pl. 20, figs. 2-5.

Holotype: 27/415, 115.00 m, slide 2, N44/4.

Diagnosis: Tricolporate pollen with an elongate oval amb and pointed pole. The exine is surface covered with a distinct ornament of spines up to 2$\mu$m in length around the equator of the grain, becoming slightly shorter towards the poles. The spines are ordered in such proximity to produce a distinct reticulation. The muri, comprising of the tips of the spinose elements (clearly displayed using LO alalysis at x1000 magnification) are fine, 0.2-0.3$\mu$m in width, delimiting the lumina to up to 1.5-2$\mu$m wide. The colpi are distinct and reach just short of the poles, displaying large endopores up to 2$\mu$m in diameter. The holotype measures 22$\mu$m in length.

Description: Grains measured range in size from 20-26$\mu$m in length and 12-14$\mu$m in width. LO analysis clearly displays the heads of the spines arranged to form the reticulation.

Discussion: *Tricolporopollenites spinoreticulatus* most closely resembles *Tricolporopollenites spinus*, Krutzsch, 1962a, but is differentiated by possessing smaller spines, a clear reticulation that is observed at certain optical sections and the absence of the small intervening pilate elements noted in *T. spinus*.

The three forms of tricolpate spinose pollen described in this study; *Tricolporopollenites spinus*, Krutzsch 1962a, *Tricolporopollenites spinoreticulatus* sp. nov. and *Tricolporopollenites* sp. A, all have a similar appearance that may lead to difficulty in distinction if preservation is poor.

*Tricolporopollenites spinoreticulatus* sp. nov. is very similar to *Tricolpopollenites hastus* sp. nov. differing only in the nature of its germinals.

Occurrence: Present in all sections.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.

*Tricolporopollenites verrucatus* sp. nov.

Pl. 20, fig. 6.

Holotype: 27/415, 85.00 m, slide 1, F44.

Diagnosis: Tricolporate pollen with an elongate oval amb and rounded poles. The exine is covered with a strong dense ornament of verrucae. The verrucae are 0.5$\mu$m high and give the grain a distinct crenate outline. The colpi are long, reaching just short of the grain margins. Exopores are large, up to 3$\mu$m in diameter. The holotype measures 19$\mu$m.

Description: Grains measured range in size from 19-24$\mu$m.

Discussion: This species is easily distinguished from other tricolporate pollen encountered in this study by its characteristic ornament. It is similar to *Tricolpopollenites verrucatus* sp. nov. in all respects other than its germinal type.

Occurrence: Present in all sections.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.

## 7.5 Tetracolporate Pollen

Genus *Tetracolporopollenites* Pflug and Thomson, 1953,

(in Thomson and Pflug, 1953).

Type sepcies: *Tetracolporopollenites sapotoides* Pflug and Thomson, 1953, (in Thomson and Pflug, 1953), p. 110, pl. 15, fig. 6-7.

Generic remarks: Tetracolporate pollen with the polar axis equal to or longer than the equatorial axis. Four germinals comprising colpi lie along the polar axis with a symmetrical distribution and pori lie along the equatorial axis with symmetrical distribution.

*Tetracolporopollenites spp.*

Description: Tetracolporate pollen with a rounded amb. The colpi are short, 15$\mu$m in length, reaching short of the poles and the large rounded pori, 3$\mu$m in diameter are aligned around the equator of the grain. The specimen noted was degraded, however, the exine appeared to have been psilate or weakly scabrate. The single grain encountered measured 24$\mu$m in length and 18$\mu$m in width.

Occurrence: 27/415.

## 7.6 Syncolporate Pollen

Genus *Boehlensipollis* Krutzsch, 1962a.

Type species: *Boehlensipollis hohli* Krutzsch, 1962a, p. 272, pl. 3. figs. 23-26.

Generic remarks: Syncolporate pollen with a concavely triangular amb and a multi layered wall, the outer layer is twice as thick as the inner with a separation between. Colpi may be sinuous in appearance and meet at the pole proximally, short of it distally and may gape. The exine may be minutely punctate to chagrenate.

*Boehlensipollis* Group B Wilkinson and Boulter, 1980.

Pl. 21, figs. 1-3.

Holotype: None as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 10 figs. 26-27.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 66.

Description: Syncolporate pollen with a deeply concave tiangular amb. The colpi meet at the poles and do not appear to show much splitting along their length. The exine is smooth to weakly scabrate. Grains measured range in size from 17-20$\mu$m in diameter.

Discussion: This pollen type is rarely recorded and its exact structure is difficult to determine due to the nature of its compression. The characteristic deeply concave, compressed/collapsed nature of the amb prevents clear detailed observation.

Occurrence: 13/603, 36/4680, 27/415.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Elaegagnaceae, Stuchlik (1964 in Krutzsch 1969).

Genus *Gothanipollis* Krutzsch, 1959b.

Type species: *Gothanipollis gothanii* Krutzsch, 1959b, p. 237, pl. 47, fig. 564.

Generic remarks: Syncolporate pollen with a triangular to concave triangular amb. The exine is smooth or may bear a slight ornament. The colpi forming the germinals connect at the pole but are more clearly defined at the amb of the grain where they tend to gape. A characteristic thickening of the exine (polar bridge) at the pole and in the inter-amb areas is characteristic of the genus.

*Gothanipollis* Group B Wilkinson and Boulter (1980)

Pl. 21, figs. 4-6.

Holotype: None as the group is not formally recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, pl. 10 figs. 18-20.

Diagnosis: No formal diagnosis exists as the group is not recognised under the rules of the I.C.B.N. See Wilkinson and Boulter, 1980, p. 65.

Description: Syncolporate pollen with a concave triangular amb. The concave interamb areas (equatorial invaginations of Krutzsch, 1959b) display a thickening of up to 1.5$\mu$m, the rest of the exine is 1$\mu$m in thickness. The colpi are usually clearly displayed reaching from the pole to the radial corners of the amb where they gape and form an invagination approximately half the distance to the pole. Splitting along the entire length of the colpi may occur in certain preservations. A distinct thickening of the exine forming arci around the trilete form of the colpi at the pole occurs. This reaches its greatest expression as a band crossing the colpi at right angles approximately half way along them, delimiting an area of triangular shape but with flattened apices. The exine is smooth to scabrate. Grains measured range in size from 17-23$\mu$m in diameter.

Discussion: The specimens observed in this study conform to those grains illustrated by Wilkinson and Boulter (1980) but display a smaller size range.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Unknown.

## 7.7 Monoporate Pollen

Genus *Cyperaceaepollis* Krutzsch, 1970.

Type species: *Cyperaceaepollis neogenicus* Krutzsch, 1970 p. 16.

Generic remarks: Rounded oval to rounded triangular shaped pollen. Germinals consist of a large main pore situated at the broadest end of the grain and several irregularly defined lacunae or 'secondary pores' positioned approximately equatorially.

*Cyperaceaepollis* spp.

Pl. 22, figs. 1-2.

Holotype: 13/603, 260.00 m, slide 1, A39/3.

Description: Monoporate pollen with a rounded oval to rounded triangular amb. The large main pore 5-7$\mu$m in diameter with ill-defined ragged margins is located at the broadest part of the grain. Approximately 5 or 6 lacunae or 'secondary' pores (areas of irregularly deliniated exine that appear as scabrate patches) 3-4$\mu$m in diameter, are positioned approximately equidistantly equatorially. Grains measured range in size from 29-32$\mu$m in length. The exine is micro punctate.

Discussion: Grains attributed to this group are rare in occurrence and are mostly poorly preserved. Attribution to a previously described species has not been possible, however, they appear to most closely resemble *Cyperaceaepollis neogenicus* Krutzsch, 1970.

Occurrence: 13/603.

Stratigraphic record: Unknown.

Botanical affinity: Cyperaceae.

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

Type species: *Graminidites medius* Cookson, 1947, p. 134, pl. 15, fig. 41.

Generic remarks: Cookson (1947) provided a description of the type species in a combined description of *Monoporites (Graminidites) medius*. Potonié (1960) provided a diagnosis for the genera as *Graminidites*.

Monoporate pollen with a circular amb. The exine is thin often displaying secondary folding. The exine is smooth to finely granulate or intragranulate. The pore is circular and surrounded by an annulus.

*Graminidites laevigatus* Krutzsch, 1970.

Pl. 22, figs. 3-4.

Holotype: Krutzsch, 1970, pl. 5, figs. 1-6.

Diagnosis: See Krutzsch, 1970, p. 60.

Description: Monoporate pollen with an originally circular amb. The exine is thin, less than 1$\mu$m thick and psilate displaying prominent secondary folding. The pore is 2-3$\mu$m in diameter and surrounded by a darker thickened annulus 1.5$\mu$m in width. Grains measured range in size from 20-26$\mu$m in diameter.

Discussion: This species is easily distinguished by its smooth psilate exine and the size of its pore.

Occurrence: 13/611, 13/603, 27/415.

Stratigraphic record: Middle Oligocene of Northen Europe to Recent, Krutzsch (1970).

Botanical affinity: Gramineae.

Genus *Sparganiaceaepollenites* (Thiergart, 1937) Krutzsch, 1970.

Type species: *Sparganiaceaepollenites polygonalis* Thiergart, 1937, p. 307, pl. 24, fig. 11.

Generic remarks: Monoporate, reticulate pollen with a rounded amb. The pore is small and often indistinct, a few microns in diameter. The pore margins are ill-defined and irregularly bounded by the elements of the ornament, no anunlus surrounds the pore. The columellate exine is expressed as a fine reticulation.

Krutzsch (1970) provided a more precise emended diagnosis, this emendation is accepted here.

*Retiovoipollis* Krutzsch, 1970, has a more elongate, oval amb.

*Sparganiaceaepollenites polygonalis* Thiergart, 1937.

Pl. 22, figs. 5-6.

Holotype: Thiergart, 1937, pl. 24, fig. 11.

Diagnosis: See Thiergart, 1937, p. 307.

Description: Monoporate, reticulate pollen with a rounded amb. The pore measures 3$\mu$m in diameter and has poorly defined ragged margins, formed by elements of the ornament, no annulus is observed. The fine columellae comprising the exine are overlain by a fine reticulation. The muri are less than 0.5$\mu$m wide. The lumina are between 0.5-1$\mu$m on the distal surface and increase slightly in size, up to 1.5$\mu$m on the proximal surface. Grains measured range in size from 20-25$\mu$m in diameter.

Discussion: The columellae under the reticulum may be observed with careful L/O analysis.

Occurrence: 13/611, 13/603.

Stratigraphic record: Miocene of Germany, Thiergart, 1937.

Botanical affinity: *Sparganium*, Typhaceae, Thiergart, 1937.

## 7.8 Triporate Pollen

Genus *Caryapollenites* Raatz, (1937) 1938, ex Potonié 1960.

Type species: *Caryapollenites simplex*, Raatz 1938, p. 19, fig. 6.

Generic remarks: Triporate pollen with a rounded triangular amb with at least one pore in a subequatorial position. The wall comprises two layers and is approximately 1$\mu$m thick. A characteristic area of thin exine is present at the pole.

Potonié validated the genus in 1960 as Raatz did not give a generic diagnosis. Krutzsch (1961d) gave an emended diagnosis emphasising the distinction of *Caryapollenites simplex* from *Subtriporopollenites anulatus* assigning thin walled forms with a more triangular amb to the former genus. Krutzsch's emendation is accepted in this study.

*Caryapollenites veripites* (Wilson and Webster, 1946) Nichols and Ott, 1978.

Pl. 23, fig. 1.

Holotype: Wilson and Webster, 1946. p. 276.

Diagnosis: See Wilson and Webster, 1946. p. 276.

Description: Triporate pollen with a convex rounded triangular amb. The pores, up to 2$\mu$m in diameter, lie subequatorially at the grain margins. A distinctive area of thinned exine, forming a circumpolar ring 10-12$\mu$m in diameter encloses an island of exine of normal thickness with a diameter of 6-7$\mu$m. The exine is psilate but may appear weakly granular. Grains measured range in size from 20-25$\mu$m in diameter.

Discussion: The character of the thinned exine at the pole is the distinguishing feature of this species.

Occurrences: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Juglandaceae, *Carya*, Nichols and Ott (1978).

Genus *Corsinipollenites* (Thiergart, 1940) Nakoman, 1965.

Type species: *Corsinipollenites oculusnoctis* Thiergart, 1940, pl. 7, fig. 1.

Generic remarks: Triporate pollen with a rounded triangular amb. The distinctive large, strongly annulate pores are positioned equatorially, however, they may appear sub-equatorial due to compression. The margins of the endexine surrounding the pores may appear characteristically ragged.

Originally described by Thiergart (1940) as *Pollenites oculus noctis.* The intended hyphen to make the name binomial, *Pollenites oculus-noctis* was erroneously omitted, hence the name appeared as a polynomial. Nakoman (1965) validly published the species as *Corsinipollenites oculusnoctis.*

*Corsinipollenites oculusnoctis* (Thiergart, 1940) Nakoman, 1965.

Pl. 23, fig. 5.

Holotype: Thiergart, 1940, pl. 7, fig. 1.

Diagnosis: See Nakoman, 1965, p. 155.

Description: Triporate pollen with a rounded triangular amb. The pores appear to be positioned sub-equatorially, however, this is a facet of compression. A distinctive thick annulus 2$\mu$m wide surrounds the pores ranging from 8-11$\mu$m wide. The endexine surrounding the pores displays a characteristic serrated/ragged appearance. The thin exine displays folding. Grains measured range in size from 22-37$\mu$m in diameter.

Discussion: The rare specimens observed conform to the diagnosis of *Corsinipollenites oculucnoctis* in all respects except size. *C. oculusnoctis* is described as a large grain of 80$\mu$m with pores of 15$\mu$m width. Specimens recorded by Wilkinson and Boulter (1980) from the western British Isles, ranged in size from 42-57$\mu$m.

Occurrence: 36/4680, 27/415.

Stratigraphic record: Lower Eocene to Upper Miocene, Krutzsch (1968d).

Botanical affinity: Onagraceae. According to Jansonius and Hills (1976) cf. *Epilobium, Fuchsia, Oenothera.*

Genus *Momipites* Wodehouse, 1933.

Type species: *Momipites coryloides* Wodehouse, 1933, p. 511, fig. 43.

Generic remarks: Triporate pollen with a subtriangular amb, the atriate pori are distributed evenly around the equator. The pori protrude only slightly proud of the amb, the exine immediately surrounding them is slightly thickened. No distinct annulus is developed. The exine may or may not display various structural modifications including polar thinnings and triradiate thickenings.

The diagnosis of Wodehouse (1933) describes simple triporate pollen with a slight thickening surrounding the pori, in the manner of *Corylus*, but does not mention the atriate nature of the pores.

Nichols (1973) in his review of the species of *Momipites* and related genera provided a more precise emended diagnosis. In this he included forms with or without various structural modification to the exine including polar thinnings and triradiate thickenings. Nichols submerged the following genera into *Momipites*: *Engelhardtiapollenites* Raatz, 1937, *Engelhardtioidites* Potonié Thomson and Thiergart, 1950, *Engelhardtioipollenites* Potonié, 1951 and *Maceopolipollenites* Leffingwell, 1971.

The emendation of Nichols (1973) is accepted in this study as it seems to encompass forms that display the features of the Juglandaceae. The genus may include forms whose morphology is not precisely that of any extant genus and include forms of a transitional morphology between two distinct extant genera.

*Momipites coryloides* Wodehouse, 1933.

Pl. 23, fig. 2.

Holotype: Wodehouse, 1933, fig. 43.

Diagnosis: See Wodehouse, 1933, p. 511-512.

Description: Triporate pollen with a subtriangular amb. The atriate pori are distributed equatorially at the apices and protrude only slightly proud of the amb. The exine immediately surrounding the pori is slightly thickened, however, no distinct annulus is developed. The exine is up to 1$\mu$m thick, psilate, a slight granation may be developed on some specimens. No structural modification of the exine exists, however, a folding of the exine produces a pseudo "triradiatus" appearance (Nichols 1973). On some specimens folds in the exine resemble the pseudocolpi of *Platycarya*.

Discussion: Specimens with folding resembling the pseudocoli of *Platycarya* are very similar to *Momipites microcoryphaeus*

Potonié, 1931a. They are not attributed to Potonié's species in this study as a plexus of types displaying varying degrees of folding resulting in similar forms have been identified. As a consequence of this, a definite boundary separating the forms cannot be drawn and hence it is thought that the splitting into two species may be, to some degree, artificial and based upon preservational aspects.

Occurrence: Present in all sections.

Stratigraphic record: Palaeocene to Miocene, Nichols (1973).

Botanical affinity: *Engelhardia-Alfaroa,* Juglandaceae, Wodehouse (1933), Nichols (1973)

*Momipites quietus* (Potonié 1931d) Nichols, 1973.

Pl. 23, figs. 3-4.

Holotype: Potonié, 1931d, pl. 4, fig. 13.

Diagnosis: See Potonié, 1931d, p. 556.

Description: Small triporate pollen with a triangular amb. The atriate pores are circular but may sometimes appear as small slits that are placed equatorially, at the apices. The exine is psilate, a large triangular area of thinned exine occurs at the poles. The band of normal exine thickness remains bordering the amb. Grains measured range in size from 10-19$\mu$m.

Discussion: Frederiksen and Christopher (1978) regarded *Momipites quietus* to be syncolpate from the illustrations of Potonié (1931d). This is not accepted here, as the specimens recorded and attributed to the species are triporate.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: *Engelhardtia*, *Alfaroa*, Juglandaceae, Nichols (1973).

*Plicatopollis* Krutzsch, 1962a.

Type species: *Plicatopollis plicatus* Krutzsch 1962a, p. 227.

Generic remarks: Triporate pollen with a triangular to rounded triangular amb. The pori are located around the equator at the apices of the amb and are connected by arci forming a triradiate structure.

*Plicatopollis* spp.

Pl. 24, fig. 1.

Description: Triporate pollen with a rounded triangular amb. The pori are connected by a triradiate structure of (thickened?) exine. The exine is thin, 0.5$\mu$m and bears a slight granation. The single specimen recorded in the study measures 18$\mu$m in diameter.

Discussion: The plicoid/triradiate structure is not terribly prominent but does differ significantly from the folding of the exine noted on specimens of *Momipites coryloides* recorded.

The Triradiatus group of *Momipites* described by Nichols (1973) appears to be of the same morphology.

The specimen recorded resembles those illustrated by Wilkinson and Boulter (1980) and is likened to *Plicatopollis plicatis* (Potonié 1934), Krutzsch 1962a, from the Eocene of Germany. Wilkinson and Boulter state that Krutzsch (1967c) considers the form genus to be mainly confined to the Eocene of Europe but does range into the Middle Oligocene.

Occurrence: 27/415.

Stratigraphic record: Eocene to Middle Oligocene of Europe, Krutzsch (1967c).

Botanical affinity: Juglandaceae.

Genus *Triporopollenites* Thomson and Pflug, 1953.

Type species: *Triporopollenites coryloides* Pflug, 1953, (in Thomson and Pflug, 1953), pl. 9 fig. 20.

Generic remarks: Triporate pollen with a triangular to rounded triangular amb. The pores are situated equatorially at the apices of the amb and do not posses an atrium, vestibulum or a post-vestibulum. The ektexine reaches the exopore whilst the endexine can be observed to terminate short of the pore.

*Triporopollenites robustus* Pflug, 1953, (in Thomson and Pflug, 1953).

Pl. 24, fig. 2.

Holotype: Pflug, 1953, (in Thomson and Pflug, 1953), pl. 8, figs. 109-149.

Diagnosis: See Pflug, 1953, (in Thomson and Pflug, 1953), p. 82.

Description: Triporate pollen with a rounded triangular amb. The wall is characteristically thick 1.5-2$\mu$m. The exine is smooth or with a slight granation. The exine surrounding the pori is thickened slightly, however, no distinct annulus is developed. A weak granation may be noted around the pori. Specimens measured range in size from 20-24$\mu$m in diameter.

Discussion: The characteristically thick wall serves as an easily distinguishing feature of this species. Whilst a true atrium is not observed, the observed termination of the endexine before the pori in some specimens does seem to indicate the possiblity of this structure developing. Elsik (1968) and Tschundy (1973) have recorded specimens with atria. Some authors have previously allocated such specimens to *Triatriopollenites aroboratus*.

Occurrence: Present in all sections.

Stratigraphic record: Late Palaeocene to Oligocene of Europe, Thomson and Pflug (1953).

Botanical affinity: Thomson and Pflug (1953) questionably suggested affinity to the Betulaceae. Fredericksen (1979) and Fredericksen and Christopher (1978) suggest an association with *Casuarina*, Casuarinaceae, an extant genus found in the Southern Hemisphere. Pollen of the Myricaceae has an almost identical morphology to *Casuarina* and may be a more suitable affinity due to its occurrence in the Northern Hemisphere.

*Trivestibulopollenites* Pflug 1953, (in Thomson and Pflug, 1953).

Type species: *Trivestibulopollenites betuloides* Pflug, 1953, (in Thomson and Pflug, 1953), P. 85, pl. 9 fig. 34.

Generic remarks: Triporate pollen with a triangular to rounded triangular amb and vestibulate pori situated around the equator.

*Trivestibulopollenites betuloides* Pflug, 1953, (in Thomson and Pflug, 1953).

Pl. 24, figs. 3-4.

Holotype: Pflug, 1953, (in Thomson and Pflug, 1953), pl. 9, fig. 34.

Diagnosis: See Pflug, 1953, (in Thomson and Pflug, 1953), p. 85

Description: Triporate pollen with a triangular to rounded triangular amb with distinctly convex sides. The exine is 0.75-1$\mu$m thick, thickening significantly around the pori to produce prominent labrae, protruding 2-2.5$\mu$m proud of the amb. The pori bear small vestibulae. Grains measured range in size from 20-22$\mu$m in diameter.

Discussion: A grain with the same morphology but measuring only 10$\mu$m in diameter was recorded in 13/611 262.00m.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: Betulaceae, Thomson and Pflug (1953).

## 7.9 Polyporate Pollen

Genus *Alnipollenites* Potonié, 1931a.

Type species: *Alnipollenites verus* (Potonié 1931a) Potonié, 1931b, p. 4.

Generic remarks: Polyzonoporate pollen. Pores vary in number between 4-6, are distributed evenly around the polygonal amb and connected by arcuate arci which vary in the strength of development. The exine is smooth.

*Alnipollenites verus* (Potonié 1931a) Potonié, 1931b.

Pl. 25 figs. 1-3.

Holotype: Potonié, 1931a, pl. 2, fig. 40.

Diagnosis: See Potonié, 1931b, p. 4.

Description: Polyzonoporate pollen with vestibulate pores evenly distributed around the polygonal amb. The pores are connected by folds of exine forming arcuate arci. The number of pores varies between 4-6 and the strength of the development of the arci varies between grains. The exine is unornamented and smooth. Grains measured range in size from 17-27$\mu$m in diameter.

Discussion: The variation in the number of pores and the development of the arci is perceived as intraspecific variation.

Occurrences: Present in all sections.

Stratigraphic record: Lower Palaeocene of Europe, Krutzsch (1970) to Recent.

Botanical affinity: *Alnus*, Betulaceae, Thomson and Pflug (1953).

Genus *Anacolosidites* Cookson and Pike, 1954.

Type species: *Anacolosidites luteoides* Cookson and Pike, 1954, pl. 1 fig 50.

Generic remarks: Isopolar pollen with a triangular to rounded triangular amb. Six pores are located towards the angles of the amb, three on each hemisphere. Sculpture is indistinct to prominent.

*Anacolosidites* spp.

Pl. 25, fig. 4.

Description: Isopolar pollen with a rounded triangular amb. Three pores are visible on one hemisphere measuring 3$\mu$m in diameter. The exine is degraded but appears to have probably been psilate. The wall is <1$\mu$m thick in the interamb area and thins at the apices. The single grain recorded measures 16$\mu$m in diameter.

Discussion: The single grain encountered is broken and degraded and may be reworked. It bears some similarity to specimens recorded by Wilkinson and Boulter (1980) (at the base of their Bovey borehole) and thought to resemble *Anacolosidites efflatus* (Potonié 1934) Erdtman 1954 and attributed to Eocene reworking.

Occurrence: 13/611.

Stratigraphic record: *Anacolosidites efflatus* ranges from Lower to Upper Eocene, Krutzsch (1957)

Botanical affinity: An affinity with modern tropical rain forest type vegetation, Collinson *et al.* (1981).

Genus *Polyatriopollenites* Pflug, 1953b.

Type species *Polyatriopollenites stellatus* Potonié, 1931b ex Pflug, 1953b, p. 115.

Generic remarks: Polyzonoporate pollen, pores positioned approximately equidistantly around the equator of the grain. The amb is generally straight sided to convexly angular. Each pori displays an atrium.

*Polyatriopollenites carpinoides* Pflug, 1953 (in Thomson and Pflug, 1953), comb. nov.

Pl. 25, fig. 5.

Holotype: Pflug, 1953 (in Thomson and Pflug, 1953), pl. 10, figs. 79-84.

Diagnosis: See Pflug, 1953 (in Thomson and Pflug, 1953), p. 92.

Description: Polyzonoporate pollen with between 5-7 atriate pori up to 1$\mu$m in diameter. The exine is thin, less than 0.5$\mu$m thick. It displays a slight tumescence around the pori resulting in a distinctive circular zone of thickened exine approximately 6$\mu$m wide surrounding each pore. Grains measured range in size from 22-27$\mu$m in diameter.

Discussion: The genus is here transferred to *Polyatriopollenites*, Pflug, 1953b, as the grains display atria.

*Polyatriopollenites carpinoides* is easily distinguished from *P. stellatus*, by the distinct zone of thickening around the pori and the thin exine that results in more folding and a less rigid structure than *P. stellatus*.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: *Carpinus*, Corylaceae, Thomson and Pflug (1953).

*Polyatriopollenites stellatus* Potonié, 1931b ex Pflug, 1953b.

Pl. 25, fig. 6.

Holotype: Potonié, 1931b, pl. 2, fig. 47b.

Diagnosis: See Pflug, 1953b, p. 115.

Description: Polyzonoporate pollen with between 5-7 weakly atriate pori up to 1$\mu$m in diameter, distributed equidistantly around the distinctly polygonal amb. The exine is 1-2$\mu$m thick, generally psilate but it may display a weak scabration. An area of thinned exine is often noted in the polar area. A slight tumescence occurs around the pori. Grains measured range in size from 22-26$\mu$m in diameter.

Discussion: See discussion for *P. carpinoides*.

Occurrence: Present in all sections.

Stratigraphic record: Wilkinson and Boulter (1980) note that Krutzsch (1967c) believes that the form genus does not become significant until the Chattian.

Botanical affinity: *Pterocarya*, Junglandaceae, Thomson and Pflug (1953).

## 7.10 Inaperturate Pollen

Genus *Inaperturopollenites* Pflug and Thomson, 1935 (in Thomson and Pflug, 1953).

Type species: *Inaperturopollenites dubius* (Potonié and Venitz, 1934), Thomson and Pflug, 1953.

Generic remarks: Inaperturate pollen, with an original spherical shape. The exine is thin, unornamented and may display characteristic secondary folds. A germinal split may be developed along a plane of symmetry across the equator of the grain and a ligule may, or may not, be observed.

Within this study Thomson and Pflug's original concept of *Inaperturopollenites* is adhered to. Forms with a germinal split (*I. hiatus*) type were assigned to *Taxodiaceaepollenites* Kremp, 1949 when Potonié, 1958 emended the diagnosis of *Inaperturopollenites*, reserving it for forms with no germinal splitting (*I. dubius* type). Krutzsch (1970) formulated a diagnosis to include only forms that display a ligula. Thomson and Pflug's 1953 concept of *Inaperturopollenites* was transferred by Krutzsch (1970) to *Cupressacites* Bolkhovitinia, 1956 ex 1960 emend. Krutzsch, 1971. Forms displaying a hiatus appearance were assigned by Krutzsch to *Inaperturopollenites* if they displayed a ligule and to *Cupressacites* if they did not.

In this study *Inaperturopollenites* is used in the original concept of Thomson and Pflug (1953) and *Taxodiaceaepollenites* is considered to be a junior synonym. The emendation of Krutzsch (1970) is rejected. This conception of *Inaperturopollenites* is followed as it is the view widely accepted. This being the case, the genus *Cupressacites* Bolkhovitinia, 1956 ex 1960 emend. Krutzsch, 1971, is here contained within *Inaperturopollenites* as it seems pointless to include the forms that may be attributed to *Cupressacites* in another genus that does not lend itself to any further taxonomic or botanical resolution. Indeed the genus *Cupressacites* has a complicated history of description and attribution, outlined by Jansonius and Hills (1976) card 3547 and 3548. They state that the rules of the I.C.B.N. did not forsee such problems as were encountered with this genus and did not provide guidance on solving them. Since the complicated history of attribution and synonymy and the view of Bolkhovitina (1960) that pollen grains of genera such as: *Thujopsis, Thuja, Juniperus,* (Cupressaceae); *Torreya,* (Taxaceae) are practically indistinguishable from each other in a fossil state, the use of a form genus *Inaperturopollenites* is here considered the simplest and clearest solution to the taxonomic attribution of such pollen. Machin (1971) notes that in the Bembridge Beds of the Isle of Wight the papillate forms of Taxodiaceae are not easily separated from non-papillate forms.

*Inaperturopollenites cuspidataeformis* (Zaklinskaja, 1957) Krutzsch 1971, comb nov.

Pl. 26, figs. 1-3.

1957, *Cupressacites cuspidataeformis* Zaklinskaja, p. 96, pl. 1, fig. 17-18.

Holotype: Zaklinskaja, 1957, pl. 1, fig. 17-18.

Diagnosis: See Zaklinskaja, 1957, p. 96.

Description: Inaperturate pollen with a more or less rounded amb. The exine is thin, 0.5$\mu$m thick and often folded displaying a dense irregular punctation. Grains measured range in size from 18-30$\mu$m in diameter.

Discussion: This species is distinguished from other species of *Inaperturopollenites* recorded in this study by the structure of the exine and its more robust appearance.

Occurrence: Present in all sections.

Stratigraphic record: Miocene to Pliocene of Europe, Krutzsch (1971)

Botanical affinity: Cupressaceae, Krutzsch (1971).

*Inaperturopollenites dubius* (Potonié and Venitz, 1934), Thomson and Pflug, 1953.

Pl. 26, figs. 4-5.

Holotype: Potonié, 1958, p. 77.

Diagnosis: See Potonié and Venitz, 1934, p. 17.

Description: Inaperturate pollen once spherical to subspherical, now displaying pronounced secondary folding. The exine is thin, less than 0.5$\mu$m and is psilate. No ligule is present. Grains measured range in size from 20-40$\mu$m in diameter.

Discussion: This commonly occurring species is distinguished from *I. hiatus* by the lack of the characteristic germinal split displayed by that species and from other species of the genus by its thin psilate wall.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Taxodiaceae-Cupressaceae, Collinson (1983) Cupressaceae, Thomson and Pflug (1953).

*Inaperturopollenites hiatus* (Potonié, 1931b), Thomson and Pflug, 1953.

Pl. 26, fig. 6.

Holotype: Potonié, 1931b, fig. 27.

Diagnosis: See Potonié, 1931b, p. 3.

Description: Spherical to subspherical pollen with a thin psilate exine. A germinal split occurs over half the way into the grain forming a characteristic gaping appearance. Grains measured range in size from 22-38$\mu$m in diameter.

Discussion: This species is easily distinguished from others in the genus by its characteristic germinal split and psilate exine. The absence of a ligule separates this species from *I.* cf. *hiatus*, see discussion for *I.* cf. *hiatus*.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Taxodiaceae, Thomson and Pflug (1953).

*Inaperturopollenites* cf. *hiatus* (Potonié, 1931b), Thomson and Pflug, 1953.

Pl. 27, figs. 1-2.

Description: Pollen assigned to this group has the same morphology as *I. hiatus* except that a ligule up to 1.5-3$\mu$m high is present along the edge of the germinal split. Grains measured range in size from 26-32$\mu$m in diameter.

Discussion: Forms with a ligule are assigned to this group and not elevated to species rank as it is the author's opinion that the ligule may be an inconsistently developed feature that may not be discernible in all modes of compression. The majority of specimens observed with the *hiatus* morphology do not appear to possess a ligule.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Taxodiaceae, Thomson and Pflug (1953).

*Inaperturopollenites insulipapillatus* (Trevisan, 1967) Krutzsch, 1971, comb nov.

Pl. 27, fig. 3.

1967, *Cupressacites insulipapillatus* Trevisan, p. 16, pl. 7, fig. 1.

Holotype: Trevisan, 1967, pl. 7, fig. 1.

Diagnosis: See Trevisan, 1967, p. 16.

Description: Inaperturate pollen with a more or less rounded amb. The exine is thin, displaying secondary folding. The exine is covered with an ornament of small granate/verrucate elements. Grains measured range in size from 24-30$\mu$m in diameter.

Discussion: This species is rarely recorded. It is here placed within the genus *Inaperturopollenites*. See discussion under Generic remarks.

Occurrence: 13/611, 13/603, 36/4680.

Stratigraphic record: Middle Eocene to Miocene, Krutzsch (1971).

Botanical affinity: Cupressaceae, Krutzsch (1971).

*Inaperturopollenites radiatus* Krutzsch, 1971 *megaradiatus* n. subfsp.

Pl. 27, fig. 4.

Holotype: Krutzsch, 1971, p. 199, figs. 1-2.

Diagnosis: See Krutzsch, 1971, p. 199.

A subform species of *Inaperturopollenites radiatus* which has a diameter greater than 40$\mu$m and bears a larger foramen.

Description: Pollen with a subcircular amb that may appear elongated along one axis. The exine is thin and bears distinctive folds radiating from a central subcircular aperture/foramen as well as other randomly occurring secondary folds. The grains are single walled, smooth but may display a fine punctation. The radial folds vary in the strength of their development. The diameter of the foramen ranges from 12-19$\mu$m. The grains measured range in size from 63-122$\mu$m along their longest axis.

Discussion: Specimens assigned to this new subform species appear like Krutzsch's specimens in all respects except for their larger size.

Occurrence: Present in all sections.

Stratigraphic record: Upper Oligocene to Miocene as *Inaperturopollenites radiatus*, Krutzsch (1971).

Botanical affinity: Unknown.

Genus *Sequoiapollenites* Thiergart, 1938.

Type species: *Sequoiapollenites polyformosus* Thiergart, 1938, p. 301, pl. 23, fig. 6.

Generic remarks: Inaperturate ligulate pollen with a subcircular amb. The ligule lies atop a germinal area of thinner exine. The exine is psilate but may display a fine punctation.

*Sequoiapollenites polyformosus* Thiergart, 1938.

Pl. 27, fig. 5.

Holotype: *Sequoiapollenites polyformosus* Thiergart, 1938, pl. 23, fig. 6.

Diagnosis: See Thiergart, 1938, p. 301.

Description: Inaperturate ligulate pollen with a subcircular amb. The wall is up to $1\mu m$ thick, comprising two layers closely adpressed. The exine is psilate but may display a fine punctation. The ligule, up to $2\mu m$ long sits atop a semicircular germinal area of thinned exine.

Discussion: This genus is differentiated from *Inaperturopollenites* cf. *hiatus* by the occurrence of the thinned exine of the germinal area and the absence of any germinal split. The bi-layered appearance of the wall may be difficult to discern on some specimens.

Occurrence: 13/611, 13/603.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: *Sequoia, Metasequoia* and *Cryptomeria,* Taxodiaceae, Thomson and Pflug (1953).

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

Type species: *Sciadopityspollenites serratus* (Potonié and Venitz, 1934, p. 15, pl. 1, fig. 6) Potonié, 1958, p. 81.

Generic remarks: Rounded to subrounded pollen with an indistinct germinal area and exitus comprising a rounded opening. The exine is covered with a dense verrucate ornament. Secondary folding of the exine may be apparent.

Potonié (1958) validated the genus by providing a diagnosis, Raatz (1937) had neglected to do this.

*Sciadopityspollenites quintus* Krutzsch, 1971.

Pl. 28, fig. 1.

Holotype: Krutzsch, 1971, pl. 55, figs. 1-6.

Diagnosis: See Krutzsch, 1971, p. 180.

Description: Pollen with a rounded amb and an indistinct germinal area. The exitus comprises a circular area with indistinct ragged margins. The exine is 1.5-2$\mu$m thick and covered with a dense ornament of irregular polygonal verrucae with rounded heads. The verrucae are mostly equidimentional, some with a tendency to an elongation reaching 2$\mu$m. The exine may display secondary folding. The single grain recorded measures 39$\mu$m in diameter.

Discussion: This species differs from *S. vertcillatiformis* by its larger, more distinct ornament and thicker wall.

Occurrence: 27/415.

Stratigraphic record: Upper Eocene to Pliocene of Europe, Krutzsch (1971).

Botanical affinity: *Sciadopitys*, Taxodiaceae, Krutzsch (1971).

*Sciadopityspollenites verticillatiformis* (Zauer, 1960) Krutzsch, 1971.

Pl. 28, figs. 2-3.

Holotype: Zauer, 1960, pl. 5, fig. 6a.

Diagnosis: See Krutzsch, 1971, p. 178.

Description: Pollen with a rounded amb and an indistinct germinal area. The exitus comprises a circular area with indistinct ragged margins. The exine is thin, generally 1$\mu$m but may be up to 1.5$\mu$m thick and covered with a densely packed ornament of small generally equidimentional, irregular to polygonal verrucae up to 1.5$\mu$m high. The thin exine displays seondary folding. Grains measured range in size from 20-35$\mu$m.

Discussion: The germinal area is often indistinct and obscured by the secondary folding. See discussion for *S. quintus*.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Middle Eocene to Miocene of Germany, Krutzsch (1971).

Botanical affinity: *Sciadopitys*, Taxodiaceae, Krutzsch (1971).

## 7.11 Monosaccate Pollen

Monosaccate conifer pollen sp. A.

Pl. 28, fig. 4.

Holotype: 36/4680 223.18m M51/1.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Monosaccate pollen with a circular saccus 56$\mu$m enclosing a circular to slightly elongated inner body, 37$\mu$m in diameter. The wall of the inner body is 3$\mu$m thick. A tear in the exine occurs in the centre of the inner body and is thought to represent the exitus.

Discussion: Only a single grain of this type was recorded. No other pollen recorded has a morphology resembling this.

Occurrence: 36/4680.

Stratigraphic record: Unknown.

Botanical affinity: A form of conifer pollen.

### 7.12 Bisaccate Pollen

Genus *Pityosporites* Seward, 1914.

Type species: *Pityosporites antarcticus* Seward, 1914, p. 23, pl. 8, fig. 45.

Generic remarks: Bisaccate pollen with a small to medium sized body (corpus). The nature of the constriction of the sacci where joined to the body divides the genus in two groups.

Hapyloxylon: small sacci not constricted at the corpus/saccus junction.

Diploxylon: small sacci distinctly constricted at the junction with the body.

Separation of the bisaccate pollen into the two types outlined above was often found to be difficult as preservation, and especially orientation, hindered the process. Where attribution to either group was not possible the pollen has been refered to *Pityosporites spp.* The haploxylonate pollen recorded conformed to the diagnosis of *Pityosporites microalatus* (Potonié 1934) Thomson and Pflug, 1953, the diploxylon pollen to *Pityosporites labdacus* (Potonié 1934) Thomson and Pflug, 1953.

The speciation of bisaccate pollen is thought to be of little use stratigraphically or palaeoenvironmentally, nevertherless, where possible speciation has been attempted.

*Pityosporites microalatus* (Potonié, 1934) Thomson and Pflug, 1953.

Pl. 29, fig. 1.

Holotype: *Pityosporites microalatus* Potonié, 1934, pl. 2, fig. 4

Diagnosis: See Thomson and Pflug, 1953, p. 67.

Description: Bisaccate pollen with a haploxylon morphology. The sacci are not constricted at the junction with the body. Grains measured range in size from 48-65$\mu$m.

Discussion: This is the most common form of bisaccate pollen recorded.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: *Pinus*, Pinaceae, Thomson and Pflug (1953).

*Pityosporites labdacus* (Potonié 1934) Thomson and Pflug, 1953.

Pl. 29, figs. 2-4.

Holotype: *Pityosporites labdacus* Potonié, 1934, pl. 6 fig. 8.

Diagnosis: See Thomson and Pflug, 1953, p. 68.

Description: Bisaccate pollen with a diploxylon morphology. The sacci are constricted at the junction with the body.

Discussion: Bisaccate pollen of this morphology occurrs infrequently throughout the section studied.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Throughout the Tertiary of Europe, Thomson and Pflug (1953).

Botanical affinity: *Pinus,* Pinaceae, Thomson and Pflug (1953).

Genus *Podocarpidites* Cookson, 1947 ex Couper 1953.

Type species: *Podocarpidites ellipticus* Cookson, 1947 p. 131, pl. 13, fig. 6.

Generic remarks Bisaccate pollen with sacci distinctly larger than the central body displaying a well-defined constriction of the sacci upon joining the central body.

Couper (1953) formally vallidated the name.

*Podocarpidites libellus* (Potonié 1931b) Krutzsch 1971.

Pl. 29, figs. 5-6.

Holotype: Potonié 1931b, fig. 33.

Diagnosis: See Krutzsch, 1971, p. 128

Description: Bisaccate pollen of small to medium size. The sacci are distinctly larger than the central body (magnisaccate) displaying distinct reticulation.

Discussion: This species may be distinguished from the similar species *Podocarpidites pococarpoides* by its smaller size.

Occurrence: 13/611, 27/415.

Stratigraphic record: Middle Oligocene to Miocene of Germany Krutzsch (1971).

Botanical affinity: Podocarpaceae, Krutzsch (1971).

## 7.13 Alete Spores

Genus *Corrusporis* Krutzsch, 1967a.

Type species: *Corrusporis tuberculatus* Krutzsch, 1967a, p. 30, pl. 89, figs.1-4.

Generic remarks: Alete miospores with a circular amb. The exine is usually quite densely covered with a uniform ornament which, dependent upon the species, may be tuberculate, granulate, verrucate, baculate or coarsely punctate. A characteristic tear or slit in the exine may be observed.

Krutzsch (1967a) notes that many mosses produce alete spores, eg. Bryaceae, Dicranaceae, Leptostomaceae, Meeseaceae, Pottiaceae and Orthotrichaceae.

*Corrusporis chattensis* (Krutzsch, 1963b) Krutzsch 1967a.

Pl. 30, fig. 1.

Holotype: Krutzsch, 1963b, pl. 33, figs. 1-5.

Diagnosis: See Krutzsch, 1963b, p. 104.

Description: Small alete miospore with a circular amb. The exine is covered with a fairly dense ornament of irregular tubucules up to 2$\mu$m long. Some elements display a characteristic distal expansion or bent tip. The wall is approximately 1$\mu$m thick and a tear may be observed in the exine. The single grain recorded measures 20$\mu$m in diameter.

Discussion: Krutzsch (1963b) recorded grains of approximately 35$\mu$m diameter. The grain recorded here is of smaller size but similar in all other respects.

Occurrence: 36/4680.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1963b).

Botanical affinity: Bryophyta, moss spores, (Krutzsch 1967a).

*Corrusporis globoverrucatus* Krutzsch, 1967a.

Pl. 30, figs. 2-4.

Holotype: Krutzsch, 1967a, pl. 88, figs. 1-4.

Diagnosis: See Krutzsch, 1967a, p. 224.

Description: Small alete miospores with a circular amb. The exine is covered with an ornament of irregular polygonal verrucae 1.5-2$\mu$m high and 1-1.5$\mu$m wide. Some elements appear as more globulate verrucae. Occasionally elements of a more baculate nature may be observed with a height of 2.5-3$\mu$m high and a width of 2$\mu$m. Elements of the ornament may be flat or round topped. The thick wall is approximately 1-1.5$\mu$m thick and a tear may be observed in the exine. Grains measured range in size from 18-30$\mu$m in diameter.

Discussion: Spores attributed to this species differ from those recorded by Krutzsch (1967a) in their smaller size.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Bryophyta, moss spores, Krutzsch (1967a).

*Corrusporis tuberculatus* subsp. *tuberculatus* Krutzsch, 1967a.

Pl. 30, fig. 5.

Holotype: Krutzsch, 1967a, pl. 89. figs. 1-4.

Diagnosis: See Krutzsch, 1967a, p. 226.

Description: Alete miospores with a circular amb. The exine is covered with a dense ornament of very tightly packed tubercules up to 4$\mu$m high and 1-1.5$\mu$m wide. Grains measured range in size from 34-40$\mu$m in diameter.

Discussion: Spores attributed to this species resemble those illustrated by Krutzsch (1967a) in all respects other than their size and the relative size of the sculpture.

Krutzsch (1967a) differentiated his subform species *Corrusporis tuberculatus* subsp. *gracilioides* upon size. It is a large form in excess of 65$\mu$m diameter.

Occurrence: 13/611, 13/603.

Stratigraphic record: Middle to Upper Oligocene of Germany, Krutzsch (1967a).

Botanical affinity: Bryophyta, moss spores, Krutzsch (1967a).

*Corrusporis tuberculatus* (Krutzsch, 1967a) *minutus* n. subfsp.

Pl. 31, figs. 1-4.

Holotype: 13/611, 100.00m, slide 3, S41/4.

Diagnosis: Small alete miospores with a circular amb. A dense ornament of tightly packed, flat-topped tubercules, slightly wider at their base, uniformly cover the exine. Tubercules range between 2-4$\mu$m in height and are up up 2$\mu$m wide at their base tapering slightly distally. The wall is distinctly thick, up to 2$\mu$m. A tear in the exine is frequently observed. Grains measured range in size from 22-25$\mu$m in diameter excluding the ornament.

Description: *Corrusporis tuberculatus* subsp. *minutus* resembles *Corrusporis tuberculatus* subsp. *tuberculatus* Krutzsch, 1967a, in all respects except in their diminutive nature.

Discussion: The thick wall, distinctive tear and small size are the distinguishing characteristics of this subform species.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Unknown.

Botanical affinity: Bryophyta, moss spores, Krutzsch (1967a).

*Corrusporis* sp. A.

Pl. 31, fig. 5.

Holotype: 36/4680, 72.05m, slide 1, M42/1.

Description: Alete miospores with a circular amb. The exine is covered with a very dense, tightly packed ornament of tuberculate/baculate elements. The elements are 2-3$\mu$m high and 1-1.5$\mu$m wide with rounded to flat tops. Occasionally some may display pointed tips. The wall is up to 1.5$\mu$m thick displaying an irregular tear. The single grain recorded measures 33$\mu$m in diameter.

Discussion: The characteristic hairy appearance of this grain serves to distinguish it from other species of *Corrusporis* encountered in this study.

Occurrence: 36/4680.

Stratigraphic record: Unknown

Botanical affinity: ? Bryophyta, moss spore.

## 7.14 Monolete Spores

Genus *Laevigatosporites* Ibrahim, 1933.

Type species: *Laevigatosporites vulgaris* Ibrahim, 1933.

Generic remarks: Monolete miospores with a reniform amb. The wall is of single layered construction. The exine is smooth, unornamented and bears a simple straight monolete mark.

*Laevigatosporites discordatus* Pflug, 1953, (in Thomson and Pflug 1953).

Pl. 32, fig. 1.

Holotype: Pflug, 1953, (in Thomson and Pflug 1953), pl. 3, figs. 40-42.

Diagnosis: See Thomson and Pflug, 1953, p. 59.

Description: Large reniform monolete miospores with a simple monolete mark. The exine is psilate and comprises a thick single layer up to 2$\mu$m in thickness. Grains measured range in size from 45-63$\mu$m in length.

Discussion: This species is differentiated from *L. haardti* by its larger size and thicker wall which often results in a darker appearance.

Occurrence: Present in all sections.

Stratigraphic record: Eocene to Miocene of Europe.

Botanical affinity: Polypodiaceae, Thomson and Pflug (1953).

*Laevigatosporites haardti* (Potonié and Veintz, 1934) Thomson and Pflug, 1953.

Pl. 32, figs. 2-3.

Holotype: Potonié and Veintz, 1934, pl. 1, fig. 13.

Diagnosis: See Potonié and Veintz, 1934, p. 13.

Description: Reniform monolete spores with a simple monolete mark. The exine comprises a single wall and is psilate, generally up to 1$\mu$m thick. Grains measured range in size from 25-37$\mu$m.

Discussion: This species differs from *L. discordatus* in its smaller size and thinnner wall.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Polypodiaceae, Thomson and Pflug (1953).

*Laevigatosporites haardti* subsp. *crassicus* Krutzsch, 1967a.

Pl. 32, fig. 4.

Holotype: Krutzsch, 1967a, pl. 53, figs. 1-3.

Diagnosis: See Krutzsch, 1967a, p. 149.

Description: A subform species of *L. haardti* with a distinctly thickened wall up to 2.5-3$\mu$m. This results in a more pronounced reniform shape to the amb. The monolete mark is strong and distinct bearing thickened margins up to 4$\mu$m thick. The single grain so far encountered measures 50$\mu$m in length.

Discussion: This subform species is easily distinguished by its thick wall.

Occurrence: 36/4680, 27/415.

Stratigraphic record: Upper Oligocene, Chattian to Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae.

Genus *Verrucatosporites* Pflug and Thomson, 1953, (in Thomson and Pflug, 1953).

Type species: *Verrucatosporites alienus* (Potonié 1931d) Thomson and Pflug, 1953. p. 59.

*Sporites alienus* Potonié 1931d, p. 556, fig. 1.

Generic remarks: Monolete miospores with a reniform amb. A simple monolete mark extends approximately 2/3 of the length of the long axis. The exine is strongly ornamented with verrucae.

Potonié (1966) listed *Verrucatosporites* as a junior synonym of *Polypodiidites*, Ross, 1949. As grains of this type are clearly illustrated by Krutzsch (1967a) and attributed to *Verrucatosporites*, and a degree of consistency with this author is thought practical, this attribution is followed in this study.

*Verrucatosporites alienus* (Potonié 1931d) Thomson and Pflug, 1953.

Pl. 33, figs. 1-2.

Holotype: Potonié, 1931d, fig. 1.

Diagnosis: See Thomson and Pflug, 1953, p. 60.

Description: Reniform monolete spores with a simple monolete mark. The exine is densely covered with large, rounded to slightly elongate verrucae, 4-5$\mu$m high. The tips of the verrucae are rounded to slightly pointed, producing a strongly crenate amb. Grains measured range in size from 38-46$\mu$m in length.

Discussion: The large sizes of the verrucae serve to distinguish this from other species of *Verrucatosporites* identified in this study.

Occurrence: 13/603, 13/603, 36/4680.

Stratigraphic record: Upper Oligocene, Chattian, to Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae, Thomson and Pflug (1953).

*Verrucatosporites balticus* subsp. *balticus* (Krutzsch, 1962a) Krutzsch, 1967a.

Pl. 33, figs. 3-4.

Holotype: Krutzsch, 1962a, pl. 2, figs. 7-12.

Diagnosis: See Krutzsch, 1962a, p. 269 and Krutzsch, 1967a, p. 177, table 3.

Description: Reniform monolete spores with a monolete mark that may display a slight thickening around its margins. The exine is densely covered with irregular polygonal verrucae, 2$\mu$m in diameter and up to 2$\mu$m high. Grains measured range in size from 29-36$\mu$m in length.

Discussion: Krutzsch (1967a) described two subspecies *V. balticus* subsp. *balticus* and *V. balticus* subsp. *major*. The distinction between the two form species is based upon size with those of subsp. *major* exceeding 38$\mu$m in length.

Occurrence: Present in all sections.

Stratigraphic record: Middle Oligocene to Pliocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae, Krutzsch (1967a).

*Verrucatosporites favus* (Potonié, 1931d) Thomson and Pflug, 1953, subsp. *favus* Krutzsch, 1967a.

Pl. 33, fig. 5.

Holotype: Thomson and Pflug, 1953, pl. 4, fig. 4.

Diagnosis: See Thomson and Pflug, 1953, p. 60.

Description: Large, reniform monolete spores with a simple monolete mark. The exine is thick and covered with low tightly packed polygonal verrucae, 2-3$\mu$m in diameter and up to 2$\mu$m high, that appear to form a reticulate pattern. Grains measured range in size from 40-45$\mu$m in length.

Discussion: Krutzsch (1967a) describes the subform species *V. favus* subsp. *magnus* as exceeding 60$\mu$m in length.

The low lying nature of the verrucate ornament of this species and thus its noticeably less crenate amb distinguish it from other species of *Verrucatospotites* described in this study.

Occurrence: 13/611, 13/603, 36/4680.

Stratigraphic record: Middle Oligocene to Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae, Krutzsch (1967a).

*Verrucatosporites favus* subsp. *pseudosecundus* (Krutzsch, 1959b) Krutzsch, 1967a.

Pl. 33, fig. 6.

Holotype: Thomson and Pflug, 1953, pl. 4, fig. 10.

Diagnosis: See Krutzsch, 1967a, table 3.

Description: Weakly reniform monolete spores. The exine is ornamented with weakly expressed, low/flat, rounded to polygonal verrucae. Practically no crenation is noted around the amb. Grains measured range in size from 27-36$\mu$m in length.

Discussion: This distinct species is easily differentiated from other forms of *Verrucatosporites* by its weakly expressed, flat verrucate ornament.

Occurrence: Present in all sections.

Stratigraphic record: Miocene of Germany, Krutzsch (1967a), Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Polypodiaceae, Thomson and Pflug (1953).

*Verrucatosporites histiopteroides* Krutzsch, 1962a, subsp. *minor* Krutzsch, 1967a.

Pl. 34, fig. 1.

Holotype: Krutzsch, 1967a, pl. 76, fig. 9.

Diagnosis: See Krutzsch, 1967a, table 3.

Description: Monolete miospores with a weakly reniform to rounded oval amb. The exine is covered with a dense ornament of slightly elongated, polygonal verrucae with a jagged/crenate outline. The heads of the verrucae are flat topped giving rise to a characteristic castellate amb. Some of the verrucae appear with slightly more rounded heads. The single grain recorded measures 37$\mu$m in length.

Discussion: This distinct species is easily differentiated from other forms of *Verrucatosporites* by its ornament of predominately flat topped verrucae and their jagged appearance in plan view.

*V. histiopteroides* subsp. *histiopteroides* has exactly the same morphology as *V. histiopteroides* subsp. *minor* but is recorded by Krutzsch (1967a) as between 50-75$\mu$m in size.

Occurrence: 13/611.

Stratigraphic record: Middle Oligocene to Middle Miocene of Germany, Krutzsch (1967a). Its main distribution is in the Upper Oligocene-Lower Miocene, Hochuli (1978).

Botanical affinity: Polypodiaceae, Krutzsch (1962a).

*Verrucatosporites poriacus* (Krutzsch, 1959b) Krutzsch, 1967a,

subsp. *poriacus* Krutzsch, 1967a.

Pl. 34, fig. 2.

Holotype: Krutzsch, 1967a, pl. 70, figs. 1-4.

Diagnosis: See Krutzsch, 1967a, table 3.

Description: Monolete miospores with a reniform amb and a simple monolete mark. The exine is ornamented with weakly expressed, low/flat, rounded to polygonal verrucae, up to 1$\mu$m in height. The verrucae are encircled by a fine punctation of the exine. Practically no crenation is noted around the amb. The single grain recorded measures 60$\mu$m in length.

Discussion: Krutzsch (1959b) referred to the punctation on this species as "Acusporid" implying a loosely arranged pattern of needle like perforations.

Krutzsch (1967a) described two subspecies *V. poriacus* subsp. *poriacus* for grain with a size range of 50-65$\mu$m and *V. poriacus* subsp. *microporiacus* for smaller forms within the range of 35-50$\mu$m.

It is felt that degradation of the exine in forms of *Verrucatosporites* might produce the acusporid punctation that characterises this species.

Occurrence: 13/611.

Stratigraphic record: Middle Eocene of Germany, Krutzsch (1967a)

Eocene to Miocene of Germany, Thomson and Pflug (1953) (recorded as *Reticuloidosporites clariformis*, pl. 4. figs. 6-8 only, considered as synonymous by Krutzsch (1967a)).

Botanical affinity: Polypodiaceae, Thomson and Pflug (1953).

*Verrucatosporites poriacus* (Krutzsch, 1959b) Krutzsch, 1967a,

subsp. *microporiacus* Krutzsch, 1967a.

Pl. 34, figs. 3-4.

Holotype: Krutzsch, 1967a, pl. 70, figs. 5-7.

Diagnosis: See Krutzsch, 1967a, table 3.

Description: Monolete miospores with a reniform amb and a simple monolete mark. The exine is ornamented with weakly expressed, low/flat, rounded to polygonal verrucae, up to 1$\mu$m in height. The verrucae are encircled by a fine punctation of the exine. Practically no crenation is noted around the amb. Grains measured range in size from 38-45$\mu$m in length.

Discussion: See discussion for *V. poriacus* subsp. *poriacus*.

Occurrence: 13/611.

Stratigraphic record: Middle Oligocene to Middle Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae.

## 7.15 Trilete Spores

Genus *Baculatisporites* Pflug and Thomson,1953 (in Thomson and Pflug, 1953).

Type Species: *Baculatisporites primarius* Wolff, 1934 p. 66, pl. 6, fig. 8.

Generic remarks: Trilete miospores with a circular to sub-circular amb. The thin exine comprises two layers and is often folded. The rays of the trilete mark almost reach to the spore margin. The exine is often densely ornamented with weak echinae, baculae or rugulae. The size of the ornament varies even on a single grain.

The emended, enlarged diagnosis of Krutzsch (1967a) is accepted here in that it proposes to maintain *Verrucosisporites* for Palaeozoic spores of Osmundoid affinity. It broadens the diagnosis of *Baculatisporites* to encompass all Mesozoic spores with Osmundoid character of ornamentation, including rugulate and baculate sculpture.

*Baculatisporites nanus* (Wolff, 1934) Krutzsch, 1959b.

Pl. 35, figs. 1-2.

Holotype: Wolff, 1934, pl.5, fig.9.

Diagnosis: See Wolff, 1934, p. 66.

Description: Small trilete miospores with a rounded to sub-rounded amb. The diameter of the grains ranges from 25-30$\mu$m. The trilete mark is prominent and reaches a little over 2/3 of the way to the equator. The exine is covered with an ornament of small round topped baculae, some tend to have slightly pointed heads but do not have a true echinate character. Some folding of the exine may be observed.

Discussion: Krutzsch (1967aa) erected five sub species, based principally upon the variation in character of ornamentation. These subdivisions are thought to be too difficult to apply with consistency to the specimens noted in this study and are therefore not adopted. The specimens recorded do, however, bear a similarity to *Baculatisporites nanus gracilis* and *Baculatisporites nanus* subfsp. A of Krutzsch (1967a).

Specimens of *Saxosporis* recorded in this study have a similar morphology but display an ornament that is distinctly echinate.

Occurrence: 36/4680.

Stratigraphic record: *Baculatisporites nanus gracilis* Middle Oligocene to Pliocene of Germany, Krutzsch (1967a). *Baculatisporites nanus* subfsp. A, Miocene of German, Krutzsch (1967)a.

Botanical affinity: Osmundaceae, Krutzsch (1967a).

*Baculatisporites primarius* (Wolff, 1934) Pflug and Thomson, 1953 (in Thomson and Pflug, 1953).

Pl.35 fig. 3.

Holotype: Wolff, 1934, pl. 6, fig. 8.

Diagnosis: Trilete miospore with a rounded to sub-rounded amb. Diameter of the grain ranges from 30-49$\mu$m. The exine comprises two layers and is often folded. The trilete mark is characteristically prominent and often split or gaping reaching approximately 2/3 of the way to the equator. The exine is covered with a dense ornament of baculae and some papillate with rounded heads.

Discussion: Krutzsch (1967a) erected five sub species based upon the variation in character of ornamentation. A variation in ornament type has been observed within single specimens, Krutzsch's subdivision can therefore not be consistently and reliably applied so is not adopted in this study.

Occurrences: Present in all sections.

Stratigraphic record: Palaeocene to Eocene of Germany, Krutzsch (1966c), Takahaski and Jux, (1982) Pliocene of Germany Thomson and Pflug (1953).

Botanical affinity: Osmundaceae, Thomson and Pflug (1953).

*Baculatisporites quintus* (Pflug and Thomson, 1953, in Thomson and Pflug, 1953) Krutzsch, 1967a.

Pl. 35, fig. 4.

Holotype: Pflug and Thomson, 1953 (in Thomson and Pflug, 1953), pl. 2, fig. 41.

Diagnosis: See Krutzsch, 1967a, p. 48.

Description: Trilete miospore with a rounded to sub-rounded amb. Diameter of the grain ranges from 33-40$\mu$m. The exine comprises two layers and is often folded. The trilete mark is characteristically prominent and often split or gaping reaching approximately 2/3 of the way to the equator. The exine is covered with a tightly packed, irregular rugulate ornament. Elements are 2-3$\mu$m in width and 1$\mu$m in height.

Discussion: Krutzsch (1967a) transferred this species from Rugulatisporites, Pflug and Thomson, 1953 (in Thomson and Pflug, 1953), to *Baculatisporites*. As a degree of compatibility has been maintained with the work of Krutzsch throughout this study and the species has an overall Osmundoid morphology, like other species of *Baculatisporites*, Krutzsch's transferral of the species is accepted. Krutzsch (1967a) described seven sub-species based upon slight variations in the character of the ornamentation. These are not recognised in this study.

Occurrence: Present in all sections.

Stratigraphic record: Oligocene to Miocene of Germany, Thomson and Pflug (1953).

Botanical affinity: Osmundaceae, Thomson and Pflug (1953).

*Baculatisporites* sp. A

Pl. 35, fig. 5.

Holotype: 27/415, 173.00m, slide 2, J46/2.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: Trilete spore with a triangular amb, the trilete mark extending just short of the amb. The exine is thin, less than 1$\mu$m thick and covered with a strong verrucate ornament. Verrucae are 1-1.5$\mu$m in diameter and 1$\mu$m high. The two grains recorded measured 38$\mu$m and 40$\mu$m in diameter.

Discussion: It is uncertain whether the triangular shape of the amb is a facet of preservation.

Occurrence: 27/415

Stratigraphic record: Unknown.

Botanical affinity: Unknown, ?Osmundaceae.

Genus *Camarozonosporites* Pant, 1954 ex Potonié 1956b emend. Klaus, 1960.

Type species: *Camarozonosporites cretaceus* (Weyland and Krieger 1953, p. 12, pl. 3, fig. 12) Potonié, 1956b, p. 65.

Generic remarks: Small trilete spores with a sub-rounded to sub-triangular amb. The rays of the trilete mark reach just short of the grain margins. The distal surface bears an ornament that may extend onto the proximal surface. A distinctive cingulum surrounds the grain, thickened in the inter-radial areas and thinning radially.

The emendation of Klaus (1960) is accepted here as it alludes to the difference in ornament between the distal and proximal surfaces.

Krutzsch (1963a) described three subgenera: *Camarozonosporites* subgen. *Camarozonosporites*, *Camarozonosporites* subgen. *Hamulatisporites* and *Camarozonosporites* subgen. *Inundatisporis* separated upon the character and distribution of ornament on the proximal and distal surfaces.

All the species of *Camarozonosporites* noted in this study can be attributed to Krutzsch's *Camarozonosporites* subgen. *Camarozonosporites*. This subgenus has hamulate sculpture restricted to the distal surface, there may be a mere suggestion of ornament wrapped onto the proximal surface. The contact area is always free from the sculpture displayed on the distal surface.

*Camarozonosporites* subgen. *Hamulatisporites* has hammulate sculpture distally that distinctly extends onto the proximal surface. *Camarozonosporites* subgen. *Inundatisporis* has hammulate ornament restricted to the distal surface and is coarsely punctate to verrucate on the contact area.

*Camarozonosporites (Camarozonosporites) decorus* (Wolff 1934) Krutzsch 1959b.

Pl. 36, fig. 1.

Holotype: Wolff, 1934, pl. 5, fig. 12.

Diagnosis: See Wolff, 1934, p. 67.

Description: Sub-rounded to sub-triangular trilete spore with a pronounced, strong distal hamulate ornament that does not extend onto the contact area. The distal sculpure is expressed around the grain margins as distinct, blunt topped undulations, up to 2$\mu$m high, which give the grain a characteristic blunted, equatorial crenation. The trilete rays reach short of the equator and are approximately 10$\mu$m long. Grains measured range in diameter from 30-35$\mu$m.

Discussion: This species is characterised by the strength of its sculpture and characteristic crenate amb.

Occurrences: 13/611, 36/4680.

Stratigraphic record: Oligocene to Pliocene of Germany, Krutzsch (1963a).

Botanical affinity: Lycopodiaceae, Krutzsch (1963a).

*Camarozonosporites (Camarozonosporites) heskemensis* (Pflanzl, 1955, in Mürriger and Pflanzl, 1955) Krutzsch, 1959b.

Pl. 36, figs. 2-3.

Holotype: Pflanzl, 1955, (in Mürriger and Pflanzl), pl. 5, fig. 3.

Diagnosis: See Mürriger and Pflanzl, 1955, p. 25.

Description: Trilete miospore with a rounded to sub-rounded amb. The distal surface bears a hamulate ornament that does not extend onto the contact area of the proximal surface. The grain is surrounded by a cingulum that narrows inter-radially. The contact area is generally psilate and sometimes a weak granation may be expressed. Rays of the trilete mark extend almost to the grain margins. Grains measured range in size from 20-35$\mu$m in diameter.

Discussion: The cingulum is a distinctive feature of this species. A form with a reduced cingulum has been noted, however, it resembles *Camarozonosporites (Camarozonosporites) heskemensis* in all other respects. This feature is thought to be attributable to intra-specific variation.

Occurrences: 13/611, 13/603, 36/4680.

Stratigraphic record: Palaeocene of Germany, Krutzsch (1959b). Middle and Upper Oligocene of Germany, Krutzsch (1963a).

Botanical affinity: Lycopodiaceae, likened to the recent species *Lycopodium cernum*, Krutzsch (1963a).

Genus *Cicatricosisporites* Potonié and Gelletich, 1933.

Type species: *Cicatricosisporites dorogensis* Potonié and Gelletich, 1933, p. 522. pl. 1, fig. 1.

Generic remarks: The original diagnosis of Potonié and Gelletich (1933) is terse and lacks clarity. The emendation of Potonié (1966) is accepted here as it better describes the ornament and alludes to relationships with *Ischyosporites*, *Stachpteris* and *Klukia*.

Trilete spores with a sub-rounded to triangular amb. A distinctive cicatricose ornament composed of a ribbing of approximately parallel striae forms ridges (muri) covering the grain. The distribution and character of these striae vary providing the characters upon which speciation is based. The trilete mark is usually quite distinct, its rays may reach the margins of the grain.

*Cicatricosisporites dorogensis* Potonié and Gelletich, 1933 ex. Potonié , 1966.

Pl. 36, figs. 4-5, pl. 37, figs. 1-2.

Holotype: Designated by Potonié, 1956b, p. 47.

Diagnosis: See Potonié and Gelletich, 1933.

Description: Trilete miospores with a convex, rounded triangular amb. The cicatricose ornament comprises a ribbing of striae approximately 1-1.5$\mu$m wide and up to 1$\mu$m high. The striae lie approximately parallel to each other displaying a slight sinuosity and have a crenation to their outline. The rays of the trilete mark extend just short of the grain margins and often stand proud of the surface. Grains measured range in size from 35-46$\mu$m in diameter.

Discussion: This species is characterised by the thin, slightly crenate striae. A morphological gradation occurs between this species and *Cicatricosisporites paradorogensis*, as some of the striae may display areas of punctation that are characteristic of the latter species.

Occurrence: 36/4680.

Stratigraphic record: Upper Jurassic to the Upper Oligocene, Wilkinson and Boulter (1980).

Botanical affinity: Schizaceae, Thomson and Pflug (1953).

*Cicatricosisporites paradorogensis* Krutzsch, 1959b.

Pl. 37, figs. 3-5.

Holotype: Krutzsch, 1959b, pl. 32, figs. 351-353.

Diagnosis: See Krutzsch, 1959b. p. 172.

Description: Trilete miospores with a convex, rounded triangular amb. The cicatricose ornament comprises a ribbing of striae up to 4$\mu$m wide. The striae lie approximately parallel to each other displaying a slight sinuosity and have a crenation to their outline. Some striae fuse to produce areas that are punctate with lumina of 1-2$\mu$m in diameter enclosed by an area of striae up to 4$\mu$m wide. The rays of the trilete mark extend just short of the grain margins and often stand proud of the surface. Grains measured range in size from 36-48$\mu$m in diameter.

Discussion: The degree of fusing of the striae producing areas of punctation is variable intraspecifically. As previously mentioned, this type of ornament is noted to a lesser degree in some specimens attributed to *Cicatricosisporites dorogensis* indicating a morphological gradation between the two species.

The punctae/lumina have been described as thin spots within thickened striae by some authors. This view is not adhered to here as it is felt that the fusing of the striae form the perceived lumina.

Occurrences: 36/4680, 27/415.

Stratigraphic record: Cretaceous of Belgium, Kedvas (1982), Oligocene of Western British Isles, Wilkinson (1979).

Botanical affinity: Schizaceae, Graus Cavagnetto (1978).

*Cicatricosisporites chattensis* subsp. *chattensis* (Krutzsch, 1961d) Krutzsch 1967a.

Pl. 38, figs. 1-6.

Holotype: Krutzsch, 1961d, pl. 1, fig. 1.

Diagnosis: See Krutzsch, 1961d, p. 302.

Description: Trilete miospores with a sub-triangular to triangular amb. A strong cicatricose ornament covers the grain comprising coarse well-spaced striae. The striae are 2-3$\mu$m wide with a spacing of up to 4$\mu$m. On the proximal surface the striae appear to display a concentric distribution around the trilete mark. On the distal surface a characteristic and distinctive triangle is formed by the striae. Grains measured range in size from 32-49$\mu$m in diameter.

Discussion: Krutzsch, 1967a, erected two subform species of *Cicatricosisporites chattensis*, *Cicatricosisporites chattensis* subsp. *chattensis* and *Cicatricosisporites chattensis* subsp. *minor*.

The characteristic strong widely spaced striae of this species distinguish it from other species of the genera.

Occurrences: 13/611, 13/603, 36/4680.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1967a), Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Schizaceae, Krutzsch (1967a).

*Cicatricosisporites chattensis* subsp. *minor* (Krutzsch, 1961d) Krutzsch 1967a.

Pl. 39, fig. 1.

Holotype: Krutzsch, 1967a, pl. 24, figs. 5-8.

Diagnosis: See Krutzsch, 1967a, p. 84.

Description: A sub form species of *Cicatricosisporites chattensis*, smaller in size with narrower, less widely spaced striations. Striae measure 1-2$\mu$m in width with a spacing of up to 3$\mu$m. Grains measured range in size from 22-31$\mu$m in diameter.

Discussion: The smaller size with the prominent strong striations serve to distinguish this subspecies. Specimens have been recorded over a smaller size range than those of Krutzsch (1967a) whose specimens ranged from 30-45$\mu$m.

Occurrence: 13/611.

Stratigraphic record: Upper Oligocene, of Germany, Krutzsch (1967a), Oligocene of the Western British Isles, Wilkinson and Boulter (1980).

Botanical affinity: Schizaceae, Krutzsch (1967a).

Genus *Deltoidospora* Miner, 1935.

Synonym: *Leiotriletes* (Naumova, 1939) Ischenko, 1952.

Type species: *Deltoidospora hallii* Miner, 1935, p. 616, pl. 24, fig. 7.

Generic remarks: Subtriangular trilete miospores with a distinct trilete mark. The rays of the trilete mark reach just short of the amb. The exine is smooth and unornamented or displays a weak infrapunctation. The exine is of sufficient thickness that secondary folding is not usually observed.

The original diagnosis of Miner (1935) is somewhat succinct and not very descriptive. The emendation of Danzé-Coursin and Laveine (1963) is accepted in this study.

Specimens of *Deltoidospora* compressed along the equatorial axis have been observed within this study. They resemble specimens of *Triplanosporites*, Thomson and Pflug (1953) in all respects except that the polar axis is not longer than the equatorial axis so may not be attributed to that genus.

Species previously attributed to *Leiotriletes* are here attributed to Deltoidospora as it is the author's opinion that the genera are synonymous.

*Deltoidospora maxoides* Krutzsch, 1962c, comb. nov.

Pl. 39, fig. 2.

1962c, *Leiotriletes maxoides* Krutzsch, p. 18, pl. 2, figs. 1-5.

Holotype: Krutzsch, 1962c, pl. 2, figs. 1-3.

Diagnosis: See Krutzsch, 1962c, p. 18.

Description: Large trilete miospores with a rounded to subrounded amb. The exine is psilate, up to 2$\mu$m thick and does not display secondary folding. The trilete rays extend short of the amb and may display a slight thickening of the exine around the trilete mark. Grains measured range in size from 50-63$\mu$m in diameter.

Discussion: The species is here transferred to *Deltoidospora* as the author regards *Leiotriletes* as a junior synonym of *Deltoidospora*.

Occurrence: Present in all sections.

Stratigraphic record: Throughout the Tertiary of Europe.

Botanical affinity: Schizaeaceae, Chandler (1955).

*Deltoidospora wolffi* Krutzsch, 1962c, comb. nov.

Pl. 39, fig. 3.

1962c, *Leiotriletes wolffi* Krutzsch, p. 26, pl. 6, figs. 1-4.

Holotype: Krutzsch, 1962c, pl. 6, figs. 1-4.

Diagnosis: See Krutzsch, 1962c, p. 26.

Description: Trilete miospores with a rounded triangular amb. The exine is psilate up to, but generally less than, 1$\mu$m thick and occasionally displays secondary folding. The trilete mark is distinct and reaches short of the amb. Grains measured range in size from 25-36$\mu$m in diameter.

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| Discussion: | This species is quite distinct from *Deltoidospora maxoides* by its size and shape. |
| Occurrence: | Present in all sections. |
| Stratigraphic record: | Early Eocene to Pliocene of Germany, Krutzsch (1962c). |
| Botanical affinity: | Unknown. |

Genus *Echinatisporis* Krutzsch, 1959b.

Type species: *Echinatisporis longechinus* Krutzsch, 1959b, p. 133, pl. 20, figs. 217-219.

Generic remarks: Trilete miospores with a rounded to subrounded amb. The exine may be psilate to grano-verrucate with an ornament of echinate-spinose elements of varying size and density. The wall is of simple structure. The trilete mark may be obscured if the ornament is dense.

Regarding the botanical affinity of this genus, Krutzsch (1963b) regards them as having a similar morphology to spores of *Selaginella* subgen. *Heterophylum*.

*Echinatisporis echinoides* subsp. *grausteinensis* Krutzsch, 1963b.

Pl. 39, figs. 4-5.

Holotype: Krutzsch, 1963b, pl. 38, figs. 6-12.

Diagnosis: See Krutzsch, 1963b, p. 114.

Description: Trilete miospores with a rounded to rounded triangular amb. The exine is 1-1.5$\mu$m thick and is covered with a dense ornament of echinae, up to 3$\mu$m long, 2-3$\mu$m wide at the base and tapering sharply to a pointed or blunted tip. The trilete mark is often obscured by the ornament, the rays of the mark reaching to or just short of the amb. Grains measured range in size from 28-33$\mu$m in diameter.

Discussion: Krutzsch (1963b) erected three subform species of his species *Echinatisporis echinoides* based upon size and the character of the ornament. The character of the three subform species appears very similar and the splitting of the species is thought by the author to be unecessary and maybe a little pedantic. Notwithstanding this, the subform species attribution has been possible in the specimens observed.

Occurrence: 13/611.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1963b).

Botanical affinity: Selaginellaceae, *Selaginella*, Krutzsch (1963b).

*Echinatisporis embryonalis* Krutzsch, 1963b.

Pl. 39, fig. 6.

Holotype: Krutzsch, 1963b, pl. 37, figs. 8-12.

Diagnosis: See Krutzsch, 1963b, p. 112.

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|---|---|
| Description: | Trilete miospore with a rounded to rounded triangular amb. The exine is 1$\mu$m thick and is covered with a dense ornament of echinae, up to 3-4$\mu$m long, up to 1.5$\mu$m wide at the base and tapering to a pointed tip. The rays of the trilete mark appear to reach to the amb. The single grain recorded measures 20$\mu$m in diameter. |
| Discussion: | The small size and proportionally longer spines serve to distinguish this species from the only other species of *Echinatisporis* recorded in this study. |
| Occurrence: | 36/4680. |
| Stratigraphic record: | Upper Oligocene, Chattian to Miocene of Germany, Krutzsch (1963b). |
| Botanical affinity: | Selaginellaceae, *Selaginella*, Krutzsch (1963b). |

Genus *Foveotriletes* Potonié 1956b.

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|---|---|
| Type species: | *Foveotriletes scrobiculatus* (Ross, 1949 ex Weyland and Kreiger, 1953), Potonié, 1956b. |
| Generic remarks: | Trilete miospores with triangular to rounded triangular ambs. The exine is covered with pits/fovea of approximately the same size forming a shallow reticulum. The rays of the trilete mark reach up to, or just short of, the amb. |

*Foveotriletes spp.*

Description: Trilete miospore with a sub triangular amb. The exine appears irregularly foveate with the fovea reaching up to 1$\mu$m in diameter. The grain margin appears slightly crenate, the fovea appearing as pits up to 0.5$\mu$m deep. The rays of the trilete mark reach short of the grain margin and appear to display a thickening of the exine around the rays. The wall is 1-1.5$\mu$m thick. The single grain recorded measures 31$\mu$m in diameter.

Discussion: The single specimen encountered was not well preserved and unsuitable for illustration. Although the specimen could not be assigned to a specific level, it did bear a similarity to *Foveotriletes crassifovearis* Krutzsch, 1962c, recorded from the Oligocene to Miocene of Germany.

Occurrence: 27/415.

Stratigraphic record: Krutzsch (1962c) recorded *Foveotriletes crassifovearis* recorded from the Oligocene to Miocene of Germany.

Botanical affinity: Unknown.

Genus *Gleicheniidites* Ross, 1949.

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

Generic remarks: Trilete miospores with a triangular to concave triangular amb. The spore wall is characteristically thickened in the interamb areas. The rays of the trilete mark reach to the margins of the spore. Tori are usually present surrounding the trilete mark proximally or distally.

The emendation of Krutzsch (1959b) is accepted in this study. This genus has been recorded from the Jurassic to the Pliocene. *Gleicheniidites* bears a striking resemblance to *Neogenisporis* Krutzsch, 1962a. Krutzsch states that his genus is a narrowly diagnosed form group characteristic of the Middle and Upper Tertiary. He states that it is

> "Very similar in habitus to 'gleichenioid' spores grouped in the genus *Gleicheniidites* 'sensu lato'; the difference between these and *Neogenisporis* cannot yet exactly be formulated; special studies are needed to do that. However, in habitus a separation is certain, as well as in stratigraphic occurrence as the last remains of *Gleicheniidites* disappear in the Lower Tertiary, while *Neogenisporis* is known from the M. Oligocene, and then already present quite regularly." (p.267)

*Neogenisporis* is not accepted in this study as spores recorded with a gleichenioid character conform with the diagnosis of *Gleicheniidites*. The diagnosis of *Neogenisporis* appears to conform to that of *Gleicheniidites*. If the author of *Neogenisporis* states that the differences between his genus and *Gleicheniidites* cannot be exactly formulated, there appears, in the opinion of this author, little hope of being able to consistently distinguish the two genera.

*Gleicheniidites senonicus* Ross, 1949.

Pl. 40, fig. 1.

Holotype: Ross, 1949, pl. 1, fig. 3.

Diagnosis: See Ross, 1949, p. 31.

Description: Trilete miospores with a triangular to concave triangular amb. The spore wall is characteristically thickened in the interamb areas where it is up to 2-3$\mu$m thick. It is thinner at the apices of the amb where it is 1$\mu$m. The exine is smooth and unornamented. The rays of the trilete mark reach to the margins of the spore and may gape slightly displaying folding. Tori may be present surrounding the trilete mark proximally or distally. Grains measured range in size from 30-37$\mu$m in diameter.

Discussion: As the species has been recorded with such a wide stratigraphic distribution, the author agrees with Wilkinson and Boulter (1980) that it is doubtful that the form has any stratigraphic or ecological significance.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Jurassic to Pliocene.

Botanical affinity: Gleicheniaceae.

Genus *Hydrosporis* Krutzsch, 1962c.

Type species: *Hydrosporis azollaensis* Krutzsch, 1962c, p. 64, pl. 25, figs. 9-15.

Generic remarks: Small trilete miospores with a circular to rounded triangular amb. The exine is smooth or displays a weak ornament. The trilete mark is usually distinct, its rays reaching short of the amb.

Smooth forms with this morphology are mostly known to occur in the freshwater fern family Salviniaceae and smooth to sculptured forms in the family Azollaceae.

*Hydrosporis azollaensis* Krutzsch, 1962c.

Pl. 40, fig. 2.

Holotype: Krutzsch, 1962c, pl. 25, figs. 9-15.

Diagnosis: See Krutzsch, 1962c, p. 64.

Description: Small trilete miospore with a circular amb. The exine is two layered and $1\mu m$ in thickness, the exoexine displaying a fine punctation. The rays of the trilete mark extend short of the amb. The single grain recorded measures $27\mu m$ in diameter.

Discussion: Krutzsch (1962c) described two subform species *Hydrosporis azollaensis azollaensis* and *Hydrosporis azollaensis gracilis*. These are not recognised within this study. The specimen recorded with this morphology has been attributed to *Hydrosporis azollaensis* as the morphology is of *Hydrosporis* *azollaensis azollaensis,* but the size range is akin to that of *Hydrosporis azollaensis gracilis.*

Occurrence: 13/611.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1962c).

Botanical affinity: Salviniaceae, Azollaceae Krutzsch (1962c).

*Hydrosporis levis* Krutzsch, 1962c.

Pl. 40, fig. 3.

Holotype: Krutzsch, 1962c, pl. 26, figs. 1-4.

Diagnosis: See Krutzsch, 1962c, p. 66.

Description: Small trilete spores with a circular amb. The exine is thin smooth and unornamented. The rays of the trilete mark extend short of the amb. Grains measured range in size from 17-20$\mu$m in diameter.

Discussion: This species is distinguished by its small size and unornamented exine.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Upper Oligocene, Chattian of Germany, Krutzsch (1962c).

Botanical affinity: Salviniaceae, Azollaceae Krutzsch (1962c).

Genus *Lycopodiumsporites* Thiergart, 1938 ex Delcourt and Sprumont, 1955.

Pl. 40, figs. 4-5.

Type species: *Lycopodiumsporites agathoecus* (Potonié, 1934, pl. 1, fig. 25.) Delcourt and Sprumont, 1955, p. 31.

Generic remarks: Trilete miospores with a triangular to rounded triangular amb. The rays of the trilete mark extend to the margins of the spore. The proximal surface is psilate while the distal surface bears a reticulate ornament. The reticulation may extend onto the margins of the proximal surface, however, the contact areas remain psilate.

Due to various supposed misidentifications, interpretations and assignation, Krutzsch (1963b) proposed to consider *Lycopodiumsporites* a *nomen dubium* and that Tertiary and Mesozoic forms of reticulate lycopodiaceoid spores be assigned to *Retitriletes*. This view is rejected here as a clear likening to extant *Lycopodium* spores is observed

Krutzsch (1963b) made a detailed study of spores of Lycopodiaceous affinity and figured 34 species and 10 subspecies. Whilst this was a considerable piece of detailed taxonomic work, many of the observations made were on a very detailed scale of features at the limit of resolution using optical microscopy, and requiring excellent preservation to identify the diagnostic features. It is felt that such division is impracticable for routine palynological analysis where the aim is to characterise the palynological assemblage and not perform a detailed piece of taxonomic work on a particular group of palynomorphs.

The use of the generic group *Lycopodiumsporites* spp. has been employed as the splitting of the genus is considered to have no real stratigraphical or ecological significance that would be consistently reliable.

Genus *Matonisporites* Couper, 1958.

Type species: *Matonisporites phlebopteroides* Couper, 1958, p. 140, pl. 20, fig. 15.

Generic remarks: Trilete miospores with a triangular amb often displaying a concavity in the inter-radial region. The trilete mark is raised and thickened. The exine is usually very thick but notably thicker at the apices of the amb, being thinner in the inter-radial areas.

*Matonisporites* spp.

Pl. 40, fig. 6.

Description: Trilete miospore with a concave triangular amb. The exine is 2-3$\mu$m thick in the inter-radial areas increasing to 5-6$\mu$m thick at the apices of the amb. The rays of the trilete mark are 25$\mu$m in length and appear slightly raised. They are surrounded by thickened exine. The single specimen recorded measures 63$\mu$m in diameter.

Discussion: The specimen recorded bears a great similarity to specimens rarely recorded by Wilkinson (1979) pl. 5 figs. 11-12 from his section at Mochras, Wales.

Occurrence: 13/603.

Stratigraphic record: As a genus from the Jurassic.

Botanical affinity: Cyatheaeceae, Wilkinson (1979).

*Muerrigerisporis* Krutzsch, 1963b.

Type Species: *Muerrigerisporis muerrigeri* (Pflanzl, 1955, in Mürriger and Pflanzl 1955) Krutzsch, 1963b, p. 23 pl. 41, fig. 1-2 reillustration.

*Cingulatisporites muerrigeri* Pflanzl, 1955, (in Mürriger and Pflanzl 1955).

Generic remarks: Trilete miospores with a spinose cingulum. The exine is covered with an ornament of spinose elements.

*?Muerrigerisporis spp.*

Description: Trilete miospore with a spinose cingulum. Spines on the cingulum are up to 5$\mu$m long and 2$\mu$m wide. The spinose elements on the spore body are up to 2-3$\mu$m in length. The specimen measured is 30$\mu$m in diameter.

Discussion: One badly preserved specimen and one partial specimen not suitable for illustration were recorded.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Throughout the Tertiary of Germany, Krutzsch (1963b).

Botanical affinity: Selaginellaceae, Krutzsch (1963b).

Genus *Polypodiaceoisporites* Potonié, 1951 ex Potonié 1956b.

Type species: *Polypodiaceoisporites speciosus* Potonié, 1951 ex Potonié, 1956b, p. 63.

*Sporites speciosus* Potonié, 1934, p. 44, pl. 1, fig. 22.

Generic remarks: Trilete cingulate miospores with a subtriangular amb with rounded apices. A distinct cingulum surrounds the grain. The rays of the trilete mark do not extend onto the cingulum. The spore body is variously ornamented with verrucae, rugulae or grana differing on the proximal and distal surfaces.

*Polypodiaceoisporites gracillimus* Nagy, 1963b.

Pl. 41, figs. 1-2.

Holotype: Nagy, 1963b, pl. 1, figs. 3-6.

Diagnosis: See Nagy, 1963b, p. 398.

Description: Trilete cingulate miospores with a subtriangular amb with rounded apices. The cingulum is 3-5$\mu$m wide. The rays of the trilete mark do not extend onto the cingulum. The spore body is ornamented with a weak verrucate and granate ornament on the proximal surface. The distal surface has a stronger verrucose ornament. Grains measured range in size from 25-40$\mu$m in diameter.

Discussion: See discussion for *Polypodiaceoisporites gracillimus* subsp. *semiverrucatus.*

Occurrence: 13/611, 13/603, 36/4680.

Stratigraphic record: Miocene, Nagy (1963b).

Botanical affinity: Polypodiaceae, Nagy, (1963b).

*Polypodiaceoisporites gracillimus* subsp. *semiverrucatus* Krutzsch, 1967a.

Pl. 41, fig. 3.

Holotype: Krutzsch, 1967a, pl. 36, figs. 1-5.

Diagnosis: See Krutzsch, 1967a, p. 108.

Description: Trilete cingulate miospore with a subtriangular amb with rounded apices. The cingulum is 4$\mu$m wide. The rays of the trilete mark do not extend onto the cingulum. The distal surface has a strong, fairly tightly packed verrucose ornament. The verrucae are approximately equidimensional having rounded heads and measuring 3$\mu$m in height and width. The single grain recorded measures 40$\mu$m in diameter.

Discussion: This sub-species is differentiated by the character of its distal ornament.

Occurrence: 27/415.

Stratigraphic record: Upper Oligocene to Miocene of Germany, Krutzsch, 1967a.

Botanical affinity: Polypodiaceae, Krutzsch (1967a).

*Polypodiaceoisporites saxonicus* Krutzsch, 1967a.

Pl. 41, fig. 4.

Holotype: Krutzsch, 1967a, pl. 37, figs. 10-11.

Diagnosis: See Krutzsch, 1967a, p. 110.

Description: Trilete cingulate miospores with a subtriangular amb with rounded apices. The psilate cingulum is 2-4$\mu$m wide. The proximal surface is ornamented with grana and small verrucae. The distal surface is covered with a larger granate and verrucate ornament, elements measuring up to 3$\mu$m. The rays of the trilete mark do not extend onto the cingulum. Specimens measured range in size from 23-30$\mu$m in diameter.

Discussion: This species is differentiated from *P. gracillimus* by its slightly narrower psilate cingulum and stronger more densely packed ornament.

Occurrence: 13/611, 13/603, 36/4680.

Stratigraphic record: Upper Oligocene to Pleistocene of Germany, Krutzsch (1967a).

Botanical affinity: *Pteris*, Pteridaceae, Krutzsch, (1967a), likens the spores to the extant *Pteris arguta*.

*Saxosporis* Krutzsch, 1963a.

Type species: *Saxosporis duebenensis* Krutzsch, 1963a, p. 48, pl.5, fig. 1-8.

Generic remarks: Trilete miospores with a rounded to sub-triangular amb. The exine is uniformly covered with an ornament of warty spinose elements.

*Saxosporis gracilis* Krutzsch and Pacltová, 1963, (in Krutzsch, 1963a).

Pl. 41, fig. 5.

Holotype: *Saxosporis gracilis* Krutzsch and Pacltová, 1963, (in Krutzsch, 1963a), pl. 6, fig. 1-6.

Diagnosis: See Krutzsch, 1963a, p. 50.

Description: Trilete miospores with a rounded amb. The exine is covered with a fairly dense ornament of spinose elements 1-1.5$\mu$m high, some more verrucate like elements may be apparent. The rays of the trilete mark reach just short of the amb and may be slightly sinuous in appearance. Grains measured range in size from 20-27$\mu$m in diameter.

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| Discussion: | Krutzsch (1963a) recorded specimens up to 45$\mu$m in size. Specimens recorded here are similar in all respects except for their smaller size. |
| Occurrence: | Present in all sections. |
| Stratigraphic record: | Oligocene to Miocene of Czechoslovakia, Pacltová (1960). |
| Botanical affinity: | Unknown. |

Genus *Stereisporites* Pflug, 1953, (in Thomson and Pflug,1953).

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|---|---|
| Type sepcies: | *Stereisporites stereoides* (Potonié and Venitz, 1934, p. 11, pl. 1, figs. 4-5) Pflug, 1953, (in Thomson and Pflug,1953), p. 53, pl. 1, figs. 64-73. |
| Generic remarks: | Small trilete, cingulate miospores with a subtriangular amb and rounded apices. The simple trilete mark does not extend onto the cingulum. The ornament on the spore body, the cingulum, and the width of the latter vary forming specific distinctions.<br>This genus contains a large number of subgenera and species principally due to the works of Krutzsch (1963b, 1966c) and to that of Schultz (1966). Since the large number of morphological groups contained within this genus are defined quite precisely by the aforementioned authors, attribution of poorly preserved specimens to one of the subgenera and species is not always possible, especially since a |

general degree of similarity is perceived throughout the morphological variability of the group.

*Stereisporites* subgen. *Distangranisporis* Krutzsch, 1963b.

Type species: *Stereisporites* subgen. *Distangranisporis sprembergensis* Krutzsch, 1963b, p. 84, pl. 23, figs. 1-4.

Subgeneric remarks: *Stereisporites* with a prominent distal ornament of a single or group of elements distinctly differentiated and more prominent than the rest of the distal ornament.

Krutzsch (1963b) states that this subgenus is mostly found in middle to late Tertiary strata.

*Stereisporites (Distigranisporis) granistereoides* Krutzsch and Sontag, 1963, (in Krutzsch, 1963b).

Pl. 41, fig. 6, pl. 42, fig. 1.

Holotype: Krutzsch, 1963b, pl. 22, figs. 11-13.

Diagnosis: See Krutzsch, 1963b, p. 82.

Description: Small trilete miospores with a subtriangular amb with rounded apices. The simple trilete mark reaches the margins of the grain. No clear cingulum is developed but the wall is up to 1.5$\mu$m thick. The proximal surface is psilate. The distal surface is covered with an ornament of equidimentional, irregular verrucae up to 2$\mu$m surrounding a larger prominent verrucose element. Grains measured range in size from 20-24$\mu$m in diameter.

Discussion: *S. (Distgranisporis) granistereoides* most closely resembles *S. (Distgranisporis) granuloides* Krutzsch, 1963b. Differentiation of the species should be clear due to the development of a cingulum on the latter.

Occurrence: 27/415.

Stratigraphic record: Pliocene of Germany, Krutzsch (1963b).

Botanical affinity: Sphagnaceae, Thomson and Pflug (1953).

*Stereisporites* subgen. *Distancoraesporis* Krutzsch, 1963b.

Type species: *Stereisporites* subgen. *Distancoraesporis germanicus* Krutzsch, 1963b, p. 62, pl. 13, figs. 14-17.

Subgeneric remarks: *Stereisporites* with a prominent distal trilobed ornament/thickening in the shape of a "triple anchor". Each branch of the trilobe may be seen to bifurcate in extremely expressed forms hence Krutzsch's analogy to the anchor.

*Stereisporites (Distancoraesporis) ancoris* Krutzsch, 1963b.

Pl. 42, fig. 2.

Holotype: *Stereisporites (Distancoraesporis) ancoris* Krutzsch, 1963b, pl. 9, figs. 20-23.

Diagnosis: See Krutzsch, 1963b, p. 54.

Description: Small trilete spores with a subtriangular amb with rounded apices. The simple trilete mark reaches the margins of the grain. No clear cingulum is developed but the wall is up to 1$\mu$m thick. The proximal surface is psilate. The distal surface bears the distinctive trilobed thickening. Each branch of the trilobe has only the beginnings of a bifurcation that is not clearly expressed. Grains measured range in size from 19-23$\mu$m in diameter.

Discussion: Krutzsch (1963b) described two subspecies *S. (Distancoraesporis) ancoris ancoris* and *S. (Distancoraesporis) ancoris longancoris*. Differentiation of the subspecies is based upon the size and length of the branches of the distal anchor. The subspecies are not accepted in this study.

Occurrence: 13/611, 27/415.

Stratigraphic record: Miocene of Germany, Krutzsch (1963b).

Botanical affinity: Sphagnaceae, Thomson and Pflug (1953).

Genus *Toroisporis* Krutzsch, 1959b.

Pl. 42, figs. 3-4.

Type species: *Toroisporis torus* (Pflug, 1953, in Thomson and Pflug, 1953), Krutzsch, 1959b, p. 90.

*Laevigatosporites neddeni* Potonié, 1931a, subsp. *torus* Pflug, 1953, (in Thomson and Pflug, 1953), p. 54, pl. 2, fig.14.

Generic remarks: Trilete miospores with a triangular to subtriangular amb. The exine comprises two layers and is psilate. Tori are present on the proximal or distal or both surfaces. The placement of the tori defines the four subspecies of Krutzsch (1959b).

*T.* (*Toroisporis*): with proximal tori.

*T.* (*Duplotoroisporis*): with proximal and distal toroid differentiations.

*T.* (*Divitoroisporis*): with proximal tori and pseudo divisive splits of the marks viz. with rather distinct pseudotorid elements.

*T.* (*Reductisporis*): with proximal tori and with reduced, rudimentary Y marks or alete.

Within this study spores conforming to the diagnosis for *Toroisporis* have not been assigned to a specific level. Their occurrences are not widespread throughout the sections studied with a single occurrence in 13/603 and 27/415. Others are predominantly limited to single occurrences at particular horizons in 13/611 and 36/4680. The compression of the specimens, often displaying pronounced constriction in the interamb areas, prevents the determination of the position and distribution of the tori. Where it was possible, the tori were thought to be proximal.

One specimen at 13/611 149.12m was noted as resembling *Toroisporis (Toroisporis) teupitzensis medioris* Krutzsch, 1962c, recorded from the Miocene of Germany.

Wilkinson and Boulter (1980) report that this genus is widely dispersed throughout their Bovey section but is rare elsewhere, suggesting a decline in this taxa after the Lower to Middle Oligocene.

Stratigraphic record: Throughout the Upper Cretaceous and Tertiary of Europe.

Botanical affinity: Gleicheniaceae.

Genus *Trilites* Cookson, 1947 ex Couper, 1953.

Type species: *Trilites tuberculoformis* Cookson, 1947 ex Couper, 1953.

*Trilites tuberculoformis* Cookson, 1947, p. 136, pl. 16, fig. 61.

Generic remarks: Trilete miospores with a rounded triangular amb and a simple trilete mark extending short of the spore margins. Proximal and distal surfaces are covered with a dense verrucose or rugulose ornament that may display a degree of anastomisation, especially around the cingulum.

The original diagnosis is brief and not very descriptive. The emended diagnosis of Dettman (1963) is accepted here as it provides a more complete description especially regarding the type of ornament. Couper (1953) designated the type species.

*Trilites multivallatus* Pflug, 1953, (in Thomson and Pflug, 1953), Krutzsch 1959b.

Pl. 42, figs. 5-6.

Holotype: Pflug, 1953, (in Thomson and Pflug, 1953), pl. 2, figs. 37-40.

Diagnosis: See Thomson and Pflug, 1953, pl. 2 fig 38

Description: Trilete miospores with a rounded triangular amb. The trilete mark is simple and extends just short of the spore margins. The spore is covered with elongated verrucose elements that display an anastomisation with each other to form a rugulate/corrugate ornament. This is especially noticeable around the margins of the trilete mark. Anastomisation of the ornament around the margins of the grain may give rise to a pseudo cingulate appearance. Grains measured range in size from 32-40$\mu$m in diameter.

Discussion: Krutzsch (1959b) regarded *Corrugatisporites solidus* as synonymous with *Triletes multivallatus*. This synonomy is accepted here.

Occurrence: 13/611, 36/4680, 27/415.

Stratigraphic record: Middle Oligocene to Miocene of Germany, Krutzsch (1967a)

Botanical affinity: *Lygodium*, Schizaeaceae, Krutzsch (1967a).

Genus *Triplanosporites* Pflug, 1952 (in Thomson and Pflug, 1952) ex Thomson and Pflug, 1953.

Type species: *Triplanosporites sinuosus* Pflug, 1953, (in Thomson and Pflug, 1953), p. 58, pl. 3, fig. 7.

Generic remarks: Trilete spores with a polar axis longer than the equatorial axis. These spores are most often noted in equatorial compression along a plane of symmetry through the polar axis, hence giving rise to an elongated triplanoid aspect. The exine is thin and psilate and the trilete mark is often indistinct.

The longer polar axis resulting in the characteritic mode of compression differentiates this genus from *Deltoidospora*.

*Triplanosporites microsinuosus* Pflanzl,1955, (in Mürriger and Pflanzl, 1955).

Pl. 43, figs. 1-2.

Holotype: *Triplanosporites microsinuosus* Pflanzl, 1955, (in Mürriger and Pflanzl, 1955), pl. 5, fig. 12a-b.

Diagnosis: See Mürriger and Pflanzl, 1955, p. 27.

Description: Trilete spores with a polar axis just longer than the equatorial axis. Specimens are preserved in equatorial compression along a plane of symmetry through the polar axis. A characteristic longitudinal fold along the polar axis is produced by the triplanoid aspect of the grain. The exine is thin, 0.5$\mu$m thick and psilate. The trilete mark is often indistinct. Grains measured range in size from 28-35$\mu$m in length and 22-32$\mu$m in width.

Discussion: This species most closely resembles *Triplanosporites sinuosus*. It is differentiated by its smaller size.

Occurrence: Present in all sections.

Stratigraphic record: Upper Oligocene to Miocene (?Pliocene), Krutzsch, (1962c).

Botanical affinity: Schizaceae.

Genus *Varirugosisporites* Döring, 1965.

Type species: *Varirugosisporites perverrucatus* (Couper, 1958) Döring, 1965, p. 40.

*Lygodioisporites perverrucatus* Couper, 1958, p. 144, pl. 23, fig. 4.

Generic remarks: Large, trilete miospores with a rounded triangular amb. The exine is ornamented both proximally and distally with large tuberose elements. These elements may display a degree of coalescence at their bases.

*Varirugosisporites megaverrucatus* Krutzsch, 1967a.

Pl. 43, fig. 3.

Holotype: Krutzsch, 1967a, pl. 17, figs. 6-9.

Diagnosis: See Krutzsch, 1967a, p. 70.

Description: Large trilete miospore with a rounded triangular amb in polar compression. In equatorial compression the contact area and limbs of the trilete mark may be observed to be raised. The exine is ornamented with large tuberose elements appearing as well rounded hemispheres around the amb of the grain. The elements resemble the verrucae on the monolete spore *Verrucatosporites alienus*. The elements of the ornament are up to 17$\mu$m long, 9$\mu$m wide and stand up to 6$\mu$m high. The elements are not so densely spaced that the exine cannot be seen between them. A complete specimen has been measured at 75$\mu$m long. Other specimens recorded were incomplete.

Discussion: In equatorial compression the grain may appear to resemble the reniform shape of *Verrucatosporites*. Indeed the ornament is not dissimilar to some of the species of this genera. The contact area and the raised limbs of the trilete mark serve to dismiss any similarity, however, these features may be somewhat obscured by the compression of the grain.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Upper Oligocene of Germany, Krutzsch (1967a).

Botanical affinity: Lygodiaceae, Krutzsch (1967a) now termed Schizaeaceae.

Genus *Verrucingulatisporites* Kedvas, 1961.

Type species: *Verrucingulatisporites verrucatus* Kedvas, 1961, p. 140, pl. 8, fig. 10.

Generic remarks: Trilete miospores with an irregular crenate cingulum. The exine is ornamented with verrucae, grana or echinae depending upon the species.

*Verrucingulatisporites undulatus* Nagy, 1963b, subsp. *undulatus* Krutzsch, 1967a.

Pl. 43, fig. 4.

Holotype: Nagy, 1963b, pl. 1, figs, 7-8

Diagnosis: See Nagy, 1963b, p. 400, table 2, fig. 13.

Description: Trilete miospore with an irregular crenate cingulum. The cingulum is psilate and measures 4-5$\mu$m wide. The trilete mark reaches to the spore margins but not onto the cingulum. The exine of the proximal and distal surfaces is ornamented with verrucae up to 3$\mu$m in diameter and 2 $\mu$m in height with rounded tips. Some of the verrucae may been seen to coalesce, especially around the cingulum.

Discussion: *V. undulatus* subsp. *undulatis* is differentiated from Krutzsch's (1967a) subspecies *V. undulatus* subsp. *microverrucatoides* by the larger ornament on the former.

Occurrence: 13/611.

Stratigraphic record: Upper Oligocene to Upper Miocene of Germany, Krutzsch (1967a).

Botanical affinity: Polypodiaceae.

## 7.16 Incertae Sedis

Echinate spore sp. A

Pl. 44, figs. 1-3.

Holotype: See 13/611, 100.00m, slide 1, P36.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: ?Alete spore with a rounded amb. The exine bears an ornament of spines with pointed or blunt tips up to 4-5$\mu$m long and a reticulate ornament with wide lumina up to 2-3$\mu$m in diameter. The spore has a bright lustrous appearance. Grains measured range in size from 15-20$\mu$m in diameter.

Discussion: These spores have only been recorded in predominantly low numbers from sparse assemblages predominantly containing a spore dominated palynoflora. They may be of Selaginoid affinity.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.

Echinate spore sp. B

Pl. 44, fig. 4.

Holotype: 13/611, 100.00 m, slide 1, L35/3.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: ?Alete spore with a rounded amb. The exine bears an ornament of small echinae up to 1-1.5$\mu$m in height arising from the junctions of the muri. The lumina of the reticulum have a diameter of up to 4-5$\mu$m. The spore has a bright lustrous appearance. Grains measured range in size from 15-20$\mu$m in diameter.

Discussion: The general morphology of Echinate spore sp. B is similar to that of Echinate spore sp. A except for the length of the spines. It has only been recorded in low numbers from sparse assemblages predominantly containing a spore-dominated palynoflora. They may be of Selaginoid affinity.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.

Echinate spore sp. C

Pl. 44, fig. 5.

Holotype: 36/4680, 72.05m, slide 1, O49.

Diagnosis: No formal diagnosis exists as the group is informally constructed for the purposes of this study and is therefore not recognised under the rules of the I.C.B.N.

Description: ?Alete spores with a rounded amb. The exine is covered with a dense ornament of echinae 1-2$\mu$m in height, some having flat tops. The spore has a bright lustrous appearance. Grains measured range in size from 16-20$\mu$m in diameter.

Discussion: These spores have only been recorded in low numbers from sparse assemblages predominantly containing a spore-dominated palynoflora. They may be of Selaginoid affinity.

Occurrence: 13/611, 36/4680.

Stratigraphic record: Unknown.

Botanical affinity: Unknown.