TURONIAN DINOFLAGELLATE CYST ASSEMBLAGES FROM SOUTHERN ENGLAND

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Abstract

Little recent work has directly addressed the variation in dinoflagellate cyst assemblages and the resulting biostratigraphy from the Turonian of southern England. Sampling (every 1-2m) of the whole succession from three areas (Dover, Sussex and the Isle of Wight), together with sedimentological and macropalaeontological detail provided a good basis for what is primarily a biostratigraphical study. Altogether 328 samples were analysed. It is one of the aims of this project to expand on the knowledge and geographical limits of dinoflagellate cyst assemblages from the Turonian. Full descriptions of all dinoflagellate cyst species have been included. Two new species are believed to have been noted, first *Litosphaeridium "chlidanum"* n.sp.(Marshall, 1983) and *?Microdinium "tuberculatum"* n.sp., which are indicators of a latest Cenomanian and Turonian age respectively. Three palynozones have been recognised for the Turonian, based upon the ranges and acmes of the following species: *Senoniasphaera rotundata, Heterosphaeridium difficile, Florentinia buspina, Florentinia torulosa* and *Endoscrinium campanula.* Cluster analysis was applied to the data sets to look for statistically related samples and thus separate palynozones. However most of the dinoflagellate cyst species are long-ranging and this did not provide any substantial evidence for any zones.

Generally the dinoflagellate cyst assemblages were of variable diversities and abundances (0-41; 0->300 respectively). The samples were barren or yielded poor assemblages at the base of the Turonian, but the flora recovered towards the middle part of the succession with increasing diversities and abundances being recorded. However, the high diversities and abundances of the Late Cenomanian were never achieved.

Samples of chalk, marl and flint were analysed for their dinocyst content to see if the assemblages were lithologically constrained. It was found that the lithology did not appear to control the cyst assemblages with low to high diversities and abundances being recorded from all lithologies. It has been noted that particular types of flint (*Thalassinoides*) may produce richer dinoflagellate cyst assemblages (higher diversities and abundances) which may be related to the diagenetic stage represented by the flint.

Statistical analyses were applied to all data sets to provide evidence to support these hypotheses. Unfortunately these methods did not produce any conclusive results. Some palaeoenvironmental interpretation has been carefully attempted using modern analogues as a guideline. The relative occurrence of three groups (*Gonyaulax, Odontochitina* and *Cyclonephelium*) have been plotted for two of the areas (Dover and Sussex) and are thought to reflect periods of changing sea-level which correspond broadly to the sea-level curves of Hancock & Kauffman (1989) and Haq *et al.* (1988).

I would like to dedicate this thesis to the memory of my grandfather, John Traquair Paul (1906 - 1990), who encouraged my curiosity in nature from an early age, and taught me to appreciate the wonders of the natural world.

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This work was carried out during the tenure of a CNAA Research Assistantship, which is gratefully acknowledged.

DECLARATION

This is to certify that the work submitted for the Degree of Doctor of Philosophy under the title "Turonian Dinoflagellate Cyst Assemblages from southern England" is the result of original work.

All authors and works consulted are fully acknowledged. No part of this work has been accepted in substance for any other degree and is not being concurrently submitted in candidature for any other degree.

Candidate: Meriel E.J. FitzPatrick

Meriel E.J. FitzPatrick

Research Supervisor: M B Hart

Professor M.B. Hart

" It cannot fail to arrest attention, that delicate as is the structure of these minutisimal creatures, there is not, in by far the greatest proportion of them, any appearance of distortion, pressure or injury of any kind; they seem to have been suddenly arrested in the full enjoyment of life, developing (so far as form and perfect structure can evidence the fact) every indication of animation exhibited by the recent species, up to the very moment of their transformation from the living to the fossil animalcule."

Henry Hopley White Esq. 1842

"In numerous instances, the organs of life appear to have been in the most perfect condition to the last. And yet they seem to have died without violence, in the most quiet manner, as it were by suspension of animation. This observation is the more remarkable, as a great proportion of these animals are aquatic and appear to have perished thus quietly in the midst of their own element."

Gideon Mantell, 1822

CHAPTER ONE INTRODUCTION

1.1 Introduction

The Chalk of southern England has intrigued geologists since the last century and before because of its uniqueness, in terms of lithological characteristics and the lack of a modern equivalent with which to compare it. As there is no direct modern analogue, Hutton's law of uniformitarianism cannot be used and no key exists to unlock the history of the past. The Chalk therefore possesses a mysterious quality, which has stimulated the curiosity and interest of geologists over the years. Every aspect of the chalk must be analysed and examined in detail, before a true or realistic interpretation of the palaeoenvironmental conditions that prevailed at the time can be made.

A brief definition of "Chalk" is included in this chapter, followed by a short discussion of the depositional history and environment of the Chalk Sea, together with the extent and nature of its outcrop.

1.1.2 The definition of 'Chalk' and chalk.

The 'Chalk' is the term generally used in northwest Europe to describe the lithostratigraphic unit (formally the Chalk Group) taken to be representative of the Late Cretaceous (Cenomanian - Maastrichtian) and Early Tertiary (Danian). It should not be confused with the lithological term 'chalk' which is defined as a biomicrite (soft, white, fine-grained, homogeneous carbonate sediment), composed largely of coccoliths, with non-carbonate minerals forming between 0.5 and 3.0 percent of the total bulk (Robinson, 1986). This definition of a pure white chalk represents the closest analogy to the original sediment. Once subjected to various diagenetic processes the sediment may be altered forming a harder, lithified equivalent. Here the term 'chalk' is used in the lithological context of the lithified sediment.

The Chalk Group is exposed over much of southern England, influencing the

gentle topography of this region. It extends from Dover and Ramsgate, onshore in the east, to Devon in the west; and as far north as Humberside (Figure 1.1) and northern Ireland. There are also some reports of a limestone equivalent of the Chalk from north western Scotland. The sediments attributed to the Turonian (which is of primary interest herein) are exposed at many places along the southern coast and at locations inland, from Dover in the east, to its most westerly exposure on the coast, at Beer in Devon. It also occurs further north at South Ferriby in Humberside and to Flamborough Head in Yorkshire.

1.1.3 Water Depths and Depositional Environment

The depth of the Chalk Sea and the depositional environment of the Chalk has long been a topic of discussion and debate. It is generally believed there is no equivalent forming today under the same conditions (Black, 1980). However, there are examples of similar coccolith-rich sediments forming where other clastic terrigenous and carbonate inputs are low. These are not as widespread as the extent of the Chalk. They are also found in water depths between 100 and 4000 m (Scholle, 1977), which is deeper than envisaged for the Chalk Sea; in low latitudinal regions with sub-tropical climates e.g. the Caribbean.

It is, therefore, believed that the Chalk was deposited in the expanded epicontinental and shallow shelf seas (Figure 1.2) that were created by high eustatic sea-levels (Wise, 1972; Bond, 1976). Depth estimates are difficult to estimate and have been variously noted as 100 and 250 m by Håkansson *et al.* (1974) for much of the Maastrichtian chalk, whereas Hancock (1976) used palaeontological and palaeogeographical evidence to indicate water depths of 100 to 600 m for deposition of the Chalk. Burnaby (1961) proposed that during the Cenomanian, the sea was between 5 and 100 fathoms (= 9 - 190 metres) based upon the relative abundances of four Chalk Marl species of foraminifera. Using the ratio of planktonic to benthonic foraminifera, Hart, (1980) suggested a depth range of 100-500m for the chalk sea during the Mid-Cretaceous.

The Chalk Sea is thought to have been of normal marine salinity (*c.*35 p.p.t.) as is indicated by the common occurrence of echinoderms and brachiopods (Hancock 1976); and the recorded occurrences of benthonic and planktonic foraminifera (Jarvis *et al.* 1988).

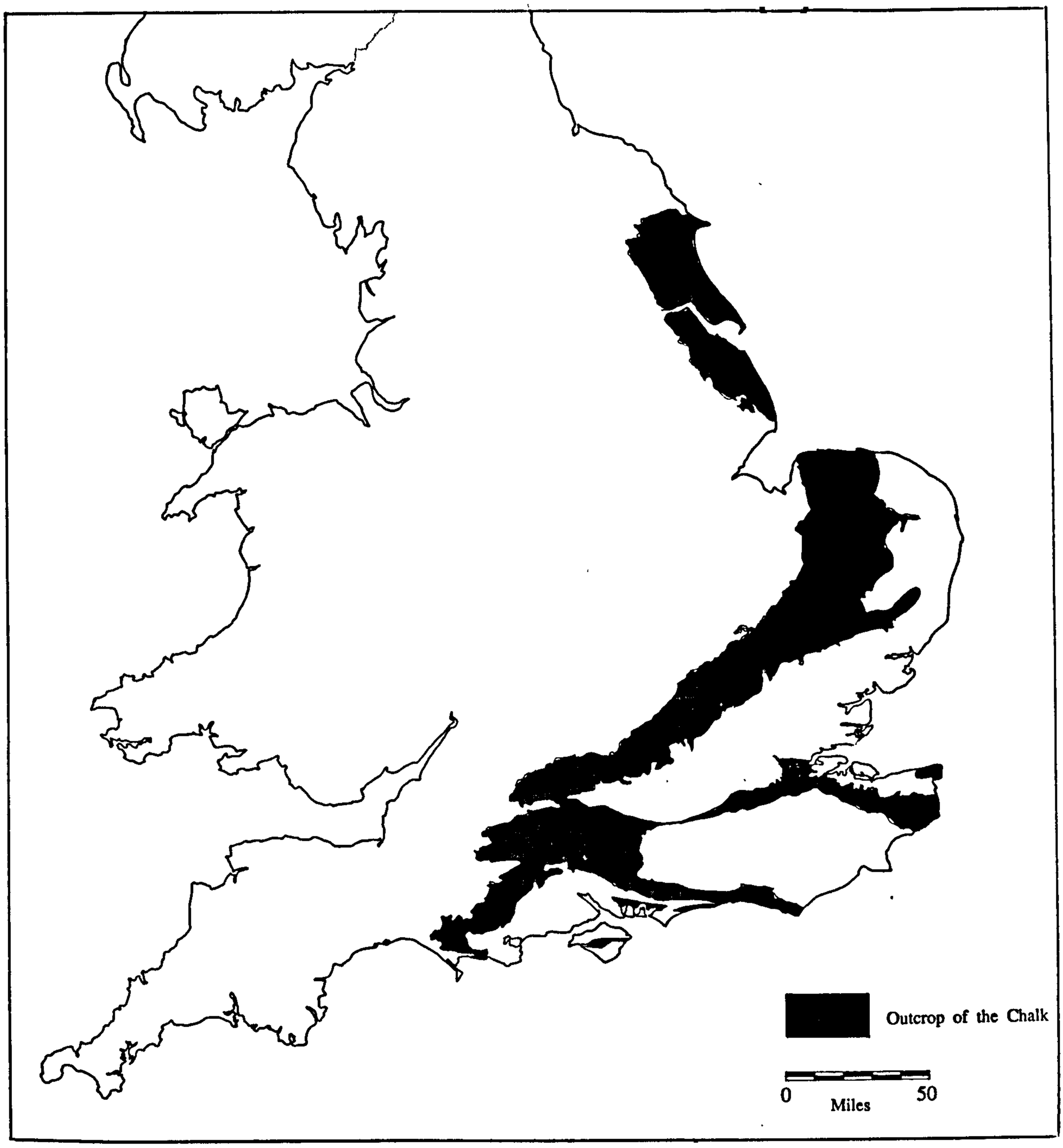
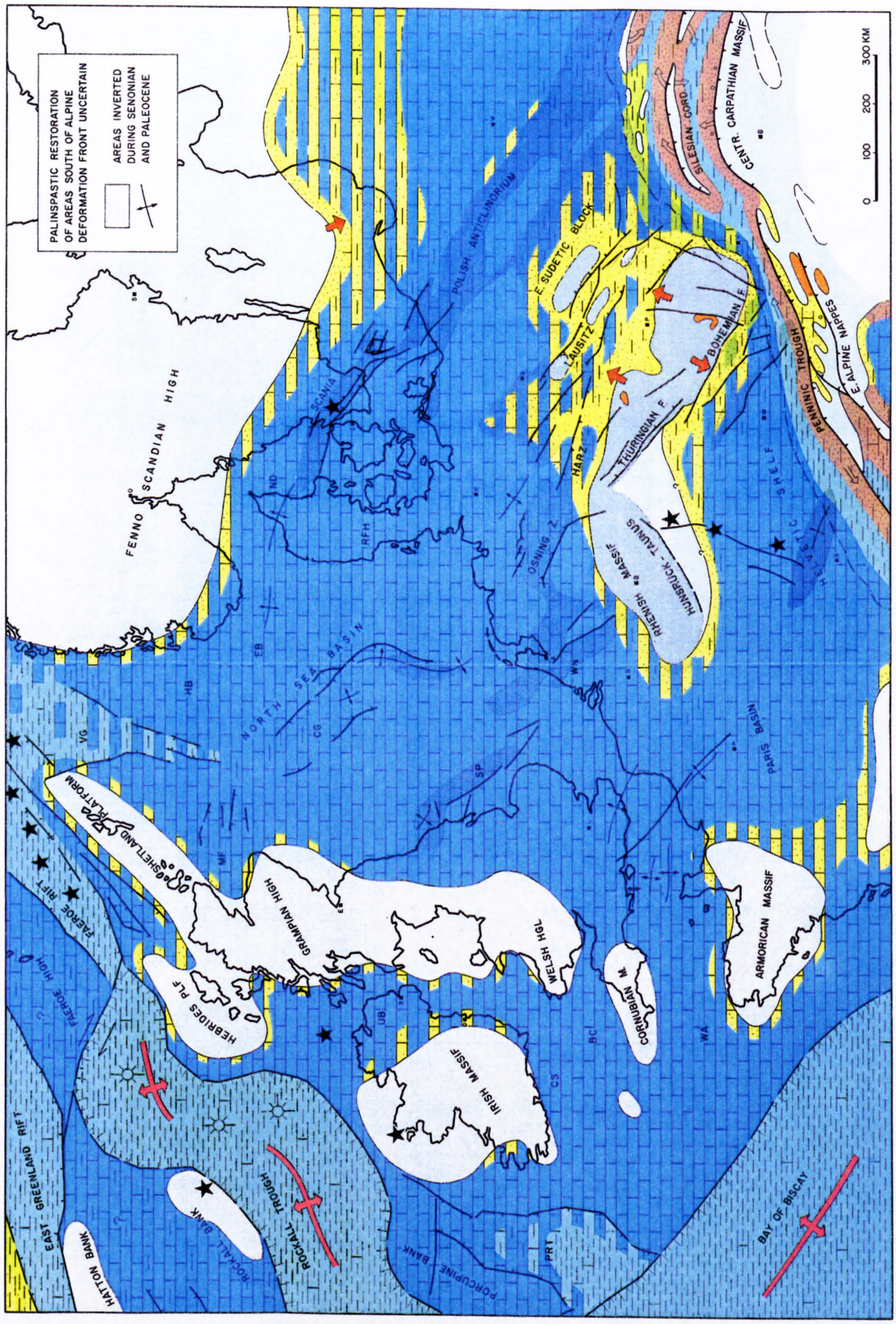


Figure 1.1 A map showing the outcrop of the Chalk in England.



CENOMANIAN-DANIAN PALAEOGEOGRAPHY.

Figure 1.2 Extent of the Chalk Sea from Zeigler (1982).

LEGEND TO PALAEOGEOGRAPHIC, ISOPACH AND TECTONIC MAPS AND TO STRATIGRAPHIC CORRELATION CHARTS

LITHOLOGICAL SYMBOLS

- Sand and conglomerate
- Sand
- Sand and shale
- Carbonate and sand
- Carbonate
- Carbonate and shale
- Shale, some carbonate
- Shale
- Organic shale
- Halite
- Sulphate
- Oolitic iron ore
- Coal
- Volcanics
- Instrusives

DEPOSITIONAL ENVIRONMENTS

- Areas of non-deposition
- Uninterpreted areas
- Continental, lacustrine
- Deltaic, coastal and shallow-marine clastics
- Shallow-marine shale
- Deeper-marine shale
- Deeper-marine clastics
- Carbonates, mainly shallow-marine
- Evaporites

TECTONIC SYMBOLS

- Normal fault
- Transcurrent fault
- Steep reverse and thrust faults, active deformation front of fold belt
- Fold axis
- Continental slope
- Sea mount
- Sea floor spreading axis
- Caledonian deformation front
- Position of future Variscan deformation front
- Position of future Alpine deformation front
- Approx. boundary between Penninic and Austro-Alpine domains

SPECIAL SYMBOLS ON PALAEOGEOGRAPHIC MAPS

- Direction of clastic influx
- Direction of marine incursion
- Direction of intra-basinal clastic transport
- Erosional edge of map interval
- 300 — Thickness of map interval in metres

STRATIGRAPHIC CORRELATION CHARTS

- Low angle unconformity
- High angle unconformity
- Erosional hiatus
- R — Rift induced
- W — Wrench induced
- i — Inversion
- F — Folding, thrusting
- U — Regional uplift
- —||— Tuffaceous series

ISOPACH MAPS

Colour scale for increasing thickness of map interval; contour interval specified on each map

- Thickness of map interval unknown or only locally known
- Map interval eroded
- Erosional edge of map interval

Key for Figure 1.2

1.1.4 Sea-level change during the Late Cretaceous

Although the Chalk is incredibly uniform throughout in its lithological characteristics, sea-level is thought to have fluctuated during the Late Cretaceous. Evidence from facies analysis, macropalaeontological and micropalaeontological methods supports this theory. More recently, sea-level changes have been interpreted with the use of seismic stratigraphy. Dinoflagellate cysts are a useful tool in assisting these and other palaeoenvironmental interpretations, to provide an ever larger picture of the palaeoenvironment of the Chalk Sea.

Sea-level began to rise significantly in the Early Cretaceous reaching a maximum in the Late Cretaceous (Haq *et al.*, 1987), however, with the discovery of palaeoshorelines and detailed facies analysis it has been shown that sea-level did not remain constant during this time. It is thought that these variations were primarily eustatic (Hancock, 1976, Hancock & Kauffman, 1979), possibly related to large scale tectonic activity (both oceanic and continental) due to increased seafloor spreading (Hays & Pitman, 1973; Donovan & Jones, 1979). A second causal hypothesis suggests that a "superplume episode" (upwelling of heat and mantle material) gave rise to a sudden increase in ocean crust production, which included changes in ridge crest lengths and production of ocean plateaus during the Early Aptian (125 Ma) (Larson, 1991 a & b). However, it alone cannot explain all the variations noted in the system. Other authors (Hughes, 1976; Matsumoto, 1977) argue that these fluctuations are overrated and that more emphasis should be placed on local tectonic controls.

Hancock & Kauffman (1979) produced a sea-level curve for the Upper Cretaceous of northwest Europe, which corresponds well with the more recent sea-level curves produced by Haq *et al.* (1987, 1988) (Figure 1.3). The trends of the curves are similar, although the latter shows a number of deviations (in the form of smaller-scale transgressions/regressions) from the overall trend. The former curve is of more relevance here, as it is partially based on data from northwest Europe, and may better reflect the sea-level fluctuations in the Anglo-Paris Basin.

It is apparent from Hancock & Kauffman's curve that sea-levels reached a maximum during the early part of the Mid-Turonian. They then fell to a minimum during the Late Turonian before rising through the latter part of the Late Cretaceous. It is more difficult to interpret the sea-level

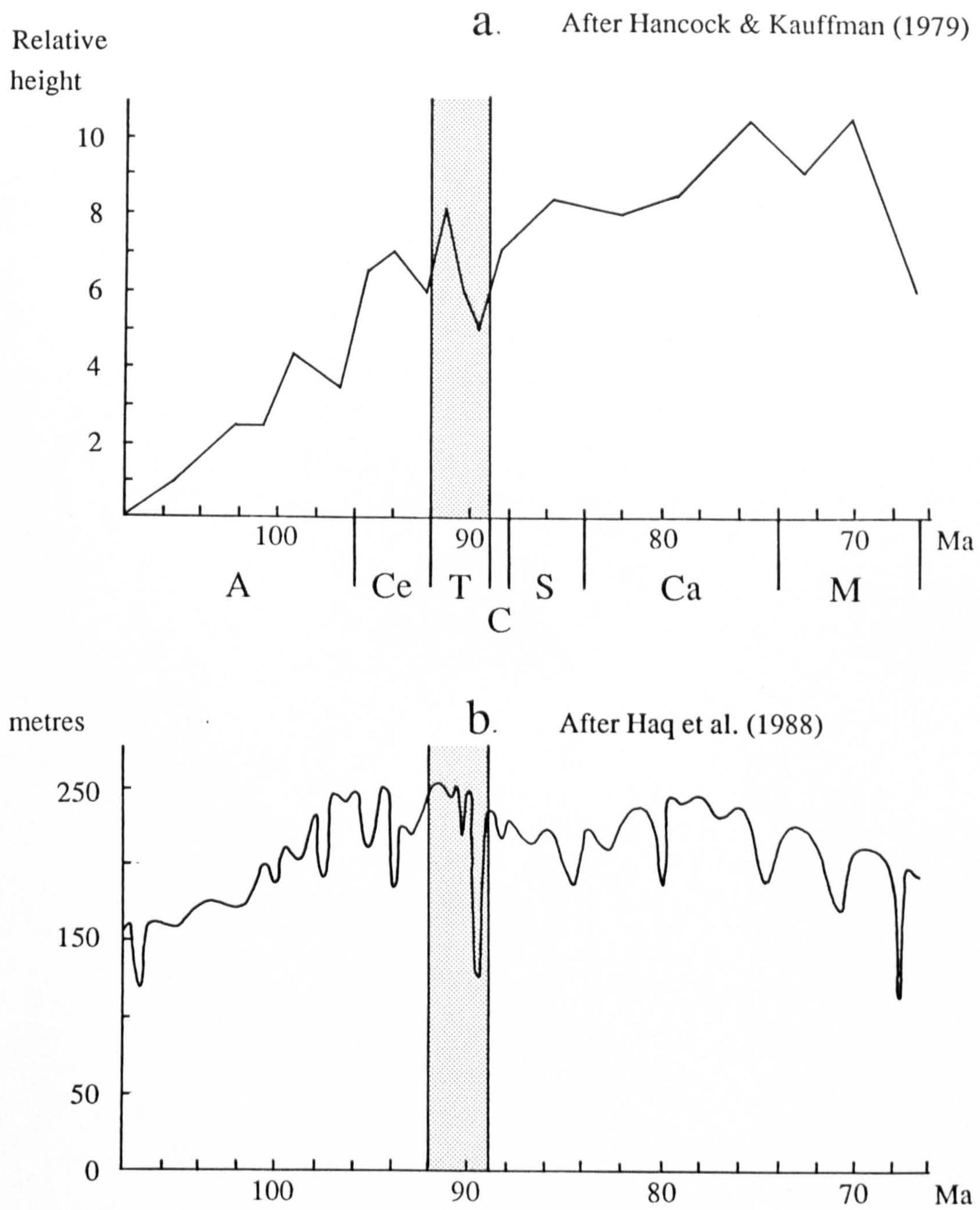


Figure 1.3 Comparison of sea-level curves produced by Hancock & Kauffman (1979) and Haq *et al.* (1988).

variations around the Cenomanian-Turonian boundary. The latest Cenomanian, Plenus Marls Formation, has been interpreted as representing a sudden, brief regression (Jefferies, 1963). Jarvis *et al.* (1988) hold an opposing view, that they represent a rapid transgression which carried on at a reduced rate into the Early Turonian. More recently, after extensive geochemical analyses, Jeans *et al.*, (1991) have expanded upon the regressional theory; they propose that the Plenus Marls were deposited as a consequence of a fall in sea-level due to a deterioration in the world's climate with the cooling and sinking of ocean waters and a withdrawal of water to form glaciers and local ice-sheets in high latitudes.

1.2 Aims and Objectives of this research.

The aims of this research are as follows:

(i) To increase the knowledge about Turonian dinoflagellate cyst assemblages from southern England, extending the limits of our knowledge within the Anglo-Paris Basin.

(ii) To improve upon the already known biostratigraphy from the Anglo-Paris Basin; little recent work from southern England has directly addressed this problem. Using the dinoflagellate cyst assemblages, it may be possible to erect a more precise palynozonation than is available at present.

(iii) To investigate whether there is any relationship between lithology and the contained dinoflagellate cyst assemblages,and to integrate results with those of other micropalaeontological groups where possible.

(iv) To use various relevant statistical techniques to analyse and aid interpretation of the data retrieved.

(v) To use the results to make some palaeoenvironmental interpretation about the deposition of the Chalk.

CHAPTER TWO LITHOSTRATIGRAPHY

2.1 Introduction.

The historical background and development of the nomenclature used to describe the Chalk (both lithostratigraphical and biostratigraphical), has left a legacy of different schemes for different regions and some confusing stratigraphic terminology. This has arisen through misuse, misunderstanding or application in the wrong situation. The lithostratigraphic schemes used in this investigation will be discussed. Finally, the definition of the Turonian stage using lithological marker horizons and various index taxa will be analyzed, with comments upon their usefulness and consistency from one region to another.

2.2 Historical Background - Lithostratigraphy

In the past many workers have proposed and modified schemes for the subdivision of the Chalk. Initially (1820's) these were based upon basic lithostratigraphic observations (e.g. colour of the chalk, presence or absence of marl bands and flints). However, the Chalk was later subdivided on the basis of palaeontological evidence, thus producing a biostratigraphical scheme. This mixture of lithostratigraphic and biostratigraphic terms and schemes has produced confusion and uncertainty at times. The relevant lithostratigraphic schemes are all shown on Table 2.1.

Two lithostratigraphic schemes have evolved (Robinson, 1986; Mortimore, 1986) for the North and South Downs respectively, but it is not until recently that these have been correlated with confidence (Wray, 1990). Other, separate lithostratigraphic schemes have been erected for the Chalk of the Northern Province (Lincolnshire, Humberside and Yorkshire) by Wood & Smith (1978) and Whitham (1991).

The first lithostratigraphic scheme for the Chalk of the North Downs was proposed by Phillips (1818, 1821). He recognised three subdivisions within

Webster 1814 Kent	Phillips 1818, 1821 Kent	Mantell 1822 Sussex	de la Beche 1825 Dorset, Devon	Dixon 1850 Sussex	Whitaker 1865 Isle of Wight	Dowker 1870 Kent	Whitaker et al. 1872 Kent	Jukes-Browne & Hill 1903	Osborne-White 1926 Sussex	Mortimore 1986 Sussex	Robinson 1986 Kent		
Chalk with flints	Upper or flinty chalk: with numerous flints few organic remains; Beds of organic remains with interspersed flints; Chalk with few flints	Upper Chalk	Chalk with flints	Upper Chalk with flints	White Chalk with frequent parallel layers of flints; Chalk with few flints; Chalk Rock	Margate Chalk: Marly chalk with a few flints; Ramsgate Chalk: Numerous flints in layers; St. Margaret's Chalk: Beds of organic remains with interspersed flints; Dover Chalk: Chalk with few flints	Margate Chalk: White chalk with a few nodular & tabular flints; Broadstairs Chalk: Chalk with flints; Chalk with many beds of organic remains & interspersed flints; Chalk with few flints	Upper Chalk	Upper Chalk	Sussex White Chalk Fmn.: Portsdown Mbr.; Culver Mbr.; Newhaven Mbr.; Seaford Mbr.; Lewes Mbr.; Ranscombe Mbr.	Ramsgate Chalk Fmn.: Margate Mbr.; Broadstairs Mbr.; St. Margaret's Mbr.; Dover Chalk Fmn.: Akers Steps Mbr.; Aycliff Mbr.; Shakespeare Cliff Mbr.	Top Rock; Chalk Rock; Melbourn Rock	MAASTRICHTIAN; CAMPANIAN; SANTONIAN; CON.; TURONIAN; CENOMANIAN
Chalk without flints	Chalk without flints: stratum containing thin beds of organic remains with few organic remains	Lower Chalk	Chalk without flints	Lower Chalk without flints	White Chalk without flints but with thin marly layers	Lower Chalk: Flintless Chalk	Chalk without flints & many thin beds of organic remains; Chalk without flints & with few fossils	Middle Chalk	Middle Chalk				
Chalk marl (inc. 'Grey Chalk')	Grey Chalk		Chalk with quartz-grains		Chalk marl	Grey Chalk	Grey Chalk	Lower Chalk	Lower Chalk	Lower Chalk	Plenus Marl Fmn.; Abbots Cliff Fmn.; East Wear Bay Fmn.		

Table 2.1 Relevant lithostratigraphical schemes developed since the last century.

the Chalk, based on its colour and the presence/absence of flints.

Webster (1814) also made a tripartite division of the Chalk based on observations he made on the Isle of Wight later substantiated by Bristow (1889).

Several lithostratigraphic marker horizons were noted and used to subdivide the Chalk into the Lower, Middle and Upper units (Jukes-Browne & Hill, 1903-4) which broadly correspond to the tripartite divisions of Phillips and Webster. Rowe (1900) described a "grit bed" directly above the *Actinocamax plenus* Zone (or Plenus Marl Formation). This had been named the Melbourn Rock Beds (Penning & Jukes-Browne, 1881) after Melbourn, southwest of Cambridge, and taken as the horizon marking the boundary between the Lower and Middle Chalk. They also used Whitaker's Chalk Rock to define the boundary between the Middle and Upper Chalk.

Mantell (1822), in East Sussex (South Downs), combined the Grey and middle Chalk to form his Lower Chalk, because the Melbourn Rock was not sufficiently obvious to suggest a major boundary. Dixon (1850) described a tripartite subdivision of the Chalk from Sussex.

De la Bêche (1825) recognised three divisions at Beer, Devon; Chalk with quartz grains, Chalk without flints and Chalk with flints.

Whitaker (1865) recognised a line of green coated nodules 8-10 feet (approximately 2.4-3 metres) below the lowest flint course, which he used to define the top of the Lower Chalk, on the Isle of Wight. This feature is representative of the Chalk Rock, which was to be later renamed the "spurious Chalk Rock" of Jukes-Browne & Hill (1903) and Rowe (1908).

Dowker (1870); Whitaker *et al.* (1872) proposed new names for Phillips' units (Table 2.1).

The most recent lithostratigraphical schemes are those proposed by Mortimore (1986) and Robinson (1986) (Table 2.2) for the White Chalk (of Rowe, 1900). Each has been developed in separate regions (ie. South and North Downs respectively), and have used the relevant historical nomenclature. As a result, they bear little or no resemblance to each other in terms of lithological or stratigraphical terms. The expansion and attenuation of the

Chalk in different areas, makes it difficult to correlate all the marker horizons.

<table>
<tr><th colspan="3">MORTIMORE 1986</th><th colspan="2">ROBINSON 1986</th></tr>
<tr><td rowspan="10">Sussex White Chalk Fmn.</td><td rowspan="3">Lewes Member</td><td>Navigat-ion</td><td rowspan="3">Ramsgate Chalk Formation</td><td rowspan="3">St. Margaret's Member</td></tr>
<tr><td>South Street</td></tr>
<tr><td>Kingston</td></tr>
<tr><td rowspan="7">Rans-combe Member</td><td>Ringmer Beds</td><td rowspan="7">Dover Chalk Fmn.</td><td rowspan="3">Akers Steps Member</td></tr>
<tr><td>Caburn Beds</td></tr>
<tr><td>Glynde Beds</td></tr>
<tr><td>New Pit Beds</td><td rowspan="2">Aycliff Member</td></tr>
<tr><td rowspan="2">Holywell Beds</td></tr>
<tr><td rowspan="2">Shakespeare Cliff Member</td></tr>
</table>

Table 2.2 Recent lithostratigraphic schemes for the Turonian of southern England

It is only recently by using the geochemical signatures of the marls that correlation is achieved with reasonable confidence (Wray, 1990; Figure 2.1). Using this method together with macropalaeontological and lithological evidence, it is possible to correlate results from Dover and Kent, with that in Sussex and the Isle of Wight.

Thus the writer has chosen to use the appropriate lithostratigraphic scheme for the area under study and to correlate them using all available information.

The Turonian or Middle Chalk is of primary interest in this investigation, and the relevant parts of the lithostratigraphic schemes of Mortimore (1986) and Robinson (1986) are shown on Table 2.2.

2.3 Historical Background - Biostratigraphy

French geologists in the latter part of the 19th Century subdivided the Chalk into fossil zones based upon macrofossil assemblages and indicator

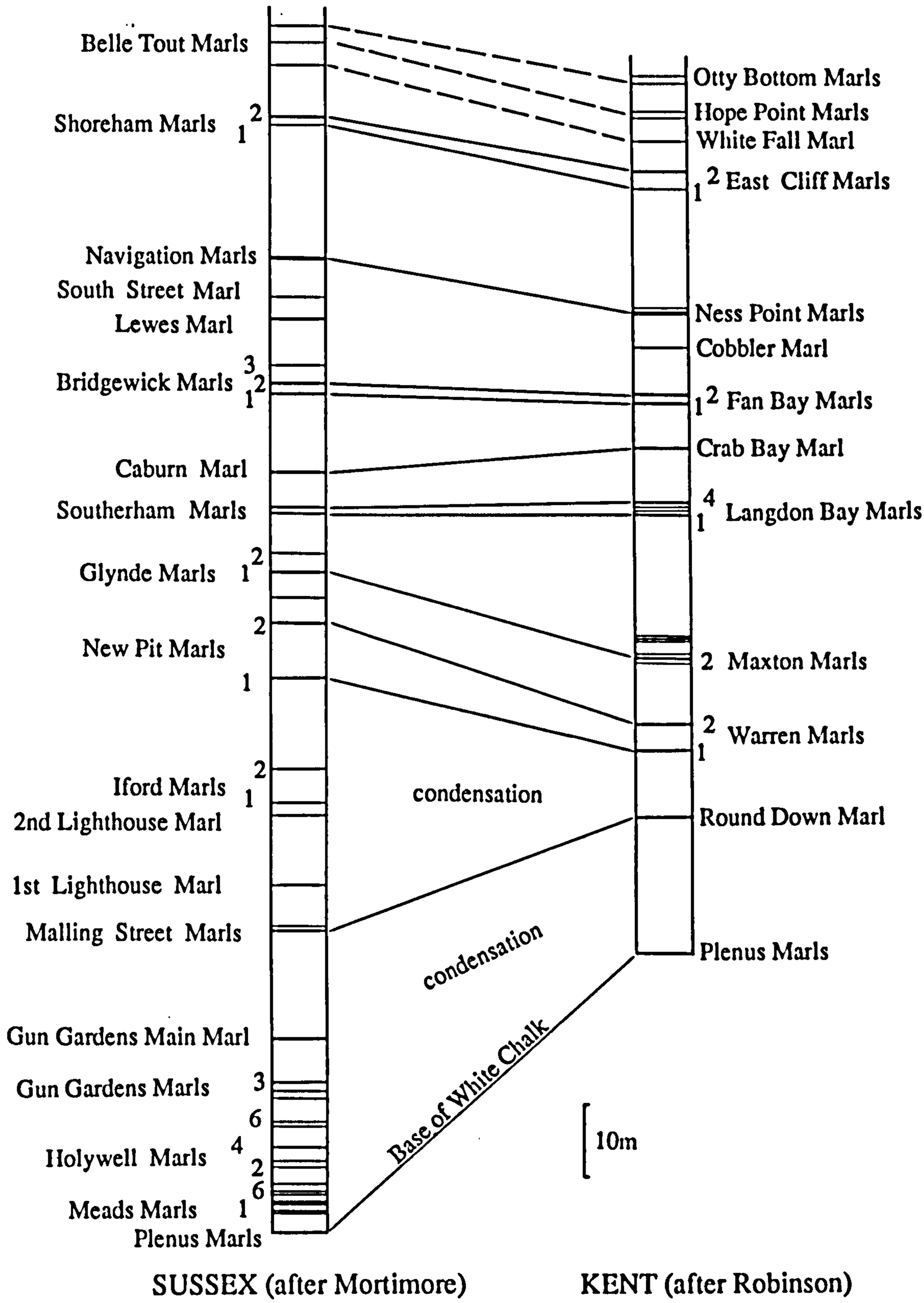


Figure 2.1 Correlation of the succession in Sussex and Kent using the geochemical signature of the marls (Wray, 1990).

species. This probably resulted from the lack of obvious lithological changes within the chalk, which does not readily lend itself to a lithostratigraphical subdivision.

Alcide d'Orbigny (1840-1843, 1847) was the first to subdivide the Chalk into stages; the Turonian and Senonian. These stages were based upon both lithostratigraphical and biostratigraphical data. The former was later separated into the Cenomanian and Turonian (corresponding to the lower and upper parts of the original stage).

Barrois (1875) used the basic tripartite divisions of the Chalk as a framework upon which to arrange his fossil zones (Table 2.3).

LITHOSTRATIGRAPHY	FOSSIL ZONES
Chalk with flints	*Belemnitella* *Micraster coranguinum* *Micraster cortestudinarium* *Holaster planus*
Chalk without flints	*Terebratulina gracilis* *Inoceramus labiatus*
Grey Chalk / Chalk Marl	*Scaphites aequalis*

Table 2.3 The biostratigraphy of Barrois (1875) and its relationship to the lithostratigraphy of the Chalk.

Hébert (1875) also created similar zones based upon palaeontological evidence from the northern coast of France between Le Harvre and Fécamp.

De Grossouvre (1889) described the Turonian and Senonian stages from the Paris Basin and made comparisons with work from other areas in France (Touraine, Charente, Corbières, Provence) and Germany (Westphalia). The zones produced were designated primarily by the presence of particular ammonites, together with other evidence from bivalves and echinoids.

Jukes-Browne (1880) considered that d'Orbigny's divisions of the Chalk (the Cenomanian, Turonian, and Senonian) correlated with the Lower, Middle and

Upper Chalk; therefore redefining the lithological units using biostratigraphic zones. Penning & Jukes Browne (1881) used the Melbourn Rock and Whitaker's Chalk Rock as mapping boundaries between their Lower/Middle and Middle/Upper Chalks respectively. These constraints were harder to apply in areas to the south of Cambridgeshire and the Chilterns, as the sequences are generally more expanded.

Rowe (1900, 1908), Brydone (1913, 1914) and Gaster (1924, 1937, 1939, 1944 & 1951) concentrated on the biostratigraphical aspects of the Chalk, and placed little emphasis on the relationship to particular lithological horizons. It seems that the emphasis on a lithostratigraphic framework had been altered.

The common usage of poorly defined marker horizons, in the past, together with the lack of a basic lithostratigraphic framework in some cases has led to confusion about the actual position of these horizons; eg. Chalk Rock & Spurious Chalk Rock; which have only recently (Bromley & Gale 1982) been resolved. Jukes-Browne & Hill (1903) combined the litho- and bio-stratigraphical schemes, and produced the subdivisions shown in Table 2.4.

2.4 The Turonian Stage

The Turonian stage was proposed by d'Orbigny (1842): "I propose to designate the following stage which has occupied me (chloritic chalk, glauconitic chalk, tuffaceous chalk and greensand), the name of Turonian, derived from the town of Tours or the area of Touraine, situated in that region."

" Later, in 1847, d'Orbigny realised that in the Turonian stage, there were two different successive ammonite and rudist faunas, and he isolated the lower part of the stage under the name Cenomanian; of which only the upper part kept the name Turonian." (translated from Lecointre 1959).

The Turonian stage is approximately represented by the Middle Chalk or "Chalk with flints" as originally defined by Phillips (1818, 1821). Various interpretations of the position of the lower boundary of the Turonian have placed it above, within or below the Plenus Marls Formation. Discussion about the most suitable index or indices (bio- or lithostratigraphical) to define this boundary stratotype, has arisen in recent years (Birkelund *et al.*, Symposium on Cretaceous Stage boundaries, Copenhagen 1983). The problem is not fully resolved, although, much progress has been made.

LITHO-UNIT	TRADITIONAL ZONES	MACRO-FOSSIL ZONES USED IN THIS STUDY
UPPER CHALK (pars.)		
MIDDLE CHALK	*Holaster planus* Zone	*Sternotaxis planus* Zone
	Terebratulina lata Zone	*Terebratulina lata* Zone
	Rhynchonella cuvieri Zone	*Mytiloides labiatus* Zone
LOWER CHALK	*Holaster subglobosus* Zone	
	Ammonites varians Zone	

Base of the Chalk →

Table 2.4 The stratigraphic terminology for the Chalk of southern England (Jukes-Browne & Hill 1903).

The base of the stage was taken, lithologically, at the base of the Melbourn Rock (Jukes-Browne & Hill, 1903). Some authors (Hancock *et al.*, 1977) have used the first appearance of the ammonite *Mammites nodosoides*, which would put the base of the stage within the Melbourn Rock, about 2 - 3 metres above the Plenus Marls.

Others prefer to use the first appearance of the ammonite *Watinoceras devonense* (Kennedy & Cobban, 1991), based upon evidence from the boundary sequence at Pueblo, Colorado, U.S.A.. Hancock (1976) chose the first appearance of *Watinoceras coloradoense* as the index taxon. Comparisons between these interpretations are shown in Table 2.5. Hancock (1989) discussed the palaeontological zones of the Turonian in detail, concluding that the ammonites and inoceramids provided the most useful macro-palaeontological indices, while the latter were undoubtedly the best, if in need of some revision.

Ammonites are too scarce in England to be of general use and so by using other palaeontological evidence, notably inoceramids, the base of the Turonian is thought to lie within the Melbourn Rock at the first appearance of *Mytiloides labiatus* (Rawson *et al.*, 1978) which coincides with the base of the ammonite zone *Mammites nodosoides* (Kennedy & Juignet, 1973).

	Ammonite Zones Pueblo	Ammonite Zones S.England	Common datum points
TURONIAN PARS.	*Collignoniceras woollgari*	*Collignoniceras woollgari*	← *C.woollgari* zone
	Mammites nodosoides	*Mammites nodosoides*	← *Mytiloides mytiloides* ← *M.nodosoides* zone
	Vascoceras birchbyi	*Watinoceras coloradoense*	← *Mytiloides labiatus*
	Pseudaspidoceras flexuosum		
	Watinoceras devonense		← *Praeglobotruncana helvetica* zone ← *Watinoceras* spp.
CENOMANIAN	*Nigericeras scottii*	*Neocardioceras juddii*	
	Neocardioceras juddii		← *N.juddii* zone
	Sciponoceras gracile	*Metoicoceras geslinianum*	← *R.cushmani* ← *Rotalipora* ← *E.septemseriatum* ← *M.geslinianum*

Table 2.5 Correlation of the ammonite zones at Pueblo, Colorado and southern England (Kennedy & Cobban, 1991).

The lowermost Turonian can also be identified, using planktonic foraminifera, with the first appearance of *Praeglobotruncana helvetica* (Bolli) (Robaszynski *et al.*, 1980; Jarvis *et al.*, 1988), however, this is often difficult due partly to the inherent nature of the nodular chalk typical of the basal Turonian (Hart, 1982), making processing difficult, or due to the difficulty of identifying of stages in the evolution from *Praeglobotruncana praehelvetica* (Trujillo).

As with the lower boundary, the definition of the upper boundary is fraught with difficulties. This is due to the historical variations in the definitions of biostratigraphical zones, and the lack of consistent lithological features.

The top of the Turonian was taken lithologically at the Top Rock of Chatwin & Withers (1908), which was used originally to separate the Middle and Upper Chalk. The corresponding units now in use are the Navigation Hardground and South Foreland Hardground 3 of Mortimore (1986) and Robinson (1986) respectively. The base of the *Micraster cortestudinarium* Zone of Rowe (1908) and Stokes (1975) coincides with these lithological markers.

CHAPTER THREE MATERIALS AND METHODS

3.1 Sections Sampled

This investigation involved the palynological analysis of samples collected from sections in Southern England. Composite sections of the Turonian were sampled from three areas: Dover, Sussex and the Isle of Wight (Figure 3.1). The sections were chosen for their completeness, lithological and palaeontological characteristics and accessibility. Lithological detail, and assistance in examining the sections was provided by Prof. R.N. Mortimore and Dr I. Jarvis. All the sections have been previously described in considerable lithological detail (Mortimore, 1986; Robinson, 1986; Woodroof, 1981), and there is no need to repeat this herein. A detailed lithological log of each section is enclosed, and should be referred to for further information. (Enclosures 1, 2, & 3). The extent of each section is shown in relation to the macro-fossil zones (Figure 3.2).

Sampling was carried out in a methodical way, the rock being marked at particular horizons of interest. ie: marl bands, fossil occurrences, etc. The sample interval was approximately 1 metre, although this varied with regard to particular horizons, and may be more or less. The main aim was to sample the whole Turonian at relatively closely spaced intervals. Samples of fresh rock were collected from as little vertical extent as was practical (5-10 cms), bagged and labelled. The size of each sample was generally between 250g - 500g, leaving plenty for reprocessing (if necessary) or for other analyses to be carried out on the same samples. The sections were thoroughly sampled at approximately 1 metre intervals unless it was unsafe or impractical to gain access to certain parts of the succession. Chalk, marl and flint samples were collected, there being no bias towards a particular lithology. Notes on the lithological and palaeontological characteristics are provided on the logs. Short notes are provided below on each of the sections, their extent, accessibility and physical state. The details of the sampling are given in Appendix 1.

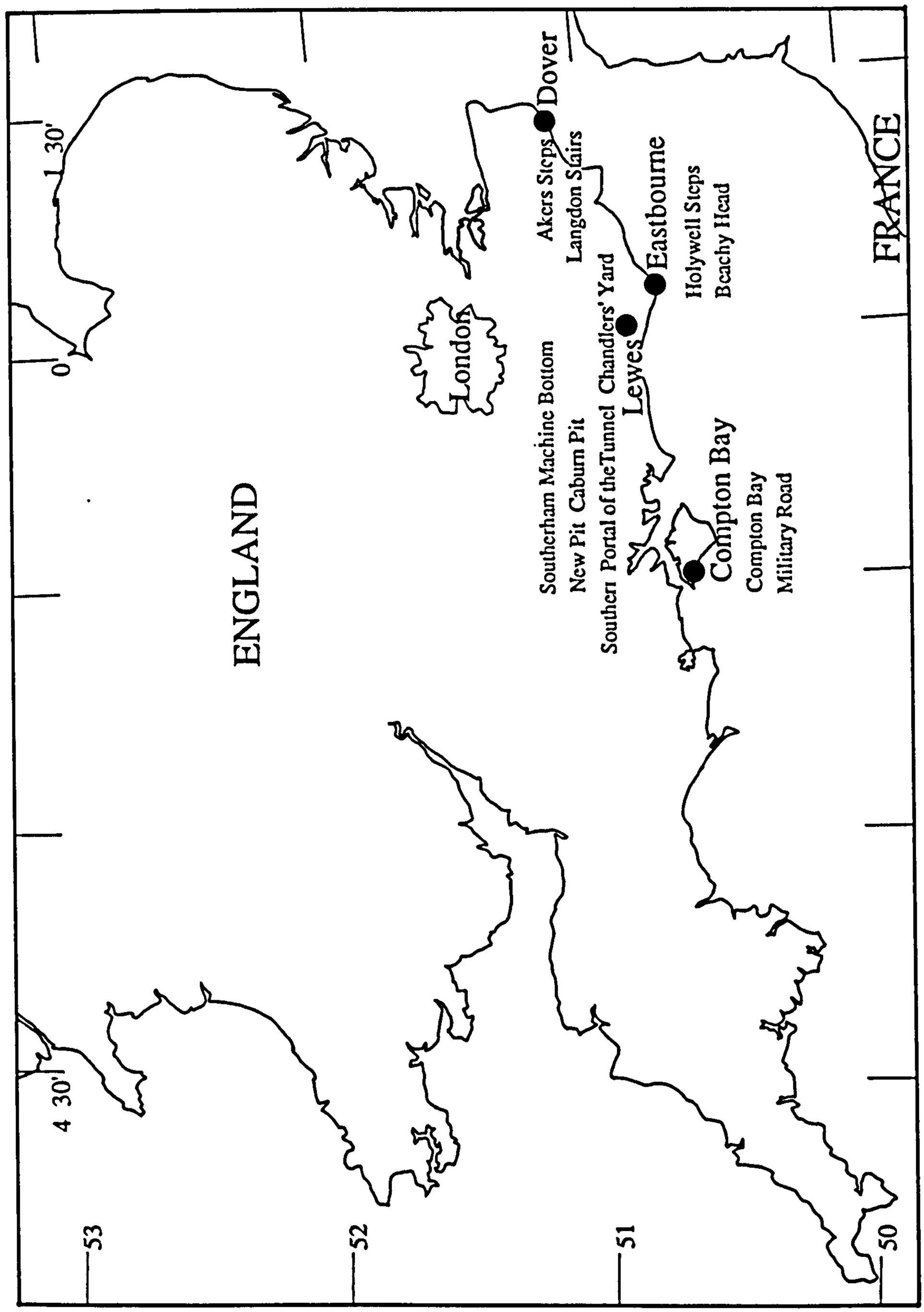


Figure 3.1 Map of England showing the areas studied.

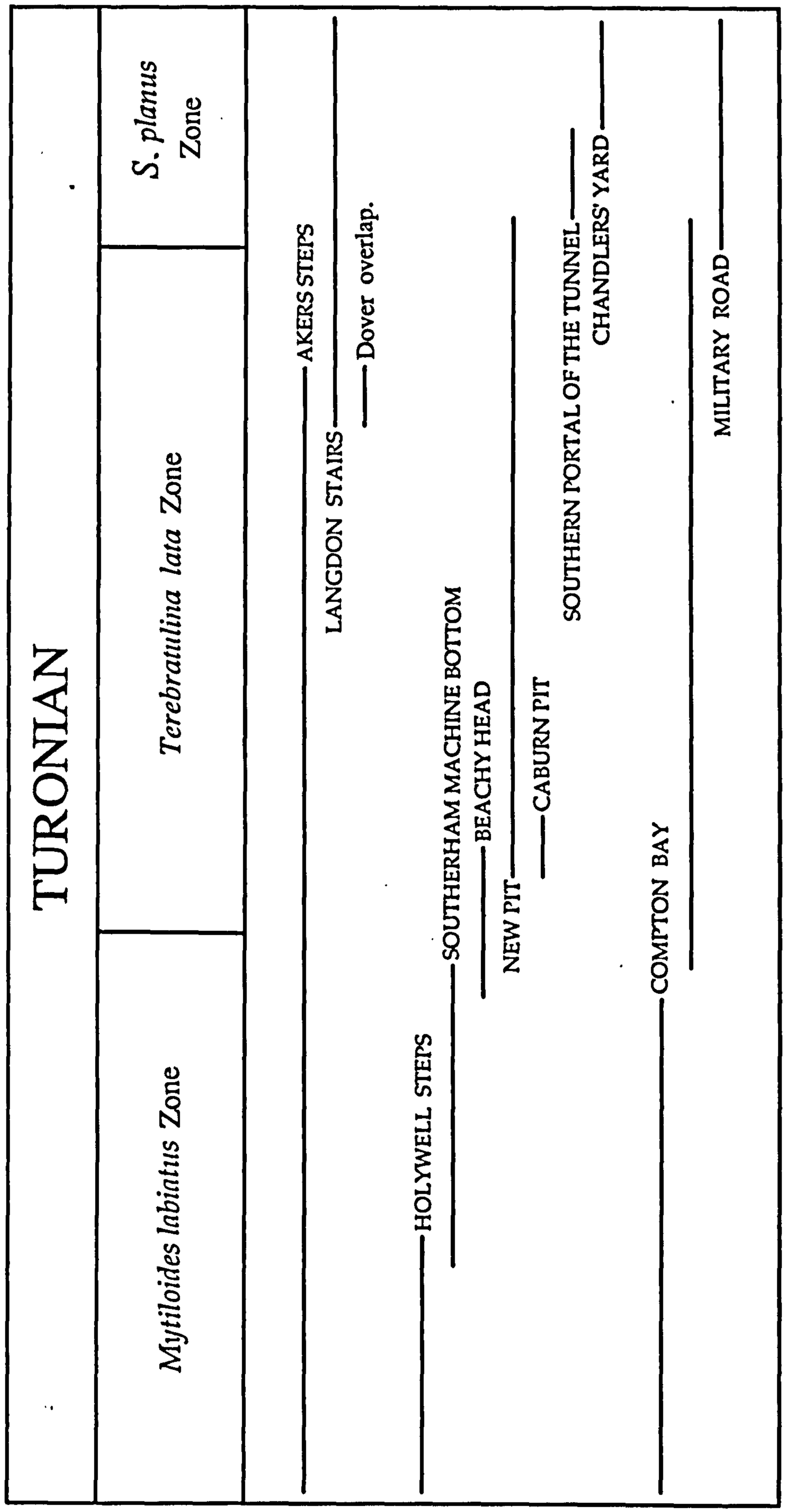


Figure 3.2 The stratigraphical extent of each section in relation to the traditional macro-fossil zones

3.1.2 Dover - Akers Steps and Langdon Stairs

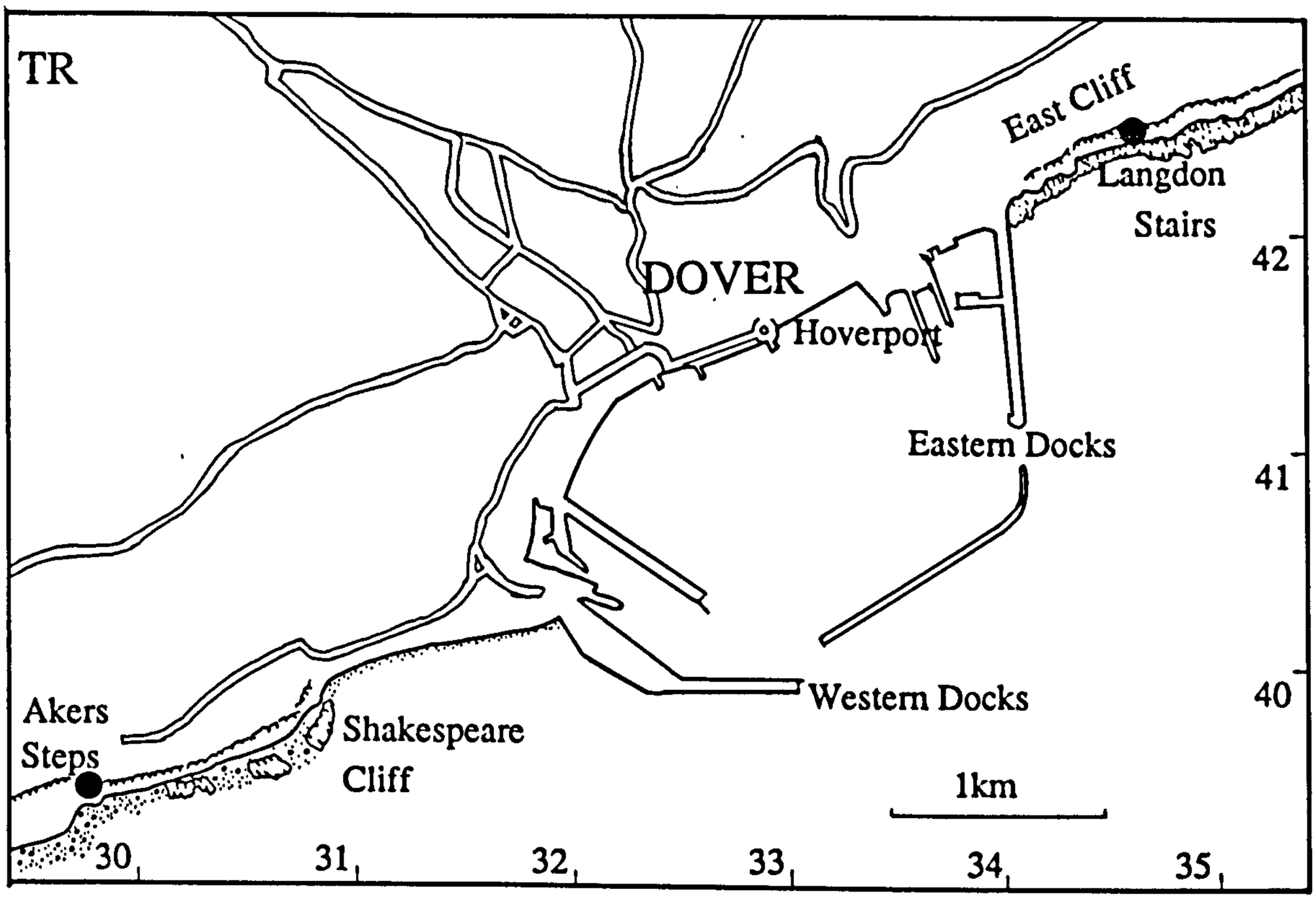
At Dover, two sections, (Akers steps (TR297394) and Langdon Stairs (TR345425)) form a composite Turonian section, on the west and east sides of Dover Harbour respectively (Figure 3.3). Easy access to both is available, though due care must be taken on the former section as the cliff path is badly worn away at the top (Figure 3.4b).

3.1.3 Sussex - Eastbourne and Lewes

In Sussex, there are several sections which constitute the Turonian. On the coast near Eastbourne (Figure 3.5) at Holywell Steps (TV602968), the basal Turonian is well exposed, and easily accessible (Figure 3.6). All the other sections except one are to be found in some of the old chalk pits inland around Mount Caburn near Lewes (Figure 3.7). The section extending into the lower part of the Turonian is that at Southerham Machine Bottom (TQ427095) (Figure 3.8a). A section at Beachy Head (TV586954) was collected to fill in the gap between Gun Gardens Main Marl and New Pit Marl 1. Part of this section has recently been covered by a rock fall, but all that was readily exposed was sampled. At New Pit (TQ424113), the section constitutes a large part of the Turonian from the New Pit Marls to the Bridgewick Marls and Kingston Columnar Flints (Figure 3.8b). The part of the section between New Pit Marl 2 and the Glynde Marl was overgrown by grass (Figure 3.9), and a section from Caburn Pit (TQ447089) was collected to fill in this gap. However, this was not totally successful, as part of this section was also inaccessible. The uppermost part of the Turonian is exposed alongside the Cuilfail Tunnel entrance near Lewes (TQ425101). Two sections are exposed here: the Southern Portal of the Tunnel, and above this the Chandlers' Yard sequence (Figure 3.10a,b), the latter being more difficult to approach.

3.1.4 Isle of Wight - Compton Bay and Military Road

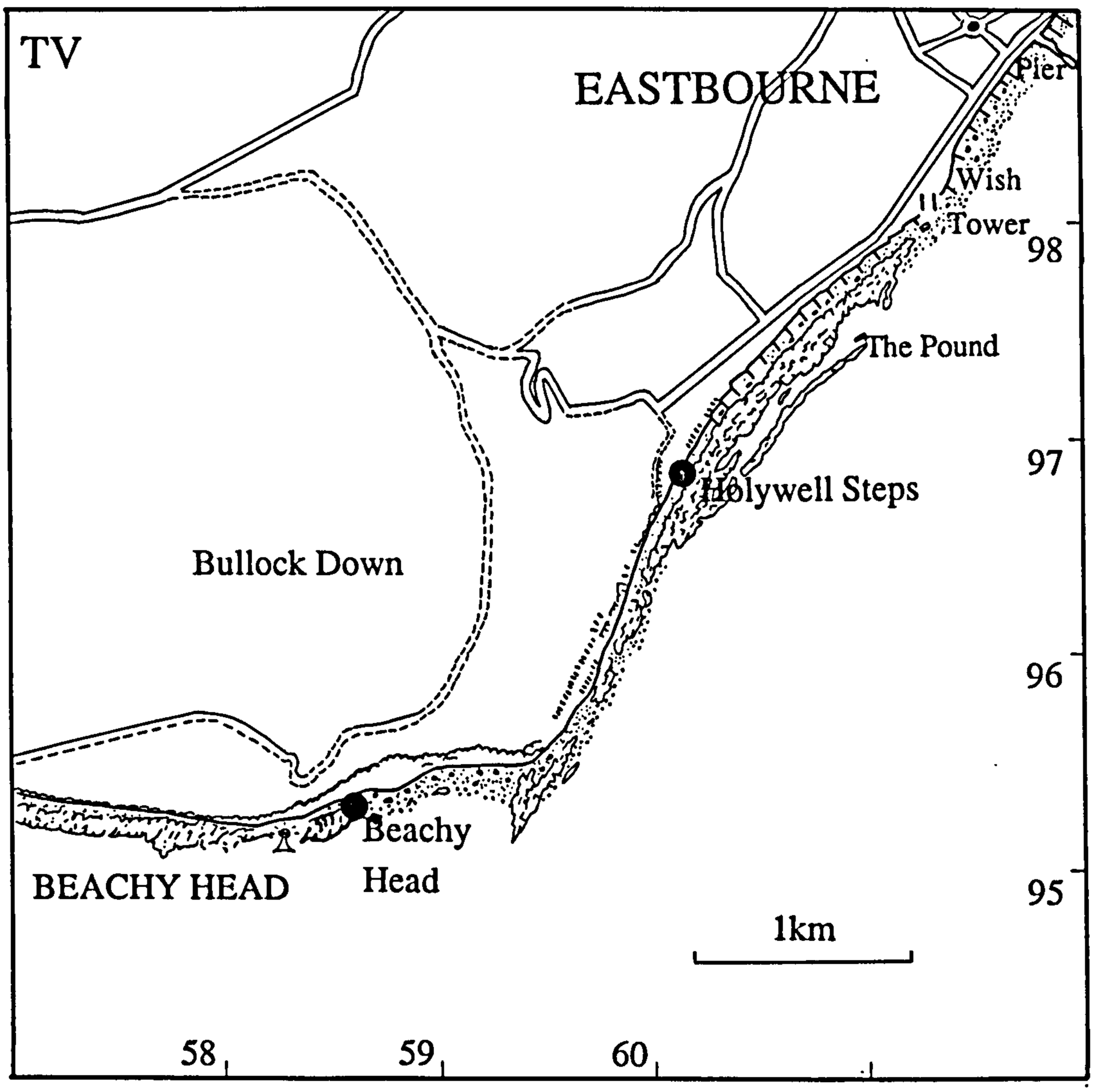
On the Isle of Wight, near Freshwater, the Turonian is exposed in two sections: Compton Bay (SZ356856) and the Military Road Cutting (SZ363857) (Figure 3.11). Both are accessible, although the former necessitates a long walk or scramble along the base of the cliffs (Figure 3.12a), with some danger of being cut off at high tide. The latter is easily accessible, although it is badly degraded and grassed over (Figure 3.12b).



Taken from the Ordnance Survey Landranger Series 1:50 000

Figure 3.3 Detailed map of Dover, Kent, showing the location of the sections sampled.

Figure 3.4 Photographs of the sections at (a) Akers Steps and (b) Langdon Stairs, Dover.



Taken from the Ordnance Survey Landranger Series 1:50 000

Figure 3.5 Detailed map of Eastbourne, Sussex, showing the location of sections sampled.

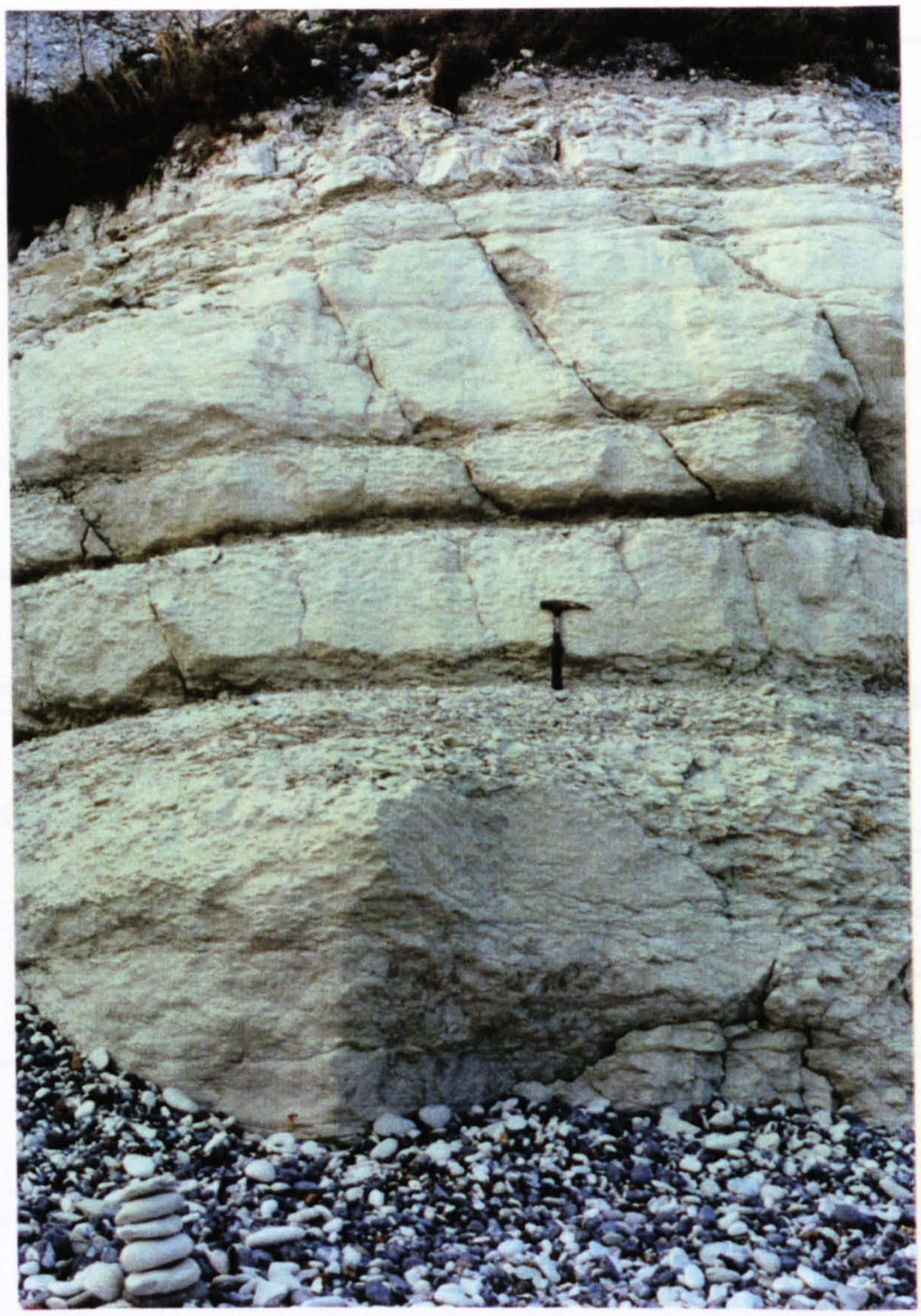
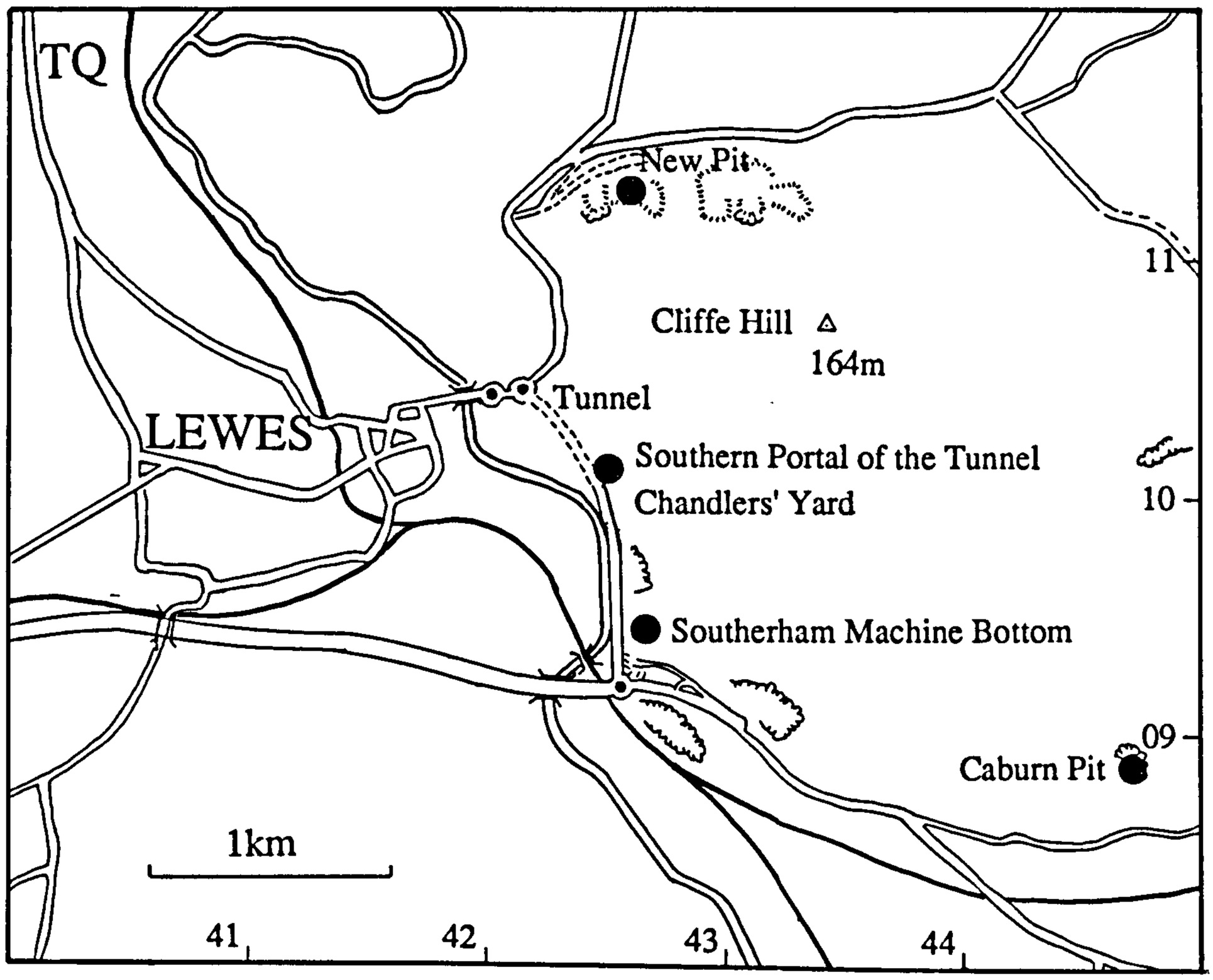


Figure 3.6 Photograph of the Melbourn Rock Beds, exposed on the coast at Holywell Steps, Sussex.



Taken from the Ordnance Survey Landranger Series 1:50 000

Figure 3.7 Detailed map of Lewes, Sussex, showing the location of sections sampled.

Figure 3.8 Photographs of the sections at (a) Southerham Machine Bottom, and (b) New Pit, Lewes, Sussex.

Figure 3.9 Photograph of the section at New Pit, Lewes, Sussex showing the grassed over part of the succession, below the Glynde Marl.

Figure 3.10 Photographs of the uppermost part of the Turonian exposed at the Chandlers' Yard, Lewes, Sussex.

Taken from the Ordnance Survey Landranger Series 1:50 000

Figure 3.11 Detailed map of the southwest coast of the Isle of Wight, showing the location of the sections sampled.

Figure 3.12 Photographs of the sections exposed (a) in the cliffs at Compton Bay and (b) along the Military Road cutting, the Isle of Wight.

3.2.1 Preparation Techniques

All the samples prepared at the University of Plymouth were processed using the palynological procedure outlined below. Techniques used and developed by various palynologists have been referred to for methodology (Barss & Williams, 1973; Hansen & Gudmundsson, 1979; Phipps & Playford, 1984; Wilson, 1971). Samples from Dover (AS & LS) were processed by the British Petroleum Research Centre, Sunbury (Jonah Chitolie *pers. comm.*). These samples were only degraded using Hydrochloric acid (HCl); no Hydroflouric acid (HF) was applied. Other samples from Sussex were processed by the Amoco Research Centre, Tulsa, Oklahoma, USA, following standard procedures. It must of course be realised that differences in processing techniques may produce bias in the results. This will be discussed in more detail in Chapter 7.

3.2.2 Standard Procedure

1. The sample was described lithologically, the surface scrubbed clean, crushed into small pieces less than 0.5cm in size (in a plastic bag using a hammer), weighed and placed in a clean, dry polypropylene beaker (300 ml).

2. The sample was dampened with distilled water; then small amounts of concentrated HCl (60 %) were added to remove any carbonate. In all cases a violent reaction was produced, and care was therefore taken to have a wash bottle of distilled water available to quieten the reaction, if necessary. More acid was added until the beaker was about half full (150 mls.)

3. Additional HCl (concentrated) was added at intervals, until there was no longer any reaction. The beaker was then filled with distilled water, and left to settle. Once the sediment had settled, it was decanted and replenished with distilled water. This process of decanting and washing was repeated until the sample was neutral (tested by Litmus paper).

4. Once neutral, the sample was again decanted. A small amount of HF (40%) was poured into a small beaker (100ml.), and slowly added to the sample, usually without a violent reaction. The samples were left in HF for 3-7 days to allow any silicates to break down, stirring daily. Once there were no more gritty pieces in the beaker, it was re-filled with distilled water, and allowed to settle. Once settled, it was repeatedly decanted and replenished with distilled water until neutral.

5. Once neutral, the sample was washed through a 20μm nylon sieve mesh,

with distilled water. This process can be accelerated by agitating the base of the sieve with one hand, so breaking the surface tension.

3.2.3 Procedures to remove any extraneous material.

1. The residue collected in the sieve was examined under the laboratory microscope to see if any further procedures were necessary to eliminate any extraneous material that would otherwise obscure the palynomorphs, and to see if oxidation was required.

2. After reaction with HF, boiling in HCl was sometimes required to remove any flourosilicates that may have formed due to incomplete removal of the carbonate fraction.
A dilute solution of HCl (50%) was heated to boiling point. The sample was placed in a small glass beaker (150 ml.), in some distilled water. Approximately 50 mls. of boiling HCl was added to the beaker which was then covered with a watch-glass and placed on a sand-bath at 100-200 °C. The sample was left to stand for between 30 minutes and 1 hour. Then it was poured into 1 litre of distilled water before being washed through a 20μm sieve, and the residue collected.

3. Some but not all samples were oxidised using Nitric Acid (HNO_3) or Schulze solution (3 parts HNO_3 : 1 part $KClO_3$). A sample was placed in a small glass beaker (150 ml.) in some water. Approximately 50-100 mls. of the oxidizing agent was added and left to react for a fixed period of time (between 2-5 mins.). Then it was poured into 1 litre of distilled water, thoroughly washed through a 20μm sieve and the residue collected. Further oxidation was carried out if required.

4. Frequently the samples only needed to be washed through a coarse sieve (250μm) to remove any fibres or large particles.

5. Samples with an unnecessary amount of heavy minerals or pieces of silica were "panned" to allow the lighter fraction to be poured off and collected, leaving the heavy fraction in the pan.

3.2.4 Slide Preparation and Analysis

1. The residues were concentrated by centrifuging at 2000 rpm for 3-5 mins. Slides were made of the resultant residue using a Glycerine/Glycerol jelly mixture, prepared as follows: 50 g Gelatine granules, 350 mls. Glycerol and

300 mls. distilled water were heated and dissolved together, but not boiled. A few drops of concentrated Phenol solution were added. The mixture was stored in a sealed container until needed.

2. Slides were made in the following manner: Two drops of the melted "jelly" mixture were put on a slide on a hot plate (120°C) and spread using a glass rod. Two drops of the residue were added and mixed with the "jelly" being careful not to introduce any air bubbles. This was left to allow excess water to evaporate. Once in a more viscous state, a coverslip was gently lowered on to the slide and left to cool. When cool the edges of the "jelly" were trimmed and sealed with varnish; and the slide labelled. Any remaining residue was stored in a plastic tube with a few drops of dilute HCl, to prevent algal growth.

3. The samples were analysed using a Jenaval microscope with x10, x25 and x50 objectives and ×10 eyepiece. Photographs were taken using an Olympus camera and automatic system, either in transmitted light or using Differential Interference Contrast (DIC). Basic logging techniques required a count of at least 300 palynomorphs per slide (unless the sample was poor), which has been shown to give a statistically reliable representation of the population (see Chapter 7). Slides were logged at ×100 and ×250 magnification. The remainder of the slide was scanned for any species not already accounted for, which were noted as being present.

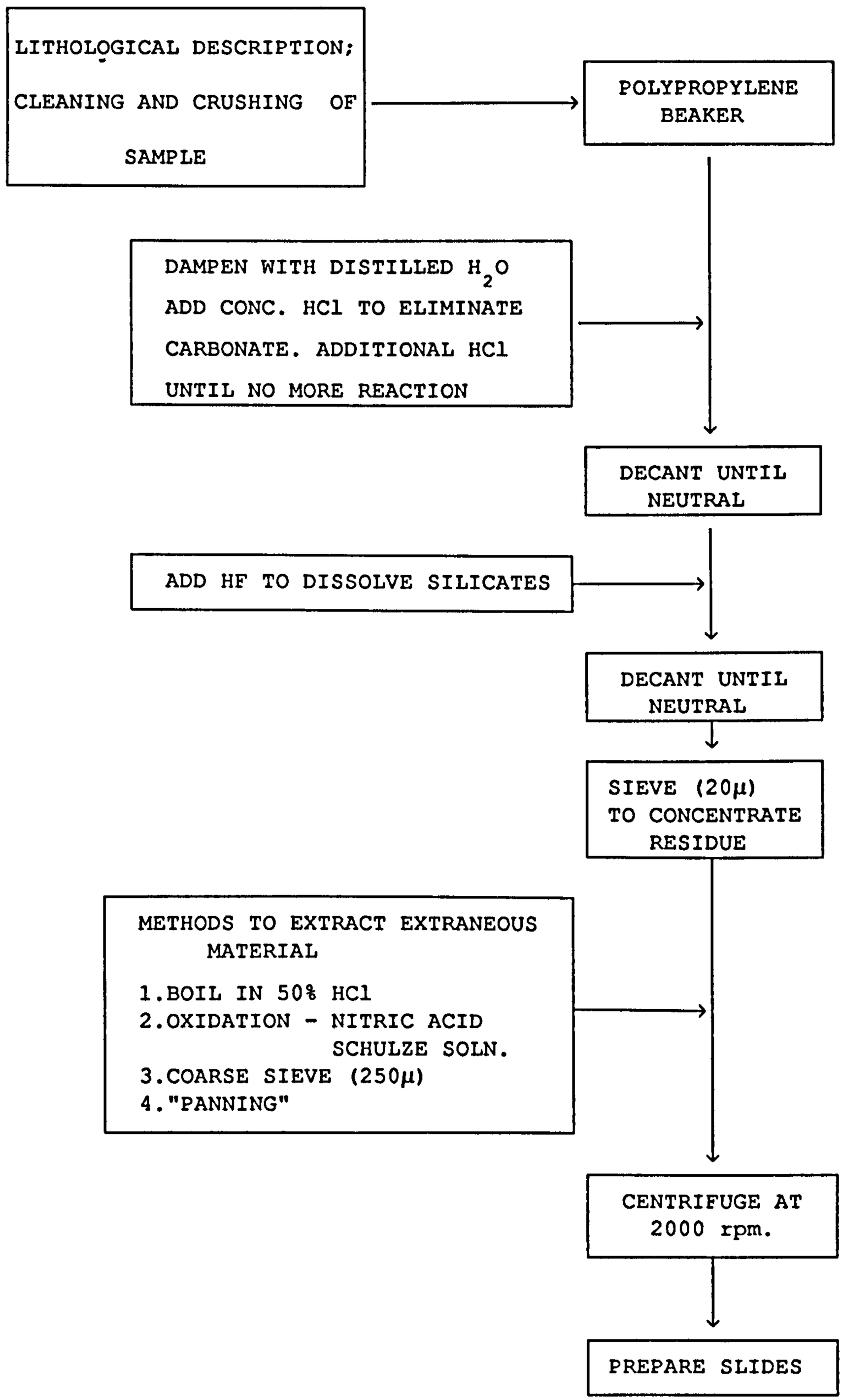


Figure 3.1 Flow Diagram of Preparation Techniques

CHAPTER FOUR SYSTEMATIC PALYNOLOGY

4.1 Introduction

The dinoflagellate cyst taxa described herein are assigned to one of three families within the Order Peridiniales - Gonyaulacaceae, Ceratiaceae, Peridiniaceae, proposed by Evitt (1975) and Stover & Evitt (1978) as a basis for a suprageneric classification. There is a single species assigned to the Order Gymnodiniales. Within this framework, the genera and species are arranged in the informal groupings of Evitt (1985).

Synonomies for each genus are recorded, and reference to the generic diagnosis and typification is made. Taxonomic problems or alterations regarding the genus may be discussed under " Remarks."

A selected synonomy list is given for each species. Reference to the original description, subsequent emendations and to the holotype are made where appropriate. "Original measurements" includes those of the holotype, and a range of other specimens, or the earliest recorded measurements quoted, in microns (μm). Each species is described in detail from specimens found in this study.

The morphological descriptions use the terms defined by Williams *et al.* (1978) and Evitt (1985) (see Section 4.3.3 for details). Intraspecific peculiarities or variations and critical discussion of associated taxonomic problems are included under "Remarks".

"Dimensions" includes measurements taken in microns (μm) of the cyst proportions and features such as length of process, height of ornament etc.. These include the minimum and maximum values, with the mean given in parentheses. Unless otherwise stated, these values are representative of 20 specimens. The Length, Width, Height and Diameter are designated by the letters L, W, H, and D respectively.

The "Occurrence" lists the sample numbers within which the species occurs in this investigation, and whether these occurrences are significant or not. A list of the sections and the abbreviations used is given below, together with the abbreviations used for the statistical analyses.

DOVER	**Sample abb.**	**Statistical abb.**
Akers Steps	AS	A
Akers Steps (overlap section)	AKS	AKS
Langdon Stairs	LS	L
Langdon Stairs (overlap section)	DOE	DOE
SUSSEX		
Holywell Steps	HW	H
Southerham Machine Bottom	SO	S
Beachy Head	BH	B
New Pit	NP	N
Caburn Pit	CA	C
Southern Portal of the Tunnel	SPT	P
Chandlers' Yard	CH	Y
ISLE OF WIGHT		
Compton Bay	CB1	-
Compton Bay	CB	-
Military Road	MR	-

The "Known stratigraphic range" is given for each species, from Robaszynski *et al.* (1980) and other ranges which are thought to be pertinent.

The Group Acritarcha includes 3 genera which cannot be assigned to the Class Dinophyceae. These are dealt with in a similar manner to the dinoflagellates.

The occurrence of the bisaccate pollen, organic foraminiferal test linings and silicified foraminifera is noted for each sample, but these groups are not dealt with in a systematic way. Only foraminiferal test linings with more than six chambers were counted, as this has been found to give an adequate measure of the faunal concentration (Traverse & Ginsberg, 1966).

4.2 Taxonomic Rank

The taxonomic rank of the palynomorphs discussed in this chapter is based upon the following criteria. Definitions of the terms "genus" and "species" are given below.

Genus - A group of animals or plants having common structural characteristics distinct from those of all other groups and usually containing several species (Raup & Stanley 1978).

Species - In taxonomy, the fundamental unit is the species. Among living forms species are groups of individuals that look alike and can interbreed, but cannot interbreed with other species. In palaeontology, where breeding capability cannot be determined, species are defined according to morphological similarities. In formal nomenclature, taxonomists follow the binomial system devised by Linnaeus. In this system each species is defined by two names: the generic (referring to the genus) and the specific (referring to the species) (Allaby & Allaby 1990).

Subspecies - Taxonomic category below species; usually a more or less permanent variety which is geographically isolated (biological definition from Raup & Stanley 1978).

4.3.1 Morphological Classification

Fossil dinoflagellate cysts are classified on a purely morphological basis, within a system that has emerged within the subject. The species that are defined are not true species in the strict meaning of the word, but "morphospecies". Morphologically similar individuals are grouped together. Some groups may be distinct; others may be less distinct, thus increasing the subjectivity of the morphogroups. All morphological features of the fossil cysts must be considered where possible in order to make objective assignments to genera and species. Throughout this study observations and conclusions of the taxonomic status of a fossil cyst have been made objectively as possible.

The informal morphogroups that have been used here are taken from Evitt (1985) and where possible genera and species have been assigned to one of these. There is a section for miscellaneous forms (Gx) which do not conform to the strict groupings. Listed below are the morphogroups and their distinguishing characteristics.

Morphogroup	Features
D	Opening at apex. Wall single layered. Longitudinal folds. Gymnodinoid shape.

Pp	Archaeopyle Type I (2a or a). 3 intercalary paraplates.
Px	Peridinioid, but not as for Pp.
Gc	Ceratioid outline. 1 apical, antapical and 1 or 2 postcingular horns.
Gv	Dorsoventrally compressed cysts. Sulcal notch offset to the left side of the ventral surface.
Gp	Hypocyst paratabulation is partiform 6‴, 1p or 6‴, 2⁗.
Gq	Quinqueform hypocyst paratabulation. Archaeopyle A (3A) 6P.
Gs	Hypocyst paratabulation indicated by parasutural features. Gonal and intergonal processes. Prominent intratabular features are absent.
Gi	Paratabulation indicated by intratabular features.
Gn	Skolochorate cysts. Spherical to ellipsoidal in shape. Non-tabular process arrangement.
Gx	Miscellaneous. Does not comply with any other category of G cyst.

The concept of a subspecies as defined above is not used here. Morphological intraspecific variation is thought to be better described as a "variety" and not as a separate isolated population. The variation is thus noted without giving it too much emphasis. It has become acceptable for palynologists to use the term subspecies inaccurately and it is felt this usage is inappropriate.

4.3.2 Genera and their position in the morphological groups

Morphogroup	Genera attributed to this morphogroup
D	*Dinogymnium*
Pp	*Eurydinium, Isabelidinium*
Px	*Palaeohystrichophora, Subtilisphaera*
Gv	*Canningia, Cyclonephelium, Senoniasphaera*
Gc	*Odontochitina, Xenascus*
Gp	*Microdinium, Rhiptocorys*
Gq	*Dinopterygium*
Gs	*Achomosphaera, Hystrichostrogylon, Spiniferites,*

Gs	*Cribroperidinium, Endoscrinium, Gonyaulacysta, Pterodinium, Stephodinium, Hystrichodinium, Xiphophoridium.*
Gi	*Callaiosphaeridium, Litosphaeridium, Florentinia, Hystrichosphaeridium, Oligosphaeridium, Kleithriasphaeridium.*
Gn	*Cleistosphaeridium, Coronifera, Dapsilidinium, Kiokansium, Pervosphaeridium, Heterosphaeridium, Exochosphaeridium*
Gx	*Apteodinium, Batiacasphaera, Ellipsodinium, Trichodinium, Prolixosphaeridium, Tanyosphaeridium, Wallodinium, Leberidocysta, Cassiculosphaeridia*

4.3.3 Dinoflagellate cyst terminology

There is an extensive amount of morphological terminology now available for the description of dinoflagellate cysts. Most of the terms in current use have been defined by various authors (Downie & Sarjeant, 1966; Evitt *et al.*, 1977 and Evitt, 1985) and a comprehensive glossary of terms has also been provided by Williams *et al.*(1978).

In the following systematic descriptions the terms used to describe the basic cyst shape, and features are those recommended by Evitt (1985), see Figure 4.1. The Kofoidean nomenclature for paratabulation is used. The prefix "para-" is used consistently *sensu* Evitt *et al* (1977) : "We recommend use of the prefix "para-" (Greek: near, beside) in conjunction with the features of the cyst which have, in the past, been described as "corresponding to", "reflecting" or being the "equivalent of" certain features of the theca, but to which have been applied the very same terms used for the thecal features cingulum, plate, sulcus, suture and tabulation".

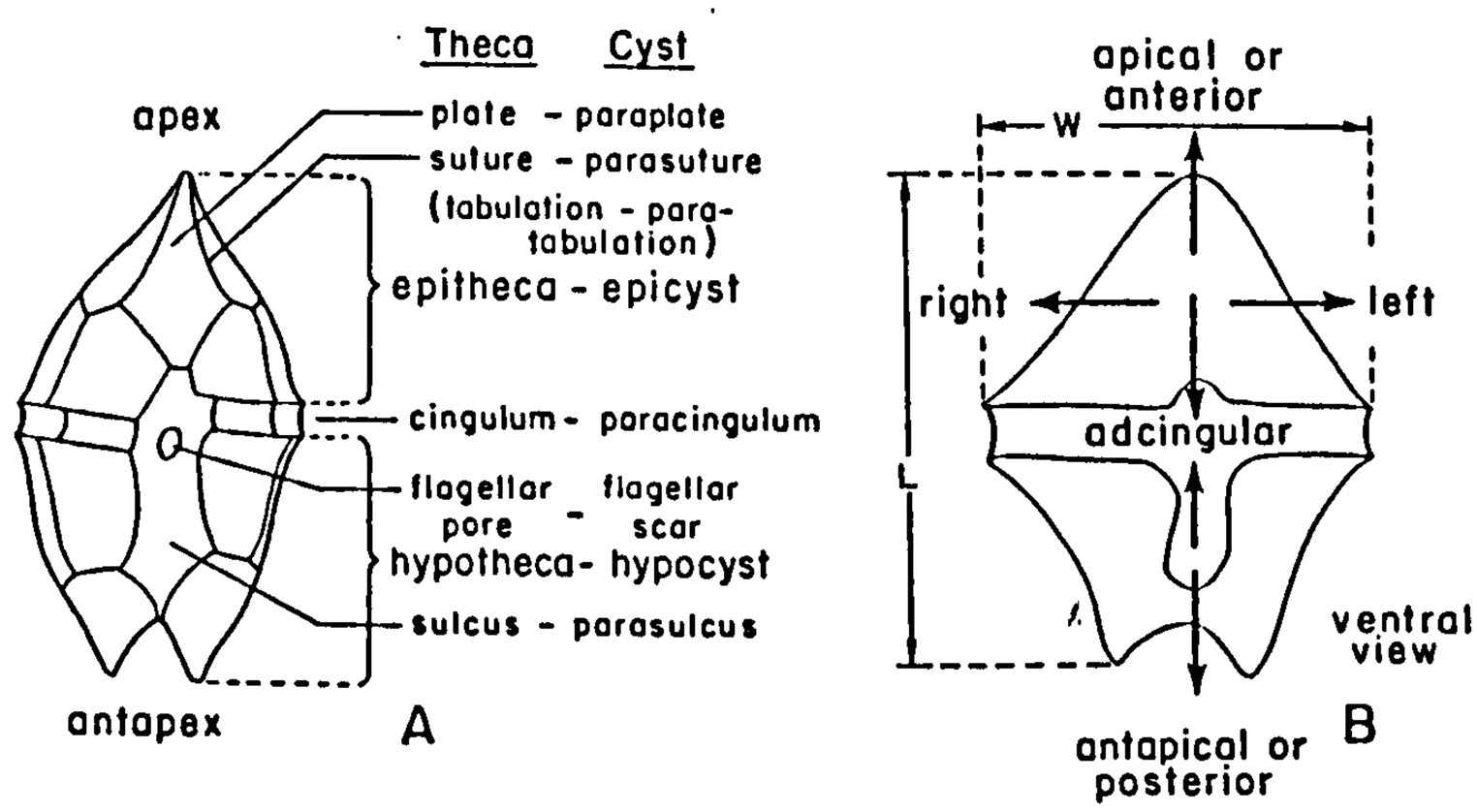


Figure 4.1 Morphological features of dinoflagellates (after Evitt, 1985)

4.4 Systematic Palynology

Division PYRRHOPHYTA Pascher 1914
Class DINOPHYCEAE Fritsch 1929
Order PERIDINIALES Haeckel 1894
4.4.1 Family GYMNODINIACEAE Pascher 1914

D Morphogroup

Genus *Dinogymnium* Evitt *et al.* 1967

Gymnodinium Evitt *et al.* 1967

Original diagnosis: Evitt *et al.* 1967, pp. 4-8
Type Species: *Dinogymnium acuminatum* Evitt *et al.* 1967

Remarks: Many species within this genus were originally assigned to the genus *Gymnodinium* Stein 1878. However, this is a modern genus described from the motile stage, and even though the fossil cysts are similar to the modern thecate form, it is taxonomically inappropriate to mix thecate and cyst species within the same generic umbrella. It seems best to follow previous workers and retain a separate generic name for thecate forms and fossil cysts. The classification used in the fossil record is purely morphological, and would be difficult to impose on modern, living dinoflagellates. The difficulties arise because it is well known that a single dinoflagellate species may produce more than one type of cyst e.g. *Gonyaulax spinifera* (Dale 1983). As a result the morphological classification would ignore the genetic background of the cysts and separate them into different taxa. A biological classification placing more importance on the genotype of the cyst would be very difficult to use in the context of fossil cysts as there is no such evidence available. An integrated system of nomenclature for thecate and cyst forms may be possible within the Quaternary and Recent, but it is not appropriate to use such a scheme here based on a small population with little resemblance to modern assemblages.

Dinogymnium sp. cf. *D. westralium* Cookson & Eisenack 1958;
emend. May 1977
Plate 1, Fig. 1

1958 *Gymnodinium westralium* Cookson & Eisenack, p.25

Original description: Cookson & Eisenack 1958, p.25
Emended description: May 1977, p.118
Holotype: Cookson & Eisenack 1958, pl.1, fig.9
Original dimensions:

	Holotype	Range
	Cyst L: 47	58-61 µm
	Cyst W: 28	48-54 µm

Description: Cyst typically biconical, ornamented by convergent longitudinal ribs from the paracingulum to the apices. Wall thin and single layered. Endo- and hypocyst approximately the same size, separated by a well defined paracingulum. Apex more rounded than the antapex. Ribs numerous and on the epicyst, seem to be pitted, however, on the hypocyst they remain smooth. Paratabular features other than the paracingulum absent. Paracingulum planar. Archaeopyle not observed, but described previously as being apical (Type A).

Remarks: The specimens observed are rare and do not reliably exhibit the typical punctate ribs. To assign them rigidly to *Dinogymnium westralium* (Cookson & Eisenack, 1958) emend. May 1977 would be incorrect. It is thought appropriate to assign them tentatively to this species.

Dimensions: Cyst L: 22 (41) 55 µm
Cyst W: 17 (31) 42 µm
5 specimens measured

Occurrence: Rare occurrences in all regions in the *Mytiloides labiatus*, *Terebratulina lata* and *Sternotaxis planus* zones.
DOE 7; MR 7; BH 9,11; SPT 2.

Known stratigraphic range: Cenomanian - Lower Maastrichtian (Cookson & Eisenack, 1958), Australia; Campanian - Maastrichtian (Evitt, 1967), U.S.A.

4.4.2 Family PERIDINIACEAE Ehrenberg 1832

Pp Morphogroup

Genus *Eurydinium* Stover & Evitt 1978

Original diagnosis: Stover & Evitt 1978, pp.104-105
Type species: *Eurydinium ingramii* (Cookson & Eisenack, 1970) Stover & Evitt 1978.

Eurydinium saxoniensis Marshall & Batten 1988
Plate 1, Figs. 2,3

Original description: Marshall & Batten 1988, pp.92-94
Holotype: Marshall & Batten 1988, pl.1, figs 10-11
Original dimensions: Holotype

Pericyst L:	52-66 µm
Pericyst W:	37-54 µm
Endocyst L:	34-55 µm
Endocyst W:	32-35 µm

Description: Peridinioid cyst, ellipsoidal to subpolygonal in shape, with a short apical horn. Left antapical horn, short and pointed; right antapical horn reduced or absent. Endo- and periphragm thin and smooth. Endocyst subspherical to ellipsoidal, conformable with the pericyst except at the apex and antapex, Circumcavate, with maximum separation of wall layers in the apical and antapical regions. Paratabulation only defined by the paracingulum and archaeopyle. Paracingulum not always well defined. Archaeopyle intercalary (Type Ia). Operculum remains attached in some cases.

Remarks: Some of the specimens observed show variation in the overall shape, becoming almost square at the antapex and lacking an antapical horn. Others display a much more rounded antapex, with one distinct and one reduced antapical horn.

Dimensions:

Pericyst L:	45 (55.9) 65 µm
Pericyst W:	37 (43.2) 55 µm
Endocyst L:	30 (34.7) 45 µm
Endocyst W:	30 (36.4) 52 µm

10 specimens measured
Occurrence: Sporadic occurrences in all localities in the *T..lata*.zone.
LS-1,4,7,10,13,15,18,26,27; DOE-2,6-13,15; CB1-36; CB-31; BH-4,5,7-11; CA-12

Known stratigraphic range: Upper Cenomanian-Lower Turonian (Marshall &

Batten, 1988), England, Germany; Latest Cenomanian (Duane, 1992), England.

Genus *Isabelidinium* Lentin & Williams 1977

Original diagnosis: Lentin & Williams 1977, p.167
Type species: *Isabelidinium korojonense* (Cookson & Eisenack, 1958) Lentin & Williams 1977

Remarks: Marshall (1988) suggested *Manumiella* Bujak & Davies 1983, may be a junior synonym of *Isabelidinium* Lentin & Williams 1977. The specimens of *Manumiella* and their descriptions indicate a more ellipsoidal to oval shaped cyst, which are generally more holocavate than *Isabelidinium*, particularly in the equatorial region. Also *Manumiella* does not exhibit a paracingulum. The two genera should be retained as separate entities for the moment.

Isabelidinium belfastense (Cookson & Eisenack, 1961) Lentin & Williams 1977
Plate 1, Figs 4,5

1961 *Deflandrea belfastense* Cookson & Eisenack: p.71, pl.11, figs 4-6

Original description: Cookson & Eisenack 1961, p.71
Holotype: Cookson & Eisenack 1961, pl.11, fig.4
Original dimensions: Holotype

Cyst L:	109 µm
Cyst W:	63 µm
Internal body:	48 x 56 µm

Description: Elongate, bi- to circumcavate cyst, with a spherical to subspherical endocyst. Endophragm smooth and thin, periphragm thin, smooth to granulate. Pericyst elongate and extended in the apical and antapical regions, forming a small apical and two antapical horns. Antapical horns of unequal length, left horn always longer. Cyst may be holocavate, with a small cavation between the lateral parts of the endo- and pericyst. Usually the cyst bulges in the equatorial region, narrowing slightly to the apices. Reflected tabulation absent on endocyst and only a poorly defined paracingulum and distinct archaeopyle present on the pericyst. Archaeopyle intercalary (Type Ia), developed by the loss of the 2a paraplate. Archaeopyle omegaform in shape, though this is not always obvious.

Operculum free.

Remarks: *Isabelidinium cooksoniae* (Alberti 1959) Lentin & WIlliams 1977 is very similar to this species *I.belfastense*, the differences being very subtle. The major difference is the shape and extent of the antapical region.

Dimensions: Cyst L: 50 (76.6) 90 µm
Cyst W: 27 (41.6) 56 µm
Endocyst L: 27 (34.1) 40 µm
Endocyst W: 25 (36.6) 45 µm
10 specimens measured

Occurrence: Rare occurrence in the *T.lata* and *S.planus* zones in Sussex. BH-4,10,11,12; NP-39; SPT-2.

Known stratigraphic range: Senonian (Cookson & Eisenack, 1961), Australia.

4.4.3 Px Morphogroup

Genus: *Palaeohystrichophora* Deflandre 1935; emend Deflandre & Cookson 1955

Original diagnosis: Deflandre 1935, pp.230-231
Emended diagnosis: Deflandre & Cookson 1955, p.257
Type species: *Palaeohystrichophora infusorioides* Deflandre 1935

Palaeohystrichophora infusorioides Deflandre 1935
Plate 1, Figs 6,7

1943 *Palaeohystrichophora paucisetosa* Deflandre, pp.507-508, text.fig.26

Original description: Deflandre 1935, pp.230-231
Holotype: Deflandre 1935, pl.8, fig.4
Original measurements: None given, but calculation from the figured specimen magnified ×666 produces the following measurements:
Cyst L: 33 µm
Maximum spine L: 6 µm

Description: Small peridinioidal cyst, covered with fine non-tabular

spines. Cyst bicavate, the endo- and pericyst separating at the apical and antapical ends. Endocyst spherical in shape, pericyst drawn out lengthways in a spindle shape. Both endo- and periphragm thin and smooth.
Solid, fine and slightly flexuous hair-like spines cover the cyst. Paracingulum defined by two parallel rows of spines (Pl.1, Fig.7). Other indications of paratabulation absent. No archaeopyle observed.

Remarks: *Palaeohystrichophora paucisetosa* Deflandre 1943, is here considered a junior synonym of *P. infusorioides* Deflandre 1935, as the number of spines present or observed on any cyst can vary. This then seems to be a subjective rather than an objective criterion on which to separate the two species. This is in agreement with Stover & Evitt (1978, p.235).

Dimensions:	Central body L:	22 (27.6) 32 µm
	Central body W:	20 (27.6) 35 µm
	Total L:	35 (43.2) 50 µm
	Total W:	27 (29.9) 37.5 µm
	Spine L:	5 (5.9) 10 µm

Occurrence: Rare to common occurrences in all areas, in the uppermost *M.labiatus, T.lata* and *S.planus* zones.
LS-1-9,11-13,15,17,19-23; AKS-2/1; DOE-1-15; CB1-26,27,30,36; CB-1,10,11,16, 18,21,24,25,31,41,43-45; BH-1-12; NP-21,22,25,29; SPT-5.

Known stratigraphic range: Upper Cretaceous flint (Deflandre, 1935), France; Turonian (Deflandre & Courteville, 1939), France; Albian - Senonian (Cookson & Eisenack, 1960), Australia; Albian - Cenomanian (Cookson & Hughes, 1964), England; Maastrichtian (Foucher & Robaszynski, 1977), Belgium; Cenomanian (Below, 1982), Morocco.

Genus *Subtilisphaera* Jain & Millepied, 1973; emend. Lentin & Williams 1976

Original diagnosis: Jain & Millepied 1973, pp.26-27
Emended diagnosis: Lentin & Williams 1976, p.119
Type species: *Subtilisphaera senegalensis* Jain & Millepied 1973

Subtilisphaera pontis-mariae (Deflandre, 1936b) Lentin & Williams 1976
Plate 1, Fig.8

1936b *Gymnodinium pontis-mariae* Deflandre: pp.167-168, pl.2, figs 7-9
1967 *Deflandrea pontis-mariae* Vozzhennikova pl.49, fig.5
1966 *Ascodinium pontis-mariae* (Deflandre) Deflandre: p.3

Original description: Deflandre 1936b, pp.167-168
Emended description: Lentin & Williams 1976, p.119
Holotype: Deflandre 1936b, pl.2, fig.7
Original measurements: Range
Cyst L: 42-52 µm
Cyst W: 24-26 µm

Description: Spindle shaped cavate cyst which may be elongate or more subspherical in shape, bearing a single apical and antapical horn. Endocyst spherical to subspherical with a thin smooth wall. Pericyst drawn out longitudinally forming the apical and antapical horns, which are pointed and closed distally. Endo- and pericyst conformable in the equatorial region, diverging towards the apices. Paratabulation absent except for a well defined paracingulum. Archaeopyle not visible.

Remarks: *Subtilisphaera pontis-mariae* (Deflandre, 1936b) Lentin & Williams 1976 differs from other members of this genus in its generally elongated spindle shape and the total reduction and absence of a second antapical horn.

Dimensions: Total cyst L: 40 (65) 85 µm
Total cyst W: 30 (36.6) 42 µm
Cyst body L: 25 (31.4) 40 µm
Cyst body W: 27 (32.7) 40 µm

Occurrence: Rare occurrences in the *M.labiatus* and *T.lata* zones in Dover and the Isle of Wight.
LS-13; CB1-36,38; CB-10,11,25,31,44; HW-2,4,5; BH-10;

Known stratigraphic range: Senonian flint (Deflandre, 1936), France; Albian - Cenomanian (Davey, 1970), Canada.

4.4.4 Family CERATIACEAE Pascher 1914

Gv Morphogroup

Genus *Canningia* Cookson & Eisenack 1960; emend. Helby 1987

Original diagnosis: Cookson & Eisenack 1960, p.251
Emended diagnosis: Helby 1987, pp.321-322
Type species: *Canningia reticulata* Cookson & Eisenack 1960

Remarks: Recently there have been some independent emendations of the original diagnosis by Dörhöfer & Davies (1980), Below (1981) and Helby (1987). Dörhöfer & Davies (1980) restricted the genus to forms with two antapical horns and a Type AI archaeopyle. Below (1981) defined the genus to include lenticular and subspherical forms with an attached, simple enlarged, apical archaeopyle. The presence of dorsal intercalary paraplates in *Canningia* Cookson & Eisenack 1960 has not been confirmed. The forms described in this study are subpolygonal to subspherical in shape, with a free apical archaeopyle. Whether this archaeopyle includes intercalary paraplates is unclear. The emendation made by Helby (1987) is recommended here, which includes subpolygonal to subspherical to forms, with two wall layers and a free apical archaeopyle. The familial assignment of this genus to the Ceratiaceae is considered tentative, as there is no evidence for a Ceratiacean paratabulation pattern, except for an offset parasulcal notch and sometimes development of antapical horns.

Canningia colliveri Cookson & Eisenack 1960
Plate 1, Fig.11

Original description: Cookson & Eisenack 1960, p.251
Holotype: Cookson & Eisenack 1960, pl.38, fig.4
Original dimensions: Holotype
Cyst L: 107 µm
Cyst W: 100 µm

Description: Subspherical to subpolygonal proximate cyst with two antapical protrusions of unequal length (may be pronounced or inconspicuous). Wall thin and slightly granular; it is not apparent whether formed of one or two layers. Paratabulation absent except for the archaeopyle (Type tA) and sometimes a faint indication of the paracingulum. Archaeopyle margin may develop accessory sutures. Operculum free.

Remarks: As the specimens examined showed little or no signs of

paratabulation it was decided to retain this species as *Canningia colliveri* Cookson & Eisenack 1960, and not *Canninginiopsis colliveri* as suggested by Backhouse (1988), as this feature was a prerequisite for the latter genus.

Dimensions: Cyst L: 45 (53) 65 µm
Cyst W: 47 (65) 7 µm

Occurrence: Rare to common occurrence in all areas in the *M.labiatus*, *T.lata* and *S.planus* zones.

AS-4,7,15,17,18,27,28,32,33,35,36-38,40,41,43-50,52,53,57,58,61,62; LS-1,3,4,8,20,29; AKS-2/2,2/5,2/6; DOE-1,4,6,11,13; CB1-27,34,36 CB-2,10,13, 15,16,18,19,20,21,22,24,28,31,32,33,41-45; MR-10,22; HW-3,5,6,8-12,15 SO-1,9,11,12,16-19,21-26; NP-2,44; CH-6.

Known stratigraphic range: Aptian (Cookson & Eisenack, 1960), Australia; Albian (Davey & Verdier, 1971), France; Berriasian - Turonian (Bujak & Williams, 1978), offshore southeast Canada.

Canningia reticulata Cookson & Eisenack 1960; emend. Helby 1987
Plate 1, Figs 9,10

1977 *Canningia palliata* Brideaux: pp.11-12, pl.3, figs 1-8
1981 *Cyclonephelium palliatum* (Brideaux) Below: p.10

Original description: Cookson & Eisenack 1960, p.251
Emended description: Helby 1987, pp.322-323
Holotype: Cookson & Eisenack 1960, pl.38, fig.1
Original dimensions: Holotype
Cyst L: 100 µm
Cyst W: 86 µm

Description: Spherical to subpolygonal cyst, with two antapical horns of unequal length. Wall two layered; endophragm smooth to granular, conformable with the periphragm except in the antapical region. Periphragm forms a fine reticulate layer, which is subtended furthest from the endophragm at the tip of the antapical horns, forming slight cavations. Antapical horns may be blunt or quite pronounced. Paratabulation absent except for that indicated by the archaeopyle margin (six precingular paraplates), and sometimes the paracingulum is vaguely defined by low ridges and a small depression. Archaeopyle apical (Type tA) with accessory sutures

developed and a distinct offset parasulcal notch; operculum free.

Remarks: Below (1981) describes this species as possessing an attached apical operculum. The emendation made by Helby (1987) recognises the holocavate nature of the cyst wall (as did Below, 1981) and also made provision for forms with free opercula. It is this emendation that is favoured here. Specimens examined here are smaller than the holotype, but of similar range to those measured by Helby (1987).

Dimensions: Cyst L: 42 (50.4) 60 µm
Cyst W: 50 (58) 77 µm

Occurrence: Rare occurrences in the *M.labiatus* and *T.lata* zones of Kent. More common in the *T.lata* and *S.planus* zones of Sussex.
AS-4,61; LS-29,30,31; BH-4,7,8,9; CA-2-5,7-9,11-14; NP-4-11,15,16,18,19,22, 23,25,26,29-36,40,45; SPT-2-5,7; CH-2,3,5,6,8,10.

Known stratigraphic range: Tithonian (Cookson & Eisenack, 1960), Australia; Cenomanian - Santonian (Williams & Brideaux, 1975), offshore Grand Bank; Early Cretaceous (Helby, 1987), Australia.

Canningia sp.B
Plate 5, Figs 5,6

Description: Large spherical to subspherical to subspherical proximate cyst, bearing numerous short non-tabular spines. Wall thin and it is not apparent whether it is formed of one or two layers. If two-layered, these are closely adpressed. Spinose ornament is irregularly spread over the whole cyst. Spines are short, tapering with acuminate or slightly blunt terminations. No paratabular features are displayed. Paracingulum and parasulcus not well defined. Archaeopyle apical (Type tA); operculum free.

Remarks: This cyst type may have affinities with *Canningia* as it is subspherical in shape, possesses a nontabular proximate ornament, and an apical archaeopyle, although a parasutural notch is not always visible.

Dimensions: Cyst L: 35 (51) 67 µm
Cyst W: 57 (64.5) 77 µm
Spine L: 1 (1.5) 3 µm

Occurrence: Rare occurrences in Dover; but rare to common occurrences in the *M.labiatus, T.lata, S.planus* zones of Sussex and rare to common

occurrences in the *M.labiatus* and *T.lata* zones of the Isle of Wight.
LS-28-30; DOE-4; CB1-36; CB-2,11,13-16,18,20,21.23-25,31,33,41-45; MR-3,29; SO-4-6,17,18; BH-1-3,6,8,9,11; CA-2-9,11-13; NP-1-20,22-38,40; SPT-2,3; CH-5,6,8.

Genus *Cyclonephelium* Deflandre & Cookson 1955; emend. Sarjeant & Stover 1978

Original diagnosis: Deflandre & Cookson 1955, p.285
Emended diagnosis: Sarjeant & Stover 1978, p.51
Type species: *Cyclonephelium compactum* Deflandre & Cookson 1955

Remarks: The generic emendation made by Dörhöfer & Davies (1980) is rejected on the basis that (i) it restricts the ornament morphology to apteate ornament only and (ii) it separates two complexes which occur at different stratigraphic levels (*Glaphyrocysta* and *Cyclonephelium*) that are very similar in morphological terms. Although Williams & Downie (1966) described the genus as having "chorate" cysts, a better description might be "proximate to proximochorate" permitting the variety in ornamentation. Ioannides *et al.*(1977) emended the generic diagnosis, restricting the ornament to the circumferential area only, however, it is common to find specimens with reduced ornament on the mid-dorsal and mid-ventral areas; thus negating the emendation. The emendation of Sarjeant & Stover (1978) is accepted here, as it describes the intraspecific variation in detail and does not make any assumptions about the paratabulation or familial affinities.
There is scant evidence for a Ceratiacean paratabulation within this genus (noted by Williams & Downie 1966), except that implied by the archaeopyle margin and sometimes the presence of antapical horns or lobes of unequal length. Therefore, this genus is only tentatively assigned to the Family Ceratiaceae.

Cyclonephelium distinctum Deflandre & Cookson 1955
Plate 1, Figs 12,13; Plate 2, fig.1

Original description: Deflandre & Cookson 1955, pp.285-286
Holotype: Deflandre & Cookson 1955, pl.2, fig.14
Original dimensions: Holotype
Cyst D: 64 - 97 µm

Process L: 2.5 - 18 µm

Description: Proximate, subspherical to subpolygonal cyst (broader than long) with or without two antapical horns, bearing a non-tabular spinose ornament. Wall single layered, with short spines of variable morphology.
Spines may be capitate to bifurcate distally and may be broader proximally. Ornament is concentrated in the circumferential area of the cyst; the mid-dorsal and mid-ventral regions bearing reduced or no ornament. No indication of paratabulation except for evidence from the archaeopyle margin (which indicates the presence of six precingular paraplates) and an offset parasulcal notch. Para- cingulum and -sulcus not defined.
Archaeopyle apical (Type $\overline{tA}$) formed by the loss of the apical paraplate series (four paraplates in total) Archaeopyle margin zig-zag, outlining the junction between the apical and the precingular paraplate series, with the sulcal notch offset to the left (Pl.2, fig.1). Operculum free.

Remarks: The original description describes "an equatorial ornamentation that extends for varying distances from the equator, but never to the poles." In fact the "poles" are ornamented, it is the mid-dorsal and mid-ventral areas that exhibit little or no ornamentation. Jansonius (1986) emended the genus *Circulodinium* Alberti (1961) and transferred *Cyclonephelium distinctum* Deflandre & Cookson (1955) to it, as the description of this species was not thought to be precise. It is felt this transfer is unnecessary; an emendation to the specific description would be sufficient, clarifying the area of sparse ornamentation.

Dimensions:	Cyst L:	40 (47.4) 57 µm
	Cyst W:	50 (56.5) 70 µm
	Process L:	3 (8.3) 15 µm
	Process W:	2 -5

Occurrence: Common occurrence in all areas throughout the three macrofossil zones. An influx has been noted in the *T.lata* zone.
AS-8,13-15,17-19,23,24,29-58,60,62; LS-1-4,6,7,9-31; AKS-2/1-2/6; DOE-1-14; CB1-26-28,32,34,36,38; CB-1,2,10,11,13,15-19,21,24,25,27-34,40-45; MR-3-5, 8-10,12,15,19-21,25-29; HW-4,6,7,9,11,15; SO-4-7,9,10,18,21; BH-1-9,11,12; CA-2-14; NP-1-5,7-32,34-36,38-40,42,44,45; SPT-1-7; CH-2-5,9.

Known stratigraphic range: Senonian (Deflandre & Cookson, 1955), Australia; Albian - Santonian (Cookson & Eisenack, 1962), Australia; Albian (Davey &

Verdier, 1971), France; Campanian (Harland, 1973), Canada; Berriasian - Maastrichtian (Bujak & Williams, 1978), offshore southeast Canada; Hauterivian - Albian (Below, 1981), Morocco.

Cyclonephelium membraniphorum Cookson & Eisenack 1962
Plate 2, Figs 4, 5 & 6

Original description: Cookson & Eisenack 1962, p.495
Holotype: Cookson & Eisenack 1962, pl.6, fig.9
Original dimensions: Holotype

Cyst L:	127 µm
Cyst W:	108 µm
Membrane H:	6 - 22 µm

Description: Lenticular cyst, spherical to subspherical in shape, possessing a circumferential, non-tabular, membranous ornament. Wall thin, two layered; endophragm smooth to slightly granular; periphragm extended into membranes of variable height and development.
Membranes are fibrous in nature, with a slight fenestrate appearance and supporting "rods" in the corners of the "funnel-like" structures (Pl.2, Figs 4 & 6). These structures are the most elaborate form of membrane observed, being continuous and fused to form "boxes". Height of membrane varies between 7 and 20 µm. Mid-dorsal and mid-ventral regions devoid of ornament. Paratabulation absent except for that implied by the archaeopyle margin - 6 precingular and 4 apical paraplates.
Archaeopyle apical (Type $\overline{tA}$) with a zig-zag margin outlining the precingular/apical junctions; accessory sutures and offset sulcal notch. Operculum free.

Remarks: The specimens observed here do not exhibit a paratabulation reflected by parasutural membranes. The membranes observed are non-tabular in their arrangement, with no regular pattern except that they are confined to the circumferential regions. Therefore the transfer of *Cyclonephelium membraniphorum* Cookson & Eisenack (1962), to *Maghrebinia* by Below (1981), is rejected. However discussion (Duane 1992) has revealed that Cenomanian forms similar to *C.membraniphorum* have a complete paratabulation, thus necessitating the erection of a new species of *Maghrebinia* to accommodate these forms, and the retention of *C.membraniphorum* for those not exhibiting a paratabulation.

Dimensions: Cyst L: 30 (40.9) 52 µm
Cyst W: 37 (48.4) 57 µm
Membrane H: 12 (14.6) 20 µm

Occurrence: Common occurrences in all areas in the *M.labiatus, T.lata* and *S.planus* zones.

AS-13,15,17-23,28,29,31,32,37,41,43-53,57-62; LS-1-4,7,8,9,12,16-25,27,30, 31; AKS-2/2,2/5.2/6; DOE-1,2,3,5-15; CB1-26,27,28,31-36,38; CB-2,10,11,15, 16,18,20-25,27-29,31-34,41-45; MR-3,8-11,21,25-28; HW-1,2,4-15; SO-1-26; BH-1-9,11,12; CA-2-8,10-14; NP-1-11,15-36,38,39,40,45; SPT-1-4,6,7; CH-6,9.

Known stratigraphic range: Albian - Cenomanian (Cookson & Eisenack, 1962), Australia; Vraconian (Davey & Verdier, 1973), France; Vraconian - Cenomanian (Below, 1981), Morocco.

Cyclonephelium compactum-membraniphorum complex Marshall & Batten 1988
Plate 2, Figs 2, 3

Original description: Marshall & Batten 1988, p.90

Description: Proximate to proximo-chorate, subspherical to subpolygonal cysts, bearing a variable ornament of low ridges to crests. Wall two layered, though not always apparent. Endophragm thin, slightly granular; periphragm thin and smooth. Ornamentation usually confined to the circumferential area of the cyst. Ridges may be fully developed to form membranes, which may be fused to form "funnel-like" structures as described in *Cyclonephelium membraniphorum.* Degenerated membranes may be represented by a series of low ridges. Low crests may develop over the normally unornamented mid- dorsal and -ventral areas.
Paratabulation absent except for that interpreted from the archaeopyle margin (six precingular and four apical paraplates present). Archaeopyle apical (Type $\overline{tA}$); operculum free.

Remarks: There appears to be considerable variation in ornamentation in *Cyclonephelium membraniphorum* and it seems to grade into forms like *Cyclonephelium compactum* Deflandre & Cookson 1955 by the disintegration of the ordered membranes, producing a series of arcuate ridges which may be linked or isolated. These may intrude on the normally unornamented mid-dorsal and -ventral regions. Although there are forms which can undoubtedly

be assigned to *C.membraniphorum*, the variety forms makes it impossible to assign them to one or other of these two species.

Dimensions:	Cyst L:	32 (44.2) 55 µm
	Cyst W:	30 (49.6) 62 µm
	Membrane H:	2 - 7 µm

Occurrence: Rare occurrences in the *M.labiatus* and *T.lata* zones of Dover, Sussex and the Isle of Wight. Rare occurrences also noted from the *S.planus* zone in Sussex.
AS-17,19-23,31,32; DOE-4,6; CB1-27,32,36,38; CB-10,22-25,27; MR-8; HW-2,4,6, 7,8,11; SO-1,12,13,15-26; NP-5,6,9,40,42.

Known stratigraphic range: Late Cretaceous (Cenomanian-Turonian) (Marshall & Batten 1988)

Genus *Senoniasphaera* Clarke & Verdier 1967

Original diagnosis: Clarke & Verdier 1967
Type species: *Senoniasphaera protrusa* Clarke & Verdier 1967

Senoniasphaera rotundata Clarke & Verdier 1967
Plate 2, fig. 7

Original description: Clarke & Verdier 1967, pp.62-63
Holotype: Clarke & Verdier 1967, pl.14, fig.2
Original dimensions:

	Holotype	Range
Overall L:	92 µm	78 - 100 µm
Overall W:	67 µm	58 - 81 µm
Inner body L:	71 µm	56 - 85 µm
Inner body W:	60 µm	50 - 77 µm
Apical horn L:	14 µm	10 - 14 µm
Antapical horns L:	8,2 µm	2 - 11 µm
Transverse furrow W:	3 µm	3 - 5 µm

Description: Subspherical to ellipsoidal cavate cyst, with two antapical horns, and sometimes two lateral horns. Antapical horns of unequal size, usually short; lateral horns short when present. Endocyst spherical to ellipsoidal, not extending into the horns. Pericyst is developed into a reticulation of thick muri and lumina (up to 3µm in diameter), to a greater

or lesser extent. Reticulation may be very fine or rather coarse with large lumina. Reflected tabulation not obvious, defined only by the archaeopyle margin which indicates the prescence of six precingular paraplates. Paracingulum usually defined, but parasulcus not visible. Archaeopyle apical (Type $\overline{tA}$) sometimes with accessory sutures developed; operculum free.

Remarks: The intraspecific variation seen in this species is confined to the size of the lumina and muri of the reticulation, and the development of the horns. It can easily be distinguished from *Senoniasphaera protrusa* Clarke & Verdier 1967, as the endocyst of *Senoniasphaera rotundata* Clarke & Verdier 1967 does not extend into the horns.

Dimensions:	Total L:	50 (59.1) 67.5 µm
	Total W:	58.5 (64.9) 73.5 µm
	Cyst body L:	40 (46.8) 52.5 µm
	Cyst body W:	43.5 (52.4) 58.5 µm

Occurrence: Common to very common occurrences in all areas in the *M.labiatus, T.lata* and *S.planus* zones.
AS-13-15,19-24,26,28,30-38,40,42,44,46,51-54,59-61; LS-2-4,6-8,9,13,15-30; AKS-2/1,2/2,2/3,2/5,2/7; DOE-5-11,13; ; CB1-26,29,31-35; CB-10,11,13-16, 18-21,29,30,32-34,41,42,45; MR-7,8,9,12,13,14,18-21,27,28,31,32; HW-16; SO-1-4,6-14,16,19,23,25,26; BH-1-3,12; CA-2-14; NP-1-13,15,17,18,22-28, 30-36,40,42,43,45; SPT-1-7; CH-2,3,5,6,8-10.

Known stratigraphic range: Santonian - Campanian (Clarke & Verdier, 1967), England.

Senoniasphaera sp. A
Plate 2, Figs 8, 9

Description: Large subspherical to subpolygonal cavate cyst with antapical and lateral protrusions. Endocyst spherical to subspherical; pericyst expanded laterally and antapically to form protuberances or sometimes more definite horns. Endophragm thick and smooth; periphragm thin and smooth with irregularly occurring lumina, forming a type of reticulation. Paracingulum well defined by thickened ridges, as are the postcingular paraplates. Archaeopyle margin indicates the presence of six precingular paraplates. Archaeopyle apical (Type $\overline{tA}$) with accessory sutures; operculum free.

Remarks: This species is very similar to *Senoniasphaera rotundata* however the reticulation is not fully developed (Pl.2, Fig.8), and is irregular in arrangement, and so these specimens have not been assigned to the aforementioned species.

Dimensions: Total L: 55 (67.1) 80 µm
Total W: 62 (78.6) 100 µm
Cyst L: 45 (51) 62 µm
Cyst W: 52 (62.5) 85 µm
Lumina W:3 (14) 22 µm

Occurrence: LS-17-21; DOE-6,7,9; CB-1; BH-1,11; CA-4,5,12,14; NP-12,18,19, 26,29,30,33; SPT-2,3; CH-6,8-10.

Known stratigraphic range: Turonian (occurs sporadically through the *Terebratulina lata* zone in Sussex and towards the base of the *Sternotaxis planus* zone in Dover).

4.4.5 Gc Morphogroup

Genus *Odontochitina* Deflandre 1935; emend.Bint 1986

Original diagnosis: Deflandre 1935, p.234
Emended diagnosis: Bint 1986, p.138
Type species: *Odontochitina operculata* (Wetzel 1933a) Deflandre and Cookson 1955
Remarks: The generic emendation by Bint (1986) is most acceptable as it allows more intrageneric variability than that of Davey (1970) and also describes a lateral and a single antapical horn rather than two antapical horns.

Odontochitina costata Alberti 1961; emend. Clarke & Verdier 1967
Plate 3, Figs 2, 5

1962 *Odontochitina striatoperforata* Cookson & Eisenack: p.490, pl.3, figs 14-19

Original description: Alberti 1961, p.31
Emended description: Clarke & Verdier 1967, pp.58-59
Holotype: Alberti 1961, pl.6, fig.12

Original dimensions: Holotype

Total L:	522 µm
Inner body L:	88 µm
Inner body W:	70 µm
Apical horn L:	324 µm
Antapical horn L:	103, 110 µm

Description: Cornucavate ceratioid cyst with a subpolygonal to subspherical endocyst, bearing one apical, antapical and lateral horn. Apical and antapical horns longer than the lateral horn. Endophragm thin and smooth; periphragm thin with longitudinal striations and/or some elongate perforations displayed on the horns (Pl.3, Figs 2, 5). Endo- and periphragm are adpressed, except at the base of the horns.
Paratabular features absent, except for the development of an apical archaeopyle (Type $\overline{tA}$);the archaeopyle margin indicates the presence of six precingular paraplates; operculum free.

Remarks: *Odontochitina costata* Alberti 1961; emend. Clarke & Verdier 1967 is rather similar to *Odontochitina operculata* Type B (this study) in terms of it's size and the shape of the endocyst, but can be distinguished by the striations on the horns of the former.

Dimensions:

Central body L:	35 (45) 55 µm
Central body W:	52 (61.4) 70 µm
Total L:	92 (130) 167 µm
Antapical horn L:	52 (90.6) 117 µm
Lateral horn L:	40 (78.3) 115 µm

Occurrence: Common to very common occurrences in all areas in the *M.labiatus, T.lata* and *S.planus* zones.
AS-4,18-22,24,26,35,38,40,42-49,53,54,57,60-62; LS-1,6,7,13-17,19,20, 23-28,30; DOE-4,8,9,14; CB1-27,28,32,36,38; CB-2,10,11,14-18,20,21, 23-25,29,33,41-45; MR-6,8,9,15,19; HW-1,2,4-15; SO-4-7,9,11,12,14-20,22-26; BH-1-3,6-12; CA-2-14; NP-1-27,29,31-38,40; CH-1-6,8,9.

Known stratigraphic range: Cenomanian & Turonian (Alberti, 1961) Germany; Cenomanian - Campanian (Clarke & Verdier, 1967), England;

Odontochitina operculata (Wetzel, 1933a) Deflandre & Cookson 1955
Type A
Plate 3, Figs 3, 4 & 6

1933a *Ceratium (Euceratium) operculatum* Wetzel: p.170, pl.11, figs 21-22
1935 *Odontochitina silicorum* Deflandre: p.234, pl.9, figs 8-10
1966 *Odontochitina operculata* (Wetzel) Sarjeant: p.208, pl.21, fig.2

Original description:	Wetzel 1933, p.170	
Holotype:	Wetzel 1933, pl.2, figs 21-22	
Original dimensions:	Holotype	
	Total L:	210: 170: ?50 µm
	Central body L:	52: 44: ?50 µm
	Horns L:	102: 88: 51 µm

Description: Small, cornucavate, ceratioid cyst with 3 horns; one apical, antapical and lateral. Endocyst small, spherical to subspherical; pericyst closely adpressed to the endocyst (Pl.3, Fig.4) except at the bases of the horns. Endo- and periphragm thin and smooth. Horns are long and tapering, closed distally; the lateral horn being the shortest.
Paratabular features absent, except for a sulcal notch in the archaeopyle margin. No accessory sutures developed in the archaeopyle margin, therefore number of precingular paraplates not discernible. Archaeopyle apical (Type $\overline{tA}$); operculum free.

Remarks: *Odontochitina operculata* Type A will be discussed with *Odontochitina operculata* Type B on page 79.

Dimensions:	Total L:	87 (137.4) 160 µm
	Cyst body L:	27 (36.9) 46 µm
	Cyst body W:	27 (42.1) 55 µm
	Antapical horn L:	60 (98.5) 135 µm
	Lateral horn L:	50 (76.8) 120 µm
	50 specimens measured.	

Occurrence: Common occurrences in all areas in the *M.labiatus, T.lata* and *S.planus* zones; less common in the *M.labiatus* zone at Dover.
AS-13,28,30,31,38,41-43,45,50,56,58,62; LS-6,7; AKS-2/1; DOE-2,3,7,8,9; CB1-26,27,32; CB-2,10,11,14-17,20,21,23-25,29,33,41-45; HW-4-7,9-11,16; SO-1,4-7,8-10,12,16-18,21,24,26; BH-1-9,11,12; CA-2-12,14; NP-1-3,5-9,11,13,

16,18-20,22,23,26,28; SPT-2-4,6,7; CH-2-6,8,9.

Known stratigraphic range: Upper Cretaceous flint (Wetzel, 1933a), Germany; Albian - Turonian (Cookson & Eisenack, 1958), Australia; Hauterivian (Gocht, 1959), Germany; Barremian - Upper Albian and Cenomanian - Senonian (Alberti, 1961), Germany; Cenomanian - Campanian (Clarke & Verdier, 1967), England; Cenomanian (Davey & Verdier, 1973), France; Maastrichtian (Foucher & Robaszynski, 1977), Belgium.

Odontochitina operculata (Wetzel, 1933a) Deflandre & Cookson 1955
Type B
Plate 3, Fig. 1

1933a *Ceratium (Euceratium) operculatum* Wetzel: p.170, pl.11, figs 21-22
1935 *Odontochitina silicorum* Deflandre: p.234, pl.9, figs 8-10
1966 *Odontochitina operculata* (Wetzel) Sarjeant: p.208, pl.21, fig.2

Original description:	Wetzel 1933a, p.170	
Holotype:	Wetzel 1933, pl.11, figs 21-22	
Original dimensions:	Holotype	
	Total L:	210: 170: ?50 µm
	Central body:	52: 44: ?50 µm
	Horns L:	102: 88: 51 µm

Description: Large, cornucavate, ceratioid cyst with 3 horns, one apical, antapical and lateral. Endo- and periphragm both thin and smooth. Endocyst large, subpolygonal to subspherical in shape; broader than long. Pericyst adpressed to the endocyst except at the base of the horns.
Horns taper, are closed distally and vary in length; the lateral horn being the shortest. The endophragm may form a small "nipple" in the base of the horns.
Paratabular features not apparent; except for those displayed by the development of the archaeopyle (Type $\overline{tA}$). No accessory sutures developed. Operculum free.

Remarks: *Odontochitina operculata* (Wetzel) Deflandre & Cookson 1955 has been subdivided here into two Types (A and B), based on variations in size and differences in gross morphology. A scatter diagram (Figure 4.2) based on the measurements of 50 specimens of each type shows that a distinction

can be made between the two, despite some overlap. Further study should substantiate these morphological differences, allowing a formal emendation and naming of the two types The difference is not only based on size, but on the nature of the endocyst which is rather different in general shape and relationship to the pericyst. In Type A the endocyst is simple and spherical, being closely adpressed to the pericyst. However in Type B, the endocyst is more polygonal in shape and forms a small "nipple" in the base of the horns and is not so closely adpressed to the pericyst.

Dimensions:	Total L:	105 (132.9) 170 µm
	Central body L:	35 (42.6) 59 µm
	Central body W:	37 (54.5) 68 µm
	Antapical horn L:	67 (96.8) 135 µm
	Lateral horn L:	52 (75.1) 130 µm

50 specimens measured.

Occurrence: Rare occurrence in the *M.labiatus* zone at Dover, but common in the *T.lata* & *S.planus* zones; common occurrence in the *M.labiatus, T.lata* and *S.planus* zones in Sussex and on the Isle of Wight.
AS-28-32,35,36,38,40-54,56-58,60-62; LS-3,4,6-14,16-18,21,23-26,28-31; AKS-2/1,2/2,2/3,2/5,2/6; DOE-1-15; CB1-27,28,31,32,34,36,38; CB-1,2,10,11, 13-33,40-45; MR-8,9,19,20,21,27,29; HW-1-16; SO-5-7,9-11,15-18,20,22-26; BH-1-12; CA-2-14; NP-1-36,38-40; SPT-1-7; CH-1-9.

Known stratigraphic range: Upper Cretaceous flint (Wetzel, 1933a), Germany; Albian - Turonian (Cookson & Eisenack, 1958), Australia; Hauterivian (Gocht, 1959), Germany; Barremian - Upper Albian and Cenomanian - Senonian (Alberti, 1961), Germany; Cenomanian - Campanian (Clarke & Verdier, 1967), England; Cenomanian (Davey & Verdier, 1973), France; Maastrichtian (Foucher & Robaszynski, 1977), Belgium.

Genus *Xenascus* Cookson & Eisenack 1969; emend. Stover & Helby 1987

Original diagnosis: Cookson & Eisenack 1969, p.7
Type species: *Xenascus ceratioides* (Deflandre, 1937) Lentin & Williams 1973
Remarks: The generic emendation of Stover & Helby (1987) is favoured as it provides a comprehensive account of the history of the genus and a detailed generic description, including comparisons of species.

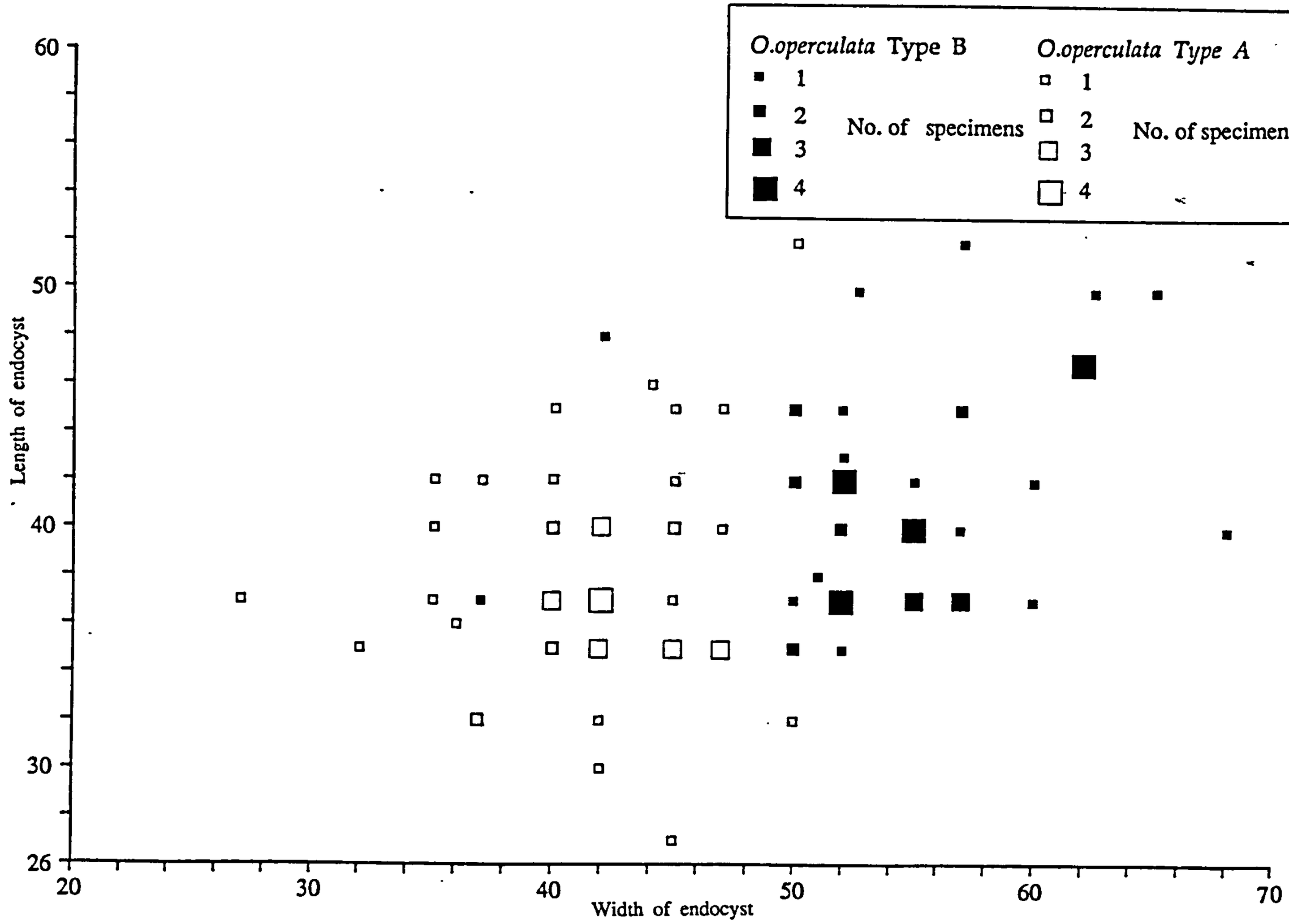


Figure 4.2 Scatter diagram of measurements of the two types of *Odontochitina operculata* recognised, Type A & B.

Xenascus ceratioides (Deflandre, 1937) Lentin & Williams 1973
Plate 3, fig. 7

1937 *Hystrichosphaera ceratioides* Deflandre: p.66-67, pl.12, figs7-8
1967 *Pseudoceratium ceratioides* (Deflandre) Clarke & Verdier: p.60
1970 *Spiniferites ceratioides* (Deflandre) Sarjeant: p.76
1971 *Phoberocysta ceratioides* (Deflandre) Davey & Verdier: p.26

Original description:	Deflandre 1937, pp.66-67	
Holotype:	Deflandre 1937, pl.12, figs7,8	
Original measurements:	Holotype	
	Total L:	172 µm
	Central body D:	40 µm

Description: Proximo-chorate to cornucavate ceratioid cyst. Endocyst spherical to subspherical in shape; pericyst elongated into one apical, antapical and perhaps two lateral horns. Apical, antapical and lateral horns broad based and conical in shape,exhibiting irregular short processes. Endophragm smooth; periphragm forming ribs and processes. Processes may be blunt to capitate distally. Paratabular features absent, excepting the development of an apical archaeopyle (Type $\overline{tA}$); archaeopyle margin indicates the presence of at least six precingular paraplates. Operculum free.

Remarks: In agreement with Lentin & Williams (1985) and Stover & Evitt (1978), *Xenascus ceratioides* (Deflandre, 1937) Lentin & Williams 1973, is here considered to be a separate, distinct species from *Xenascus australensis* Cookson & Eisenack 1969.

Dimensions:	Total L:	80 (105.7) 132 µm
	Total W:	50 (68) 82 µm
	Cyst body L:	37 (44.8) 57 µm
	Cyst body W:	35 (45.7) 62 µm
	Antapical horn L:	37 (62.3) 82 µm
	10 specimens measured.	

Occurrence: Rare occurrence in the *T.lata* and *S.planus* zones at Dover; in the *M.labiatus, T.lata* and *S.planus* zones in Sussex and the *T.lata* zone on the Isle of Wight.
LS-1,2,4,10-13,16,17,21,27,29,30; DOE-9,11,13; CB-18; ; SO-11; NP-24,29,30; CA-2; SPT-2-7; CH-2,3,5,9.

Known stratigraphic range: Senonian (Deflandre, 1937), France; Late Cenomanian - Campanian (Clarke & Verdier, 1967), England; Albian - Maastrichtian (Yun, 1981), cosmopolitan.

4.4.6 Family GONYAULACACEAE Lindemann 1928

Gp Morphogroup

Genus *Microdinium* Cookson & Eisenack 1960; emend. Stover & Evitt 1978

Original diagnosis: Cookson & Eisenack 1960, p.6
Emended diagnosis: Stover & Evitt 1978, pp.65-66
Type species: *Microdinium ornatum* Cookson & Eisenack 1960

Remarks: Following the recommendation of Lentin & Williams (1989) *Microdinium* will not be treated as a junior synonym of *Phanerodinium* Deflandre 1937. The emended generic diagnosis of Stover & Evitt is favoured, as it describes the variability of the paratabulation in more detail.

Microdinium ornatum Cookson & Eisenack 1960
Plate 4, Figs 1,2

Original description: Cookson & Eisenack 1960,pp.6-7
Holotype: Cookson & Eisenack 1960, pl.2, figs 3,4, text-fig.2
Original dimensions:

	Holotype	Range
Cyst L:	29 µm	28 - 38 µm
Cyst W:	27 µm	27 - 36 µm

Description: Small proximate, ellipsoidal cyst. Epi and hypo-cyst of unequal size, separated by a broad paracingulum. Epicyst smaller and narrower than hypocyst.
Paratabulation defined by low ridges perforated by holes, thus having the appearance of a "string of beads". Paratabulation defined as 4′, ?3a, 6″, 6c, 6‴, 1p, 1⁗. Partiform arrangement of parasulcal and antapical paraplates. Archaeopyle apical (Type tA̅ or tAtI if intercalary plates included). Operculum may be free or attached.

Dimensions: Cyst L: 27 (31.1) 37 µm
Cyst W: 22 (29.9) 37 µm
Ridge H: 1-2 µm

Occurrence: Rare occurrence in the *T.lata* zone at Dover and in the *M.labiatus* and *T.lata* zones of Sussex and the Isle of Wight.
LS-2,3,9,11; DOE-2,3,8,14; CB1-26,36; CB-18,29; HW-4; SO-9; BH-1-12; NP-21,25.

Known stratigraphic range: Albian - Lower Turonian (Cookson & Eisenack, 1960), Australia; Cenomanian - Santonian (Clarke & Verdier, 1967), England.

?Microdinium "tuberculatum" n.sp
Plate 4, Figs 3-13

Origin of name: *"tuberculatum"* - tuberculate ornament on the cyst surface.
Holotype: Plate 4, Figs 3,6; SPT2 (R34-2), Upper Turonian - *Sternotaxis planus* zone.
Paratype: Plate 4, Figs 4,5

Description: Small spherical to subspherical proximate cyst, bearing low parasutural crests and some intratabular ornament. Wall two layered, endo- and periphragm being closely adpressed. Endo- and periphragm both thin and smooth to slightly granular. Parasutural crests are low and sometimes thickened. Intratabular ornament comprises one or two small tubercles per paraplate, or may be combined to form simple ridges.
Paratabulation well defined by these crests; gonyaulacacean- 4′, 6″, 6c, 6‴, 1p, 1⁗, 1-5s, (Figure 4.2). Antapical paraplate sexiform. Paracingulum well defined, offset slightly, paraplates elongated hexagonal in shape. Parasutural plates not always discernible, but they have been discerned in some specimens (Pl.4, Figs 5 & 6).Precingular paraplates camerate (1″, 3″, 6″) or pleinate (2″, 4″, 5″). Archaeopyle apical (Type tA), with accessory sutures. Operculum free.

Remarks: This new species belongs to the gonyaulacacean family, however its generic affinities are not immediately apparent, but it is similar to the genus *Microdinium*, in terms of size and ornament. However it does not possess the unequal size of epi- and hypo-cyst typical of *Microdinium*. It also possesses a similar partiform antapical arrangement to *Microdinium*. So it is tentatively placed in this genus.

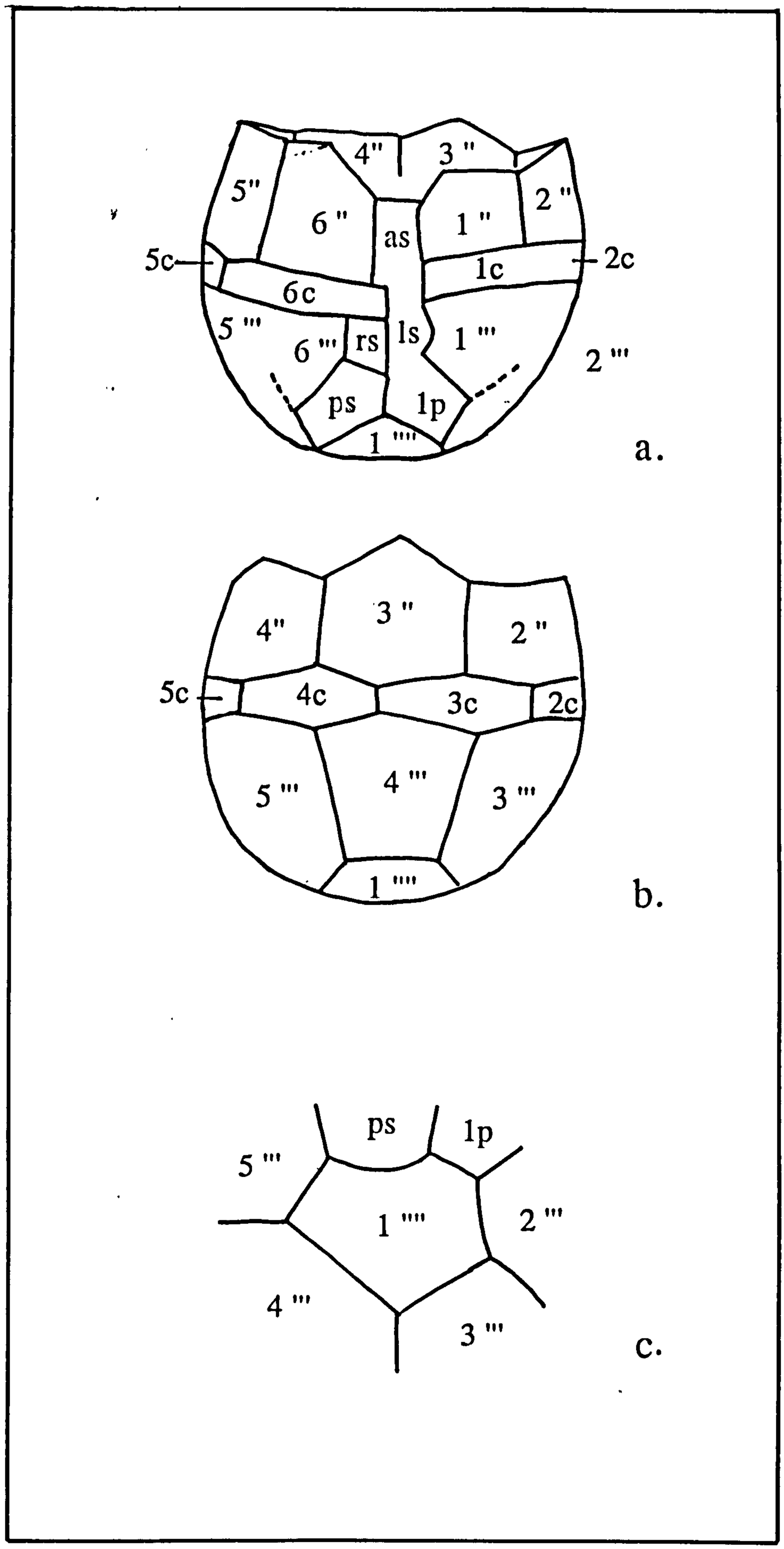


Figure 4.3 Paratabular features of *?Microdinium tuberculatum.*

Dimensions: Cyst L: 25 (31.5) 40 µm
Cyst W: 30 (36.9) 50 µm
Cingulum W: 2 (3.2) 5 µm
30 specimens measured

Occurrence: Rare occurrence in the *S.planus* zone at Dover and on the Isle of Wight, in the *M.labiatus, T.lata* & *S.planus* zones in Sussex.
LS-16,17,23-25,27-29; DOE-1,3,4; ; CB-2,11,25; BH-6,9,12; NP-21,25; SPT-2; CH-1,2.

Known stratigraphic range: Turonian (occurs in the *Sternotaxis planus* zone at Dover and sporadically throughout the sequence in the *Mytiloides labiatus, Terebratulina lata* and *Sternotaxis planus* zones in Sussex).

Genus *Rhiptocorys* Lejeune-Carpentier & Sarjeant 1983

Original diagnosis: Lejeune-Carpentier & Sarjeant 1983, p.5
Type species: *Rhiptocorys veligera* (Deflandre 1937) Lejeune-Carpentier & Sarjeant 1983.

Remarks: *Rhiptocorys* Lejeune-Carpentier & Sarjeant 1983 is not treated here as a junior synonym of *Phanerodinium* Deflandre 1937, in agreement with Lentin & Williams (1989), as the archaeopyle of the holotype of the latter cannot be ascertained. Below (1987) considered *Rhiptocorys* to be a synonym of *Fibradinium* Morgenroth 1968, *Microdinium* Cookson & Eisenack 1960; emend. Stover & Evitt 1978, and *Subtilidinium* Morgenroth 1968, but it is preferred here to retain *Microdinium* and *Rhiptocorys* as separate genera (the others were not found in this investigation). The two genera can be distinguished on the basis of the archaeopyle types, apical in *Microdinium* and epicystal in *Rhiptocorys*.

Rhiptocorys veligera (Deflandre) Lejeune-Carpentier & Sarjeant 1983
Plate 4, Figs 14, 15

1937 *Micrhystridium veligerum* Deflandre: p.81, pl.12, fig.9
1943 *Ceratocorys veligera* (Deflandre); emend. Lejeune-Carpentier: pp.24-25, figs 1-6
1969 *Microdinium veligerum* (Deflandre) Davey: p.136, pl.3, fig.6, pl.4, fig.4.

Original description: Deflandre, 1937, p.81
Emended description: Lejeune-Carpentier & Sarjeant, 1983, pp.5-8
Holotype: Deflandre 1937, pl.12, fig.9
Original dimensions:

	Holotype	
Cyst D:	-crests:	18 µm
Cyst D:	+crests:	25 µm

Description: Small subspherical proximate cyst, bearing parasutural crests. Wall thick, granular, forming low thick ridges. Epi- and hypo-cyst of unequal size, the former being $^1/_3$ the size of the latter.
Parasutural crests have the appearance of thickened ridges, and are large relative to the central body. Paratabulation not fully discernible, particularly on the epicyst, which is relatively small. Paracingulum distinct (4-5 paraplates), and postcingular paraplates well defined (4-5 paraplates). Archaeopyle epicystal (Type tAtP); operculum free.

Remarks: *Rhiptocorys veligera* (Deflandre, 1937) Lejeune-Carpentier & Sarjeant 1983, is not assigned to the genus *Microdinium*, as it has been described as possessing an epicystal archaeopyle (Lejeune-Carpentier & Sarjeant, 1983), although this feature is not always apparent, and *Microdinium* has an apical archaeopyle only.

Dimensions:

Cyst L:	25 (29) 35 µm
Cyst W:	25 (28.5) 32 µm
Crest H:	2 (2.5) 3 µm

10 specimens measured.

Occurrence: Rare occurrence in the *T.lata* zone of Dover and the Isle of Wight and in the *M.labiatus* & *T.lata* zones of Sussex.
LS-9,11; DOE-7; CB-2; BH-4,9,12.

Known stratigraphic range: Upper Cretaceous flint (Deflandre, 1937), France; Senonian flint (Lejeune-Carpentier & Sarjeant, 1983), Belgium.

4.4.7 Gq Morphogroup

Genus *Dinopterygium* Deflandre 1935; emend. Stover & Evitt 1978

1960 *Oodnadattia* Eisenack & Cookson
1960 *Toolognia* Cookson & Eisenack

Original diagnosis: Deflandre 1935.p.231
Emended diagnosis: Stover & Evitt 1978, pp.204-205
Type species: *Dinopterygium cladoides* Deflandre 1935

Dinopterygium cladoides Deflandre 1935
Plate 5, Figs 2, 4

1960 *Oodnadattia tuberculata* Eisenack & Cookson: pp.6-7, pl.2, figs 10-14

Original description: Deflandre 1935, p.231
Holotype: Deflandre 1935, pl.8, fig.6
Original dimensions: Holotype

Central body D:	50 × 40 µm	Deflandre 1936
Total:	65 × 78 µm	pp.181-182

Description: Cyst spherical to polygonal, circular ambitus in apical-antapical view. Wall two layered, endophragm may be slightly granular and bear strong tubercles; periphragm thin and generally smooth. Endo- and periphragm conformable in intratabular areas.
Parasutural membranes, formed by periphragm are usually well developed, thin and often deformed.
Paratabulation gonyaulacacean, with a single quinqueform antapical and 5 postcingular paraplates. The number of precingular paraplates is not certain but is probably > 5. Paracingulum and parasulcus well defined by parasutural membranes. Archaeopyle epicystal (Type $\overline{tAtP}$), apparent as most specimens found consist of the hypocyst only. Operculum free.

Remarks: This rather infrequently occurring species is usually observed as the hypocyst only; both lateral and apical-antapical compressions exhibited.

Dimensions: Central body L x W: 75 (75) 75 x 100 (100) 100 µm
Total L x W: 42 (47) 52 x 62 (62) 62 µm
5 specimens measured
Occurrence: Rare occurrence in the *M.labiatus* & *T.lata* zones in Sussex BH-1,3,4,6; NP-21.

Known stratigraphic range: Upper Cretaceous flint (Deflandre, 1935), France; Upper Cretaceous (Deflandre & Cookson, 1955), Australia; Albian (Eisenack & Cookson, 1960), Australia; ?Cenomanian - ?Turonian (Jain & Millepied, 1975),

Senegal; Albian - Vraconian (Below, 1981), Morocco.

Dinopterygium medusoides (Cookson & Eisenack, 1960)
Stover & Evitt 1978
Plate 5, Figs 1, 3

1960 *Toolongia medusoides* Cookson & Eisenack 1960, p.14

Original description: Cookson & Eisenack 1960, pl.3, figs 11,12
Original dimensions: Holotype
Overall D: 90 x 100 µm

Description: Cyst spherical to polygonal, with a circular ambitus in apical-antapical view, bearing prominent parasutural membranes. Wall two layered, endophragm smooth, periphragm thin and smooth, being developed into high parasutural membranes. Endo- and periphragm conformable except in parasutural areas.
Parasutural membranes are well developed, often folded, and reflect a gonyaulacacean paratabulation, with a single quinqueform antapical and 5 postcingular paraplates. Parasulcal area well defined. Archaeopyle epicystal (Type $\overline{tAtP}$), operculum free.

Remarks: This species differs from *Dinopterygium cladoides* Deflandre 1935, emend Stover & Evitt 1978, in only one respect, that is that the endophragm is smooth in the former, and tuberculate in the latter. Yun 1981 stated "*Toolongia medusoides* Cookson & Eisenack 1960 is with certainty a junior synonym of the present species (*D. cladoides)* and indeed, solely on the polar view." However, he omitted any reference to the tuberculate nature of the endophragm. Therefore this emendment is not considered valid. The two species are described separately herein. Further detailed work on the two species would be necessary to clarify the position.

Dimensions: Central body L x W: 37 (40.8) 50 x 37 (41.4) 50 µm
Total L x W: 60 (69.8) 87 x 67 (71.8) 77 µm
5 specimens measured
Occurrence: Rare occurrence in the *T.lata* zone in Sussex
BH 2,3

Known stratigraphic range: ?Campanian - Santonian (Cookson & Eisenack,

1960), Australia.

4.4.8 Gs Morphogroup

Genus *Achomosphaera* Evitt 1963

Original diagnosis: Evitt 1963, p.163
Type species: *Achomosphaera ramulifera* (Deflandre, 1937) Evitt 1963

Remarks: Evitt (1963) erected the genus *Achomosphaera* to accommodate forms which were similar to *Spiniferites* Mantell 1850; emend. Sarjeant 1970, but which differed by suppression of the parasutural crests.
The process morphology is similar, although the processes in some species of *Achomosphaera* are more irregular and do not always show the primary trifurcation and subsequent bifurcation typical of *Spiniferites*. *Achomosphaera* by virtue of lacking parasutural crests does not exhibit an obvious paratabulation. However in comparison with *Spiniferites* and examination of the archaeopyle it is possible to recognise the gonal position of the processes (Pl.6, Fig.5). Evitt (1963) showed the processes to be "sutural" by "the positional relationships of it's processes to other features (e.g. poles, equator, archaeopyle)".
During this study, these genera were not commonly found. However, once found, it was usually quite straightforward to assign specimens to one or other of these genera. It was found that specimens although not always preserved very well, did or did not have parasutural crests. Sometimes these parasutural markings were very subtle, and these specimens were more difficult to assign to the correct genus. There were some forms which possessed parasutural crests on the hypocyst and not on the epicyst; it was these forms which created problems in designating the correct genus. The genus was chosen by the predominant characteristics, but this illustrates that there is some gradation between the two genera. It was considered possible to maintain these two genera in the scope of this study as the majority of specimens distinctly belonged to one or other genus.
majority of specimens distinctly belonged to one or other genus.

Achomosphaera ramulifera (Deflandre, 1937) Evitt 1963
Plate 6, Figs 1, 2

1937 *Hystrichosphaeridium ramuliferum* Deflandre: p.74, pl.14, figs 5-6; pl.17, fig.10.

Original description:	Deflandre 1937, p.74.	
Emended description:	Evitt 1963, p.163	
Holotype:	Deflandre 1937, pl.14, fig.5.	
Original measurements:	Holotype	
	Central body D:	35 × 45 µm
	Total D:	90 - 100 µm
	Process L:	45 - 50 µm

Description: Cyst ellipsoidal to subpolygonal in shape, possessing gonal and intergonal processes (being $^1/_2$ to $^2/_3$ the central body length). Wall two layered, endo- and peri-phragm being conformable, except at the base of the processes. Periphragm smooth to slightly granular.

Gonal processes hollow, broad based and strong, dividing medially into two branches which may trifurcate with bifid terminations. Some processes simple, tapering distally, where they trifurcate and terminate in bifid tips. Processes most flamboyant, (larger with broad membranous bases probably formed by the fusion of two smaller processes) in the polar and paracingular regions (Pl.6, Fig.1). No parasutural septa connect the processes proximally.

Paratabulation absent, except for the archaeopyle and some alignment of processes. Archaeopyle reduced precingular (Type P), polygonal in shape, formed by the loss of the 3″ paraplate; operculum free.

Remarks: The gonal processes in this species sometimes become very elaborate and seem to be formed by the fusion of two processes. It seems that the process length of the species described herein is shorter than in the holotype. However, other authors have described specimens in which the processes may be up to 35 µm in length (Davey & Williams, 1966a). It might be considered that the measurements of the holotype were extreme and not the norm observed.

Dimensions:	Central body L:	27 (34.2) 42 µm
	Central body W:	25 (28.7) 37 µm
	Max. Process L:	15 (20.5) 27 µm
	10 specimens measured.	

Occurrence: Rare occurrence in the *T.lata* zone at Dover. Sporadic

occurrence in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight. LS-1; DOE-2,3,4,8,11,12,15; CB1-27,36; CB-21,24,25,31,44; HW-4; BH-4,6,7,9,11,12; NP-21.

Known stratigraphic range: Senonian flint (Deflandre, 1937), France; Cenomanian - Eocene (Davey, 1969), England, France & U.S.A.; Senonian (Corradini, 1973), Italy; Upper Turonian (Foucher, 1974), France.

Achomosphaera reginensis Corradini 1973
Plate 6, Fig. 3

Original description:	Corradini 1973, p.171.
Holotype:	Corradini, 1973, pl.27, fig.2.
Original dimensions:	Holotype
Central body D:	54 × 66 µm
Process L:	20 - 30 µm

Description: Cyst oval to ellipsoidal in shape, bearing approximately 25 solid gonal processes. Wall seemingly single layered and smooth. Processes taper distally, bifurcate medially, each branch trifurcating and terminating in bifid tips. These primary branches are usually parallel to the central body surface (Pl.6, Fig.2). Paratabulation is absent, except for the archaeopyle. Archaeopyle reduced precingular, (Type P), polygonal in shape; being formed by the loss of the 3″ paraplate (not always easily observed); operculum free.

Remarks: It was noted that the larger more complexly branched processes usually occupied gonal positions, and the simpler ones were found in between. No "faint lines connecting adjacent processes " as found in the original material were observed herein, and so it remains as this species.
The difference between *Achomosphaera ramulifera* (Deflandre, 1937) Evitt 1963 and *Achomosphaera reginensis* Corradini 1973 is based on the nature of the processes; being simple, with the primary branches parallel to the cyst body in the latter.

Dimensions:	Central body L:	32 (37.8) 42 µm
	Central body W:	30 (34.7) 37 µm
	Max. process L:	15 (18.3) 22 µm
	10 specimens measured.	

Occurrence: Rare occurrence in the *M.labiatus* zone at Dover and in the *M.labiatus, T.lata* & *S.planus* zones of Sussex and the Isle of Wight.
LS-1,2,3; DOE-2,4,7,8,11,12,,14; CB1-27,28,36,38; CB-10,11,16,21,25,27,44; HW-1,2,4,6; BH-1,2,3,4,5,6; NP-21.

Known stratigraphic range: Senonian (Corradini, 1973), Italy.

Achomosphaera sagena Davey & Williams 1966a
Plate 6, Figs 4, 5 & 6

1967 *Achomosphaera reticulata* Clarke & Verdier: pp.41-42; pl.8, figs 2-3; text-fig.16

Original description:	Davey & Williams 1966a, p.51	
Holotype:	Davey & Williams 1966a, pl.2, figs 1-2	
Original dimensions:	Holotype	
	Central body D:	48 µm
	Max. length of process:	20 µm

Description: Cyst ellipsoidal to subspherical in shape, bearing gonal processes. Wall very thick (3µm), with a strongly reticulate surface (Pl.6, Fig.4).
Processes slender, tapering distally, trifurcate with bifid terminations. Often the reticulation extends from the cyst wall into the proximal part of the processes (Pl.6, Fig.5). Processes generally $^{1}/_{4}$ cyst body length.
Indications of paratabulation absent, as there are no parasutural crests between the process bases, excepting the archaeopyle. Archaeopyle reduced precingular (Type P), polygonal in shape (Pl.6, Fig.5); formed by the loss of 3″ paraplate; operculum free.

Remarks: This is a distinctive species of *Achomosphaera* which has a strongly reticulate wall structure. According to Fechner (1985) the reticulate nature of the central body is identical to that of *Achomosphaera reticulata*, Clarke & Verdier 1967. Following the original descriptions, there is no doubt that it is in fact a junior synonym of this species. The only variable is the length of the processes in relation to the central body.

Dimensions: Central body L: 37 (46.9) 57 µm
Central body W: 35 (43.2) 52 µm
Max. process L: 12 (17.2) 22 µm

Occurrence: Rare occurrence in the *M.labiatus* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-1,3,11; CB-16,31; CB1-36; BH-1-9,11,12; NP-21,25.

Known stratigraphic range: Cenomanian (Davey *et al.*, 1966), England; Cenomanian (Davey, 1969), England & France; Late Albian - Cenomanian (Davey & Verdier, 1973), France.

Genus *Hystrichostrogylon* Agelopoulos 1964; emend. Stover & Evitt 1978

Original diagnosis: Agelopoulos 1964, pp.673-674
Emended diagnosis: Stover & Evitt 1978, p.164
Type species: *Hystrichostrogylon membraniphorum* Agelopoulos 1964

Remarks: Stover & Williams (1987) considered *Diphasiasphaera* Duxbury 1980 to be a junior synonym of this genus. However the specimens figured by Duxbury (1980) and the description all refer to a cyst type which is noticeably different to *Hystrichostrogylon* Agelopoulos 1964, emend. Stover & Evitt 1978, in that it does not possess distinct trifurcate processes and the outer membrane or periphragm is more continuous. Therefore the synonomy proposed by Stover & Williams is here rejected.

Hystrichostrogylon membraniphorum Agelopoulos 1964
Plate 7, Figs 8, 9

Original description: Agelopoulos 1964, pp.674-675
Holotype: Agelopoulos 1964, text-fig.1
Original dimensions: Holotype
Central body L: 45 µm
Central body W: 40 µm
Process L: 13-29 µm
Process W: 2-6 µm

Description: Cyst subspherical to ellipsoidal, with two distinct wall layers forming an endo- and peri-cyst. Endocyst subspherical to ellipsoidal

in shape with a smooth, thin wall. Pericyst subtended by gonal processes and does not completely enclose the endocyst; it is " umbrella-like " in it's structure. The pericyst encloses the ventral surface of the endocyst only and is attached at the base of processes in the apical and antapical region. Processes slender and trifurcate distally with bifid tips. Paratabulation not distinct, as parasutural membranes are absent; paracingulum and parasulcus undefined. Archaeopyle precingular (Type P), subrounded in shape; formed in the endocyst only. Operculum free.

Remarks: This species occurs infrequently, but is distinctive and from its process morphology it is thought to show some affinities with the *Spiniferites* "group" and in fact may be a variety of this group.
The range quoted from Lentin & Williams (1989) of "Late Eocene" is obviously extended in this study to include older occurrences of Turonian and Late Cretaceous age. The *Spiniferites* "group" occurs throughout the Late Cretaceous and this related genus is thought to probably have a similar range.

Dimensions: Cyst L: 27 (37.2) 45 µm
Cyst W: 27 (36.3) 50 µm
Process L: 12 (13.6) 17 µm
Membrane H: 10 (14.8) 17 µm
5 specimens measured.

Occurrence: Rare occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex.
LS-2-4; DOE-7; NP-25; BH-2-5,9,11

Known stratigraphic range: Late Eocene (Agelopoulos, 1964), Germany.

Genus *Spiniferites* Mantell 1850; emend. Sarjeant 1970

Xanthidium (Ehrenberg, 1838) White 1842
Hystrichosphaera Wetzel 1933b
Hystrichosphaera (Wetzel) Deflandre 1937
Hystrichokibotium Klumpp 1953

Original diagnosis: Mantell 1850, p.191
Emended diagnosis: Sarjeant 1970, p.75
Type species: *Spiniferites ramosus* (Ehrenberg, 1838) Mantell 1854,

Loeblich & Loeblich 1966

Remarks: The generic name *Spiniferites* was used originally by Mantell 1850, then forgotten, and only rediscovered by Sarjeant (1964). It was then suggested that the junior synonym *Hystrichosphaera* Wetzel 1933b, should be retained as it was in common use. However, this proposal was rejected by the Committee on Fossil Plants of the I.A.P.T. (International Association for Plant Taxonomy). Between the submission and rejection of this proposal, Loeblich & Loeblich 1966 validated the genus by choosing a type species. Discussion of *Spiniferites* and *Achomosphaera* as related genera has already been noted on pages 88-89.

Spiniferites ?dentatus (Gocht, 1959) Lentin & Williams 1973; emend. Duxbury 1977.
Plate 6, Fig. 8

Original description: Gocht 1959, p.75-76, pl.4, fig.11; pl.7, fig.19.
Emended description: Duxbury 1977, p.49-50
Holotype: Gocht 1959, pl.4, fig.11
Original measurements: Holotype

Total cyst L:	73 µm
Total cyst W:	70 µm
Central body D:	55 × 47 µm
Crest H:	5-15 µm

Description: Elongate, ellipsoidal chorate cyst bearing well developed parasutural crests and gonal processes. Wall two layered; endophragm thick and smooth; periphragm thin and smooth; forming parasutural crests.
Gonal processes trifurcate distally, and connected proximally by the parasutural crests. Parasutural crests divided into evenly spaced processes which bifurcate, and may have trifid terminations. The number and length of parasutural processes varies between specimens.
Paratabulation not very distinct. Paracingulum distinct and helicoidal; parasulcus also distinct, but individual parasulcal plates not apparent. Apparent paratabulation consists of 4′, 6″, ?6c and is not distinct on the hypocyst. Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate. Operculum free.

Remarks: Much variation of the parasutural crests and their processes is

observed in this species. Some specimens seem to have divided crests only on the hypocyst, with the epicyst bearing only simple crests. The crests are usually half the length of the processes. This species has been provisionally assigned to the genus *Spiniferites*, on the basis of its gonal processes, and parasutural crests, although the complete paratabulation has not yet been deciphered. This species has previously been described from the Early Cretaceous and its appearance in Turonian sediments dramatically increases its range.

Dimensions:	Cyst L:	37 (44.9) 62 µm
	Cyst W:	32 (39.6) 62 µm
	Process L:	12 (15.7) 25 µm
	Crest L:	5 (7.5) 12 µm

10 specimens measured

Occurrence: Sporadic occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-2-4,9,11,17; DOE-4,7,8,11,12; CB1-26; HW-2,3; BH-1-3,7.

Known stratigraphic range: Hauterivian (Gocht, 1959), Germany; Hauterivian - Barremian (Duxbury, 1977), England.

Spiniferites multibrevis (Davey & Williams, 1966a) Below 1982
Plate 6, Fig. 7; Plate 7, Figs 1, 2

1966a *Hystrichosphaera ramosus* var. *multibrevis* Davey & Williams pp.35-36, pl.1, fig.4, pl.4, fig.6, text fig. 9

Original description: Davey & Williams 1966a, pp.35-36
Holotype: Davey & Williams 1966a, pl.4, fig.6

Original measurements:		Holotype London Clay	Range Haut-Barr	Range Cen.
Central body (D)	35 x 44.5 µm	35-39 µm	34-47 µm	31-46 µm
Process Length	up to 14 µm	up to 16 µm	up to 12 µm	up to 19 µm

Description: Subspherical to ellipsoidal chorate cyst, bearing gonal processes and parasutural crests. Wall two layered; endophragm smooth to slightly ornamented; periphragm thin and smooth forming the processes and crests.
Gonal processes solid and tapering, tapering distally. Parasutural crests

connect the processes basally, and may develop processes along their length. Number and size of parasutural processes varies. Processes 1/4 of the cyst diameter.

Paratabulation gonyaulacacean 4′, 6″, 6c, ?6‴, 1⁗. Paracingulum distinct, offset one cingulum width and helicoidal. Parasulcus discernible, but individual paraplates not apparent. Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of the third precingular paraplate; operculum free.

Remarks: *Spiniferites multibrevis* (Davey & Williams, 1966a) Below 1982 can be distinguished from the *Spiniferites ramosus* "group" on the basis of it's shorter processes with relation to it's cyst body.

Dimensions:	Cyst L:	37 (42.7) 50 µm
	Cyst W:	32 (38) 42 µm
	Process L:	7 (9.1) 10 µm
	10 specimens measured.	

Occurrence: Rare ocurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.

LS-2-4,9; DOE-2,7,13-15; CB1-26; CB-18,25,44; BH-3,5-7,11,12; NP-21,39.

Known stratigraphic range: Hauterivian - Eocene (Davey & Williams, 1966a), England; Aptian (Davey, 1978), Africa; Hauterivian - Aptian (Below, 1982), Morocco.

Spiniferites ramosus (Ehrenberg) Loeblich & Loeblich 1966
var. *ramosus* (1973)
Plate 7, Figs 3, 7

1838 *Xanthidium ?ramosum* Ehrenberg: pl.1, figs 1-2, 5
1932 *Hystrichosphaera furcata* (Ehrenberg) Wetzel: p.136
1966a *Hystrichosphaera ramosa* (Ehrenberg) var. *ramosa* Davey & Williams: p.33, pl.1, figs.1,6; pl.3, fig.1; text-fig.8

Original description: None given by Ehrenberg
Holotype: None given by Ehrenberg
Lectotype: Davey & Williams 1966a, p.32 (Ehrenberg 1838, pl.1, fig.5)

Original measurements:	Lectotype	
Davey & Williams 1966	Central body D:	42 × 48 µm

Process L: 13 - 25 μm

Description: Subspherical to ellipsoidal chorate cyst, bearing both gonal and parasutural processes. Wall two layered; endophragm smooth and thin, periphragm thin and smooth forming the apparent crests.
Gonal processes solid, tapering distally, trifurcating and subsequently bifurcating. Low parasutural crests connect adjacent processes basally, and may develop into processes which bifurcate.
Paratabulation defined by parasutural crests is gonyaulacacean - 4′, 6″, 6c, 6‴, ?1p, 1⁗. Paracingulum distinct, with elongate hexagonal shaped paraplates. Parasulcal region lacks ornament, but is distinct, being devoid of ornament. Archaeopyle reduced precingular (Pl.7, Fig.7) (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate; operculum free.

Remarks: There seems to be a great variety in the size of this subspecies in the current investigation. Also the shape of the central cyst body may vary from being ellipsoidal to being more spherical.

Dimensions: Cyst L: 35 (48.3) 80 μm
Cyst W: 27 (41.2) 62 μm
Process L: 10 (17.2) 25 μm

Occurrence: Rare to common occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-1-4,6,9-11,16,17,24,29; DOE-2,3,6-9,11-15; CB1-26-29,31,32,36; CB-21,24,25,33; MR-18; HW-2,3; BH-1-9,11,12; NP-20,21,25.

Known stratigraphic range: Late Cretaceous flint (Ehrenberg, 1838), Delitzsch ?Germany; Albian - Cenomanian (Cookson & Hughes, 1964), England; Middle Barremian - Eocene (Davey & Williams, 1966a), England.

Spiniferites ramosus (Ehrenberg) Loeblich & Loeblich 1966
var. *gracilis* (Davey & Williams, 1966a) Lentin & Williams 1973
Plate 7, Figs 4, 5

1959 *Hystrichosphaeridium plicatum* Maier: p.318, pl.33, fig.1
1966a *Hystrichosphaera ramosa* var.*gracilis* Davey & Williams: pp.34-35, pl.1, fig.5; pl.5, fig.6

Original description: Davey & Williams 1966a, pp.34-35

Holotype: Davey & Williams 1966a, pl.5, fig.6

Original measurements:	Holotype	Range
Central body D:	35 × 43 µm	28 - 33 µm
Process L:	17 - 23 µm	up to 20 µm

Description: Subpolygonal to ellipsoidal chorate cyst bearing gonal and sutural processes with parasutural crests. Wall two layered; endophragm thin and smooth, periphragm thin and smooth forming the processes. Endo- and peri-phragm adpressed except where the processes arise.
Processes slender and long, solid or hollow. Gonal processes trifurcate; sutural processes bifurcate. Low parasutural crests indicate the paratabulation, with 4 apical, 6 precingular, 6 cingular, 6 postcingular and a single antapical paraplate being defined. although it is not always clear. Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of paraplate 3″; operculum free.

Remarks: This variety differs from the others of this species by displaying a greater number of finer, longer processes.

Dimensions:		
	Cyst body L:	37 (41.1) 52 µm
	Cyst body W:	27 (33.4) 42 µm
	Process L:	15 (18.8) 22 µm

10 specimens measured.

Occurrence: Rare occurrence in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-2-4,9,11,17,18; DOE-3,7,13-15; CB1-26,32; CB-1,11,21,25,31; BH-1-12; NP-25,39.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966a), England; Cenomanian - Miocene (Davey, 1969), England, France & U.S.A.; Senonian (Corradini, 1973), Italy; Turonian (Foucher, 1974), France.

Spiniferites ramosus (Ehrenberg) Loeblich & Loeblich 1966
var. *reticulatus* (Davey & Williams, 1966a) Lentin & Williams 1973
Plate 7, Figs 10, 11

1966a *Hystrichosphaera ramosa* var. *reticulata* Davey & Williams p.38, pl.1, figs 2,3

Original description:	Davey & Williams 1966a, p.38		
Holotype:	Davey & Williams 1966a, pl.1, figs 2,3		
Original measurements:	Holotype		Range
	Central body D:	36 × 42 µm	33 - 59 µm
	Process L:	up to 14 µm	up to 17 µm

Description: Ellipsoidal chorate cyst with gonal processes and parasutural crests. Wall two layered; endophragm thin and smooth; periphragm thin and reticulate.

Gonal processes taper distally, trifurcate with bifid tips; joined proximally by low parasutural crests. Reticulate network also visible on the processes and the parasutural crests, although not always clear.

Paratabulation defined as 4′, 6″, 6c, 5-6‴, ?1p, 1⁗, although this is not always complete. Paracingulum helicoidal, offset >1 cingulum width, composed of elongated hexagonal paraplates; parasulcus clearly defined. Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of the third precingular paraplate; operculum free.

Remarks: This variety is very distinctive due to it's noticeable reticulate ornament. It is also rather larger than any of the other variety.

Dimensions:	Cyst L:	40 (49.9) 57 µm
	Cyst W:	37 (42.8) 50 µm
	Process L:	15 (17.8) 22 µm

10 specimens measured.

Occurrence: Rare occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex.

LS-2,4,9,11; DOE-4,13; CB--10,14,21; BH-4; NP-39.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966a), England; Albian and Cenomanian (Davey, 1969), U.S.A and England respectively.

Spiniferites sp.

Plate 7, Fig. 6

Description: Subspherical to ellipsoidal chorate cyst, bearing parasutural crests with gonal and intergonal processes. Wall two layered, peri- and endo-phragm thin and smooth.

Gonal processes tapering, distally trifurcate with bifid tips. Intergonal processes arise from parasutural crests with simple furcate endings.

Paratabulation may be defined as 4′, 6″, 6c, 5-6‴, ?1p, 1⁗; however this is not always discernible. Archaeopyle precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate; operculum free.

Remarks: These specimens of *Spiniferites* were not particularly well preserved. They exhibit enough features to assign them to the genus, however the detail needed for specific identification was not displayed. Therefore these forms are grouped together here.

Dimensions: Cyst L: 37 (40) 46 µm
Cyst W: 35 (37) 39 µm
Process L: 14 (16) 20 µm
10 specimens measured.

Occurrence: Rare to common occurrence in the *T.lata* zone at Dover.
DOE-1,2,2F,3,4,5,7,8,9,9F,10-15

Known stratigraphic range: Members of this genus have a reported stratigraphic range from the Oxfordian (Deflandre, 1937) to the Pleistocene (Fries, 1951).

Genus *Criboperidinium* Neale & Sarjeant 1962; emend.Davey 1969

1978 *Millioudodinium* (Stover & Evitt) Duxbury 1980
1984 *Meristaulax* (Sarjeant) Stover & Williams 1987

Original diagnosis: Neale & Sarjeant 1962, p.443
Emended diagnosis: Davey 1969, p.125
Type Species: *Criboperidinium sepimentum* Neale & Sarjeant 1962

Criboperidinium sp.
Plate 8, Fig. 1

Description: Cyst large, ellipsoidal to subspherical, bearing a prominent apical horn. Wall thin (autophragm), slightly granular. Apical horn broad based and tapering distally to a blunt tip, length approximately 1/5 that of the cyst body length.
Some faint paratabular features are visible, defined by low parasutural crests. These features are longitudinal in orientation and may be growth lines, but could be paratabular, except that no distinct paratabulation can

be discerned. Paracingulum narrow but distinct, defined by low ridges and a depression between; slightly offset. Parasulcus defined by an area of little or no ornament. Archaeopyle enlarged precingular (Type P) formed by the loss of the 3″ paraplate; subrounded in shape. Operculum free.

Remarks: The specimens examined occur infrequently, are poorly preserved and do not exhibit enough paratabular features or ornamental information to assign them to a single species. The large size of the cysts, together with some faint parasutural markings, apical horn and precingular archaeopyle, allow them to be placed within this genus.

Dimensions: Cyst L: 37 (58.2) 82 µm
Cyst W: 35 (54.4) 72 µm
Apical horn L: 7 (9.8) 17 µm

Occurrence: Rare occurrence in the *S.planus* zone at Dover and on the Isle of Wight and in the *T.lata* & *S.planus* zones of Sussex.
LS-25,26,28; CA-8; NP-30; SPT-2,4,5,7; CH-2,3,4,5,9.

Known stratigraphic range: Members of this genus are known to occur from the Late Jurassic - Middle Miocene (*pers. comm.* Dr.R.Davey).

Genus *Endoscrinium* (Klement, 1960) Vozzhennikova 1967

1977 *Athigmatocysta* Duxbury

Original description: Klement 1960, p.18
Emended description: Vozzhennikova 1967, p.174
Type species: *Endoscrinium galeritum* (Deflandre 1937) Vozzhennikova 1967

Remarks: *Endoscrinium* (Klement, 1960) Vozzhennikova 1967 is herein retained as a separate genus to *Scriniodinium* Klement 1957 in agreement with Lentin & Williams (1989). Stover & Evitt (1978) and Jan du Chêne *et al.* (1986) considered *Endoscrinium* to be a junior synonym of *Scriniodinium.* The status of *Endoscrinium* as a junior synonym of *Scriniodinium* is rejected here, on the basis that the former exhibits a complete paratabulation, and the latter only exhibits partial paratabulation. This presence or absence of paratabulation is thought to be a reliable criterion on which to separate taxa at a generic level. There still seems to be some question about the

paratabulation pattern of *Endoscrinium.* There have been quotations in the literature describing the paratabulation of this genus e.g. :

Klement (1960): 3-4′,6″,5‴,0-1p,0⁗

Vozzhennikova (1967): (3-4)a,6np,5zd,(0-1)cp′+0a′

Jan du Chêne *et al.*(1986): "Vozzhennikova 1965 figured a specimen attributed to *Endoscrinium galeritum* (Deflandre, 1937) that seemed to show an antapical paraplate 1⁗."

Specimens observed herein did not exhibit an antapical paraplate, thus the synonomy is rejected. The paratabulation as exhibited by the specimens described here was: ? 3-4′, 5″, 4-5‴, 0⁗. The detail of the apical, paracingular and parasulcal plates was not refined.

Endoscrinium campanula (Gocht, 1959) Vozzhennikova 1967
Plate 8, Fig. 2

1959 *Scriniodinium campanula* Gocht : pp.61-62, pl.5, fig.1

Original description: Gocht 1959, pp.61-62
Holotype: Gocht 1959, pl.5, fig.1
Original dimensions: Holotype

Total L:	104 µm
Total W:	91 µm
Central body L:	74 µm
Central body W:	72 µm
Apical horn L:	16 µm

Description: Cavate, ellipsoidal to polygonal cyst, with an apical horn. Wall two layered, endo- and peri-phragm smooth and thin. Endo- and peri-cyst both ellipsoidal to polygonal in shape, but separated by a cavity of constant width. Apical horn short, blunt and formed of the periphragm only. Antapex subrounded to subangular, but not actually forming a horn. Paratabulation indicated by low parasutural ridges on the periphragm (? 4′, 5″, ? c, ? s, 4-5‴, 0⁗) and by the archaeopyle developed in both wall layers. Paracingulum not well defined. Archaeopyle reduced precingular (Type P); subquadrate in shape, formed by the loss of the 3″ paraplate in both wall layers; operculum free.

Remarks: The holotype figured by Gocht (1959, pl.5, fig.1) shows a slightly different shape and morphology to the paratype (*ibid.*, pl.4, fig.6). From

examination of the specimens here, it is thought they adhere more closely with the morphology of the paratype. However a minority of specimens do exhibit the more globular morphology of the holotype.

Dimensions:	Total L:	67 (83.6) 100 µm
	Total W:	57 (71) 80 µm
	Central body L:	55 (63.9) 77 µm
	Central body W:	48 (54.5) 65 µm
	Apical horn L:	3 (5.5) 12 µm

Occurrence: Rare occurrence in the *T.lata* zone at Dover and sporadic occurrences in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-1-4,6,9,11,18; DOE-2-14; CB1-26,36; CB-11,14,16,18,20,21,23,31,44; HW-6; BH-1-12; NP-2,15,21,25.

Known stratigraphic range: Hauterivian (Gocht, 1959), Germany; Albian - Cenomanian (Cookson & Hughes, 1964), England; Turonian - Coniacian (Foucher, 1976), France; Berriasian - Barremian (Duxbury, 1977), England.

Genus *Gonyaulacysta* Deflandre 1964; emend. Sarjeant 1982b

1966 *Psaligonyaulax* Sarjeant

Original diagnosis: Deflandre 1964, p.5030
Emended diagnosis: Sarjeant 1982, pp.27-28
Type species: *Gonyaulacysta jurassica* (Deflandre, 1938) Norris & Sarjeant 1965; emend. Sarjeant 1982b

Gonyaulacysta cassidata (Eisenack & Cookson, 1960) Sarjeant 1966
Plate 8, Figs 7, 10

1960 *Gonyaulax helicoidea cassidata* Eisenack & Cookson: p.3, pl.1, figs 5-6
1966 *Psaligonyaulax deflandrei* Sarjeant: pp.137-138, pl.14, figs 7-8, text-fig.12

Original description: Eisenack & Cookson 1960, p.3
Emended description: Sarjeant 1966, p.125
Holotype: Eisenack & Cookson 1960, pl.1, figs 5-6

Original dimensions: Holotype

Cyst L:	83 µm
Cyst W:	52 µm

Description: Slightly elongate, bicavate cyst with parasutural membranes. Wall two layered, endophragm smooth; periphragm thin bearing some tubercles. Endocyst spherical to subspherical; pericyst elongated with an apical horn and a blunt antapex. Parasutural membranes with denticulate margins define a gonyaulacacean paratabulation - 4′, 5″, 6c, 6‴, 1⁗. Paracingulum well defined, offset and slightly laevorotatory (Pl.8, Fig.10). Parasulcus elongate, widening posteriorly. Archaeopyle reduced precingular (Type P), subangular in shape; formed by the loss of the 3″ paraplate; operculum free.

Remarks: Jan du Chêne *et al.* (1986) figured line drawings of the species *Gonyaulacysta cassidata* (Eisenack & Cookson, 1960) Sarjeant 1966 and *Psaligonyaulax deflandrei* Sarjeant 1966. The only major difference noted is the size of the antapical pericoel. This being the only difference and the fact that the latter belongs to a monospecific genus, it is here considered to be a junior synonym of *G.cassidata.*

Dimensions:

Central body L:	45 (46) 47 µm
Central body W:	35 (36) 37 µm
Total L:	67 (76) 85 µm
Total W:	40 (40) 40 µm
Apical horn L:	5 (6) 7 µm

Occurrence: Rare occurrence in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* zone of Sussex.
LS-3,4,9,17,18,19,21,22; DOE-2,7; BH-11.

Known stratigraphic range: Aptian - Cenomanian (Eisenack & Cookson, 1960), Australia; Cenomanian (Davey *et al.* 1966), England; Hauterivian (Duxbury, 1977), England; Cenomanian (Below, 1981), Morocco.

Genus *Pterodinium* Eisenack 1958; emend.Jan du Chêne *et al* 1986

Original diagnosis: Eisenack 1958, p.395
Emended diagnosis: Jan du Chêne *et al*, 1986, p.273
Type species: *Pterodinium aliferum* Eisenack 1958

Remarks: The recent generic emendations by Yun (1981) and Sarjeant (1985) are refuted, and that of Jan du Chêne *et al.* 1986 is favoured by the author. *Pterodinium* is shown to be more closely related to the genus *Impagidinium* than *Rhynchodiniopsis* and *Leptodinium* by the presence of a subtriangular 6″ paraplate.

Pterodinium cingulatum (Wetzel, 1933b) Below 1981, var. *cingulatum* (1973)
Plate 8, Figs 5, 8

1933b *Cymatiosphaera cingulata* Wetzel: p.28, pl.4, fig.10
1955 *Hystrichosphaera cingulata* (Wetzel) Deflandre & Cookson: p.267
1958 *Spiniferites pterotus* Cookson & Eisenack: p.50, pl.11, fig.7

Original description: Wetzel 1933b, pl.4, fig.10
Emended description: Below 1981, p.114
Holotype: Wetzel 1933b, pl.4, fig.10
Original measurements: Holotype
Cyst dimensions: 50:42:50 µm

Description: Ellipsoidal to subspherical proximate cyst with parasutural flanges. Wall two layered, endophragm thin and smooth, to slightly granular; periphragm smooth and thin, forming parasutural crests.
Parasutural crests highest in gonal positions, and lowest in mid-gonal positions. Crests may have slightly frilled or entire margins.
Paratabulation gonyaulacacean defined as 4′, 6″, 5-6c, 5‴, 1p, 1⁗, 4s. Paracingulum well defined, composed of elongate to lozenge shaped paraplates; offset >1 paracingulum width and helicoidal. Parasulcal plates discernible, defined by low ridges (Pl.8, Fig.5). Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate. Operculum free.

Remarks: There is some variability in the relative height of the parasutural crests and their distal morphology, however this is thought only to be of intraspecific value.

Dimensions: Cyst L: 35 (43) 57 µm
Cyst W: 30 (38.8) 57 µm
Crest H: 5 (8.5) 12 µm

Occurrence: Rare occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-1-4,6,8,9,11,20; DOE-6; CB1-26-28,36,38; CB-11,16,21,25,29,31,44; BH-1-12; NP-21,25.

Known stratigraphic range: Tertiary (Deflandre & Cookson, 1955), Australia; Eocene (Morgenroth, 1966), Belgium; Cenomanian (Davey, 1969), U.S.A.; Barremian (Davey, 1974), England; Turonian - Campanian (Foucher, 1976), France; Maastrichtian (Foucher & Robaszynski, 1977), Belgium; Hauterivian - Cenomanian (Below, 1981), Morocco.

Pterodinium ?cornutum Cookson & Eisenack 1962
Plate 8, Fig. 9

Original description: Cookson & Eisenack 1962, p.490
Holotype: Cookson & Eisenack 1962, pl.3, figs 1-3

Original dimensions:	Holotype	Range
Overall L:	83 µm	78-86 µm
Overall W:	76 µm	70-76 µm
Cyst L x W:	62 x 48 µm	(52-62) x (48-58) µm

Description: Ellipsoidal to subspherical proximate cyst bearing parasutural crests and a distinct apical horn. Wall two layered; endophragm smooth to slightly granular and thin. Periphragm thin and smooth forming parasutural crests and horn.
Apical horn, short and tapering distally with crests converging at the apex, which is closed and rounded. Parasutural crests are highest in gonal positions, and in between are of slightly lesser heights, with an entire or slightly frilled margin.
Paratabulation gonyaulacacean defined as 4′, 6″, ?5-6c, 5‴, 1p, 1⁗, ?s. Paracingulum well defined by high crests, offset 1 paracingulum width and helicoidal; parasulcus not so well defined. Archaeopyle precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate. Operculum free.

Remarks: The transfer of this species to *Gonyaulacysta* by Yun (1981) is rejected here, on the basis that the nature of the parasutural crests is more similar to that of *Pterodinium* than *Gonyaulacysta,* and although it displays an apical horn, it is tentatively assigned to the former genus.

It differs in it's paratabulation pattern as the parasulcal plates are not as well defined as those of *Pterodinium cingulatum* (Wetzel, 1933b) Below 1981, var. *cingulatum* (1973).

Dimensions:	Cyst L:	35 µm
	Cyst W:	32 µm
	Crest H:	5-7 µm
	Apical horn:	12 µm

Occurrence: Very rare ocurrence in the *T.lata* zone of Dover and Sussex. BH-2,7; DOE-2.

Known stratigraphic range: Aptian - Albian (Cookson & Eisenack, 1962), Australia.

Genus *Stephodinium* Deflandre 1936a; emend. Davey 1970

Original diagnosis: Deflandre 1936a, p.58
Emended diagnosis: Davey 1970, p.347
Type species: *Stephodinium coronatum* Deflandre 1936a, p.58, text-fig. 104

Stephodinium coronatum Deflandre 1936a
Plate 8, Figs 3, 4, 6

1962 *Stephodinium australicum* Cookson & Eisenack: p.491, pl.2, figs 5-10
1964 *Stephodinium europaicum* Cookson & Hughes: p.50, pl.8, figs 9-17

Original description:	Deflandre 1936a, p.58	
Holotype:	Deflandre 1936a, text-fig.104	
Original measurements:	Deflandre 1936b	
	Cyst L (inc. horn)	56 µm
	Cyst W (less ring)	38 µm
	Cyst W (inc. ring)	70 µm

Description: Large subspherical to ellipsoidal camocavate cyst. Endocyst subspherical to ellipsoidal, with a blunt apical horn. Endophragm thick and smooth. Pericyst in contact with endocyst at apices and in the mid-ventral area, with maximum separation in the paracingular region.
Periphragm thin and smooth, thickened along parasutures thus defining the paratabulation. Paratabulation usually incomplete, 4 apical, 6 large precingular paraplates and paracingulum normally visible. Archaeopyle

reduced precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate, developed in both the endo- and peri- cyst; operculum free.

Remarks: This species is most commonly found compressed dorso-ventrally with a paracingular "ring" around the equatorial region. It's distinctive morphology makes it instantly recognisable.

Dimensions:	Central body L:	37 (43.6) 52 µm
	Central body W:	35 (43.2) 48 µm
	Periphragm L:	52 (65.2) 72 µm
	Periphragm W:	25 (32) 48 µm
	Apical horn L:	3.5 (5.4) 6.5 µm

5 specimens measured.

Occurrence: Rare occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex.
DOE-1,8; NP-21; BH-3-6,9.

Known stratigraphic range: Upper Cretaceous flint (Deflandre, 1935), France; ?Cenomanian (Manum & Cookson, 1964), Arctic Canada; Albian - Cenomanian (Davey, 1970), England;

Genus *Hystrichodinium* Deflandre 1935; emend. Clarke & Verdier 1967

1961 *Heliodinium* Alberti

Original diagnosis: Deflandre 1935, pp.17-18
Emended diagnosis: Clarke & Verdier 1967, pp.37-38
Type species: *Hystrichodinium pulchrum* Deflandre 1935, emend. Clarke & Verdier 1967

Remarks: *Hystrichodinium* Deflandre 1935 was originally described as not exhibiting a paratabulation. This is the main distinction from *Heliodinium* Alberti 1961, which exhibits a full paratabulation. In fact *Hystrichodinium* often displays a partial if not complete paratabulation and also has an obvious precingular archaeopyle. Following Clarke & Verdier (1967), who state " From examination of a great number of specimens it cannot any longer be said that *Hystrichodinium* is non-tabulate although this feature is not always clearly displayed." and also "accepting that *Hystrichodinium* possesses tabulation and a precingular archaeopyle its

morphological similarity with *Heliodinium* Alberti becomes readily apparent," *Heliodinium* is considered to be a junior synonym of *Hystrichodinium.*

Hystrichodinium pulchrum Deflandre 1935
Plate 9, Figs 1, 2

Original description:	Deflandre 1935, pp.17-18	
Holotype:	Deflandre 1935, pl.5, fig.1, text-figs 9-11	
Original dimensions:	Holotype	
	Cyst L:	44/55 µm
	Cyst W:	42-48 µm
	Total L:	110-125 µm

Description: Subpolygonal to ellipsoidal chorate cyst, bearing numerous parasutural processes. Epi- and hypo-cyst of equal size. Wall two layered, endophragm smooth to granular with scattered small tubercles; periphragm thin and smooth.

Processes long, hollow and tapering to the tips; often flattened and ribbon-like; arranged along parasutural margins and may be joined proximally by low ridges defining the paratabulation.

Paracingulum distinct and offset; well defined by ridges and concentration of ornament. Archaeopyle reduced precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate; operculum free.

Remarks: *Hystrichodinium pulchrum* Deflandre 1935 was subdivided into three varieties by Deflandre 1936b, with one adhering to the original description, var. *globosum*, distinguished by its smaller size and globular shape and var. *densispinum* which possesses more numerous processes of shorter length. These varieties are here considered to show nothing more than intraspecific variation and are all included under *H.pulchrum.*

Dimensions:	Cyst L:	37 (44.7) 59 µm
	Cyst W:	32 (41.6) 48 µm
	Process L:	17 (22.6) 28 µm

Occurrence: Common occurrence in the *T.lata* zone at Dover and in the LS-2-4,6,11,17,19; DOE-1,2,4-11,13-15; CB1-27,36; CB-16,21,25,31; BH-1-8,11,12; NP-21,25; CH-4,5.

Known stratigraphic range: Upper Cretaceous flint (Deflandre, 1935), France;

Valanginian - Senonian (Gocht, 1959), Germany; Cenomanian - Santonian (Clarke & Verdier, 1967), England.

Hystrichodinium voigtii (Alberti, 1961; emend. Sarjeant, 1966)
Davey 1974
Plate 9, Fig. 3

1961 *Heliodinium voigtii* Alberti: p.33, pl.8, fig.2

Original description:	Alberti 1961, p.33	
Emended description:	Sarjeant 1966, pp.142-143	
Holotype:	Alberti 1961, pl.8, fig.2	
Original dimensions:	Holotype	
	Cyst L:	48 µm
	Cyst W:	38 µm
	Process L:	16-22 µm

Description: Subpolygonal to ellipsoidal chorate cyst bearing flattened blade-like processes and parasutural crests. Epi- and hypo-cyst of equal size with square apex and antapex. Wall two layered, endophragm smooth to finely granular; periphragm thin and smooth.
Processes blade-like, tapering distally arising from what may be parasutural membranes. Parasutural membranes strongest in the paracingular area, and paratabulation not well defined in other areas. Paracingulum distinct, defined by parallel membranes; helicoidal, offset one cingulum width. Archaeopyle reduced precingular (Type P) subrounded in shape; formed by the loss of the 3″ paraplate; operculum free. The archaeopyle is not always obvious.

Remarks: Backhouse (1988, p.91) suggested *Hystrichodinium voigtii* (Alberti, 1961; emend. Sarjeant, 1966) Davey 1974, may be a junior synonym of *Hystrichodinium oligacanthum* Deflandre & Cookson 1955, as it possesses a similar number of processes and it's morphology is generally similar. This cannot be commented upon here as no specimens thought to be *H.oligacanthum* were observed. *H.oligacanthum* is characterised by fewer processes which are concentrated on the lower rim of the girdle (Cookson & Eisenack, 1955). Whatever the taxonomic status of these two species, they are both distinct from *H.pulchrum* which does not have such well developed parasutural membranes in the paracingular region and is ornamented.

Dimensions:	Cyst L:	40 (45.3) 55 µm
	Cyst W:	35 (40.1) 47 µm
	Process L:	17 (21.5) 25 µm

10 specimens measured.

Occurrence: Rare occurrence in the *T.lata* zone of Dover and Sussex. LS-22; CB-11,44.

Known stratigraphic range: Early Barremian - ?Early Aptian(Alberti, 1961), Germany; Cenomanian (Sarjeant, 1966), England.

Genus *Xiphophoridium* Sarjeant 1966

1967 *Pyramidium* Clarke & Verdier, p.182

Original diagnosis: Sarjeant 1966, pp.146-147
Type species: *Xiphophoridium alatum* (Cookson & Eisenack, 1962) Sarjeant 1966

Xiphophoridium alatum (Cookson & Eisenack, 1962) Sarjeant 1966
Plate 9, Figs 4, 6

1962 *Hystrichodinium alatum* Cookson & Eisenack: pp.487-488, pl.2, fig.1
1967 *Pyramidium alatum* Clarke & Verdier: p.40

Original description: Cookson & Eisenack 1962, pp.487-488
Holotype: Cookson & Eisenack 1962, pl.2, fig.1
Original measurements:

	Holotype	Range
Overall L:	125 µm	100 - 120 µm
Overall W:	96 µm	92 - 100 µm
Shell D:	70 x 52 µm	

Description: Spherical to subspherical cyst, bearing flanges which are developed into processes. Wall two layered; endophragm smooth with tubercles. Periphragm thin and smooth.
Parasutural flanges well developed, and processes arise from them. Processes slender, tapering, and closed distally. Paratabulation not easily discernible, except the paracingulum which is well defined. Archaeopyle not observed in these specimens.

Remarks: *Xiphophoridium alatum* (Cookson & Eisenack, 1962) Sarjeant 1966 is similar to *Hystrichodinium pulchrum* but can be distinguished on the basis of its parasutural flanges, and its apical archaeopyle. However, this feature was not noted in the specimens examined herein.

Dimensions:	Cyst D:	50 (50.6) 52 µm
	Flange H:	10 (11.2) 12 µm
	Max. process L:	20-25 µm
	5 specimens measured	

Occurrence: Rare occurrence in the *T.lata* zone of Dover and in the *M.labiatus* & *T.lata* zones of Sussex.
LS-9,30; BH-4,6,11,12.

Known stratigraphic range: Albian - Cenomanian (Cookson & Eisenack, 1962), Australia; Cenomanian (Sarjeant, 1966), England; Turonian (Foucher, 1974), France.

4.4.9 Gi Morphogroup

Genus *Callaiosphaeridium* Davey & Williams 1966b; emend. Duxbury 1980

1967 *Hexasphaera* Clarke & Verdier

Original diagnosis: Davey & Williams 1966b, p.103
Emended diagnosis: Duxbury 1980, p.113
Type species: *Callaiosphaeridium asymmetricum* (Deflandre & Courteville, 1939) Davey & Williams 1966b

Callaiosphaeridium asymmetricum
(Deflandre & Courteville, 1939) Davey & Williams 1966b
Plate 9, Figs 5, 7, 8

1939 *Hystrichosphaeridium asymmetricum* Deflandre & Courteville: p.100, pl.4, fig.12.
1967 *Hexasphaera asymmetrica* Clarke & Verdier: pp.42-44, pl.7, figs 1-3, text-fig.17

Original description: Deflandre & Courteville 1939, p.100
Emended description: Davey & Williams 1966b,

p.104.Holotype: Deflandre & Courteville 1939, pl.4, figs 1,2

Original dimensions: Holotype

Cyst D:	40 µm
Process L:	22-34 µm

Description: Cyst spherical to subspherical in shape, bearing six tubular, paracingular processes and simple gonal processes in the apical and antapical areas. Wall two layered; both endo- and peri-phragm thin and smooth. Paracingular processes hollow and tubular, open distally, terminating with spines; intratabular. Pre- and post-cingular processes simple, bifid distally, connected by basal parasutural membranes of varying height.

Paratabulation indicated by these parasutural membranes and the paracingular processes, is typically gonyaulacacean - 6 paracingular plates (Pl.9, Figs 7,8), 5 postcingular plates, with a single, hexagonal antapical paraplate (Pl.9, Fig.5). Archaeopyle epicystal (Type $\overline{AP}$), the margin occurring just above the paracingular processes; operculum not seen.

Remarks: All of the specimens examined were of the hypocyst only; the epicyst was not observed. The unusual nature of the paracingular processes (tubular with recurved distal spines, and the simple bifid gonal processes linked by parasutural membranes) makes this species distinctive from all others. The generic emendation by Duxbury (1980) is accepted here as it allows for some variation in the height of the parasutural crests in the epi- and hypo-cystal areas.

Dimensions:

Cyst D:	35 (39.3) 50 µm
Process L:	15 (21.5) 27 µm
Process W:	7 (12) 15 µm

15 specimens measured.

Occurrence: Sporadic occurrence in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.

LS-2,3,8,9,11; DOE-2,4,7,11,14,15; CB-16,18,21,33; BH-1-6,11,12; CA-4,5; NP-21.

Known stratigraphic range: Turonian - Senonian (Deflandre & Courteville, 1939), France; Hauterivien - Early and Middle Barremian (Davey & Williams, 1966b), England; Albian - Turonian and Cenomanian (Davey, 1969), England &

U.S.A. respectively; Maastrichtian (Kjellström, 1973), Sweden.

Genus *Litosphaeridium* Davey & Williams 1966b; emend.
Lucas-Clark 1984

Original diagnosis: Davey & Williams 1966b, pp.79-80
Emended diagnosis: Lucas-Clark 1984, pp.181-182
Type species: *Litosphaeridium siphoniphorum* (Cookson & Eisenack, 1958) Davey & Williams 1966b

Remarks: The most recent generic emendation by Lucas-Clark (1984) is favoured here, as it supercedes that of Davey & Verdier (1973) in terms of the detailed discussion of the genus and its problems.

Litosphaeridium sp. cf. *L.siphoniphorum*
Davey & Williams 1966b; emend. Lucas-Clark 1984 var. *siphoniphorum*
Lucas-Clark 1984
Plate 14, Figs 9, 11

1958 *Hystrichosphaeridium siphoniphorum* Cookson & Eisenack: p.44, pl.11, figs 8-10

Original description: Cookson & Eisenack 1958. p.44
Emended description: Lucas-Clark 1984, p.186
Holotype: Cookson & Eisenack, pl.11, fig.8
Original dimensions: Holotype

Overall D:	76 µm
Shell D:	43 µm
Process L:	19 - 24 µm

Description: Spherical to subspherical chorate cyst, bearing intratabular hollow processes. Wall two layered, endophragm and periphragm closely adpressed except at the base of the processes. Both are ornamented, the periphragm granular to reticulate, and endophragm more finely granular.
Processes subcylindrical in shape, tapering slightly distally, being almost conical. Process tips truncated with a well defined rim, and open ended.
Paratabulation reflected by the processes, there being one process per paraplate, thus defining 6 precingular, 6 postcingular and a single antapical paraplate. Paracingular and parasulcal processes absent.

Archaeopyle apical (Type $\overline{tA}$); operculum free.

Remarks: The specimens observed were rarely found and are thought possibly to be reworked from the Cenomanian. Frequently they were not very well preserved, but did exhibit the salient features of this taxonomic division, except that they were of a much smaller size generally. The range of the diameter of the central body from Davey (1969) is 21 (34) 47 µm, confirming this. Therefore they are tentatively placed within this variety.

Dimensions:	Cyst L:	25 (23.5) 27 µm
	Cyst W:	22 (23.2) 25 µm
	Process L:	12-15 µm
	Process W:	5-7 µm

5 specimens measured.

Occurrence: Very rare occurrence in the *T.lata* zone at Dover and the *M.labiatus* & *T.lata* zones of Sussex.
LS-24; DOE-4,13; HW-2,4,5; BH-1.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966b), England; Albian - Cenomanian (Davey, 1969), England, France & U.S.A.; Cenomanian - Turonian (Lucas-Clarke, 1984), U.S.A.

Litosphaeridium "chlidanum" Marshall 1983
Plate 14, Fig. 6

Original description:	Marshall 1983, p.80-82	
Holotype:	Marshall 1983, pl.13, figs 16-18, text-fig.18	
Original dimensions:		Range
	Cyst D:	36 - 49 µm
	Max. process L:	18 - 26 µm

Description: Chorate cyst, spherical to subspherical in shape, bearing intratabular processes. Wall two layered, endo- and peri- phragm both thin and smooth.
Processes tubular, expanded sharply and then parallel distally, open ended, with a finely denticulate margin.
Reflected tabulation is not easily discerned, except that there are no paracingular processes, but 5-6 precingular, 5 postcingular, 1 posterior intercalary, and a single antapical paraplate are defined. Archaeopyle

apical (Type $\overline{tA}$) operculum free.

Remarks: The specimens examined were not very well preserved and it was difficult to discern the paratabulation precisely. This species is thought to be an important marker, defining the base of the Turonian by its disappearance.

Dimensions: Cyst D: 25 (32.2) 37 x 25 (27.6) 32 µm
Process L: 12 (15.8) 20 µm
Process W: 7 (9.8) 12 µm

Occurrence: Rare occurrence in the lowest part of the *M.labiatus* zone in Sussex.
HW-7,8,9,11.

Known stratigraphic range: Latest Cenomanian (Marshall & Batten, 1988), England & Germany; Latest Cenomanian (Duane, 1992), England.

Genus *Florentinia* Davey & Verdier 1973; emend. Duxbury 1980

1976 *Silicisphaera* Davey & Verdier

Original diagnosis: Davey & Verdier 1973, pp.185-186
Emended diagnosis: Duxbury 1980, p.119
Type species: *Florentinia laciniata* Davey & Verdier 1973

Remarks: Davey & Verdier (1976) (Text-fig.5) figured a species of *Silicisphaera* Davey & Verdier 1976 bearing a large antapical process, thus invalidating the original diagnosis which states "the antapical process is not distinctive or particularly large." The emendment of the generic diagnosis by Duxbury (1980) permits the inclusion of forms with an indistinct antapical horn. Duxbury (1980) further considered " the variability of the antapical process to be an intrageneric feature." Thus *Silicisphaera* effectively becomes a junior synonym of *Florentinia.* Yun (1981) continued to separate the two genera on the basis that " this genus (*Florentinia*) can be distinguished from *Silicisphaera* by a single marked antapical process." The proven variability of the processes of *Florentinia* makes this an unreliable feature, so the emendation by Duxbury (1980) is followed here.

Florentinia buspina (Davey & Verdier, 1976) Duxbury 1980
Plate 10, Figs 7, 8; Plate 11, Figs 1, 2

1976 *Silicisphaera buspina* Davey & Verdier: pp. 321-322, pl.2, fig.15, text-fig.13
1981 *Florentinia miscella* Yun: pp.49-51, pl.6, figs 7, 13-14, pl.8, fig.15, text-fig.13

Original description:	Davey & Verdier 1976, p.321-322	
Emended description:	Duxbury 1980, p.121	
Holotype:	Davey & Verdier 1976, pl.2, figs 1-3	
Original dimensions:	Holotype	
	Cyst D:	46 × 57 µm
	Process L:	up to 22 µm

Description: Cyst spherical to subspherical, bearing large paratabular processes. Wall thick, two-layered; endophragm rough and densely granular; periphragm thin and smooth.
Processes are hollow, variable in size and may be simple, bifurcate, trifurcate or complex. Process width varies considerably, but length is more constant. Largest, most complex processes occupy the postcingular region. Antapical process indistinct.
Reflected tabulation gonyaulacacean, defined by one process per paraplate - 4′, 6″, ?6c, 5‴. Archaeopyle reduced precingular (Type P), formed by the loss of the 3″ paraplate. Accessory archaeopyle sutures between the apical and precingular paraplate series may be developed to reveal existence of precingular paraplates 2″ and 4″. Operculum free.

Remarks: *Florentinia miscella* Yun 1981 is thought to be a junior synonym of this species as it bears processes of variable size and complexity; the largest and most complex occupying the postcingular region; thus being similar to *Florentinia buspina* (Davey & Verdier, 1976) Duxbury 1980.

Dimensions:	Cyst L:	35 (45.2) 47 µm
	Cyst W:	30 (47.2) 50 µm
	Process L:	10 (14.2) 24 µm
	Process W:	12 (17) 22 µm

Occurrence: Common occurrences in the *T.lata* zone at Dover and sporadic occurrences in the *M.labiatus, T.lata* & *S.planus* zones of Sussex and the

Isle of Wight.
LS-1-4,7-9,11,13,16,17,20; DOE-1,3,4,6,8,10-15; CB1-26,36; CB-15,16,29,31, 41,45; HW-6,7; BH-1-9,11,12; CA-2,12; NP-21.

Known stratigraphic range: Turonian - Senonian (Davey & Verdier, 1976), France.

Florentinia deanei (Davey & Williams, 1966b) Davey & Verdier 1973
Plate 10, Figs 1-6

1966b *Hystrichosphaeridium deanei* Davey & Williams: p.58, pl.6, figs 4,8
1967 *Hystrichosphaeridium stellatum* Maier in Clarke & Verdier: p.55, pl.12, fig.2

Original description:	Davey & Williams 1966b, pp.58-59	
Emended description:	Davey & Verdier 1973, p.187	
Holotype:	Davey & Williams 1966b, pl.6, fig.8	
Original dimensions:	Holotype	
	Cyst D:	46 × 47 µm
	Antapical process L:	35 µm
	Antapical process W:	31 µm
	Process L:	15-30 µm

Description: Chorate, spherical to subspherical cyst, bearing intratabular processes. Wall two-layered, endophragm smooth; periphragm slightly granular.
Processes of unequal size (length and width) and different morphology. Pre- and post-cingular processes usually broad based and tapering; tubular, closed distally with serrate margins. Apical processes are simple, slender and lagenate. Paracingular processes are similar but not as slender; parasulcal processes fine. Antapical process usually enlarged, subconical, and may be open or closed distally.
Reflected tabulation gonyaulacacean defined by the processes - 4′, 6″, 6c, 5‴, 1⁗. Archaeopyle combination (apical and precingular), Type AP; formed by the loss of the 3″ paraplate, and the apical series. Apical series of paraplates may be partially detached from the precingular series by the development of accessory archaeopyle sutures. Operculum free or attached.

Remarks: The specimen of *Hystrichosphaeridium stellatum* Maier figured by

Clarke & Verdier (1967) (pl.12, Fig.2) is undoubtedly *Florentinia deanei* (Davey & Williams, 1966b) Davey & Verdier 1973, by the nature of it's processes. However, examination of the original description and the figured specimens do not confirm that all the original specimens of *H.stellatum* should be junior synonyms of *Florentinia deanei.*

A few of the specimens observed here and assigned to this species, exhibit extreme development of the processes, such that they are very broad and cylindrical (Pl.10, Figs 5,6). They are similar to *Hystrichokolpoma unispinum* Williams & Downie 1966, but this species is restricted to the Eocene and so these specimens have been included within *F.deanei.* Davey & Verdier (1976) suggested that *F.deanei* and *H.unispinum* appear to be identical and therefore synonymous. However, before such a change could be made it would be necessary to examine the type specimens of Williams & Downie.

Florentinia deanei differs from *F. buspina* (Davey & Verdier, 1976) Duxbury 1980 by exhibiting simple tubular processes and usually an enlarged antapical process. The latter has complex processes which bi or trifurcate, terminating in an acuminate "crown", and does not possess a distinctive antapical process.

Dimensions: Cyst D: 27 (36.9) 52 × 25 (37.8) 57 µm
Process L: 7 (23.2) 30 µm
Process W: 5 (9.2) 20 µm

Occurrence: Common occurrences in the *T.lata* & *S.planus* zones at Dover and sporadic occurrences in the *M.labiatus, T.lata* & *S.planus* zones of Sussex and the Isle of Wight.

AS-13,17; LS-1-4,6,9,15-17,19-21,23-27; DOE-1,2,4,5,8,9,12-15; CB1-26,32,36; CB-1,2,10,1116,18,21,24,25,28,31,44,45; HW-4,5; SO-8; BH-1-9,12; NP-21; SPT-2,3,5.

Known stratigraphic range: Eocene (Davey & Williams, 1966b), England; Late Albian - Coniacian (Davey & Verdier, 1976), France.

Florentinia aff.*ferox* (Deflandre, 1937) Duxbury 1980
Plate 11, Figs 5, 6

1937 *Hystrichosphaeridium ferox* Deflandre: p.72, pl.14, figs 3,4
1963 *Baltisphaeridium ferox* (Deflandre) Downie & Sarjeant: p.91
1969 *Hystrichokolpoma ferox* (Deflandre) Davey: p.159

Original description: Deflandre 1937, p.72
Holotype: Deflandre 1937, pl.14, figs 3,4
Original dimensions: Holotype

Cyst D:	46 µm
Cyst W:	36 µm
Total L:	78 µm
Process L:	15-17 µm

Description: Spherical to subspherical chorate cyst, bearing variable closed paratabular processes. Wall two layered, endo-phragm granular and peri-phragm smooth and thin.

Processes hollow, dividing medially into finger-like tapering projections. Largest processes occupying pre- and post-cingular positions. Narrower, slender, simple processes define the paracingulum and parasulcus. Antapical process large and distinct.

Paratabulation defined by intratabular processes - 4′, 6″, 6c, 5‴, 1⁗. Archaeopyle precingular (Type P) formed by the loss of paraplate 3″; operculum free.

Dimensions:

Cyst D:	45 (46) 50 µm
Process L:	12-15 µm

6 specimens measured

Occurrence: Rare occurrence in the *M.labiatus* & *T.lata* zones of Dover and Sussex.

DOE-12,13,15; AS-62; LS-1,4; BH-1,9.

Known stratigraphic range: Early - Middle Turonian (Davey & Verdier, 1976).

Florentinia torulosa (Davey & Verdier, 1976) Lentin & Williams 1981

Plate 11, Figs 3, 4

1976 *Silicisphaera torulosa* Davey & Verdier: pp.328-330, pl.10, fig.11

Original description: Davey & Verdier 1976, pp.328-330
Holotype: Davey & Verdier 1976, pl.10, fig.11
Original dimensions: Holotype

Cyst D:	57 × 58 µm
Process L:	up to 18 µm

Description: Chorate, spherical to subspherical cyst, bearing distinctive paratabular processes. Wall two layered and thick, endophragm densely granular; periphragm thin and slightly granular.
Processes are hollow, of similar shape and morphology, but differ in size. Pre- and post-cingular processes are broadbased and taper distally, terminating in a blunt, rounded, closed manner (almost pyramidal in shape). Other processes are narrower, but of the same nature.
Reflected tabulation defined by this process arrangement gonyaulacacean - 4′, 6″, ?c, 5‴, 1⁗. Archaeopyle appears to be reduced precingular (Type P) but is not always observed. Operculum free.

Remarks: This species is very distinctive and unlike others of the genus because of the rounded appearance of the processes.Lentin & Williams (1989) tentatively assigned *Florentinia torulosa* (Davey & Verdier, 1976) Lentin & Williams 1981 to this genus. It is treated here as a *bona fide* member of this genus as it fulfills the required criteria by having intratabular processes of a variable morphology and a precingular archaeopyle.

Dimensions: Cyst D: 42 (47.8) 62 × 38 (47.2) 57 µm
Process L: 10 (12.8) 17 µm
Process W: 15 (19.4) 27 µm

Occurrence: Common occurrence in the *T.lata* zone of Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-2,3,4; AKS-2/6; DOE-2,6,7,11,12; CB1-36; CB-16,18,21,31; BH-2-6,8,9,12.

Known stratigraphic range: Turonian - Senonian (Davey & verdier, 1976), France.

Florentinia sp.
Plate 11, Figs 7, 8

Description: Spherical to subspherical chorate cyst bearing paratabular processes. Wall apparently two layered, endophragm smooth to slightly granular; periphragm thin and smooth forming processes. Processes tubular, parallel sided, closed distally with a slightly digitate margin. Paratabulation defined by processes, one per paraplate. Archaeopyle precingular (Type P), formed by the loss of the 3″ paraplate. Operculum free.
Remarks: Forms thought to show the main characteristics of the genus, but

which exhibited few specific characteristics clearly have been assigned here.

Dimensions:	Cyst D:	35 (36) 37 µm
	Process L:	11 (12) 13 µm
	2 specimens measured	
Occurrence:	Rare occurrence in the *T.lata* zone of Dover. DOE-2,9	

Known stratigraphic range: Members of this genus are known to occur from the Barremian - Maastrichtian (Davey & Verdier, 1976).

Genus *Hystrichosphaeridium* Deflandre 1937; emend. Davey & Williams 1966b

Original diagnosis: Deflandre 1937, p.68
Emended diagnosis: Davey & Williams 1966b, pp. 55-56
Type species: *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) Deflandre 1937, emend. Davey & Williams 1966b

Remarks: The generic emendation of Davey & Williams (1966b), and their reallocation of species to different genera based on the type of archaeopyle, paratabulation, number and type of processes and the cyst shape, has been very important for the advancement of taxonomic classification and subdivision of the dinoflagellates as a group.

Hystrichosphaeridium bowerbankii Davey & Williams 1966b
Plate 12, Figs 1-4

Original description:	Davey & Williams 1966b, pp.69-70	
Holotype:	Davey & Williams 1966b, pl.8, fig.4	
Original dimensions:	Holotype	
	Total D:	85 × 78 µm
	Central body D:	39 × 29 µm
	Process L:	24-26 µm

Description: Subspherical to ellipsoidal, elongated chorate cyst, bearing paratabular hollow processes. Wall two layered, endophragm smooth; periphragm thin and smooth.

Processes tubular, parallel sided, open distally, terminating in recurved spines. A circular marking is noticeable where the processes join the cyst body. Wall layers conformable except at the base of the processes, where they separate.

Paratabulation gonyaulacacean defined by the process arrangement - 4′, 6″, 6-7c, 5-6‴, 1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$) with an irregular margin and free operculum.

Remarks: *Hystrichosphaeridium bowerbankii* Davey & Williams is similar to *Hystrichosphaeridium recurvatum* (White); emend. Davey & Williams 1966b, in general morphology but the latter is smaller in size.

Dimensions:	Cyst L:	27 (31.5) 37 µm
	Cyst W:	20 (29.3) 40 µm
	Process L:	17 (23.5) 27 µm
	Spine L:	3 (4.7) 7 µm

Occurrence: Common and persistent occurrences in all areas in the *M.labiatus, T.lata & S.planus* zones.

AS-13,14,15,22,24,27,29-32,38,40,42,43,46,48-50,53,57,61,62; LS-1-4,6,7,8,9, 11,12-17,19-31; AKS-2/1,2/2,2/4,2/6; DOE-1,4-15; CB1-26,27,28,32,34,38; CB-1,2,11,15,16,23-25,27-31,33,41-45; MR-8,19,27; HW-7,8,9,15; SO-1,15; BH-1-9; CA-2-13; NP-1-11,13,15-36,38; SPT-1-7; CH-1-3,5,6,8,9,10.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966b), England; Albian, Cenomanian - Turonian (Davey, 1969), England.

Hystrichosphaeridium conispiniferum Yun 1981

Plate 12, Figs 5, 6

Original description:	Yun 1981, pp.30-31
Holotype:	Yun 1981, pl.2, fig.4
Original dimensions:	Holotype
Cyst D:	42 (47) 51 µm
Process L:	39 µm
Process W - distally:	4 (5) 6 - 7.5 (8.5) 9 µm
Process W - base:	5 (7.8) 12 - 15 (16.5) 18 µm

Description: Spherical to subspherical chorate cyst, bearing elongate conical processes. Wall two layered, endophragm thin and smooth; periphragm

thin and smooth forming the processes. Processes hollow, broad based, tapering distally with open ends. Processes may reflect a paratabulation - 4′, 6″, 6-7c, 5‴, 1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$); operculum free.

Remarks: The specimens observed here resemble those described by Yun (1981), characterised by the process morphology, but are not as distinctly conical and have narrower bases. The processes are not of a normal tubular or cylindrical form. This species is distinguished by it's process morphology.

Dimensions:	Cyst L:	22 (28.2) 32 µm
	Cyst W:	22 (28.3) 37 µm
	Process L:	15 (19.3) 25 µm
	10 specimens measured.	

Occurrence: Sporadic occurrences in the *M.labiatus* & *T.lata* zones at Dover and in the *M.labiatus, T.lata* & *S.planus* zones of Sussex.
AS-13,19; DOE-2,5,8; HW-2-5,7-13; SO-1,4,7,9-12,18,20,24-26; BH-1,2; CA-4,5; NP-1,2,9,13,15,18,40; CH-5.

Known stratigraphic range: Early Maastrichtian (Zaitzeff & Cross, 1970), U.S.A.; Santonian (Yun, 1981), Germany.

Hystrichosphaeridium tubiferum (Ehrenberg, 1838) Deflandre 1937,
var. *tubiferum* emend. Davey & Williams 1966b
Plate 12, Fig. 7

1838 *Xanthidium tubiferum* Ehrenberg: pl.1, fig.16
1904 *Ovum hispidum (X.tubiferum)* Ehrenberg: Lohmann: p.21
1933b *Hystrichosphaera tubifera* (Ehrenberg) O.Wetzel: p.40, pl.4, fig. 16
1937 *Hystrichosphaeridium tubiferum* (Ehrenberg) Deflandre: p.68
1940 *Hystrichosphaeridium tubiferum* (Ehrenberg) Lejeune-Carpentier: p.218, figs 1-4

Original description:	O.Wetzel 1933b, p.40	
Emended description:	Davey & Williams 1966b, pp.56-58	
Holotype:	Ehrenberg 1838, pl.1, fig.16	
Original dimensions:	Holotype	
	Cyst D:	33 × 34 µm
	Process L:	27 - 29 µm

Description: Spherical to subspherical chorate cysts, bearing hollow intratabular processes. Wall two layered, endophragm thin and smooth; periphragm thin and smooth to slightly granular. Processes tubular, expanding distally, forming a denticulate margin. Paracingular and parasulcal processes usually more slender. Reflected tabulation typically gonyaulacacean - 4′, 6″, 6c, 5‴, 1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho; with a zig-zag margin and sometimes short accessory notches. Archaeopyle margin indicates the camerate and planate nature of the precingular paraplates. Operculum free.

Remarks: Forms sometimes attributed to *Hystrichosphaeridium tubiferum* (Ehrenberg) in the past have been incorrectly assigned e.g. Deflandre 1937 pl.12, fig.14; pl.13, figs 2,14. The original diagnosis was very broad and so encompassed much variability in process morphology and number. The most recent emendation (Davey & Williams, 1966b) is quite specific and these problems should not arise so easily in future.

Dimensions:	Cyst L:	26 (32) 39 µm
	Cyst W:	27 (31) 33 µm
	Process L:	19 (22) 27 µm

Occurrence: Sporadic occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* zones of Sussex.
LS-2,4,11,23,25; AKS-2/2; DOE-1,4,7,8,10-13; HW-12,13.

Known stratigraphic range: Eocene (Davey & Williams, 1966b), England; Albian - Turonian and Cenomanian (Davey, 1969) of England and France respectively.

Hystrichosphaeridium tubiferum (Ehrenberg) var. *brevispinum*
(Davey & Williams, 1966b) Lentin & Williams 1973
Plate 12, Fig. 8

Original description:	Davey & Williams 1966b, p.58	
Emended description:	Lentin & Williams 1973, p.80	
Holotype:	Davey & Williams 1966b, pl.10, fig.10	
Original dimensions:	Holotype	
	Central body D:	32 × 36 µm
	Process L:	up to 11 µm
	Process W:	up to 11 µm

Erratum: This species was recorded in the material discussed, however after subsequent discussion the specimen figured is thought to be incorrectly assigned.

Description: Spherical to subspherical chorate cysts, bearing hollow intratabular processes. Wall two layered, endophragm thin and smooth; periphragm thin and smooth to slightly granular. Processes tubular, expanding distally, forming a denticulate margin. Paracingular and parasulcal processes usually more slender. Reflected tabulation typically gonyaulacacean - 4′, 6″, 6c, 5‴, 1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho; with a zig-zag margin and sometimes short accessory notches. Archaeopyle margin indicates the camerate and planate nature of the precingular paraplates. Operculum free.

Remarks: Forms sometimes attributed to *Hystrichosphaeridium tubiferum* (Ehrenberg) in the past have been incorrectly assigned e.g. Deflandre 1937 pl.12, fig.14; pl.13, figs 2,14. The original diagnosis was very broad and so encompassed much variability in process morphology and number. The most recent emendation (Davey & Williams, 1966b) is quite specific and these problems should not arise so easily in future.

Dimensions:	Cyst L:	26 (32) 39 µm
	Cyst W:	27 (31) 33 µm
	Process L:	19 (22) 27 µm

Occurrence: Sporadic occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* zones of Sussex.
LS-2,4,11,23,25; AKS-2/2; DOE-1,4,7,8,10-13; HW-12,13.

Known stratigraphic range: Eocene (Davey & Williams, 1966b), England; Albian - Turonian and Cenomanian (Davey, 1969) of England and France respectively.

Hystrichosphaeridium tubiferum (Ehrenberg) var. *brevispinum*
(Davey & Williams, 1966b) Lentin & Williams 1973
Plate 12, Fig. 8

Erratum: This species was recorded in the material discussed, however after subsequent discussion the specimen figured is thought to be incorrectly assigned.

Central body D:	32 × 36 µm
Process L:	up to 11 µm
Process W:	up to 11 µm

Description: Chorate cyst, spherical to subspherical in shape, bearing tubular, paratabular processes. Wall two layered, endo- and peri-phragm both thin and smooth.

Processes short, tubular, expanding and open distally, terminating in a serrate margin. Process length remains constant but the width varies, the narrower ones occupying positions of smaller paraplates.

Paratabulation gonyaulacacean defined by the process arrangement, one per paraplate - 4′, 6″, ?6c, 5‴, 1⁗ . Archaeopyle apical (Type A) formed by the loss of the apical series of paraplates, with the development of some accessory notches. Operculum free.

Remarks: *Hystrichosphaeridium salpingophorum* (Deflandre) Davey & Williams 1966b is similar to *Hystrichosphaeridium tubiferum* (Ehrenberg) subsp. *brevispinum* (Davey & Williams, 1966b) Lentin & Williams 1973, but the latter is large with fewer, relatively shorter processes. The suggestion by Below (1982) that this species is a junior synonym of *?Dapsilidinium fucosum* (Valensi, 1955) Davey & Williams 1969 is rejected here on the basis that the processes observed are expanded distally with a denticulate margin whereas those of *?D.fucosum* are more cylindrical with a less serrated margin. The holotype was described from the Early Eocene (Davey & Williams, 1966b) and is extended dramatically by being recorded in this study.

Dimensions:	Cyst L:	30 (37) 50 µm
	Cyst W:	30 (34.7) 42 µm
	Process L:	12 (14.7) 17 µm
	Process W:	5 (14.9) 18 µm

10 specimens measured.

Occurrence: Sporadic occurrences in the *M.labiatus* & *T.lata* zones at Dover and in the *M.labiatus, T.lata* & *S.planus* zones of Sussex.

AS-11,30,41,43; SO-4,5,6,9,15,26; NP-1,2,4,5,6,7,8,9,10,12,20; SPT-2,4; CH-9

Known stratigraphic range: Eocene (Davey & Williams, 1966b), England; Campanian - Maastrichtian (May, 1980), U.S.A.

Genus: *Oligosphaeridium* Davey & Williams 1966b; emend. Davey 1982

Original diagnosis: Davey & Williams 1966b, pp.70-71

Emended diagnosis: Davey 1982, p.13

Type species: *Oligosphaeridium complex* (White, 1842) Davey & Williams

1966b

Remarks: The main feature separating forms of this genus from *Hystrichosphaeridium* Deflandre 1937, Davey & Williams 1966b, is that the cysts do not reflect a complete paratabulation, as the paracingular and parasulcal plates are not represented by intra-tabular processes.

Oligosphaeridium complex (White, 1842) Davey & Williams 1966b
Plate 13, Figs 1, 2

1842 *Xanthidium tubiferum complex* White: p.39, pl.4, fig.11
1940 *Hystrichosphaeridium elegantulum* Lejeune-Carpentier: p.222, text-figs 11-12

Original description:	White 1842, p.39	
Emended description:	Davey & Williams 1966b, pp.71-74	
Holotype:	White 1842, pl.4, fig.11 (lost)	
Neotype:	Davey & Williams 1966b, pl.7, fig.1	
Original dimensions:	Neotype	
	Central body D:	35 × 35 µm
	Process L:	22 - 25 µm

Description: Chorate cyst, spherical to subspherical in shape, bearing 14 processes (without operculum). Wall two layered, composed of thin, smooth endo- and peri-phragm.
Processes tubular, tapering and then expanding, opening distally to form an aculeate or secate margin.
Reflected tabulation gonyaulacacean although the para-cingulum and -sulcus are not represented; 4′, 6″, 0c, 6‴, ?1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho in shape; operculum free. Accessory sutures developed between the precingular paraplates. Free opercula often observed.

Remarks: *Oligosphaeridium complex* (White, 1842) Davey & Williams 1966b can be distinguished from *Oligosphaeridium asterigerum* by it's non-parallel tubular processes and the gradual expansion of their distal tips at > 90° to the shaft of the processes.

Dimensions: Cyst body L: 27 (34.5) 48 µm
Cyst body W:27 (33.9) 42 µm

Process L: 27 (31.8) 35 µm

Occurrence: Common, persistent occurrences in all areas in the *M.labiatus, T.lata & S.planus* zones.
AS-4,5,7,8,11,13-15,17,26-41,43,45-54,56,57,59-62; LS-1-4,6,7,8,9,11,12-31; AKS-2/1,2/4,2/6; DOE-1,2,5,6,7,9-14; CB1-26,32-34,36,38; CB-2,10,11,16-34, 41-44; MR-8,9,13,21,27,28,29; HW-4-9,11,13-16; SO-1,3-26; BH-1-9,11,12; CA-2-14; NP-1-20,22-36,38-40,42,43,45; SPT-1-7; CH-1-6,8-10.

Known stratigraphic range: Senonian (White, 1842), England; Barremian - Eocene (Davey & Williams, 1966b), England; Valanginian - Barremian (Duxbury, 1977), England.

Oligosphaeridium sp. cf. *O.complex* (White, 1842) Davey & Williams 1966b
Plate 13, Figs 3, 5

1842 *Xanthidium tubiferum complex* White: p.39, pl.4, fig.11
1940 *Hystrichosphaeridium elegantulum* Lejeune-Carpentier: p.222, text-figs 11-12

Original description:	White 1842, p.39	
Emended description:	Davey & Williams 1966b, pp.71-74	
Holotype:	White 1842, pl.4, fig.11 (lost)	
Neotype:	Davey & Williams 1966b, pl.7, fig.1	
Original dimensions:	Neotype	
	Central body D:	35 × 35 µm
	Process L:	22 - 25 µm

Description: Spherical to subspherical chorate cyst bearing approximately 14 processes (without operculum). Wall two layered; endophragm thin and smooth to slightly granular; periphragm thin and smooth forming the processes.
Processes broad based, tubular and open distally, tapering medially and then expanding. Distal margins frilled or aculeate.
Reflected tabulation gonyaulacacean, but both para-cingulum and -sulcus are not represented. Configuration is 4′, 6″, 0c, 6‴, ?1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho in shape, with a zig-zag margin; operculum free. Accessory sutures often developed between the precingular paraplates.

Remarks: This form is similar to *O.complex*, but the processes are shorter and stouter and sometimes of unequal length. The general nature of the processes and the cyst shape make it very like the aforementioned species.

Dimensions:	Cyst body L:	27 (33) 37 µm
	Cyst body W:	25 (33.5) 40 µm
	Process L:	15 (23.2) 27 µm
	Process W-base:	5 (7.25) 10 µm

Occurrence: Rare occurrence in the *T.lata* zones of Dover and Sussex. LS-30,31; NP-31,32

Known stratigraphic range: This rare species occurs only sporadicaly throughout the Turonian.

Oligosphaeridium poculum Jain 1977
Plate 13, Figs 4, 6

Original description:	Jain 1977, p.181	
Holotype:	Jain 1977, pl.1, figs 1-3	
Original dimensions:	Holotype	
	Cyst D:	80 µm
	Process H:	6 µm
	Process W- distal:	up to 24 µm
	Process W- proximal:	up to 16 µm

Description: Proximo-chorate cyst, spherical to subspherical in shape, bearing paratabular processes. Wall two layered, both endo- and peri-phragm thin and smooth. Wall layers adpressed except at the base of the processes where they separate.
Processes are vasiform (Pl.13, Fig.4), being much narrower proximally than distally. Distal extremities expanded and open with a denticulate margin (Pl.13, Fig.6). Basal contact of the processes with the cyst body sharply defined by a small circular marking.
Paratabulation gonyaulacacean, defined as 4′, 6″, 0c, 6‴, ?1p, 1⁗. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho in shape; operculum free.

Remarks: The unusual process morphology distinguishes this species from all others of the same genus.
This species has previously been described from Early Cretaceous sediments. It's occurrence here extends the range somewhat into the Late Cretaceous,

although it is not a frequent component of the assemblages.

Dimensions: Cyst body L: 30 (36.7) 45 µm
Cyst body W: 37 (43) 55 µm
Process L: 5 (8.1) 10 µm
Process W: 12 (16.8) 22 µm
10 specimens measured.

Occurrence: Rare occurrences in the *T.lata* zone at Dover and in the *M.labiatus, T.lata* & *S.planus* zones of Sussex.
LS-6,30; HW-11,12; SO-5; NP-2,4,16; ; SPT-1,5; CH-9

Known stratigraphic range: Early Albian (Jain, 1977), southern India.

Oligosphaeridium prolixispinosum Davey & Williams 1966b
Plate 13, Fig. 7

Original description: Davey & Williams 1966b, pp.76-77
Holotype: Davey & Williams 1966b, pl.8, fig.3
Original dimensions: Holotype
Central body D: 40 × 20 µm
Process L: 18 - 24 µm

Description: Elongate chorate cyst, bearing paratabular processes. Wall two layered, endo- and peri- phragm both thin and smooth. Wall layers conformable except where they separate at the bases of the processes.
Processes tubular, tapering slightly and then expanding distally to form 5 to 6 delicate spines (Pl.13, Fig.7). Basally processes form a circular contact with the cyst body.
Paratabulation gonyaulacacean, appears to be (4′),6″, ?c, 6‴, 1p, 2⁗, and sometimes slender sulcal processes are present. Archaeopyle apical (Type $\overline{tA}$), tetra-ortho in shape; with accessory notches sometimes displayed in the margin. Operculum free.

Remarks: *Oligosphaeridium prolixispinosum* Davey & Williams 1966b has processes of similar morphology to those of *H.bowerbankii*, except they are fewer in number and the distal spines are much longer in the former.

Dimensions: Cyst body L: 30 (36.1) 50 µm
Cyst body W: 12.5 (23.8) 27 µm

Process L: 22 (23) 27 µm
Spine L: 5 (9.4) 19 µm

Occurrence: Sporadic occurrences in all zones in Dover and Sussex and in the *T.lata* zone on the Isle of Wight.
AS-18-21,23,48,49,52; LS-2-4,17,22-24,27,29; DOE-1,3,4,6,10; CB-2,10,16,21, 23,40,41,43; MR-8; BH-1,2,4,6,8,12; CA-2,3,5,12-14; NP-2,3,5-8,17-22; SPT-2-4,7; CH-2,3,6.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966b), England; Pre- Cenomanian - Middle Turonian (Robaszynski *et al.*, 1980), France.

Genus *Kleithriasphaeridium* Davey 1974

1976 *Diversispina* Benson

Original diagnosis: Davey 1974, pp.55-56
Type species: *Kleithriasphaeridium corrugatum* Davey 1974

Remarks: *Diversispina* Benson 1976 is clearly a junior synonym of *Kleithriasphaeridium* Davey 1974, by the intratabular, fibrous nature of the processes and the precingular archaeopyle.

Kleithriasphaeridium readei (Davey & Williams, 1966b) Davey & Verdier 1976
Plate 13, Fig. 8

1966b *Hystrichosphaeridium readei* Davey & Williams: pp.64-65, pl.6, fig.3

Original description: Davey & Williams 1966b, pp.64-65
Emended description: Davey & Verdier 1976, p.314
Holotype: Davey & Williams 1966b, pl.6, fig.3
Original dimensions: Holotype
Cyst D: 41 × 45 µm
Process L: 23 - 29 µm

Description: Chorate cyst, spherical to subspherical, bearing intratabular processes. Wall two layered, endophragm smooth and thin; periphragm fibrous and thin forming the processes.
Processes tubular, of varying width (the widest occupying the postcingular

and antapical positions), expanding distally with an aculeate margin. Processes may appear striated; this is due to their fibrous nature. Some thickened ribs or fibres connect adjoining processes by extending from the base of one process to the next.
Paratabulation gonyaulacacean, though this is not always discernible: 4′,6″,6c,5‴,1p,1⁗,xs. Parasulcal processes fine and slender. Archaeopyle precingular (Type P), pentagonal in shape; formed by the loss of the 3″ paraplate. Operculum free.

Remarks: *Kleithriasphaeridium readei* (Davey & Williams, 1966b) Davey & Verdier 1976 can be easily distinguished from other gonyaulacacean chorate cysts by the fibrous nature of the processes. Davey & Verdier (1976) noted "it is always obvious that no ribs radiate from the processes surrounding the archaeopyle to the archaeopyle margin and presumably to the third precingular process." This feature was not apparent on the specimens observed here.

Dimensions:	Cyst L:	30 (38.8) 50 µm
	Cyst W:	30 (37.3) 42 µm
	Process L:	20 (26.1) 32 µm
	Process W:	3-10 µm

Occurrence: Sporadic occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *S.planus* zones of Sussex and the Isle of Wight.
LS-1-4,9; DOE-1,4,8,9,11-14; CB1-15,18,21,24,25; CB-15,18,21,24,25; BH-1-4,6-9,12; NP-21,25.

Known stratigraphic range: Late Cenomanian (Davey & Williams, 1966b), England; Senonian (Davey & Verdier, 1976), France.

4.4.10 Gn Morphogroup

Genus *Cleistosphaeridium* Davey *et al.* 1966

1984 *Laticavodinium* Wilson and Sarjeant

Original diagnosis: Davey *et al.* 1966, p.166.
Type species: *Cleistosphaeridium diversispinosum* Davey *et al.* 1966

Cleistosphaeridium sp. cf. *armatum* (Deflandre, 1937) Davey 1969
Plate 14, Fig. 5

1937 *Hystrichosphaeridium armatum* Deflandre: pp.76-77, pl.16, figs 6,7
1967 *Baltisphaeridium armatum* Clarke & Verdier, pp.71-72, pl.13, fig.3

Original description:	Deflandre 1935, pp. 76-77	
Emended description:	Davey 1969, pp.153-154	
Holotype:	Deflandre 1937, pl. 16, fig. 6	
Original dimensions:	Holotype	
	Cyst L:	25 µm
	Cyst W:	18 - 20 µm
	Process L:	10 - 15 µm

Description: Small, spherical to subspherical cyst bearing numerous non-tabular "blade like" processes. Wall of average thickness (layers not discernible) and granular in appearance. Processes hollow, flattened and erect; taper distally to a point, and are usually $^1/_2$ the cyst diameter Paratabulation absent. Archaeopyle apical (Type tA) but this feature is rarely observed.

Remarks: As this species is rarely observed with an archaeopyle it is difficult to orientate specimens. This lack of an obvious archaeopyle necessitates a provisional placement within this species. This species of *Cleistosphaeridium* can be distinguished from the others by the erect "blade-like" nature of its processes.

Dimensions:	Cyst D:	20 (29.4) 37 x 17 (27.4) 37 µm
	Process L:	7 (10.3) 15 µm
	10 specimens measured.	

Occurrence: Common persistent occurrence in all zones at Dover and sporadic occurrences in all zones in Sussex and on the Isle of Wight. AS-4,5,11,13,14,15,17,19,20,21,23,27,29,31,35,38,41 42,44-48,52,54-62; LS-1,11,12,18,19,20,26; AKS-2/2; DOE-8; CB1-36; CB-15,16,33; MR-13; HW-1,2,11; SO-5,9,15,22; BH-5; NP-9,15,21,22,30,32; SPT-2.

Known stratigraphic range: Cenomanian (Davey 1969), England & France.

Cleistosphaeridium clavulum (Davey, 1969) Below 1982
Plate 14, Fig. 2

1969 *Cleistosphaeridium polypes* var. *clavulum* Davey: p.154, pl.6, figs 9-10

1973 *Cleistosphaeridium polypes* var. *clavulum* Lentin & Williams: p. 30

Original description: Davey 1969, p. 154
Emended description: Below 1982, p. 154
Holotype: Davey 1969, pl. 6, fig. 9
Original dimensions: Holotype
Cyst D: 29 × 32 µm
Process L: 12 - 13 µm

Description: Small cyst spherical to subspherical, bearing numerous non-tabular processes (about 30 in number). Wall thin, smooth to slightly granular, layers not discernible. Processes solid, slender, and flexuous, terminating in capitate tips. Paratabulation absent.
Archaeopyle apical (Type tA) but rarely observed. Operculum free.

Remarks: This species of *Cleistosphaeridium* is distinguished from the others by the "pin head" like nature of the process tips (Pl.14, Fig.2) It's taxonomic status has been increased from variety to subspecies, and then to a specific level by independent re-examinations by Lentin & Williams (1973) and Below (1982) respectively.

Dimensions: Cyst D: 30 (35.8) 47 x 30 (33.4) 40 µm
Process L: 12 - 13 µm
Occurrence: Rare occurrence in the *M.labiatus* & *T.lata* zones of Sussex and more persistent occurrences in the *T.lata* & *S.planus* zones of the Isle of Wight.
CB-2,10,11,15,16,18,21,22,31,41-45; MR-12,13; HW-9; SO-5,11,12; NP-1,2,3,9

Known stratigraphic range: Cenomanian (Davey, 1969), England.

Cleistosphaeridium multispinosum (Singh, 1964) Brideaux 1971
Plate 14, Fig. 1

1964 *Baltisphaeridium multispinosum* Singh: pp.141-142, pl. 20, figs 1-2

1969 *Cleistosphaeridium aciculare* Davey: p.158, pl.6, figs 11,12

Original description:	Singh 1964, pp. 141-142	
Emended description:	Brideaux 1971, p. 93	
Holotype:	Singh 1964, pl. 20, figs 1-2	
Original dimensions:	Holotype	
	Cyst D:	41 µm
	Process L:	10 µm

Description: Cyst spherical to ellipsoidal, bearing numerous non-tabular processes. Wall thin, smooth to finely granular apparently formed of a single layer.

Processes solid, slender and tapering; closed distally and sometimes bifurcate close to the tips. Process length approximately $^1/_3$ of cyst body diameter. Processes are densely and randomly packed on the cyst surface and may be slightly flexuous.

All indications of paratabulation absent. Archaeopyle apical (Type tA); however this is rarely observed. Often the only indication of an archaeopyle is a split, which might be interpreted as an archaeopyle suture.

Remarks: The form *Cleistosphaeridium aciculare* Davey 1969 was commented upon by Brideaux 1971 as being a partial synonym of *Cleistosphaeridium multispinosum* (Singh, 1964), the process morphology, size and dimensions being consistent and comparable with the latter. It is felt that these two species could in fact be treated as one, and synonomised on the basis of their unquestionable similarity. This is the treatment being followed herein; however further detailed examination of the holotypes would be necessary to confirm this.

This species of *Cleistosphaeridium* is unlike other species because the processes may divide at the tips in a splayed manner.

Dimensions:	Cyst D:	30 (37) 47 x 32 (34.3) 50 µm
	Process L:	10 (12.4) 15 µm
Davey 1969	Cyst D:	32 (43) 54 µm
	Process L:	8 (13.9) 21 µm
Brideaux 1971	Cyst D:	18 - 59 (min.) x 24 - 59 (max.) µm
	Process L:	3 - 16 µm

Occurrence: Common occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus, T.lata* & *S.planus* zones of Sussex and the Isle of

Wight.
LS-1-4,8,9,12-17,22-27; AKS-2/1-2/5,2/7; DOE-1-15; CB1-26,27,32,36,38; CB-1,2,10,11,13-21,23,24,25,27,29,31,33,41; MR-1,7,8,9,13,18,21,28,29; HW-2,3,4,6,7; SO-6,12,14,15; BH-1-6,8,9,10,12; CA-2,3,4,7-13; NP-1,2,4-9,12,13,15-22,24-30,32-38,40,42-45; SPT-2-5,7; CH-1,3,4,5.

Known stratigraphic range: Middle Albian (Singh, 1964), Canada; Middle - Late Albian (Brideaux, 1971), Canada; Albian - Cenomanian (Davey, 1969), U.S.A.

Genus *Coronifera* Cookson & Eisenack 1958; emend. May 1980

Original diagnosis: Cookson & Eisenack 1958, p.45
Emended diagnosis: May 1980, p.48
Type species: *Coronifera oceanica* Cookson & Eisenack 1958; emend. May 1980.

Remarks: The emended generic diagnosis of May (1980) is favoured as he assumed the precingular paraplate "appears to be the main excystment aperture as it is generally missing, while the apical plate is generally only dislodged". As other authors have described a combination archaeopyle, this is a reasonable criterion to include it. Davey (1974) emended the original diagnosis to permit the presence of a precingular archaeopyle and suggested a combination archaeopyle. Shaozi and Norris (1988) also described the genus with a variable archaeopyle type, but essentially these only represent stages of a combination archaeopyle's development (Type AP). The main archaeopyle is thought to be formed by the loss of a precingular paraplate; the apical paraplates may be involved in the formation of a secondary opening which is not always apparent.

Coronifera oceanica Cookson & Eisenack 1958; emend. May 1980
Plate 14, Figs 4, 7

1964 *Coronifera monstruosa* Tasch *et al.* : p.195, pl.1, fig. 12

Original diagnosis: Cookson & Eisenack 1958, p.45
Emended diagnosis: May 1980, pp.48-49
Holotype: Cookson & Eisenack 1958, pl.12, fig. 6

Original dimensions: Holotype

Cyst D:	57 × 48 µm
Antapical process L:	17 µm

Description: Subspherical to ellipsoidal cyst, bearing numerous non-tabular processes and a distinctive antapical process. Wall thin, two layered. Endophragm smooth, periphragm forming numerous processes and low membranes giving the cyst a "wrinkled" appearance.
Processes solid; morphology variable from simple, slender tapering or acuminate forms, to those which are bifurcate or trifurcate.
Proximally, processes are connected by low membranes (?parasutural). Apical process distinctive, branched distally, and often larger than the other processes. Antapical process very distinctive, being large and tubular with a denticulate margin (Pl.14, Fig.7) No indication of parasulcus or paracingulum. Paratabulation indicated by the archaeopyle and antapical process. Archaeopyle reduced precingular (Type P), formed by the loss of the third precingular paraplate (3″) Operculum free.

Remarks: The specimens examined herein possessed a precingular archaeopyle and did not exhibit the combination (Type Aa + P) archaeopyle described by May (1980). It may be that the primary archaeopyle is precingular, and there is a secondary stage when the apical portion is lost. This may reflect natural variation within the species, or an ecophenotypic effect within the population. Other authors (Shaozi & Norris, 1988) have also observed a combination archaeopyle, but in morphological detail the specimens are the same as those described with precingular archaeopyles only. The unique and distinctive morphology of this species argues for taxonomic continuity unless it can be proved otherwise.

Dimensions:

Cyst diameter L:	27 (36.6) 47 µm
Cyst diameter W:	22 (35) 42 µm
Antapical process L:	12 (15.9) 22 µm
Antapical process W:	5 (5.8) 12 µm

10 specimens measured

Occurrence: Sporadic occurrences in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones in Sussex.
DOE-6,8,15; HW-3,6; BH-4,7.

Known stratigraphic range: Albian (Cookson & Eisenack, 1958), Australia;

Turonian - Campanian (Foucher, 1976), France; Campanian - Maastrichtian (May, 1980), U.S.A.; Hauterivian - Cenomanian (Below, 1982), Morocco.

Genus *Dapsilidinium* Bujak *et al.* 1980

1966b *Polysphaeridium* Davey & Williams

Original diagnosis: Bujak *et al.* 1980. pp.27-28
Type species: *Dapsilidinium pastielsii* (Davey & Williams, 1966b) Bujak *et al.* 1980

Dapsilidinium laminaspinosum (Davey & Williams, 1966b)
Lentin & Williams 1981
Plate 14, Figs 8, 10

1966b *Polysphaeridium laminaspinosum* Davey & Williams: pp.94-95, pl.8, fig.8
Original description: Davey & Williams 1966b, pp.94-95
Holotype: Davey & Williams 1966b, pl.8, fig.8
Original Dimensions: Holotype
Cyst D: 27 × 27 μm
Process L: 11-15 μm

Description: Chorate cyst, spherical to subspherical, bearing numerous (about 30) flattened non tabular processes. Wall two layered; endophragm thin & smooth, periphragm forming the cylindrical processes.
Processes hollow, cylindrical but flattened with open ends and entire margins (Pl.14, Fig.8). Proximal processes form a characteristic circular marking on the cyst body. Distal processes splay into distal endings (Pl.14, Fig.10).
Indications of paratabulation absent. Archaeopyle apical (Type $\overline{tA}$), with accessory sutures, rarely seen. Operculum free.

Remarks: Davey & Williams 1966b calculated upon finding a six sided archaeopyle and that there were two processes per paraplate. The specimens observed here did not exhibit processes with any apparent relationship to a paratabulation pattern However they showed some regular arrangement and it is possible they reflect the paratabulation. On this basis this genus is placed in the Gonyaulacaceae and into the informal grouping Gn of Evitt

(1985).

Dimensions: Cyst D: 22 (28.1) 35 x 22 (26.9) 35 µm
Process L: 7 (15.4) 22 µm
Process W: 2.5 (2.8) 5 µm

Occurrence: Sporadic occurrences in all areas in the *M.labiatus, T.lata* & *S.planus* zones.
AS-13,22,43,53,57,61,62; LS-4,16,22,24; DOE-1,2,3,5,8,9; CB-11,13,15,16, 17,20,21,29,31,33,41,42,44; MR-27,28; HW-2,4,6,8; SO-4,15,16,22; BH-4-6; CA-6,7,9; NP-1-3,6,7,9-18,20,27,29,30,34; SPT-2,3,4,7; CH-3.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966b), England.

Genus *Kiokansium* Stover & Evitt 1978; emend. Duxbury 1983

Original diagnosis: Stover & Evitt 1978, p.167
Emended diagnosis: Duxbury 1983, pp.48-49
Type species: *Kiokansium polypes* (Cookson & Eisenack, 1962) Below 1982; emend. Duxbury 1983

Kiokansium polypes (Cookson & Eisenack, 1962) Below 1982; emend. Duxbury 1983
Plate 14, Fig. 3

1962 *Hystrichosphaeridium recurvatum* var. *polypes* Cookson & Eisenack: p.491, pl.4, fig.11
1969 *Cleistosphaeridium polypes* (Cookson & Eisenack) Davey: p.159, figs 7,8
1979a *Bacchidinium polypes* (Cookson & Eisenack) Davey: p.555, pl.1, fig.7

Original description: Cookson & Eisenack 1962, p.491
Emended description: Duxbury 1983, p.49
Holotype: Cookson & Eisenack 1962, pl.4, figs 11-13
Original dimensions: Holotype
Cyst D: 50 × 54 µm
Process L: 15 - 25 µm

Description: Spherical to subspherical cyst bearing numerous solid processes. Wall thought to be single layered and rough. Processes non-tabular, solid and tapering distally, terminating in a minute division

(looks like a "pinhead").
Paratabulation absent, except perhaps along the paracingulum where processes may be aligned. Archaeopyle precingular (Type 2P) formed by the loss of two precingular paraplates. Operculum free.

Remarks: *Kiokansium polypes* (Cookson & Eisenack, 1962) Below 1982; emend. Duxbury 1983 is similar in it's process morphology to *Cleistosphaeridium ?multispinosum* (Singh, 1964) Brideaux 1971, but they can be easily distinguished on the basis of their archaeopyle types.

Dimensions:	Cyst L:	35 (39) 42 µm
	Cyst W:	32 (35.5) 40 µm
	Process L:	12 (12.9) 15 µm
	10 specimens measured.	

Occurrence: Sporadic occurrences in the *T.lata* zone in all areas.
LS-1,7; CB-2,10; SO-14; BH-2; NP-7,17,22.

Known stratigraphic range: Albian - ?Cenomanian (Cookson & Eisenack, 1962), Australia; Hauterivian - Aptian (Below, 1982), Morocco; Aptian - Early Albian (Duxbury, 1983), England.

Genus: *Pervosphaeridium* Yun 1981

Original diagnosis: Yun 1981, pp.26-27
Type species: *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937) Yun 1981

Pervosphaeridium sp. cf. P. *pseudhystrichodinium* (Deflandre, 1937) Yun 1981
Plate 14, Fig. 13

1937 *Hystrichosphaeridium pseudhystrichodinium* Deflandre: p.25, pl.15, figs 3,4
1965 *Baltisphaeridium pseudhystrichodinium* Downie & Sarjeant: p.95
1969 *Exochosphaeridium pseudhystrichodinium* Davey *et al.* : pp.16-17

Original description: Deflandre 1937, p.25
Holotype: Deflandre 1937, pl.15, fig.3
Original dimensions: Holotype

Cyst D:	38 × 45 µm
Cyst L - processes:	49 × 54 µm
Total L:	80 × 90 µm

Description: Medium sized spherical to subspherical cyst bearing numerous non-tabular processes. Wall thick (3µm), probably two-layered; endophragm smooth; periphragm thick.

Processes of uniform length and morphology, connected basally by thickenings along the cyst surface, almost forming a reticulation. Processes tapered with acuminate terminations. Apical process distinctive and branched distally with a bifid termination.

Paratabular features absent. Archaeopyle precingular (Type 2P), formed by the loss of paraplates 3″ and 4″ (both camerate in shape). Operculum free.

Remarks: The specimens observed rarely displayed the typical 2P archaeopyle, thus making their inclusion in this species doubtful. However, their general morphology was similar enough to allow their tentative assignment here.

Dimensions:		
	Cyst L:	47 (50.9) 62 µm
	Cyst W:	42 (48.9) 60 µm
	Process L:	8 (12.1) 15 µm

Occurrence: Common to very common occurrences in all zone sat Dover and more sporadic occurrences in the *M.labiatus* & *T.lata* zones of Sussex and on the Isle of Wight.

AS-11,13,17,44,45,48,49,52,53,55-62; LS-1-8,9,12,13,22,27,29; AKS-2/2,-2/5,2/7; DOE-1-15; CB1-26,27,32,33,36; CB-10,11,18,20,21,22,23,31; MR-5,6,7; HW-1,2,4,8; BH-1-4,6-9; NP-17-21,24,25,30-32,34,36.

Known stratigraphic range: Late Cretaceous flint (Deflandre, 1937), France; Danian (Wetzel, 1952), Germany; Late Albian (Davey & Verdier, 1973), France.

Pervosphaeridium monasteriense Yun 1981

Plate 14, Fig. 12

Original description:	Yun 1981, pp.27-28	
Holotype:	Yun 1981, pl.5, fig.3	
Original measurements:	Holotype	Range
Cyst D:	50 x 60 µm	46 (50) 57 x 42 (43.5) 63 µm

Process L: upto 36 µm 42 (53.5) 63 µm

Description: Medium sized, spherical to subspherical cyst bearing numerous nontabular processes. Wall thick (3µm) and two layered, endophragm smooth. Periphragm forms processes which are joined basally by thickened ribs.
Processes taper distally, with blunt tips. Basal ribs (3 or 4) radiate from the base of the processes across the cyst body (Pl.14, Fig.12).
Paratabular features absent, except the precingular archaeopyle. Archaeopyle (Type 2P) formed by the loss of paraplates 3″ and 4″ (both camerate in shape). Operculum free.

Remarks: *Pervosphaeridium monasteriense* Yun 1981, differs from *Pervosphaeridium* sp. cf. P. *pseudhystrichodinium* by having blunt processes, a more strongly ribbed periphragm and always a distinct archaeopyle.

Dimensions:	Cyst L:	47 (58.6) 70 µm
	Cyst W:	45 (54.5) 75 µm
	Process L:	12 (16.1) 22 µm

Occurrence: Rare occurrences in the *T.lata* zone at Dover and in the *M.labiatus* & *T.lata* zones in Sussex.

LS-2-4; HW-6; BH-2-8,11,12.

Known stratigraphic range: Cenomanian - Santonian (Yun, 1981), Europe & Canada.

Genus *Heterosphaeridium* Cookson & Eisenack 1968; emend. Yun 1981

Original diagnosis: Cookson & Eisenack 1968, p.115
Emended diagnosis: Yun 1981, pp.45-46
Type species: *Heterosphaeridium conjunctum* Cookson & Eisenack 1968

Heterosphaeridium difficile (Manum & Cookson, 1964) Ioannides 1986
Plate 15, Figs 1, 3

1964 *Hystrichosphaeridium difficile* Manum & Cookson: pp.12-14, pl.3, figs 1-3, 7

Original description: Manum & Cookson 1964, p.12-14
Emended description: Ioannides 1986, p.24
Holotype: Manum & Cookson 1964, pl.3, fig.1

Original dimensions: Holotype

Cyst D:	91 µm
Process L:	25 µm

Description: Subspherical to spherical chorate cyst, bearing large non-tabular processes. Wall thick, two layered, endophragm smooth; periphragm finely reticulate.

Processes of constant length, but vary considerably in width; tubular in shape, expanding distally to form an everted irregularly serrated margin. Proximally the processes may be connected by "ribs" or thickenings on the periphragm. Processes are fibrous in nature and may be fenestrate to a greater or lesser extent, the fenestrations being elongate to oval in shape. Processes do not appear to reflect a tabulation as they number about 30 and are irregularly placed. Archaeopyle margin indicates the presence of 6 precingular paraplates.

Archaeopyle apical (Type $\overline{tA}$), tetra-ortho in shape; with well developed accessory sutures; operculum free (Pl.15, Fig.3).

Remarks: This is one of the few Turonian index species, appearing throughout the sequence but with variable abundances. It is a distinctive and useful marker.

Dimensions:

Cyst L:	33 (48.2) 62 µm
Cyst W:	37 (52.3) 65 µm
Process L:	7.5 (13.6) 22 µm
Process W:	10 (15.5) 20 µm

Occurrence: Common to very common occurrences in all areas in the *M.labiatus* & *T.lata* zones becoming more sporadic in the *S.planus* zone. An influx has been noted in the *T.lata* zone.

AS-7,11,12,30,31,32,34,35,36,39-42,47,48,54,55,58,59; LS-3,8,9,10,24,27,29; AKS-2/1,2/6; DOE-1-7,9; CB1-36; CB-2,16,18-29,31,33,34,41-44; MR-8,9,11,27,28; HW-1-6,11; SO-1,4-6,9,11,15-26; BH-2,3,5,6,11,12; CA-2-5,7,9,12-14; NP-1-4,7,8,10-22,24,26,29,30,32,34,35; SPT-2; CH-5,9.

Known stratigraphic range: Late Cretaceous (Manum & Cookson, 1964), Arctic Canada; Albian - Cenomanian (Davey, 1969), U.S.A.

Heterosphaeridium heteracanthum (Deflandre & Cookson, 1955)
Eisenack & Kjellström 1971
Plate 15, Fig. 2

1955 *Hystrichosphaeridium heteracanthum* Deflandre & Cookson: p.276, pl.2, figs 5-6, text-figs 40-41
1963 *Baltisphaeridium heteracanthum* Downie & Sarjeant: p.91
1966 *Cleistosphaeridium heteracanthum* Davey *et al.* :p.168

Original description:	Deflandre & Cookson 1955, p.276	
Emended description:	Eisenack & Kjellström 1971, p.451	
Holotype:	Deflandre & Cookson 1955, pl.2, fig.5	
Original dimensions:	Holotype	
	Cyst D:	56-107 µm
	Process L:	5-36 µm

Description: Spherical to subspherical proximo-chorate cyst, bearing numerous non-tabular processes. Wall thick, two layered; endophragm granular, periphragm thin and smooth forming the processes.

Process morphology variable; solid short processes with acuminate, bifid or digitate tips. Process length approximately $^{1}/_{5}$ of cyst diameter. No alignment or arrangement of processes reflecting tabulation; processes are uniformly distributed over the cyst surface. Archaeopyle apical (Type $\overline{tA}$) with a relatively straight margin and sulcal notch. Operculum free.

Remarks: The assignment of this form to *Cleistosphaeridium heteracanthum* Davey *et al.* 1966 is rejected here on the basis of its large size and variable ornament, following Eisenack & Kjellström 1971.

Dimensions:	Cyst L:	37 (48.1) 57 µm
	Cyst W:	40 (56.1) 62 µm
	Process L:	10 (12.9) 16 µm

Occurrence: Common occurrences in the *M.labiatus* & *T.lata* zones in all areas, with sporadic occurrences in the *S.planus* zone of Sussex.
AS-4,5,9,19,26,33,36,38,41,48,56-58; LS-1; AKS-2/1-2/5; DOE-1-3,5,7,9,11-14; CB1-26,27,28,33,34,36,38; CB-2,11,15,18,21,31,33,41,44; HW-2,4-13,15,16; SO-1,3-26; NP-1-20,23,24,36,40,42.

Known stratigraphic range: Senonian, Palaeocene - Eocene (Deflandre &

Cookson, 1955), Australia; Cenomanian (Sarjeant, 1966), England.

Genus *Exochosphaeridium* Davey *et al.* 1966

Original diagnosis: Davey *et al.* 1966, p.165
Type species: *Exochosphaeridium phragmites* Davey *et al.* 1966

Exochosphaeridium sp. cf. *E. arnace* Davey & Verdier 1973
Plate 15, Figs 5, 8

Original description: Davey & Verdier 1973, p.184
Holotype: Davey & Verdier 1973, pl.1, figs 3, 6
Original dimensions: Holotype
Cyst L: 45 µm
Cyst W: 36 µm
Process L: 10 - 15 µm

Description: Cyst spherical to subspherical, bearing numerous fine processes which are connected proximally. Wall thick and hard to define into one or two layers. Wall surrounded by a diffuse zone of a fibrous nature from which the fine processes arise.
Processes fine and acuminate, solid, tapering distally with closed tips. Apical process distinctive, longer than the others; branched distally into first order members. Paratabulation defined only by the archaeopyle - ? enlarged precingular (Type P), subangular in shape; formed by the loss of a mid-dorsal paraplate (probably 3″). Operculum free.

Remarks: The specimens described here are compared with *Exochosphaeridium arnace* Davey *et al.* 1966 as the processes are of a finer nature and the diffuse zone is rather broader than in the original description and figure.

Dimensions: Cyst L: 37 (44) 50 µm
Cyst W: 37 (43.3) 50 µm
Process L: 10 (12.8) 17 µm
10 specimens measured.

Occurrence: Sporadic occurrences in the *S.planus* zone at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight, with some occurrences being recorded in the *S.planus* zone of Sussex.
LS-20,23-25; DOE-4,12-15; CB-10,16,18,31,33,41,44,45; HW-4;
BH-2,3,5,6,8,9,11; NP-25.

Known stratigraphic range: Cenomanian (Clarke & Verdier, 1967), England; Late Albian (Davey & Verdier, 1973), France.

Exochosphaeridium phragmites Davey *et al.* 1966
Plate 15, Fig. 6

Original description: Davey *et al.* 1966, pp.165-166
Holotype: Davey *et al.* 1966, pl.2, figs 9, 10
Original dimensions: Holotype
Cyst D: 49 × 56 µm
Process L: up to 22 µm

Description: Cyst spherical to subspherical, bearing numerous non-tabular processes. Wall two layered, endophragm smooth and thick; periphragm granular.
Processes slender, bifurcating medially and terminating distally in a point, or truncated with a blunt tip. Apical process distinct, digitate distally and longer than the other processes. Paratabulation defined only by the archaeopyle and the alignment of processes along the dorsal paracingulum.
Archaeopyle ?enlarged precingular (Type P), subangular in shape; formed by the loss of the 3″ paraplate. Operculum free.

Remarks: *Exochosphaeridium phragmites* Davey *et al.* 1966 is considered to be easily distingiushed from *E.arnace* as the latter exhibits a dense, diffuse zone from which the fine processes arise and *E.phragmites* lacks such a zone and posses processes of a more discrete and different nature.

Dimensions: Cyst L: 35 (40.1) 52 µm
Cyst W: 30 (36.2) 43 µm
Process L: 14 (16.9) 20 µm
10 specimens measured

Occurrence: Sporadic occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus, T.lata* & *S.planus* zones in Sussex.
LS-4,6,8,9,11,13,17,18,20,29,31; DOE-1-4,6-9,11; CB-16,28,31; BH-1-9,11,12; CA-2; NP-21,25,27; CH-4-6.

Known stratigraphic range: Cenomanian (Davey *et al.*, 1966), England; Albian - Cenomanian (Davey, 1969), England; Senonian (Corradini, 1973), Italy; Turonian (Foucher, 1974), France.

4.4.11 Gx Morphogroup

Genus *Apteodinium* (Eisenack, 1958); emend. Lucas-Clark 1987

Original diagnosis: Eisenack 1958, p.386
Emended description: Lucas-Clark 1987, p.168
Type species: *Apteodinium granulatum* Eisenack 1958

Apteodinium deflandrei (Clarke & Verdier, 1967);
emend. Lucas-Clark 1987
Plate 15, Fig. 4

1967 *Gardodinium deflandrei* Clarke and Verdier: pp.26-28, pl.3, figs 10-12; text fig. 10
1978 *Aldorfia deflandrei* Stover and Evitt: p.140
Original description: Clarke & Verdier 1967, pp.26-28
Emended description: Lucas-Clark 1987, pp.172-174
Holotype: Clark & Verdier 1967, pl.3, fig.10
Original dimensions: Holotype

Central body L:	52 µm
Central body W:	40 µm
Apical horn L:	8 µm

Description: Cyst small, ellipsoidal to ovoidal with a short apical horn. Wall consists of two layers: ectophragm smooth; periphragm formed of a discontinuous spongy layer, giving the cyst outline a "fuzzy" appearance.
Apical horn formed by the periphragm only (being approximately $^1/_6$ cyst body length), rounded at the apex.
Paracingulum defined by low ridges and a slight depression between. Paratabulation other than this, and that indicated by the archaeopyle absent. Archaeopyle enlarged precingular (Type P), subrounded in shape; formed by the loss of a mid dorsal paraplate (3″ or 4″ of Lucas-Clark, 1987); operculum free.

Remarks: According to the emended description of Lucas-Clark (1987), this species lacks a Q paraplate and so does not fulfill the criteria to be placed in the genus *Aldorfia*. However, as the material described here was not observed on a Scanning Electron Microscope (SEM), it was impossible to describe the paratabulation. It is assigned to this genus because in all

other respects it fulfills the necessary criteria.

Dimensions:	Central body L:	30 (38.6) 50 µm
	Central body W:	30 (36.3) 45 µm
	Apical horn L:	3 (4.8) 7 µm

Occurrence: Sporadic occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight, with rare occurrences in the *S.planus* zone of Sussex.

LS-4,7,11,17,21; DOE-12; CB1-26; CB-24,29,31,41; HW-6; BH-3-6,9,11,12; SO-14,15; SPT-2,7; CH-3,4

Known stratigraphic range: Cenomanian - Santonian (Clarke & Verdier, 1967), England;

Genus *Batiacasphaera* Drugg 1970

Original diagnosis: Drugg 1970
Type species: *Batiacasphaera compta*, Drugg 1970

Batiacasphaera euteiches (Davey, 1969) Davey 1979b
Plate 15, Figs 9, 11

1969 *Chytroeisphaeridia euteiches* Davey: p.141, pl.3, figs 8-9

Original description:	Davey 1969, p.141
Holotype:	Davey 1969, pl.3, fig.8
Original dimensions:	Holotype
	Cyst L: 53 µm
	Cyst W: 59 µm

Description: Proximate cyst subspherical to ellipsoidal in shape, without processes, usually broader than long. Wall thick (3µ) with a spongy appearance and granular surface, but cannot be discerned as two separate layers (Davey, 1969), therefore an autophragm.
Paratabulation absent except for the archaeopyle. Precingular paratabulation can be discerned from the archaeopyle margin inferring the presence of 6 precingular plates and an anterior parasulcal plate. The remainder of the paratabulation cannot be resolved Archaeopyle apical (Type $\overline{tA}$-tAa) with accessory sutures often developed at the parasulcal notch.

Operculum free but sometimes seen attached; formed by 4 apical paraplates.

Remarks: The author follows Lentin & Williams (1989) in not accepting the generic emendation made by Dörhöfer & Davies (1980). *Kallosphaeridium ringnesiorum* is similar to *Batiacasphaera euteiches* (Davey, 1969) Davey 1979b, however the former always possesses an attached operculum and does not have such a thick wall.

Dimensions: Cyst L: 40 (56.1) 65 µm
Cyst W: 40 (56.3) 65 µm

Occurrence: Common to sporadic occurrences in all areas in the *M.labiatus, T.lata* & *S.planus* zones.
AS-4,8,11,12,13,14,15,17,19,33,36,37,39,40; LS-9,11,15,17,26,28,29; AKS-2/1,2/3,2/4,2/7; DOE-1-14; CB1-28; CB-1,11,14,15,18,31; MR-20; HW-9,10,16; SO-2, 4-7,11,13-26; BH-2,3,6,7,8,9,11,12; CA-2,3,11,12,13; NP-2,3,9-16,18-38,40,42-45

Known stratigraphic range: Cenomanian (Davey, 1969), France; Late Cenomanian - Turonian (Robaszynski, 1980), France.

Genus - *Ellipsodinium* Clarke & Verdier 1967

Original diagnosis: Clarke & Verdier 1967, pp.68-69
Type species: *Ellipsodinium rugulosum* Clarke & Verdier 1967

Ellipsodinium rugulosum Clarke & Verdier 1967
Plate 15, Figs 7, 10

Original description: Clarke & Verdier 1967, p.69
Holotype: Clarke & Verdier 1967, pl.14, fig. 6
Original dimensions: Holotype
Cyst L: 40 µm
Cyst W: 39 µm
H of ledges: up to 15 µm

Description: Small proximate cyst, subspherical to ellipsoidal, bearing a coarse, distinct, longitudinally arranged reticulum. Wall two layered, endophragm smooth, periphragm forming non-tabular muri which are distally "frilled" and define elongated rectangular luminae, which are approximately

parallel to the longitudinal axis of the cyst (Pl.15, Fig.10). Convergent muri seem to thicken.

Paratabular features absent, excepting a distinct paracingulum and archaeopyle. Paracingulum offset slightly, subdivided by longitudinal muri, and edges defined by the absence of the reticulum. Archaeopyle reduced precingular (Type P) formed by the loss of the 3″ paraplate; subpolygonal in shape. Operculum free.

Remarks: This small reticulate cyst is very distinctive, and is not easily confused with any other species.

Dimensions: Cyst L: 30 (37.7) 55 µm
Cyst W: 27 (31.2) 37 µm
Muri H: 1 - 2 µm

Occurrence: Sporadic occurrences in the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight.
LS-2,9,11; DOE-8,9; CB1-26,32,36,38; CB-11,14,16,18,20,21,23,25,31,44; HW-1,2,3,6,7,8; BH-2,4,5,8,9,11,12; CA-4; NP-21.

Known stratigraphic range: Cenomanian - Santonian (Clarke & Verdier, 1967), England; Pre- Cenomanian - Turonian (Robaszynski *et al.*, 1980), France.

Genus *Trichodinium* Eisenack & Cookson 1960; emend. Clarke & Verdier 1967

Original diagnosis: Eisenack & Cookson 1960, p.5
Emended diagnosis: Clarke & Verdier 1967, pp.18-19
Type species: *Trichodinium pellitum* Eisenack & Cookson 1960

Trichodinium castanea (Deflandre, 1935) Clarke & Verdier 1967
Plate 15, Figs 12, 13

1935 *Palaeoperidinium castanea* Deflandre: p.229, pl.6, fig.8
1959 *Apteodinium ciliatum* Gocht: p.65, pl.8, figs 5-6

Original description: Deflandre 1935, p.229
Emended description: Clarke & Verdier 1967, pp.19-20
Holotype: Deflandre 1935, pl.6, fig.8
Original dimensions: Gocht 1959

Cyst D: 78 × 64 µm
Apical horn L: 8 µm

Description: Spherical to subspherical proximate cyst bearing a non-tabular spinose ornament, and a small apical horn. Wall thick (2µm) and strongly ornamented, separate wall layers not discernible.
Spines seem to show some arrangement linearly, perhaps penitabular. Paratabulation absent, except for a distinct parasulcus and planar paracingulum, defined by concentrated rows of spines (Pl.15, Fig.13). Archaeopyle ?reduced precingular (Type P), subangular in shape; formed by the loss of the 3″ paraplate; operculum free.

Dimensions: Cyst L 42 (50) 55 µm
Cyst W: 37 (44.8)50 µm
Spine L: up to 2 µm
Horn L: 2 (3) 5 µm

Occurrence: Rare occurrences in the *M.labiatus* zone on the Isle of Wight, in the *T.lata* zone at Dover and in both these zones in Sussex.
LS-2,6,7,9,11; DOE-1,3-8,12,13; CB1-26,32,36; CB-31; BH-1-9,11,12; NP-21.

Known stratigraphic range: Late Cretaceous (Deflandre, 1935), France; Pre-Cenomanian - Late Turonian (Robaszynski *et al.*, 1980), France; Hauterivian - Cenomanian (Below, 1982), Morocco;

Genus: *Prolixosphaeridium* Davey *et al.* 1966; emend. Davey 1969

Original diagnosis: Davey *et al.* 1966, p.171
Emended diagnosis: Davey 1969, p.160
Type species: *Prolixosphaeridium parvispinum* (Deflandre, 1937) Davey *et al.* 1969
Remarks: Members of this genus may be distinguished from the similar genus *Tanyosphaeridium* Davey & Williams 1966, by their processes which usually taper, and are closed distally.

Prolixosphaeridium conulum Davey 1969
Plate 16, Figs 1, 2

Original description: Davey 1969, pp.160-161
Holotype: Davey 1969, pl.8, fig. 5

Original measurements:	Holotype	Range
Cyst L:	47 µm	38 (43.8) 50 µm
Cyst W:	27 µm	20 (25.9) 29 µm
Process L:	11-16 µm	11 (15.1) 18 µm

Description: Elongate, ellipsoidal chorate cyst, bearing numerous nontabular processes (usually 30). Wall two layered; endophragm thick and densely granular; periphragm thin and smooth, forming the processes. Wall layers adpressed except at the base of the processes.
Processes hollow, tapering distally from a broad base to a closed acuminate tip. Processes seem to be aligned in rows encircling the cyst; but not reflecting any tabulation. Archaeopyle apical (Type $\overline{tA}$), accessory sutures developed and sulcal notch present. Operculum free.

Dimensions:		
	Cyst body L:	40 (46.8) 52 µm
	Cyst body W:	22 (27.7) 36 µm
	Process L:	10 (13.6) 18 µm

Occurrence: Common occurrences in the *M.labiatus* & *T.lata* zones at Dover and on the Isle of Wight and in the *M.labiatus, T.lata* & *S.planus* zones fo Sussex.
AS-22,29; LS-3,6,12,21,27; DOE-3,4,6,8,9,10,12; CB1-28,36; CB-2,11,15,16,18, 21-25,31,33,41,44; MR-8; HW-2,4-6,8,11,16; SO-4-6,19,11,12,15,17,24,26; BH-1-3,5,7-9,11,12; CA-2-5,7,8,10,11; NP-1-5,7,9,10,25,30,35.

Known stratigraphic range: Cenomanian (Davey, 1969), England; Cenomanian - Turonian (Robaszynski *et al.*, 1980), France.

Genus *Tanyosphaeridium* Davey & Williams 1966b

Original diagnosis: Davey & Williams 1966b, p.98
Type species: *Tanyosphaeridium variecalamus* Davey & Williams 1966b

Remarks: *Tanyosphaeridium* Davey & Williams 1966b is very similar to *Prolixosphaeridium* Davey *et al.* 1966, emend. Davey 1969, in its elongate cyst shape and it's process number, but the processes differ by being flared and open distally in the former genus. These two genera have already been discussed on p.131.

Tanyosphaeridium variecalamus Davey & Williams 1966b
Plate 16, Figs 3, 4 & 7

Original description: Davey & Williams 1966b, pp.98-99
Holotype: Davey & Williams 1966b, pl.6, fig.7, text-fig.20
Original measurements:

	Holotype	Range
Central body L:	34 µm	30-43 µm
Central body W:	14 µm	14-20 µm
Process L:	12-16 µm	12-24 µm
Process no:	26 µm	-

Description: Elongate, ellipsoidal chorate cyst, bearing numerous non-tabular processes. Wall two layered, endophragm smooth to slightly granular; periphragm thin and smooth. Processes tubular and cylindrical, flared slightly at their distal tips, with open ends. Reflected tabulation not apparent, though the processes are arranged in concentric rings around the central body. Archaeopyle apical (Type $\overline{tA}$); usually a sulcal notch is visible in the archaeopyle margin. Operculum free.

Remarks: The number of processes is variable between 24-30; thus they do not have a paratabular arrangement; there may be more than one process per paraplate.

Dimensions:

Cyst L:	22 (31) 52 µm
Cyst W:	11.5 (16.2) 22 µm
Process L:	10 (13.6) 17 µm

Occurrence: Rare occurrences in the *M.labiatus* & *T.lata* zones at Dover and in the *T.lata* & *S.planus* zones of Sussex and the Isle of Wight.
LS-2,17,19,28,31; DOE-6,9,14; CB-11; MR-8; BH-1,5-9,12; NP-25.

Known stratigraphic range: Cenomanian (Davey & Williams, 1966b), England; Pre- Cenomanian - Late Turonian (Robaszynski *et al.*, 1980), France.

Genus *Wallodinium* Loeblich & Loeblich 1968, *nom subst. pro*
Diplotesta Cookson & Eisenack 1960, *non* Brogniart 1874

Original diagnosis: Cookson & Eisenack 1960, p.256
Type species: *Wallodinium glaesneri* (Cookson & Eisenack, 1960) Loeblich & Loeblich 1968

Wallodinium anglicum (Cookson & Hughes, 1964) Lentin & Williams 1973

Plate 16, Figs 5, 6

1964 *Diplotesta anglicum* Cookson & Hughes, pp.56-57, pl.11, figs 1-5

Original description: Cookson & Hughes, pp.56-57

Holotype: Cookson & Hughes, pl.11, fig. 2

Original measurements:

	Holotype	Range
Total L:	126 µm	34-80 µm
Total W:	44 µm	29-44 µm
Capsule L:	52 µm	25-54 µm
Capsule W:	24 µm	17-23 µm

Description: Elongate, crescent shaped circumcavate cyst. Endocyst elongate, ellipsoidal and biconvex. Pericyst separated from endocyst, elongate with one straight or slightly concave, the other strongly convex , converging at blunt rounded apices. Endo and periphragm both thin and smooth. No paratabular features displayed. Archaeopyle apical (Type tA); Operculum free.

Remarks: This species is tentatively placed within the Class Dinophyceae as it possesses what appears to be an apical archaeopyle and a double wall layered structure. However it does not display any apparent paratabulation, making its taxonomic position unclear. It is thought to show some similarities to *Fromea*, in that it has an apical archaeopyle and a general subspherical shape.

Dimensions:

Total L:	72 (93) 110 µm
Total W:	35 (40) 45 µm
Central body L:	47 (58.5) 85 µm
Central body W:	20 (27.5) 40 µm

5 Specimens measured

Occurrence: Rare occurrence in the *M.labiatus* zone of Sussex and the Isle of Wight and in the *T.lata* zone at Dover.

LS-4; BH-11; CB1-36.

Known stratigraphic range: Cenomanian (Cookson & Hughes, 1964), England; Late Albian - Cenomanian (Davey & Verdier, 1973), France.

Genus *Leberidocysta* Stover & Evitt 1978

Original diagnosis: Stover & Evitt 1978, p.59
Type species: *Leberidocysta chlamydata* (Cookson & Eisenack, 1962) Stover & Evitt 1978

Remarks: The suggestion by Mehrotra & Sarjeant (1984) that this genus is a junior synonym of *Polygonifera* Habib 1972 is rejected after consideration of the original description and figures given by Habib (1972). *Polygonifera* is shown to display a distinct paracingulum and an endocyst which is eccentrically displaced within the pericyst. Neither of these features are apparent in *Leberidocysta.*

Leberidocysta chlamydata Cookson & Eisenack 1962
Stover & Evitt 1978
Plate 16, Figs 8, 9

1962 *Hexagonifera chlamydata* Cookson & Eisenack. p.496, pl.7, figs1-3 & 5-8

Original description: Cookson & Eisenack 1962, p.496
Holotype: Cookson & Eisenack 1962, pl.7, fig.2
Original dimensions: Holotype

Total L:	75 µm
Total W:	76 µm
Central body:	60 x 50 µm

Description: Circumcavate, ellipsoidal cyst, with two distinct wall layers. Endocyst subspherical to ellipsoidal in shape, thick walled with a granular ornamentation (Pl.16, Fig.8). Pericyst ellipsoidal in shape, separated from the endocyst by a cavation of variable width (10 - 20 µm). Periphragm thin and smooth, and may be folded or sometimes incomplete.
Features indicating paratabulation are absent. Archaeopyle apical (type $\overline{tA}$), with a zig-zag margin. Archaeopyle margin indicates the presence of 6 precingular paraplates. Operculum free.

Remarks: This species can be readily distinguished from *Leberidocysta defloccata* (Davey & Verdier, 1973) Stover & Evitt 1978, by the smooth endophragm of the latter.

Dimensions:	Total L:	40 (60.1) 82 µm
	Total W:	25 (56.5) 74 µm
	Central body L:	25 (40.1) 50 µm
	Central body W:	32 (43.8) 52 µm
	10 species measured	

Occurrence: Sporadic occurrence in the *T.lata* zone at Dover and more persistent occurrences in the *M.labiatus, T.lata* & *S.planus* zones of Sussex and the Isle of Wight.

LS-1; DOE-1,2,7,8,10,11,12,14; CB1-26,36; CB-2,10,11,13,16-18,20,21,33,40, 41,44; MR-19; HW-5,9; BH-3,12; CA-2,12; NP-3,11,13,21,30; SPT-2,7.

Known stratigraphic range: Albian - Cenomanian (Cookson & Eisenack, 1962), Australia; Late Albian - Cenomanian (Davey & Verdier, 1973), France; Pre-Cenomanian - Middle Turonian (Robaszynski *et al.*, 1980), France.

Leberidocysta defloccata (Davey & Verdier, 1973)
Stover & Evitt 1978
Plate 16, Figs 11, 12

1973 *Hexagonifera defloccata* Davey & Verdier:p.198, pl.3, fig.8
1976 *Thalassiphora defloccata* Lentin & Williams: p.85
1981 *Disphaeria defloccata* (Davey & Verdier, 1973) Yun: p.70
1984 *Craspedodinium defloccata* Mehrotra & Sarjeant: p.50

Original description:	Davey & Verdier 1973, p.198
Holotype:	Davey & Verdier 1973, pl.3, fig.8
Original dimensions:	Holotype
	Central body D: 58 x 41 µm
	Total D: 68 x 90 µm

Description: Circumcavate, ellipsoidal cyst with two separated wall layers. Endocyst spherical to subspherical in shape, thick walled with a smooth surface. Pericyst ellipsoidal in shape, separated from the endocyst by a cavation of variable width (5 - 20 µm) Periphragm thin and smooth, often folded or damaged.

Paratabular features absent, except that indicated by the archaeopyle margin - the presence of 6 precingular paraplates. Archaeopyle apical (Type $\overline{tA}$); operculum free.

Remarks: The operculum was never observed attached to the cyst as described by Davey & Verdier (1973). Otherwise the only variability noticed was one of size.

Dimensions:	Total L:	50 (58.4) 72 µm
	Total W:	47 (58.1) 75 µm
	Central body L:	37 (42.4) 55 µm
	Central body W:	35 (41.9) 55 µm
	10 specimens measured	

Occurrence: Sporadic occurrences in the *M.labiatus*, *T.lata* & *S.planus* zones at Dover and the *M.labiatus* & *T.lata* zones of Sussex and the Isle of Wight. LS-2,24,25; CB-15,16,18,21,24,25,27,31,33,43-45; MR-8; HW-4,5,8,11; SO-5,11,15,26; BH-2,4-7,11,12; CA-2,5; NP-1,3,11,13,21,30; SPT-2-7.

Known stratigraphic range: Late Albian - Cenomanian (Davey & Verdier, 1973), France; Pre- Cenomanian - Late Cenomanian (Robaszynski *et al.*, 1980), France.

Genus *Cassiculosphaeridia* Davey 1969

Original diagnosis: Davey 1969, p.141
Type species: *Cassiculosphaeridia reticulata* Davey 1969

Cassiculosphaeridia reticulata Davey 1969
Plate 16, Figs 10, 13, 14

Original description: Davey 1969, p.142
Holotype: Davey 1969, pl.4, fig.3
Original dimensions: Holotype
Cyst D: 38 × 38 µm
Crest H: 4 - 6 µm

Description: Cyst subspherical to ellipsoidal bearing a strong reticulation, developed by a series of connected ridges. Wall two-layered; endophragm slightly granular, conformable with the periphragm, which has a coarse reticulate nature. Membranous crests arise from the reticulation. Paratabulation absent. Archaeopyle apical (Type tA); operculum unattached and was not found, so it's shape is uncertain; from the archaeopyle margin it is probably tetra in shape.

Remarks: This species is similar to *Valensiella ovulum* (Deflandre, 1947) Eisenack 1963, in that it also possesses a continuous reticulation, with membranes extending from it, and an apical archaeopyle. However *V. ovulum* is generally larger than *Cassiculosphaeridia reticulata* Davey 1969. This division of the two taxa purely on a matter of size seems to be arbitrary. If the two species were proved to be conspecific, then *V. ovulum* would have priority.

Dimensions: Cyst D: 32 (39.6) 50 × 27.5 (35.7) 45 µm
Crest H 2 (3.3) 5 µm

Valensiella ovulum Holotype

	without crests	with crests
Cyst L	48 - 55 µm	55 - 65 µm
Cyst W	37 - 45 µm	44 - 55 µm

therefore crest H: 3.5 - 5

Occurrence: Rare occurrences in the *M.labiatus* & *T.lata* zones of Sussex and more persistent occurrences in the *T.lata* & *S.planus* zones at Dover and in the *M.labiatus* & *T.lata* on the Isle of Wight.
LS-1,2,4-10,12,14-22,26,28-31; DOE-1,2,4-8,11-14; CB1-26-28,36,38; CB-1,2,11,13-18,21,23,25,27,29,31,32,33,41,43,45; MR-8; HW-2,4,6; BH-2,3,6,9,12.

Known stratigraphic range: Cenomanian (Davey, 1969), England & France; Pre-Cenomanian - Santonian (Robaszynski *et al.*, 1980), France.

4.4.12 Miscellaneous Groups

Group ACRITARCHA
Subgroup Pteromorphitae Wetzel 1952

Genus *Pterospermella* (Wetzel 1952) Eisenack 1972

Original diagnosis: Wetzel 1952
Emended diagnosis: Eisenack 1972
Type species: *Pterospermella danica* Wetzel 1952

Pterospermella spp.
Plate 17, Fig. 5

Description: Spherical to subspherical central body, surrounded by a broad

equatorial membrane. Central body may be smooth to finely granular. Equatorial membrane is thin and smooth, with an entire margin, and may have a folded appearance. No excystment features are apparent.

Dimensions: Central body D: 15 (24.7) 30 × 12 (25.4) 30 µm
Total D: 40 (46.9) 57 × 37 (47.6) 57 µm

Occurrence: Rare occurrence in the *M.labiatus, T.lata* & *S.planus* zones in Sussex.
HW-5,6,10; CA-11; NP-16; SPT-3,4; CH-7.

Known stratigraphic range: Late Jurassic - Recent

Subgroup Polygonomorphitae Downie, Evitt & Sarjeant 1963

Genus *Veryhachium* Deunff; emend. Downie & Sarjeant 1963

Original diagnosis: Norris & Sarjeant 1965, p.62

Type species: *Veryhachium trisculum* (Deunff) Deunff 1954

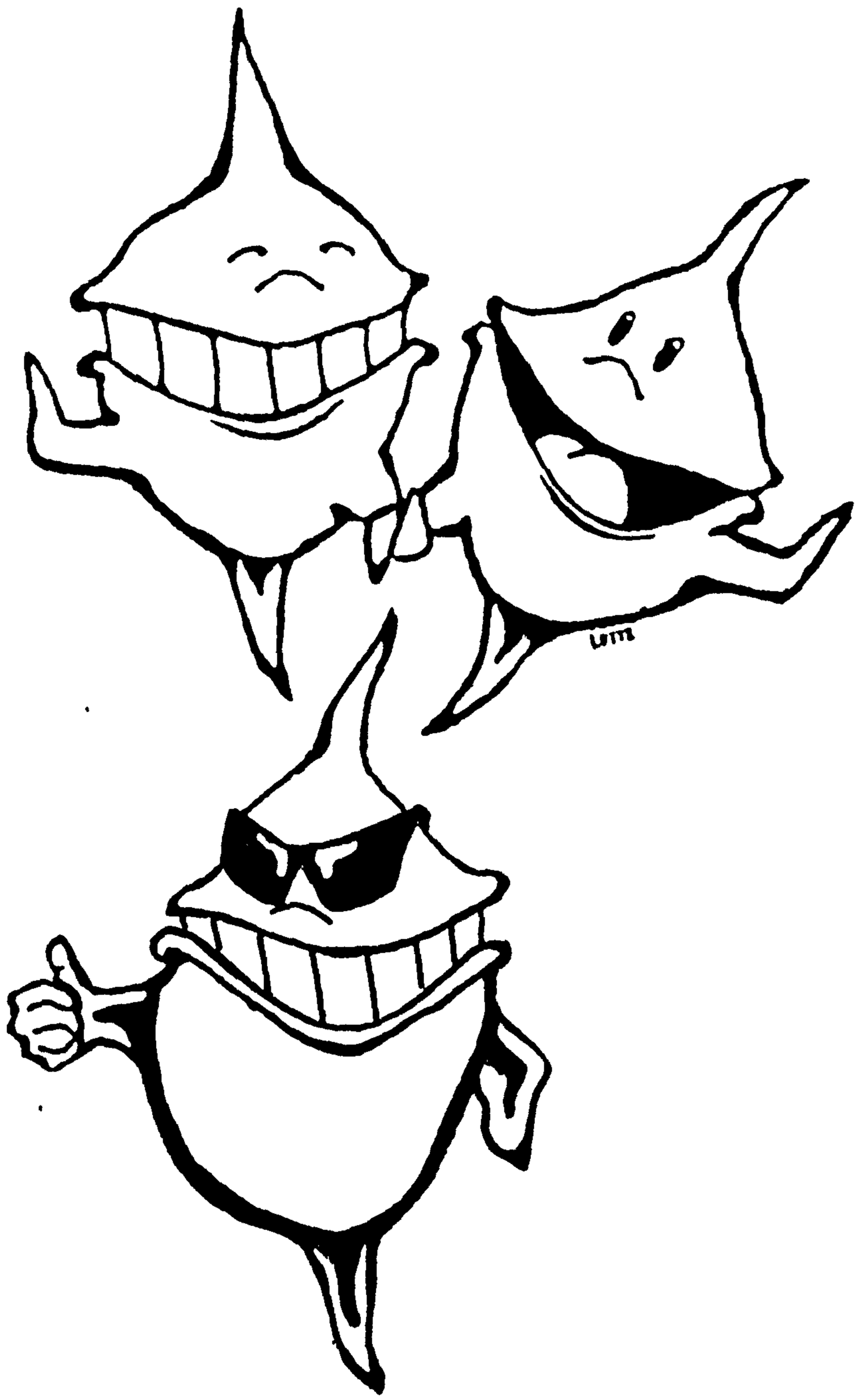
Veryhachium spp.
Plate 17, Fig. 1

Description: Sub-polygonal to sub-triangular central body, bearing 6-8 long processes at the corners. Wall thin and smooth, single layered. Processes slender, tapering slightly distally, with an acuminate termination. Processes develop from the central body wall and are hollow. No excystment feature was observed in any of the specimens.

Dimensions: Central body D: 17 (19.4) 25 × 20 (21.6) 25 µm
Process L: 12 (17.5) 25 µm
10 specimens measured.

Occurrence: Rare occurrence in the *M.labiatus* & *T.lata* zones in Sussex.
SO-8; BH-6,9,11,12.

Known stratigraphic range: Devonian - Recent



CHAPTER FIVE BIOSTRATIGRAPHY

5.1 Introduction

One of the main purposes of this investigation was to produce a zonation scheme based upon the dinoflagellate cyst assemblages from the Turonian of southern England. It was hoped to modify the already existing zonation schemes from the Anglo-Paris Basin of Foucher (1981, table 3, p.334) and Clarke & Verdier (1967, text-fig.33. p.80-81). In this chapter previous research will be outlined and then the results of the present study will be discussed.

5.2 History of Palynological Research.

Some of the first observations of dinoflagellate cysts were made by Christian Gottfrieg Ehrenberg, Gideon Mantell and Henry Hopley White in the early to middle 19thCentury; the latter two gentlemen carrying out their research in England, whilst the former worked in Germany. The original method of examining dinoflagellate cysts involved looking at very thin flakes of flint under a microscope. It was while using this method that the first dinoflagellate cysts were described, originally named "*Xanthidia*", and now placed in various chorate genera (see Sarjeant, 1991, for a full history). The flint flakes that were examined must have originated from Upper Cretaceous chalk (Turonian-Maastrichtian) containing flint bands. Mantell (1845) made an important discovery about these microfossils, concluding that they were composed of an organic substance and were not siliceous as previously thought by Ehrenberg (1838) and Reade (1839), after heating experiments caused them to blacken.

Since the late 19th Century, the knowledge and descriptions of dinoflagellate cysts from the Upper Cretaceous has expanded rapidly with contributions being made by Georges Deflandre (1936 a,b, 1937) Otto and Wolfang Wetzel (1933, 1952 respectively), Alfred Eisenack (1963) and Marie Lejeune-Carpentier (1937, 1938, 1939, 1940), .to name but a few. They all

examined dinoflagellate cysts from Upper Cretaceous sediments from northwestern Europe; each increasing the number of species recognised and adding to the information about these organic-walled microfossils.

5.3 Recent Palynological Research.

The relevant research carried out on the dinoflagellate cyst assemblages of the Turonian of southern England and the Anglo-Paris basin in recent years is as follows.-

5.3.1 Clarke & Verdier (1967) described the dinoflagellate cyst assemblages of samples from the Cenomanian to Campanian interval on the Isle of Wight, theirs being the first attempt at a palynozonation for this part of the Cretaceous. They only analysed two samples from the base of the Turonian and two more from the upper part. Their results defined two zones within the Turonian (Table 5.1).

<table>
<tr><th>AGE</th><th>Palaeontological Zone</th><th>Top Occurrences and Palynozones</th></tr>
<tr><td rowspan="3">TURONIAN</td><td>Holaster planus</td><td rowspan="3">Cyclonephelium membraniphorum (pars.)</td></tr>
<tr><td>Terebratulina lata</td></tr>
<tr><td>Rhynchodiniopsis cuvieri</td></tr>
<tr><td></td><td></td><td>↰ Scriniodinium campanula</td></tr>
</table>

Table 5.1 Palynozonation defined by Clarke & Verdier 1967

The lower palynozone was defined by the presence of *Scriniodinium campanula*, *Pyramidium alatum*, *Cyclonephelium hughesii* Clarke & Verdier 1967,

Cometodinium obscurum Deflandre & Courteville 1939 and was named after the first of these species. This zone was assigned a ?Cenomanian - Turonian age. The base of the second (higher) zone was defined by the last appearance of *Scriniodinium campanula* together with the occurrence of *Cyclonephelium membraniphorum* and *Coronifera oceanica.* This zone was assigned a Turonian to Coniacian/Santonian age. Unfortunately due to the large sampling interval there exists some gaps in our knowledge of the succession of microfloras and the position of some of the zonal boundaries is not known in relation to the macrofossil zones or lithostratigraphy. The contact between the two zones within the Turonian was not described by Clarke & Verdier (1967) and thus a complete section through the Turonian was not provided for southern England.

It was also noted that the samples from the Late Turonian and Coniacian were not as rich and diverse as those from older parts of the section.

5.3.2 Marshall (1983) investigated Turonian dinoflagellate cyst assemblages as part of a larger study from Beachy Head, South Ferriby (Humberside) and various sections from northern Germany. However, only five spot samples from Beachy Head were examined, making any stratigraphical interpretation vague and of little use biostratigraphically. In comparison with the Cenomanian palynomorph assemblages, those produced from the Turonian sediments were of lower diversities and abundances. Marshall & Batten (1988) have also described the flora from the black shales of Humberside that are associated with the Late Cenomanian oceanic anoxic event.

5.3.3 In more recent years Tocher & Jarvis (1987) described the stratigraphy and dinoflagellate cysts of the Cenomanian-Turonian formations from Beer, southeast Devon (Figure 5.1). The succession is much thinner than those observed at Dover, Sussex and on the Isle of Wight with well developed hardgrounds representing periods of non-deposition and erosion.

The resulting palynomorph assemblages were variable, with a total of 78 species recorded. The dinoflagellate cyst assemblages were dominated by *Palaeohystrichophora infusorioides*, with *Cyclonephelium distinctum*, *Odontochitina costata*, *O.operculata*, *Oligosphaeridium complex*, and *Spiniferites ramosus ramosus* also being common. Typical Turonian markers were also present including *Heterosphaeridium difficile* and *Senoniasphaera rotundata* (Foucher 1981).

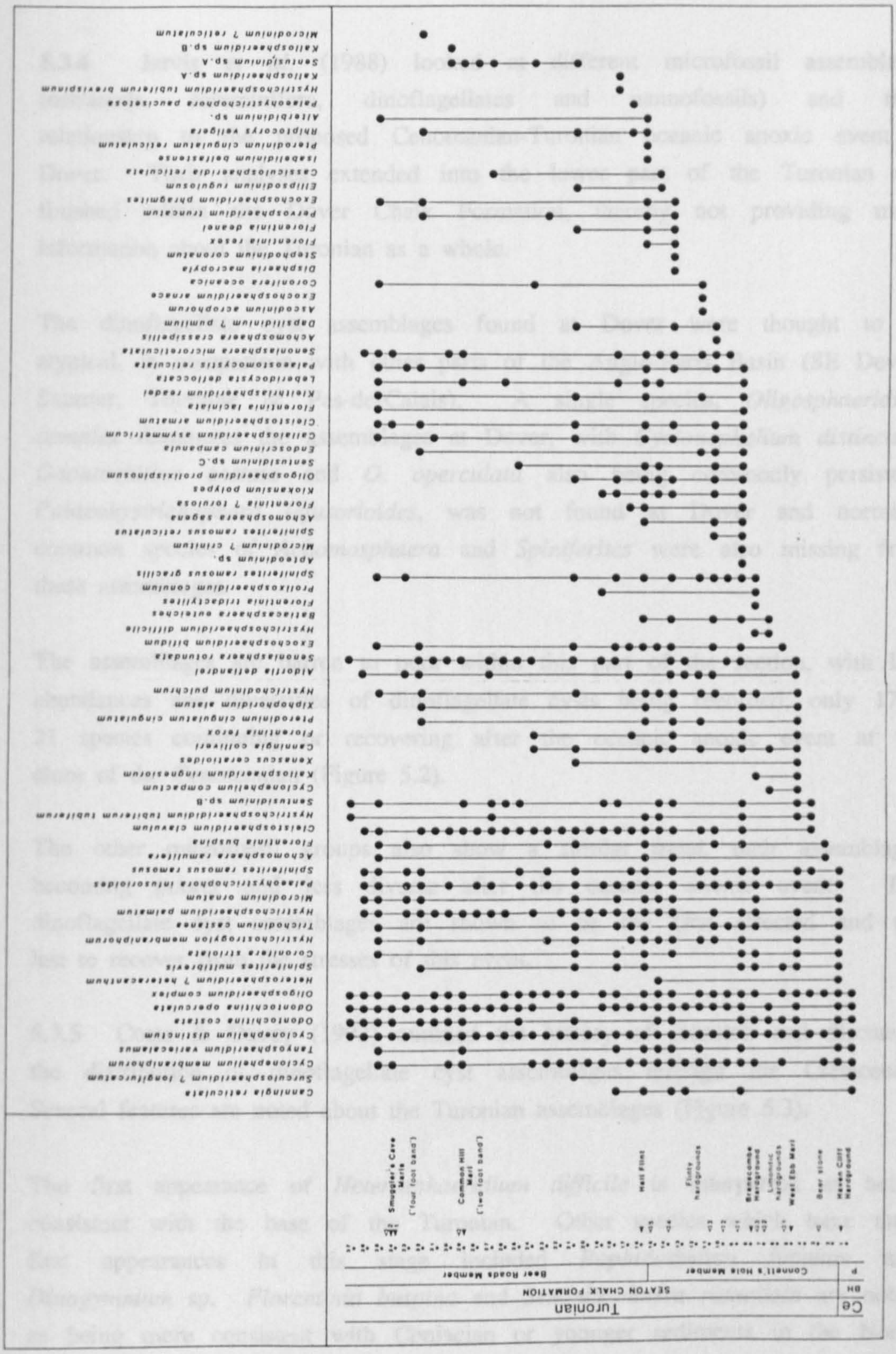


Figure 5.1 Stratigraphic distribution of dinoflagellate cysts from Beer, southeast Devon (Tocher & Jarvis, 1987).

5.3.4 Jarvis *et al.* (1988) looked at different microfossil assemblages (ostracods, foraminifera, dinoflagellates and nannofossils) and their relationship to the proposed Cenomanian-Turonian oceanic anoxic event at Dover. Their analyses extended into the lower part of the Turonian and finished within the Dover Chalk Formation, thereby not providing much information about the Turonian as a whole.

The dinoflagellate cyst assemblages found at Dover were thought to be atypical, in comparison with other parts of the Anglo-Paris Basin (SE Devon, Saumur, Touraine & Pas-de-Calais). A single species, *Oligosphaeridium complex* dominates the assemblages at Dover, with *Cyclonephelium distinctum*, *Odontochitina costata* and *O. operculata* also being commonly persistent. *Palaeohystrichophora infusorioides*, was not found at Dover and normally common species of *Achomosphaera* and *Spiniferites* were also missing from these assemblages.

The assemblages are barren to poor within this part of the section, with low abundances and diversities of dinoflagellate cysts being recorded; only 17 - 21 species continuing or recovering after the oceanic anoxic event at the close of the Cenomanian (Figure 5.2).

The other microfossil groups also show a similar trend, their assemblages becoming poorer and less diverse after the oceanic anoxic event. The dinoflagellate cyst assemblages are shown to be the first affected and the last to recover from the stresses of this event.

5.3.5 Costa & Davey (1992) outlined the history of research and discussed the distribution of dinoflagellate cyst assemblages through the Cretaceous. Several features are noted about the Turonian assemblages (Figure 5.3).

The first appearance of *Heterosphaeridium difficile* is interpreted as being consistent with the base of the Turonian. Other species which have their first appearances in this stage included *Raphidodinium fucatum* and *Dinogymnium* sp. *Florentinia buspina* and *Senoniasphaera rotundata* are noted as being more consistent with Coniacian or younger sediments in the North Sea. One characteristic of early Turonian dinoflagellate cyst assemblages from both the Chalk Group and the Shetland Group is the acme occurrence of *Heterosphaeridium difficile.*

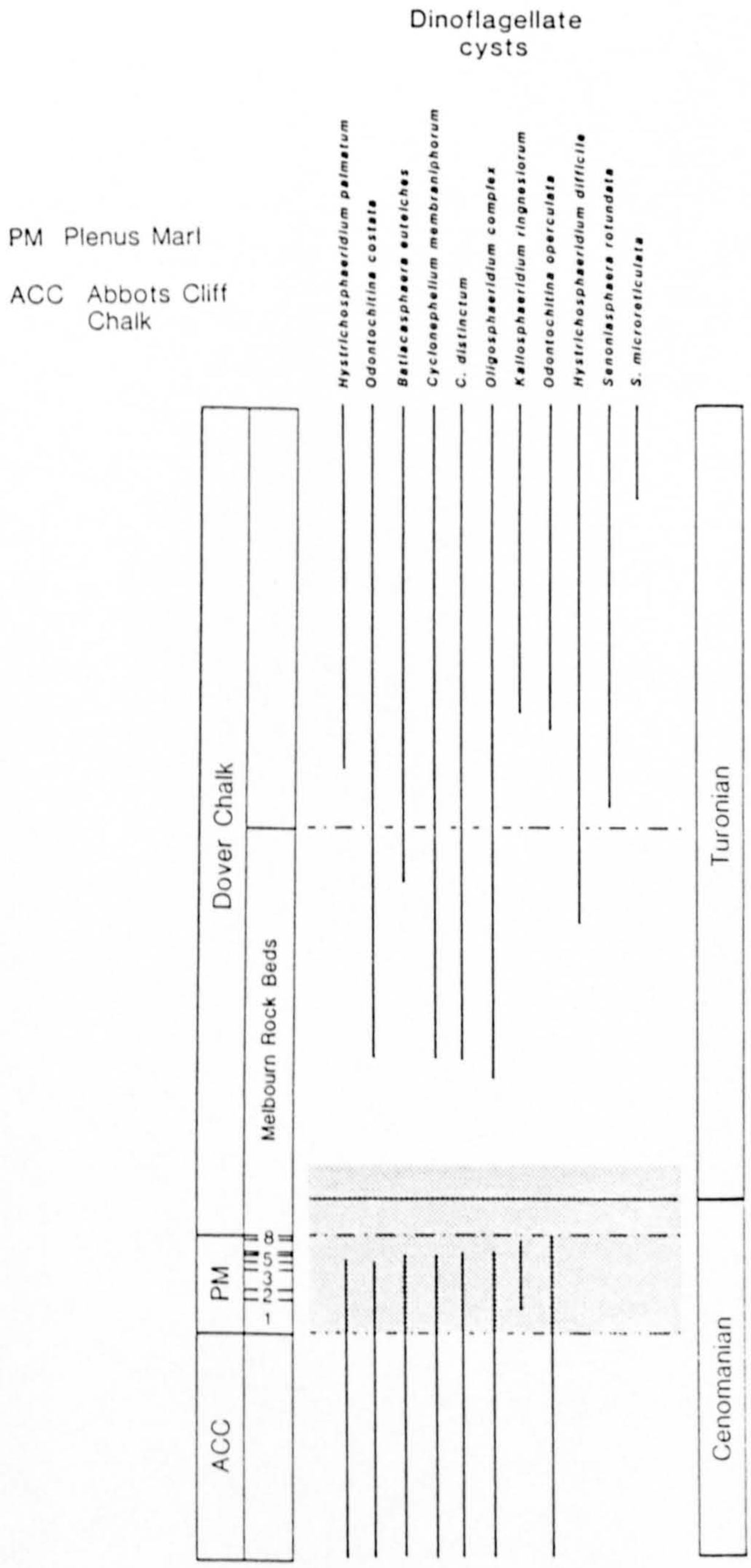


Figure 5.2 Distribution chart of selected dinoflagellate cyst species from the Cenomanian-Turonian boundary succession at Dover (Jarvis *et al.*, 1988).

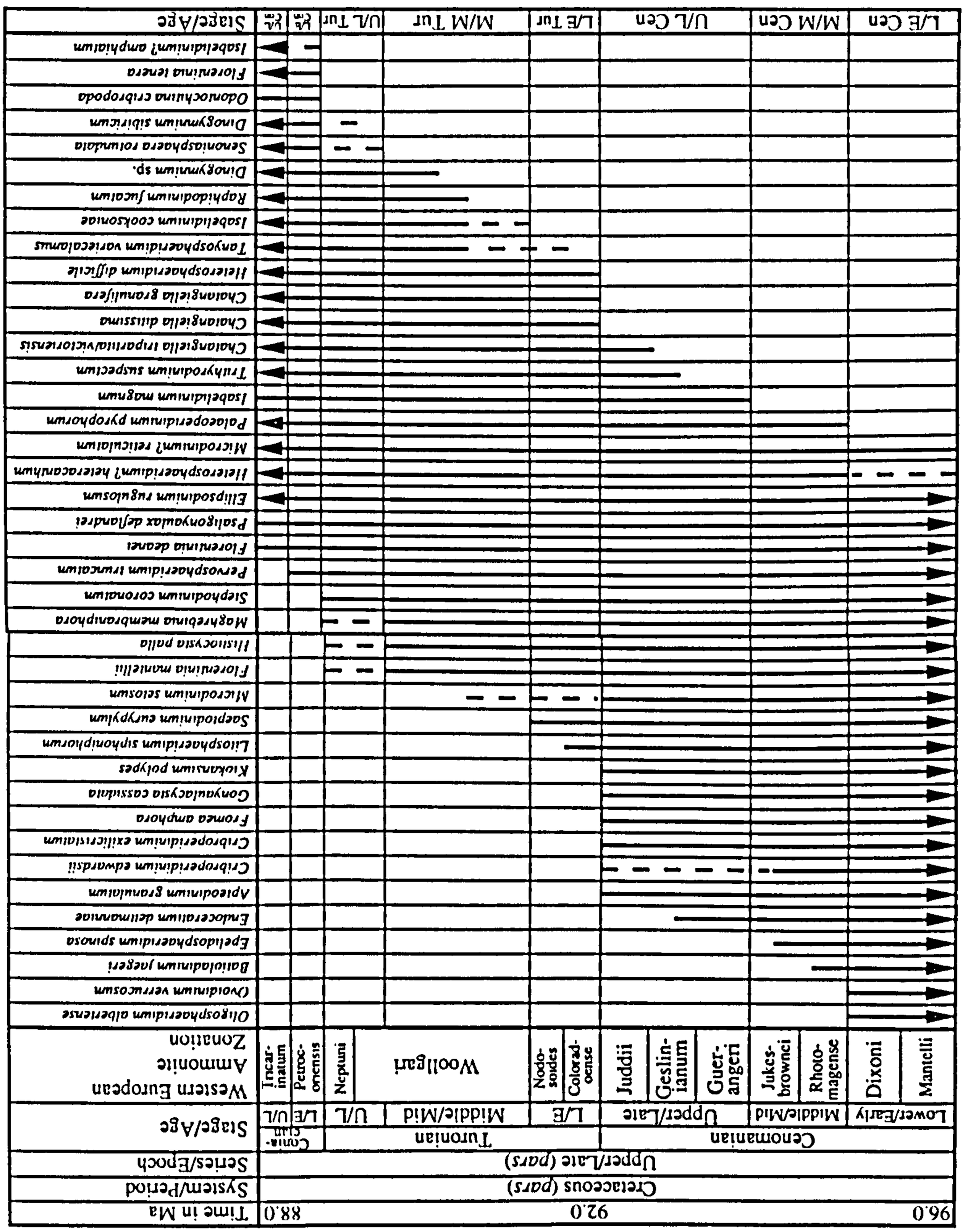


Figure 5.3 Stratigraphic distribution of dinoflagellate cyst species from the Upper Cretaceous (Costa & Davey, 1992).

There are some discrepancies between results from onshore sections (Clarke & Verdier, 1967) and those from the northern North Sea. The Chalk Group assemblages differ from those of the Shetland Group by the low representation of peridinioid dinoflagellate cysts in the former and the greater abundances and diversities of the same group in the latter.
Other features of Turonian associations noted by Costa & Davey (1992)include the last common occurrences of *Palaeohystrichophora infusorioides* and *Surculosphaeridium? longifurcatum.* Taxa which became extinct during or towards the end of the Turonian included *Maghrebinia membraniphora, Florentinia mantellii, Saeptodinium eurypylum* and *Histiocysta palla.*

5.3.6 Extensive work has been carried out on the Turonian sections of northern France by Foucher.
Foucher (1974, 1975, 1976a,b and 1979), has described the dinoflagellate cyst assemblages from Upper Cretaceous flints sampled from various localities within the Anglo-Paris Basin. The flints were not prepared in the standard palynological manner, thin-sections being made of a quarter to half a millimetre in thickness, depending on the transparency of the flint. The floras were abundant and diverse with up to 94 species being recorded. However the poorest assemblages were observed in Upper Turonian flints. Four significant associations were recognised, within the limits of the basin.

The assemblages typical of the Upper Turonian are of particular relevance here. Important taxa described from this interval included, *Cleistosphaeridium huguoniotii, Cyclonephelium membraniphorum, Florentinia deanei, Kleithriasphaeridium readei, ?Microdinium crinitum, Spiniferites crassimuratus*, and *Stephodinium coronatum* (Foucher, 1976a).
Foucher (1976b) recognised an Upper Turonian-Coniacian assemblage zone. Taxa typical of this interval include, *Oligosphaeridium prolixispinosum, Endoscrinium campanula, "Hystrichosphaeridium" pterophorum, Achomosphaera tridactylites, Deflandrea victoriensis, Dinogymnium marthae, "Gymnodinium" torulosum*, and *Palaeoperidinium pyrophorum.* Foucher (1979) has synthesised all the available data from the Anglo-Paris Basin (personal and in the literature) but did not define the assemblage zones precisely.

Foucher (1981), correlated his six dinoflagellate cyst zones with the known ammonite stratigraphy for the Albian to Turonian interval. The appearance of *Senoniasphaera rotundata* at the base of the *Collignoniceras woollgari*

Zone (base of the Middle Turonian), is used to define the *S.rotundata* Interval zone. *Heterosphaeridium difficile*, *Florentinia buspina*, and *Florentinia ?torulosa* appear at the same or similar stratigraphical level (Figure 5.4).

Foucher (in Robaszynski *et al.*, 1980) integrated the dinoflagellate cyst results with those of other micro- and macrofossil groups and the lithostratigraphy, forming a comprehensive biostratigraphy for the Aptian to Santonian interval of the successions in the Boulonnais (Figure 5.5a). The palynomorph assemblages were generally diverse with abundant populations being recovered, except at the base of the Turonian where the recovery was poor. The palynomorph zones described for the Turonian included those of *Florentinia ferox* and *Senoniasphaera rotundata*, as were previously reported.

A similar integrated study of the stratotype Turonian (Saumurois and Touraine), was undertaken by Robaszynski *et al.* (1982). In the Saumurois, three marker species of dinoflagellate cysts were noted. The first two (*Epelidosphaeridia spinosa* and *Litosphaeridium siphoniphorum*) having their highest occurrences in the Middle and Late Cenomanian respectively; the third (*Florentinia clavigera*) appearing at the base of the Turonian. Boreholes at Civray-de-Touraine yielded rich dinoflagellate assemblages with several index taxa recorded. These are illustrated in Figures 5.5 b,c for comparison with the other zonations produced by Foucher.

5.4 Biostratigraphical Results

The results for each section are presented on distribution charts in the form of relative occurrences (Figures 5.6 - 5.12). These are based upon a count of 300 palynomorphs which has been shown to be statistically reliable (Buzas, 1979), unless there are <300 specimens in a sample; in which case all specimens are counted (the total is shown at the base of the chart for each sample). Abundance is defined as the number of specimens counted per slide. Diversity is defined as the number of species in a sample. Further discussion of these measurements is found in Chapter 7. The species are arranged in their morphological groups as outlined in Chapter 4. The raw data sets are provided in Appendix 2. The data sets formulated from the raw data into the morphogroups of Evitt (1985) are also provided in Appendix 3.

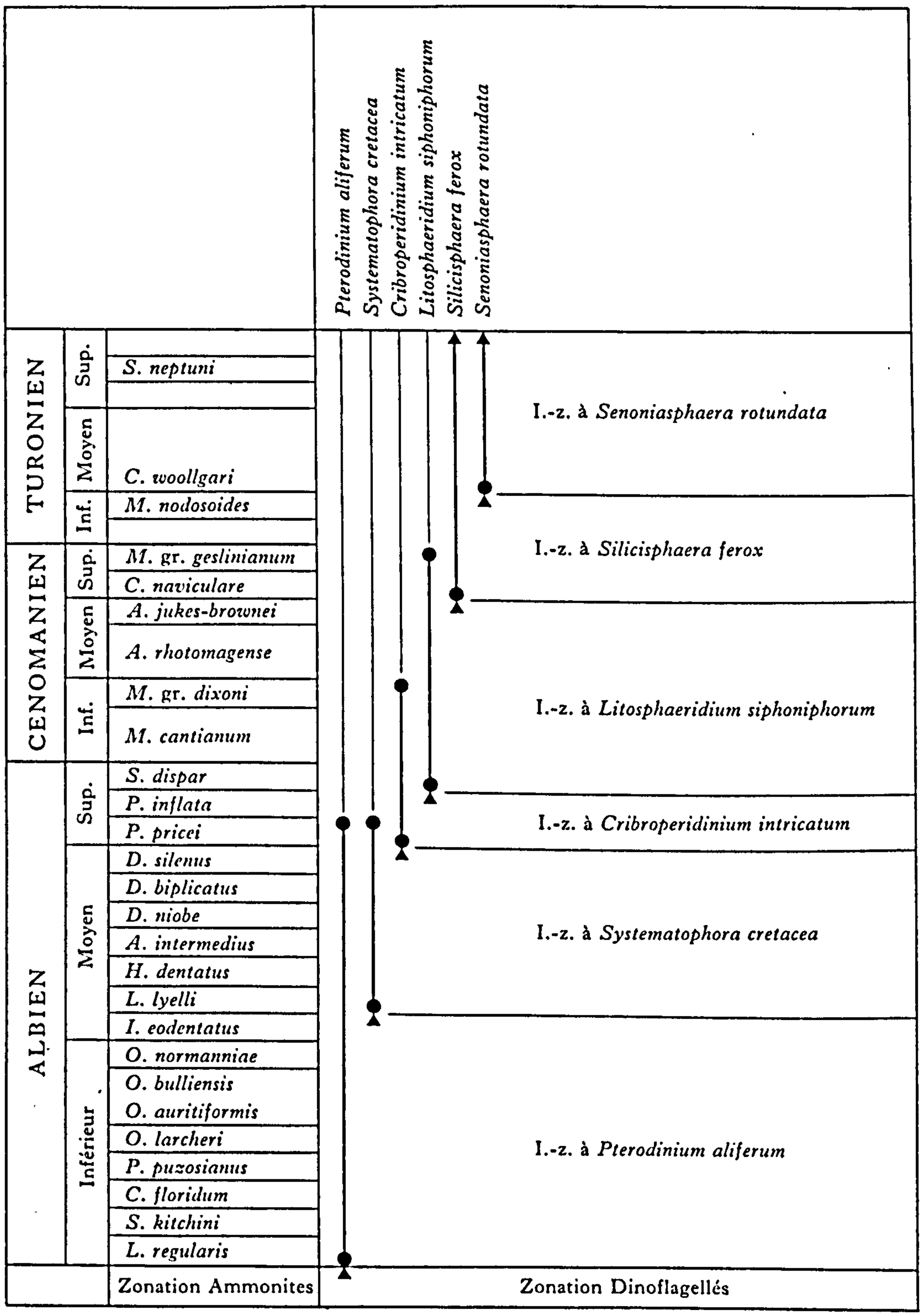


Figure 5.4 Significant bioevents from the Turonian (Foucher, 1981)

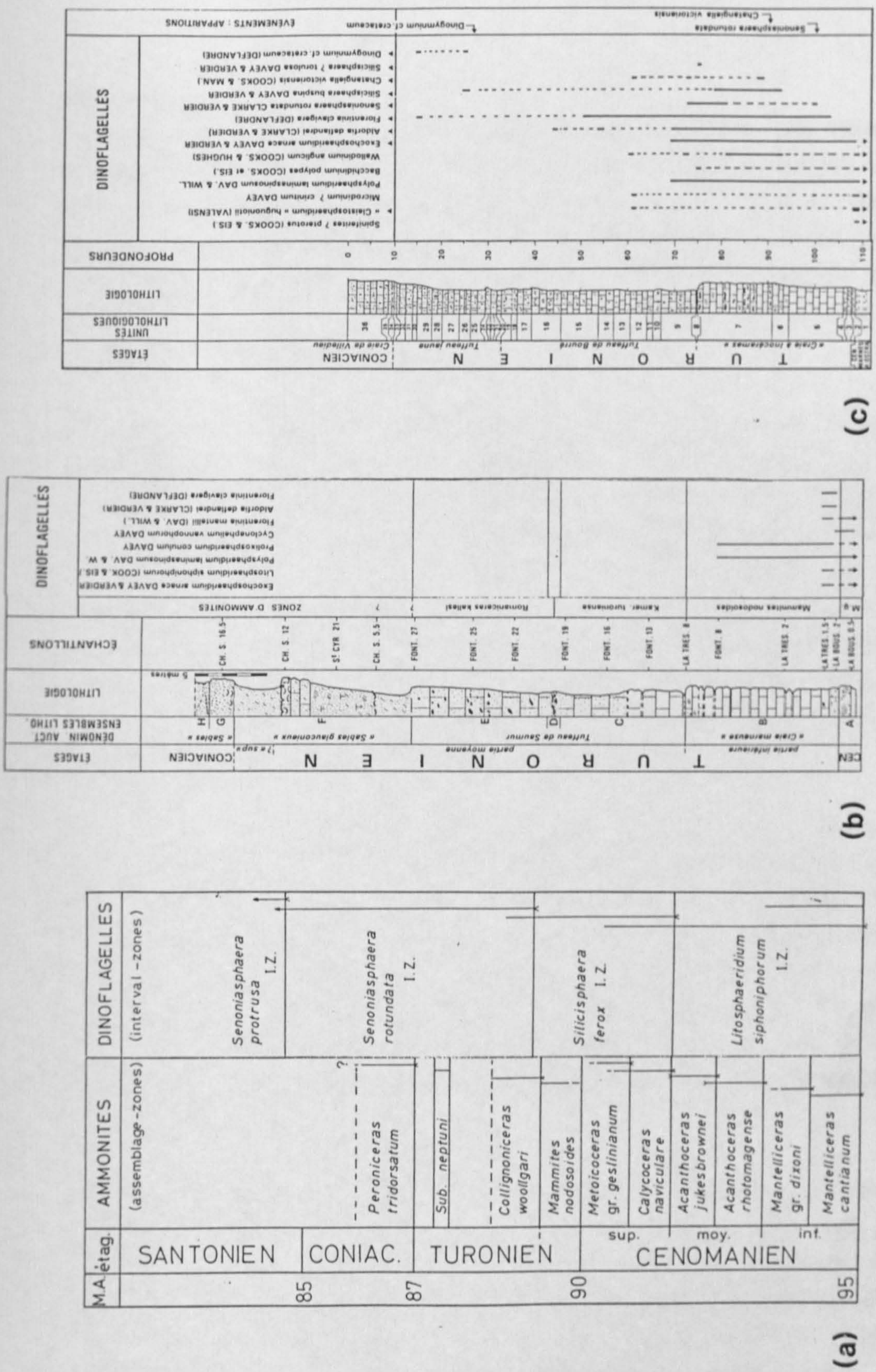


Figure 5.5 Palynoevents from the Turonian of **(a)** Boulonnais (Robaszynski *et al.*, 1980), **(b)** Saumurois (Robaszynski *et al.*, 1982) & **(c)** Civray-de-Touraine (Robaszynski *et al.*, 1982)

5.4.1 Dover

Generally the dinoflagellate cyst assemblages recovered from this region are of variable abundances and diversities, with poor or barren samples at the base of the Turonian succession from Akers Steps. The recovery improves into the middle part of the stage. The assemblages are dominated by four morphogroups (Gv, Gc, Gi and Gn), each of which is represented by one or more dominant taxa. There are very minor occurrences of the other morphogroups Gs; Gx, Pp and Px.

The first few metres of the Shakespeare Cliff Member are barren of palynomorphs, with the first dinoflagellate cysts occurring in AS4 (*Oligosphaeridium complex* and *Odontochitina costata*). *Heterosphaeridium difficile* appears above this in sample AS7, and *Cyclonephelium distinctum* occurs at the level of AS8. *Pervosphaeridium* sp. c.f. *P.pseudhystrichodinium* appears in A11, whilst *Odontochitina operculata* Type B, *Senoniasphaera rotundata* and *Cyclonephelium membraniphorum* all occur for the first time in sample AS13. *Odontochitina operculata* Type A appears in AS15. It is apparent that all these important species occur or re-occur within the lower part of the *Mytiloides labiatus* macrofossil Zone.

Influxes or acmes of some of these species are very noticeable and seem to occur sporadically. There is an influx of *Heterosphaeridium difficile* within the *Mytiloides labiatus* Zone, in AS11 and AS12. A distinct acme of *Cyclonephelium distinctum* occurs higher up in the *Terebratulina lata* Zone in samples AS45 and AS46, just above the Lydden Spout Flint. At the stratigraphical level of the Langdon Bay Marls, there is an increase in numbers of *Odontochitina costata* in LS1, LS2 and LS3. This is almost directly followed by an influx of *Pervosphaeridium pseudhystrichodinium,* in AS58 and AS59.

Palaeohystrichophora infusorioides is superabundant (interpreted here as comprising >70% of the sample) in the flint samples LS9 and LS11. *Cyclonephelium distinctum* remains persistent throughout the remainder of the section, as do *Cyclonephelium membraniphorum, Hystrichosphaeridium bowerbankii, Oligosphaeridium complex* and *Cassiculosphaeridia reticulata.* There is an influx of *Senoniasphaera rotundata* in samples LS22 to LS27.

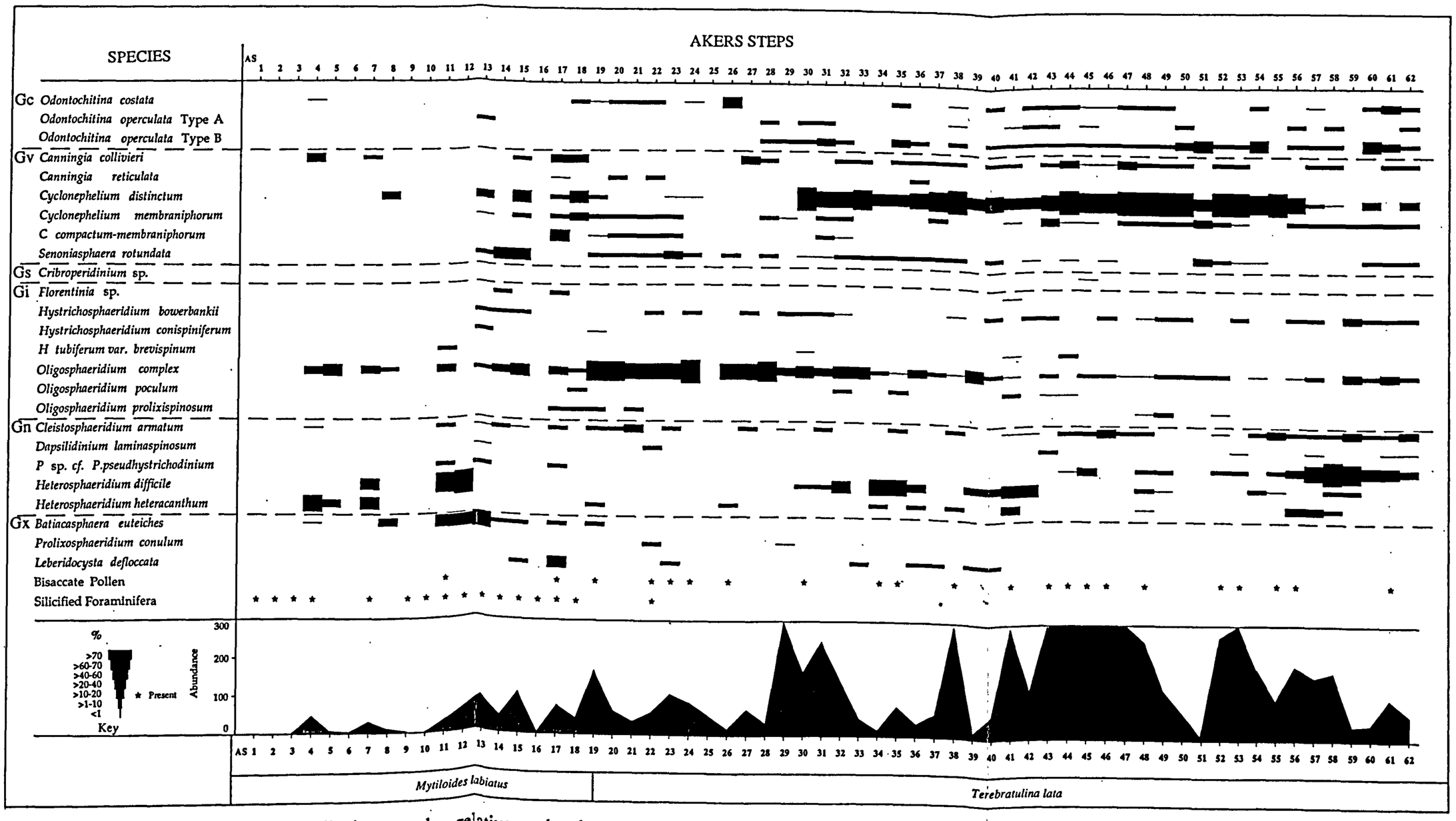


Figure 5.6 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Akers Steps, Dover.

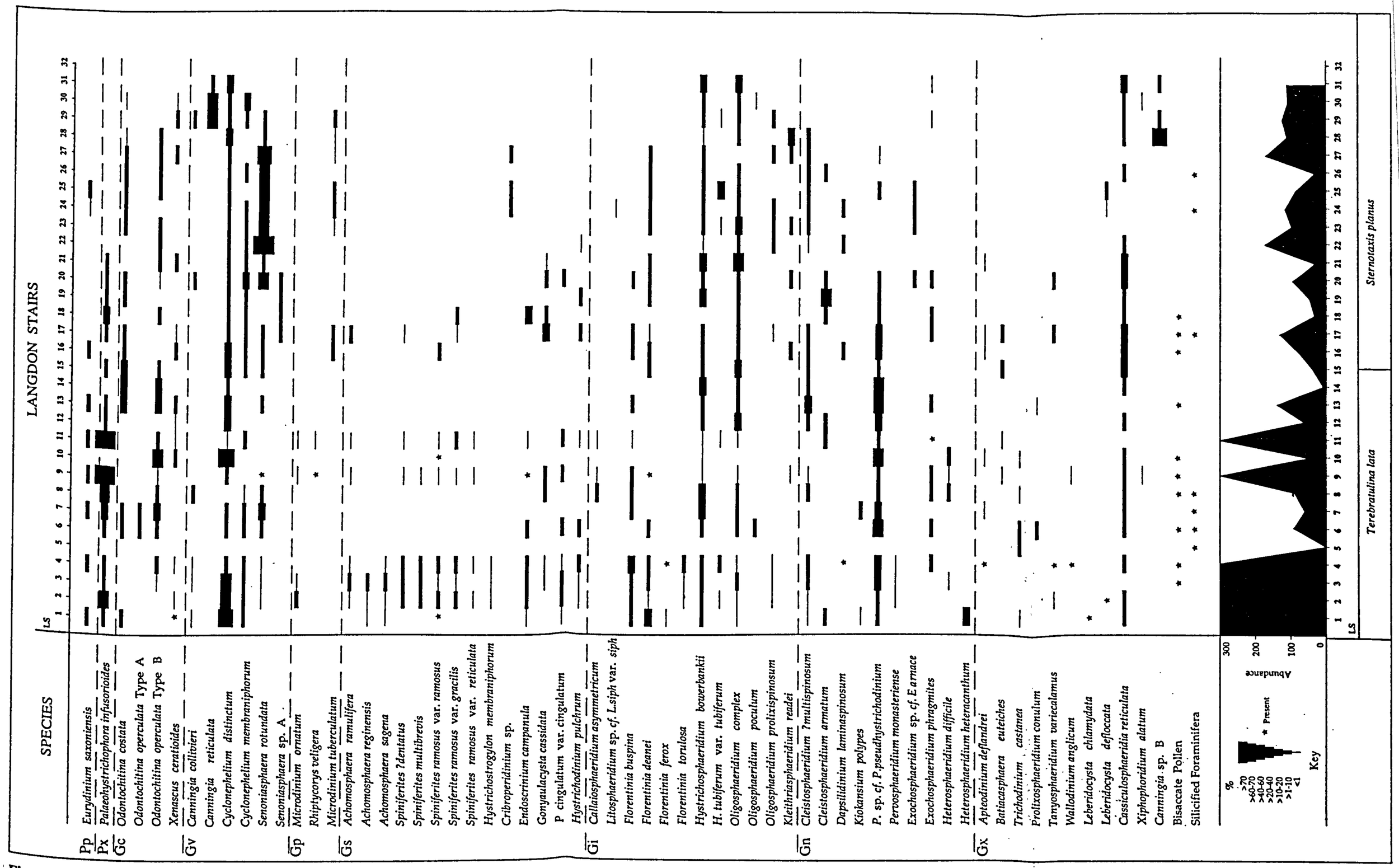


Figure 5.7 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Langdon Stairs, Dover.

5.4.2 Sussex

The recovery is generally good with samples with abundant floras, although the diversity remains variable. Generally the assemblages from all the sections are dominated by the same morphogroups as at Dover (Gc, Gv, Gn and Gi), with Gs, Px and Pp becoming more frequent in the samples from Beachy Head.

Most of the common Turonian species have their first occurrences within the Melbourn Rock Beds at the level of HW1 (*Heterosphaeridium difficile, Odontochitina costata, O.operculata* Type B and *Cyclonephelium membraniphorum*). Other species occur a few metres above this level, *Oligosphaeridium complex* occurs in HW3; *Cyclonephelium distinctum* and *Odontochitina operculata* Type A appear in HW4 and *Senoniasphaera rotundata* occurs from the level of sample HW16. The last appearance of *Litosphaeridium chlidanum* occurs in HW11, indicating the uppermost part of the Cenomanian (Duane, 1992).

There is an influx of *Cyclonephelium membraniphorum* within the Melbourn Rock Beds in HW7 and HW8. Influxes of *Oligosphaeridium complex* and *Heterosphaeridium difficile* are noted at SO5, and SO17, SO22, SO23 and SO24 respectively, still in the *Mytiloides labiatus* Zone. *Palaeohystrichophora infusorioides* dominates the assemblages from Beachy Head. The common taxa yielded from samples from Caburn Pit include *Odontochitina* spp., *Oligosphaeridium complex, Cyclonephelium distinctum* and *Cyclonephelium membraniphorum.* In samples NP1-NP13, the genus *Odontochitina* dominates the assemblages together with *Heterosphaeridium difficile* in samples NP10-NP13. Further distinct acmes of *Cyclonephelium distinctum* and *Pervosphaeridium pseudhystrichodinium* are also noted at NP22, NP24, NP27, NP28 and NP30 respectively, which at this level are within the *Terebratulina lata* Zone. In the upper Turonian, at the level of the South Street Marl, there is an influx of *Senoniasphaera rotundata* in SPT5-SPT7.

5.4.3 Isle of Wight

Recovery is variable, with moderate abundances yielded by the samples from Compton Bay, and poor abundances from the samples from the Military Road section. Again the assemblages are dominated by the four morphogroups (Gc, Gv, Gi and Gn).

Almost all of the common species occur at the base of the section at Compton Bay, within the Melbourn Rock Beds, at the level of CB1-26 (*Senoniasphaera*

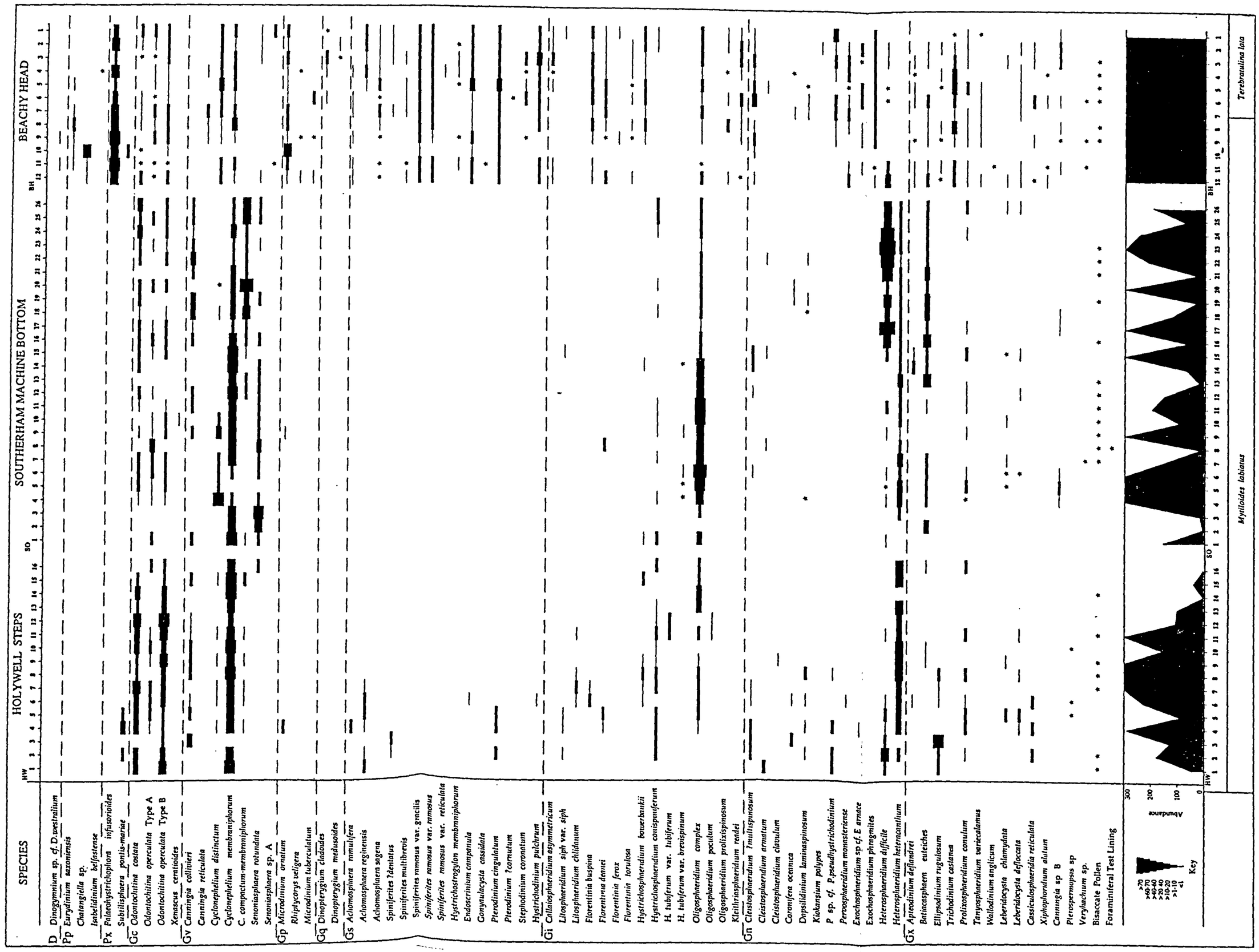


Figure 5.8 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Holywell Steps, Southerham Machine Bottom & Beachy Head, Sussex.

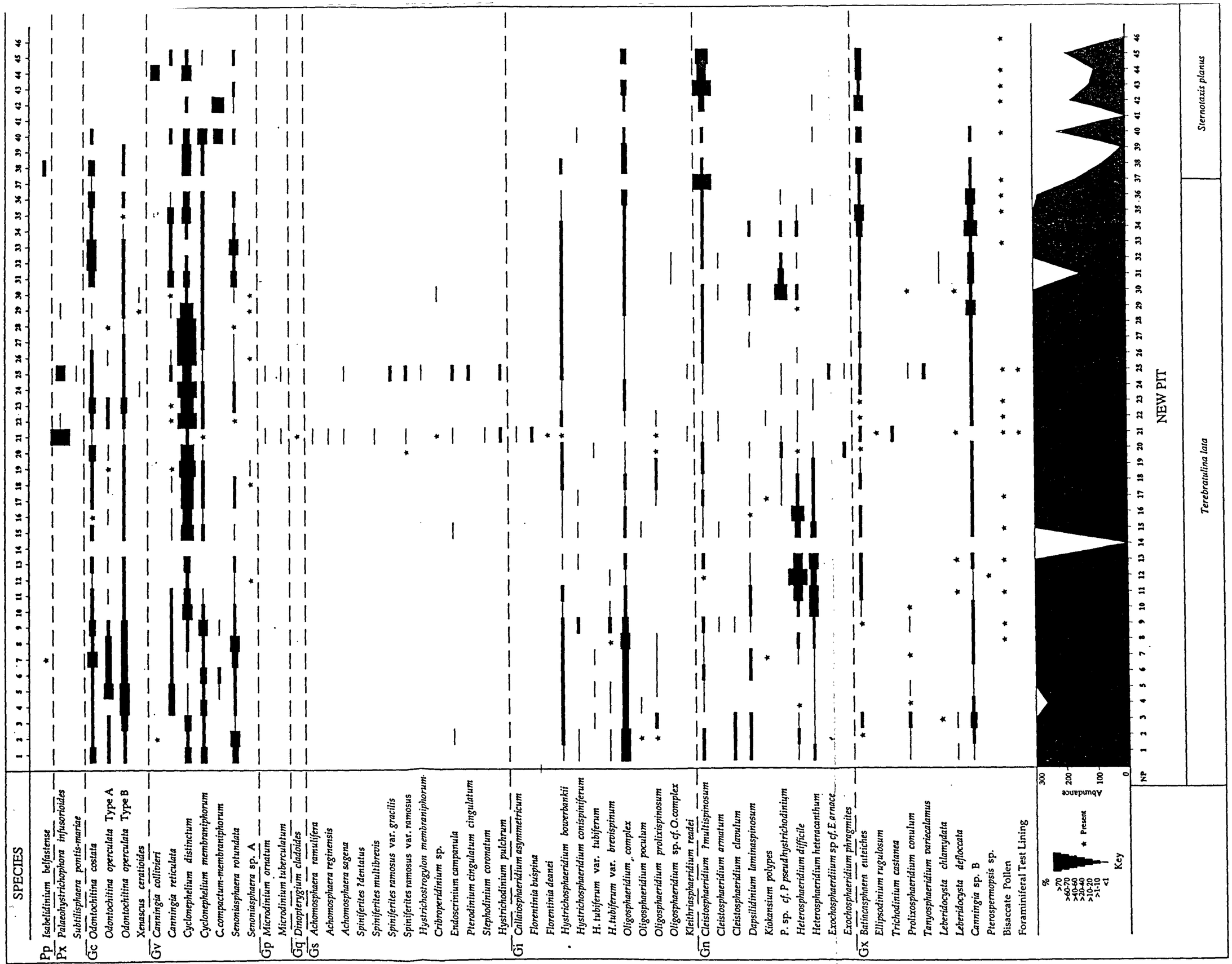


Figure 5.9 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from New Pit, Sussex.

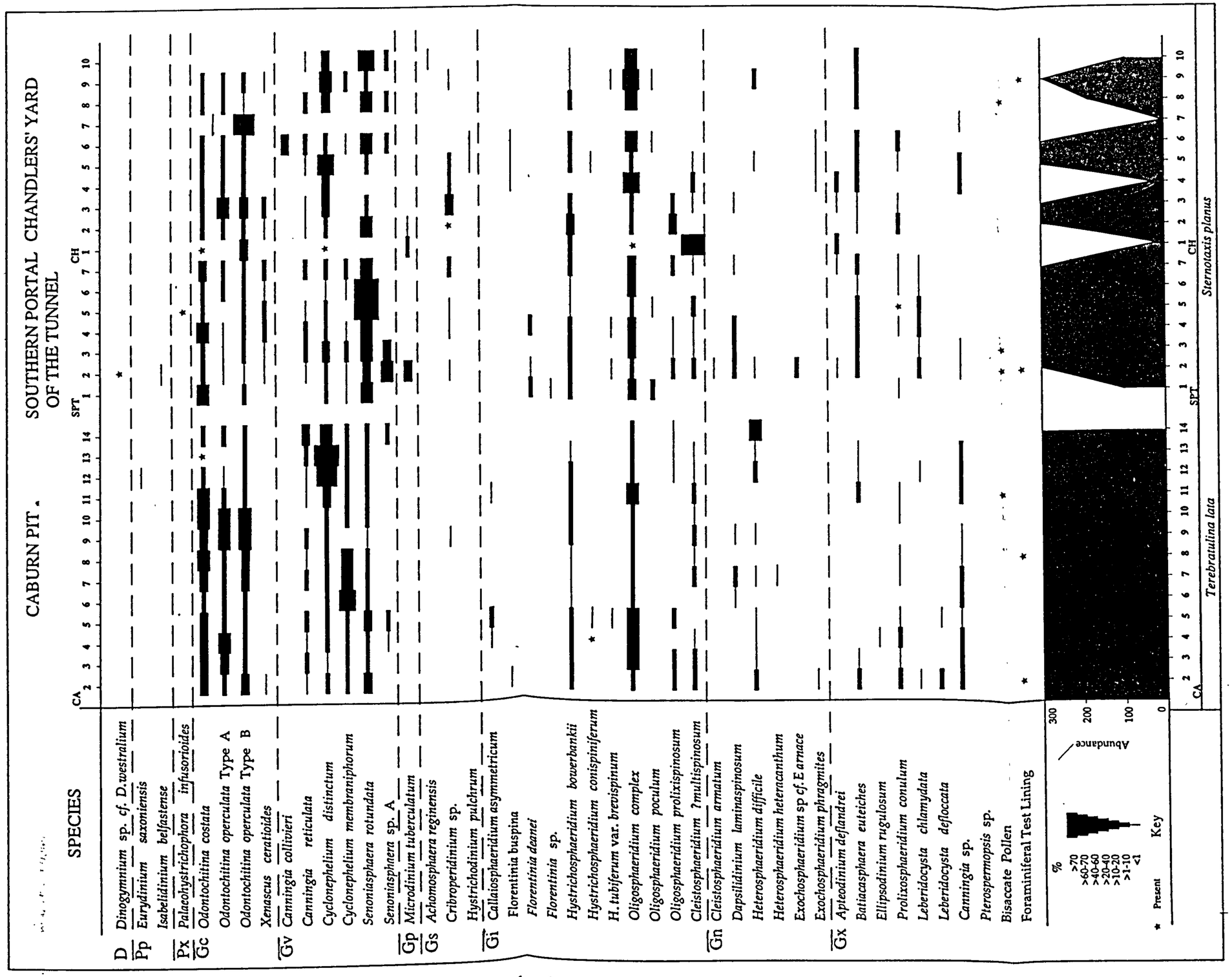
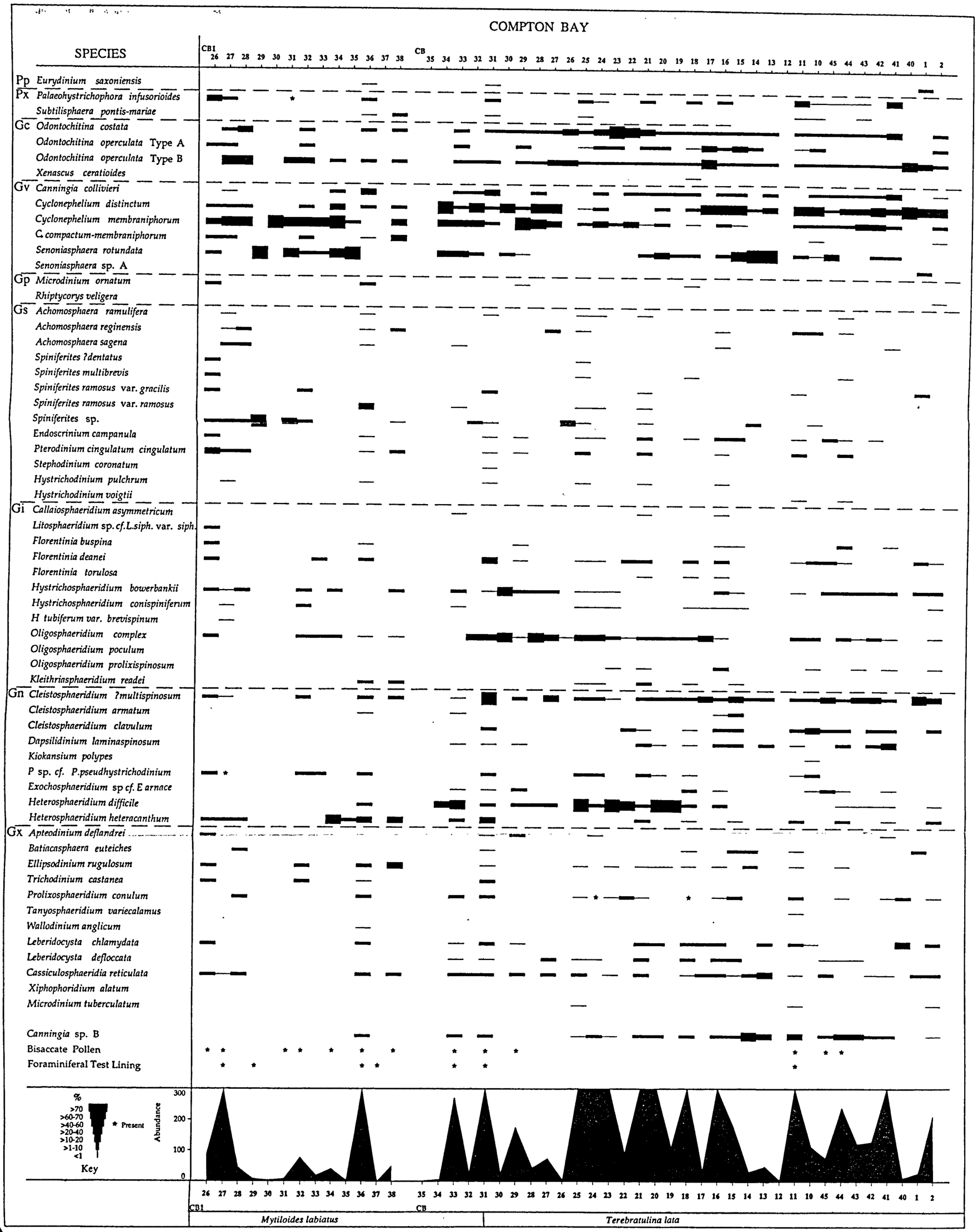


Figure 5.10 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Caburn Pit, Southern Portal of the Tunnel & the Chandlers' Yard, Sussex.

Figure 5.11 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Compton Bay, Isle of Wight.



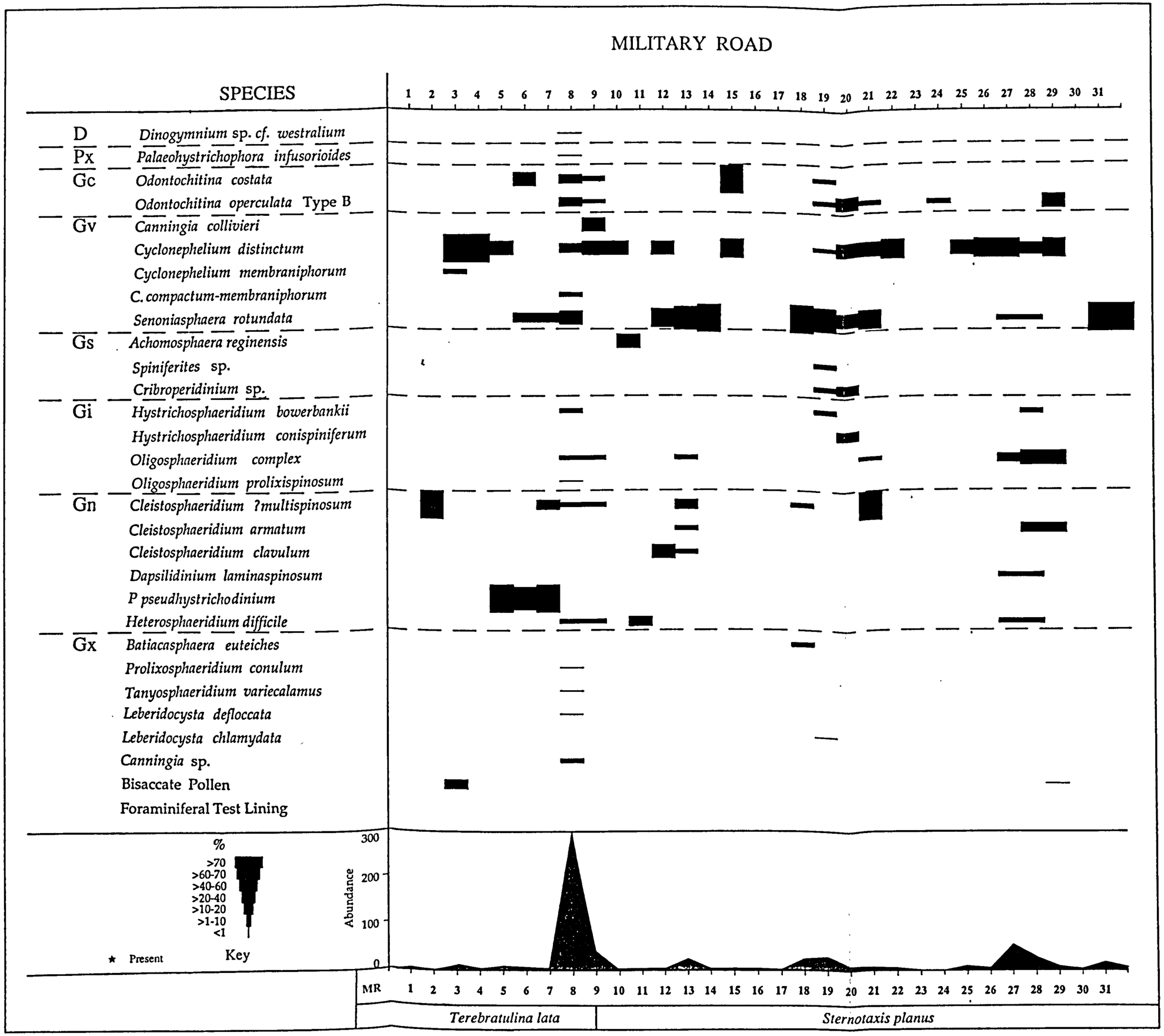


Figure 5.12 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from the Military Road, Isle of Wight.

rotundata, Cyclonephelium distinctum, Cyclonephelium membraniphorum, Oligosphaeridium complex, Pervosphaeridium sp. c.f. *P.pseudhystrichodinium* and *Odontochitina operculata* Type A). *Odontochitina costata* and *O.operculata* Type B appear for the first time in CB1-27 and *Heterosphaeridium difficile* occurs unusually far above the Melbourn Rock Beds (approx. 17m) in sample CB1-36.

There are influxes of *Cyclonephelium membraniphorum* in samples CB1-30 to CB1-34 and CB29. *Cyclonephelium distinctum* dominates the assemblages in CB35 to CB27 and in samples CB11-CB2. Just below the New Pit Marl some influxes of *Heterosphaeridium difficile* and *Odontochitina costata* are found at CB25, CB23 and CB23-CB20 respectively. *Senoniasphaera rotundata* has an acme occurrence at the top of the *Mytiloides labiatus* Zone at the level of CB13 and CB14.

The uppermost Turonian samples from the Military Road section are dominated by *Cyclonephelium distinctum, Senoniasphaera rotundata* and *Pervosphaeridium* sp. c.f. *P.pseudhystrichodinium.*

5.5.1 Discussion of the Biostratigraphical Results.

Generally the dinoflagellate cyst populations from the Turonian are of variable diversity and abundances. At the base of the stage in the first few metres of the Melbourn Rock Beds samples are barren or yield low diversity assemblages. The samples above the Melbourn Rock Beds yield an increasingly rich dinoflagellate cyst flora (diversity >15) with many species reappearing after the effects of the oceanic anoxic event associated with the Plenus Marl Formation at the end of the Cenomanian stage (Jarvis *et al.*, 1988). This gradual increase in diversity and abundance reaches a maximum by the middle part of the Turonian.

At certain intervals the dinocyst populations are almost monospecific or dominated by one or two species. The dominant species alternates between *Cyclonephelium distinctum, Cyclonephelium membraniphorum, Senoniasphaera rotundata, Heterosphaeridium difficile* and *Pervosphaeridium pseudhystrichodinium.* These five species are rather large and robust, possessing proximo-chorate ornament with the exception of *S.rotundata* which is a cavate cyst. They belong either to the Gv or Gn morphogroups of Evitt (1985).

Other morphogroups are represented, infrequently and not always persistently. The peridinioid morphogroups (Pp, Px) are poorly represented by occasional occurrences of *Eurydinium saxoniensis, Subtilisphaera pontis-mariae, Isabelidinium cooksoniae, Chatangiella* sp. and *Palaeohystrichophora infusorioides.* The gonyaulacoid groups, Gs, Gi, and Gq, rarely occur but only as a small proportion of the whole assemblage. Some species belonging to the Gi (*Oligosphaeridium complex, Hystrichosphaeridium bowerbankii, Florentinia* spp.), and the Gc (*Odontochitina operculata* A & B, *Odontochitina costata*) morphogroups are persistent but sporadic in their occurrence throughout the Turonian. They not as dominant as those already mentioned.

P.infusorioides becomes superabundant in some samples, notably the flints (LS9, LS11; NP21). This would indicate some preferential preservation of these small, delicate forms in this medium rather than the surrounding chalk.

5.5.2 Comparison with previous results from the Anglo-Paris Basin

By comparison with previous findings (as discussed earlier in this chapter) few alterations can be made as a result of this investigation. The results herein mainly support the previous findings, with some additions or differences of opinion which will be discussed. Generally much of the previous work has concluded that the Turonian does not yield as rich or diverse a flora as other parts of the succession (e.g. Cenomanian). Certainly, this was found to be the case in the areas studied.

The zones suggested by Clarke & Verdier (1967) are of little value as they were based upon only a few samples from stratigraphically distinct parts of the succession (separated by approximately 80 metres). The last appearance of *Scriniodinium campanula* within the *R.cuvieri* Zone was taken to define the base of the second of their assemblage zones. This species does have a last appearance within the upper Turonian from the results of this investigation (in samples LS18, NP25, and CB42) and so may be a useful indicator, but of latest *T.lata* - earliest *S.planus* Zone.

Marshall (1983) concentrated on the boundary between the Cenomanian - Turonian successions. One species (*Litosphaeridium chlidanum*) was interpreted as being a marker taxon for the uppermost Cenomanian. This species is also present in samples from Holywell Steps (HW6-HW8 and HW11),

Sussex and is interpreted here as indicating a latest Cenomanian - earliest Turonian age.

Tocher & Jarvis (1987) regarded the first appearance of *H.difficile* and *S.rotundata* together with the occurrence of *Florentinia buspina* and *F.torulosa* as being indicative of an early to mid-Turonian age in southeast Devon. In contrast, the first appearances of the *H.difficile* are found to vary from the latest Cenomanian (HW1) to several metres higher in the succession (AS7 and CB1-36). *S.rotundata* also occurs for the first time at varying stratigraphic levels; earliest Turonian (CB1-26, HW16) and early Turonian (AS12). *F.buspina* is found to occur in the early Turonian (HW6, HW7, CB1-26), and sporadically throughout the rest of the sequence. It does not occur at Dover until the level of LS1, which is near the top of the *T.lata* Zone. *F.torulosa* occurs mainly in the early to middle Turonian (latest *M.labiatus* to latest *T.lata* Zones) and is not present above the *T.lata* Zone. It is interesting to note that *P.infusorioides* appears to dominate the assemblages at the levels of the flint bands.

The results of this study agree with Jarvis *et al.* (1988) in that dinoflagellate cyst assemblages from Dover are atypical in comparison with assemblages from other parts of the Anglo-Paris Basin. The lack of common species of *Achomosphaera* and *Spiniferites* is thought to be inherent for the Turonian as a whole, with neither genus being consistently represented throughout the succession in Dover, Sussex or the Isle of Wight.

Costa & Davey (1992) note several features about Turonian dinoflagellate cyst assemblages. The first appearance of *H.difficile* as described, is not thought always to be consistent with the base of the Turonian. As this investigation did not include any material from the North Sea, it is not possible to comment upon detailed comparison with assemblages from this region. However, it is apparent from this work that peridinioid forms are poorly represented in the Turonian sequence of southern England.

Comparison with the zonations produced and modified by Foucher (1974, 1975, 1976a, b, 1977, 1980, 1981, 1982) for the Anglo-Paris Basin is discussed below.

The earlier publications (Foucher 1974, 1975, 1976a,b,1977) analysed and documented the dinoflagellate cyst content of Upper Cretaceous flints.

These were found to yield rich and diverse assemblages of dinoflagellate cysts. The flints analysed during this investigation yield similar assemblages in which *P.infusorioides* is superabundant and the genera *Achomosphaera* and *Spiniferites* are relatively common, in comparison with chalk samples from the same level (LS8, LS9, LS10 & LS11). These are discussed in detail in Chapter 6.

The later publications dealt with sediment samples from different parts of the Anglo-Paris Basin. Some useful index taxa and their ranges were identified, as discussed earlier. The first appearances of *S.rotundata* and *F.buspina* are variable from the early Turonian at Sondage de Civray, to the base of the middle Turonian in the North-occidental region. A zonation for the Turonian was erected (Figure 5.4), based upon two of the typically Turonian species. *Florentinia.* aff. *ferox* is not used in this study as a stratigraphically useful form, but *S.rotundata* is. Its first appearance, although a little variable, is a good indicator for Turonian sediments, and its "flood" in the upper part of the succession is a good late Turonian bioevent. Further research in the 1980s has not refined this zonation, except to expand the geographical limits of knowledge of Turonian dinoflagellates to more westerly parts of the Anglo-Paris Basin..

The assemblages are, in the main, dominated by similar forms (*Odontochitina* spp., *H.difficile, H.heteracanthum, O.complex*) to those found in southern England, with *Achomosphaera* and *Spiniferites* occurring rarely to commonly.

5.6.1 Stratigraphically Useful Forms and Palynozonation

As there is a lack of stratigraphically useful forms (many re-occur after their apparent demise at the end of the Cenomanian, and few occur for the first time within the Turonian), the few typically Turonian forms are used together with influxes of particular species are used here to produce a new palynozonation for the Turonian of southern England.

Palynozone I

One species thought to be an important index taxon is *Litosphaeridium "chlidanum"* (Marshall 1983). This form is found in the Upper Cenomanian sediments of Humberside (Duane 1992), and it is also present in some of the lowermost samples from the Holywell Steps section, on the Sussex coast. It has its last appearance in HW11, which is just below where the index ammonite *Mammites nodosoides* was found (at the level of HW14). It is

therefore believed to be useful in characterising the uppermost Cenomanian and, as a result, the base of the Turonian. The last appearance can be used to define the top of Palynozone I.

Palynozone II

However, there are some typically Turonian forms making their first appearance within or just below the base of this stage, notably *Heterosphaeridium difficile, Senoniasphaera rotundata* and *Florentinia buspina.* The first occurrence of these forms is variable, from the very uppermost Cenomanian (within the Melbourn Rock Beds), to a few metres above the base of the Melbourn Rock Beds, where the macro-biostratigraphical base of the stage is taken (Kennedy & Cobban 1991). These first occurrences define the base of Palynozone II. *Oligosphaeridium complex* has a consistent occurrence throughout this zone.

Palynozone III

Florentinia torulosa has its first appearance at the top of the *M.labiatus* Zone and has its last appearance just below the base of the *T.lata* Zone. The first appearance of this species defines the base of Palynozone III. This palynozone is also characterised by influxes of *Heterosphaeridium difficile* and *Cyclonephelium distinctum* in the middle of the *T.lata* Zone.

Palynozone IV

The last occurrence of *Endoscrinium campanula* is used to define the base of Palynozone IV. The acme occurrence of *Senoniasphaera rotundata,* noted in the upper part of the succession of each region, is thought to be of potential correlative value, occuring within the *Sternotaxis planus* Zone. At Dover, it occurs just above the Fan Bay Marls (in samples LS20 - LS29). In Sussex, a similar event is noted above the Bridgewick Marls (in samples SPT1 - SPT7), which are correlated with the Fan Bay Marls at Dover (Wray 1991). On the Isle of Wight, this bioevent is also found to occur 4 metres below the Lewes Marl (in samples MR11 - MR23). This event occurs within Palynozone IV.

These stratigraphically useful species and their acme events have been summarised in Figure 5.13.

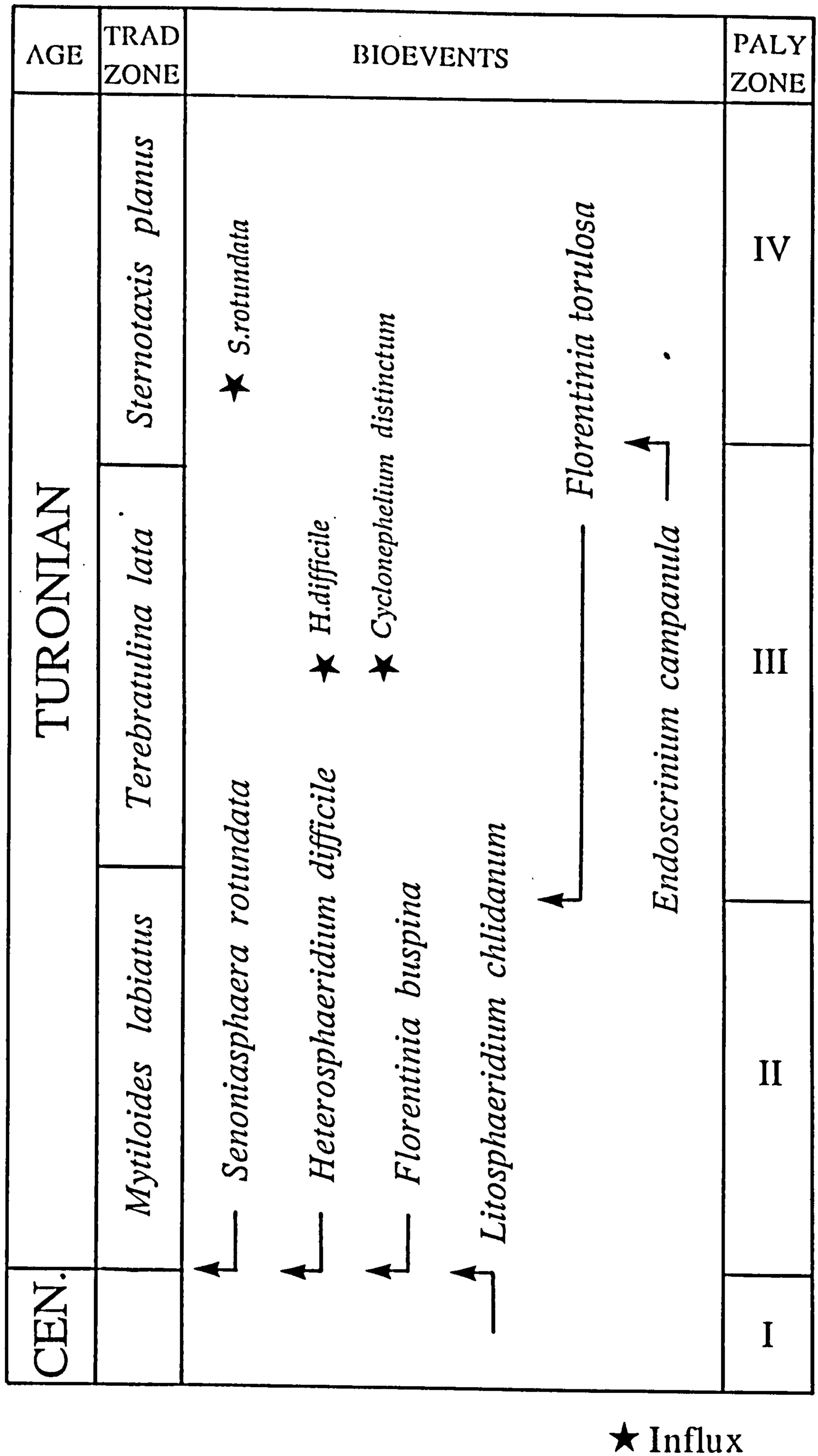


Figure 5.13 Palynozonation for the Turonian of southern England

Comparison with other parts of the Anglo-Paris Basin is limited because assemblages from southern England are not always found to be consistent with the assemblages from France. The first appearance of *S.rotundata* in France seems to be consistent with an Early Turonian age. In France the first appearance of *F.torulosa* has a similar first appearance in the middle part of the Turonian but appears for the first time at a slightly higher stratigraphical level. The absence of *H.difficile s.s.* from some of the French samples is surprising as it is thought to be a useful Turonian marker.

5.6.2 Conclusions

Some development of existing palynozonations has been attempted during the course of this investigation and the result is shown in Figure 5.13. As the Turonian is only some 3my in duration, it is not surprising that further refinement of the biostratigraphy is difficult. However the limitations of this palynozonation must be realised and comparison with other work, particularly from France, has shown it is not always found to be consistent with the microplankton assemblages recovered there. There are other factors controlling the assemblages, either different water masses within the basin, or proximity to the shoreline, affecting the production of cysts at different times. These in turn are determined by local geological variations, faulting and uplift affecting the positioning of local geographical highs and lows in the basin.

The palynozonation appears to work for the northern part of the Anglo-Paris Basin, but would need further modification to be applied to other regions. It would not be easily applied to the northern North Sea where the assemblages are markedly different, and the lithologies belong to a different facies.

CHAPTER SIX CHALKS, MARLS AND FLINTS

6.1 Introduction

During this biostratigraphical investigation of the Turonian succession, several interesting features were noted that required further detailed examination. Different trends and changes in the dinoflagellate cyst assemblages have already been noted (see Chapter 5), and it was decided to test their lithological relationship. Each minor study involves analysis and assessment of the dinoflagellate assemblages in relation to different lithological aspects of the Turonian. It is hoped that these results will help the understanding of the controls on the distribution of dinoflagellate cysts within the sequence.

6.2.1 The overlap between the Akers Steps and Langdon Stairs sections, near Dover.

The Turonian at Dover is composed of a composite section from Akers Steps and Langdon Stairs (as already discussed in Chapter 1, see Enclosure 1). There is an "overlap" between the two sections at the stratigraphic level of the Langdon Bay Marls. There is minimal difference in measurement between the two marls (approximately 1-2cms) from the two sections and they have been correlated with confidence for some time. Equivalent samples at this stratigraphical level were examined for their dinoflagellate cyst content (Figure 6.1).

6.2.2 Sampling and Results

The first samples (AS1-62; LS1-31) analysed from these sections were found to be different in terms of the abundance (number of specimens per slide) and diversity (number of species in a sample) of the dinoflagellate cyst assemblages, particularly concerning the samples from within and around the "overlap" (Enclosure 1; Figure 6.1). The samples from Akers Steps yielded dinoflagellate cyst assemblages that were low in diversity (<20 species)and abundance (<100 specimens). The equivalent samples from Langdon Stairs

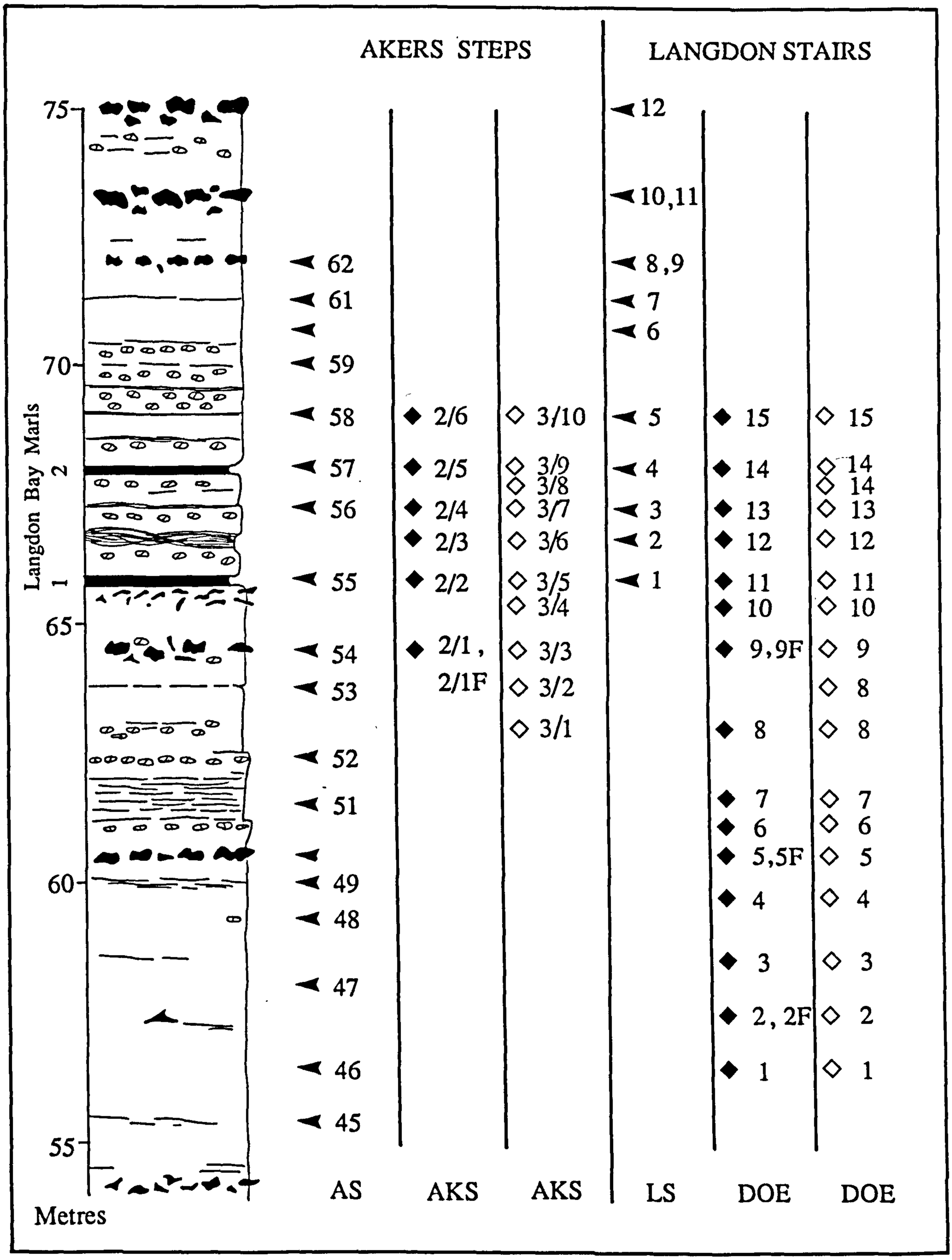


Figure 6.1 Sampling of equivalent horizons at the stratigraphical level of the Langdon Bay Marls, Dover.

produced dinoflagellate cyst assemblages with significantly greater abundances (>300 specimens) and diversities (20 - 40 species). Figures 6.2 and 6.3 show these differences visually.

Mean species diversity: Akers Steps AS (55-62) = 8
Langdon Stairs LS (1-11) = 22

It was decided that before any further conclusions were drawn and to test the reliability of the results, a second set of samples from the "overlap" be taken from exactly the same horizons and analysed for their palynomorph content. The repeat samples (AKS, DOE) and their positions are shown on Figure 6.1.

These samples were processed in the normal manner as outlined in Chapter 3. The resultant dinoflagellate cyst assemblages supported the previous findings and samples were examined statistically to substantiate these. The species diversities and abundances are again very different for the two sections (Figure 6.4 & 6.5). Quantitative analyses were performed by measuring an aliquot of residue on to a slide. This can then be related to the dry weight of sediment processed and quoted in terms of cysts per gramme of sediment (Figure 6.6). It must be noted that this does not give a measure of primary productivity at the time of deposition.

Mean species diversity: Akers Steps AKS (2/1 - 2/6) = 10
Langdon Stairs (DOE 10 - 15) = 30

Mean abundance : Akers Steps (AKS 2/1 - 2/6) = 56
Langdon Stairs (DOE 10 - 15) = 322

6.2.3 Palynological and Micropalaeontological Assemblages

Cyst Occurrences

Some common long-ranging dinoflagellate cysts occurring in both sections include *Oligosphaeridium complex, Odontochitina operculata, Odontochitina costata, Cyclonephelium distinctum, Cyclonephelium membraniphorum,*and *Hystrichosphaeridium bowerbankii.* Two typically Turonian forms which also occur are *Heterosphaeridium difficile* and *Senoniasphaera rotundata.* Cyst distributions are shown in Figure 6.7.

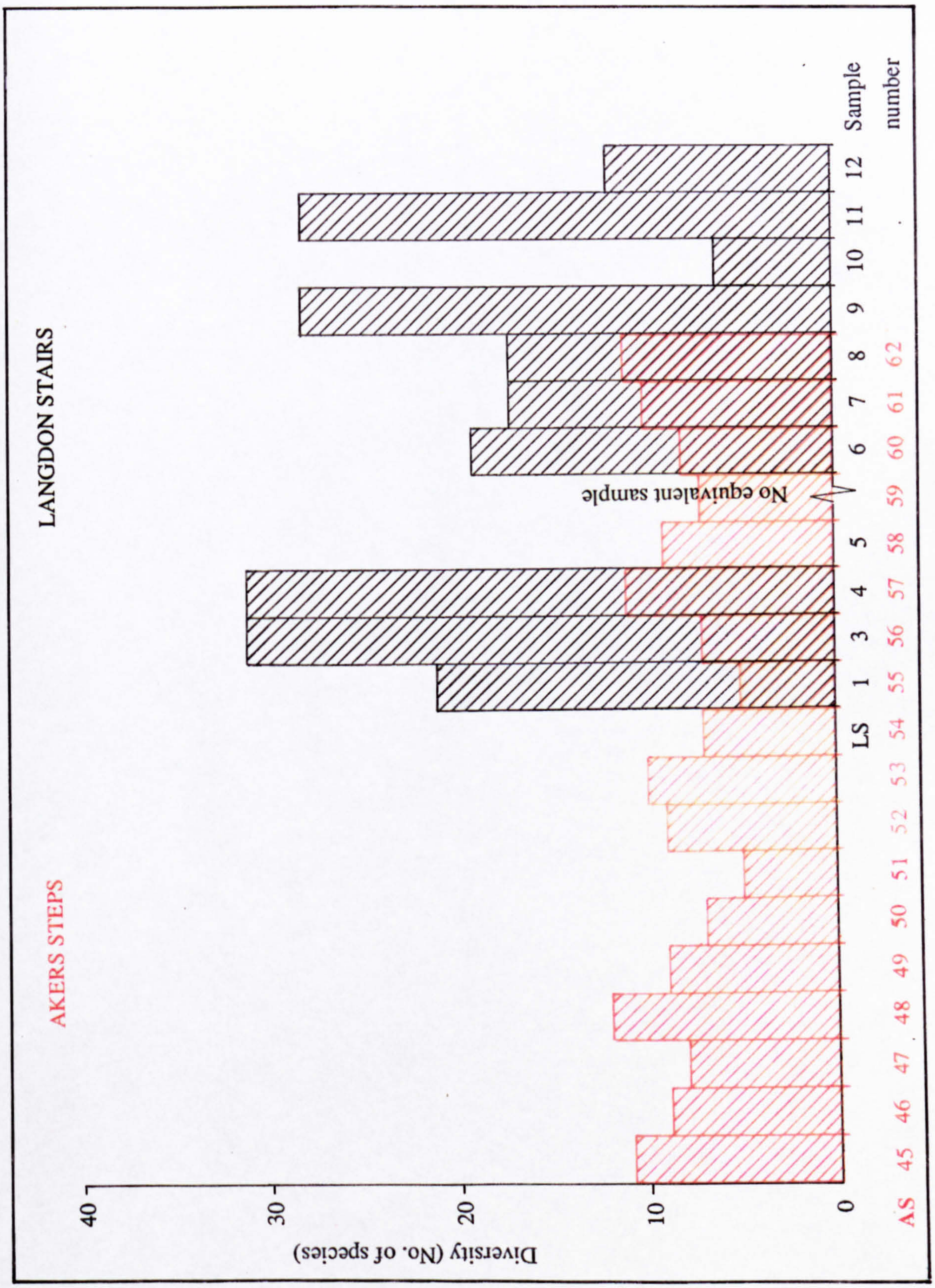


Figure 6.2 Species diversity of equivalent samples from Akers Steps (AS) & Langdon Stairs (LS), Dover.

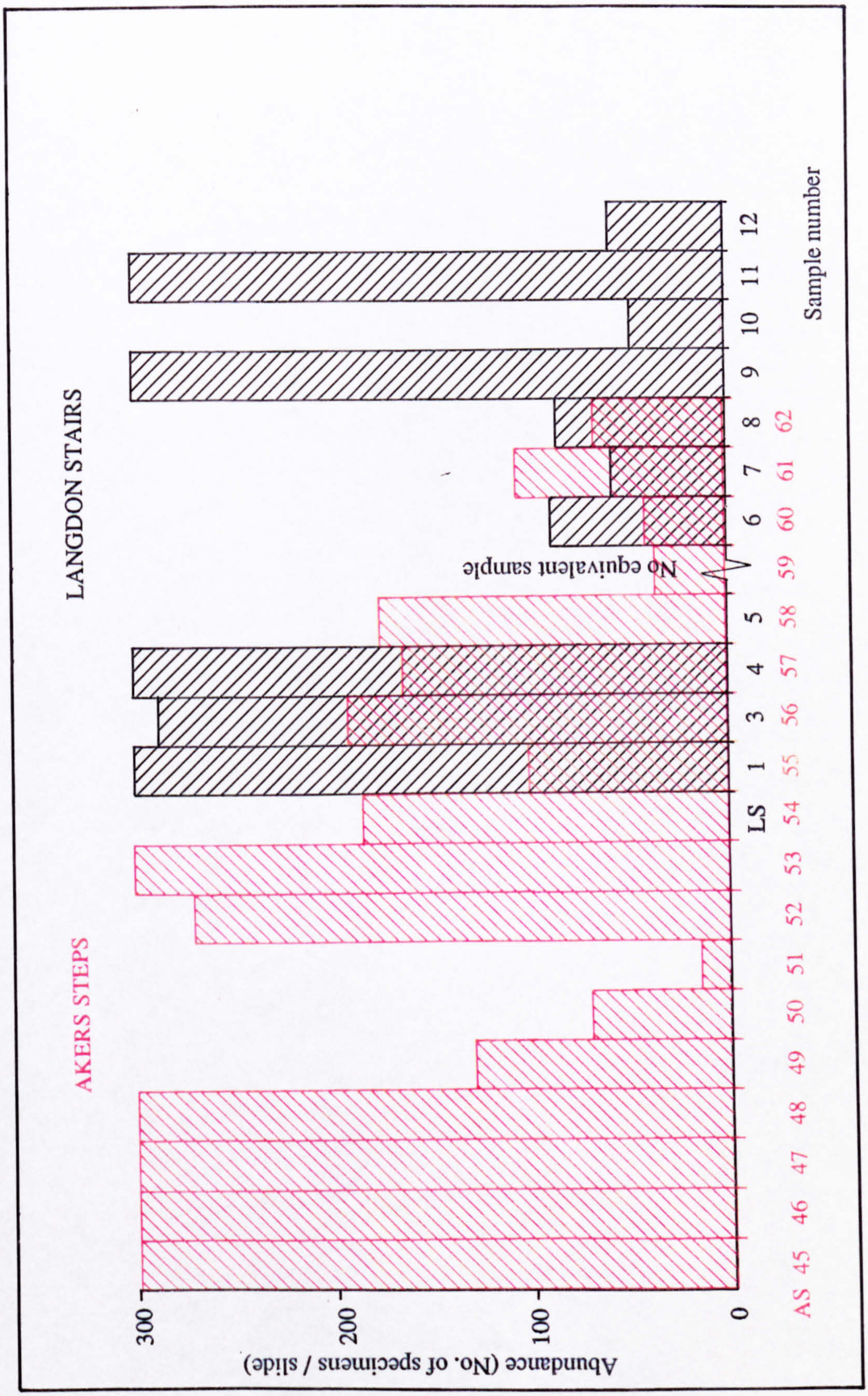


Figure 6.3 Abundance of equivalent samples from Akers Steps (AS) & Langdon Stairs (LS), Dover.

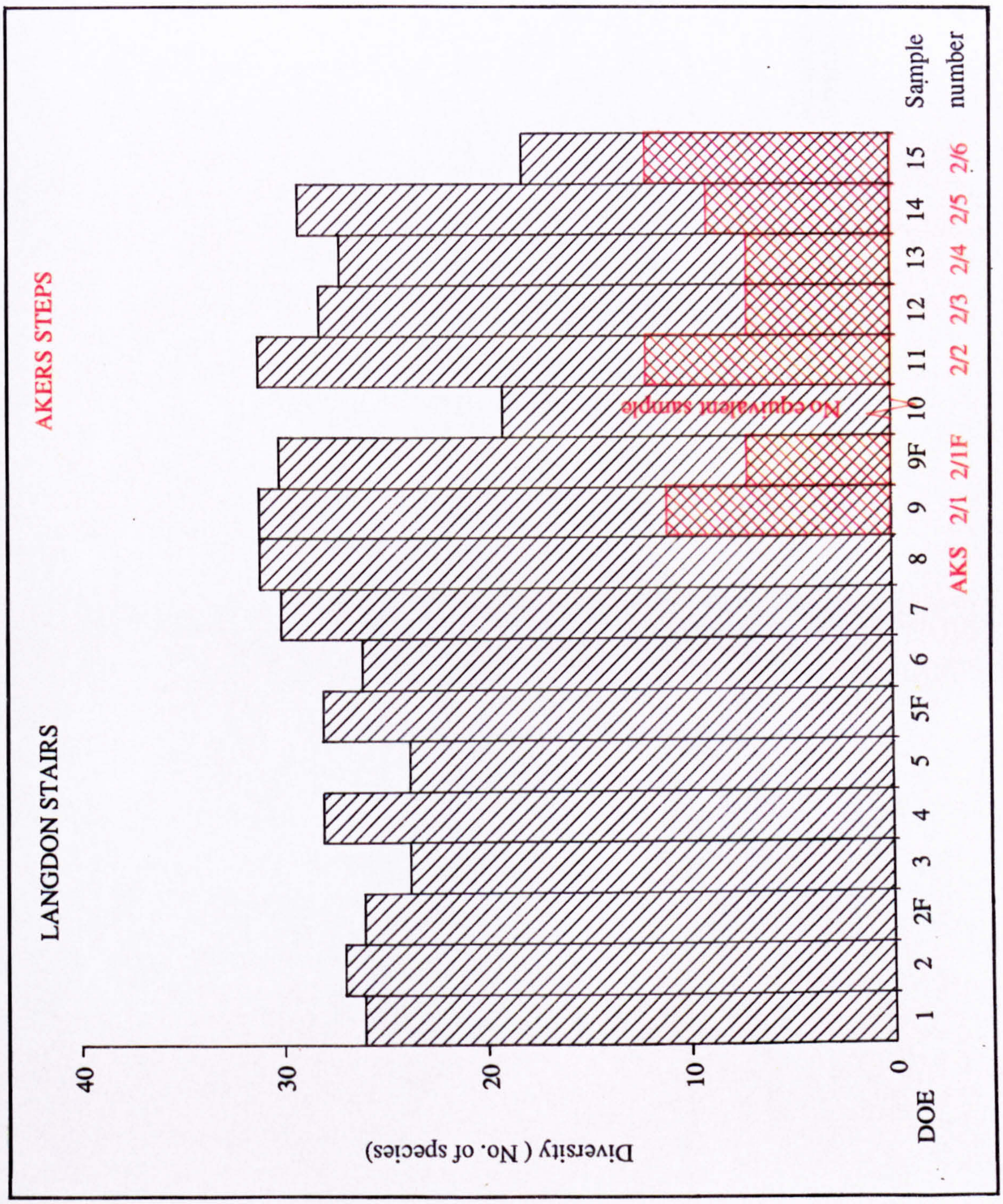


Figure 6.4 Diversity of equivalent samples from Akers Steps (AKS) & Langdon Stairs (DOE), Dover.

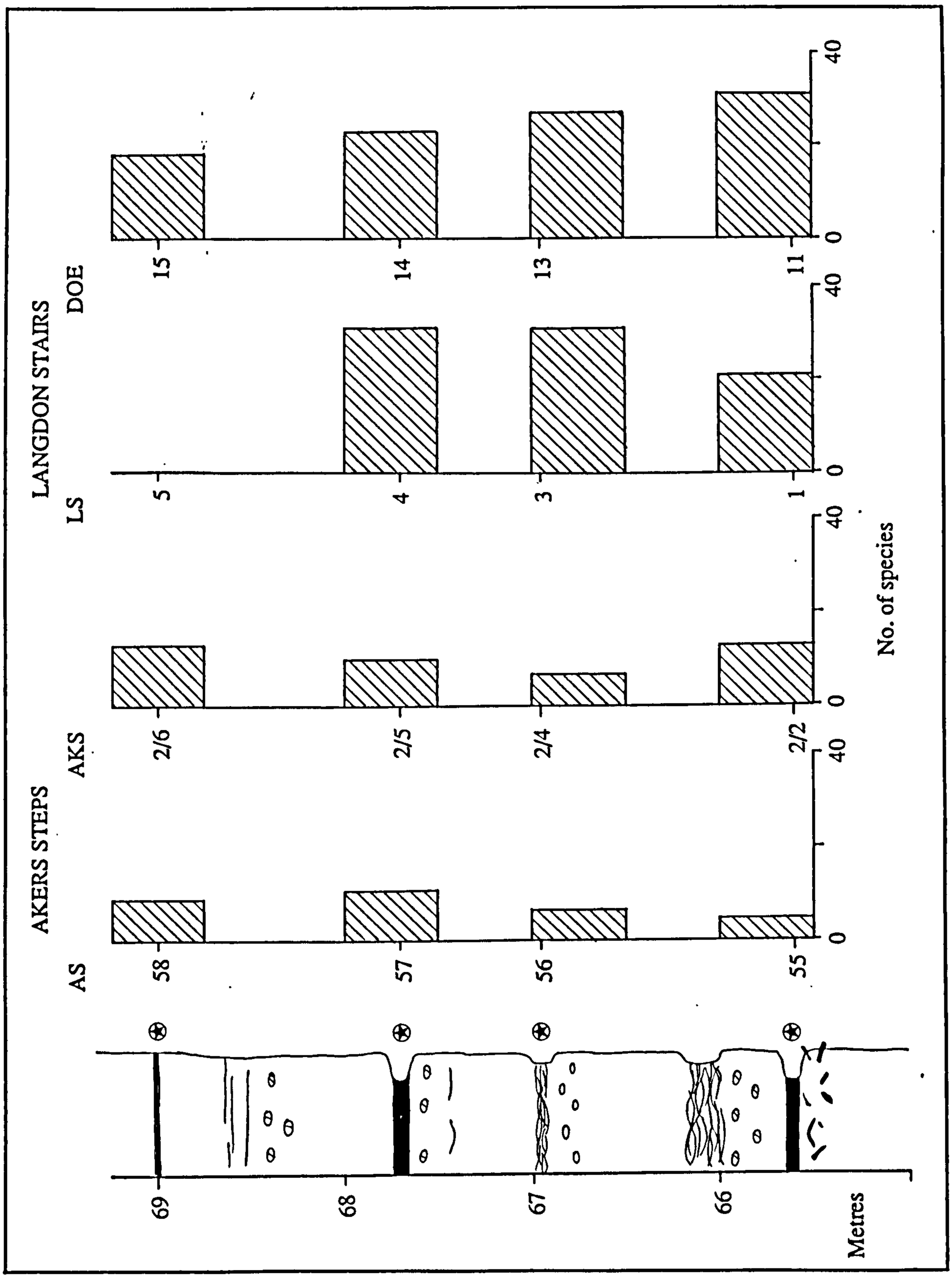


Figure 6.5 Species diversity of equivalent samples from Akers Steps (AS, AKS) & Langdon Stairs (LS, DOE), Dover.

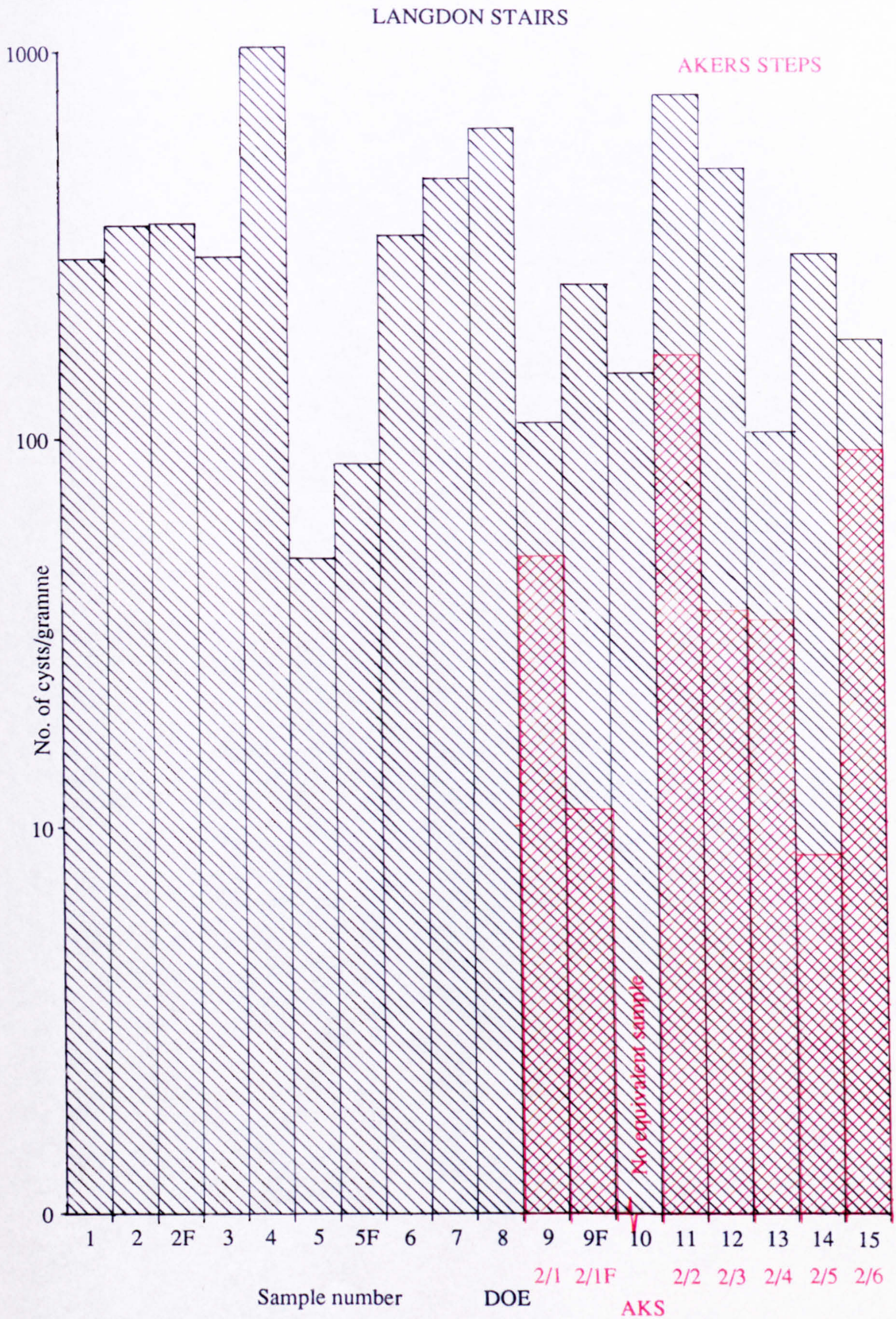


Figure 6.6 Quantitative results of equivalent samples from Akers Steps (AKS) & Langdon Stairs (DOE), Dover.

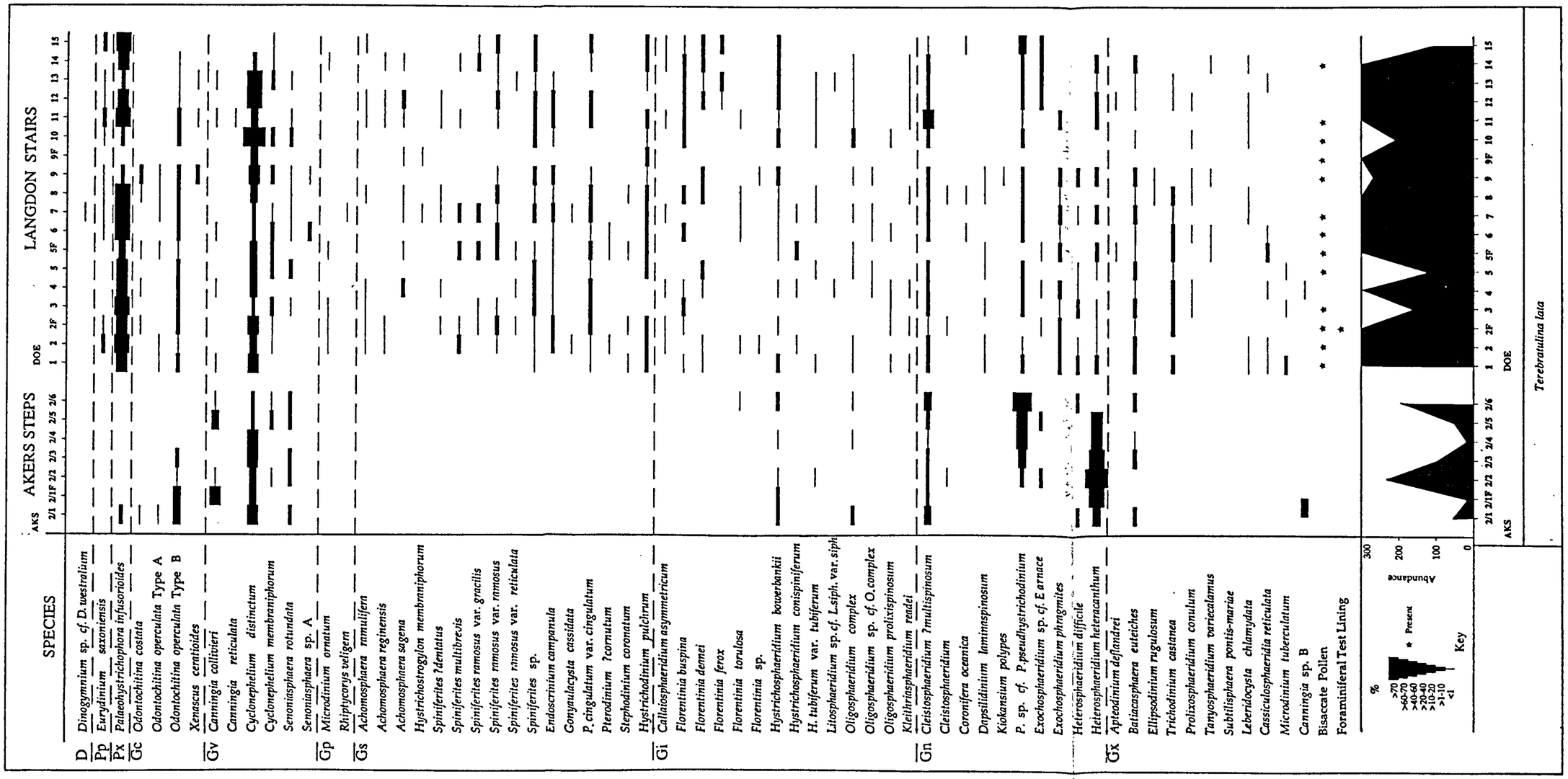


Figure 6.7 Stratigraphic distribution and relative abundance of dinoflagellate cyst species from Akers Steps (AKS) & Langdon Stairs (DOE), Dover.

There are some obvious differences in species composition between the two sections. Notably, there is a curious lack of the genera *Spiniferites, Achomosphaera and Palaeohystrichophora* in the samples from Akers Steps. The samples from Akers Steps are dominated by *Cyclonephelium distinctum, Pervosphaeridium* sp. cf. *P.pseudhystrichodinium* and *Heterosphaeridium heteracanthum.* In contrast the dominant species from the Langdon Stairs samples are *Palaeohystrichophora infusorioides* and *Cyclonephelium distinctum.* The assemblages from Langdon Stairs include more unusual and varied forms, particularly species of *Florentinia* and some small proximate cysts, including *Ellipsodinium rugulosum, Endoscrinium campanula, Exochosphaeridium phragmites, Microdinium ornatum* and *Trichodinium castanea.* In addition some species of *Achomosphaera, Spiniferites* and *Palaeohystrichophora* are represented in the samples from Langdon Stairs. These statements are true for both sample sets. However, in the repeat samples from Langdon Stairs there are some minor occurrences of *Senoniasphaera* sp., *Dinogymnium* sp. and *Stephodinium coronatum*, which were not found in the first sample set.

Comparison with the Southerham Marls from Sussex

The Langdon Bay Marls have been correlated with the Southerham Marls from Sussex (see Chapter 2). The samples from Sussex were collected from the stratigraphic level of the Southerham Marls (NP27-NP30); only the samples from the marl bands (NP27 & NP30) are equivalent to samples from Dover (AS55, AKS2/2, LS1, DOE11 and AS57, AKS 2/5, LS4, DOE14). Both samples from Sussex have high abundances (>300 specimens), but relatively low diversities (11 and 15 respectively). Comparison with the results from Dover show a greater similarity with the samples from the Akers Steps section, which have low abundances and low diversities.

Micropalaeontological Analysis

Foraminiferal and nannofossil assemblages from a suite of equivalent samples (DOE1-DOE15, AKS3/1-AKS3/10) were kindly analysed by Dr. Joachim Schönfeld and Dr. Jackie Burnett (Figure 6.1) respectively. The results of which will be discussed below, but the detail of their work is included in Appendix 4.
Ostracod analysis of the sections at Dover is being undertaken by Ian Slipper, from the same sample horizons as used in this study. His initial results are also included in Appendix 4.

Foraminiferal Analysis

Three pairs of equivalent samples from the "overlap" were analysed for their foraminiferal content. These equivalent samples are shown in relation to others in Figure 6.1. The faunal composition of the two sections was similar, but selected species have considerably different proportions.

Nannofossil Analysis

Ten equivalent sample pairs were analysed from the two sections (Figure 6.1), for their nannofossil content. The diversities range from 32 to 54 for samples from Akers Steps; and from 22 to 57 for samples from Langdon Stairs. Mean diversities were calculated and were similar for both sections. The nannofossil assemblages from Akers Steps and Langdon Stairs were similar in terms of their constituent taxa, with most species occurring throughout the two sections (See Appendix 4).

Ostracod Analysis

The ostracod analysis of the Turonian succession at Dover, includes results from the "overlap". These show few differences between the two sections, with a similar fauna being recorded (for details see Appendix 4).

6.2.4 Interpretation of Palynological Results

Statistically the results from the two sections (AKS, DOE) have been shown to be significantly different, based on Cluster Analysis and the Shannon-Weiner Index of diversity. Details of the statistical methods used can be found in Chapter 7. The dendogram clusters the samples into two distinct separate groups (Figure 6.8) indicating that the two groupings are statistically different.

As the results were repeated and proven to be real and not erroneous arising out of processing or collecting methods, some explanation for this difference in the content of the dinoflagellate cyst assemblages is necessary. The possible explanations are as follows:

(i) The results represent a real situation in which two very different populations existed during the time when the sediments were being deposited.

(ii) Some of the dinoflagellate cysts were winnowed out of the sediments, by bottom currents, thus producing different populations actually preserved or preferentially preserved when the sediments became lithified. There is also the possibility that different morphologies may behave hydrodynamically different and may be more susceptible to winnowing e.g.chorate forms may be

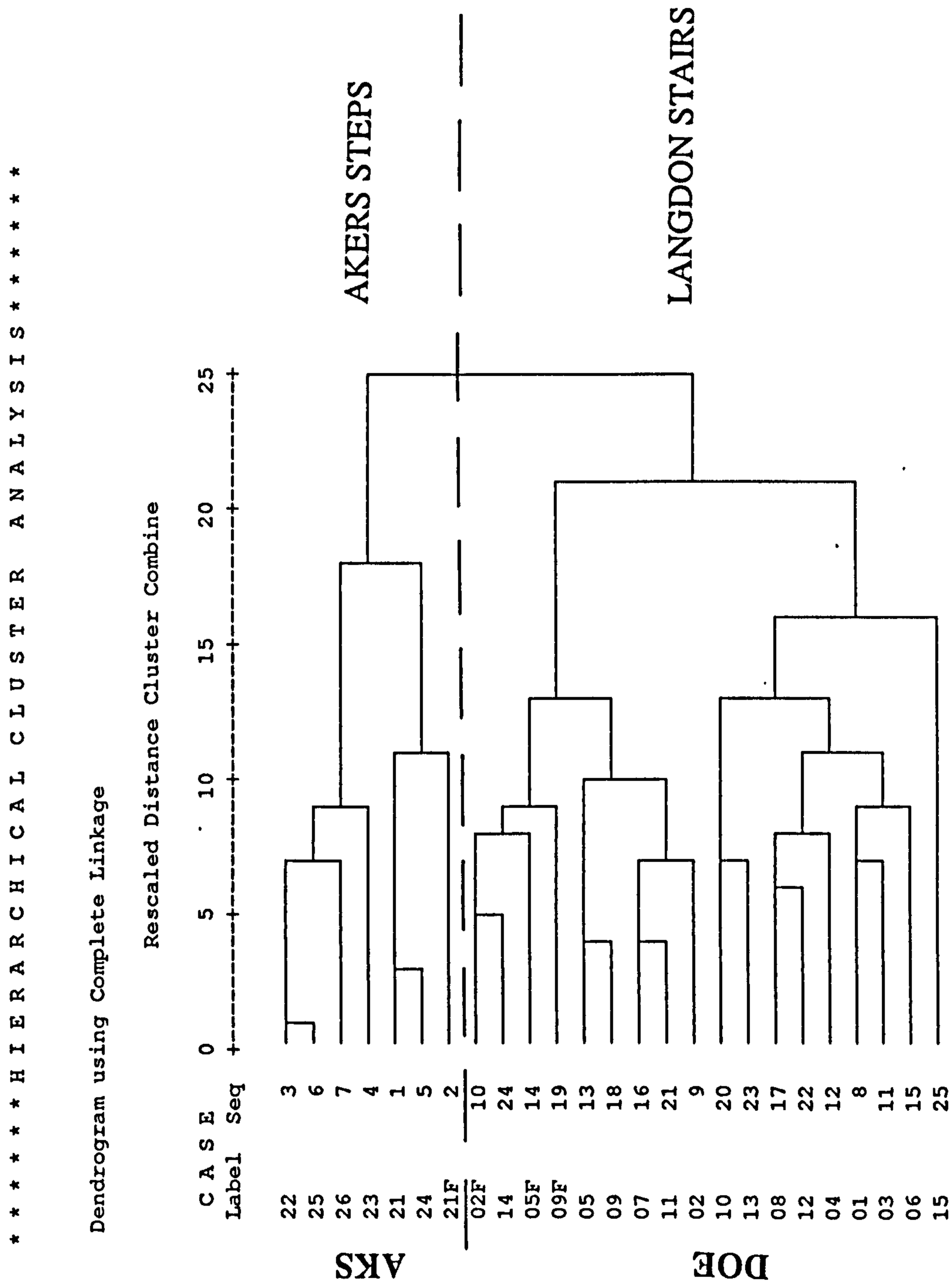


Figure 6.8 Dendrogram produced from Q-mode hierarchical cluster analysis of data from AKS & DOE samples..

more buoyant due to their longer processes.
(iii) That the different weathered states of the two sections may have affected the cyst assemblages.

The "Chalk Sea" of the Cretaceous has no equivalent at the present time, so it is hard to make comparisons about the depositional environment (see Chapter 1). However, it is generally thought to be a shallow shelf sea (100 -300m), situated at the time approximately 40°N of the Cretaceous equator.

The first explanation could be possible, but in a shallow, relatively uniform shelf sea, such as the Late Cretaceous sea is thought to have been, one would not expect the plankton populations to vary so dramatically over such a small distance.

There were probably currents which may have had a winnowing effect on the sediments. However, the extremely fine nature of the constituents of the chalk (coccospheres and coccoliths) must have required relatively still conditions to be deposited or settle out of the water column, unless deposited as faecal pellets. Thus the second explanation for the differences in the assemblages is possible but cannot be proved here.

The sediments found in this part of the Turonian are very similar in character with the only slight difference being the thickness of the marl seams. Thus one might assume that the conditions in which these sediments were deposited were the same. If the conditions were the same, it is most likely that the water conditions were the same in these two parts of the same basin, only 5km apart.

However, the accumulation rates of the benthonic and planktonic foraminifera would support the hypothesis that there were differences in the hydrodynamic regimes of the two areas, producing rather different floras (further discussion of this can be found in Appendix 4).

The section at Akers Steps is exposed close to the top of the cliff (Figure 6.9a) Here the section is badly weathered and the cliff path must be negotiated with care. In order to collect fresh samples it is necessary to excavate deep into the cliff. At Langdon Stairs the Southerham Marls are exposed at the base of the cliff; the second marl forming a large platform (Figure 6.9b) which is probably affected by unusually high tides.

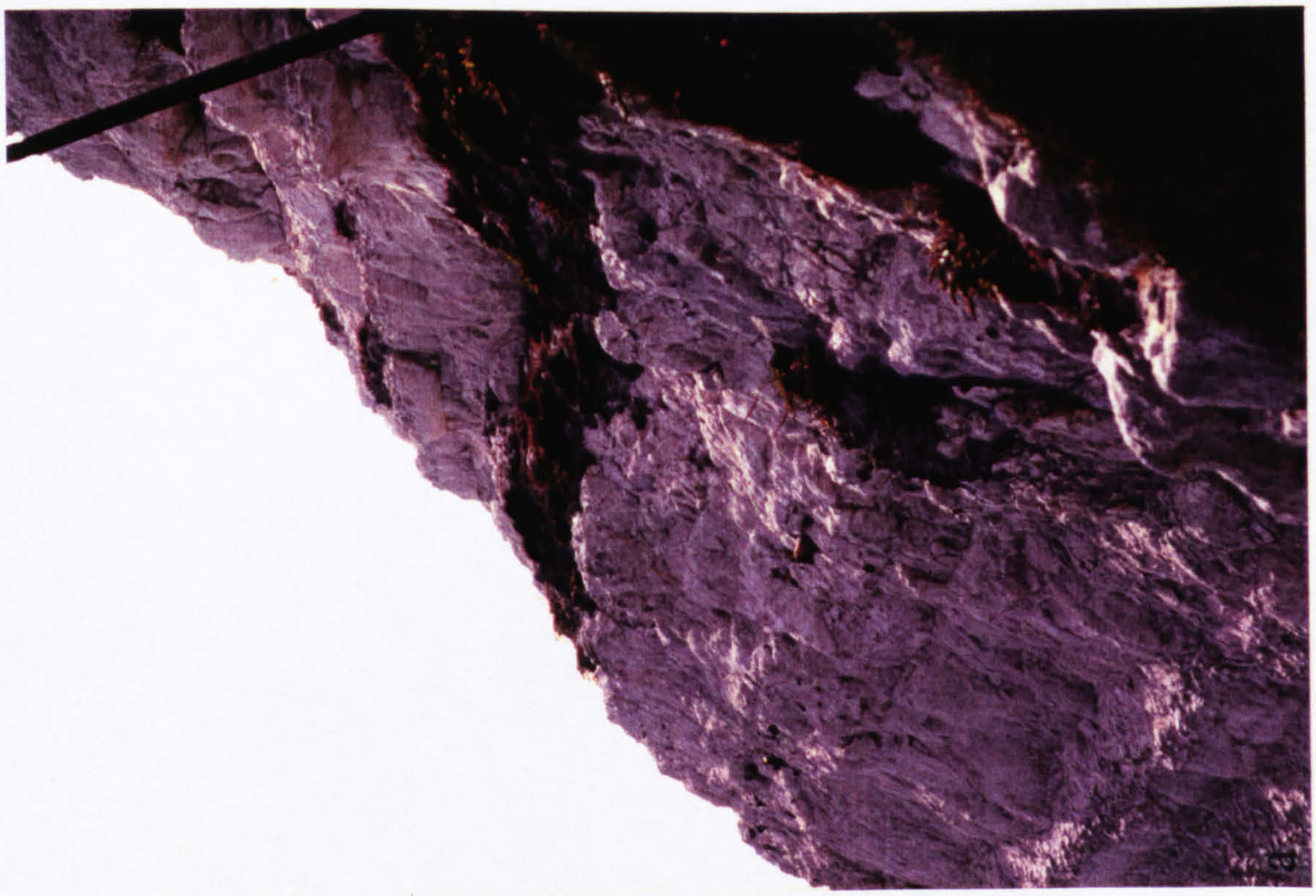


Figure 6.9 Photographs of (a) the top of the Akers Steps section, showing the ledge produced by Langdon Bay Marl 1. (b) Langdon Stairs, illustrating the ledge on which Langdon Bay Marl 1 is found.

Equivalent samples of both chalk (DOE15, AKS2/6) and marl (DOE11, AKS2/2) were examined under a Scanning Electron Microscope (SEM) to investigate the preservation state of the coccoliths. Signs of dissolution and etching of the coccoliths were not found. It was discovered that there was little difference in the state of the samples at this level (Figure 6.10). Even though the preservation of the coccoliths was similar, the different weathered states of the two sections is thought to be a possible reason for the variation in the dinoflagellate cyst assemblages.

6.2.5 General Interpretation

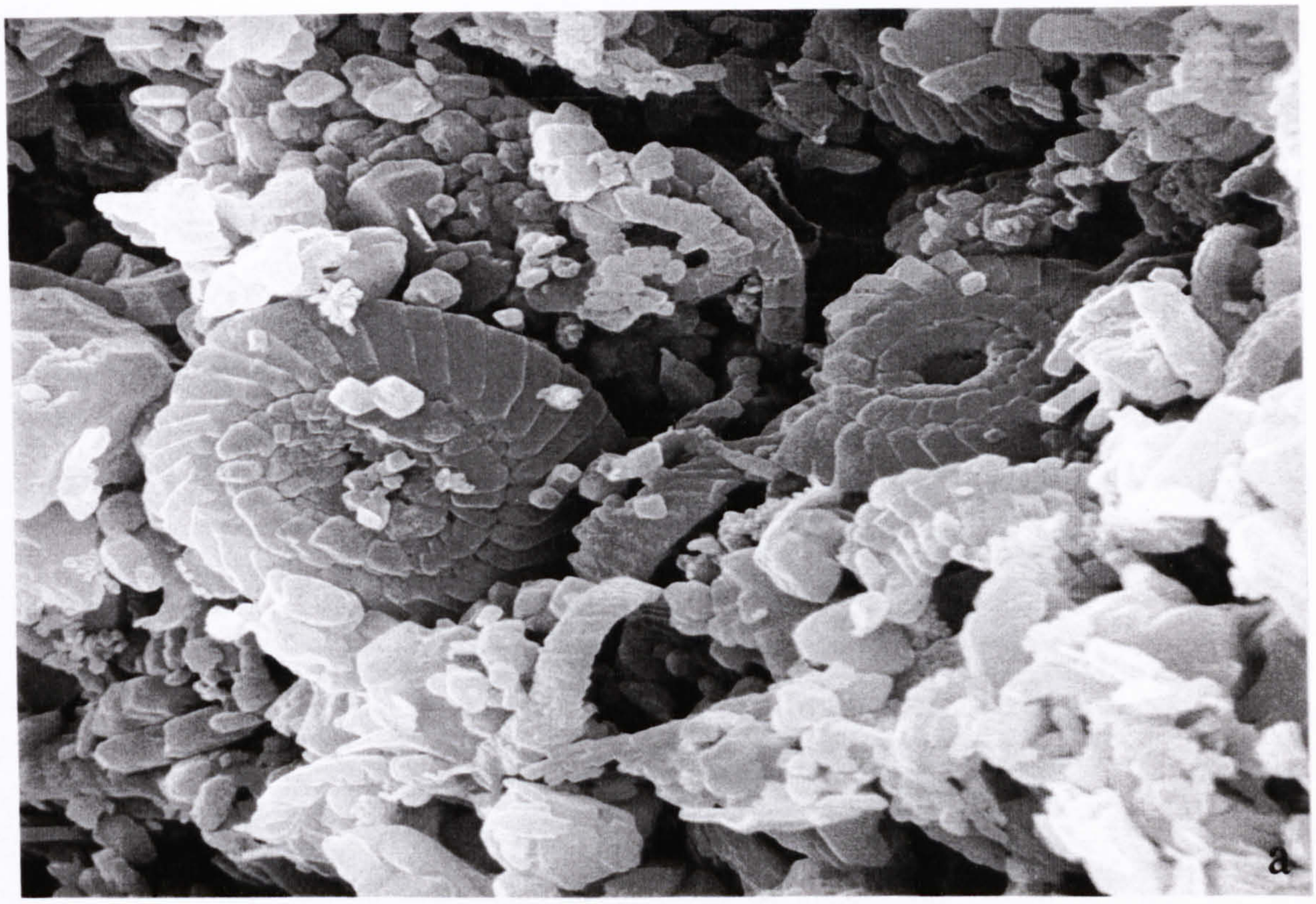
Using all the evidence from the other microfossil groups analysed, a general interpretation may be made. The foraminiferal assemblages show the least similarity between the two sections, perhaps indicating local variations in the hydrodynamic regime. However, the ostracod and nannofossil assemblages are quite similar, thus opposing this explanation. If the difference in the dinoflagellate cyst assemblages is due to differential weathering, then it is quite possible that the other groups, being calcareous were not affected in the same manner and that in fact the two sections did originally contain the same floras and faunas.

6.3.1 Dinoflagellate cyst assemblages from three middle Turonian marl bands, and their relationship to the foraminiferal assemblages.

Marl bands represent periods of lowered carbonate production and/or increased accumulation of clay minerals (which may comprise up to 75% of sediment). Their composition is different to the chalks which they alternate with. It was felt that the preservation of dinoflagellate cysts might be affected by the lithological differences, therefore analysis of marl bands and their neighbouring chalks was undertaken to investigate this.

Marl is defined in the Concise Oxford Dictionary of Earth Sciences as: "A calcareous clay that can originate from deposition under marine or lacustrine conditions, containing 35-65% soft calcium carbonate, the remainder of the sediment being clay."

Marl bands have been used as the basis of detailed correlations of the chalk in the south of England and the Anglo-Paris Basin (Mortimore 1986, Robinson 1986, and Mortimore & Pomerol 1987), as they extend laterally for remarkable distances. A typical marl band (Glynde Marl from New Pit, Sussex) is illustrated in Figure 6.11. Despite their lithostratigraphical significance, their mode of origin is uncertain. There have been various



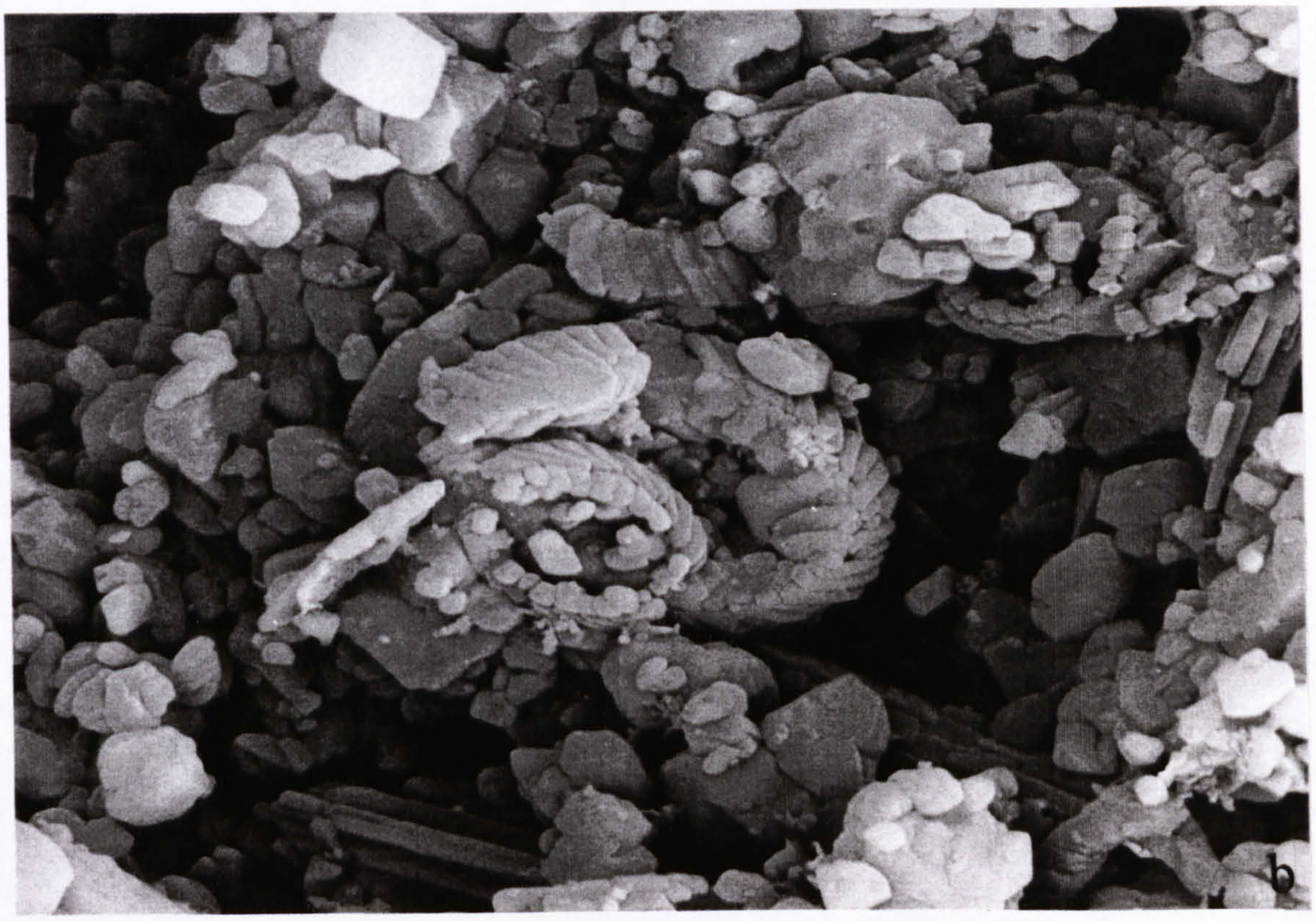


Figure 6.10 Scanning Electron Micrographs of equivalent chalk samples from (a) Langdon Stairs (DOE15) and (b) Akers Steps (AKS2/6).

Figure 6.11 Photograph of a typical marl band (Glynde Marl from New Pit, Lewes).

proposals as to their origin and these fall into two main schools of thought. The first describes a primary or detrital origin whilst the second prefers a secondary origin related to the dissolution of calcium carbonate.

6.3.2 Foraminiferal Analysis

Leary & Wray (1989) analysed the foraminiferal assemblages across three middle Turonian marl bands, from Burghclere (Figure 6.12), Berkshire (SU 475589). The marl bands concerned were New Pit Marls 1 & 2 and the Glynde Marl.

The foraminiferal assemblages were shown to change with lithology (Figure 6.13). Generally the pre- and post-marl samples were found to be dominated by the planktonic groups (forming at least 55% of the total assemblage). The planktonic assemblages are dominated by non-keeled morphotypes. In contrast the intra-marl assemblages are dominated by benthic foraminifera and the planktonic assemblage is predominantly composed of keeled forms. Their conclusion was that the fauna was affected by the introduction of volcanic ash into the water column; thus explaining both the lateral extent of the marls and the changes in the fauna.

Keeled foraminifera are thought to be associated with deeper water, whereas non-keeled forms are thought to be indicative of shallower water (pers. comm. Dr.G.Coles). The presence of keeled and non-keeled forms may therefore reflect the changing water-depth, as well as, or instead of the effect of falling ash.

An alternative explanation for the faunal composition of the marls is that there is dissolution of the thin walled non-keeled planktonics and the calcareous benthonics (gavellinellids and lenticulinids). This could also produce an increase in the benthonics in comparison with the planktonics.
These fluctuations are obvious in the Glynde Marl (I_2) and New Pit Marl 2(I_3). However they are not so apparent in New Pit Marl 1 (I_1), where the percentage of the gavellinellids and lenticulinids is reduced but not as much as in the other two marls.

6.3.3 Palynological Analysis

The same samples were processed and analysed for their palynomorph content, the results reflecting the trend shown by the planktonic foraminifera. The marls appeared to contain a reduced planktonic fauna in comparison with the

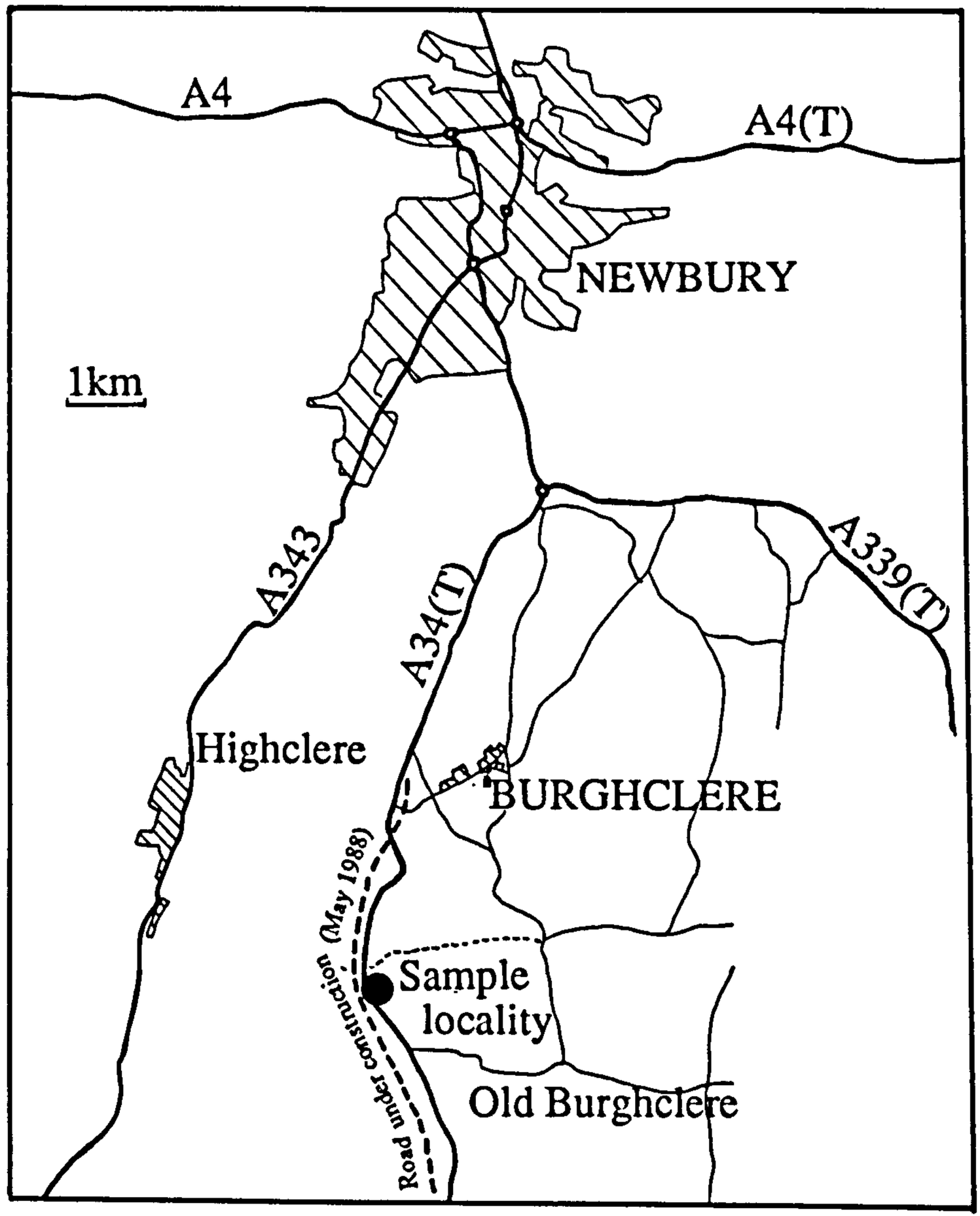


Figure 6.12 Location map of Burghclere.

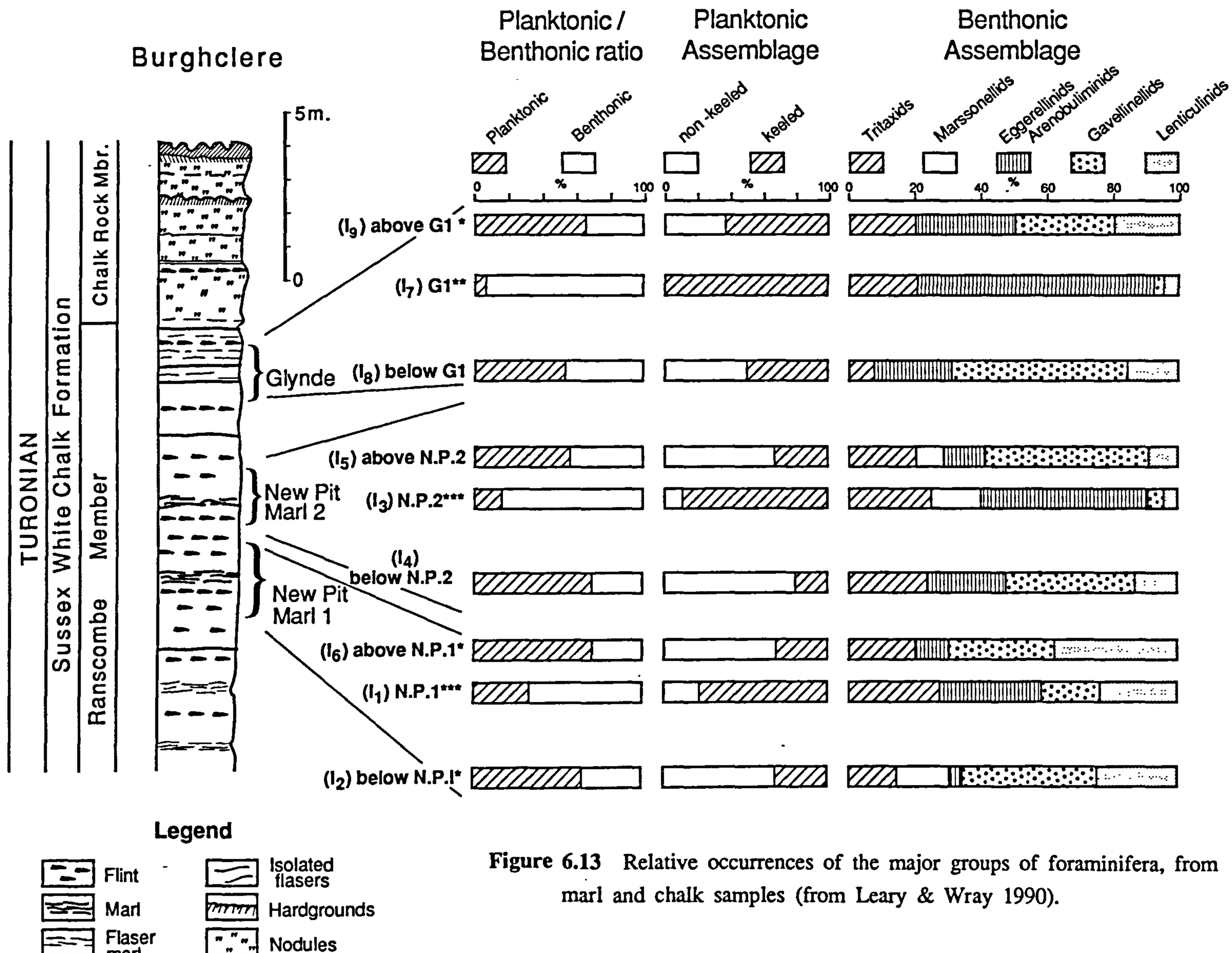


Figure 6.13 Relative occurrences of the major groups of foraminifera, from marl and chalk samples (from Leary & Wray 1990).

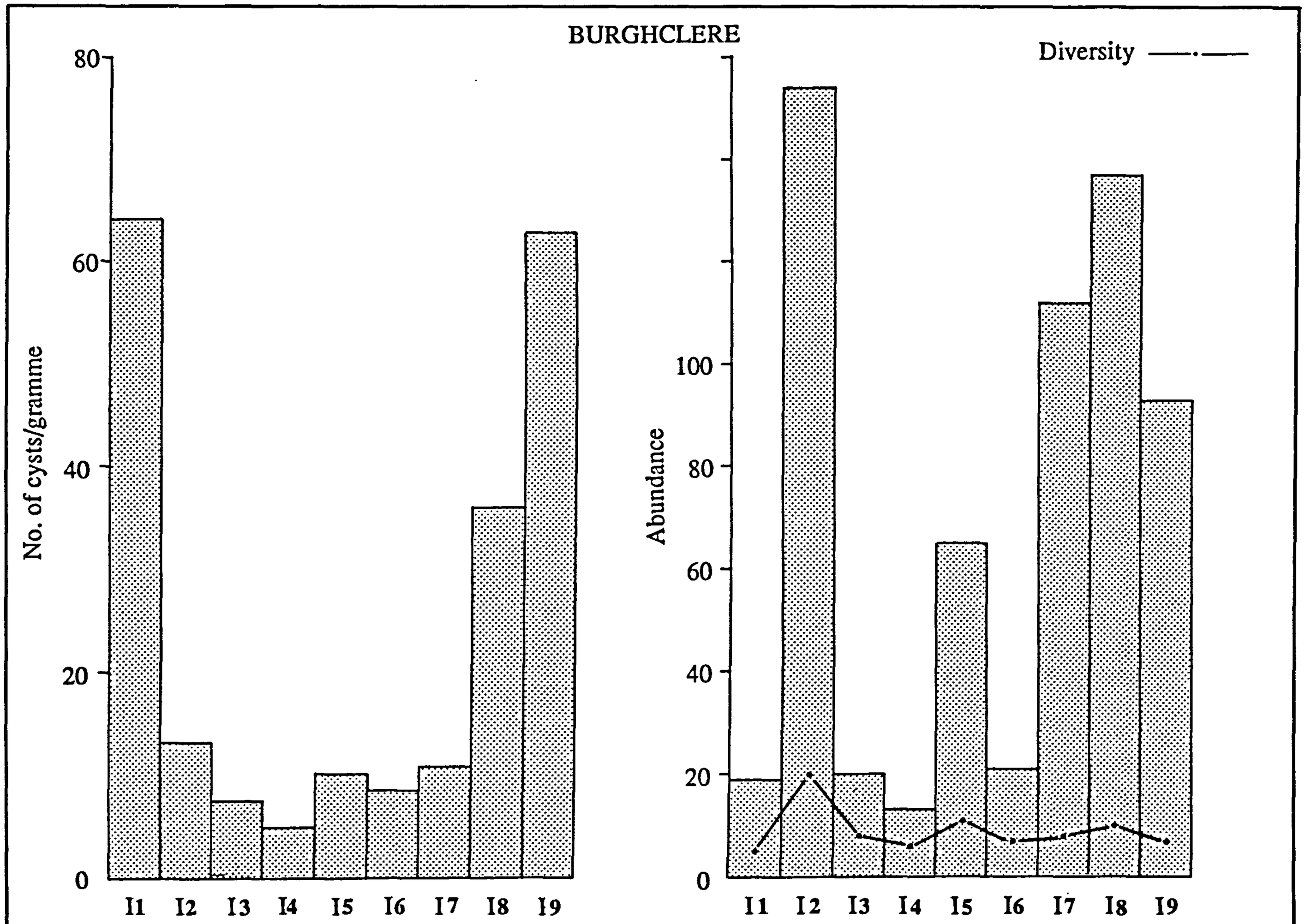


Figure 6.14 Qualitative & quantitative results of palynological analysis of samples from Burghclere.

chalks above and below. It must be noted that the abundances are low, so conclusions must be tentative. The dinoflagellate cyst abundances counted are greatest in the marls (Figure 6.14); the quantitative results agree with this statement for the New Pit Marl 1, but disagree for the New Pit Marl 2 and the Glynde Marl (Figure 6.14). As these results are not totally convincing due to their poor numbers, it could be tested by repeating the process, although this would have to be carried out at a different location, as the section at Burghclere has since been covered. This was not attempted within this investigation.

In general the assemblages are low in abundance (<154) and diversity (<20). The assemblages include characteristic taxa such as *Cyclonephelium distinctum*, *Cyclonephelium membraniphorum*, *Odontochitina costata*, *Odontochitina operculata* Type A and B, *Senoniasphaera rotundata*, *Oligosphaeridium complex*, *Hystrichosphaeridium bowerbankii*. These are generally ceratiacean or peridiniacean in their morphology, except for the last two species mentioned which are gonyaulacacean.

6.3.4 Palynological Interpretation

The dinoflagellate cyst assemblages yielded from these marls and chalks are not of such diversity and abundance to be able to make any reliable interpretation (Figure 6.14). It is sufficient to say that the marls and chalks all exhibited low diversity (<12 species), except for I_1 which had a diversity of 20. With regard to the abundances, these were all <160 specimens per slide. It is felt to base any interpretation on these results would be misleading and incorrect.

6.3.5 An Alternative Explanation for the Formation of the Marls

An alternative idea, based on discussion with Prof. M.B. Hart, suggests that the marls may be related to a period of local anoxia, similar to that which existed during the formation of the Plenus Marls (Jarvis *et al.*, 1988) where there was a loss of clay sized carbonate (due to winnowing or by dissolution) together with a concentration of clay and preservation of dinoflagellate cysts and a change in the plankton. It has also been noticed that prominent marls disappear from the U.K. succession once sea-level falls towards the end of the Turonian. They are therefore thought to form as a function of sea-level highs near the threshold of the oxygen minimum zone.

6.4.1 Comparison between dinoflagellate cyst assemblages from flints and chalks at the same stratigraphic level.

Some of the first dinoflagellate cysts were described from thin flakes of flint pebbles (Ehrenberg, 1838; White, 1842; Deflandre, 1935, 1936) as chemical processing techniques were not developed until the 1950s. It is a reasonable assumption to make that the formation of flint may preserve the fragile cysts in a better state than in the marls or chalks at similar levels.

6.4.2 The Stratigraphic Occurrence of Flint

The first common and persistent flints in the Chalk of southern England occur within the middle Turonian, approximately 5 metres above the Glynde Marls (Mortimore 1986). Regular flint bands are uncommon below the Lewes Chalk Member.

This appearance of regular flint bands has long been partly the basis for the tripartite division of the Chalk, which is easily recognizable in the field (see Chapter 2). The stratigraphical distribution of flints has been incorporated into most of the biostratigraphical and lithostratigraphical schemes that have evolved since the work of Phillips (1818); their presence or absence being used to define separate stratigraphic units. The maximum of flint development is taken at or about the base of the *Sternotaxis planus* Zone (Mortimore & Wood 1986), and has been designated the "Basal complex" (Stokes 1975). Other flint bands are present in the succession in Sussex (thalassinoidean burrow form flints called the Lewes Flints), but are not apparent at Dover due to condensation of the succession.

6.4.3 The Formation of Flint

Flint formation and development is covered in the volume edited by Sieveking & Hart (1986). There is no consensus of opinion as to the original cause of formation of flints. It is generally accepted however, that the flint bands were formed by replacement of the host carbonate in horizons more or less parallel to the sea-bed (Kennedy & Juignet 1974; Garrison & Kennedy 1977). This makes them extremely important for correlation purposes (Mortimore & Wood 1986).

It is thought that many flints were first initiated or centered around burrows which were enriched in organic matter and were in contrast to the surrounding sediments in terms of their porosity and permeability. Thus

confining the silicification to the burrow itself. More nodular flints may have formed when the margins of the original burrow became overgrown with silica. The burrow therefore was not the cause of silicification but only served to modify the pattern of silicification caused by another process altogether. Clayton (1986) used chemical analyses to show changes through the sediment to the centre of the flint: "the chemical gradients set up by this local and extreme inequality in distribution of organic matter in the anaerobic environment provide the basis for a model to explain the diagenetic alteration of the chalk around the burrow."

6.4.4 Sampling of Flint

Samples of chalk and the equivalent flint were collected from the same stratigraphical level (Table 6.1) to investigate the dinoflagellate assemblages in these lithologies and between different types of flint. Listed below are the sample numbers and their locations (see Enclosures 1, 2, & 3 for details).

The samples were processed in the usual manner (see Chapter 3), although the flints needed more additions of HF than the other lithologies.

Some of the flints were also thin-sectioned (AKS and DOE) to investigate the original preservation of the dinoflagellate cysts and to recreate the conditions under which they were first described.

6.4.5 Palynological Results

The first results (LS8, LS9, LS10 & LS11) were striking in that the dinoflagellate cyst assemblages were quite different for the flint and the chalk samples. The assemblages produced from the flints were very rich both in abundances and diversities; but the chalks from the same stratigraphic level were poor by comparison on both accounts (Figures 5.6, 5.7). Other flints that were analysed did not produce the same results. Some flints (NP39, NP41) from Sussex were as poor or as barren as the surrounding chalks. It was thought that the dinoflagellate cyst assemblages produced may vary according to the type of flint from which they are extracted.

There are different types of flint categorised by their general morphology and shape and these have been commonly associated with a variety of trace fossils, typically *Thalassinoides* (Figure 6.15a), *Zoophycos* (Figure 6.15b), *Chondrites* and *Bathichnus* (paramoudras) (Bromley, Schulze & Peake 1975; Bromley & Ekdale 1986). Other more "nodular" flints (Figure 6.16a), thought to be overgrown burrow flints assume a more obvious bedding-parallel habit.

Section	Chalk	Flint
Langdon Stairs (LS)	8 10	9 11
Akers Steps (AKS)	2/1	2/1F
Langdon Stairs (DOE)	2 5 9	2F 5F 9F
Military Road (MR)	25	8 26
New Pit (NP)		21 39 41 44
Southern Portal of the Tunnel (SPT)		1 2 4
Chandler's Yard (CH)	3	4

Table 6.1 Flint and chalk samples analysed.

Figure 6.15 Photograph of a (a) *Thalassinoides* type flint (Lewes Flint) and (b) a *Zoophycos* type flint (Chandlers' Yard).

Figure 6.16 Photograph of (a) a nodular type flint and (b) a tabular flint (both from the Military Road, Isle of Wight) .

Other flints are thought to form along joints, and are not bedding parallel (Figure 6.16b). A typical example of a *Thalassinoides* burrow flint investigated here is the Lewes Flint (SPT2). Overgrown "nodular" flints are found throughout, examples of which are the Breaky Bottom Flint (SPT1) and the Bridgewick Flint (NP39).

The diversity and abundances of the chalks and flints from each region were plotted (Figures 6.17). These results do not show any significant differences between the lithologies, with both chalks and flints producing high and low abundances and diversities.

The abundances and diversities for the different types of flint were plotted (Figure 6.18) and it is noticeable that there is little support for the idea that different forms of flint yield different dinoflagellate cyst assemblages (in terms of diversity and abundance). The typical *Thalassinoides* type flints generally produce high abundances and diversities of dinoflagellate cysts. The nodular type flints yield variable assemblages in terms of abundance and diversity, from those which are poor to those that are extremely rich.

What is noticeable from Figure 6.18 is that the results fall into separate fields which have been marked as such. These fields combine the Nodular and *Thalassinoides* flint samples. The cluster labelled (I) envelopes all the samples from Dover (LS9, LS11, DOE2F & DOE9F), together with one from Sussex (SPT2). DOE5F appears as a solitary point. Three points (SPT4, MR8 & NP21) form a second cluster (II) with slightly lower diversities. The third cluster (III) combines flint samples from Sussex, Dover and the Isle of Wight. There appears to be a relationship between the flints and the region from which they were sampled.

Recent research (*pers. comm.* Ian Brooks, 1990) has shown that some dinoflagellate cysts are preserved as hollow moulds and not as organic material and would therefore not be extractable by normal palynological processing methods. It is a possibility that during the diagenetic process responsible for the formation of flint, organic material becomes degraded. With further diagensis, this may become totally obliterated. Nodular flints may represent further silicification of an original burrow, with expansion of silicification into the surrounding sediment, resulting in the destruction of organic matter. This may be an alternative explanation for

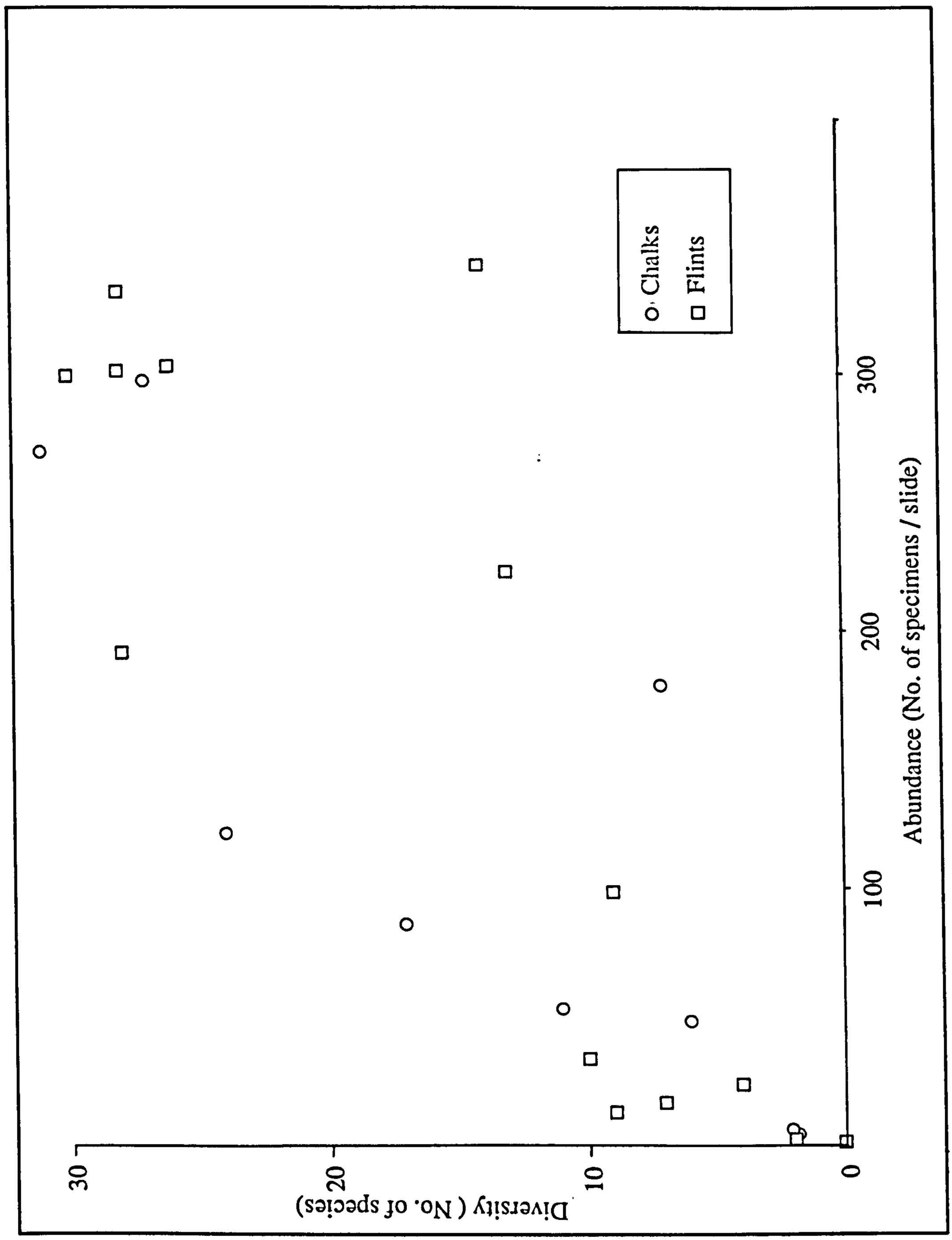


Figure 6.17 Diversity versus abundance of chalk and flint samples from Dover, Sussex and the Isle of Wight.

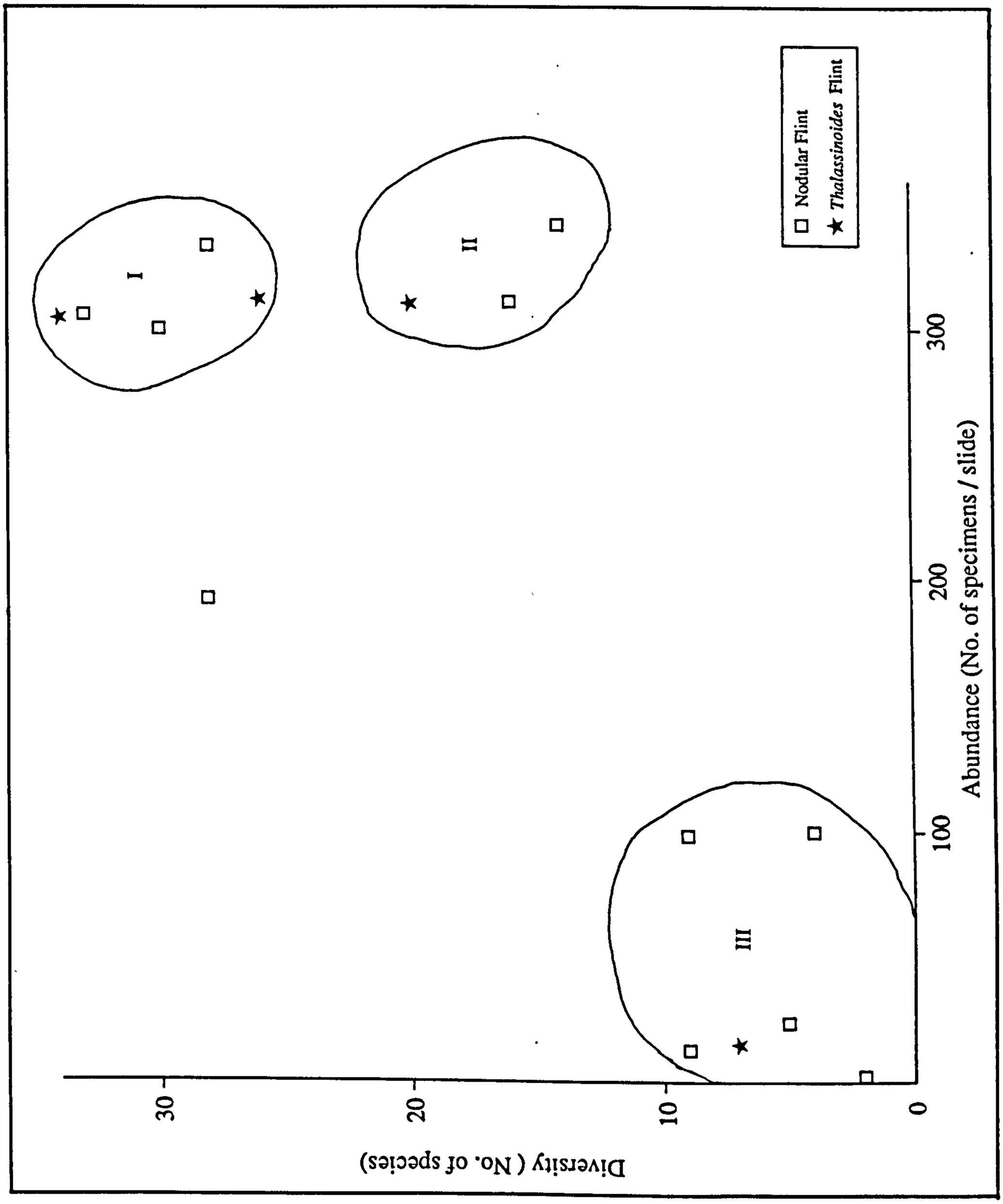


Figure 6.18 Diversity versus abundance of the different flint types from Dover, Sussex and the Isle of Wight.

the paucity of assemblages associated generally with nodular flints.

Therefore it would not be possible to distinguish the type of flint by its dinoflagellate cyst abundance and diversity alone. It would be necessary to repeat this exercise on many more burrow and "nodular" flints to finally prove or disprove this hypothesis.

6.5 Conclusions

The different dinoflagellate cyst assemblages recovered from the "overlap" section at Dover appears to be due solely to the weathered nature of the cliff-top section at Akers Steps. The evidence from the foraminiferal analysis would suggest some differences in the hydrodynamic regime at the time of deposition. But the nannofossil and ostracod analyses do not support this latter theory.

The marl bands from Burghclere are unlikely to be volcanic in origin. Although the dinoflagellate cyst assemblages cannot provide much support for any interpretation discussion has shown that the foraminiferal assemblages present could be due to dissolution of thin walled non-keeled planktonics and calcareous benthonic forms. It is possible that this dissolution was due to expansion of the oxygen minimum zone, which was a direct result of high sea-levels.

Comparison of the dinoflagellate cyst assemblages between flint and chalk samples has shown that in some, but not all cases the flints seem to preferentially preserve a more abundant and diverse assemblage. It is possible that the type of flint may have some control on this, but further investigation would be necessary to substantiate this. There may also be some differences in the preservational quality between chalks and flints, with the silica providing a better mode of preservation for small delicate forms like *Palaeohystrichophora infusorioides*. Further discussion of the dinoflagellate cyst assemblages from the different lithologies can be found in Chapter 7.

CHAPTER SEVEN RESULTS AND STATISTICAL ANALYSES

7.1 Introduction.

The results obtained during the course of this investigation have been analysed using various statistical methods, to aid interpretation of the data sets and to test if real relationships exist between them and to see if there are any lithological constraints.

Statistical methods must be applied very carefully to any problems but in particular when examining palaeontological data. When analysing a fossil population one cannot be certain that there is 100% recovery. This fundamental incompleteness of the fossil record is dependant on many taphonomic and post-depositional criteria, which have been discussed previously (Raup & Stanley, 1978). An important assumption is always made that all species belonging to the original population are represented in the fossil record. This applies equally when looking at palynological samples. There is another factor affecting palynological analyses, particularly when examining fossil dinoflagellate cyst assemblages. At the present time, only 10 - 15% of dinoflagellates form organic walled cysts (Wall & Dale, 1968; Dale, 1976; Evitt, 1970; Davey & Rogers, 1975); the remainder being composed of silica, carbonate or those that are not known to form cysts of any type. As a result the fossil record is inherently biased towards the organic walled cysts which are preferentially preserved and more resistant than the other types of cyst. It is not possible to make direct comparisons and interpretations between the fossil cyst and original populations (Wall, 1976). This must be borne in mind when analysing and interpreting fossil dinoflagellate cyst assemblages in terms of their palaeoenvironmental implications.

7.2 The implications of bias.

Sampling was carried out in a systematic manner, taking care to sample all lithologies at a reasonable interval (50cms - 1metre) and noting particular

horizons of interest with regard to macrofossils and lithological change. The samples analysed here were processed in different laboratories, which may produce some bias in the results. However, standard palynological methods were used and each laboratory has high standards of cleanliness and methods to avoid contamination between samples, and from local water and airborne sources. Such protective methods involve using distilled water at all stages of preparation, cleaning utensils thoroughly between samples and batches. The dinoflagellate cyst populations yielded were highly variable in terms of diversity and abundance and this will be discussed in detail at a later stage (see page 253). Another factor which may also introduce some bias is the subjective identification of species, although this was carried out as objectively as possible by a single person, so reducing this bias significantly.

It is desirable to select a random assemblage, representative of the whole sample, with as little bias as possible. The larger the sample size, the more reliable the results can be expected to be, for most general assemblages. A count of 300 specimens has been shown to produce significantly reliable results (Buzas 1979).
Each region and the results of the statistical analyses will be dealt with in turn and the conclusions discussed in Section 7.5 (page 255).

7.3.1 Statistical methods used.

Various statistical methods can be employed to assist interpretation of data sets and to seek relationships between variables. The methods must be chosen carefully to avoid unnecessary and irrelevant techniques, which may produce spurious results. The methods used in this investigation are simple analyses of the raw data sets (Appendix 2), producing measurements of Diversity, Abundance, and Dominance. Cluster analysis was also performed on the raw data sets (numbers of each species in each sample) and on data sets formulated by using the morphological groups of Evitt (1985) (Appendix 3). Each measurement, its calculation and results will be discussed for each region in turn.

7.3.2 Diversity (S)

There are many indices which measure diversity in particular situations. The simplest of these is the number of species present in a sample or Species Richness Index (Magurran, 1988). It is the most widely adopted diversity index and is easily calculated.

7.3.3 Diversity (H′)

A second diversity index, the Shannon-Weiner Index of Diversity (H′) is calculated using the equation below (Magurran, 1988):

$$H' = - \Sigma\, p_i \ln p_i \qquad (p_i = n_i / N)$$

Where p_i equals the proportion of individuals found in the ith species

The value of H′ is related to species diversity but is also influenced by the underlying species abundance (Magurran, 1988). It assumes that all species are represented in the sample. Failure to include all species from the population in the sample increases the error. The value of the Shannon-Weiner Diversity Index is usually found to fall between 1.5 and 3.5, and only rarely exceeds 4.5 (Margalef, 1972). It measures relative diversity. The higher the value, the more diverse the population. Theoretically it has no absolute maximum. The Shannon-Weiner Diversity Index (H′) is thought to be more meaningful than the Species Richness Index (S) as it takes the abundance of the population into consideration.

7.3.4 Abundance (N)

Abundance is a measure of the sample size, in this case the number of specimens counted per slide. There was generally more than one slide per sample and these were also examined for any extra species not already noted in the 'count' of 300. In all cases a 'count' of at least 300 specimens was attempted but not always achieved, as some samples were relatively poor. Experience suggests that when N >300, the results will be more reliable (Buzas 1979).

7.3.5 Dominance (D)

This measure considers the nature of the assemblage and whether it is dominated by one or more species. Dominance is calculated as follows, taken from Goodman (1979).

$$D = \frac{\text{Total number of the two most common species}}{\text{Total number of specimens counted (Abundance)}}$$

Highest dominance = 1; No dominance = 0.5 ; Lowest dominance = 0

Dominance measures the relative dominance of an assemblage by only two species. The dominance and diversity results are plotted against each other and seem to show an inverse relationship. The more diverse a population becomes the lower its dominance.

7.3.6 Cluster Analysis

Cluster analysis is a statistical technique used to divide a set of data into groups or clusters so that each group or cluster is more or less homogeneous and distinct from all other groups. The results produced by cluster analysis may emphasize natural breaks or groups, thus enhancing associations. Generally there are many clustering techniques that can be used (Sneath & Sokal, 1973):

(i) Partitioning methods
(ii) Arbitrary origin methods
(iii) Mutual similarity
(iv) Hierarchical clustering

Hierarchical cluster analysis was employed, as this method is commonly used in palaeontological and biological analysis, as a method of recognising species or groups..

The results of hierarchical cluster analysis can be represented by a dendrogram, with the levels of similarity at which observations are merged forming the "branches" of the tree. More detailed information about cluster analysis can be found in Everitt (1981), Parks (1966), Davis (1986) and Harker *et al.* (1990).

<u>R-mode and Q-mode Analysis</u>

There are two methods of comparison, relationships between organisms (R-mode) or assemblages (Q-mode) (Harker *et al.*, 1990). R-mode analysis compares species by species with species occurring in the same samples being grouped together; whereas Q-mode analysis compares assemblages and clusters them on the basis of their species content. Both methods of analysis were used in this investigation.

<u>Single and Complete Linkage</u>

There are several methods of hierarchical cluster analysis that can be used, each producing a graphical representation of the results in the form of a dendrogram. Each method has a different way of defining distance or similarity between individuals and groups. The raw data (absolute numbers of each species, or of morphogroups per sample) is used for this analysis.

For the Single Linkage (or nearest neighbour) method the basic procedure is to produce a similarity or distance matrix of the samples and species content. Those pairs that have the highest similarities are grouped and the matrix recomputed. This is done by averaging the similarities that the combined observations have with other observations. This process is repeated until the similarity matrix is reduced to 2 x 2. The opposite is used for the Complete Linkage (or furthest neighbour) method, in which those pairs that are least similar are grouped.

Hierarchical cluster analysis was performed on data sets, based upon morphological groupings (see Chapter 4 formulated from the raw data and defined by Evitt (1985) to further investigate the results. It was hoped that using modified data sets, the clustering and dendrograms produced might be more conclusive.

Both R-mode and Q-mode analyses were performed on the morphogroup data sets to look for relationships between the distribution of the eleven different morphogroups.

7.4.1 Dover - Statistical Results

Diversity (S)

The diversity varied from 0 to 35, with the diversity generally increasing upwards through the succession. These diversities have been plotted against lithology to see if any direct correlation between the two variables exists. From each of the plots, for chalks, marls (Figures 7.1 & 7.2) it is apparent that no such relationship exists. Some of the flint samples (LS9, LS11) do exhibit unusually high diversities. Generally speaking the samples from Langdon Stairs yielded higher abundances and diversities, than those from Akers Steps.

Diversity (H′)

The diversity (H′) varied between <0.01 to 2.31, with the mean value being 0.87. The lowest values <0.01 relate to barren samples. Generally the more diverse samples (S > 20) have a value greater than 1.0. But some samples with a low diversity (S = 8), and a high abundance (>300), also have a H′ value >1. The Shannon Weiner index of diversity is plotted against the normal species richness index (S) (Figure 7.3). There is a broad scatter and more abundant samples (>200 specimens) appear to have generally higher diversities.

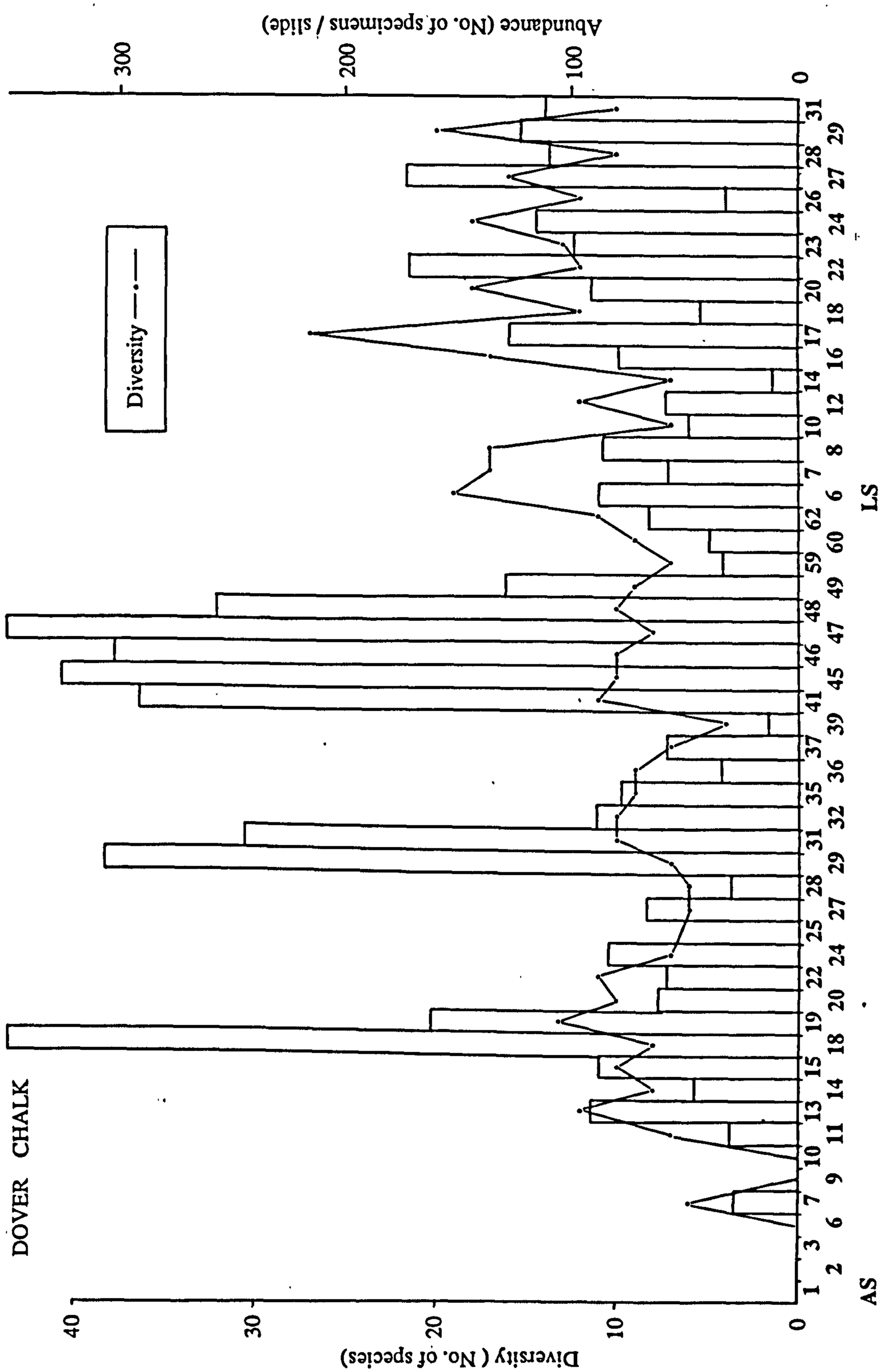


Figure 7.1 Species diversity (S) of chalk samples from Dover.

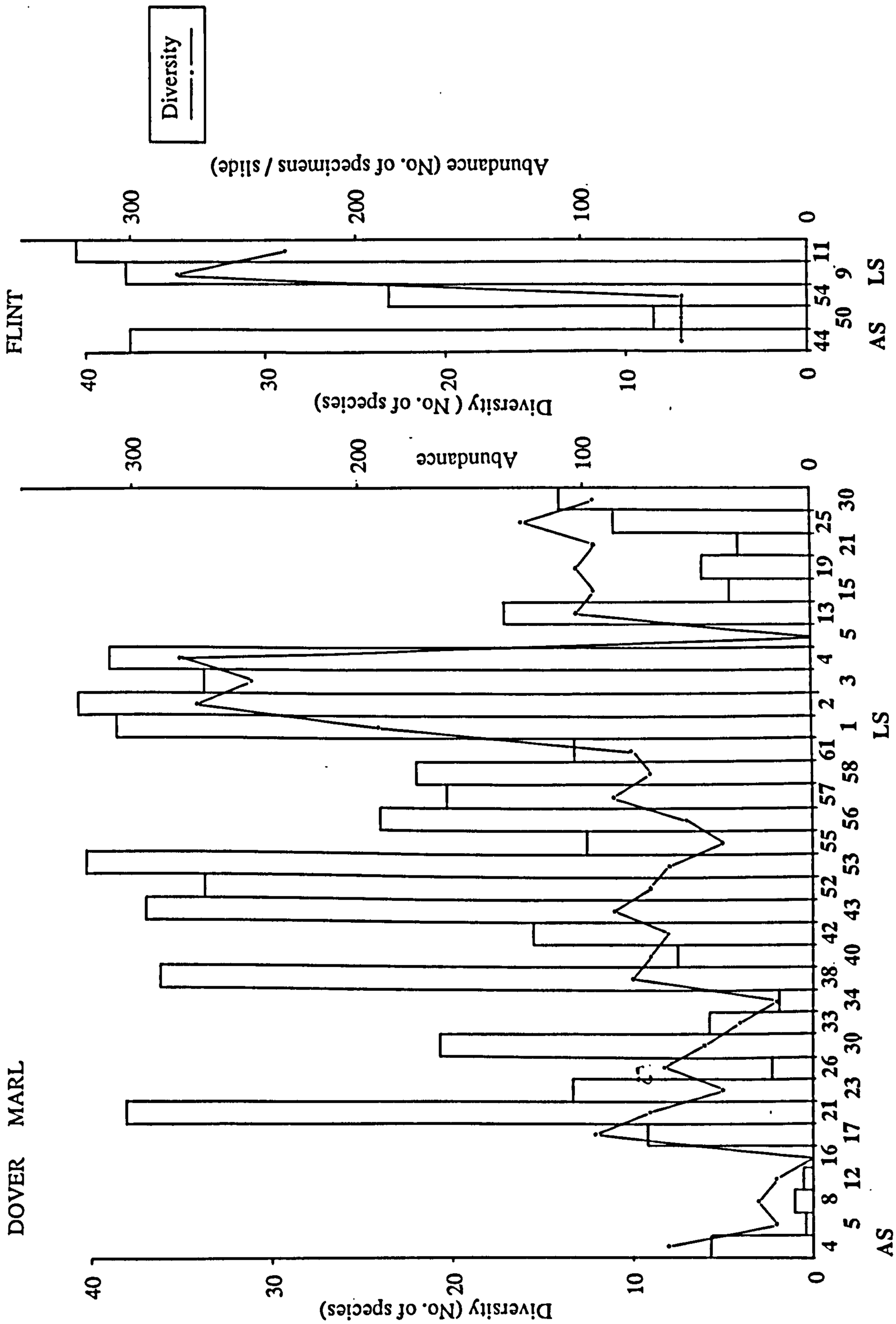


Figure 7.2 Species diversity (S) of marl and flint samples from Dover.

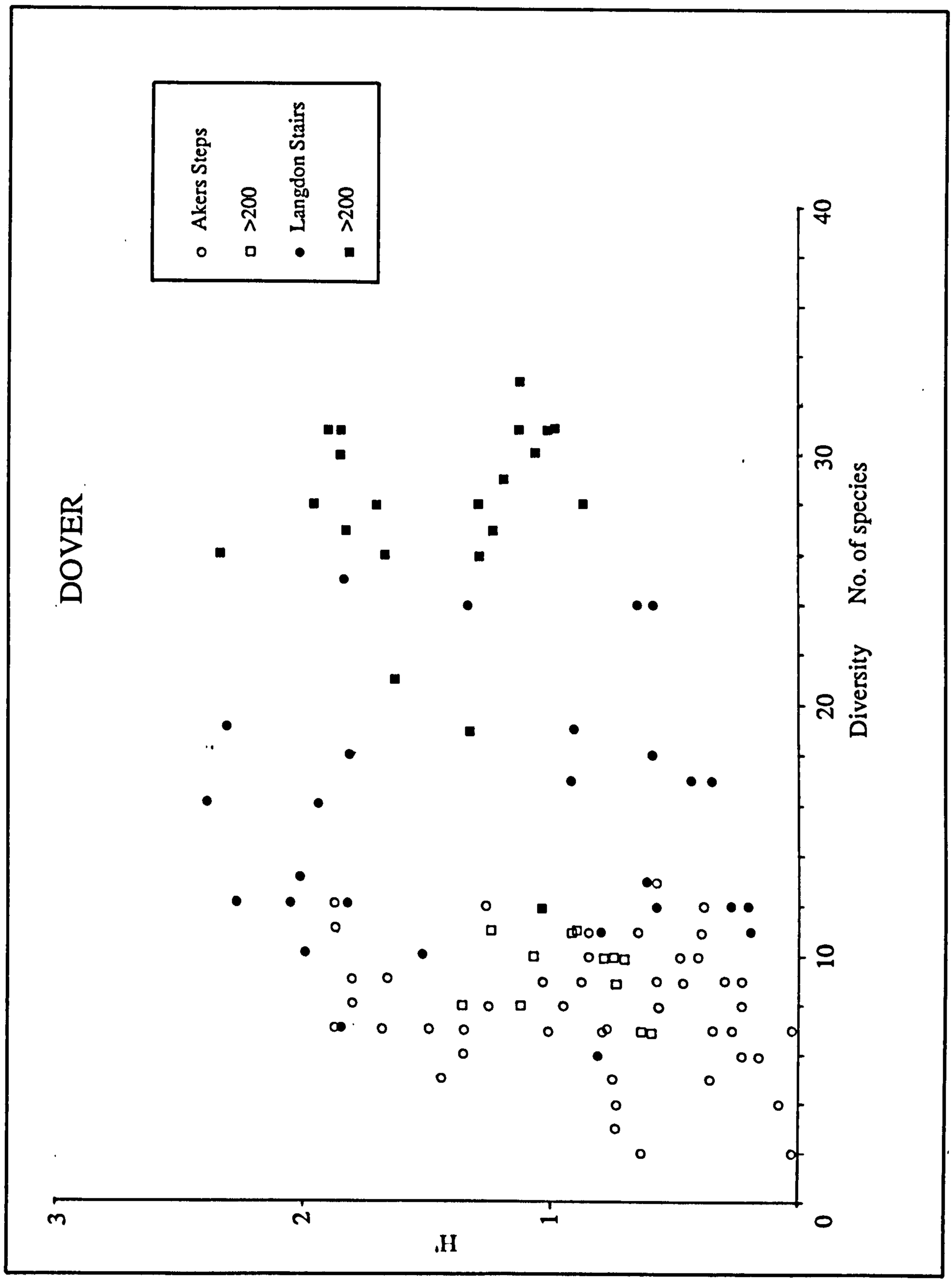


Figure 7.3 Species diversities S versus H′ (Dover).

Abundance (N)

Abundances varied greatly from 0 to 322. However this variability does not seem to be constrained by lithology and its cause is difficult to quantify. Some samples of each lithology are abundant whereas others are totally barren.

Dominance (D)

The results are plotted against the species richness index (S), for each lithology (Figure 7.4). All of the flint samples from Dover except two show a high diversity and high dominance. *Palaeohystrichophora infusorioides* is one of the forms which becomes superabundant in the flints and its dominance is clearly shown (Figure 5.7, in samples LS9, LS11). The majority of the chalks and marls lie in one area, of low diversity and high dominance. Such clumping of the data may be expected, where the samples are of low diversity and a dominance of one or two species is more easily established.

Cluster Analysis (Species)

(i) Q-mode analysis using complete linkage of the raw data set produced the dendrogram shown in Figure 7.5. This is a complete linkage dendrogram and does exhibit some large scale clustering. There are five clusters that can be recognised, as indicated. The first groups barren or very poor samples. The second clusters samples from Langdon Stairs, except for two samples. The third clusters samples from Akers Steps. The fourth cluster groups most of the remaining samples from Akers Steps, and a single sample from Langdon Stairs (LS10). The last small cluster contains only four samples from Akers Steps. This cluster analysis appears to have grouped samples from the same sections.

Cluster Analysis (Morphogroups)

(i) Q-mode analysis using the single linkage method of the normalised data set produced the dendrogram figured in Figure 7.6. The normalised data set is produced by converting the absolute numbers of each species per sample into a percentage of the total number of specimens counted. Generally, there does not seem to be any trend, but samples from the same section are grouped together, with some exceptions.

(ii) R-mode analysis using the single linkage method produced the dendrograms shown in Figure 7.7. Both the raw data and normalised plots exhibit a similar trend. Morphogroups D, Pp, Gp, and Gq are clustered

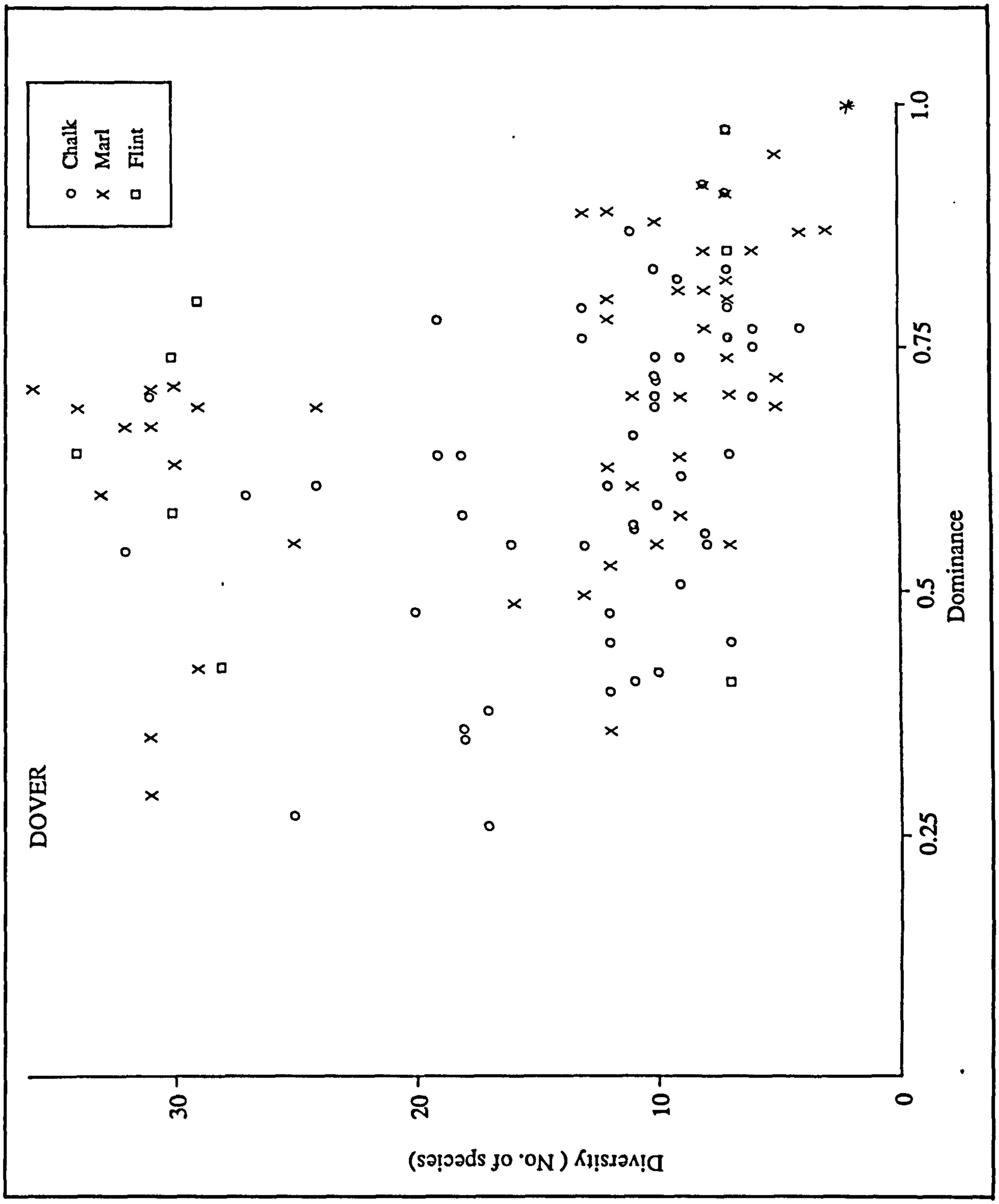


Figure 7.4 Dominance versus species diversity (S) (Dover).

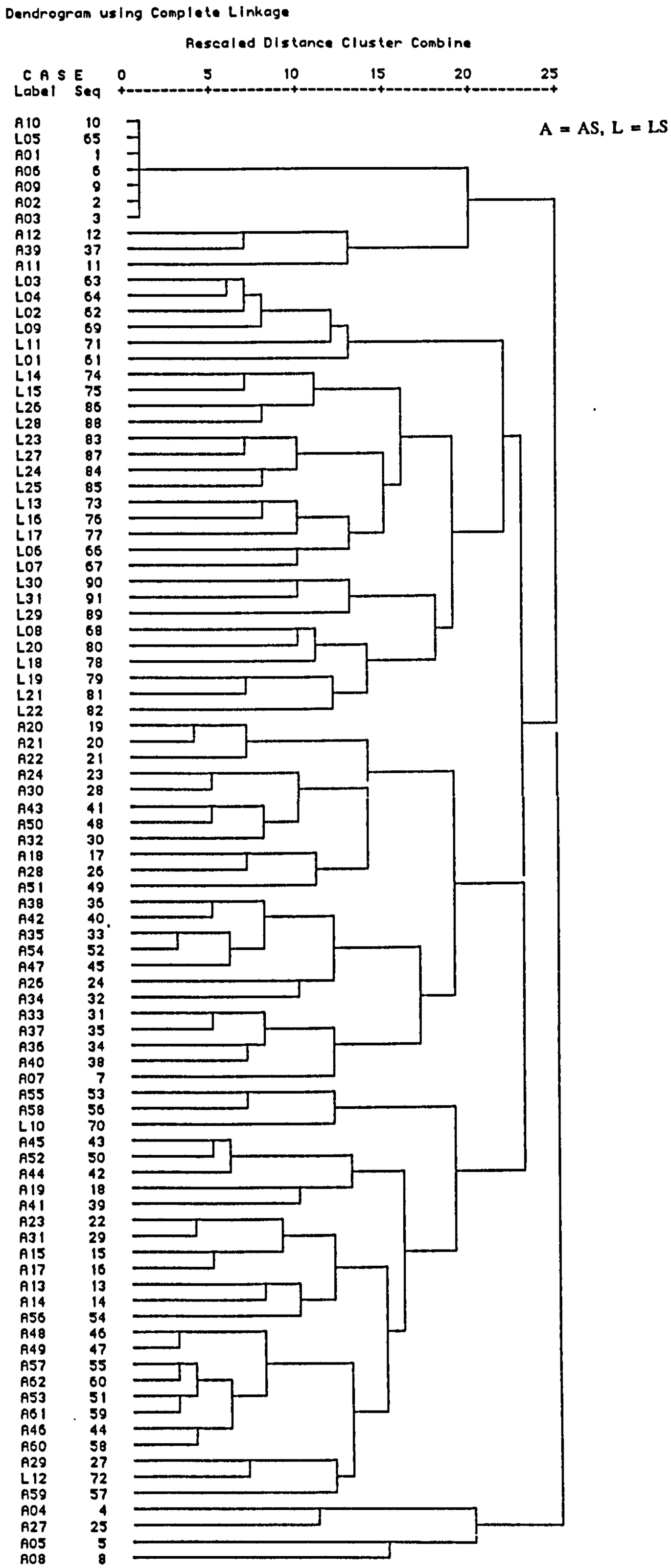


Figure 7.5 Dendrogram produced by Q-mode cluster analysis of the raw data from Dover.

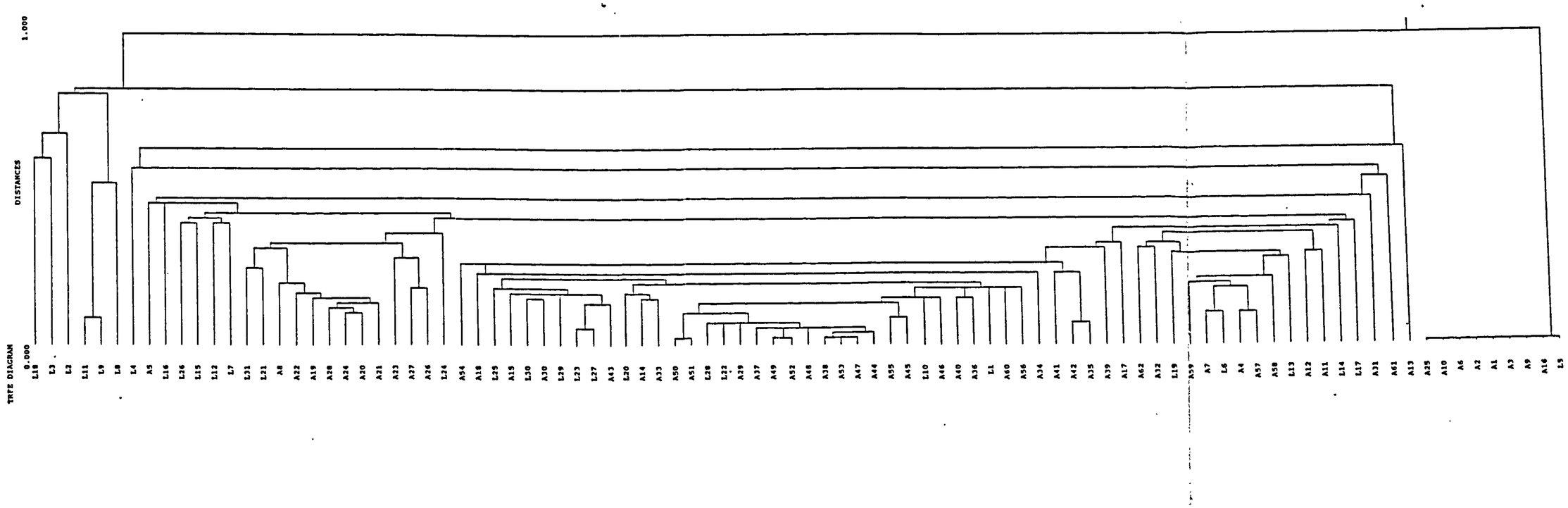
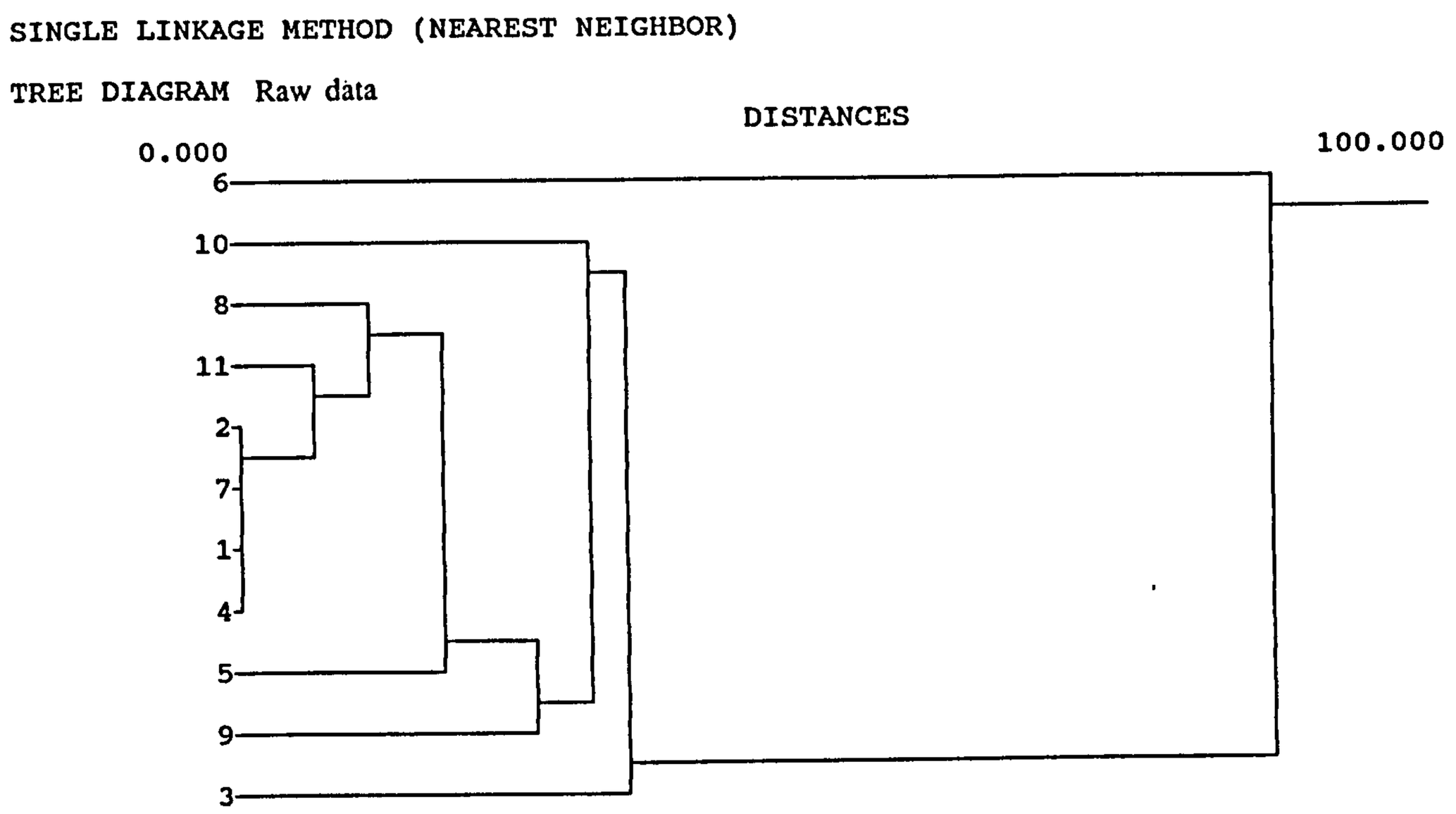


Figure 7.6 Dendrogram produced by Q-mode cluster analysis of the morphological groupings from Dover.

A = AS, L = LS



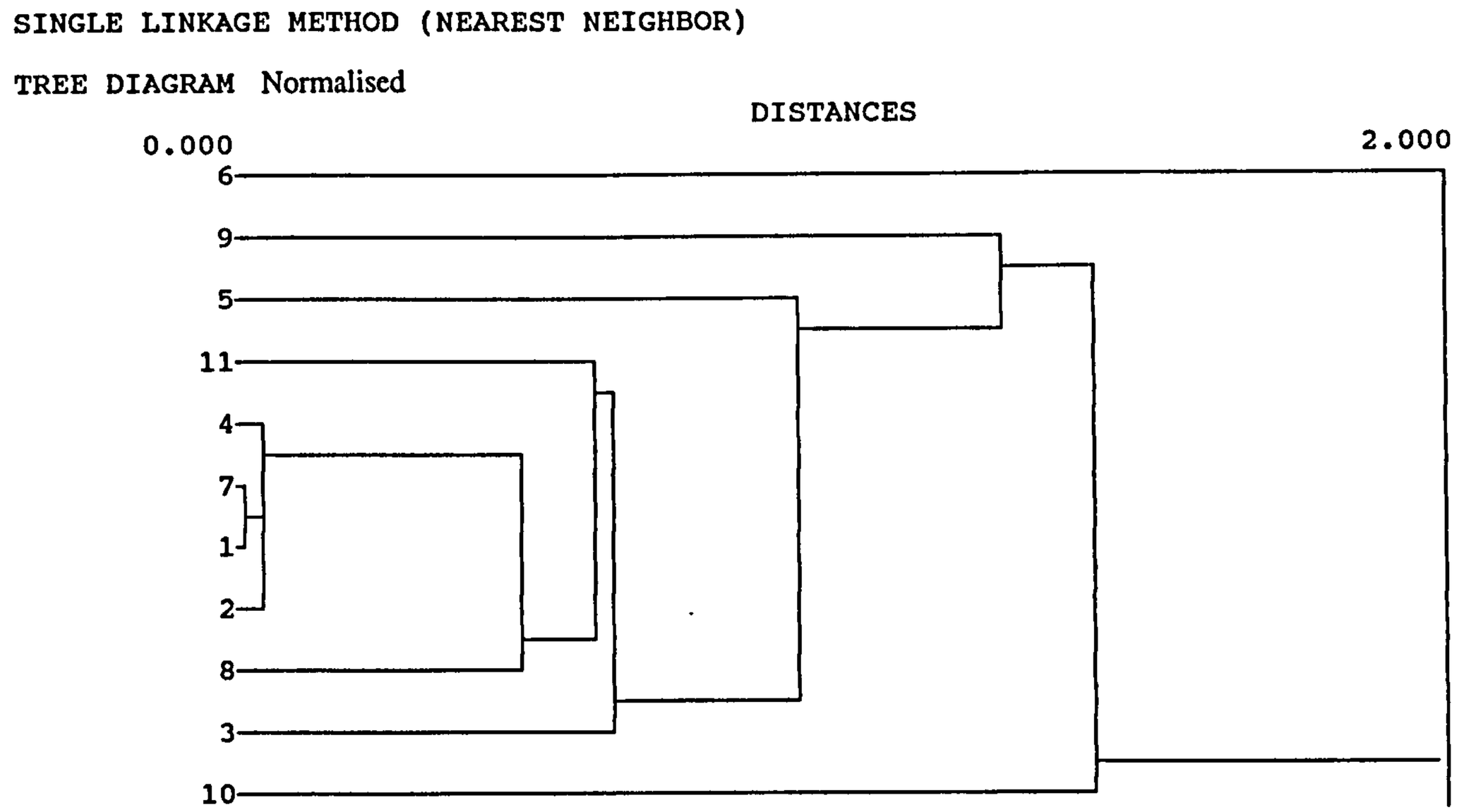


Figure 7.7 Dendrograms produced by R-mode cluster analysis of the morphological groupings from Dover.
The key to the morphological groupings is as follows: 1-D; 2-Pp; 3-Px; 4-Gp; 5-Gc; 6-Gv; 7-Gq; 8-Gs; 9-Gi; 10-Gn; 11-Gx

closely indicating a positive relationship between them. These groups are represented by infrequently occurring taxa. Groups D, Pp and Gp comprise generally small proximate or cavate genera, with thin walls, whereas group Gq is made up of large thin-walled, crested forms. This association is therefore thought to be one of occurrence rather than morphological similarity and must be interpreted carefully.

Some of the morphogroups which seem to be unassociated include groups Gv, Px, Gi and Gn. The most dissimilar groups in terms of their occurrence are Gv and Gn. They appear to be almost mutually exclusive. This can be easily tested by plotting the occurrence of the two groups against each other (Figure 7.8a). The general trend suggests that when Gv is high Gn is low, and vice versa. However there are many points which fall between zero and 20 (Gn) and 50 (Gv), making this interpretation a little dubious. To test this relationship further Gv and Gn for the Dover Overlap have been plotted against each other (Figure 7.8b). This graph does suggest a similar relationship. Correlation coefficients for these relationships have not been calculated, hence no statistical significance can be attached to them.

7.4.2 Sussex - Statistical Results

Diversity (S)

The species richness index varies between 0 and 38 and the mean value is 16. The samples at the base of the sequence are of moderate diversity (<20) becoming most diverse within the middle of the succession. Lithological constraints on the diversity are again not apparent (Figure 7.9, 7.10, 7.11), with generally abundant samples throughout the sequence, yielding very variable diversities. It has been noted that the diversities are greatest in the samples from Beachy Head.

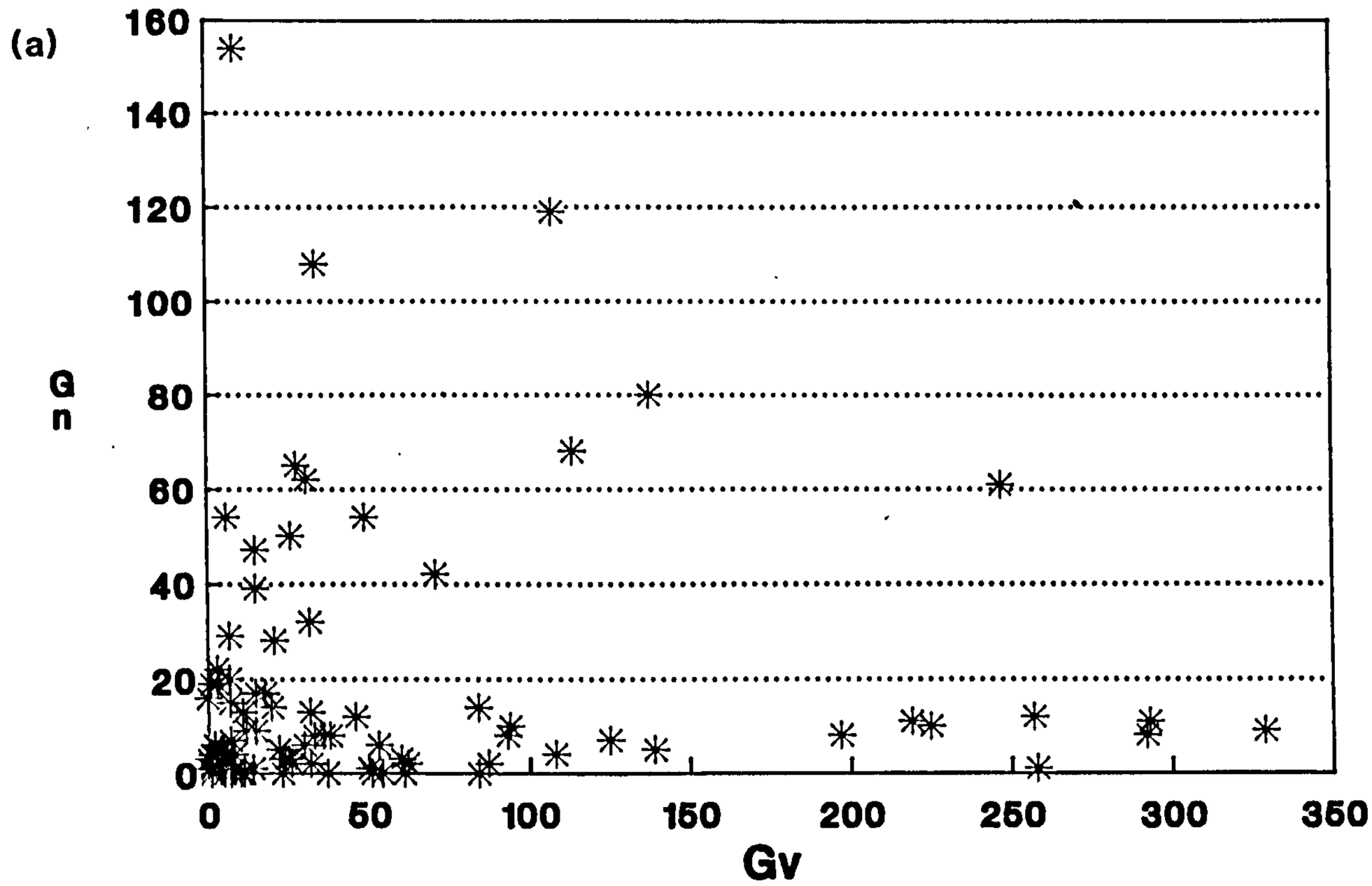
Diversity (H')

This measurement varied between 0.01 and 2.53 and the mean value is calculated as 1.32. The diversity is generally <20, yet the Shannon Weiner diversity index fluctuates from 0.8 to >2.0. This must be a reflection of the underlying slight variation in abundance of the samples. The two diversity indices are plotted on Figure 7.12. Although there is a broad scatter a positive correlation can be detected.

Abundance (N)

The abundances are generally good (most samples have >300 specimens) with

Dover (Akers Steps & Langdon Stairs)



Dover Overlap

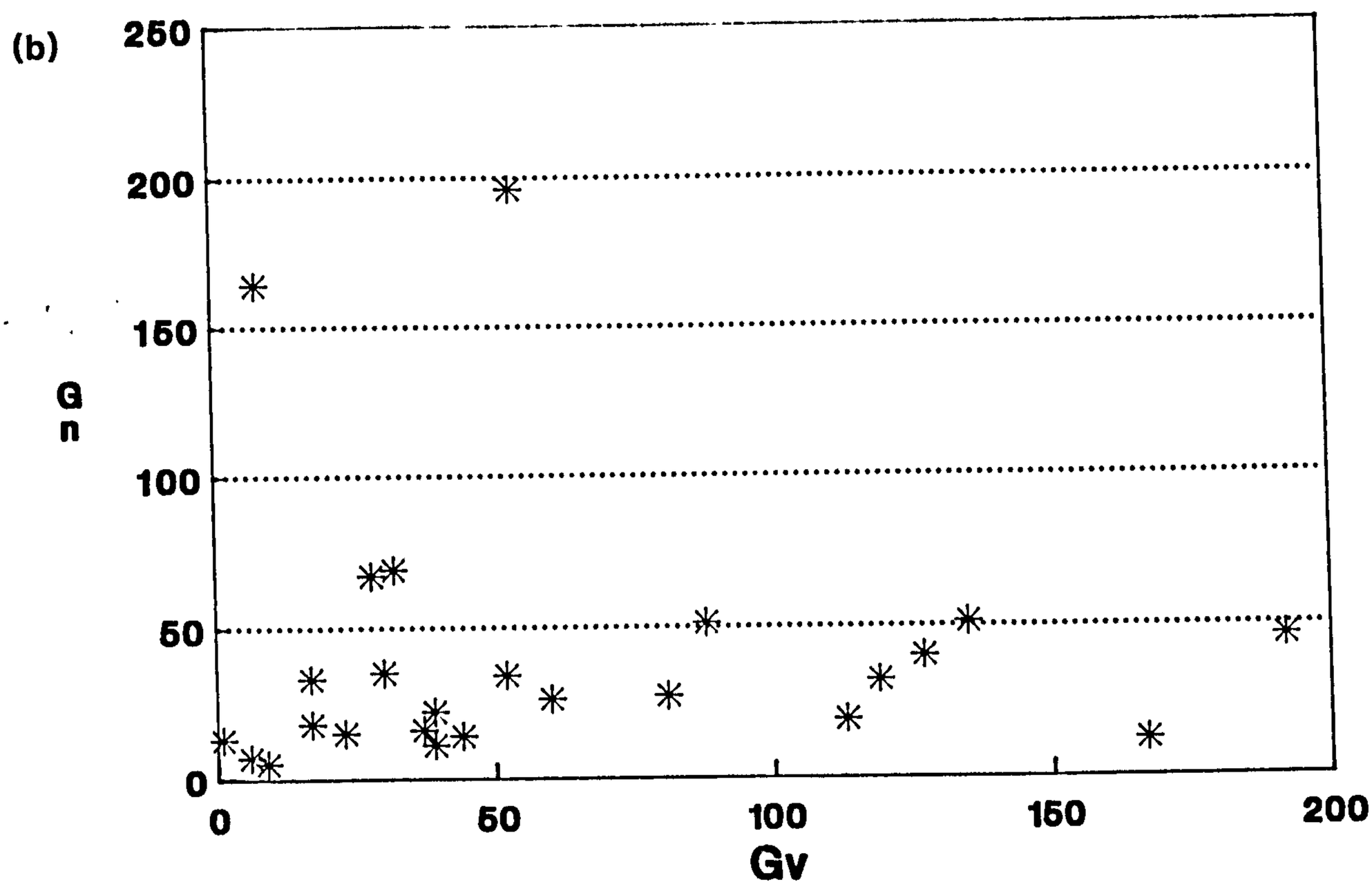


Figure 7.8 Absolute occurrences of the (a) Gv versus Gn morphogroups and (b) Gv versus Gn morphogroups from Dover.

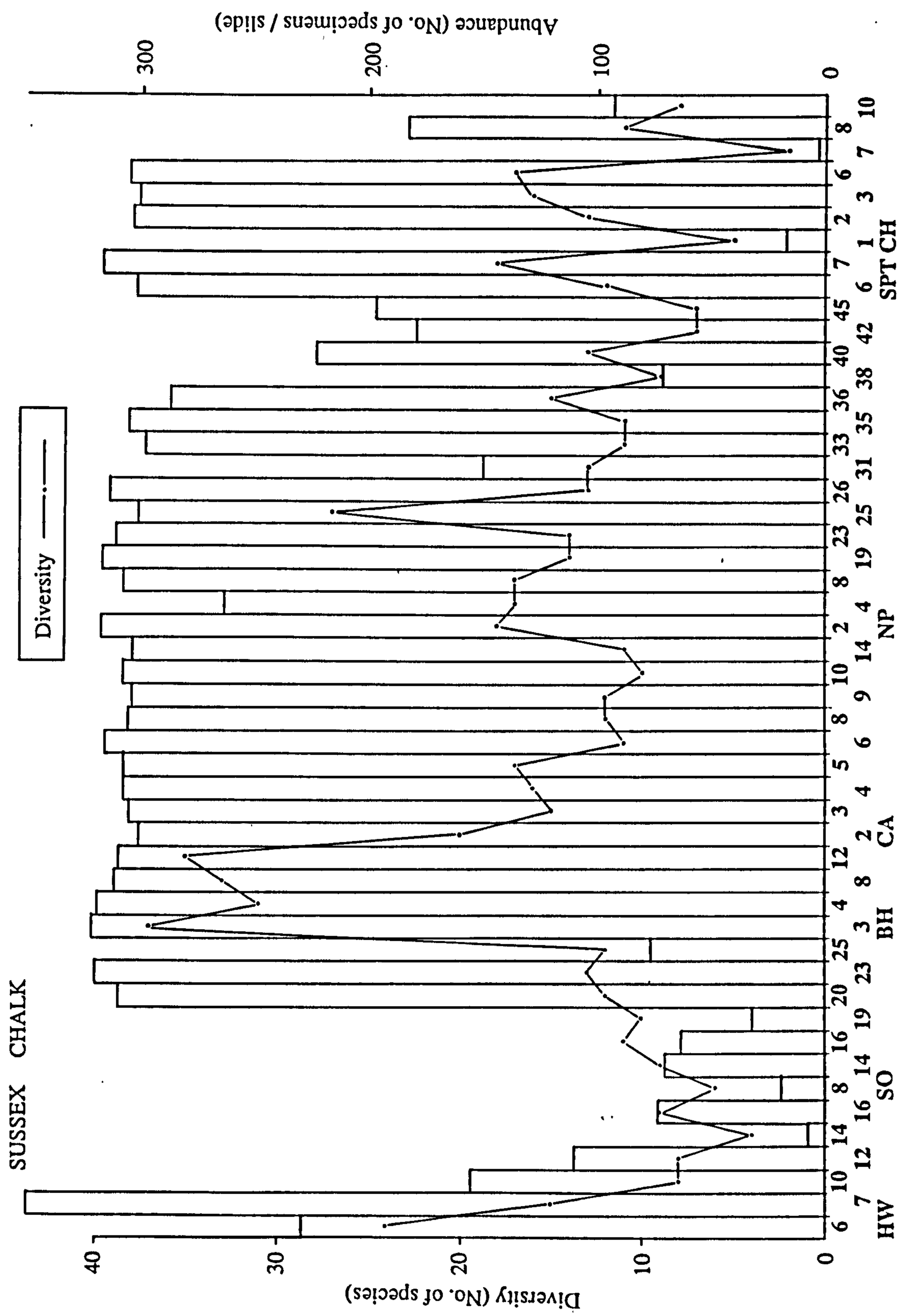


Figure 7.9 Species diversity (S)of chalk samples from Sussex.

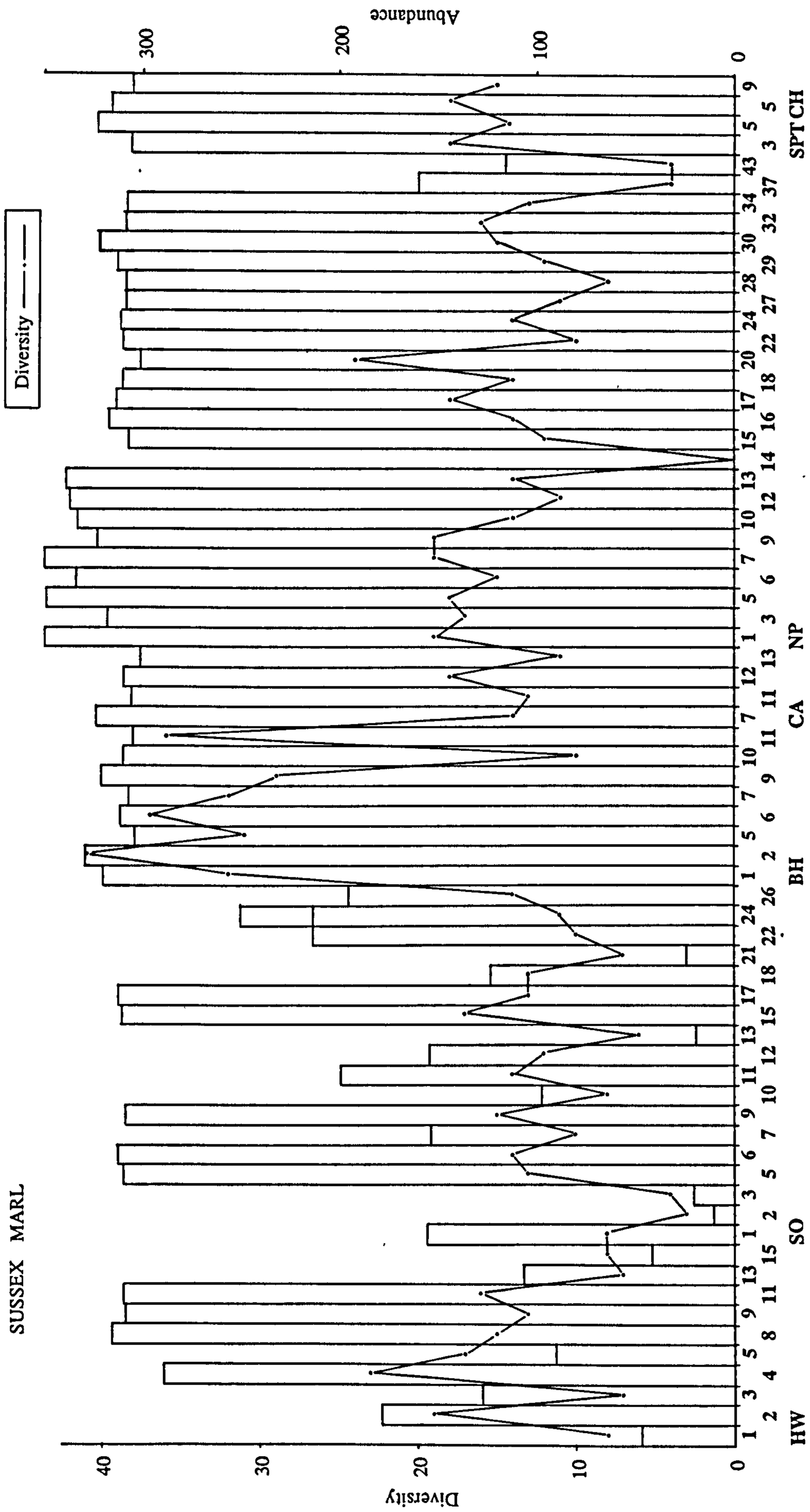


Figure 7.10 Species diversity (S) of marl samples from Sussex.

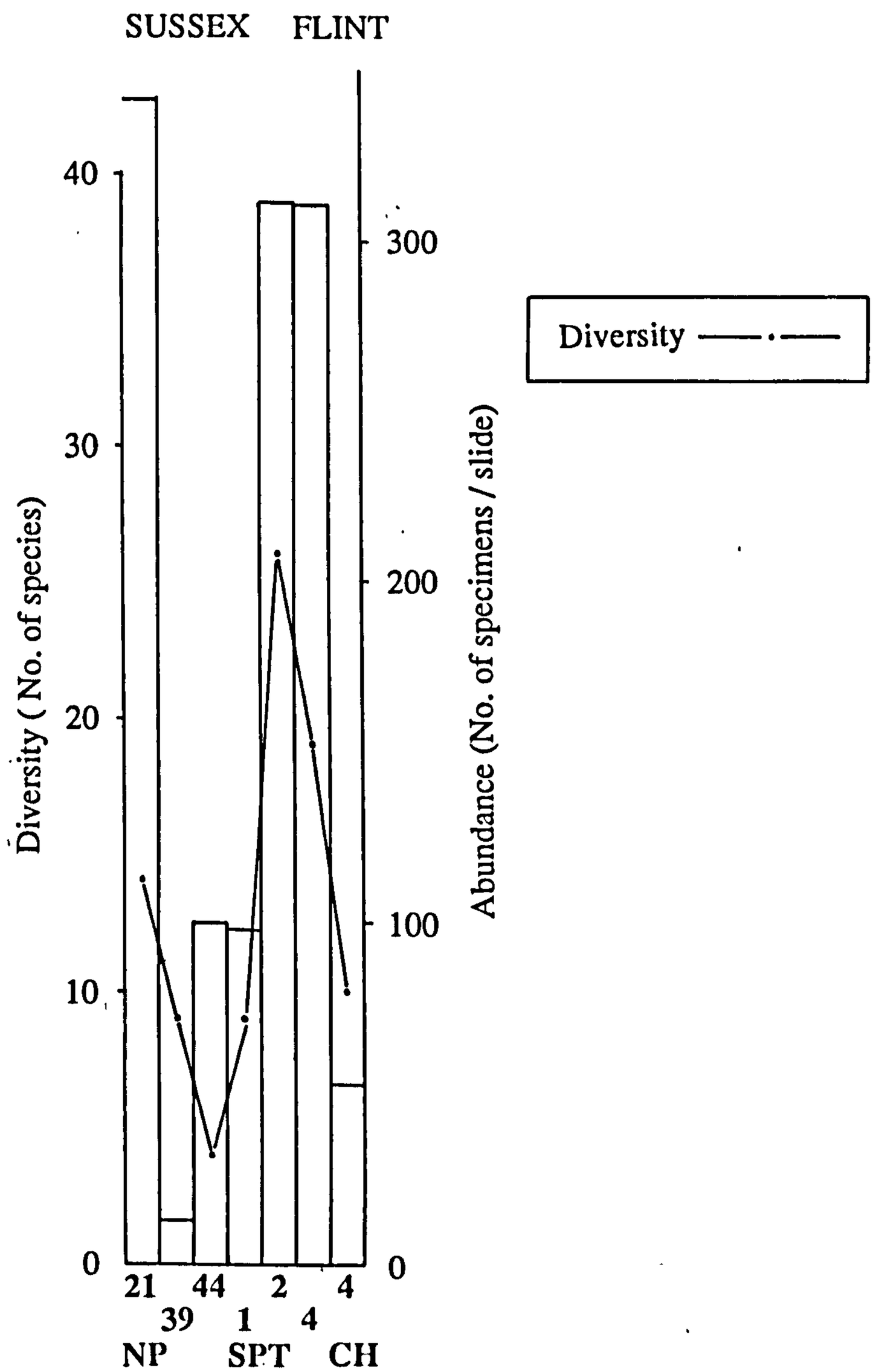


Figure 7.11 Species diversity (S) of flint samples from Sussex.

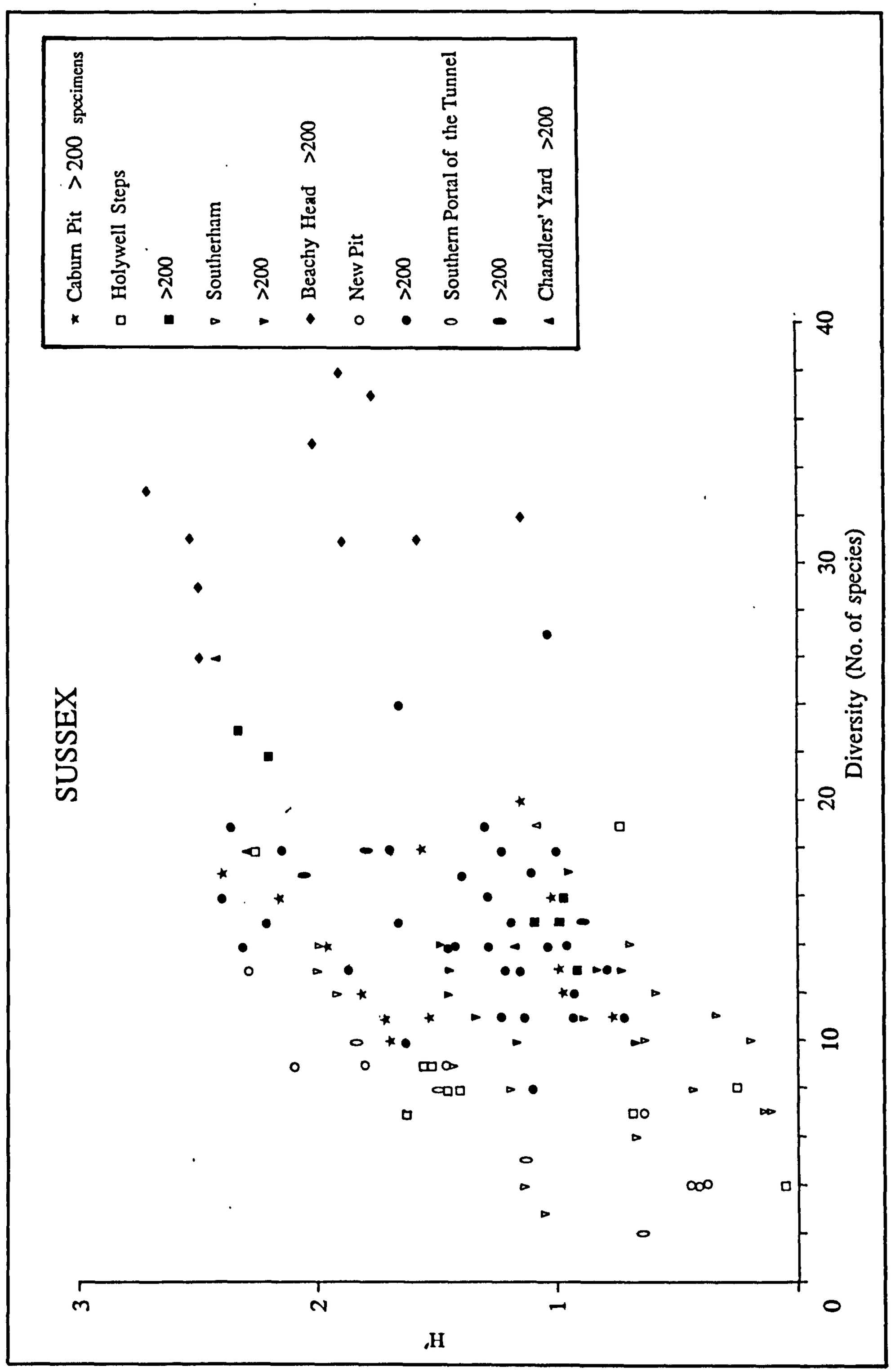


Figure 7.12 Species diversities S versus H′ (Sussex).

the mean value being 242. However the range is from 0 to 411. Such reliably high abundances allow the statistical results to be interpreted with confidence.

Dominance (D)

The dominance is plotted against the species richness index (Figure 7.13).
A large proportion of the samples have a significant dominance, together with a moderate diversity. The flint samples do not show the same trend as those from Dover; they are less diverse but the dominance is similar. Otherwise all three lithologies have a broad spread. A negative correlation may be interpreted from this data set, but it has not been tested for statistical significance.

Cluster Analysis (Species)

(i) Q-mode analysis of the raw data set using complete linkage method, produced the dendrogram shown in Figure 7.14. As with the same type of dendrogram produced for Dover, this one seems to cluster samples from the same or similar stratigraphical level together.

Cluster Analysis (Morphogroups)

The data set had to be divided into two parts (HW, BH, SO & CA) and NP, SPT, & CH as it was too large to be handled by the program.

(i) Q-mode analysis using the complete linkage method produced the dendrograms shown in Figures 7.15 a & b. These dendrograms appear to group samples from the same or similar stratigraphic level.

(ii) R-mode analysis was also performed on the data from Sussex. The data set had to be subdivided into two as it was too large for the program. Figures 7.16, 7.17 show the dendrograms produced from both the standard and normalised data sets. A similar trend is shown by both the normalised and unnormalised data sets.

As at Dover morphogroups D, Pp, Gp, and Gq are clustered closely. The reasons for this are thought to be the same as at Dover and their association is assigned to rare occurrence. The most distantly related groups are Gc, Gi, Gn, and Gv, which correspond closely with those at Dover. These morphogroups are plotted against each other to see if this negative relationship is real. (Figures 7.18, 7.19). Gc does not show a very strong

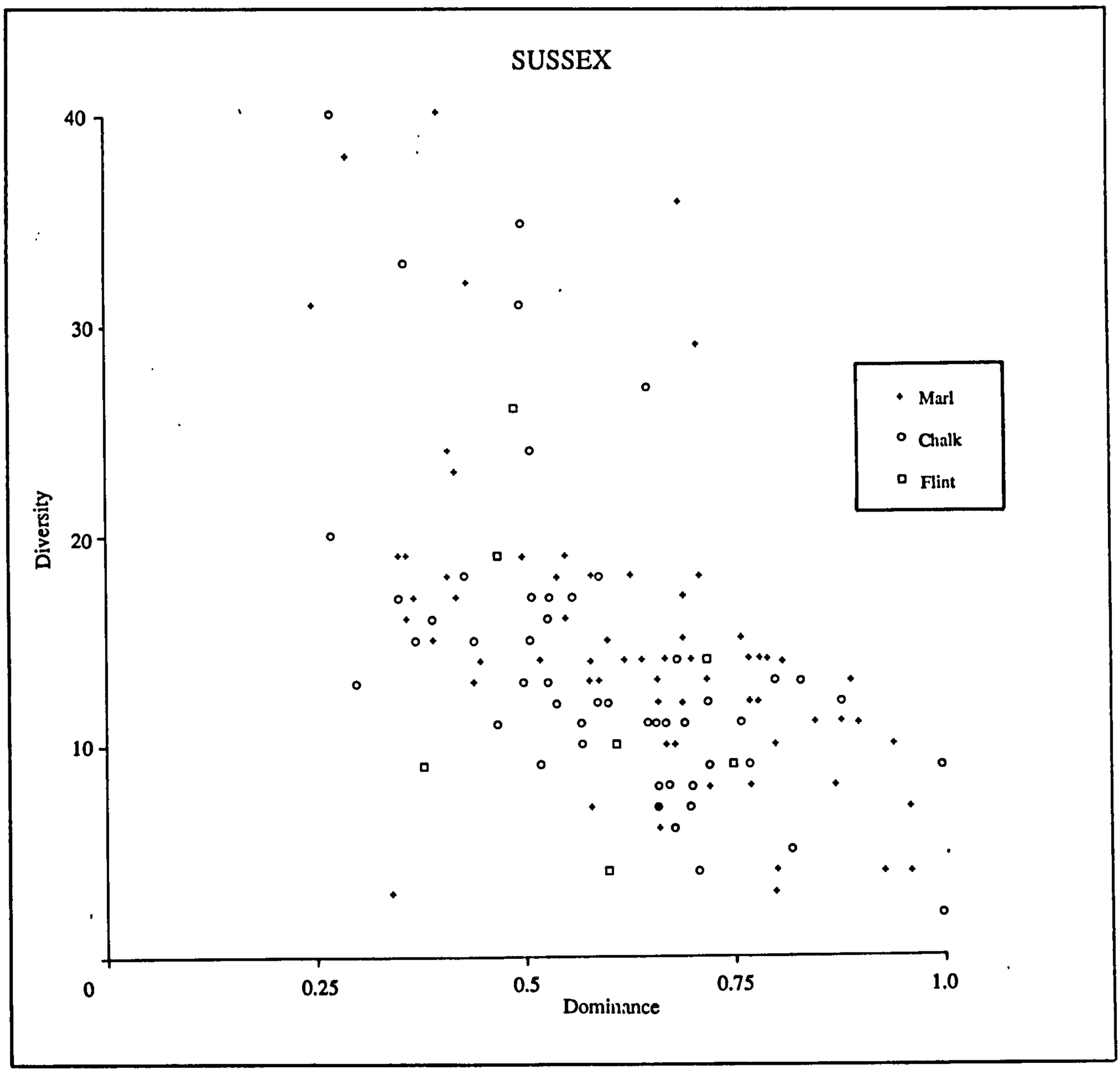


Figure 7.13 Dominance versus species diversity (S) (Sussex).

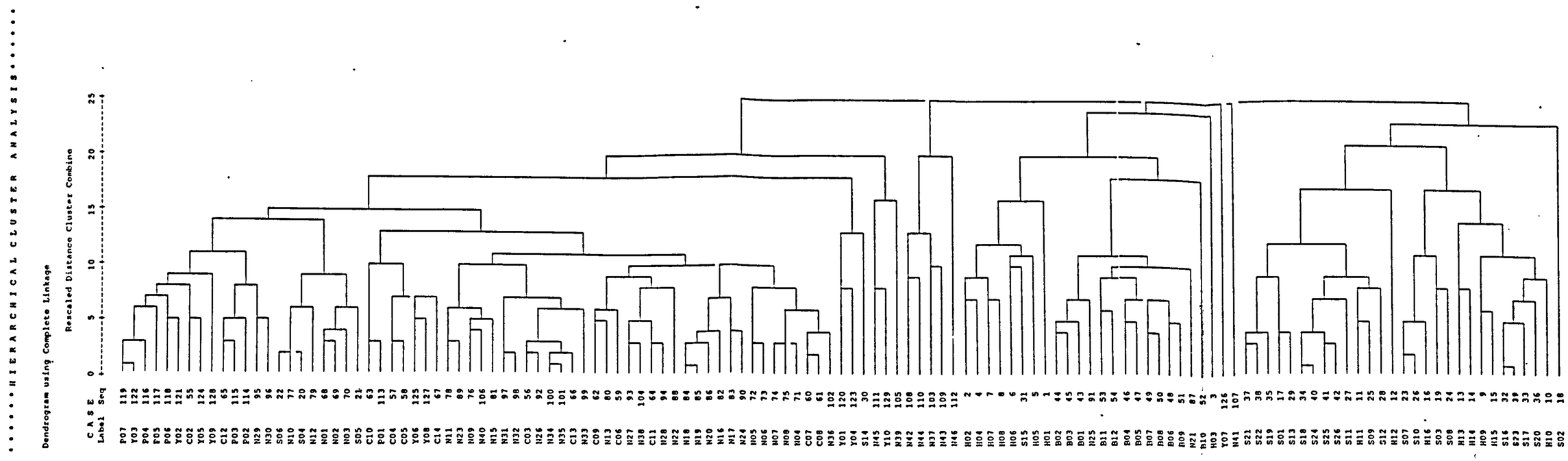


Figure 7.14 Dendrogram produced by Q-mode cluster analysis of the raw data from Sussex.

H = HW, B = BH, S = SO, N = NP, C = CA, P = SPT, Y = CH

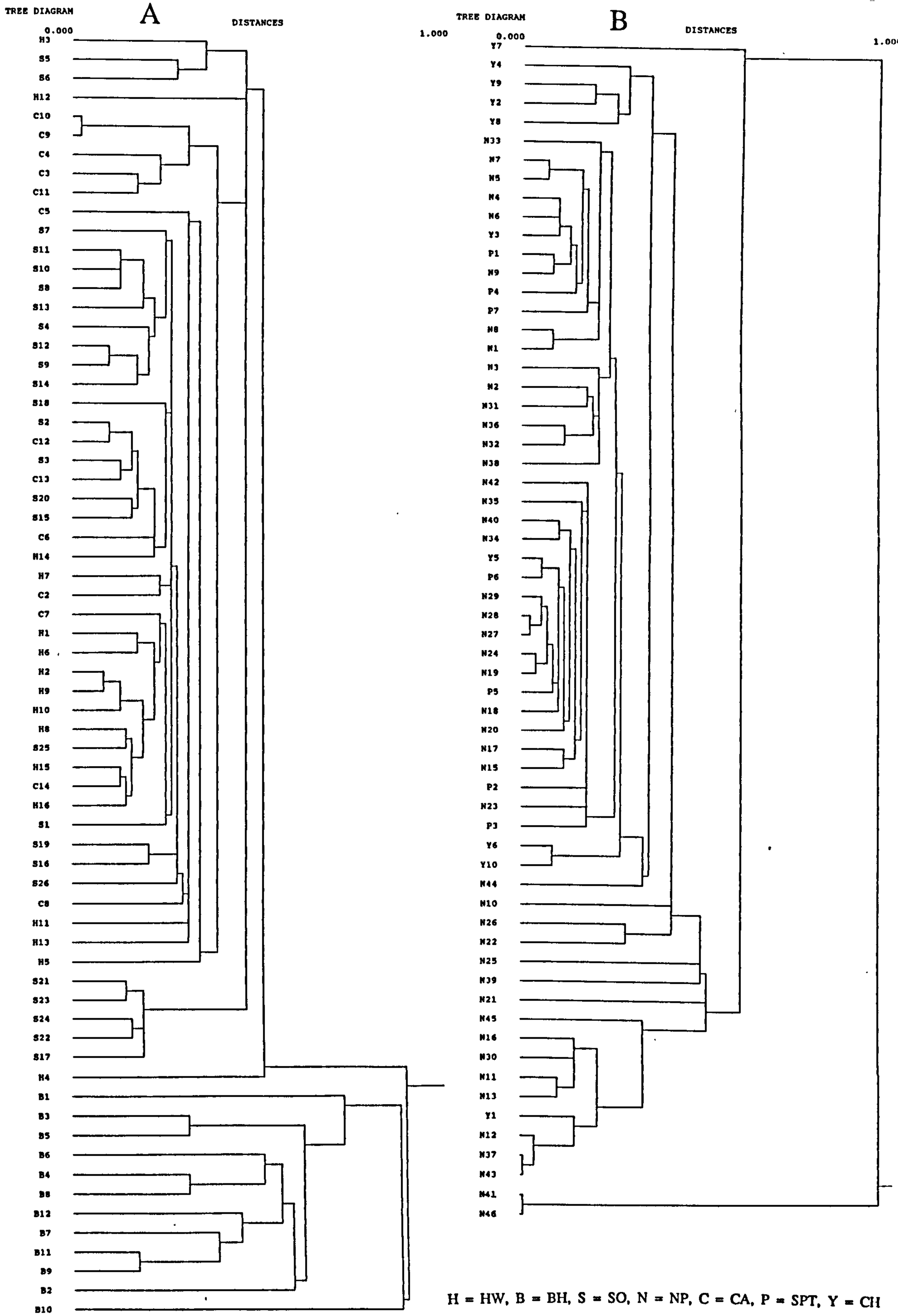


Figure 7.15 Dendrograms produced by Q-mode cluster analysis of the morphological groupings from Sussex.

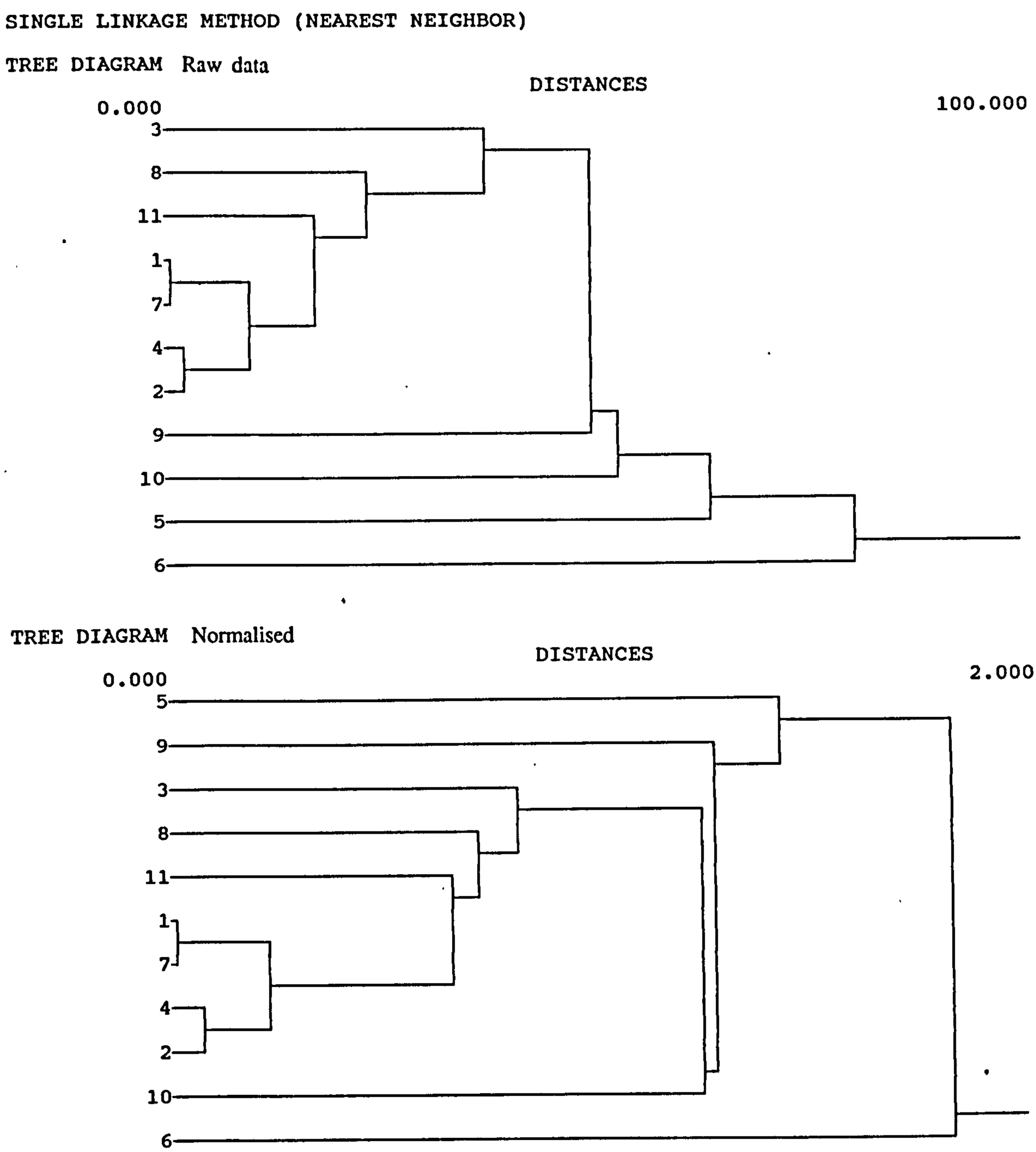


Figure 7.16 Dendrograms produced by R-mode cluster analysis of the morphological groupings from Sussex.
The key to the morphological groupings is as follows: 1-D; 2-Pp; 3-Px; 4-Gp; 5-Gc; 6-Gv; 7-Gq; 8-Gs; 9-Gi; 10-Gn; 11-Gx

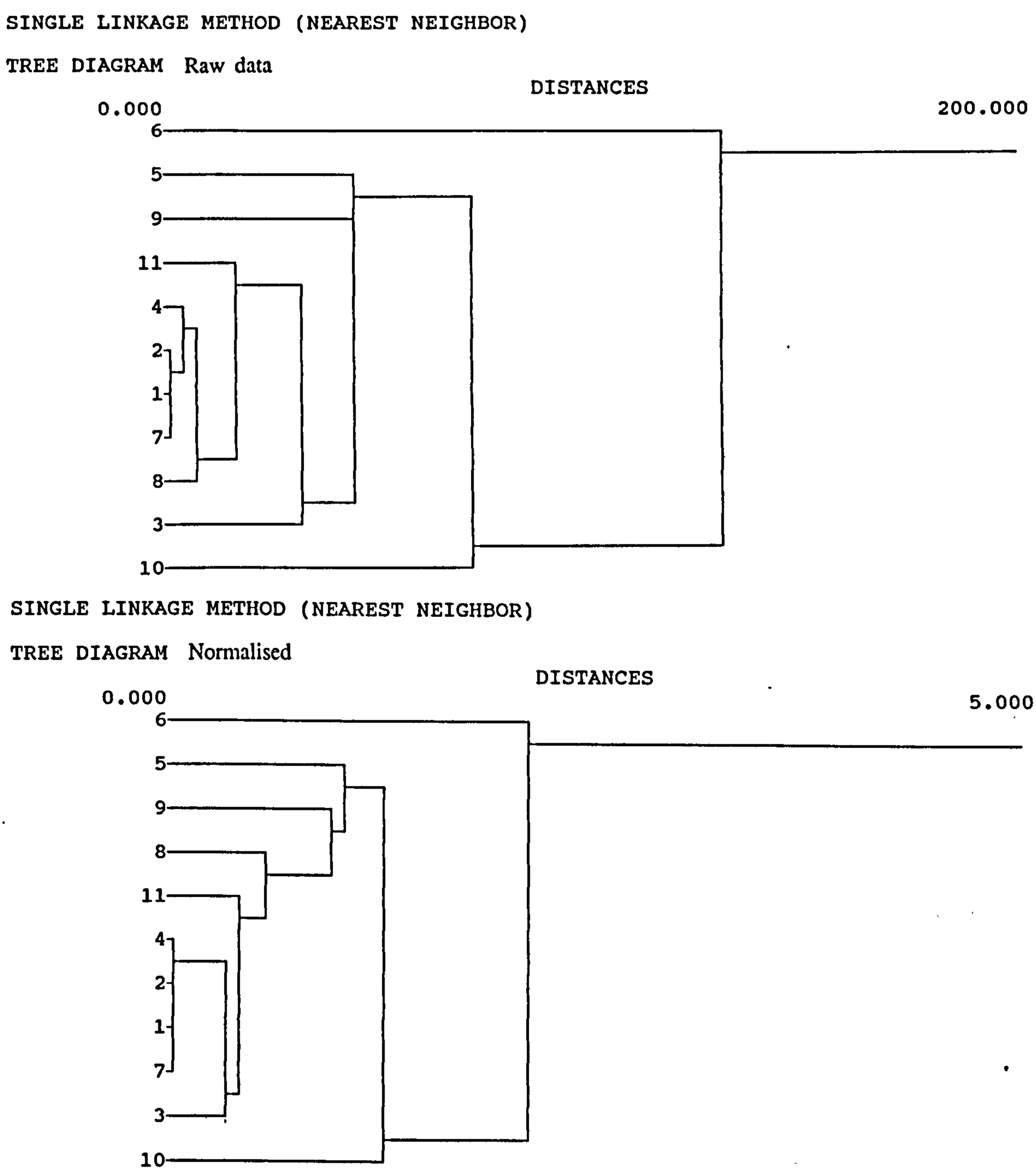


Figure 7.17 Dendrograms produced by R-mode cluster analysis of the morphological groupings from Sussex.
The key to the morphological groupings is as follows: 1-D; 2-Pp; 3-Px; 4-Gp; 5-Gc; 6-Gv; 7-Gq; 8-Gs; 9-Gi; 10-Gn; 11-Gx

relationship with Gi (Figure 7.18a). When Gv is >150, Gc is nearly always <100, and the graph shows a slight negative relationship (Figure 18b). Gv and Gn were also plotted (Figure 7.19a) and also seem to show a slight negative relationship. Therefore the likelyhood of Gn and Gc occurring together is greater than either of these groups occurring with Gv. The relationship between Gc and Gn is not shown to be truly positive (Figure 7.19b) and so the relationship between them is not certain. The same morphogroups were plotted again for the Dover data sets. Gc and Gi do not show any definite relationship (Figure 7.20a). Gc verses Gv exhibits a faint negative relationship (Figure 7.20b) for both data sets from Dover. Gv and Gn show a similar relationship. Gc and Gn were plotted (Figures 7.21a & b) and a slight positive relationship can be discerned.

7.4.3 Isle of Wight - Statistical Results

Diversity (S)

The diversity varied between 0 and 37 with the mean value calculated as 9. There seems to be a relationship between lithology and diversity, as the marls generally yield the most diverse assemblages (Figure 7.22). Of four flints sampled only one (MR8) yielded a moderately diverse assemblage (16) and the chalks are low in diversity (<10) also (Figure 7.23).

Diversity (H′)

As the Shannon Weiner index of diversity takes into account the abundance of the samples, these results must be analysed with caution. The results range from <0.01 to 2.54 and the mean value is 1.19. Some samples with low abundances produce a H′ value of one or greater. This puts the reliability of this method into question. The two diversity indices are plotted on Figure 7.24. There is no apparent relationship between them.

Abundance (N)

Poor abundances dominated the samples from this region. They varied from 0 to 315. The mean value is calculated as 72. It is felt that with such a generally low abundance the results of any further statistical analyses would be misleading and therefore this has not been attempted for this region.

Dominance (D)

The dominance varies from 0.24 to 1.0. The samples with a value of 1.0 are those with a limited abundance and only one or two species. Dominance

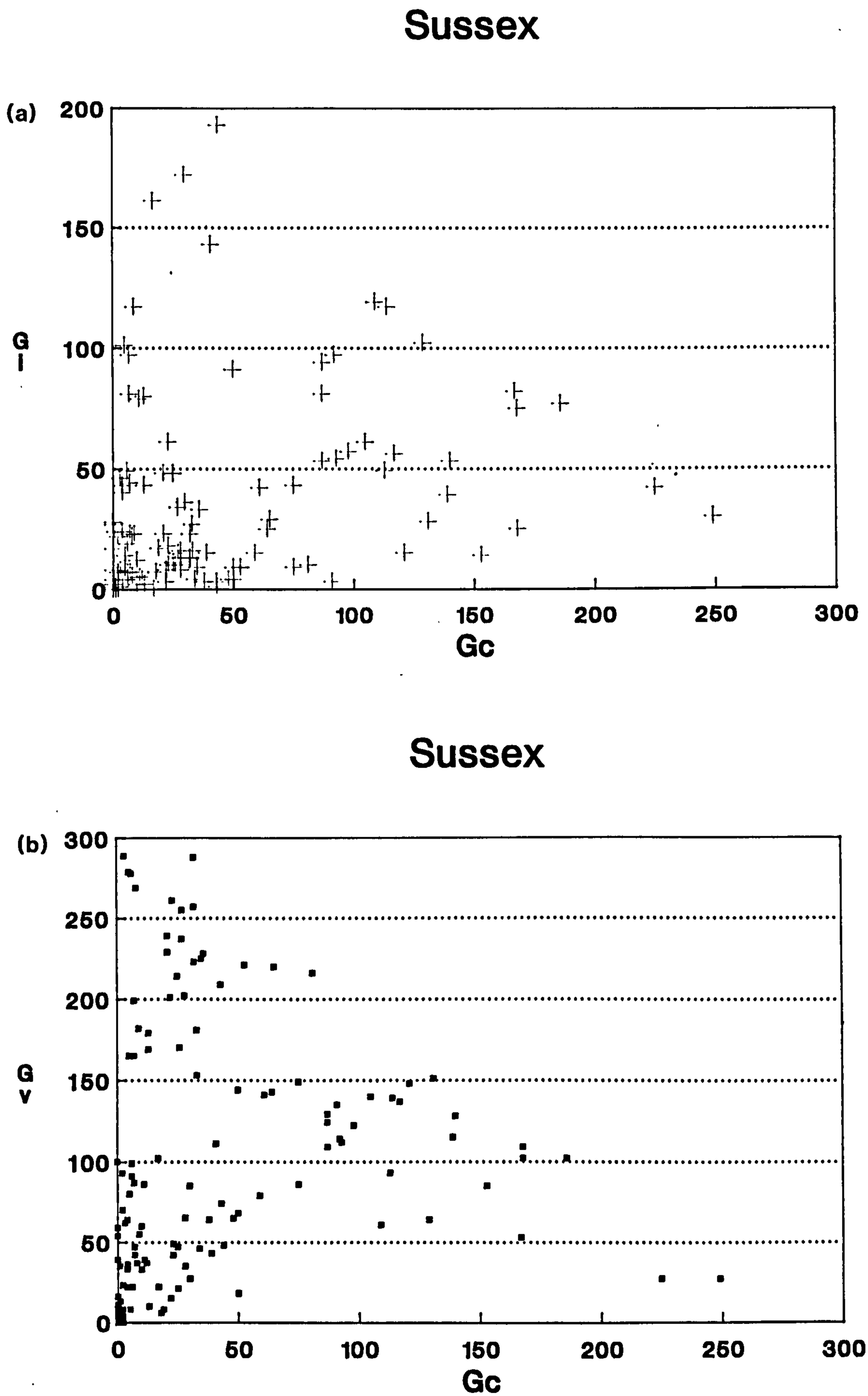
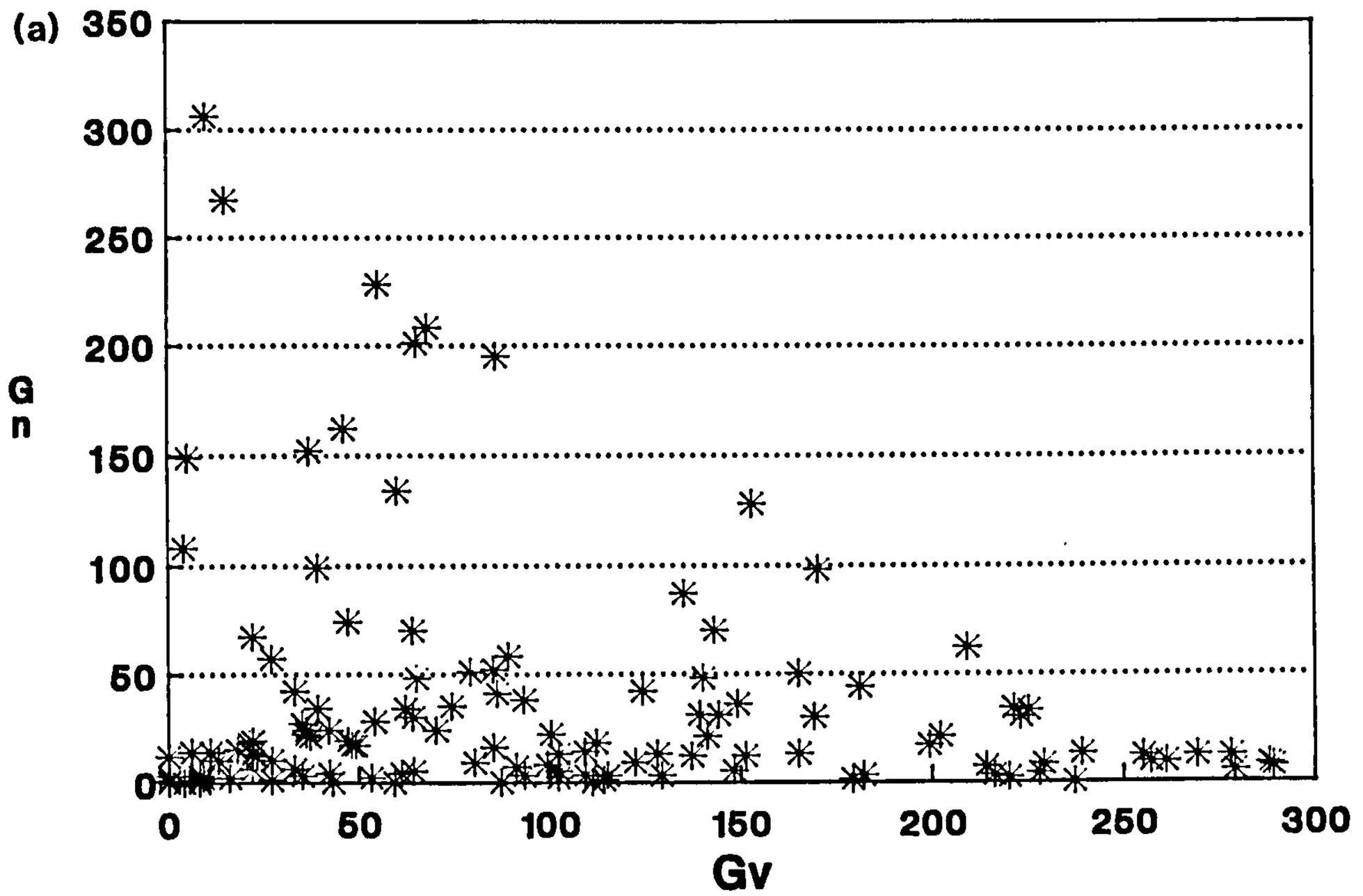


Figure 7.18 Absolute occurrences of the (a) Gc versus Gi morphogroups and (b) Gc versus Gv morphogroups from Sussex.



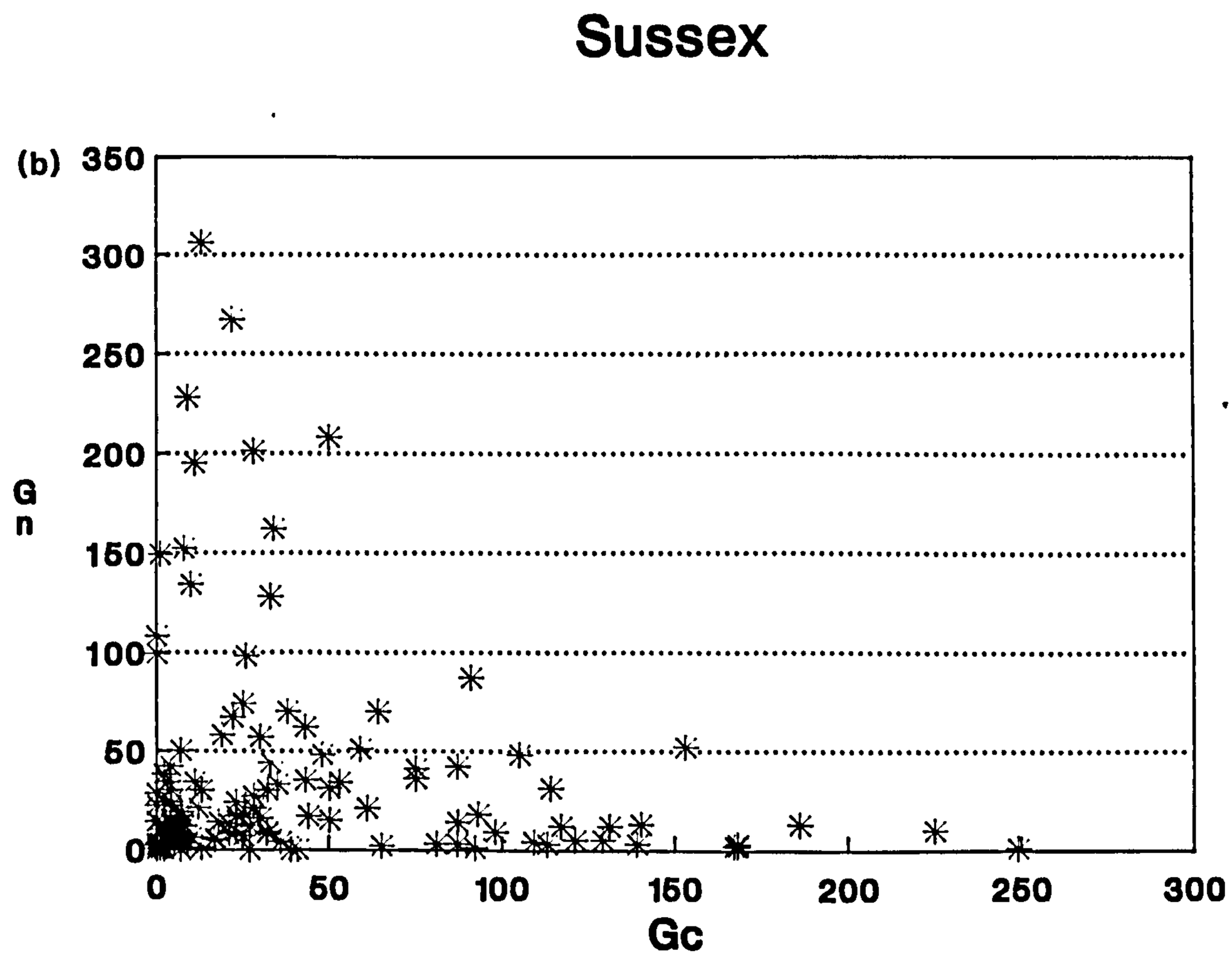
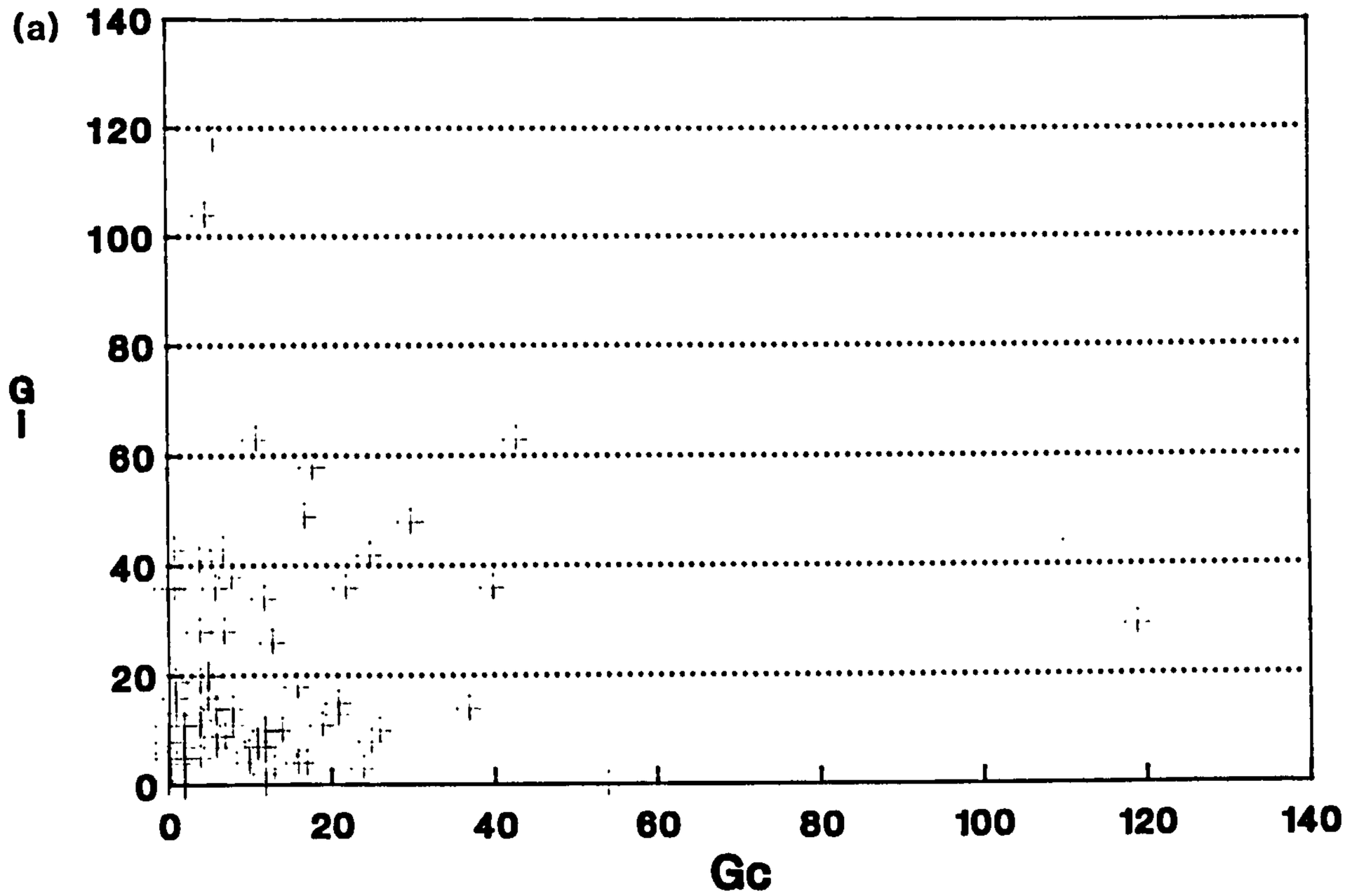


Figure 7.19 Absolute occurrences of the (a) Gv versus Gn morphogroups (b) Gc versus Gn morphogroups from Sussex.



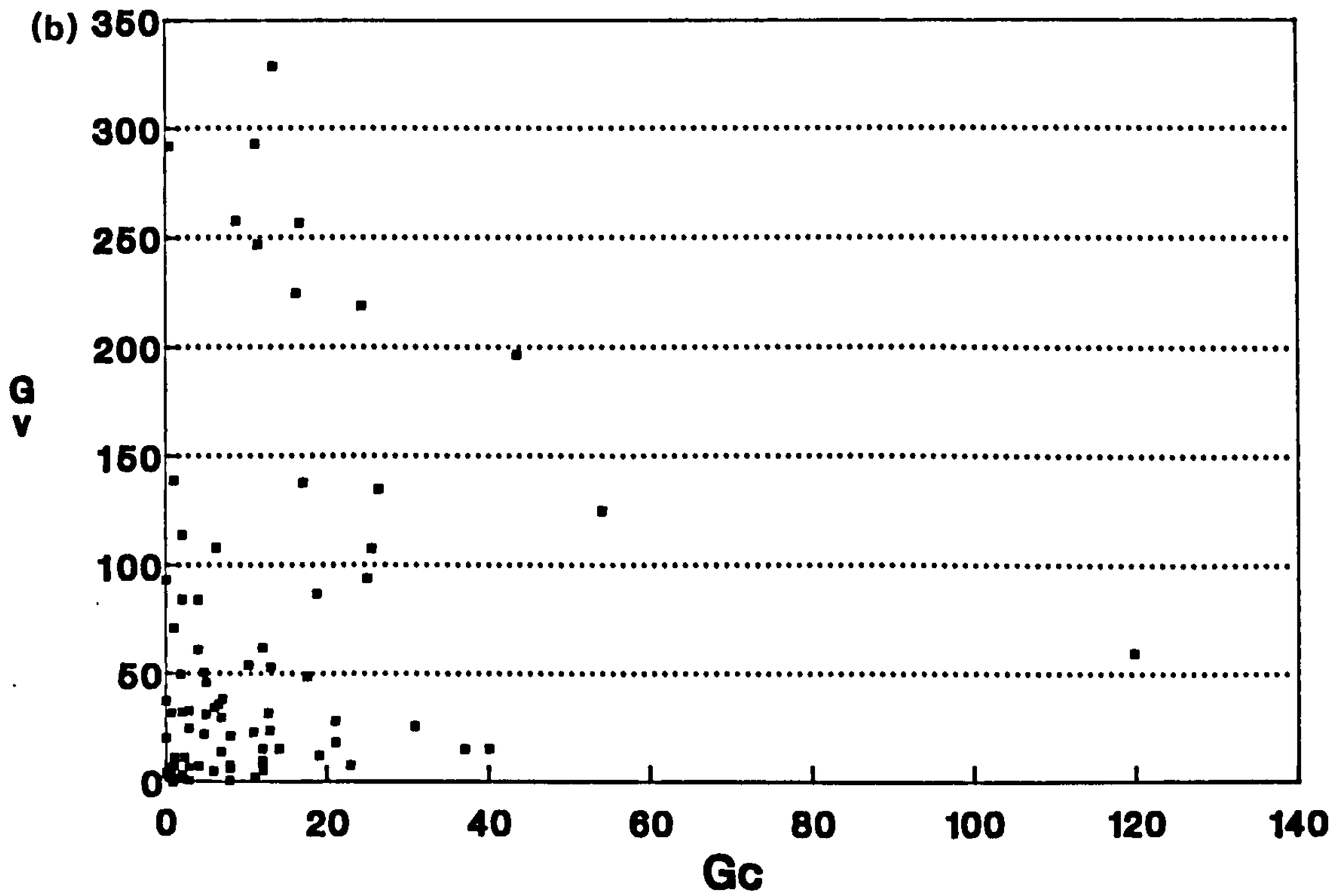


Figure 7.20 Absolute occurrences of the (a) Gc versus Gi morphogroups (b) Gc versus Gv morphogroups from Dover.

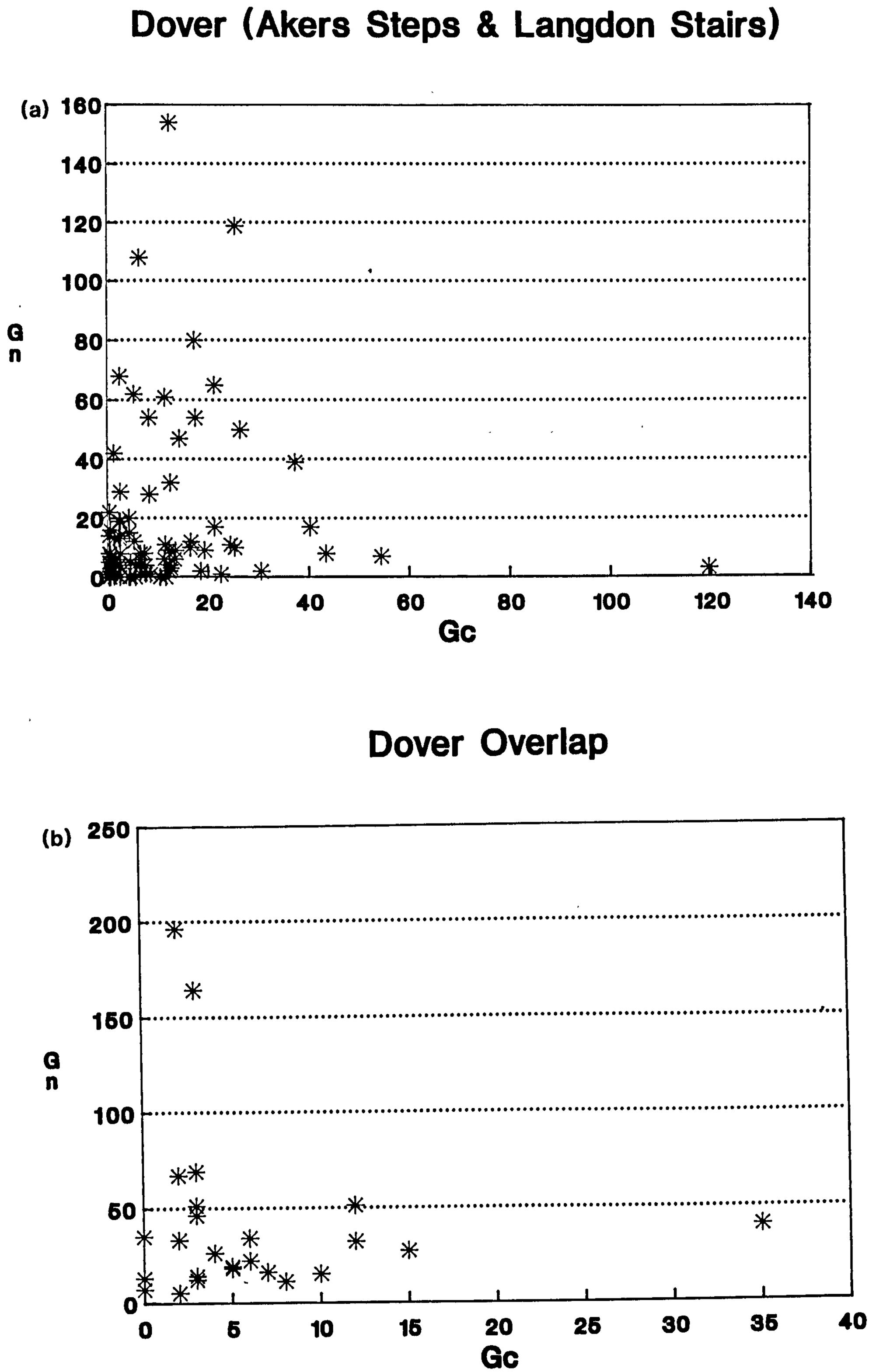


Figure 7.21 Absolute occurrences of the Gc versus Gn morphogroups from (a) Dover and (b) Dover overlap.

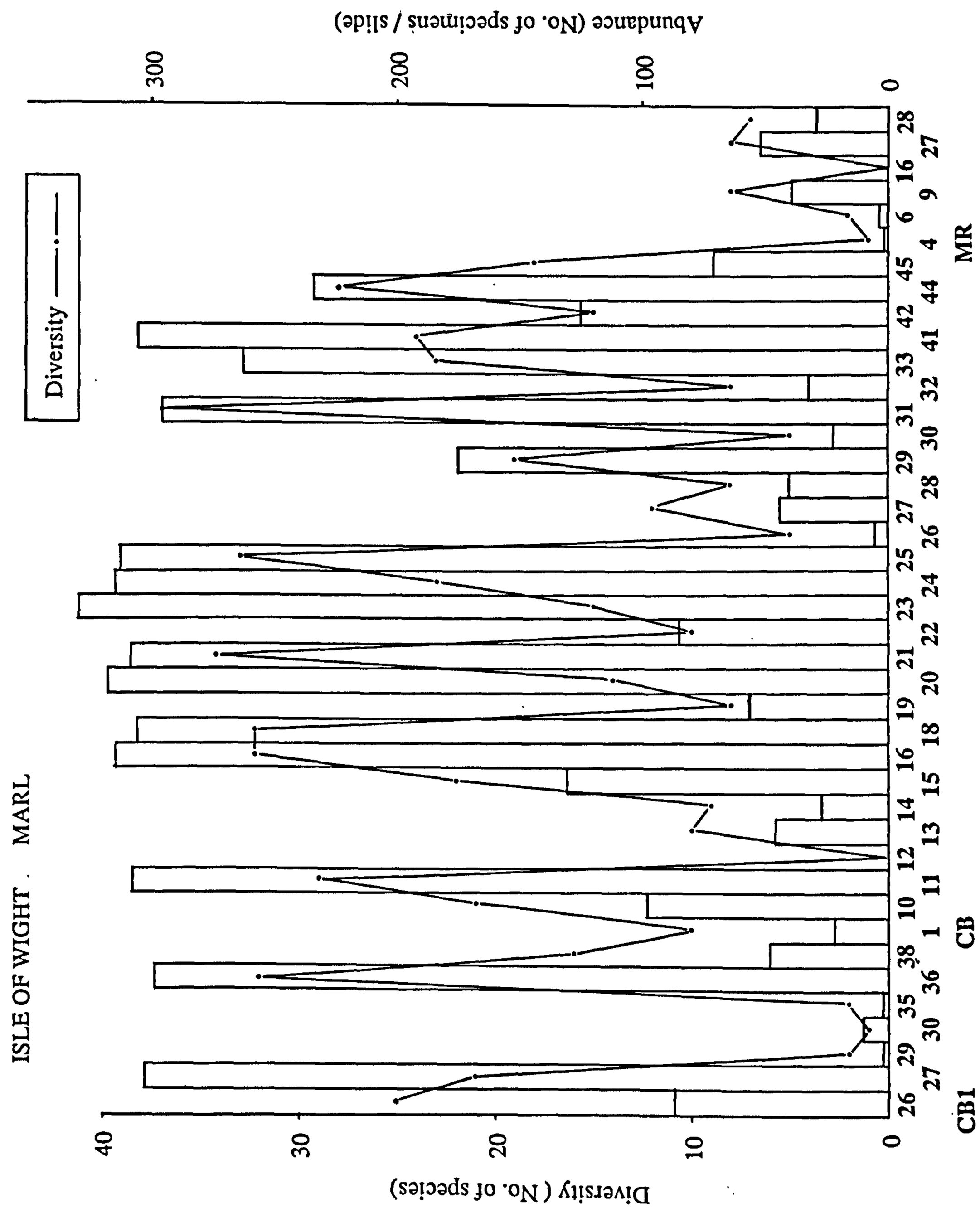


Figure 7.22 Species diversity (S)of marl samples from the Isle of Wight.

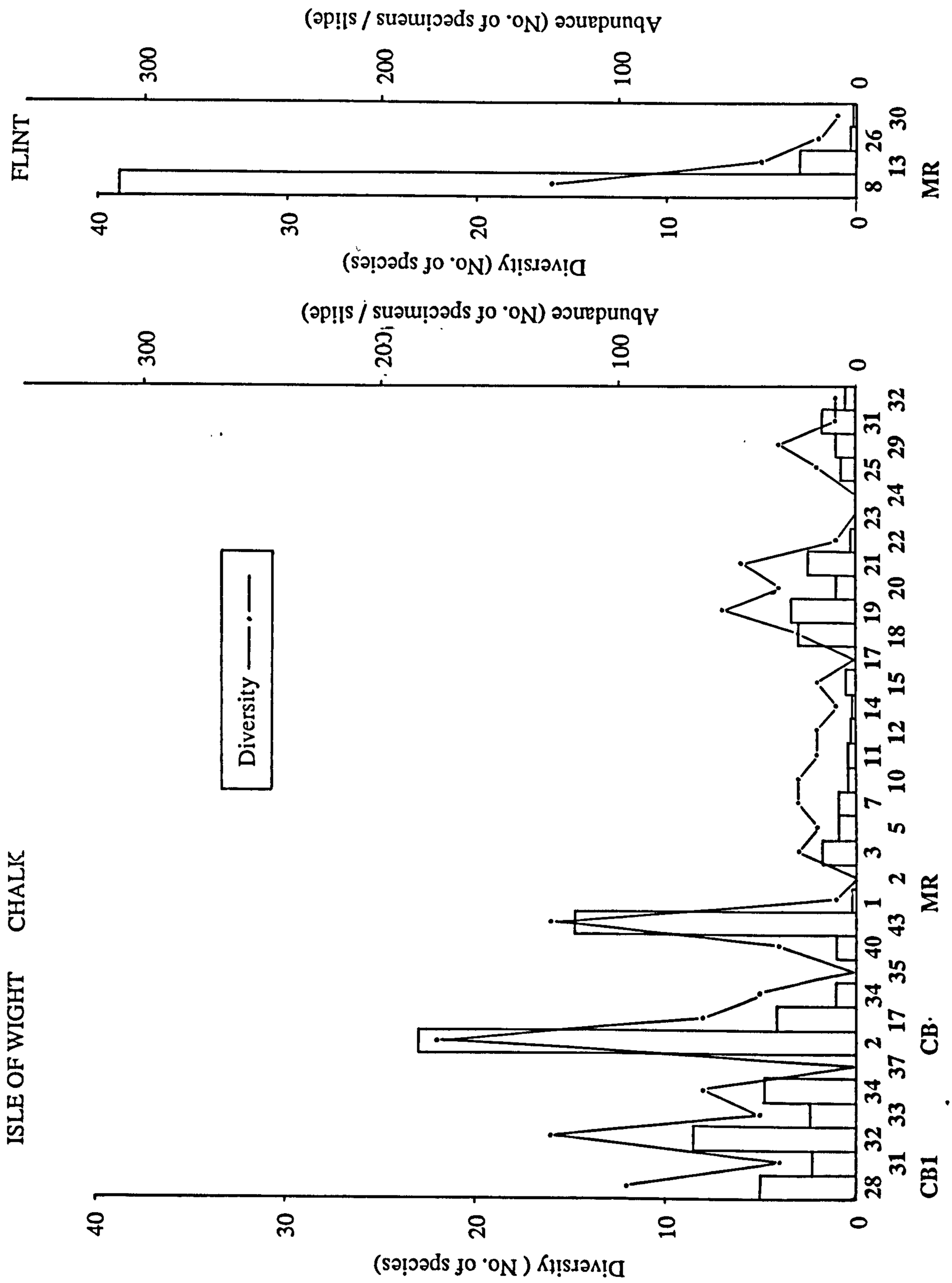


Figure 7.23 Species diversity (S) of chalk and flint samples from the Isle of Wight.

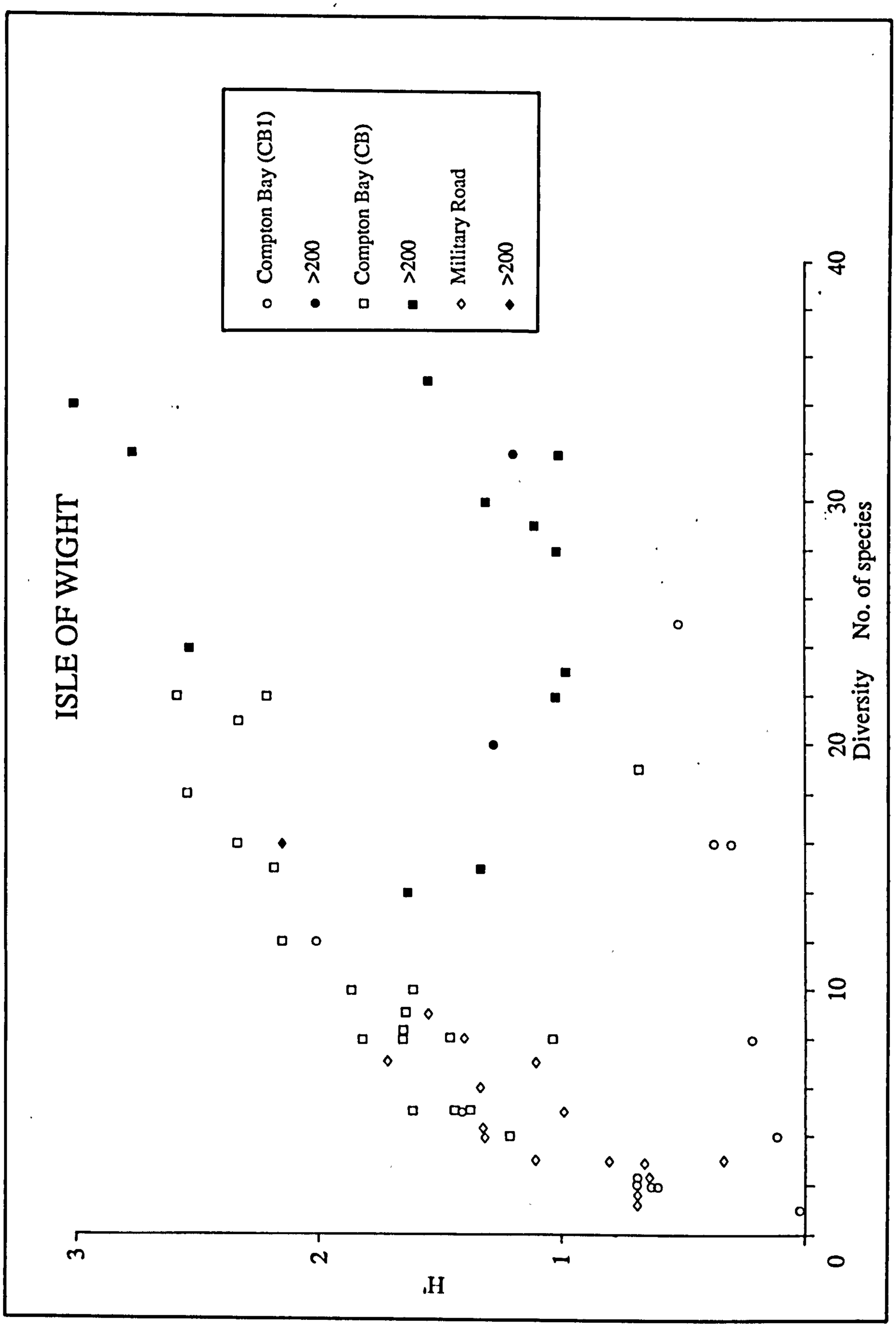


Figure 7.24 Species diversities S versus H′ (Isle of Wight).

plotted against diversity (S) exhibits a negative relationship, as was found in Sussex (Figure 7.25).

7.5 Discussion of results

General observations from all the statistical analyses will be discussed here.

7.5.1 Diversity

The diversity (S) varied greatly from 0 to 38. The mean diversity for each section and region has been calculated and is shown in Table 7.1. This variation in diversity does not seem to be defined by lithological constraints, with all lithologies displaying low and high diversities (Figures 7.1, 7.2, 7.9, 7.10, 7.11, 7.22, 7.23). However the generally low diversity assemblages do occur in sections that are poorly exposed and badly weathered (Akers Steps, Military Road and Southerham Machine Bottom). Although the freshest samples possible were collected, the sections may have been weathered more deeply, being exposed at the top of sea-cliffs or inland. Some more fragile species or those with thinner walls may become preferentially weathered out e.g. *Palaeohystrichophora infusorioides.*

7.5.2 Abundance

Abundances varied throughout the sections studied, and did not seem to be constrained by lithology. The mean abundances for each section and region are shown on Table 7.1. Low abundances correlated well with low diversities, which is to be expected. The greater the sample size, the higher the probability of finding another species, therefore increasing the diversity, although this was not always found to be the case.

7.5.3 Dominance

The dominance varied greatly in all three regions. When plotted against the species richness index (S) a negative relationship is apparent. This has not been measured by means of statistical methods and is only an observation. A more diverse assemblage is less likely to be dominated by one or two species. The flint samples from Dover displayed both high diversities and dominance. This may reflect the superabundance of *P.infusorioides* in some of these samples. In contrast the flint samples from Sussex have low diversities, but a similar dominance.

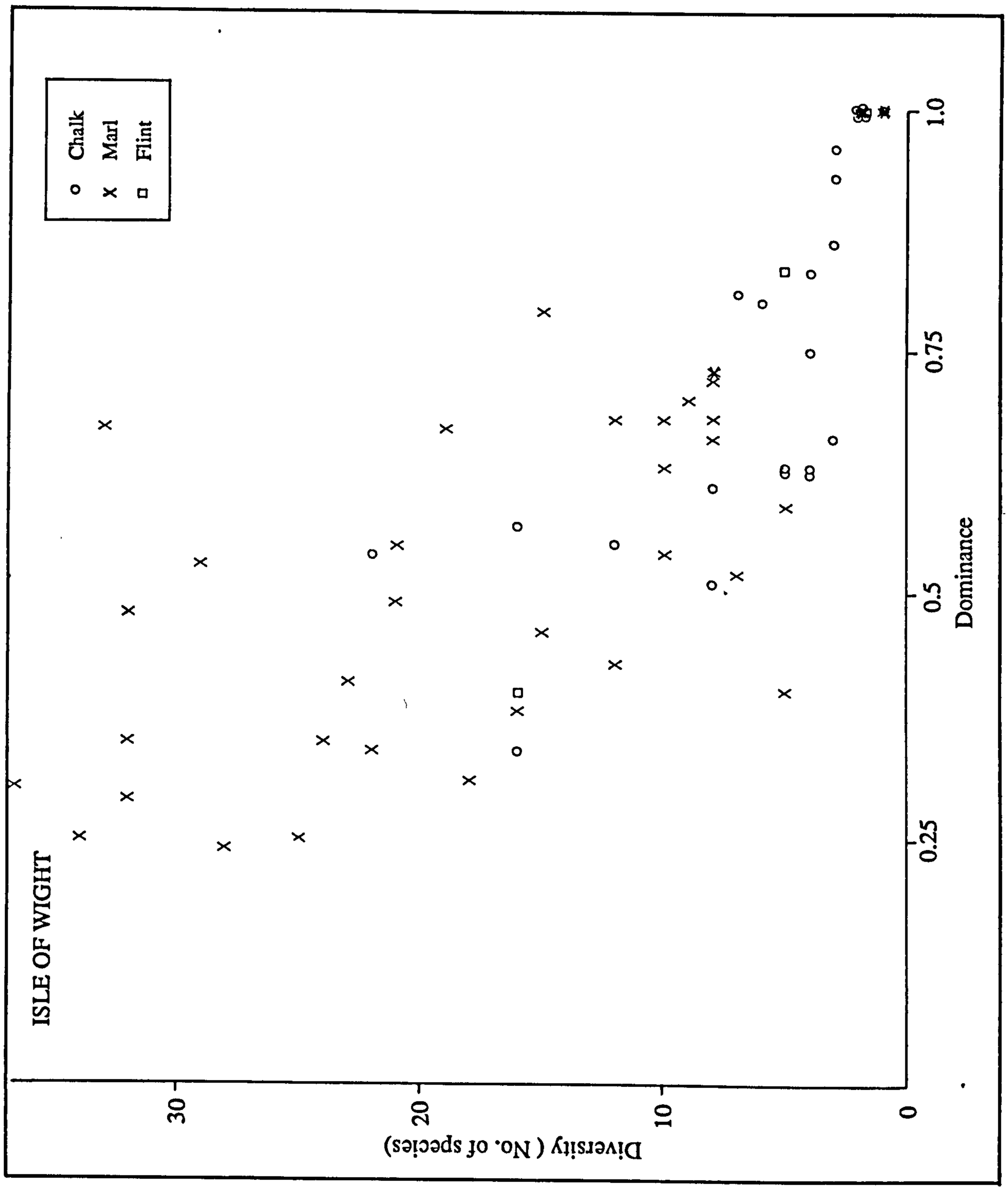


Figure 7.25 Dominance versus species diversity (Isle of Wight).

SECTION	Diversity	Abundance
Akers Steps	7	105
Langdon Stairs	18	127
Dover	13	116
Compton Bay	15	125
Military Road	3	19
Isle of Wight	9	72
Holywell Steps	13	172
Southerham Machine Bottom	11	168
Beachy Head	32	314
New Pit	13	268
Caburn Pit	14	308
Southern Portal of Tunnel	17	281
Chandlers Yard	12	186
Sussex	16	242

Table 7.1 Mean diversities and abundances of each section and region.

7.5.4 Cluster Analysis

Q-mode analysis (Species)

The results of the hierarchical cluster analysis using the raw data sets and Q-mode analysis are shown in Figures 7.5 & 7.14. Generally each dendrogram shows some large scale clustering, usually grouping samples from the same section (Figure 7.5), or grouping sections which are of a similar age (Figure 7.14). However, none of the dendrograms display convincing groups and do not aid biostratigraphic subdivision. This is not surprising as most of the species identified are long-ranging and occur throughout the Turonian and there seems to be little if any lithological constraint on the assemblages. Many of the samples from different sections and lithologies may be similar, but not similar enough to produce distinct clusters on the dendrogram.

Q-mode analysis (Morphogroups)

The dendrograms produced by this form of cluster analysis tend to cluster samples from a similar stratigraphic level, although this is not always the case. Samples from the same locality are also sometimes grouped together (BH samples - Figure 7.15).

R-mode analysis (Morphogroups)

Similar trends are produced for the data sets from Dover and Sussex, with the D, Pp, Gp & Gq morphogroups always being clustered closely (Figures 7.7, 7.16, 7.17). This is thought to be due to their infrequent occurrence. The most dissimilar morphogroups are found to be Gc, Gv, Gn & Gi. These morphogroups are plotted against each other to try to clarify what their relationships are, but there are no conclusive results, but it is thought to be correlated with their different morphologies.

7.6.1 Conclusions

The techniques used have not produced any conclusive results, with regard to relationships between samples or the lithological constraints of the dinoflagellate cyst populations, but do serve to support the basic trends described in Chapter 5. This may be due to the inherently low diversity assemblages associated with the Turonian generally.

CHAPTER EIGHT CONCLUSIONS

8.1 Introduction

This concluding chapter summa rises the most important results made from this investigation and discusses their significance for biostratigraphical, palaeooceanographical and palaeoenvironmental interpretations.

8.2 Biostratigraphy

Dinoflagellate cyst assemblages have been recovered from 328 samples from Turonian sections in Kent, Sussex and on the Isle of Wight. Although the samples were poor or barren of palynomorphs at the base of the succession, the flora recovered during the Turonian, with increasing diversities and abundances being recorded. The flora suffered the after-effects of the oceanic anoxic event at the close of the Cenomanian, and in response to this they are known to have become locally extinct (Jarvis *et al.*, 1988).
These Turonian assemblages served as a basis on which to produce an improved palynostratigraphy for the Turonian. Three zones within the stage were recognised by the first and last appearances of individual taxa and some influxes of taxa. As the Turonian is only thought to have been of 3 million years duration it is not surprising that further refinement of the palynostratigraphy is difficult.

One species thought to be an important index taxon is *Litosphaeridium "chlidanum"* (Marshall 1983). This form is found in the Upper Cenomanian sediments of Humberside (Duane 1992) and is also present in some of the lowermost samples from the Holywell Steps section, on the Sussex coast. It is believed to be regionally useful in characterising the uppermost Cenomanian and, as a result, the base of the Turonian. The last appearance can be used to define the top of Palynozone I.

There are some typically Turonian forms making their first appearance within or just below the base of this stage, notably *Heterosphaeridium difficile*,

Senoniasphaera rotundata and *Florentinia buspina.* The first occurrence of these forms is variable, from the very uppermost Cenomanian (within the Melbourn Rock Beds), to a few metres above the base of the Melbourn Rock Beds, where the macro-biostratigraphical base of the stage is taken (Kennedy & Cobban 1991). These first occurrences define the base of Palynozone II. *Oligosphaeridium complex* has a consistent occurrence throughout this zone. *Florentinia torulosa* has its first appearance at the top of the *M.labiatus* Zone and its last appearance just below the base of the *T.lata* Zone. The first appearance of this species defines the base of Palynozone III. This palynozone is also characterised by influxes of *Heterosphaeridium difficile* and *Cyclonephelium distinctum* in the middle of the *T.lata* Zone.

The last occurrence of *Endoscrinium campanula* is used to define the base of Palynozone IV. The influx of *Senoniasphaera rotundata* noted within the *Sternotaxis planus* Zone in the upper part of the succession of each region is thought to be of potential correlative value.

Comparison with other parts of the Anglo-Paris Basin is limited because assemblages from southern England are not always found to be consistent with the assemblages from France. The first appearance of *S.rotundata* in France seems to be consistent with an Early Turonian age. In France the first appearance of *F.torulosa* has a similar first appearance in the middle part of the Turonian but appears for the first time at a slightly higher stratigraphical level. The absence of *H.difficile s.s.* from some of the French samples is surprising as it is thought to be a useful Turonian marker.

Foucher in Robaszynski *et al.*(1980 & 1982) analysed 11, 18 & 29 samples from the whole Turonian of the Boulonnais, Saumurois and Civray-de-Touraine respectively. However the detailed sampling carried out for this investigation improves these previous palynozonations. As has just been demonstrated this more detailed palynozonation appears only to work well in southern England and in northern France. This may be a result of the differences in sampling intervals making detailed comparisons uncertain. It is not easily applied to parts of France where some of the index taxa are absent (Saumurois & Civray-de-Touraine). Their absence may be a reflection of the palaeoenvironment (see Section 8.5.2), perhaps cooler water (23°C) may be indicated by the very common occurrence of *P.infusorioides* as this has been associated with cooler water conditions (Duane, 1992), or due to

positioning within the basin, with the Saumurois and Civray-de-Touraine being located to the southwest of Paris. Nor is it easily applied to the northern North Sea where different facies exist and the dinoflagellate cyst assemblages are dominated by different, mainly peridinioid forms, which generally indicate a reduced salinity environment (Harker *et al,* 1990; Bradford & Wall, 1984).

8.3 Statistical results

Statistical measurements of the relationships between the dinoflagellate cyst assemblages and lithology were made to look for clustering of samples which may be useful for biostratigraphical subdivisions.

Diversity and abundance indices varied greatly throughout the succession and therefore are not lithologically controlled. Dominance also varied greatly and while it appears to show a negative relationship with diversity this has not been statistically established.

Various clustering methods using the raw data and the morphological groups formulated from it do not exhibit any significant clustering that can be applied in a biostratigraphical sense. However the R-mode analysis of the morphogroups did show some trends. The D, Pp, Gp and Gq morphogroups were always closely grouped. This is interpreted as being due to their rare occurrence, which is their only similarity. Other groups which have unrelated occurrences include Gc, Gv, Gi and Gn, which when plotted against each other did not show any conclusive trends (see Section 7.4.1 & 7.4.2) either of being mutually exclusive or dependant on each other. This suggests that these groups are morphologically quite distinct which may have some bearing on their relationships, and might imply that they were not associated in a palaeoecological sense. Tests of statistical significance are needed to interpret these relationships objectively.

8.4 Lithological relationship to dinoflagellate cyst assemblages

The chalks and marls from the "overlap" part of the sections at Dover yielded very different dinoflagellate cyst assemblages (in terms of abundance and diversity). Repeat samples confirmed the original findings, that the assemblages from Akers Steps and Langdon Stairs were very different. The foraminiferal analysis supported the palynological results as the assemblages were similar but showed some specific differences between the two localities. However the nannofossil and ostracod analyses disagreed

with the palynological results, as the faunas were very similar and did not indicate any great variation between the two sections. The accumulation rate calculated using the foraminiferal data (see Appendix 4) was different and may imply variable hydrodynamic regimes at the two localities. This idea is refuted on grounds that if different hydrodynamic regimes prevailed, the ostracod and nannofossil results would also reflect this. It is thought that the different organic assemblages may be an artefact of differential weathering of parts of the sections. If this is the case future sampling programmes must consider the condition of the sections to be sampled very carefully and use borehole or foreshore material where possible.

Each of the three marl bands from Burghclere, exhibited a slight increase in the abundance and diversity of the dinoflagellate cyst assemblage, but these were small and the total number few so little emphasis can be placed on their interpretation. The variable foraminiferal populations present could be due to the dissolution of thin-walled, non-keeled planktonics and calcareous benthonic forms. This dissolution may be a direct result of high sea-levels, which caused the oxygen minimum zone to expand, forming conditions similar to those which existed during the deposition of the Plenus Marls, but probably on a smaller scale. This idea of marls forming due to expansion of the oxygen minimum zone is preferred to the volcanic origin proposed by Leary & Wray (1989) as there is no evidence that the clay minerals illite and montmorillonite (common in marl bands) are of volcanic origin (Jeans, 1968) and in fact are probably of detrital or neoformational origin. The variable foraminiferal assemblages present are likely to be due to dissolution and not the effects of ash falling through the water column.

Comparison of the dinoflagellate cyst assemblages from flint and chalk samples, has shown that in some cases the flints seem to preferentially preserve a more abundant and diverse assemblage. The type of flint may have some control on this. Nodular flints are thought to represent further stages of silicification, which may alter the organic fossils whereas *Thalassinoides* flints preserve a more diverse and abundant assemblage. Further investigations of a variety of flints would be necessary to finally prove or disprove this suggestion. There appears to be no lithological constraints on the dinoflagellate cyst assemblages produced from either chalk or marl samples, with variable diversities and abundances being recorded from both lithologies. The diversities (10 - 30) are generally low to moderate. These diversities may be related to a stressed environment,

such as in a restricted basin. However, the high sea-levels that are thought to have prevailed during parts of the Turonian would have connected the seaways and there would have been a through flow of currents, allowing the introduction of species to most parts of the basin. Parts of the basin may have remained cut-off by topographic features which would have permitted the existence of low diversity different floras.

8.5.1 Palaeoenvironmental significance of dinoflagellate cysts

The palaeoenvironmental significance of recent and fossil dinoflagellate cyst assemblages has been discussed in many papers (Vozzhennikova, 1967; Scull *et al.*, 1966; Wall & Dale 1968; Downie *et al.*, 1971; Harland, 1973; Dale, 1976; Dale, 1983; Harker *et al.* 1990). The ecological factors affecting these assemblages are only now beginning to be understood. Salinity, water temperature, water depth (McKee *et al.*, 1959; Reid, 1975; Köethe, 1990) and distance from the shoreline (Wall *et al.*, 1977; Downie *et al.*, 1971) are known to affect the distribution of dinoflagellate cysts in the marine environment.

Dinoflagellate cysts occur in both marine sediments and in fresh-water conditions at the present time (e.g. *Ceratium* Schrank 1793). They are known to form in response to environmental stresses usually producing "temporary" cysts. In this way the cell can over-winter or become dormant during periods of low nutrient levels, abnormal temperatures, or salinities, until such time it receives a stimulus to excyst and return to its thecate stage in the water column. Most, if not all, are accepted as hypnozygotic bodies of the sexual life-cycle (Evitt, 1985).

Several trends have been recognised in the occurrence of genera, species and informal morphogroupings or families. There is a wealth of information covering this relatively new subject and only those of direct relevance are discussed here.

Vozzhennikova (1967) described thick-walled, cavate cysts as being characteristic of inner neritic conditions and thin-walled, chorate cysts as characteristic of open, stable marine conditions. This hypothesis has been substantiated by (Scull *et al.*, 1966; Brideaux, 1971 & Downie *et al.*, 1971) but not by work on modern cysts so too much emphasis must not be placed on it.

Harland (1973) recognised that the number of gonyaulacoid species was greater than the number of peridinioid species in an open marine environment. He calculated a ratio (the GP ratio) from the number of gonyaulacoid species divided by the number of peridinioid species. This ratio was found to increase in offshore sediments. Dale (1976) discovered that the number of gonyaulacoid species was greater than the number of peridinioid species in Trondheimsfjord, Norway, despite the greater abundance of living peridinioid thecae in the living plankton. Harker *et al.* (1990) agreed that gonyaulacoid species predominate in more open marine conditions, and that the predominance of peridinioid species indicates a more stressed environment.

Four major groups of different affinities were noted (Harker *et al.*, 1990); those of gonyaulacoid, peridinioid, gymnodinioid and uncertain origins. Fossil gonyaulacoids were divided into three basic types, those related to the modern genus *Gonyaulax* Diesing 1866, those related to the modern genus *Ceratium* Schrank 1793 and those represented by the genus *Cyclonephelium* Deflandre & Cookson 1955; emend. Sarjeant & Stover 1978, which has no direct modern analogues but is questionably related to the ceratioid forms. The first two appear to be most common in stable marine sediments, and the third is more common in near-shore, unstable environments, as discussed previously.

It must be noted that the dinoflagellate cyst assemblages can only be used to indicate relative changes in water depth and no absolute depths can be inferred.

Bisaccate pollen has been found to be more abundant offshore than in the sediments closer to its source (Traverse & Ginsberg, 1966), but its use as an indicator of proximity to a terrestrial source is rather dubious, due to its ease of transportation. Other organic walled microfossils noted for their palaeoenvironmental significance include spores, plant derived debris, acanthomorph acritarchs and foraminiferal test linings. A predominance of land derived material (spores and plant debris) may indicate proximity to a terrestrial source or an increase in terrestrial material in comparison to marine components and is useful in determining palaeoenvironmental conditions.

The controls on dinoflagellate cyst assemblages are many and variations in

assemblages from the Anglo-Paris Basin would indicate that conditions varied from place to place, despite the high sea-levels and uniform shelf sea. Such parameters as proximity to shoreline and water depth have an important association with specific dinoflagellate cyst assemblages. The water depth may have been determined by the underlying geological features with topographical highs providing shallower regions and perhaps restricting circulation of water masses. Such restricted areas may have been short-lived, but others may have developed increased salinities and thus a stressed environment. It is variables such as these that may have affected the dinoflagellate cyst assemblages, but which are difficult to quantify.

There are thus no single dinoflagellate cyst species which can be considered specific to a particular palaeoenvironmental setting, but a series of assemblages and predominance of certain species which could be strongly indicative of certain conditions.

8.5.2 Palaeoenvironmental interpretation

The palaeoenvironmental interpretations that can be drawn from these results are limited by the sample interval (approximately 1 metre) so that only generalised comments can be made with any confidence. The sample coverage of the Turonian as a whole does, however provide a strong basis for these general comments.

The depth of the Chalk Sea has been the topic of debate for many years. The depositional environment has already been discussed (Chapter 1), but a short summary is given here. The depth may have been below normal wave-base to allow settling and accumulation of the coccoliths and clays (Reid, 1973). As there is almost no evidence for algal growth, deposition was probably below the photic zone (Scholle, 1977). These statements indicate that the chalk facies was deposited in a shallow shelf sea of between 100-300 metres depth (Reid, 1973). Normal salinities are envisaged for the chalk sea, as there is widespread occurrence of many invertebrate groups, such as brachiopods, echinoderms and porifera, that cannot survive in lower salinities (Hancock, 1976).

<u>Dover</u>

There appears to have been little terrestrial influence during the Turonian as few bisaccate pollen and spores are recorded. Three families

(Peridiniaceae, Ceratiaceae & Gonyaulacaceae) were plotted on a triangular diagram (Figure 8.1) to investigate if any relationship exists between their occurrences. The Family Gymnodiniaceae was omitted as it only has a very restricted occurrence. No particular trend is recognisable and each family has some high occurrences. The Peridiniaceae are rarely present and the assemblages are dominated by Gonyaulacoid and Ceratioid genera and species. This indicates that the palaeoenvironment fluctuated between near-shore, shallow and deeper water marine conditions, following Harker *et al.*, (1990). This variation in the depth of water was probably due to a series of transgressive and regressive sequences which may have been locally modified by tectonics.

Three representative groups *Gonyaulax, Cyclonephelium & Odontochitina* (as used by Harker *et al.*, 1990) were plotted as a percentage of the three groups, for each sample (Figure 8.2). These particular groups were chosen because they represent the three basic types of fossil gonyaulacoid dinoflagellate cysts (see Section 8.4.1) and are thought to have specific palaeoenvironmental associations.

The informal morphogroups used in this investigation are representative of these three groups. Morphogroups Gn and Gi are representative of the group *Gonyaulax*. *Odontochitina* (morphogroup Gc) represents the *Ceratium* group and *Cyclonephelium* (morphogroup Gv) is representative of the third group. This exhibits the dominance of *Cyclonephelium* in relation to the two other groups throughout much of the succession, interpreted as reflecting an unstable near-shore environment. During the early and latest parts of the Turonian *Odontochitina* and *Gonyaulax* become more dominant reflecting a deeper water, more stable marine environment. This would broadly agree with the sea-level curves (Figure 8.3) of Hancock & Kauffman (1979), and Haq *et al.* (1988), that recognise a period of transgressive conditions during the early and latest part of the Turonian, providing additional confirmation for the fluctuating sea-levels during this stage.

Sussex

The three familial subdivisions (Gonyaulacoid, Peridinioid and Ceratioid) were also plotted for the data collected from Sussex (see Figure 8.4) to investigate their relationships. The Gymnodinioid Family was not included as it has a rather restricted occurrence. No apparent relationship is evident.

DOVER

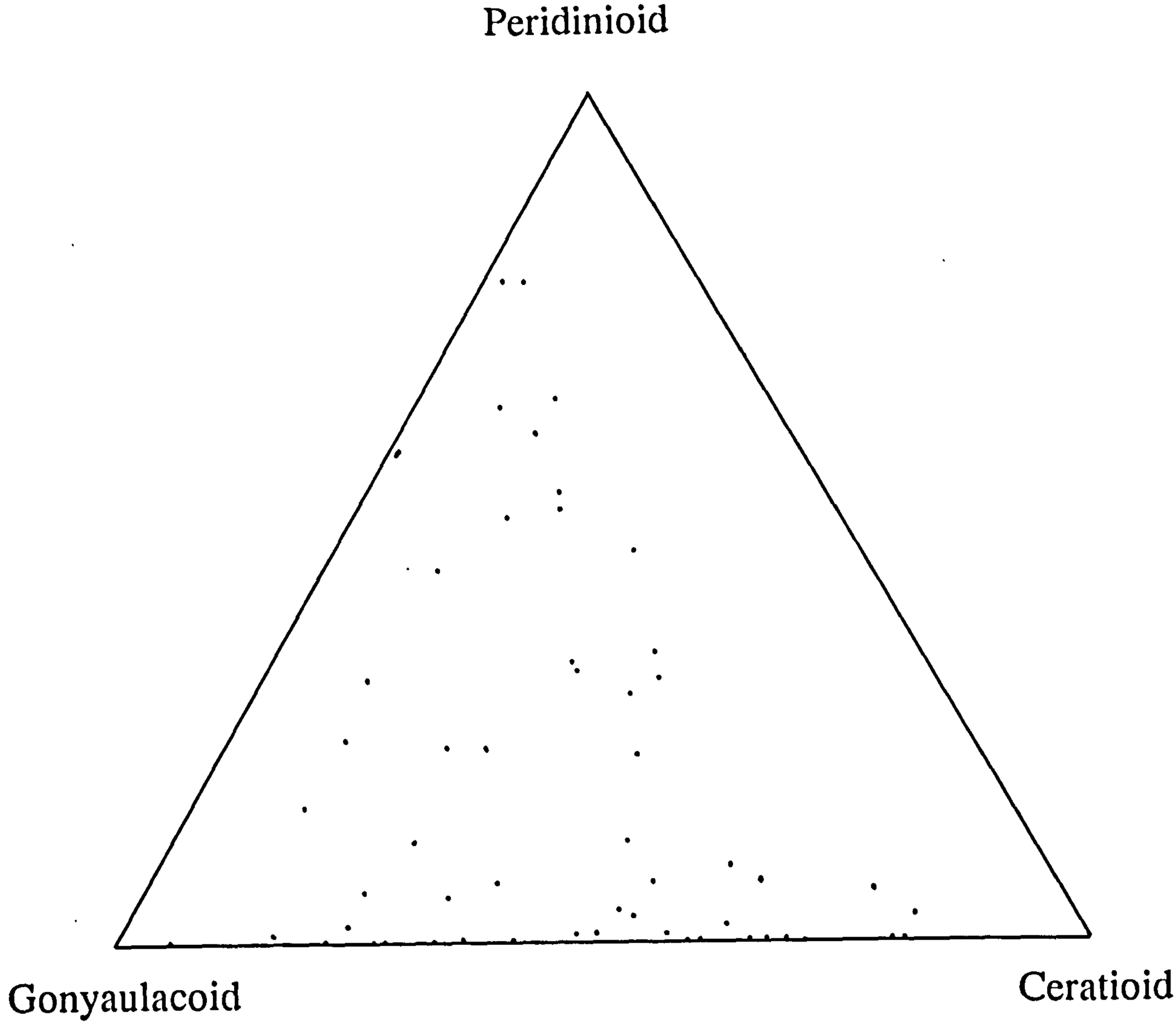


Figure 8.1 Triangular plot of the three families (Gonyaulacaceae, Ceratiaceae and Peridiniaceae) for Dover.

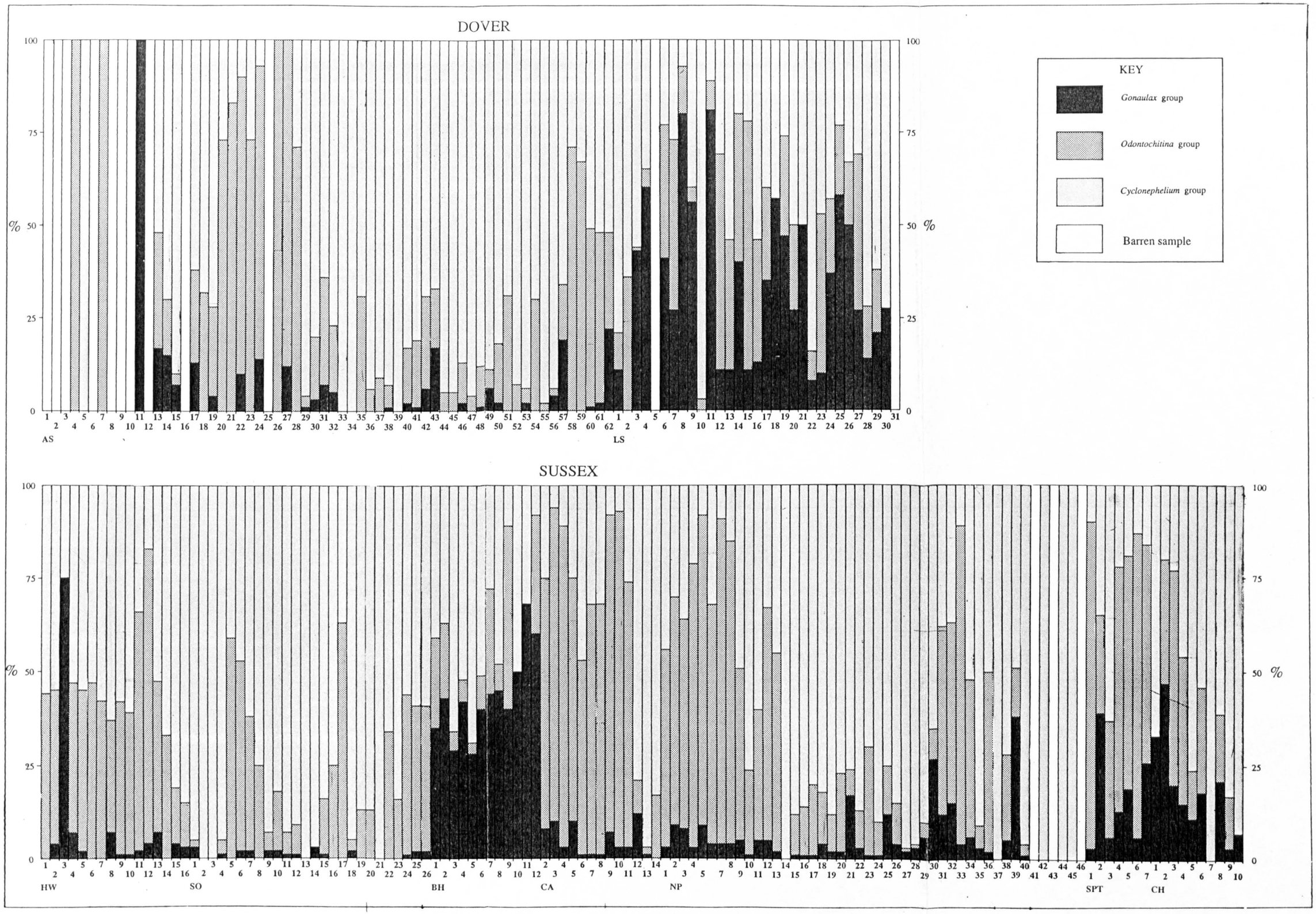


Figure 8.2 Bar-chart showing the percentage occurrence of the three groups *Gonyaulax, Odontochitina* and *Cyclonephelium* for (a) Dover and (b) Sussex.

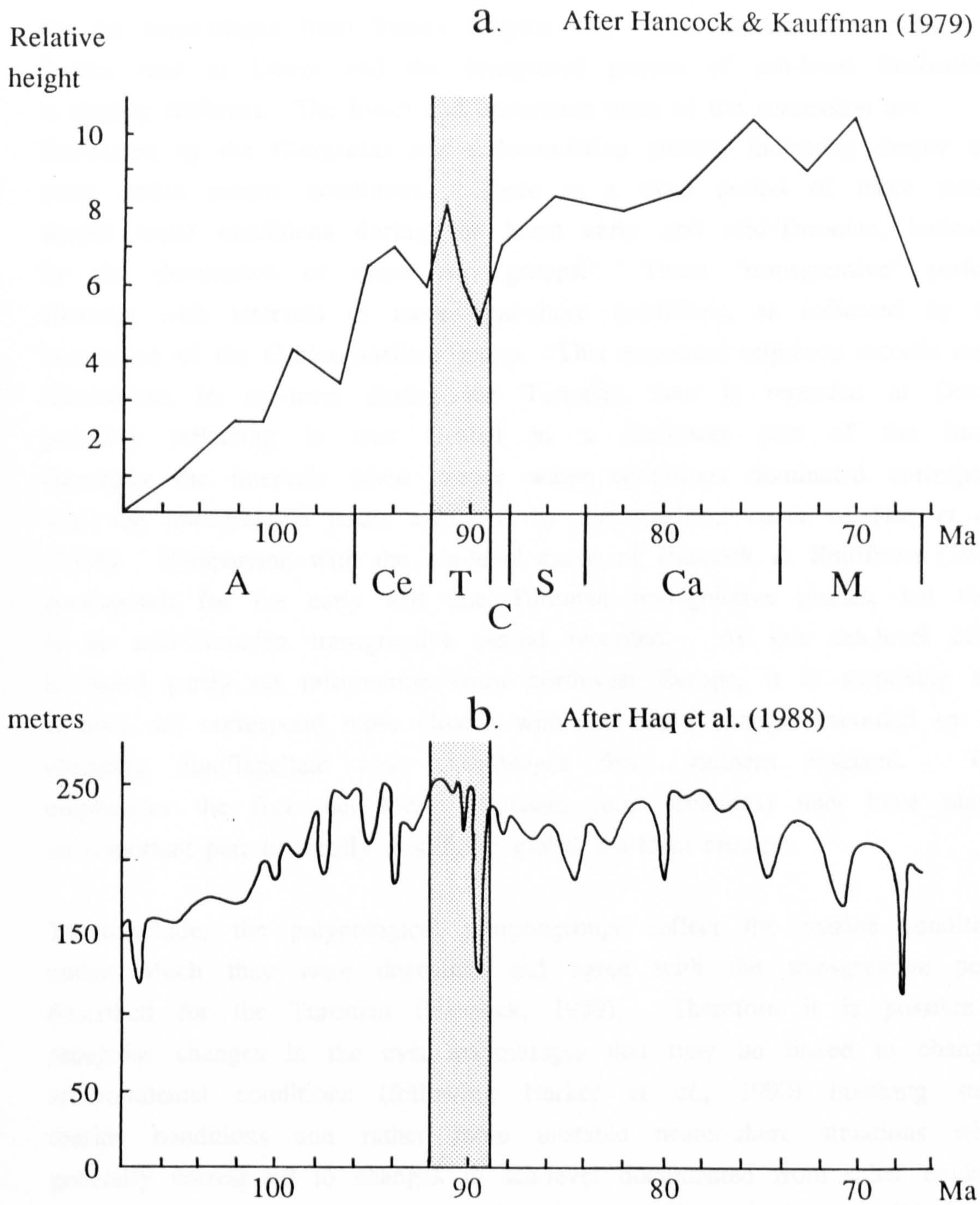


Figure 8.3 Comparison of sea-level curves produced by Hancock & Kauffman (1979) and Haq *et al.* (1988).

The three representative groups of Harker *et al.* (1990) were also plotted for the assemblages from Sussex (Figure 8.4) The succession is thicker in Sussex than at Dover and the interpreted pattern of sea-level fluctuations is slightly different. The lower and uppermost parts of the succession are dominated by the *Gonyaulax* and *Odontochitina* groups, indicating deeper and more stable marine conditions. There is a third period of more stable, deeper water conditions during the latest early and mid-Turonian, indicated by the dominance of these two groups. These "transgressive" periods alternate with intervals of more near-shore conditions, as indicated by the dominance of the *Cyclonephelium* group. This expanded sequence records more fluctuations in sea-level during the Turonian than is recorded at Dover, probably reflecting is was located in a shallower part of the basin. Generally the intervals when deeper water conditions dominated correspond with the transgressive peaks exhibited by the sea-level curve of Haq *et al.*, (1988). Comparison with the sea-level curve of Hancock & Kauffman (1979) corresponds for the early and late Turonian transgressive phases, but there is no mid-Turonian transgressive period recorded. As this sea-level curve is based partly on information from northwest Europe, it is surprising that it does not correspond more closely with the depth changes recorded by the changing dinoflagellate cyst assemblages from southern England. This emphasises the fact that local influences (e.g. tectonics) may have played an important part in locally modifying global sea-level changes.

To conclude, the palynological morphogroups reflect the marine conditions under which they were deposited and agree with the transgressive peaks described for the Turonian (Hancock, 1989). Therefore it is possible to recognise changes in the cyst assemblages that may be linked to changing environmental conditions (following Harker *et al.*, 1990) invoking stable marine conditions and rather more unstable nearer-shore situations which generally correspond to changes in sea-level documented from other evidence by Haq *et al.*, (1988), Hancock & Kauffman (1979) and Hancock (1989). If these changes are studied more carefully it is apparent that the dinoflagellate cyst assemblages at Sussex record a third fluctuation of marine conditions during the latest early and mid-Turonian, which may be accounted for by local tectonics or it may have been missed in the extant global record. No attempt is nor can be made as to the causal mechanism for these global sea-level changes (see Chapter 1) on the basis of these new observations.

SUSSEX

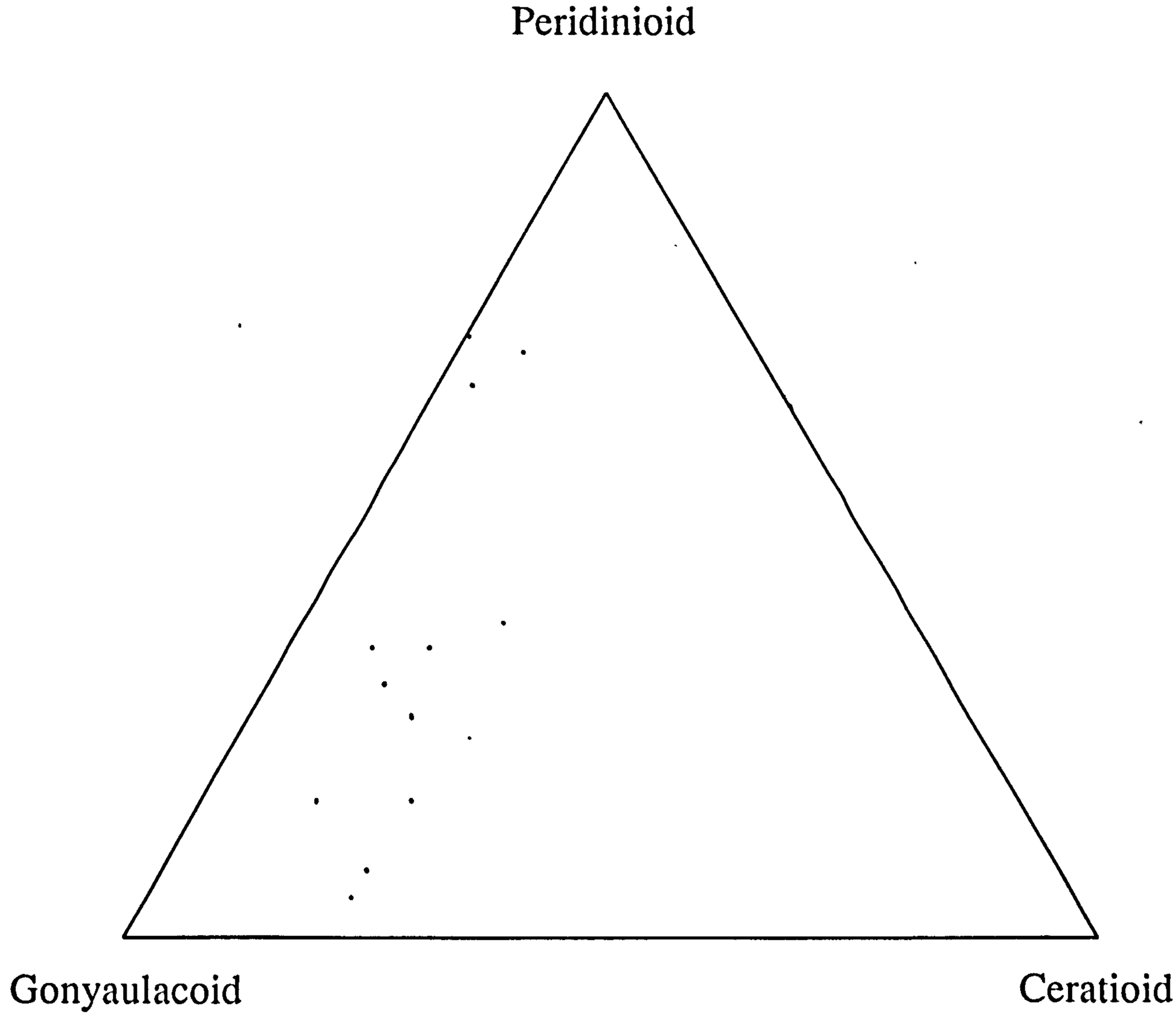


Figure 8.4 Triangular plot of the three families (Gonyaulacaceae, Ceratiaceae and Peridiniaceae) for Sussex.

8.6 Final comment

The aims and objectives outlined at the beginning of this study have been fulfilled as far as possible. The knowledge of Turonian dinoflagellate cyst assemblages has been expanded and some new species described. Three palynozones have been defined for the Turonian stage using the ranges and influxes of selected species. Turonian assemblages from other parts of the Anglo-Paris Basin were found to have limited correlation with these. Investigation of the lithological constraints on the dinoflagellate cyst assemblages failed to produce much positive evidence, but the different types of flint were found to yield variable dinoflagellate cyst assemblages which are thought to be related to the diagenetic stage which the flints represent. Statistical methods applied to the data sets did not produce any conclusive results to support the theories put forward or to define palynozones based on the dinoflagellate cyst assemblages although they did draw attention to the relationships between the various morphogroups which otherwise would not have been so evident. Palaeoenvironmental interpretation suggests that the dinoflagellate cyst assemblages correspond to broad sea-level changes.

Suggestions for further work would require a comparative study of Turonian sections in northern England and northern Germany on the same scale. Graphical correlation of known lithological horizons, macrofossil zones and the first and last occurrences of the dinoflagellate cyst species used for definition of the palynozones in the Turonian has been attempted, but, further work including as much known data as possible would be necessary to make final conclusions. Quantitative palynological analyses of the different lithologies would either support or contradict the findings here as to the lithological constraints on the dinoflagellate cyst assemblages. Analyses of selected equivalent flint and chalk samples may provide additional information about the preservation of organic-walled microfossils in the different types of flints. Integration of data from other micro- and macrofossil groups would add to the successful palaeoenvironmental and biostratigraphical analyses carried out here and test the use of these palynological results in other regions.

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PLATE DESCRIPTIONS

The photographs were taken using a Karl-Zeiss-Jenar (Jenaval) microscope (Serial No. 854274) with an Olympus camera attachment (Serial No. PM10AD), under transmitted light and in some cases Differential Interference Contrast conditions.

Each specimen photographed is named specifically, followed by the authors name and year. The sample number is given (following the scheme of letters depicting the section from which the samples came). England -finder references are used to locate specimens on the slide. A brief description of the view and focus are provided and salient features noted may be indicated by an arrow.

All specimens are magnified × *c.* 500 unless otherwise stated in the plate description.

All slides are archived in the Department of Geological Sciences, University of Plymouth, Plymouth, Devon.

PLATE 1

1. *Dinogymnium* sp. *cf. westralium* Cookson & Eisenack 1958, emend. May 1977: DOE 7 (M44-3). Lateral view; high focus. Slight indication of apical paraplates becoming loosened.

2, 3. *Eurydinium saxoniensis* Marshall & Batten 1988: LS 9 (C45). **2.** Dorsal view; low focus showing the intercalary archaeopyle; **3.** Ventral view;high focus showing the endocyst and antapical region.

4, 5. *Isabelidinium belfastense* (Cookson & Eisenack 1961) Lentin & Williams 1977: NP 39 (K38). **4.** Dorsal view; low focus showing the intercalary archaeopyle. **5.** Ventral view; high focus showing the antapical portion of the cyst.

6. *Palaeohystrichophora infusorioides* Deflandre 1935: BH2 Ao2 (U37-3). Lateral view; low focus showing overall "spindle" shape of the cyst and also shows the antapical separation.

7. *Palaeohystrichophora infusorioides* Deflandre 1935: LS 12 (G56). Lateral view; high focus showing the alignment of the spines along the paracingulum.

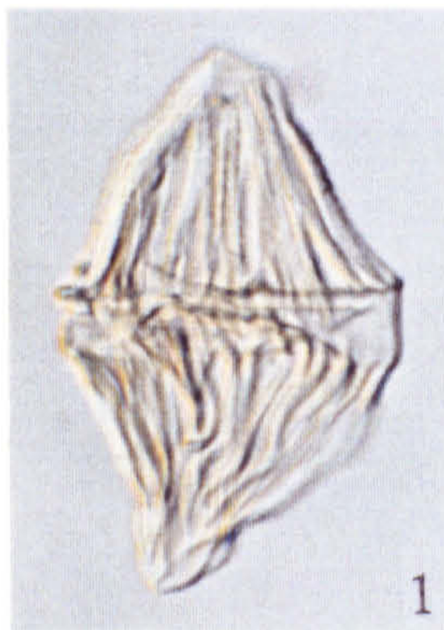
8. *Subtilisphaera pontis-mariae* (Deflandre 1936) Lentin & Williams 1976: BH 1 (K37-3). Lateral view; high focus.

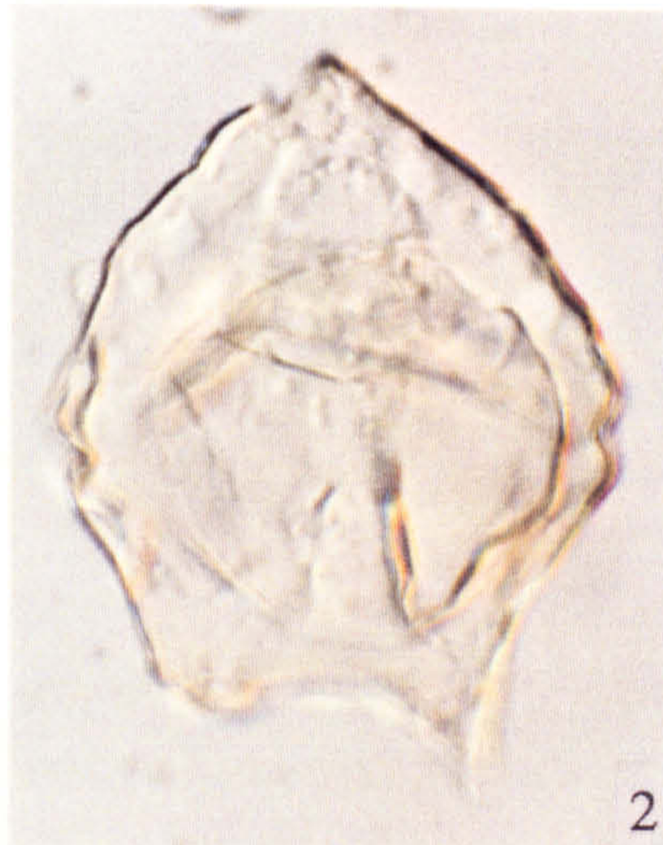
9, 10. *Canningia reticulata* Cookson & Eisenack 1960, emend. Helby 1987: NP 31 Ao1 (K43-1). **9.** Ventral view; high focus showing the offset sulcal notch and accessory archaeopyle sutures. **10.** Median focus showing the separation between the endo- and peri-phragm in the antapical region and the paracingular region.

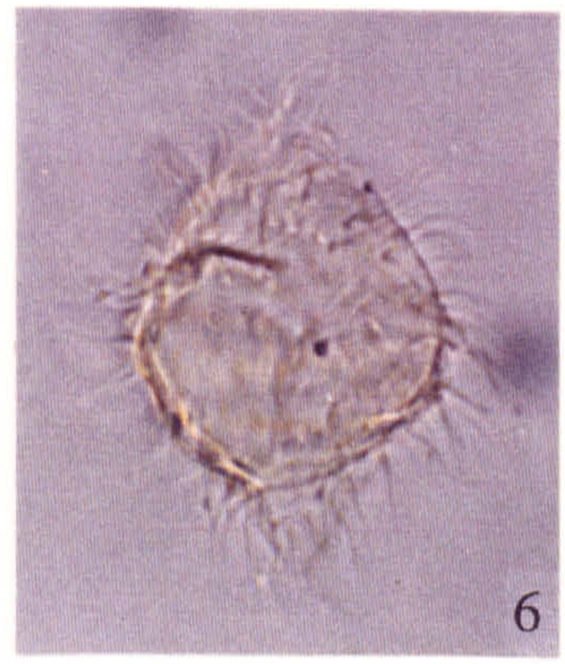
11. *Canningia collivieri* Cookson & Eisenack 1960: NP44 (L34-3). Oblique lateral view; high focus showing the general ceratioid shape of the cyst, with unequal antapical horns (bulges). There is little relief of the surface ornament.

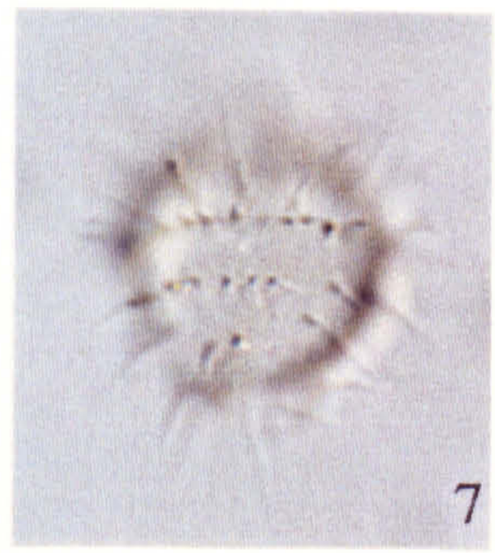
12, 13. *Cyclonephelium distinctum* Deflandre & Cookson 1955: DOE 4 (T41). **12.** Ventral view; high focus showing the offset sulcal notch. **13.** Dorsal view; low focus. Note in both the bald mid-dorsal and mid-ventral regions, and the capitate nature of the processes.

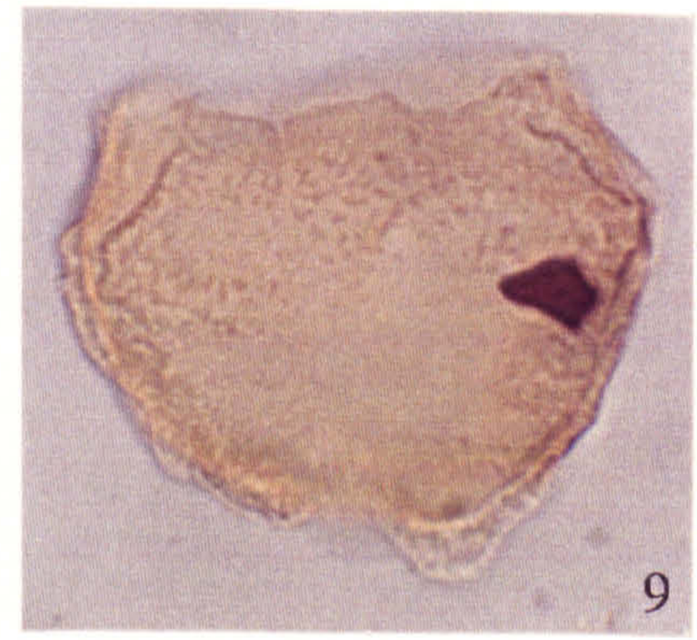
PLATE 1

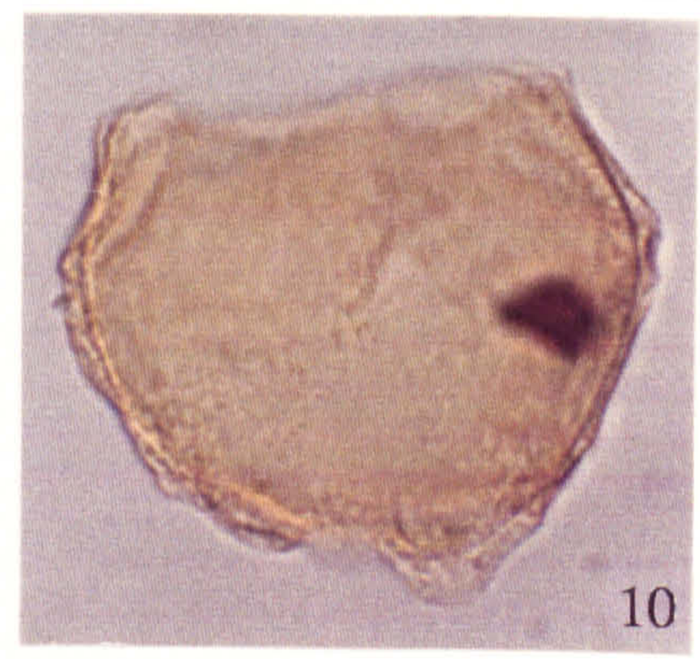


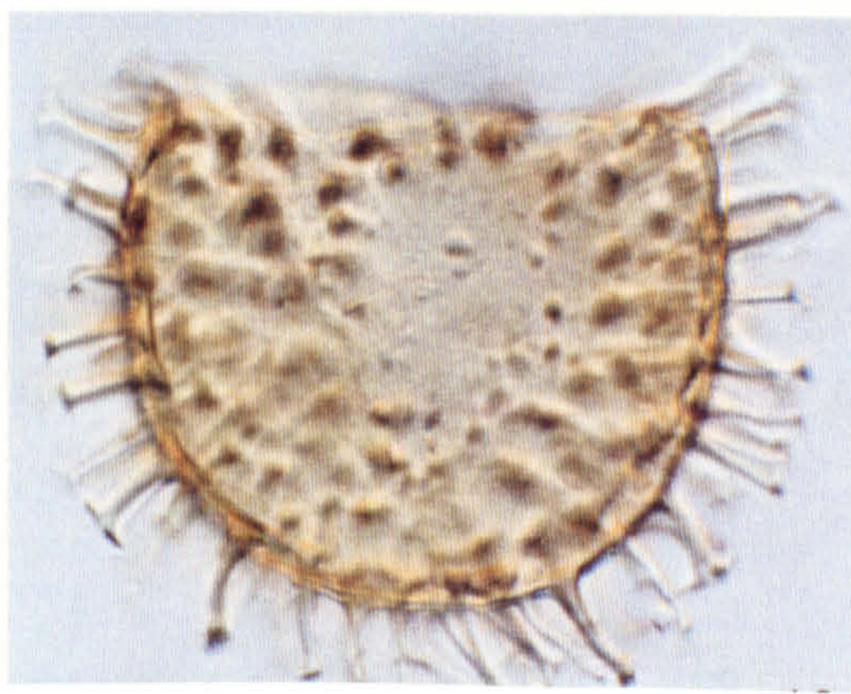












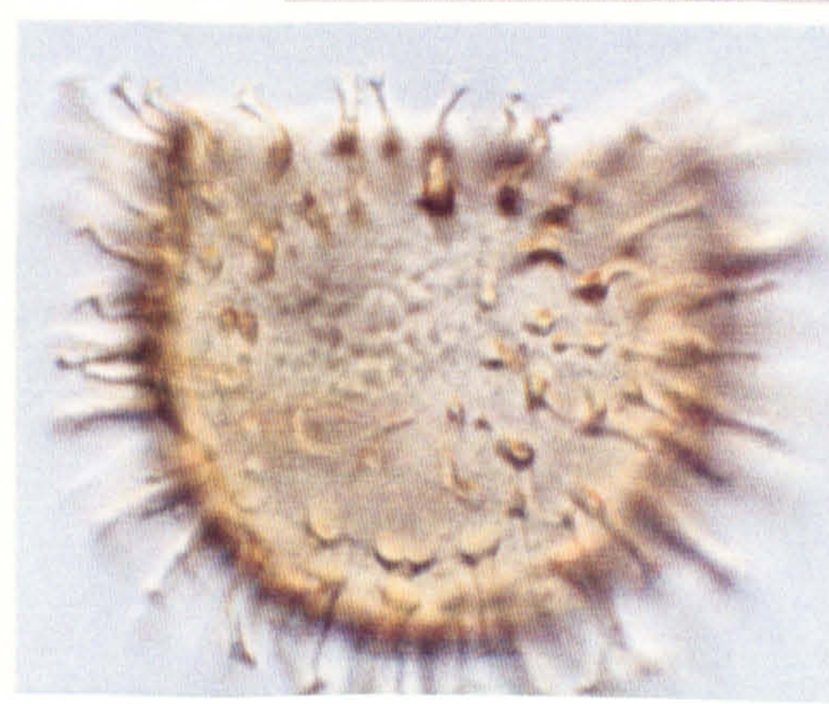


PLATE 2

1. *Cyclonephelium distinctum* Cookson & Eisenack 1955: NP 15 Ao1 (E39). Ventral view;high focus displaying the offset parasulcal notch, and accessory archaeopyle sutures.

2, 3. *Cyclonephelium compactum - membraniphorum* complex Marshall & Batten 1988: HW 4 (F45). **2.** Oblique dorsal view; low focus. **3.** Oblique ventral view; high focus showing the poor development of the marginal crests.

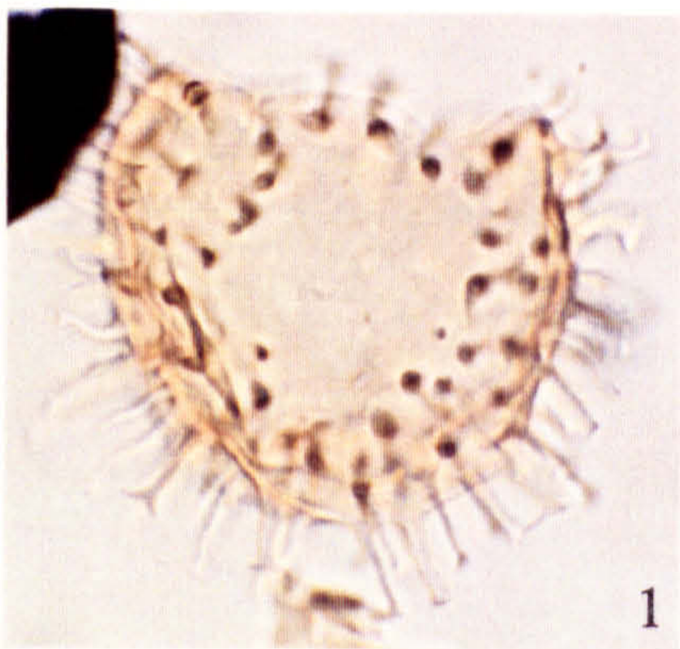
4, 5. *Cyclonephelium membraniphorum* Cookson & Eisenack 1962: BH 1 Ao2 (D29-2). **4.** Dorsal view; high focus showing the circumferential arrangement of the membranes and the "bald" mid-do rsal area. **5.** Ventral view; low focus, displaying the offset parasulcal notch and accessory sutures.

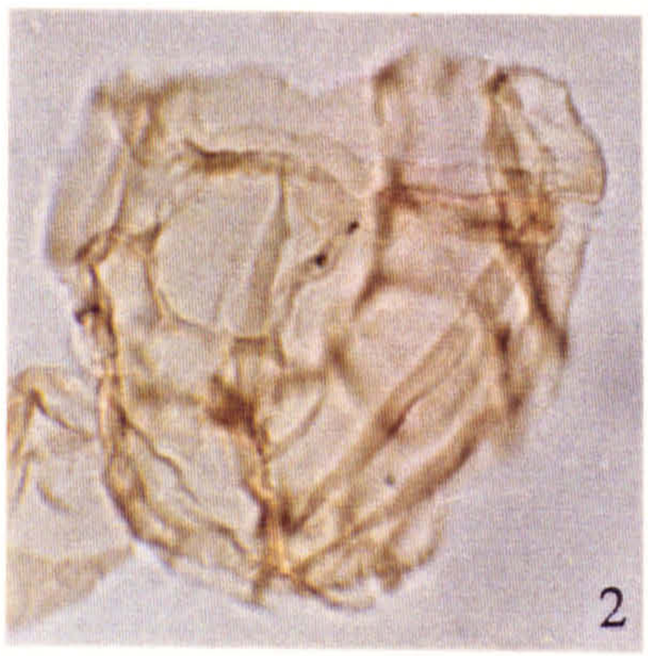
6. *Cyclonephelium membraniphorum* Cookson & Eisenack 1962: LS 3 (Q59-4). Oblique ventral view; high focus displaying well developed membranous crests fused to form "boxes."

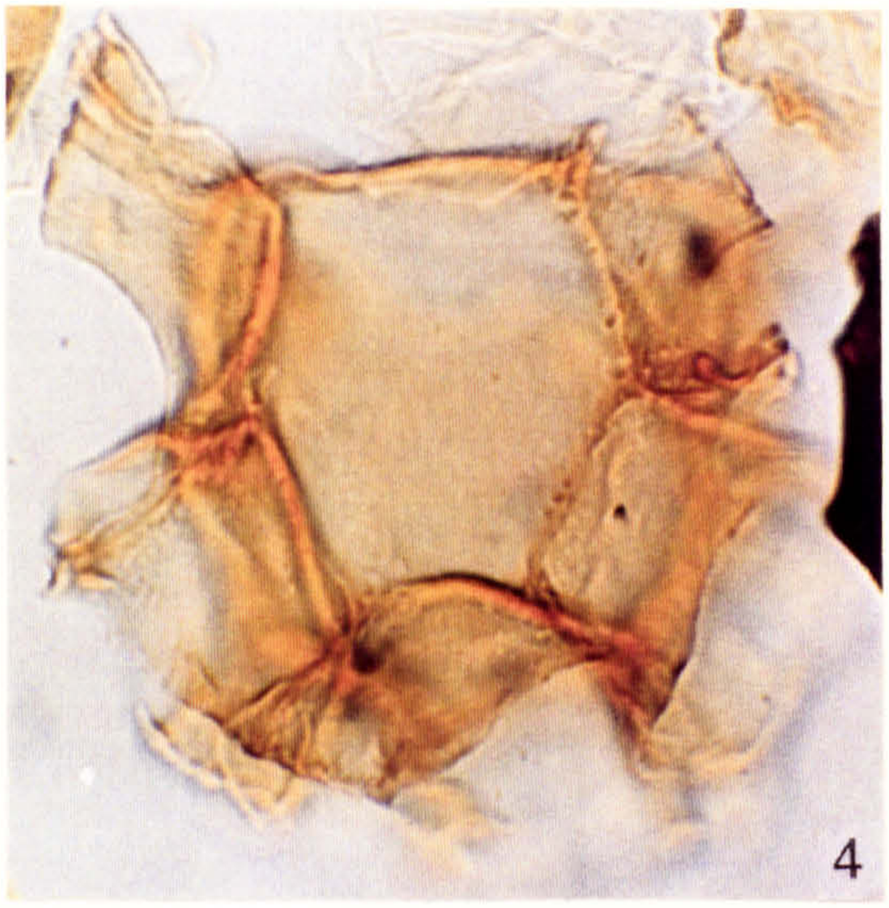
7. *Senoniasphaera rotundata* Clarke & Verdier 1967: AS 43 (E48). Dorsal view; high focus showing the archaeopyle margin, with the operculum still remaining. Note the spherical endocyst. (Magnification × 338)

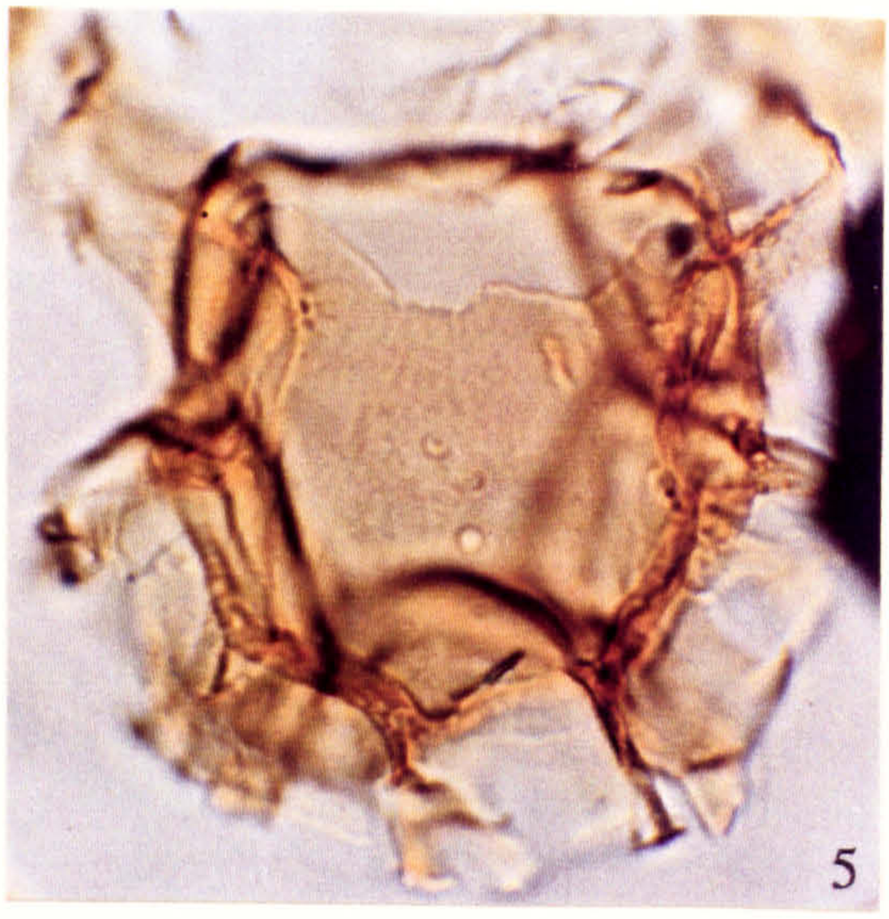
8, 9. *Senoniasphaera* sp. A DOE 7 (L51). **8.** Dorsal view; high focus displaying raised crests that define the paracingulum. **9.** Ventral view; low focus showing the large lumina in the periphragm.

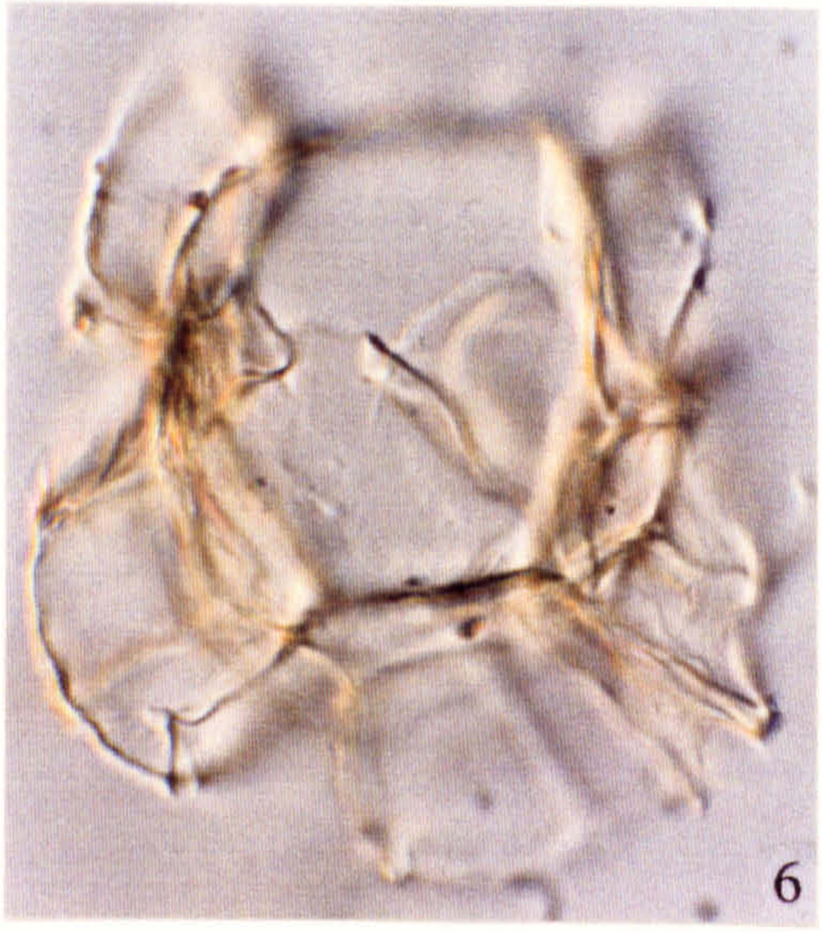
PLATE 2

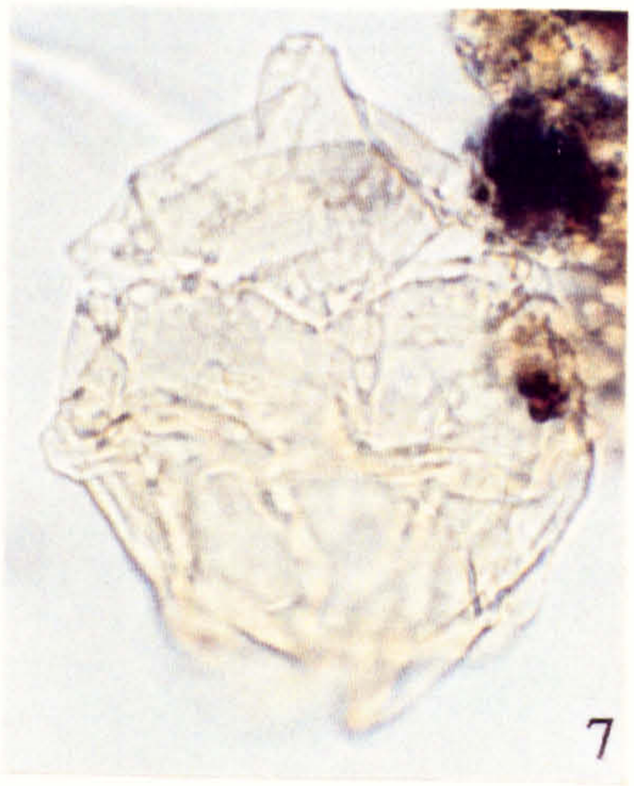


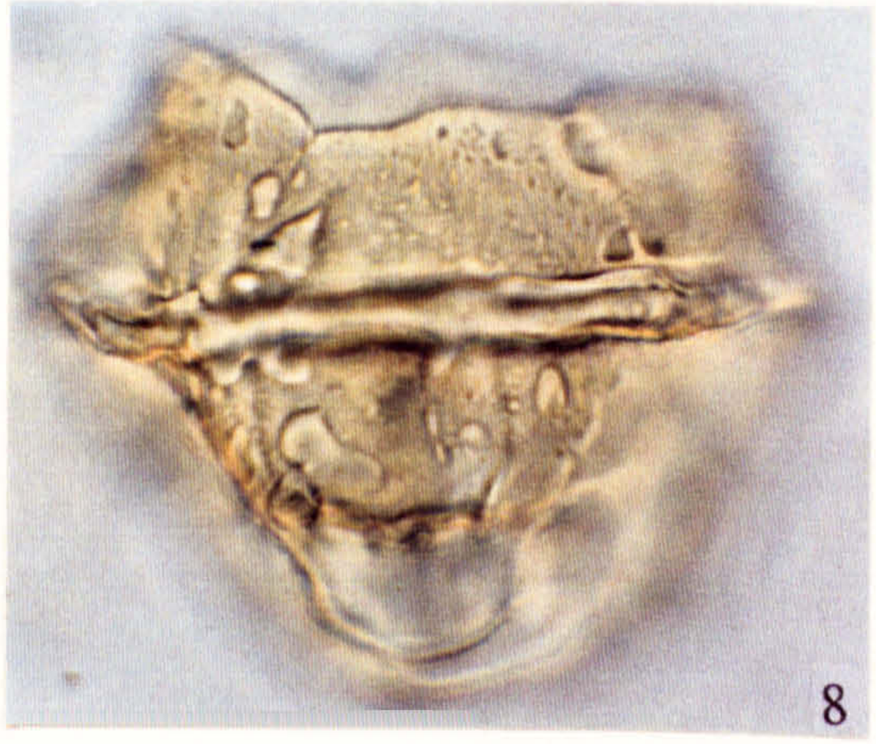












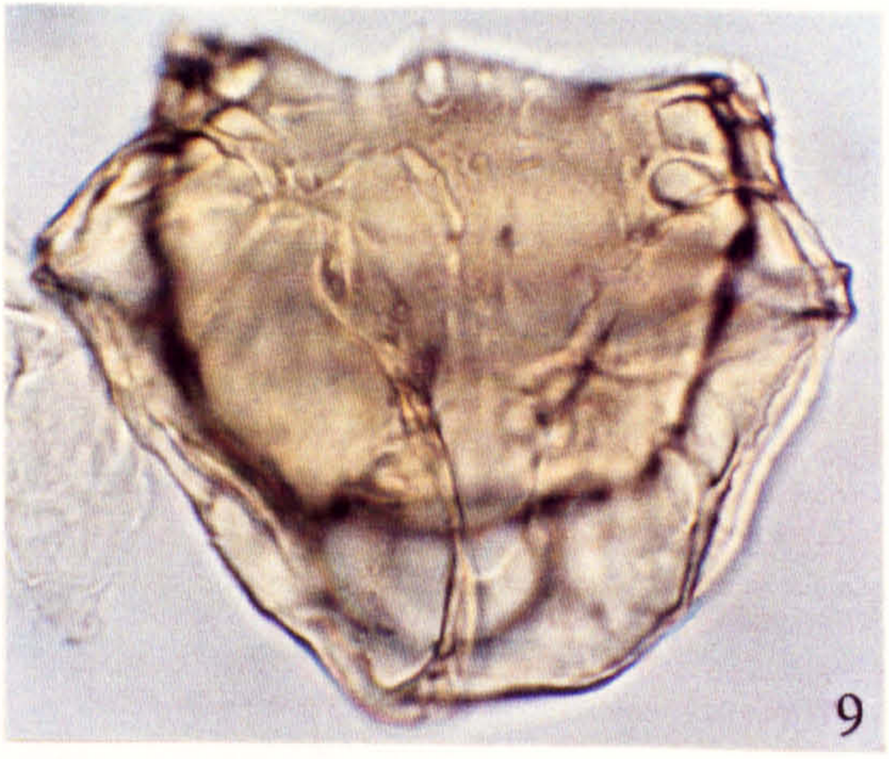


PLATE 3

1. *Odontochitina operculata* Type B (Wetzel 1933) Deflandre & Cookson 1955: AS 53 (Y51). Dorsal view; low focus. Note the sub-polygonal shape of the endocyst.

2. *Odontochitina costata* Alberti 1961, emend. Clarke & Verdier 1967: AS 26 (B56-4). Right oblique dorsal view; low focus. Note the striations on the periphragm of the horns and the "nipple" at the base of the antapical horn.

3, 4. *Odontochitina operculata* Type A (Wetzel 1933) Deflandre & Cookson 1955: AS 27 (E47-3). **3.** Oblique ventral view; high focus showing the archaeopyle margin with slight parasulcal indentation, and sub-spherical shape of the endocyst. **4.** Dorsal view; low focus displaying the narrow, delicate horns and the subspherical endocyst.

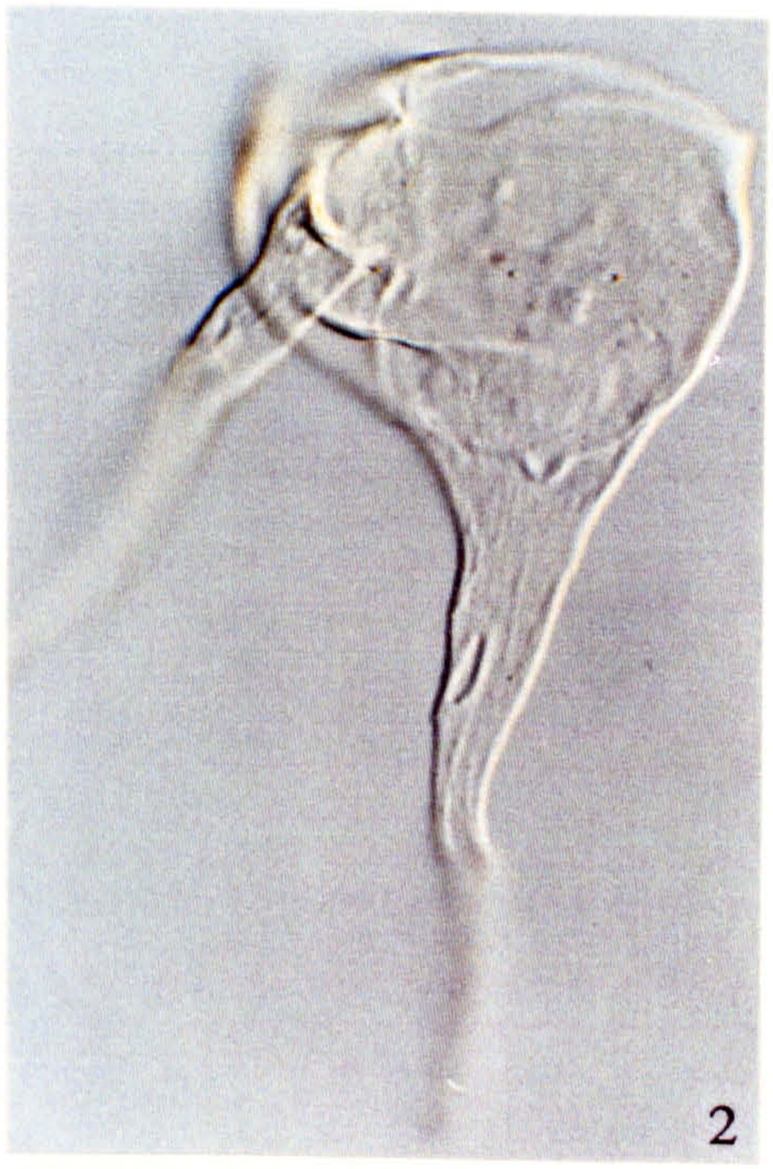
5. Operculum of *Odontochitina costata* AS 53 (Y53). Apical operculum, with longitudinal striations.

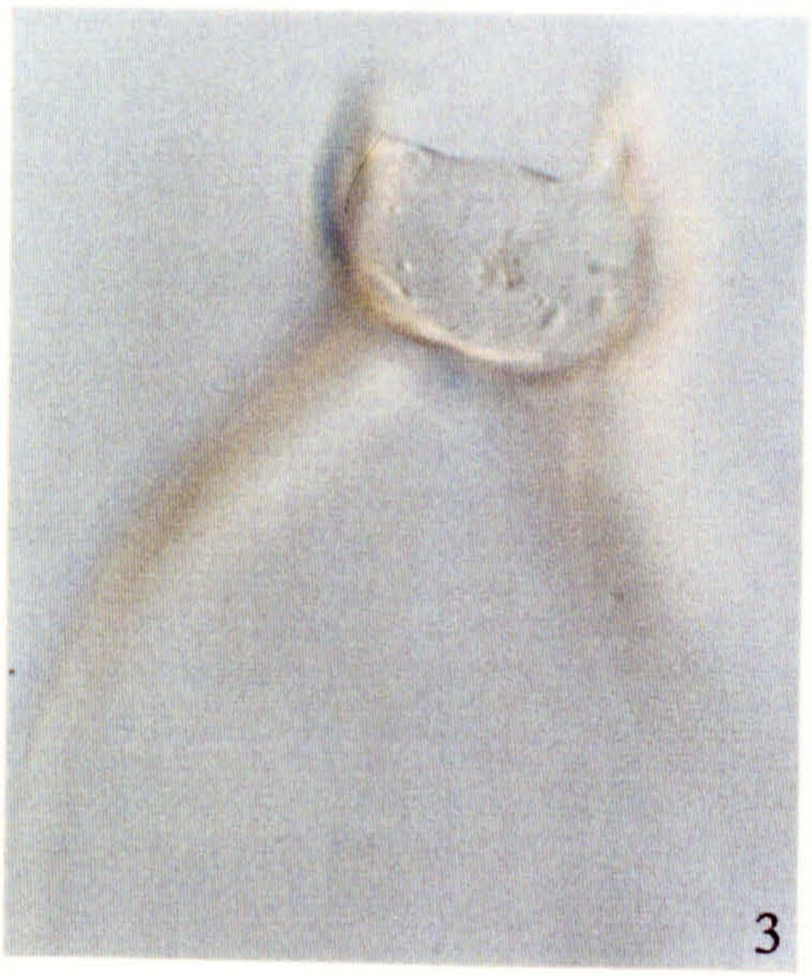
6. Operculum of *Odontochitina operculata* Type A AS 53 (Y53-4). Apical operculum displaying the long, thin horn typical of this variation.

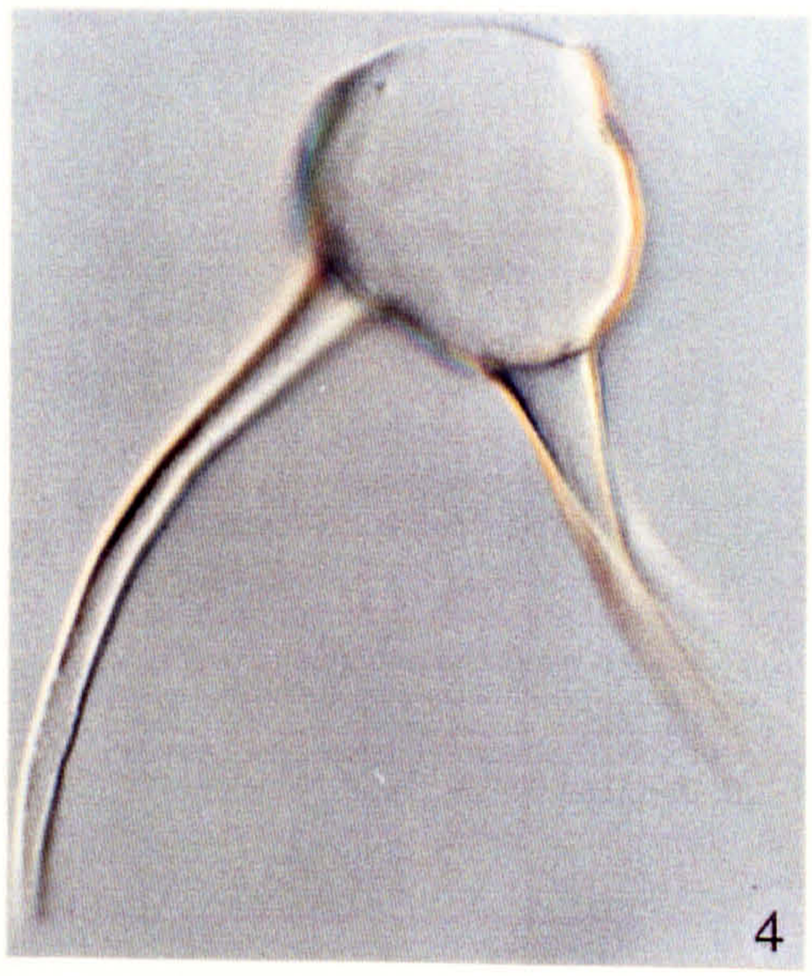
7. *Xenascus ceratioides* (Deflandre 1937) Lentin & Williams 1973: NP 30 (B32). Dorsal view; high focus showing the sub-spherical endocyst and ornamented periphragm.

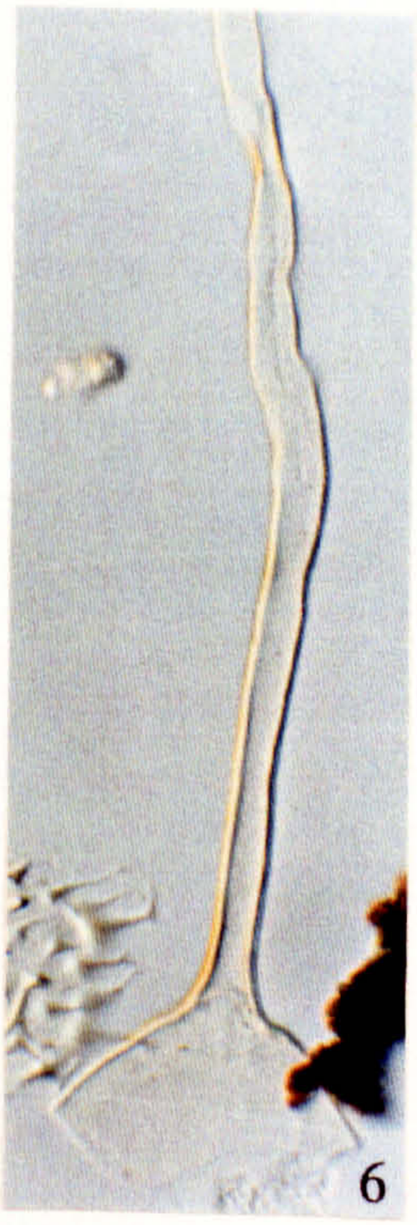
(All specimens magnified × 410).

PLATE 3









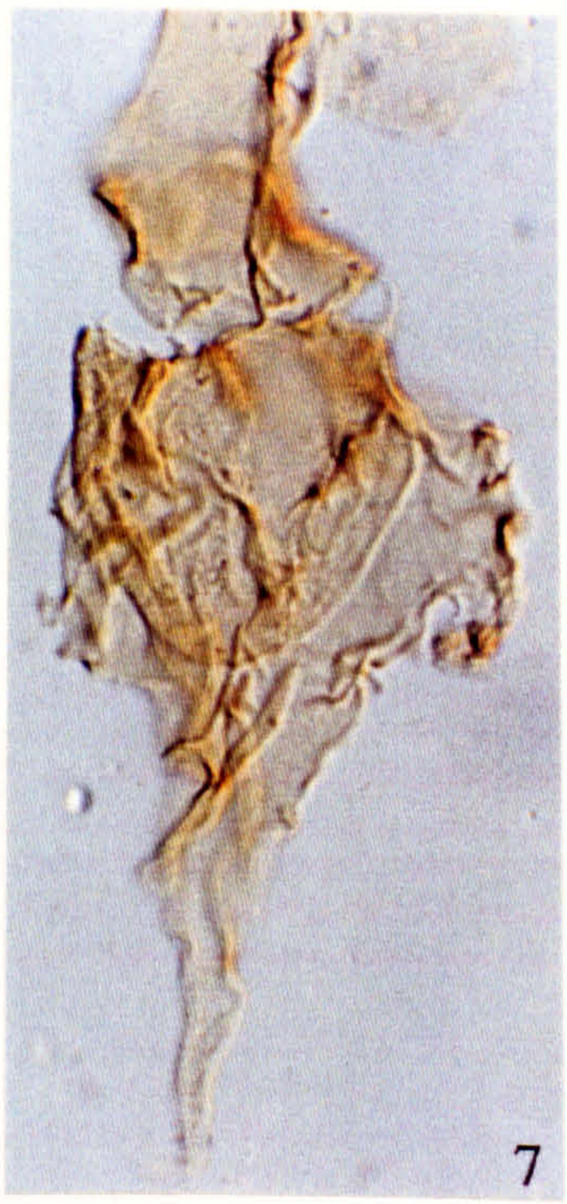


PLATE 4

1, 2. *Microdinium ornatum* Cookson & Eisenack 1960: BH 3 Ao1 (E55-3). **1.** Dorsal view; high focus displaying the broad paracingulum and large hypocyst with respect to the epicyst. **2.** Ventral view; low focus showing the detail of the parasulcal region and the attached operculum. Note the ornament defining the paraplate boundaries.

3, 6. *?Microdinium tuberculatum* sp. nov.: SPT 2 (R34-2) Holotype. **3.** Dorsal view;low focus showing the paracingular plates and the intra-tabular tuberculate ornament. **6.** Ventral view; high focus displaying the parasulcal area in detail (3 paraplates and 1p paraplate visible).

4, 7. *?Microdinium tuberculatum* sp. nov.: SPT 2 (R34-2) Paratype. **4.** Dorsal view; low focus showing the large postcingular paraplate (4 "'). **7.** Ventral view; high focus displaying the offset paracingulum and the camerate nature of the 6th precingular paraplate.

5, 8. *?Microdinium tuberculatum* sp. nov.: SPT 2 (Q28-2). **5.** Ventral view; high focus showing the offset paracingulum and the anterior, posterior parts of the parasulcus. **8.** Dorsal view; low focus showing a variation in the ornament, in the form of fine ridges.

9, 12. *?Microdinium tuberculatum* sp. nov.: NP 25 (P54-3). **9.** Apical view; high focus showing the circumferential relief of the ornament. **12.** Oblique antapical view low focus displaying the antapical paraplate and the adjacent postcingular paraplates.

10, 11. *?Microdinium tuberculatum* sp. nov.: NP 21 Ao2 (F56-4). **10.** Apical view; high focus displaying the camerate or pleiniate nature of the precingular paraplates. **11.** Antapical view; low focus showing the sexiform nature of the antapical paraplate.

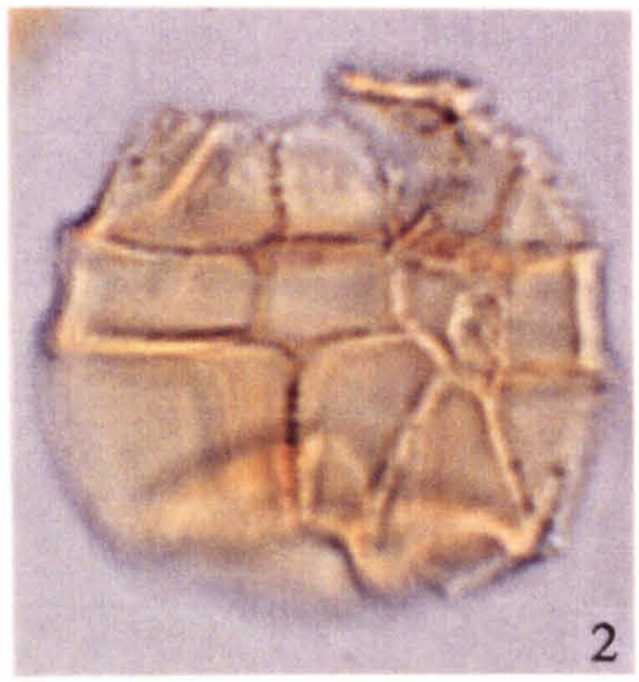
13. *?Microdinium tuberculatum* sp. nov.: LS 9 (E49). Oblique right lateral view, showing the losenge shape of the paracingular plates.

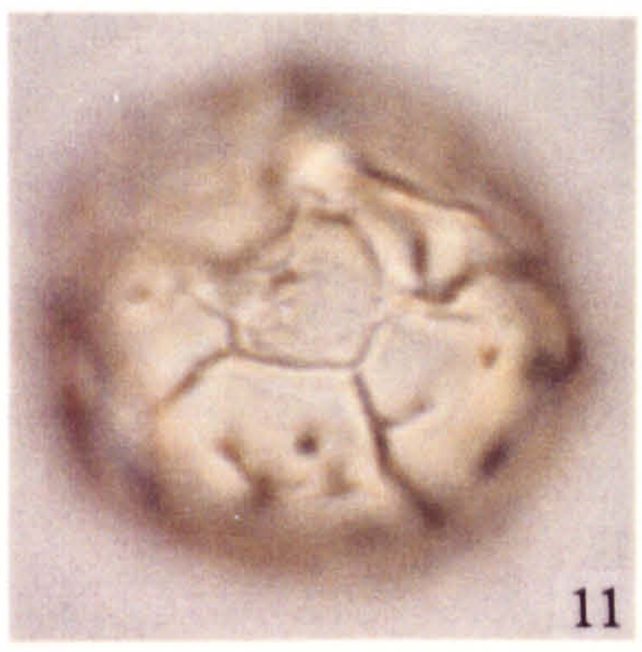
14. *Rhiptocorys veligera* (Deflandre) Lejeune-Carpentier & Sarjeant 1983: LS 9 (F55-1). Lateral view; high focus displaying the large hypocyst with respect to the epicyst, and the broad paracingulum. (Magnified × 845).

15. *Rhiptocorys veligera* Lejeune-Carpentier & Sarjeant 1983: BH 12 (H61). Oblique antapical view; high focus.

(All specimens magnified × 1025, except where otherwise stated)

PLATE 4





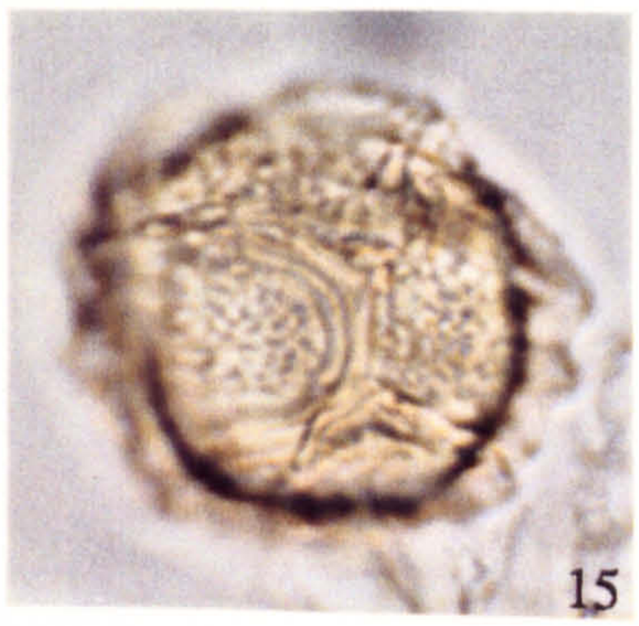


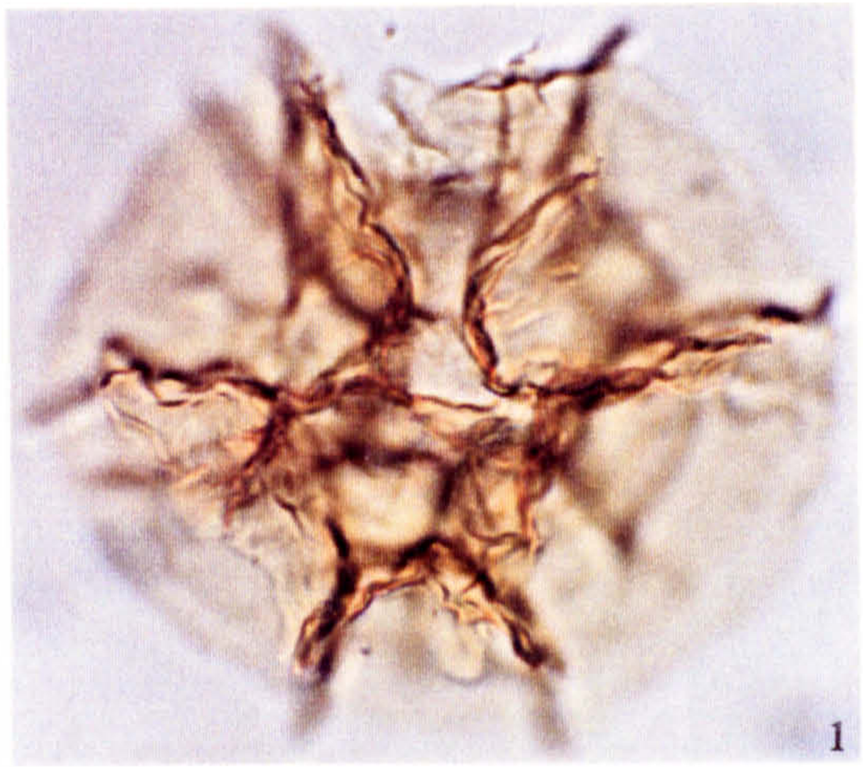
PLATE 5

1, 3. *Dinopterygium medusoides* (Cookson & Eisenack 1960) Stover & Evitt 1978: NP 21 Ao2 (N34). **1.** Apical view; high focus. **3.** Antapical view; low focus with the paracingular flange well defined.

2, 4. *Dinopterygium cladoides* Deflandre 1935: BH 4 Ao1 (G55-2). **2.** Lateral view; low focus showing the extent of the parasutural flanges. **4.** Oblique apical view; high focus displaying the precingular paraplates

5, 6. *Canningia* sp.B: BH 1 (M36). **5.** Median focus, apical portion inside cyst. **6.** Ventral view; high focus showing the archaeopyle margin and the parasulcal notch.

PLATE 5



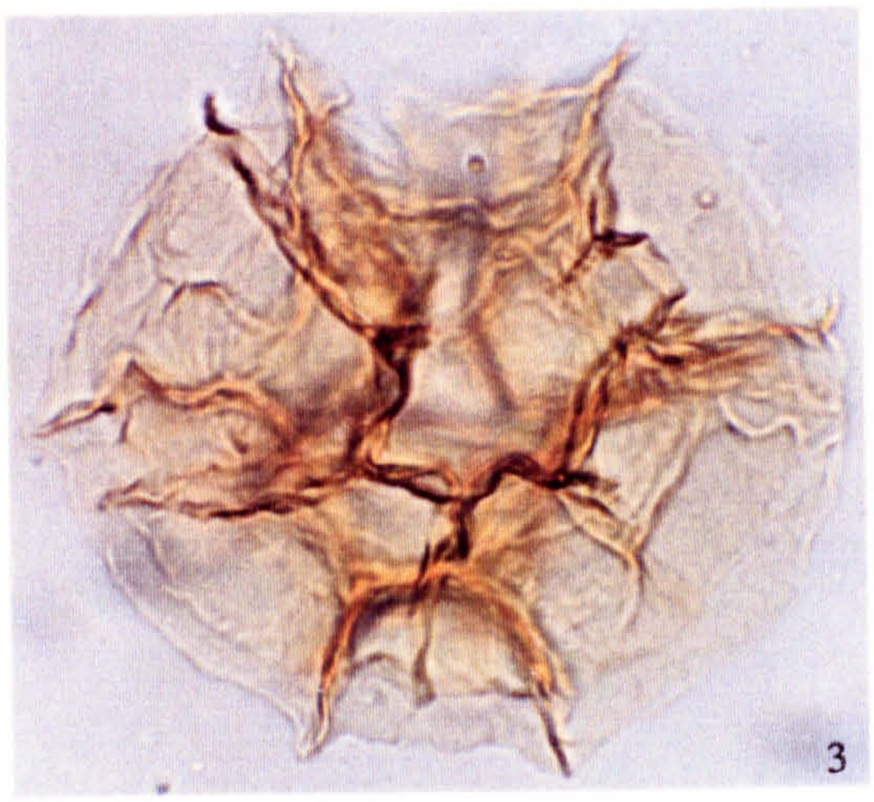


PLATE 6

1, 2. *Achomosphaera ramulifera* (Deflandre 1937) Evitt 1963: LS 11 (G56-1). **1.** Lateral view; low focus showing the fusion of processes to form a broader base. **2.** High focus on the distal tips of the process endings.

3. *Achomosphaera reginensis* Corradini 1973: BH1 (X59). Apical view; high focus. Note primary branching of the processes is parallel to the central body.

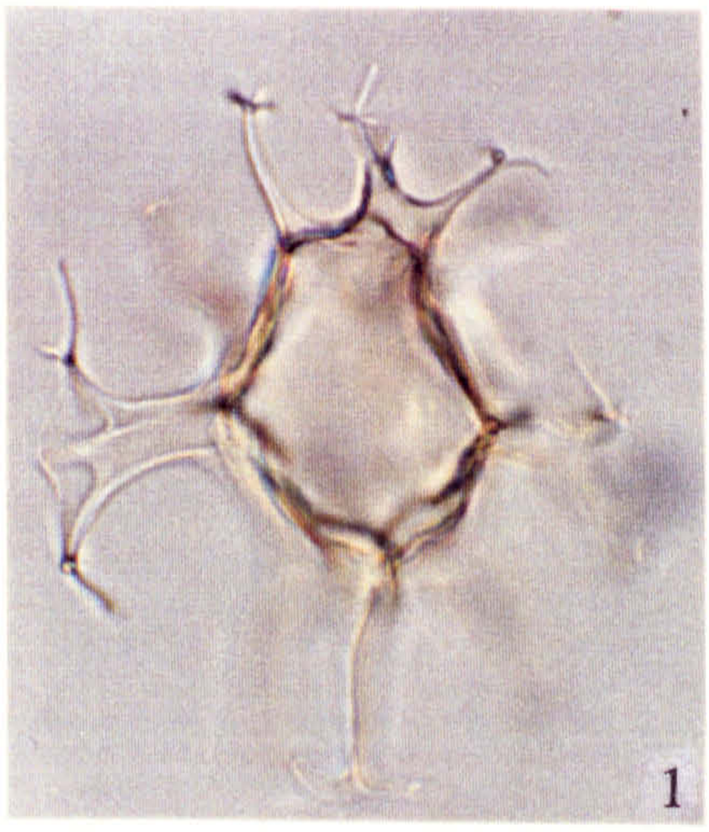
4, 6. *Achomosphaera sagena* Davey & Williams 1966a: BH 3 (D51-2). **4.** Lateral dorsal view; high focus displaying the precingular archaeopyle. **6.** Lateral ventral view; low focus showing the thick wall with a reticulate ornament which is also noticeable in the bases of the processes.

5. *Achomosphaera sagena* Davey & Williams 1966a: BH 8 Ao3 (C45-2). Dorsal view; high focus displaying clearly the reduced nature of the precingular archaeopyle.

7. *Spiniferites multibrevis* (Davey & Williams 1966a) Below 1982: BH 11 (E44-2). Dorsal view; low focus showing the reduced precingular archaeopyle and the relatively short processes.

8. *Spiniferites ?dentatus* (Gocht 1959) Lentin & WIlliams 1973, emend. Duxbury 1977: BH 7 (B41-1). Dorsal view; median focus displaying the precingular archaeopyle and the digitate parasutural crests.

PLATE 6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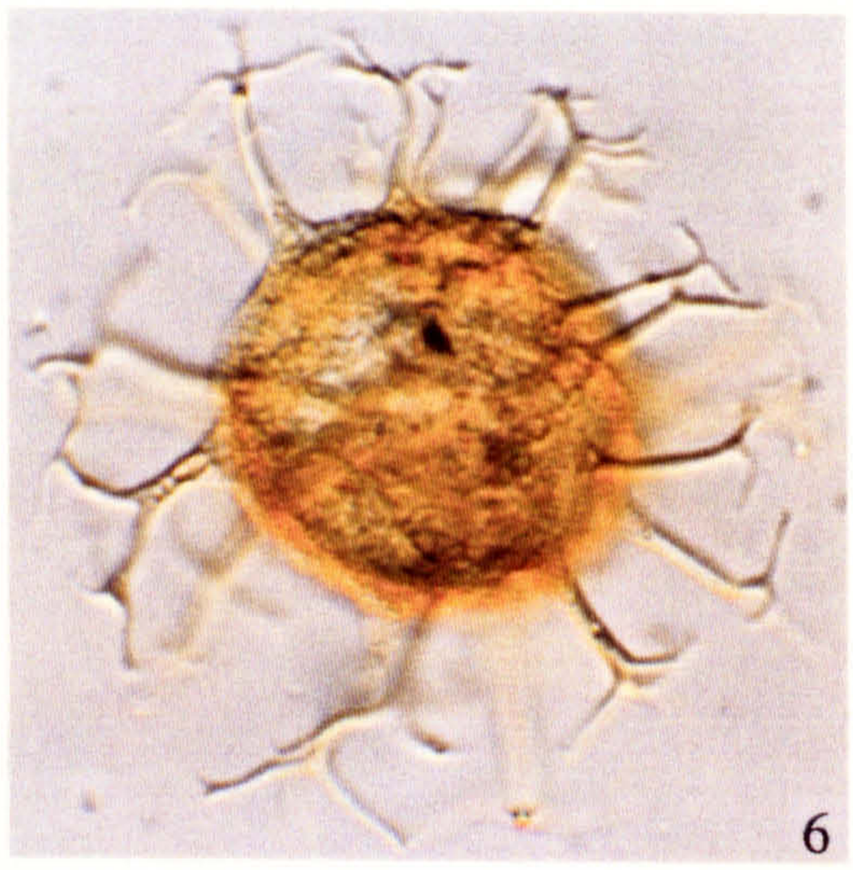
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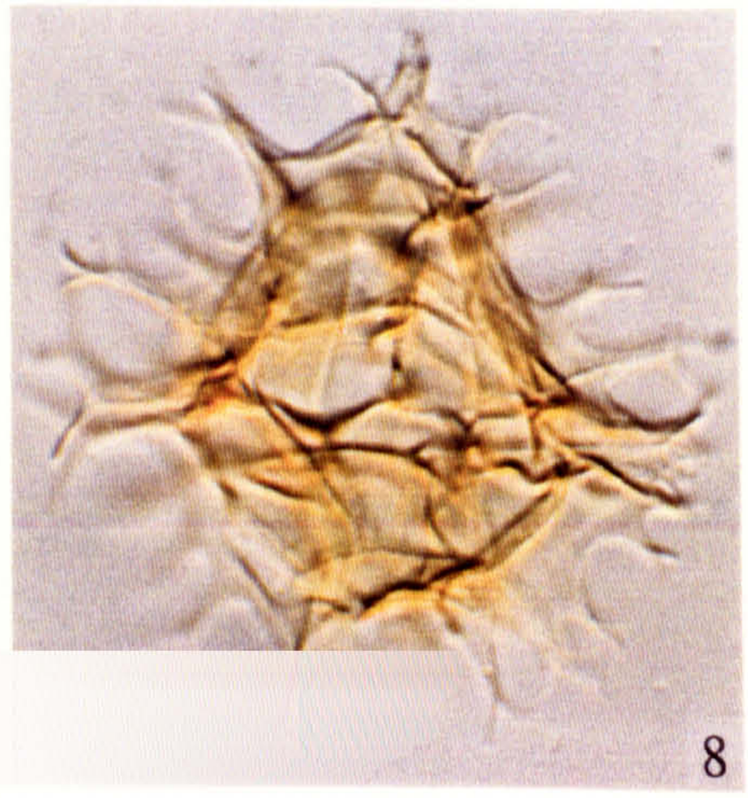
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PLATE 7

1, 2. *Spiniferites multibrevis* (Davey & Williams 1966a) Below 1982: BH 3 (Q32-4). **1.** Right lateral view; low focus showing the precingular archaeopyle. **2.** Left lateral view; high focus showing the edge of the parasulcal region.

3. *Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich 1966 var. *ramosus* (1973): BH 8 Ao3 (C43-3). Oblique dorsal view; high focus displaying the precingular archaeopyle and it's reduced nature. Note the well developed parasutural crests.

4, 5. *Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich 1966 var. *gracilis* (Davey & Williams 1966a) Lentin & Williams 1973: BH 4 (P54-4). **4.** Right lateral view; low focus showing the edge of the precingular archaeopyle. **5.** Oblique left lateral view; high focus showing detail of the hypocyst. Note the reduced parasutural crests and the slender, delicate processes.

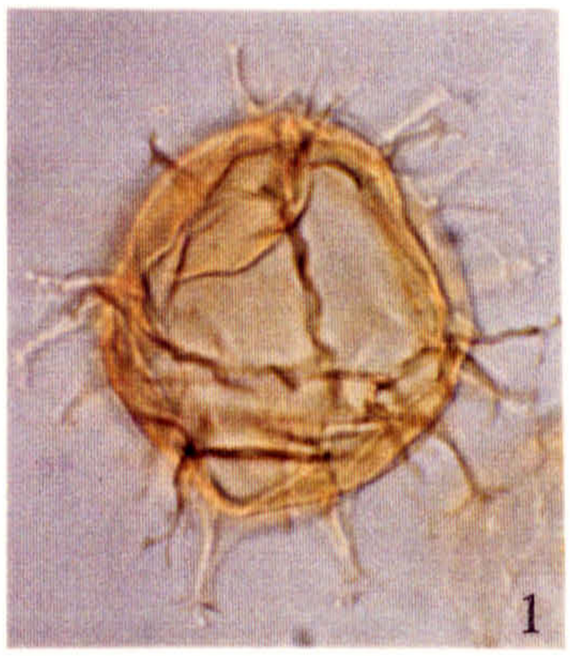
6. *Spiniferites* sp. LS 9 (C32-2). Right lateral view; high focus showing the typical process morphology, with parasutural crests.

7. *Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich 1966a var.*ramosus* (1973): BH 5 (D31). Dorsal view; high focus displaying the reduced precingular archaeopyle and the typical trifurcate processes with bifid tips.

8, 9. *Hystrichostrogylon membraniphorum* Agelopoulos 1964: BH 2 Ao2 (P36-4). **8.** Right lateral view; high focus showing the precingular archaeopyle. **9.** Left lateral view; low focus displaying the "umbrella-like" pericyst which encloses the ventral side of the cyst.

10, 11. *Spiniferites ramosus* (Ehrenberg) Loeblich & Loeblich 1966 var. *reticulata* (Davey & Williams 1966a) Lentin & Williams 1973: LS 2 (C50). **10.** Left lateral view; low focus showing the precingular archaeopyle. **11.** Right lateral view; high focus displaying the parasulcal region and the reticulate ornament of the cyst.

PLATE 7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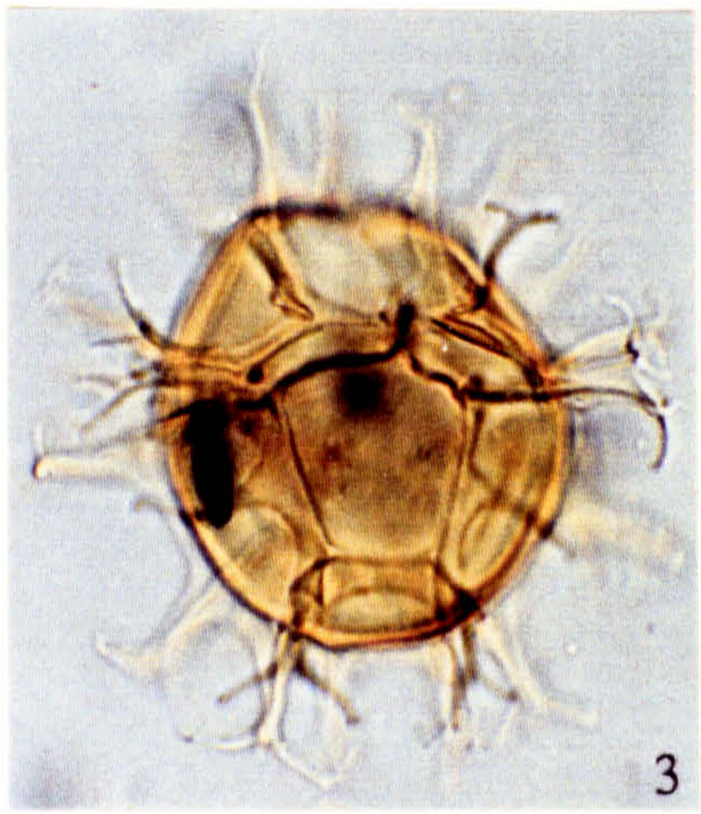
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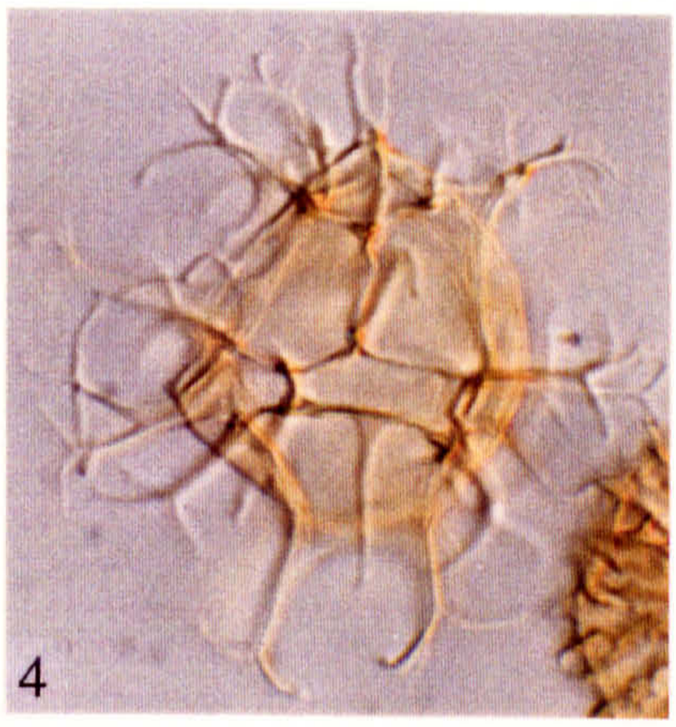
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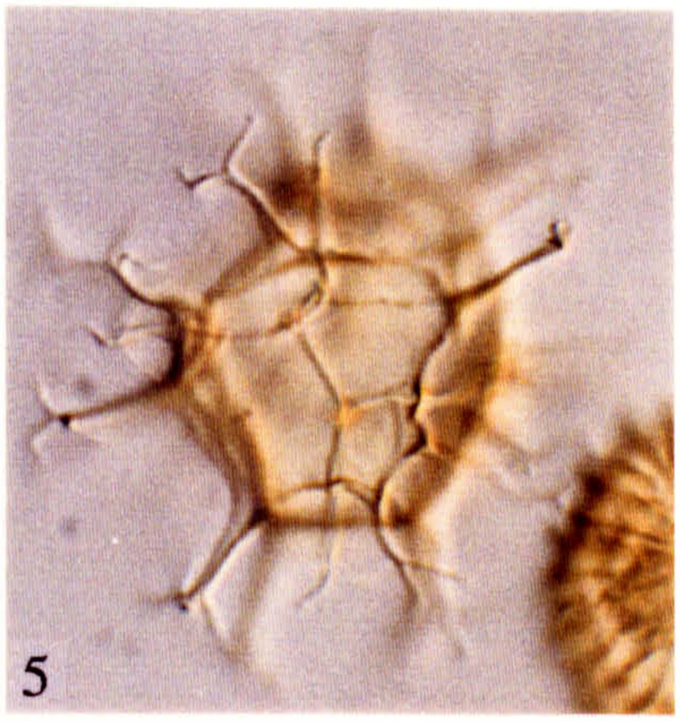
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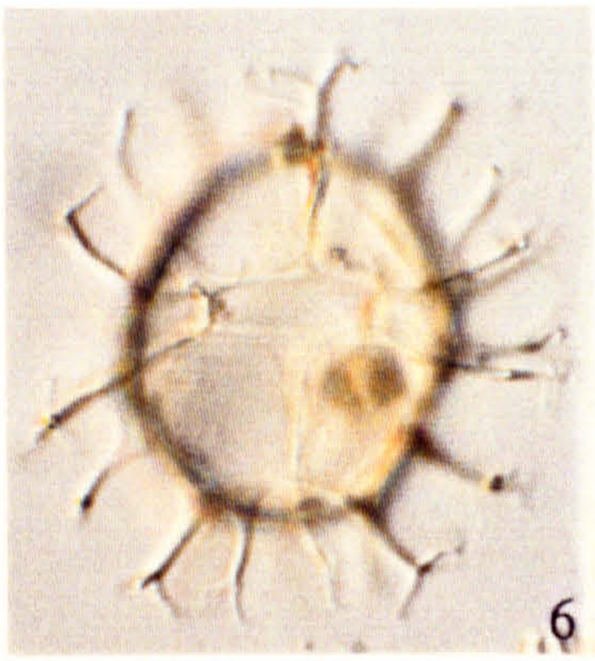
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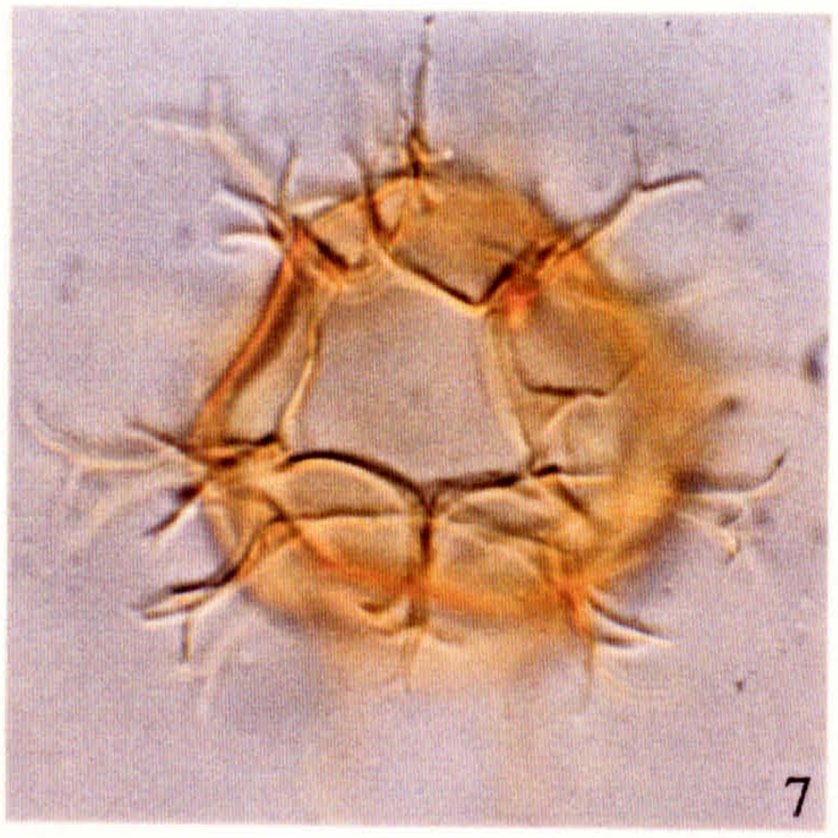
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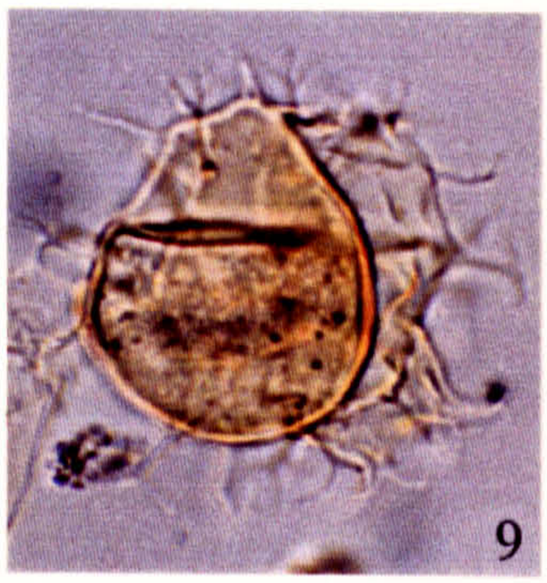
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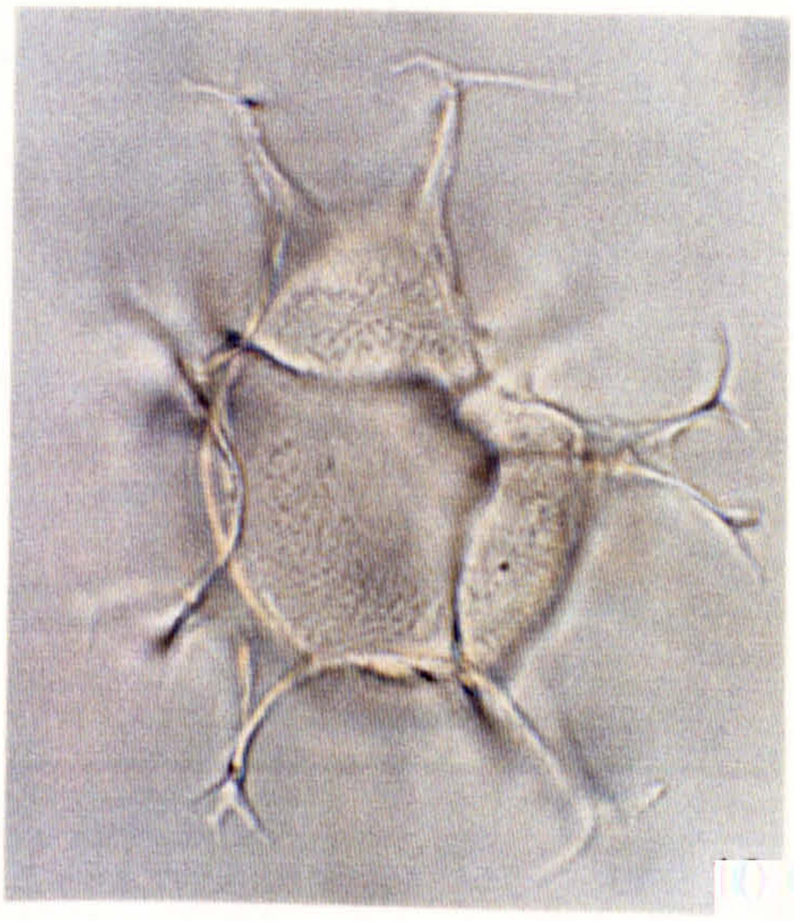
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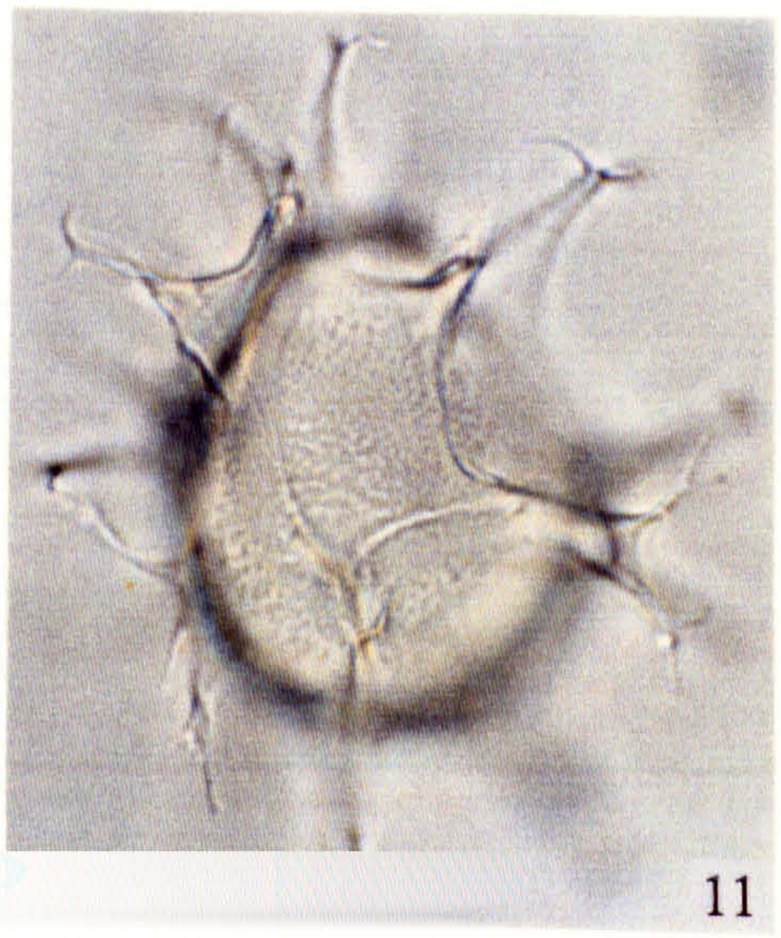
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PLATE 8

1. *Cribroperidinium* sp. SPT 5 Ao1 (C59-3). Oblique dorsal view; high focus showing the precingular archaeopyle.

2. *Endoscrinium campanula* (Gocht 1959) Vozzhennikova 1967: DOE 8 (i) (F47-4). Left dorsal view; high focus showing the precingular archaeopyle and the subspherical endocyst.

3, 4. *Stephodinium coronatum* Deflandre 1936a: BH4 Ao1 (E27-1). **3.** Apical view, focused on the precingular archaeopyle. Note the attachment of the pericyst to the ventral surface. **4.** Apical view; high focus. Note the parasutural markings on the pericyst defining the apical and precingular series of paraplates.

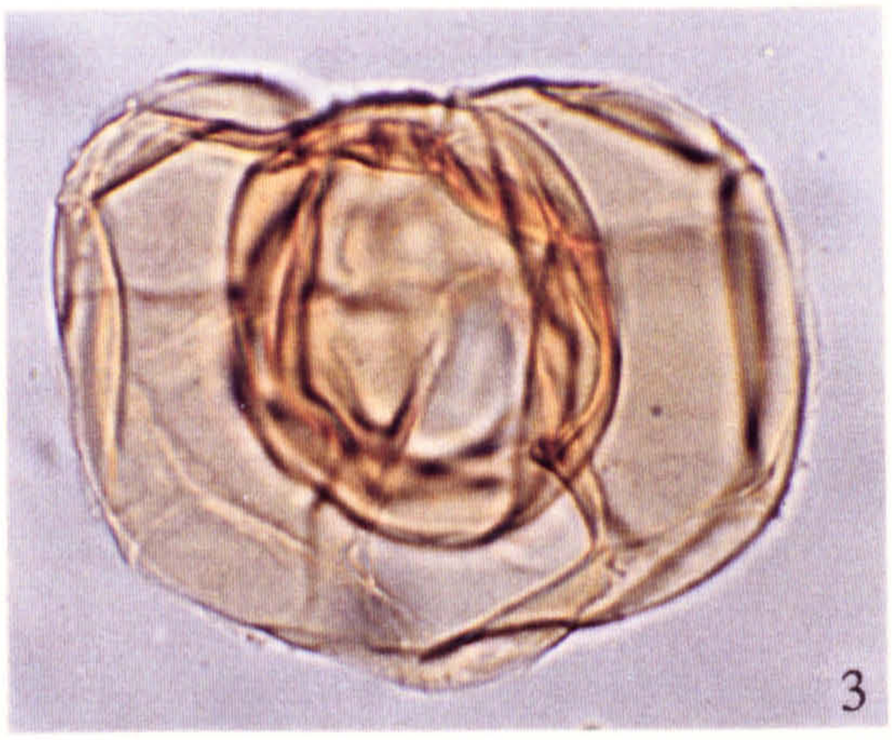
5, 8. *Pterodinium cingulatum* (Wetzel 1933) Below 1981 var. *cingulatum* (1973) NP 25 Ao2 (C31-3). **5.** Ventral view; low focus showing the detail of the parasulcal area, with the large posterior parasulcal plate and the two smaller right and left anterior parasulcal plates. **8.** Dorsal view; high focus displaying the reduced nature of the precingular archaeopyle, and the well developed parasutural crests.

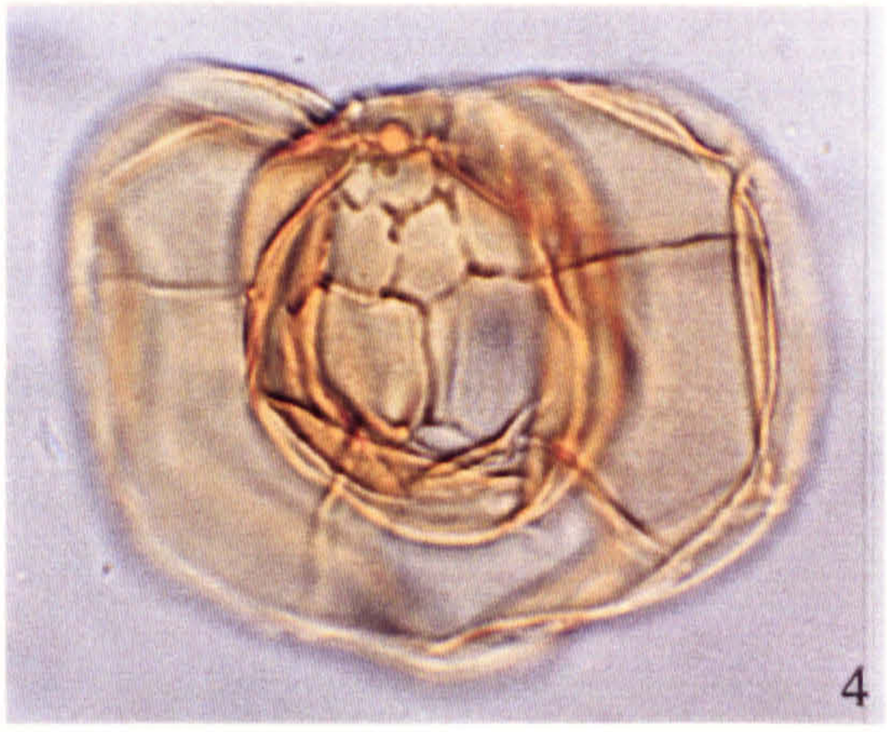
6. *Stephodinium coronatum* Deflandre 1936a: BH3 (Q33-3). Ventral view; showing the cavation restricted to the paracingular region.

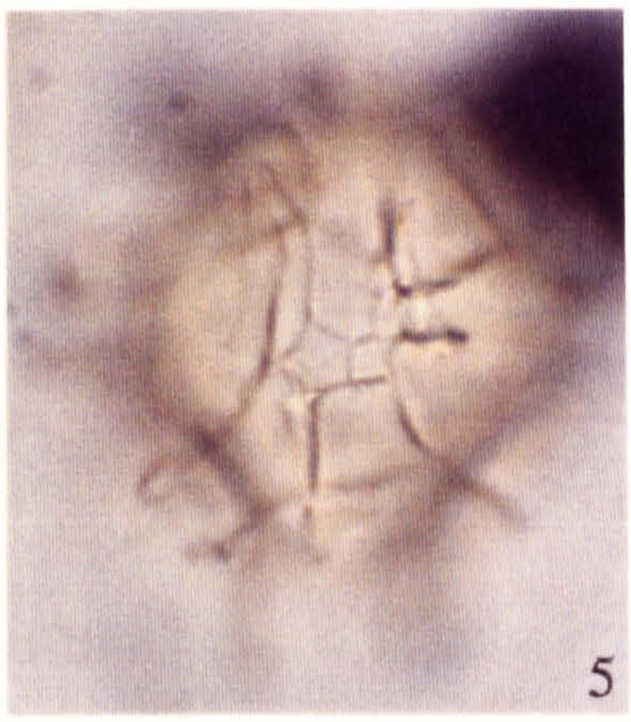
7, 10. *Gonyaulacysta cassidata* (Eisenack & Cookson 1960) Sarjeant 1966: BH 12 (B42). **7.** Dorsal view; low focus showing the precingular archaeopyle and the small separation at the antapex of the cyst. **10.** Ventral view; high focus displaying the offset paracingulum, the apical cavation and the tuberculate ornament.

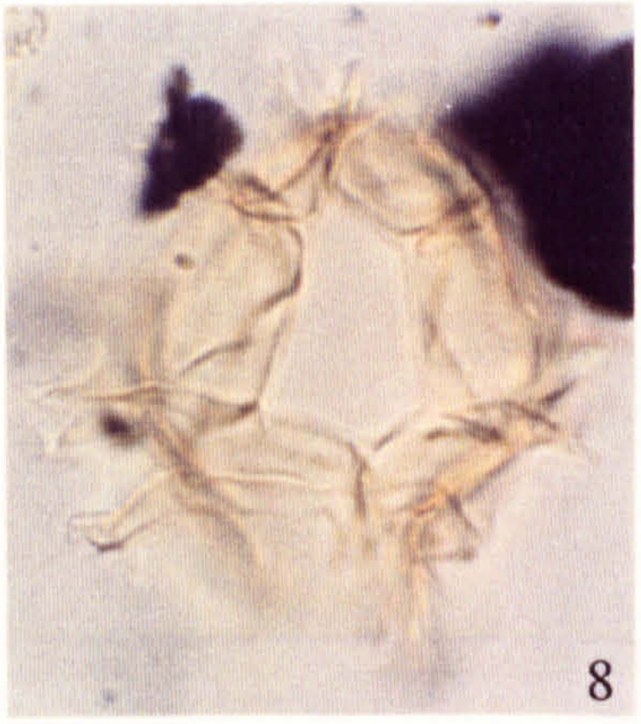
9. *Pterodinium ?cornutum* Cookson & Eisenack 1962: BH 2 (K59-2). Lateral view; high focus displaying the parasutural crests and the prominent apical horn.

PLATE 8









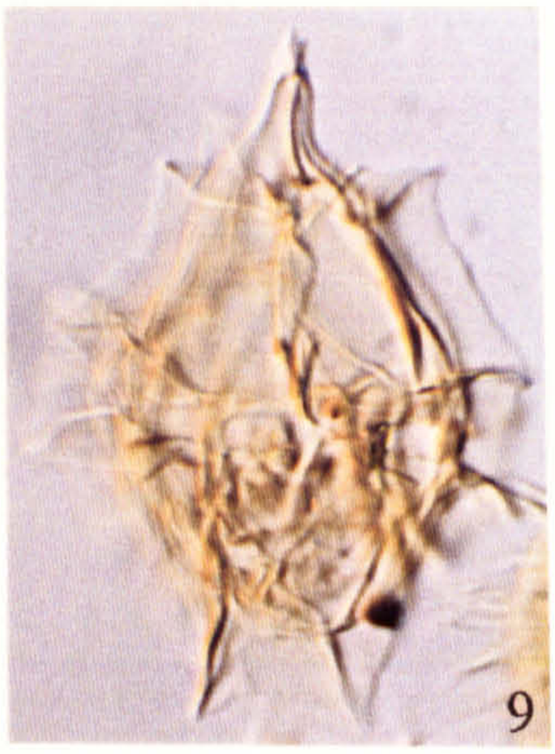


PLATE 9

1, 2. *Hystrichodinium pulchrum* Deflandre 1935: NP 21 (V36-4). **1.** Oblique dorsal view; high focus displaying the precingular archaeopyle. **2.** Oblique ventral view; high focus showing the alignment of processes along the paracingulum. (Magnified × 410).

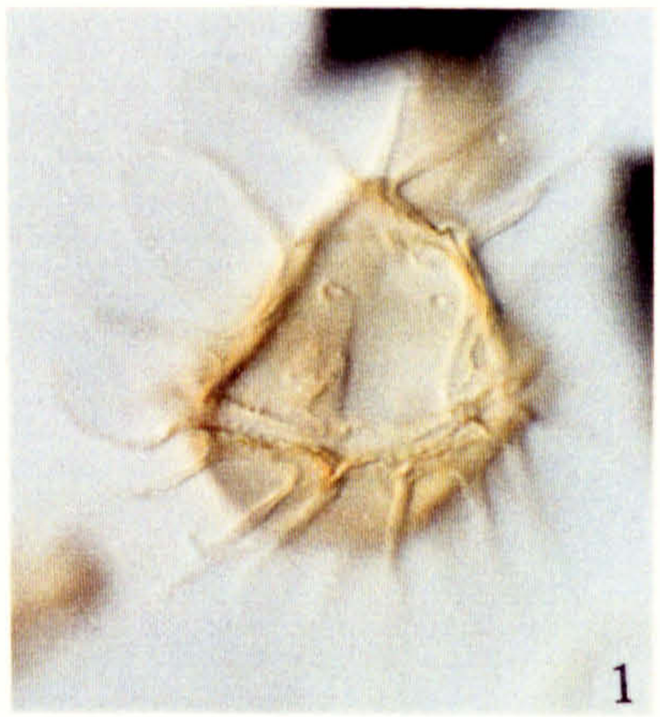
3. *Hystrichodinium voigtii* (ALberti 1961, emend. Sarjeant 1966) Davey 1974: BH 3 (W48). Apical view; high focus displaying the precingular archaeopyle and the crest that defines the paracingulum.

4, 6. *Xiphophoridium alatum* (Cookson & Eisenack 1962) Sarjeant 1966: BH 12 (U27-1). **4.** Lateral view; low focus, on the central body. **6.** Lateral view; high focus, showing the detail of the process morphology.

5. *Callaiosphaeridium asymmetricum* (Deflandre & Courteville 1939) Davey & Williams 1966b: LS 11 (D53-3). Oblique antapical view; high focus showing the quinqueform nature of the antapical paraplate.

6, 8. *Callaiosphaeridium asymmetricum* (Deflandre & Courteville 1939) Davey & Williams 1966b: LS 9 (H60-4). **6.** Apical view of the hypocyst; low focus displaying the archaeopyle margin. The tubular processes define the paracingular plates; therefore the operculum must comprise the apical and precingular series of paraplates only. **8.** Oblique antapical view; high focus showing the morphology of the gonal processes and the crests that connect them proximally.

PLATE 9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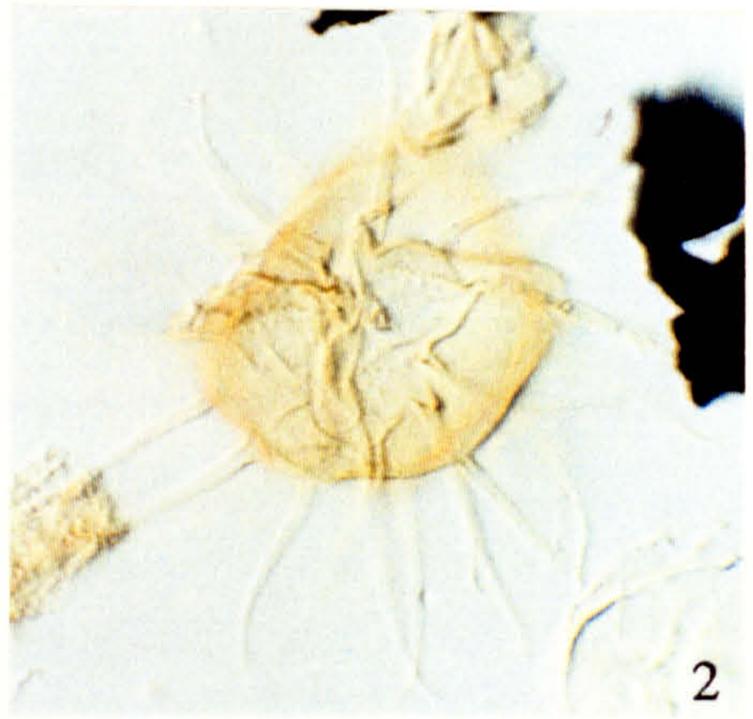
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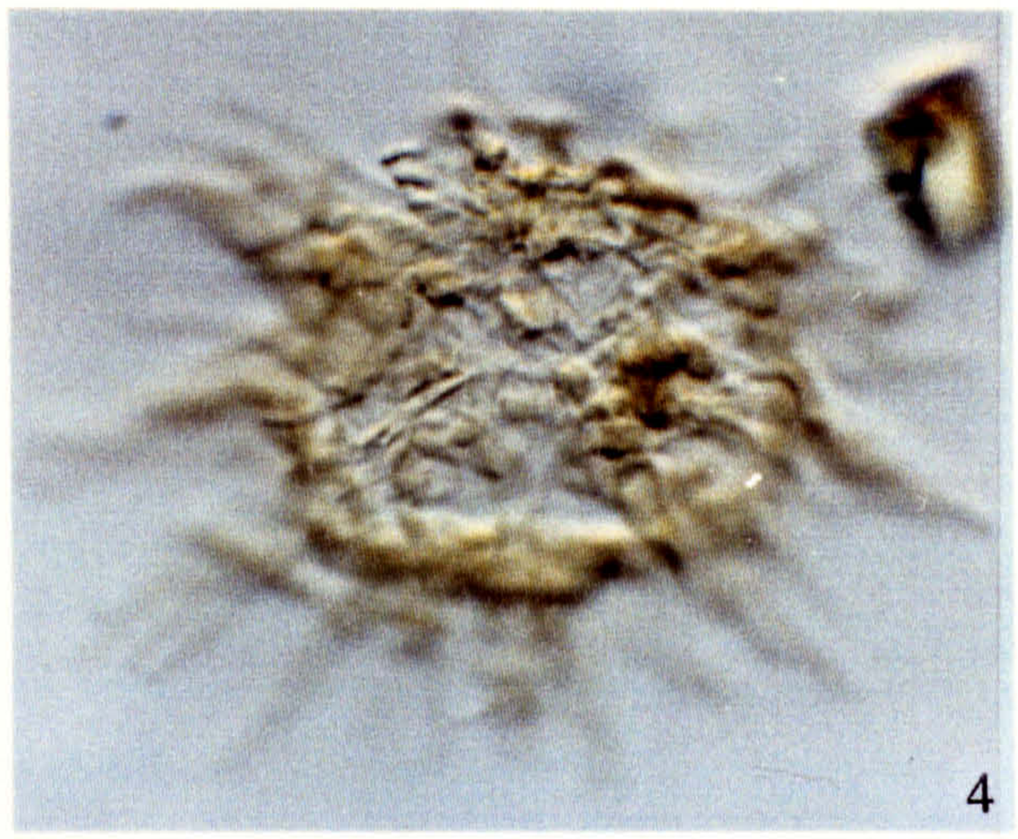
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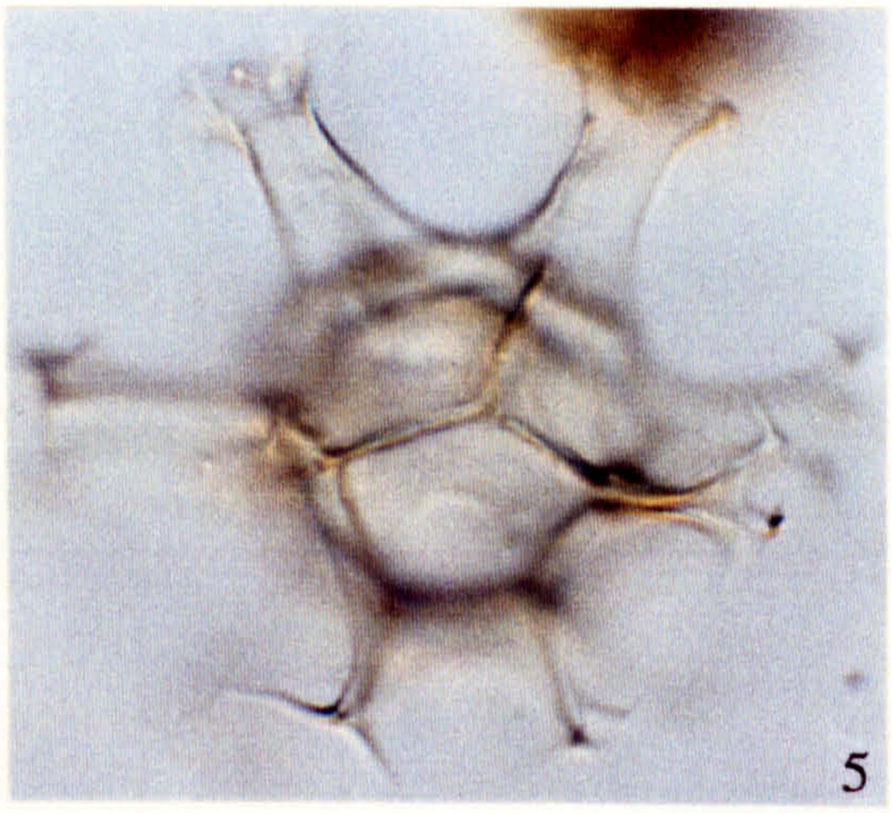
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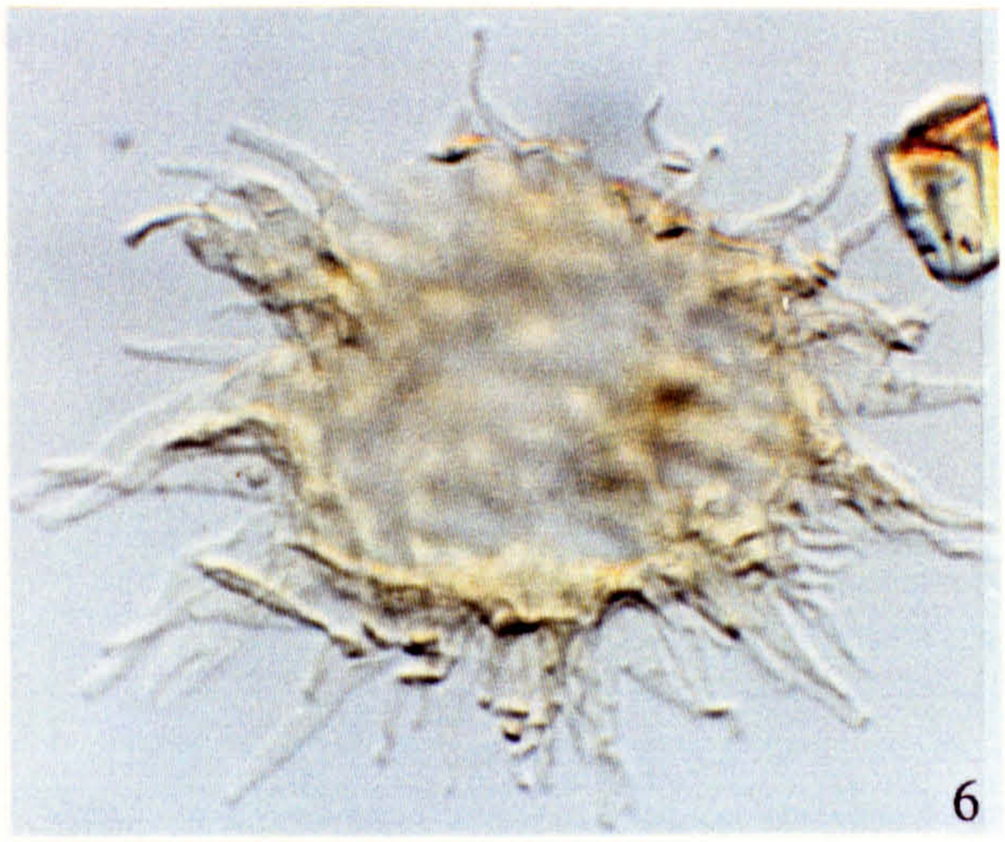
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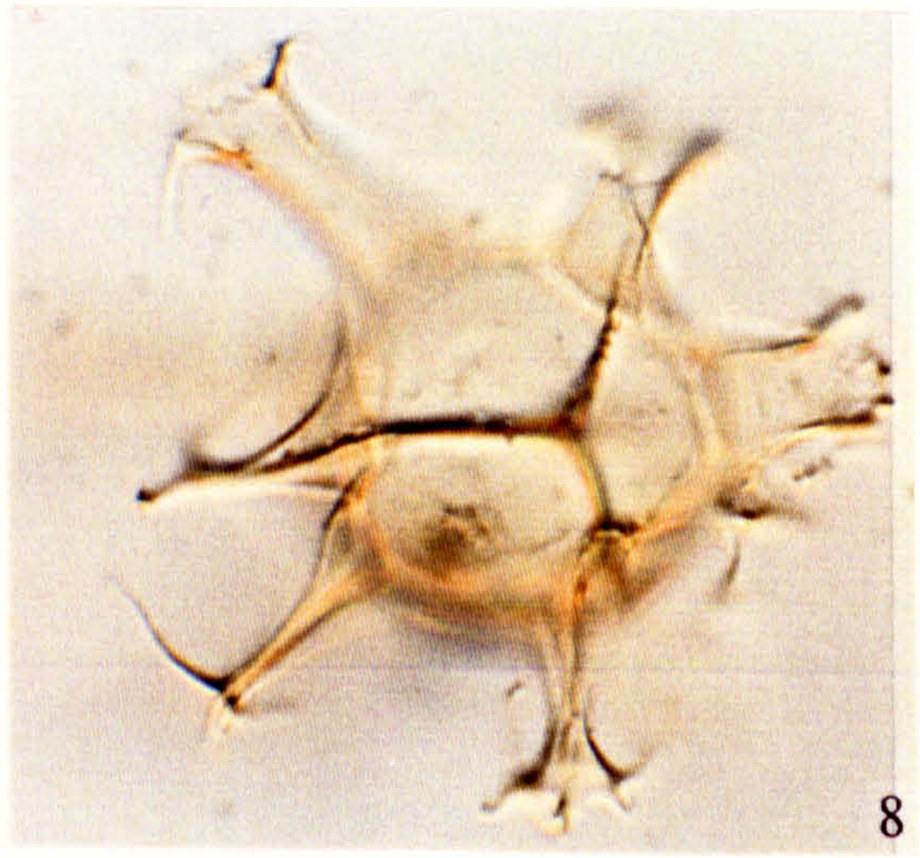
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PLATE 10

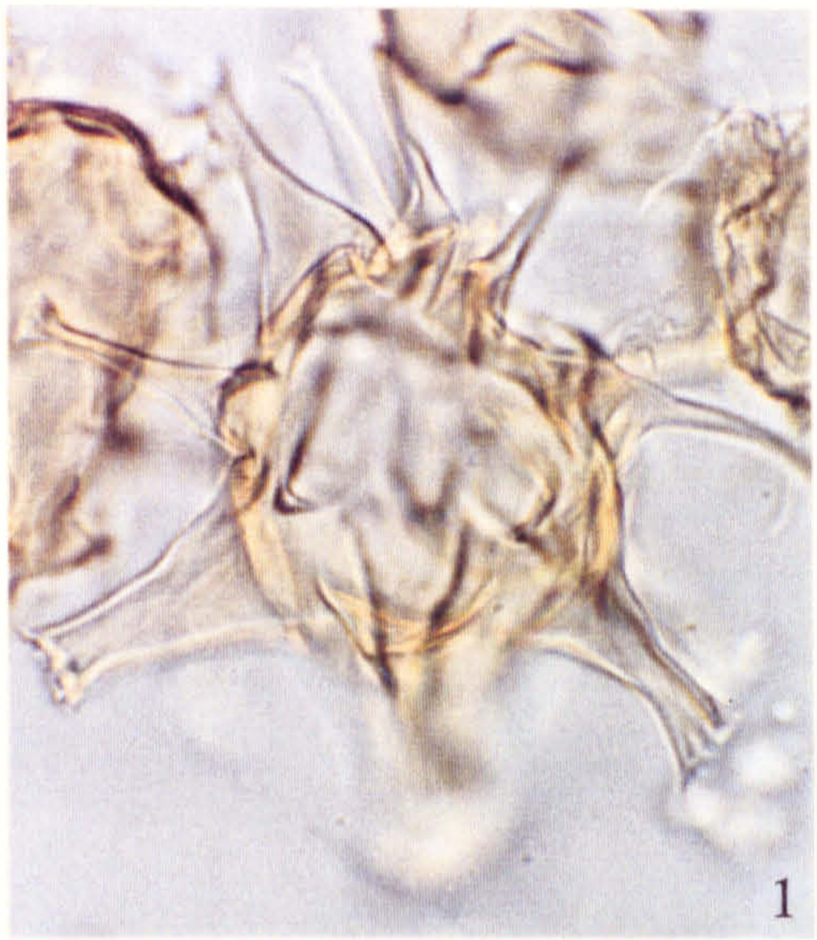
1, 2. *Florentinia deanei* (Davey & Williams 1966b) Davey & Verdier 1973: BH 12 (H61). **1.** Oblique ventral view; low focus showing the variation in process size and shape. **2.** Oblique dorsal view; high focus displaying the precingular archaeopyle, and the prominent antapical process.

3, 4. *Florentinia deanei* (Davey & Williams 1966b) Davey & Verdier 1973: SPT 2 Ao2 (F48-1). **3.** Dorsal view; high focus on the combination archaeopyle. **4.**Median focus showing the variation in process morphology; note the open, digitate endings.

5, 6. *Florentinia deanei* (Davey & Williams 1966b) Davey & Verdier 1973: DOE 8(i) (D38-3). **5.** Lateral view; low focus. This specimen exhibits an exceptionally large, broad antapical horn. **6.** Lateral view; high focus. The other processes are also broad and stout in comparison with other specimens. (Magnified × 410).

7, 8. *Florentinia buspina* (Davey & Verdier 1976) Duxbury 1980: NP 21 Ao2 (M41-4). **7.** Dorsal view; high focus exhibiting the operculum still in place. **8.** Median focus showing the process complexes.

PLATE 10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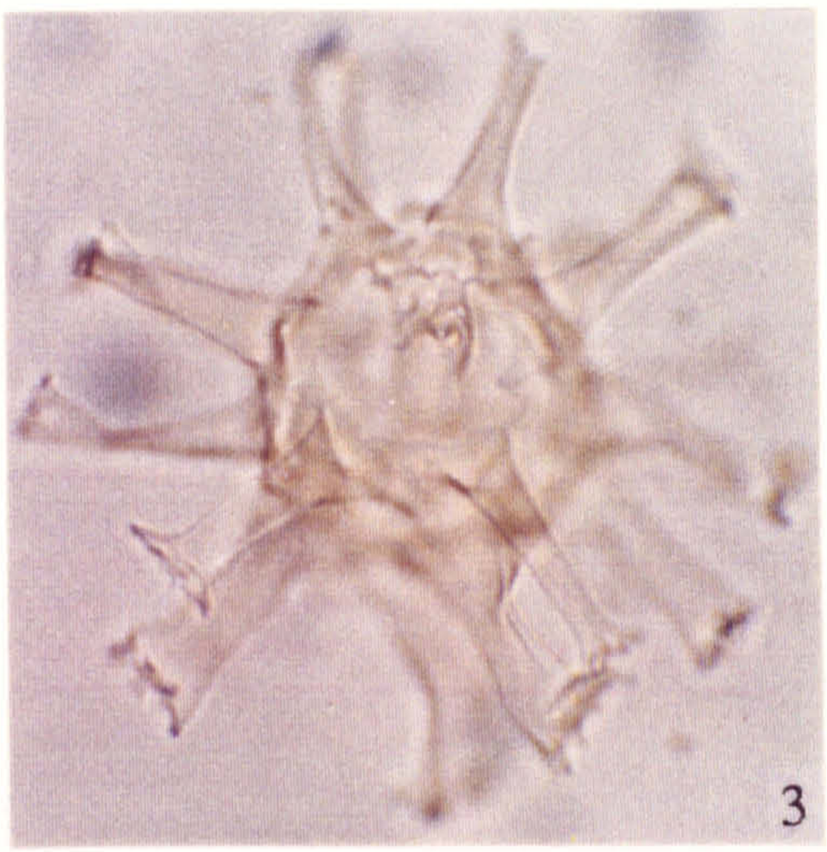
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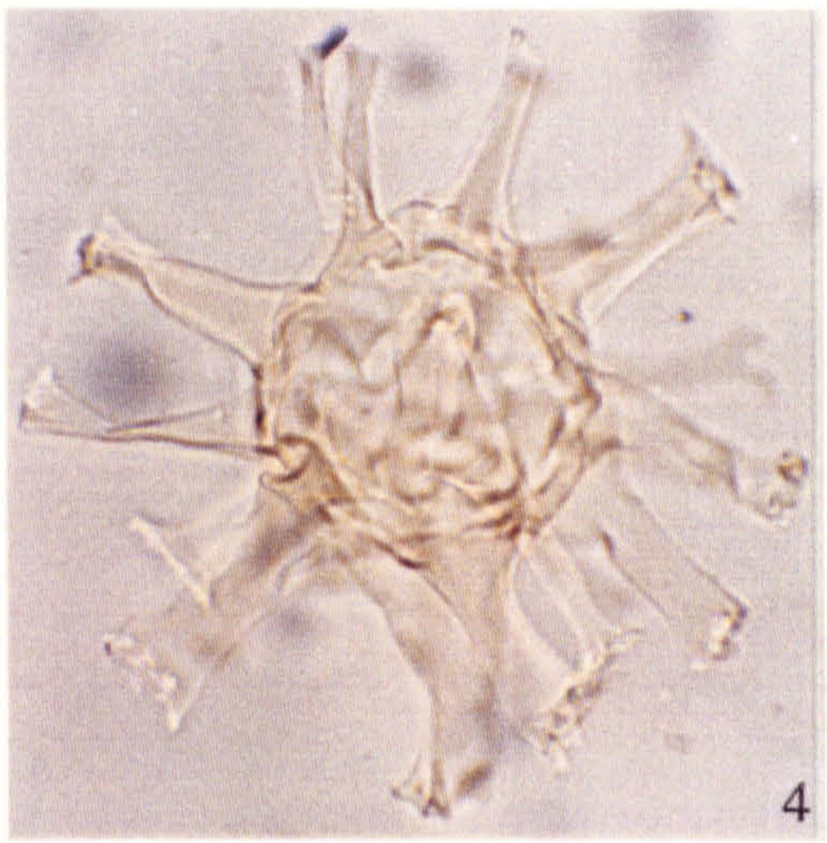
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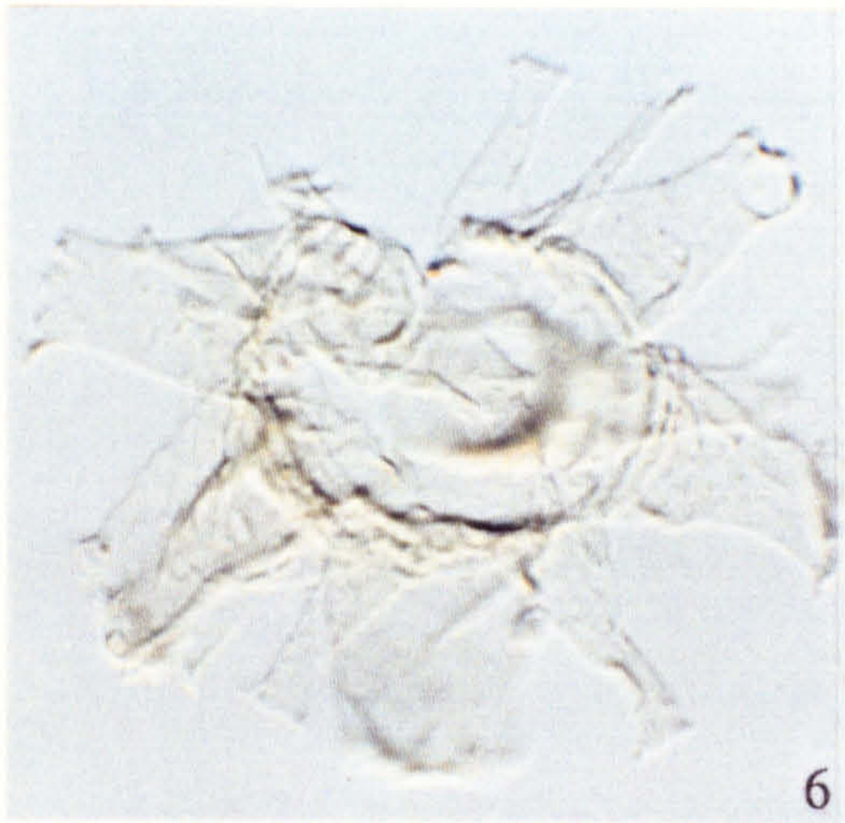
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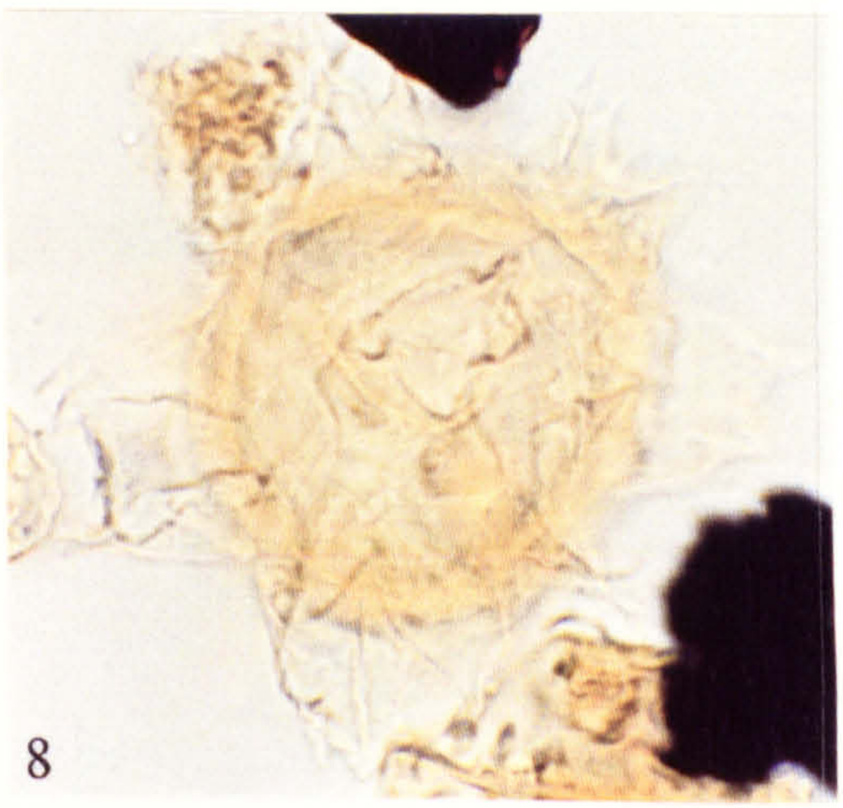
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PLATE 11

1, 2. *Florentinia buspina* (Davey & Verdier 1976) Duxbury 1980: NP 21 Ao2 (T39-4). **1.** Ventral view; low focus showing the rough nature of the cyst wall and the complex process morphology. **2.** Dorsal view; high focus exhibiting the combination apical and precingular ("keyhole") archaeopyle.

3. *Florentinia torulosa* (Davey & Verdier 1976) Lentin & Williams 1981: BH 6 (D60). Oblique dorsal view; low focus displaying the precingular archaeopyle.

4. *Florentinia torulosa* (Davey & Verdier 1976) Lentin & Williams 1981: BH 6 (D60). ? Apical view; high focus, showing the thick, rough endophragm and the conical nature of the processes.

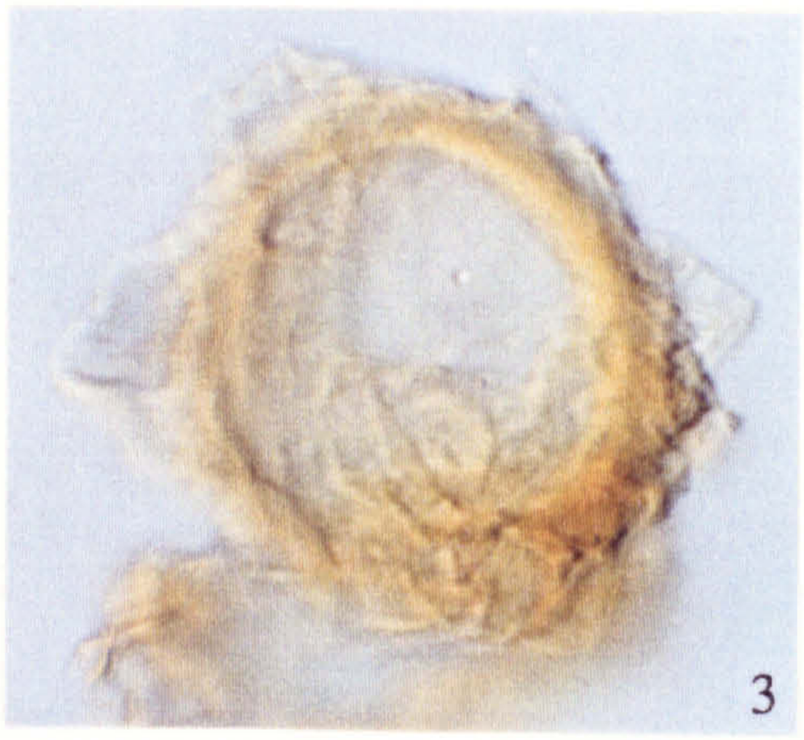
5. *Florentinia ferox* (Deflandre 1937) Duxbury 1980: Lateral view; median focus showing the thick, granular nature of the endophragm and the large antapical process.

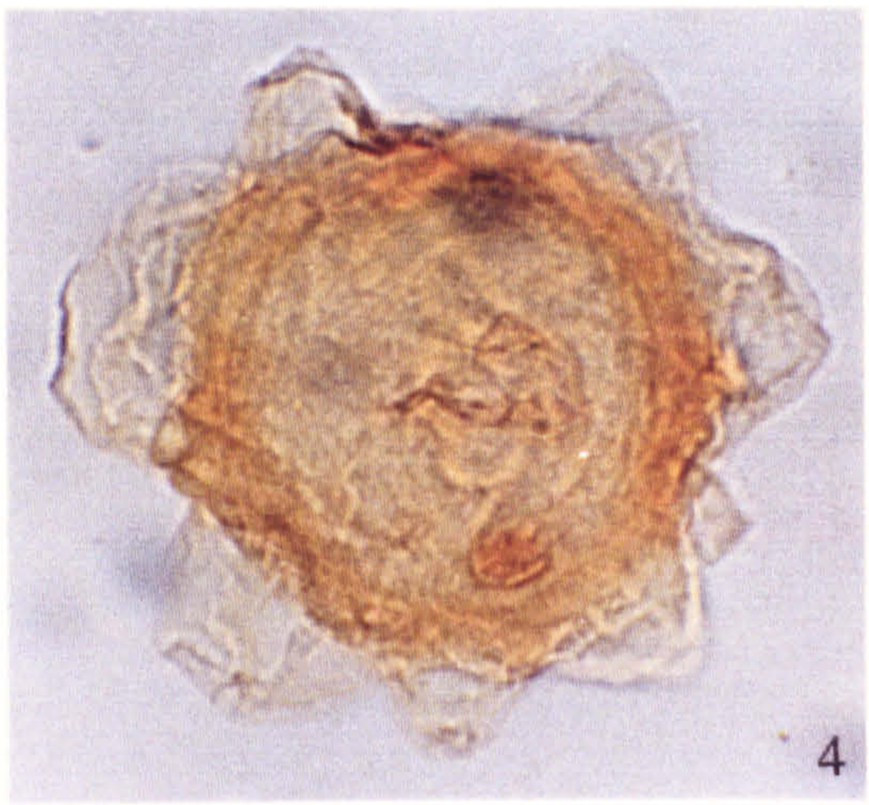
6. *Florentinia ferox* (Deflandre 1937) Duxbury 1980: BH 1 Ao2 (D30-1). Ventral view; median focus displaying the variable process morphology; note the large antapical process.

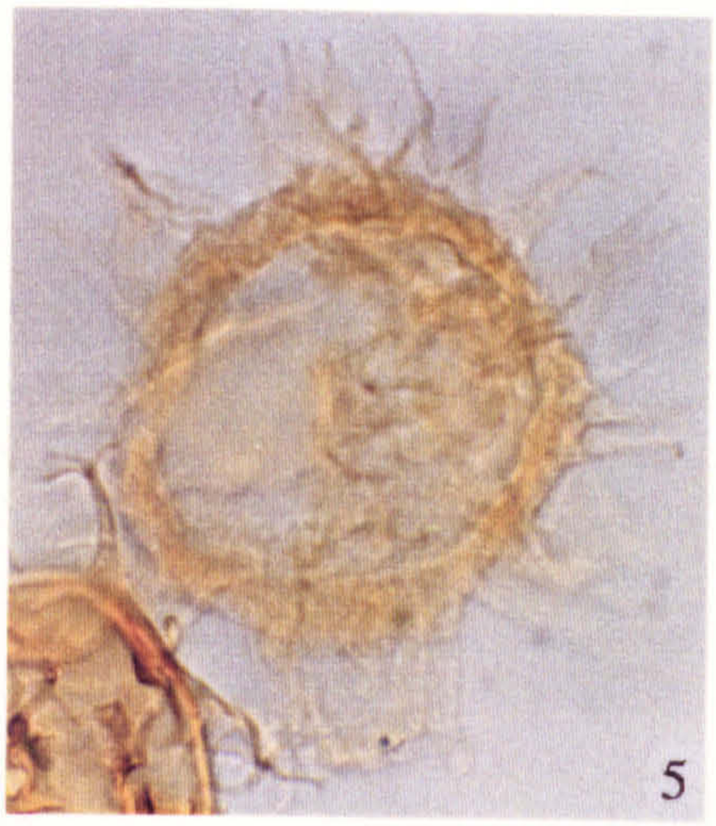
7. *Florentinia* sp. BH 12 (E44-2). Oblique ventral view; high focus showing the variable process morphology.

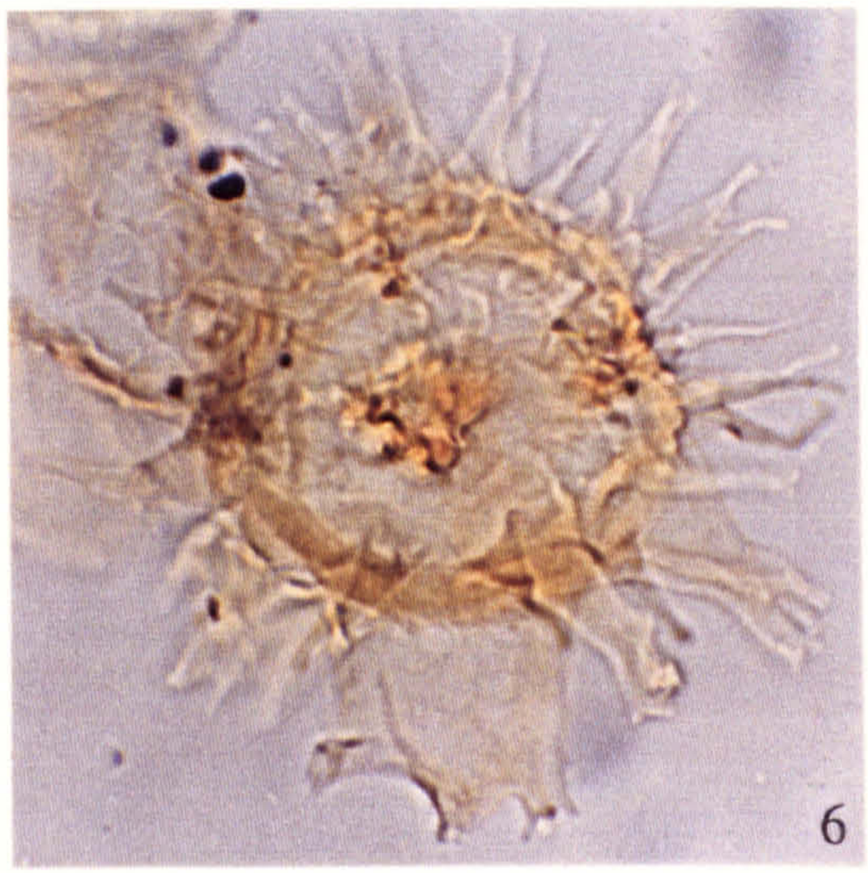
8. *Florentinia* sp. BH 9 Ao1 (B31-2). Lateral view; low focus, showing the variable process morphology.

PLATE 11









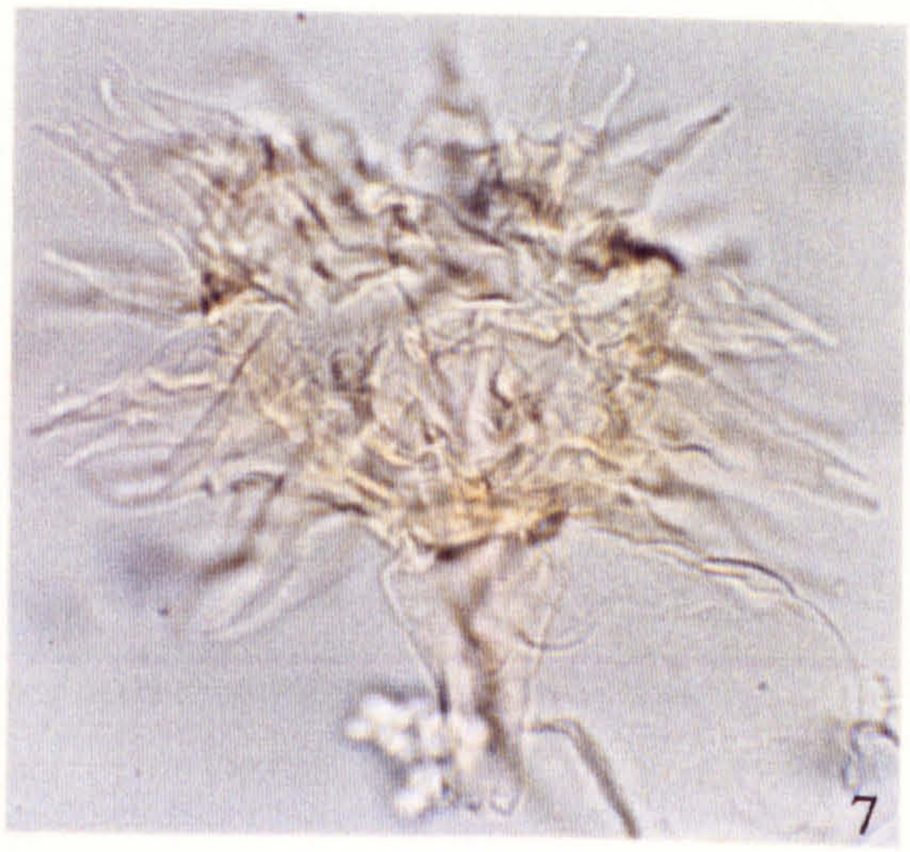


PLATE 12

1, 2. *Hystrichosphaeridium bowerbankii* Davey & Williams 1966b: DOE 10 (K35). **1.** Apical view; low focus. Note the subspherical central body, slender processes and the terminal spines. **2.** Antapical view; high focus. Note the circular markings formed at the junction between the process and the endocyst.

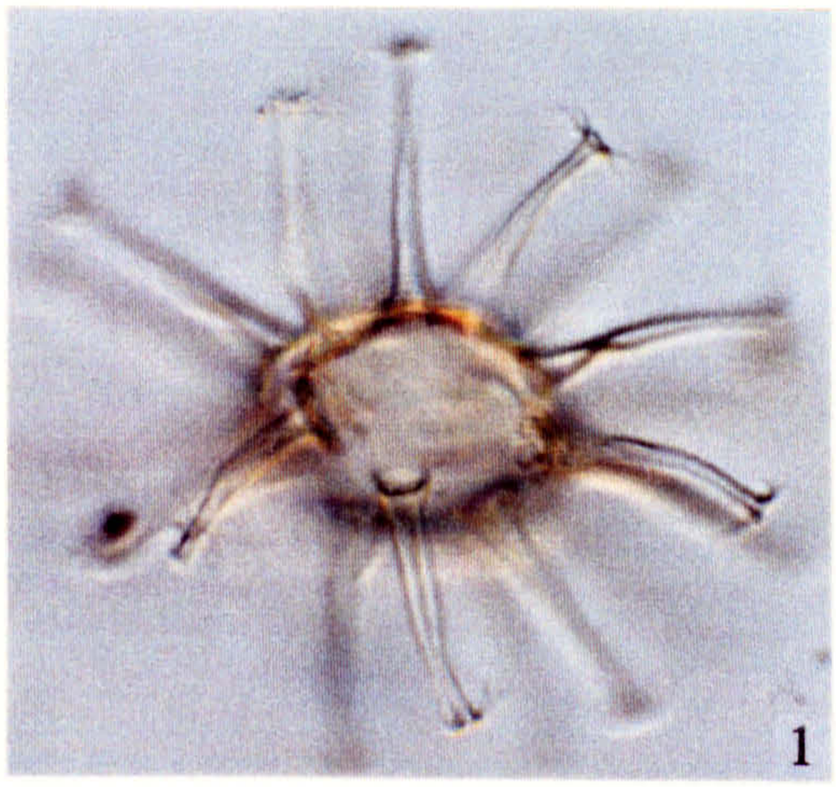
3, 4. *Hystrichosphaeridium bowerbankii* Davey & Williams 1966b: NP 29 Ao1 (X33). **3.** Dorsal view; high focus displaying the paratabular arrangement of the processes; note the terminal spines. **4.** Ventral view; low focus showing the paratabular arrangement of the processes.

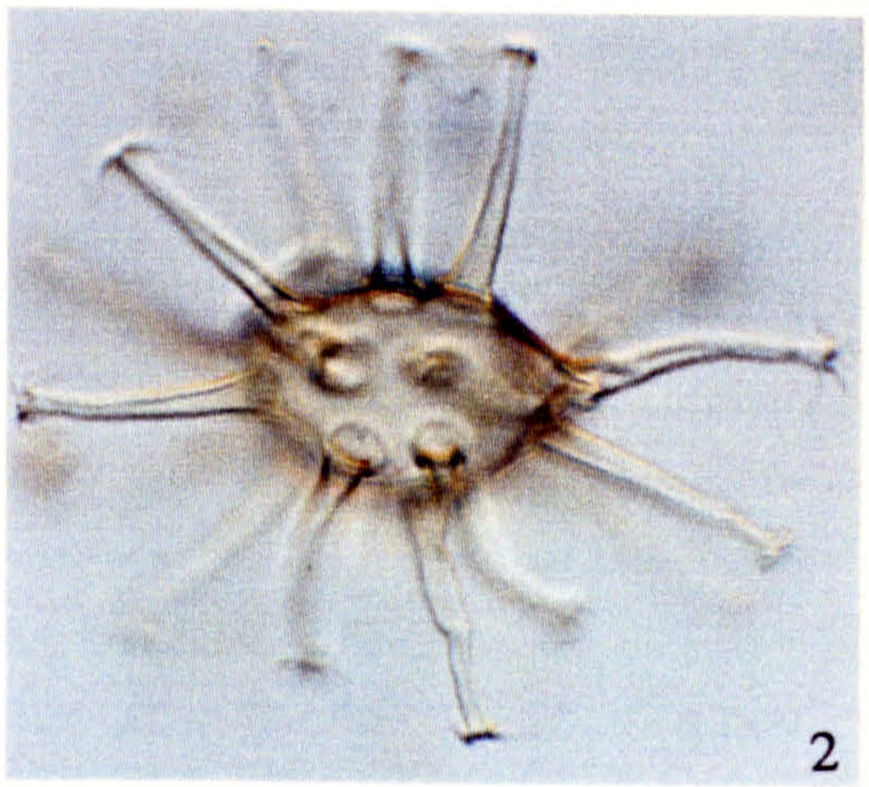
5, 6. *Hystrichosphaeridium conispiniferum* Yun 1981: BH1 Ao2 (C47-3). **5.** Apical view; low focus showing the paratabular arrangement of processes. **6.** Antapical view; high focus, note the processes taper proximally.

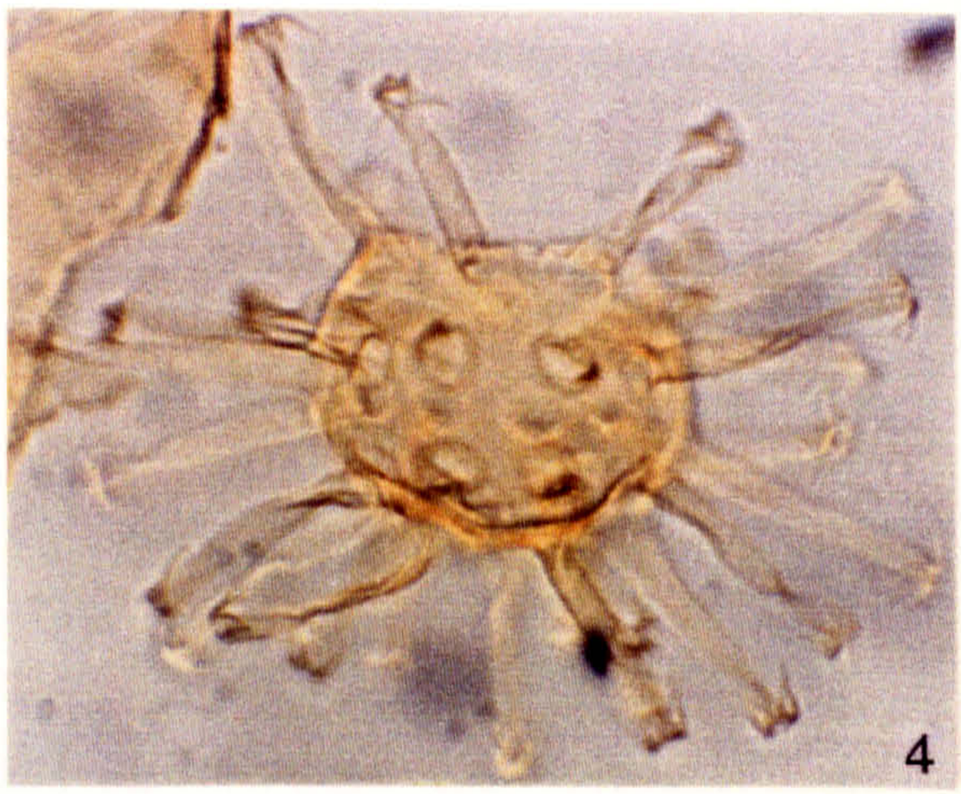
7. *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) Deflandre 1937 var. *tubiferum* emend. Davey & Williams 1966b: BH 2 (B55). Dorsal view; high focus showing the apical archaeopyle and the plate centered processes.

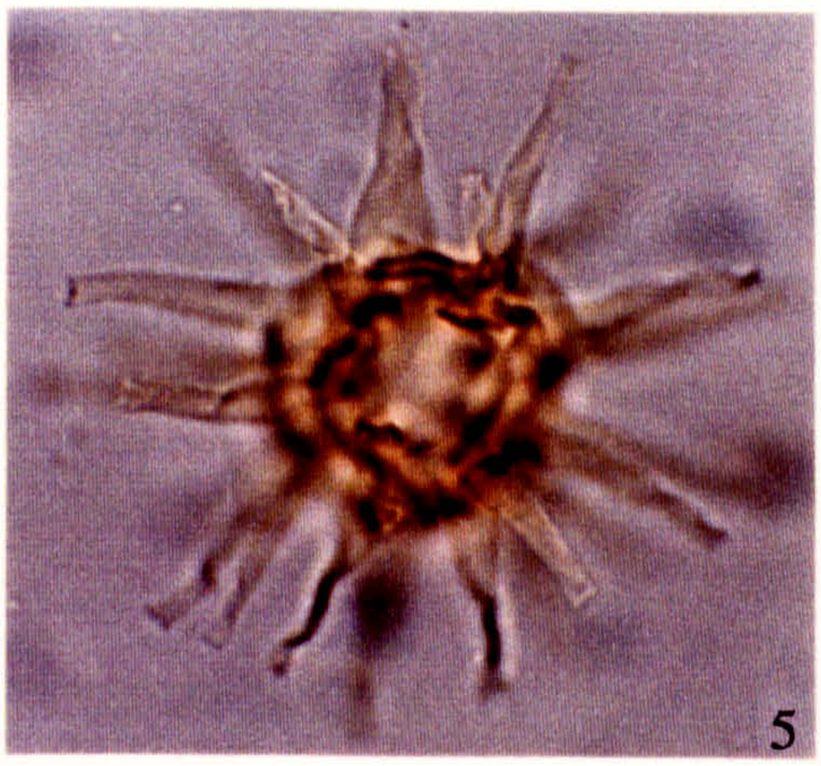
8. *Hystrichosphaeridium tubiferum* (Ehrenberg 1838) var.*brevispinum* (Davey & Williams 1966b) Lentin & Williams 1973: CH 9 Ao2 (X44-1). Oblique ventral view; high focus displaying the apical archaeopyle (operculum still attached), paratabular processes which are short and tubular with serrated distal margins.

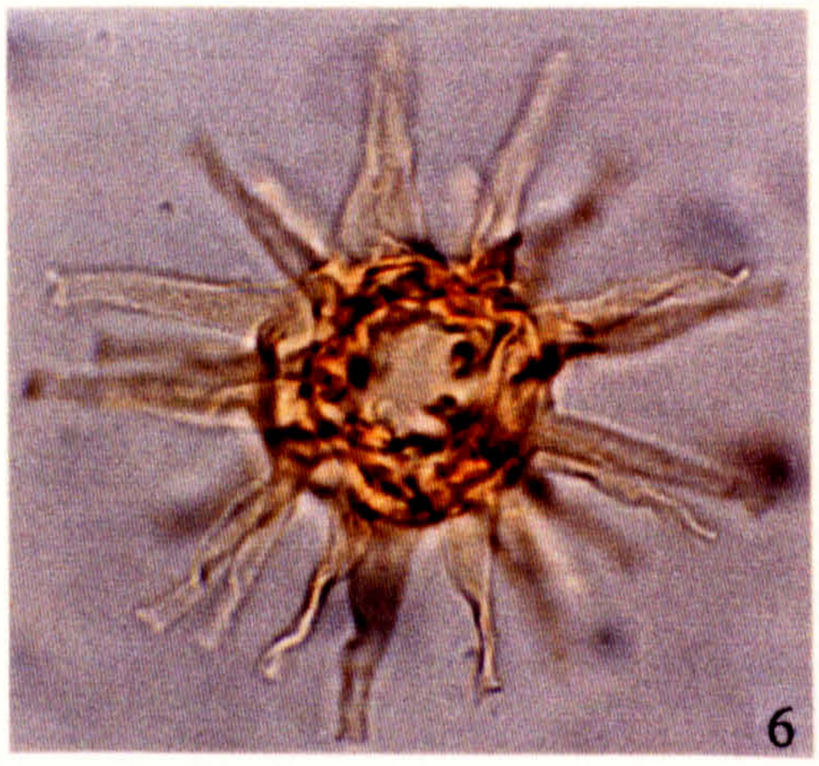
PLATE 12

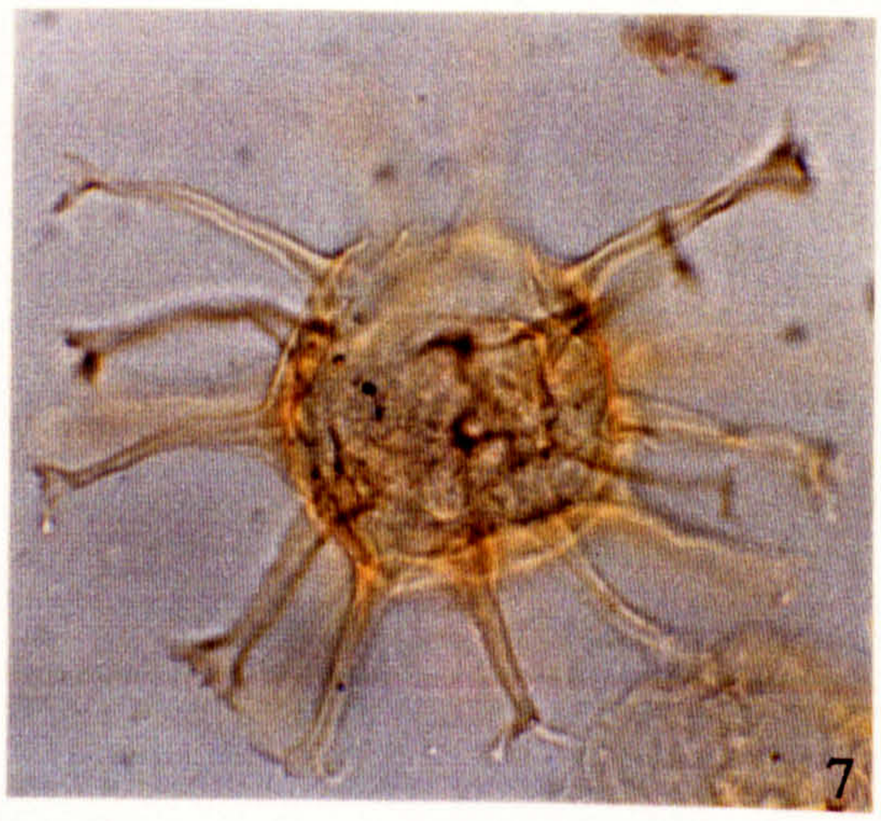












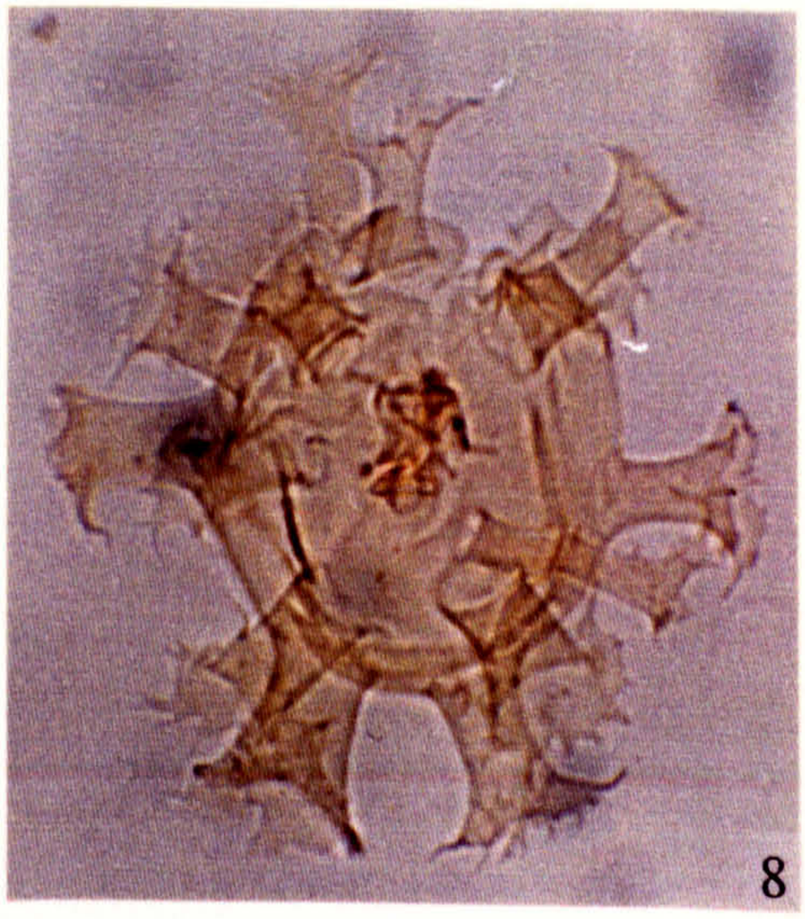


PLATE 13

1, 2. *Oligosphaeridium complex* (White 1842) Davey & Williams 1966b: SO 1 (F33-1). **1.** Oblique apical view; low focus displaying the archaeopyle margin and the paratabular nature of the processes. **2.** Oblique antapical view; high focus showing the paratabular processes and their elaborate distal endings.

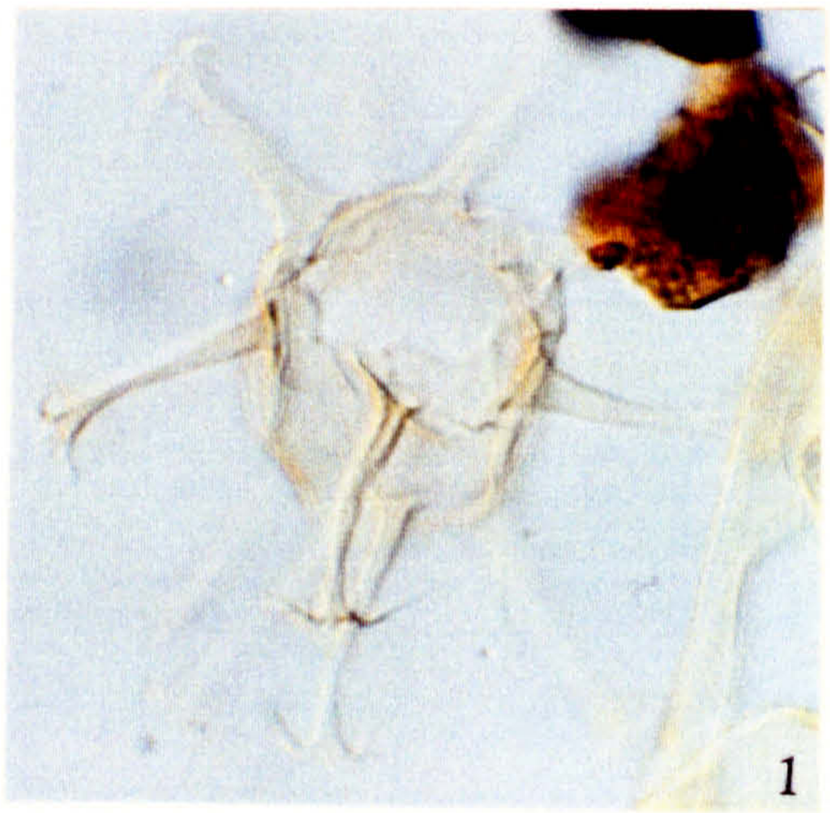
3, 5. *Oligosphaeridium* sp. *cf. O.complex* (White 1842) Davey & WIlliams 1966b: LS 31 (R42-4) **3.** Oblique ventral view; high focus showing the variable process morphology. **5.** Dorsal view; low focus displaying the apical archaeopyle margin and the plate-centered precingular processes.

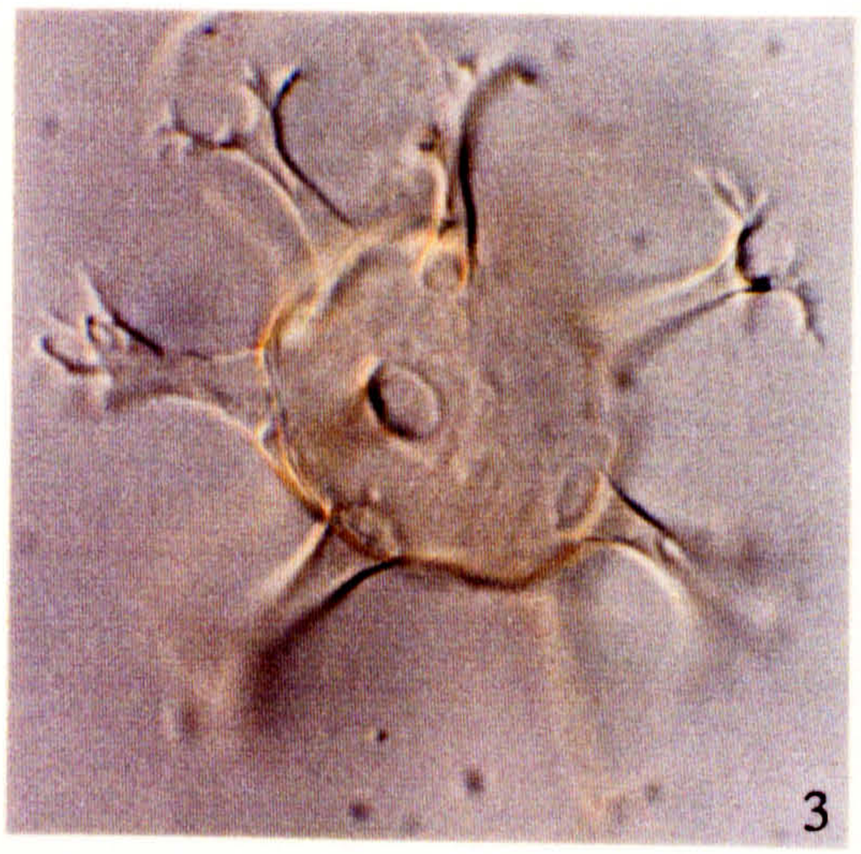
4, 6. *Oligosphaeridium poculum* Jain 1977: AS19 (M62-2) **4.** Ventral view; median focus showing the intratabular nature of the processes and the apical archaeopyle margin with a sulcal notch. Note the infundibular nature of the processes. **6.** High focus, exhibiting the expanded distal margins of the processes.

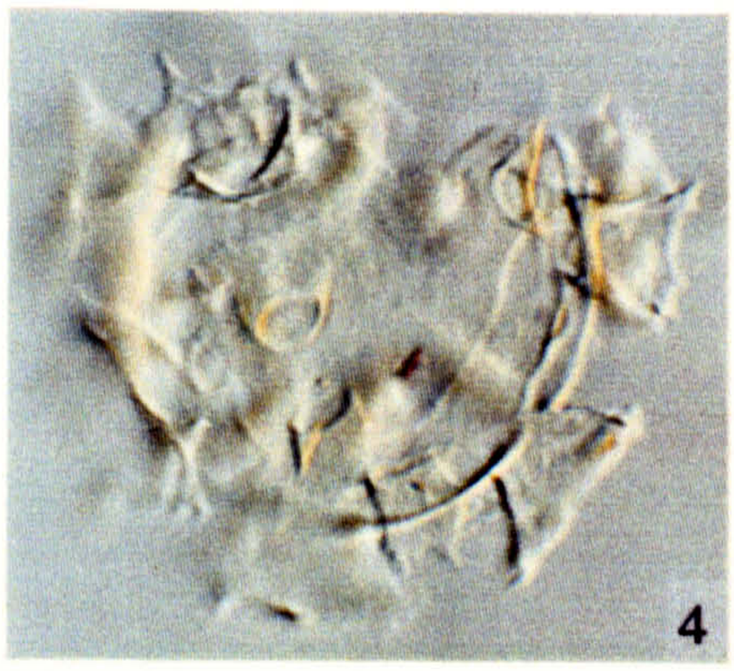
7. *Oligosphaeridium prolixispinosum* Davey & Williams 1966b: AS 18 (O32-4). Right lateral view; high focus displaying the apical archaeopyle and the process morphology with fine terminal spines.

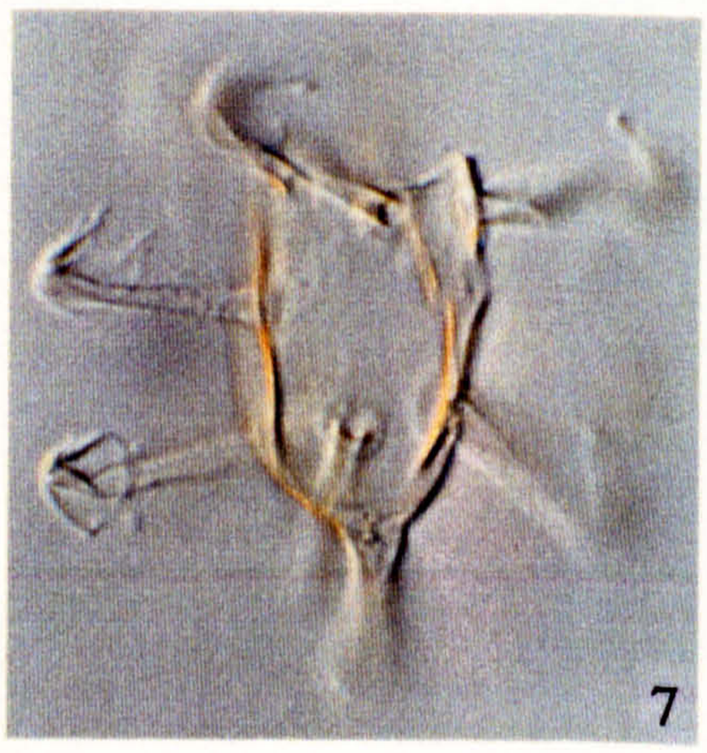
8. *Kleithriasphaeridium readei* (Davey & Williams 1966b) Davey & Verdier 1976: BH 2 Ao2 (B56-4) Dorsal view; high focus displaying the precingular archaeopyle and the intratabular processes with longitudinal striations.

PLATE 13









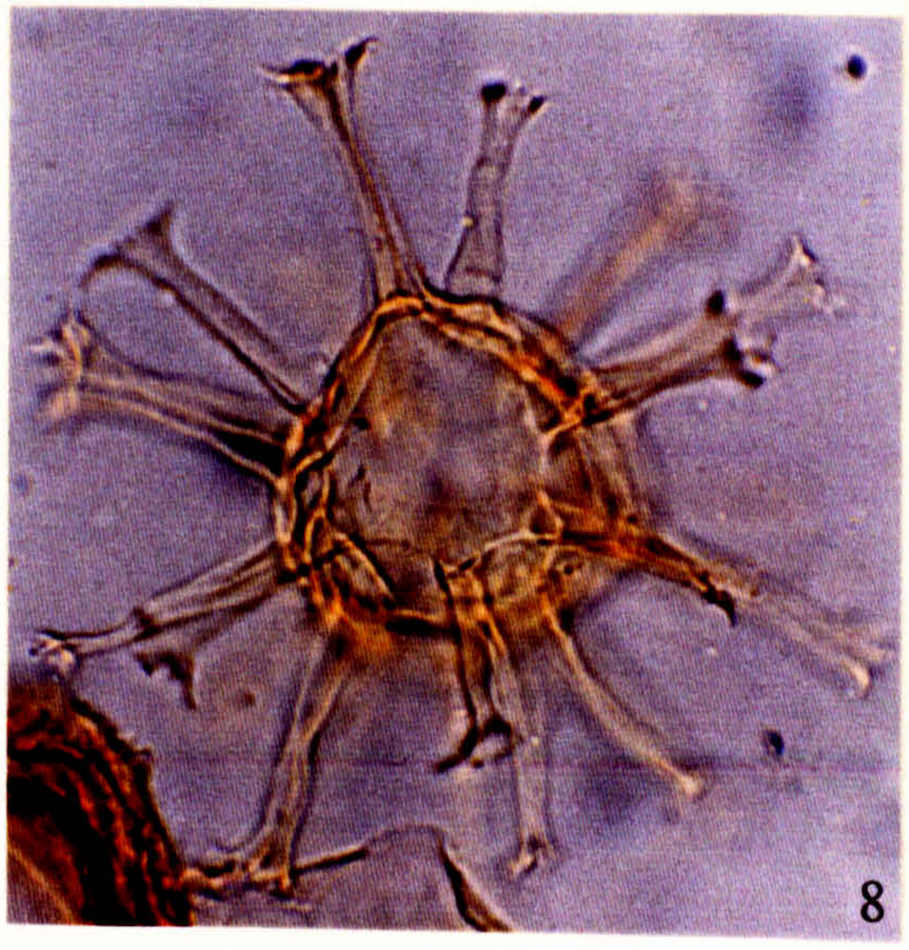


PLATE 14

1. *Cleistosphaeridium multispinosum* (Singh 1964) Brideaux 1971: BH 6 (H59-2). Lateral view; high focus. Note the slender, closed processes.

2. *Cleistosphaeridium clavulum* (Davey 1969) Below 1982: BH 1 (M36-4). Lateral view; high focus. Note the capitate nature of the processes.

3. *Kiokansium polypes* (Cookson & Eisenack 1962) Below 1982, emend. Duxbury 1983 NP 22 (B36). Oblique dorsal view; high focus showing the precingular archaeopyle.

4, 7. *Coronifera oceanica* Cookson & Eisenack 1958, emend. May 1980: DOE 8(i) (B47-2). **4.** Right lateral view; high focus displaying part of the archaeopyle margin. **7.** Low focus to show the distinct antapical process.

5. *Cleistosphaeridium* sp. *cf. armatum* (Deflandre 1937) Davey 1969: BH 6 (A35). Lateral view; low focus displaying the short, blade-like processes.

6. *Litosphaeridium chlidanum* Marshall 1983: HW 7 (H60). Lateral view; high focus displaying the intratabular processes. Note the process morphology, expanding distally.

8. *Dapsilidinium laminaspinosum* (Davey & Williams 1966b) Lentin & Williams 1981: BH 4 (G57). Lateral view; low focus showing the apical archaeopyle (operculum still attached); note the short cylindrical processes.

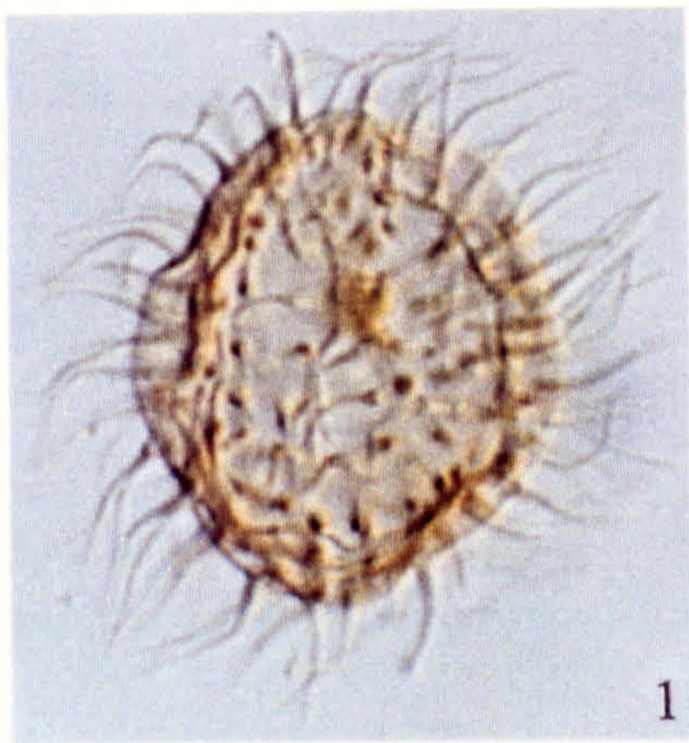
9, 11. *Litosphaeridium* sp. *cf. L. siphoniphorum* Davey & Williams 1966b; emend. Lucas-Clark 1984 var.*siphoniphorum* Lucas-Clark 1984: DOE 4 (K41). **9.** Lateral view; low focus displaying the apical archaeopyle margin and the intratabular simple, tubular processes. **11.** Oblique lateral view: high focus showing the postcingular and antapical region.

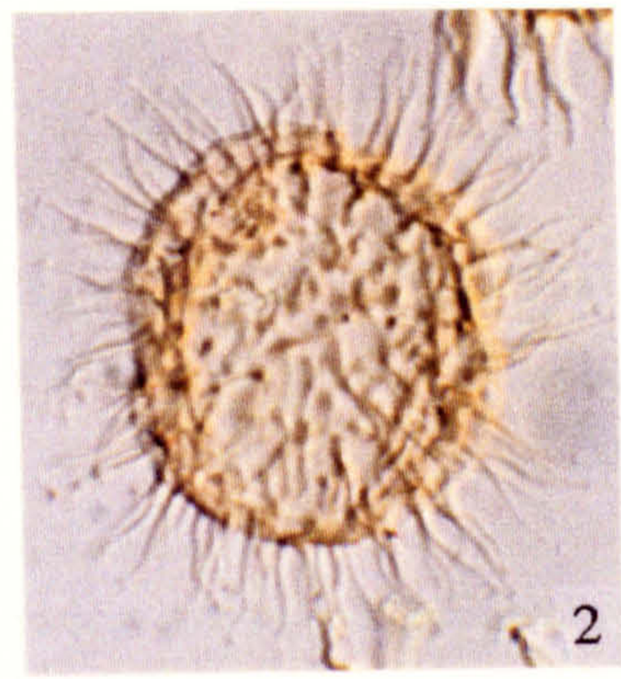
10. *Dapsilidinium laminaspinosum* (Davey & Williams 1966b) Lentin & Williams 1981: BH 5 Ao1 (A51-3). Lateral view; high focus displaying the apical archaeopyle margin and the cylindrical processes that expand slightly distally.

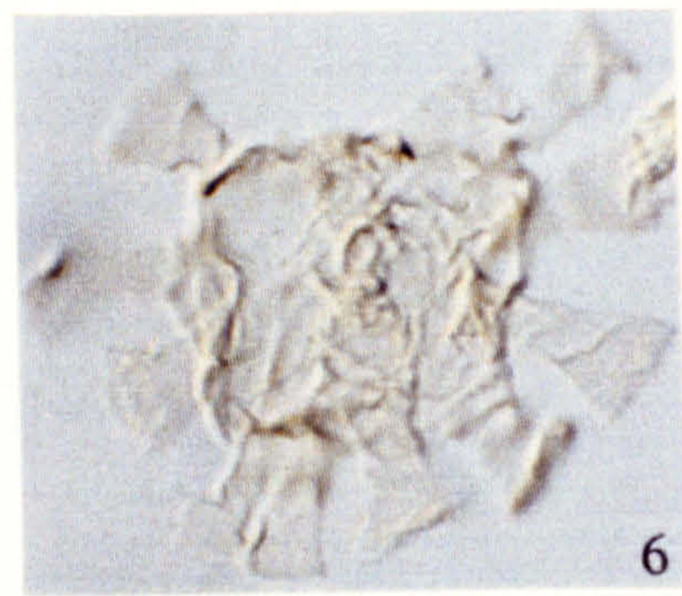
12. *Pervosphaeridium monasteriense* Yun 1981: BH 4 Ao1 (D33). Dorsal view; high focus exhibiting the characteristic 2P archaeopyle. Note the stout truncated processes and the ribbed surface of the cyst.

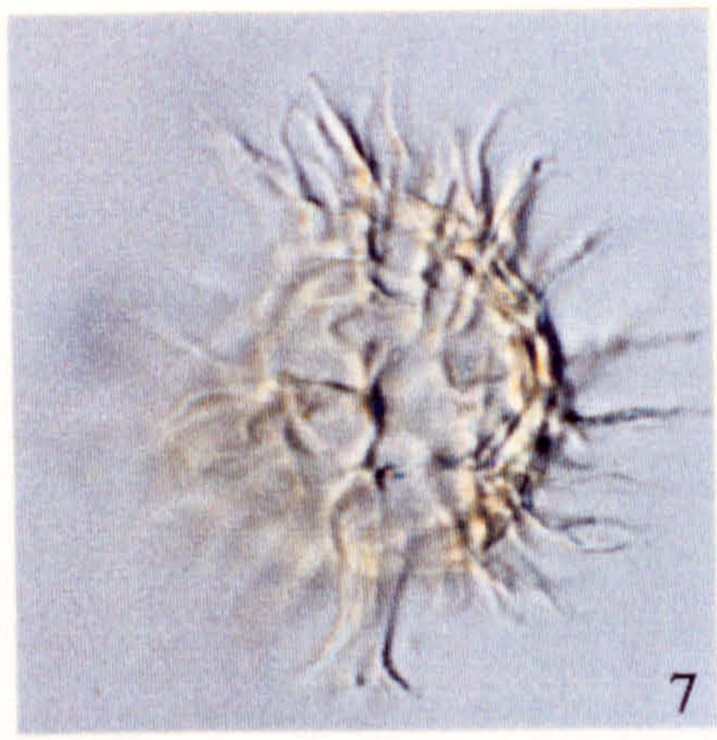
13. *Pervosphaeridium* sp. *cf. pseudhystrichodinium* (Deflandre 1937) Yun 1981: BH 11 Ao2 (B33). Dorsal view; high focus displaying the 2P archaeopyle. Note the tapering, closed processes.

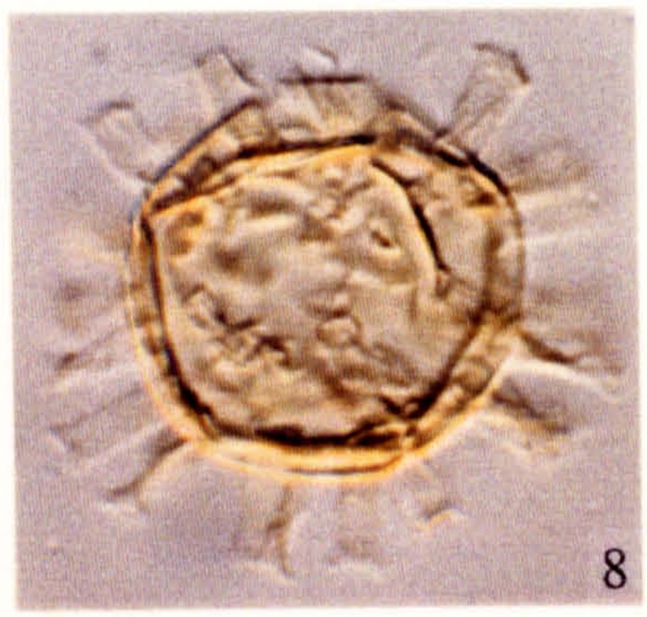
PLATE 14

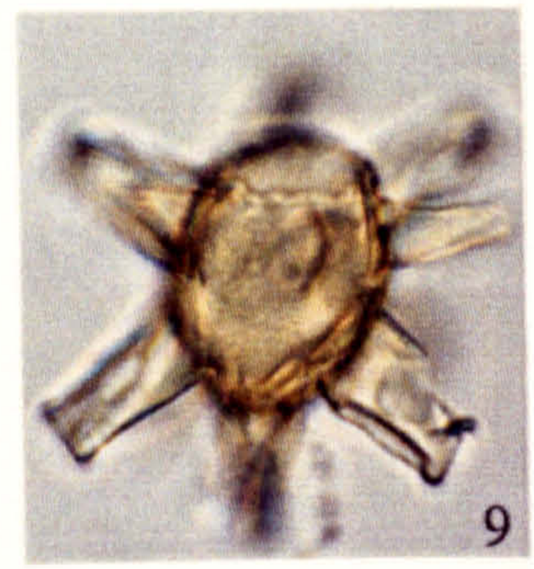


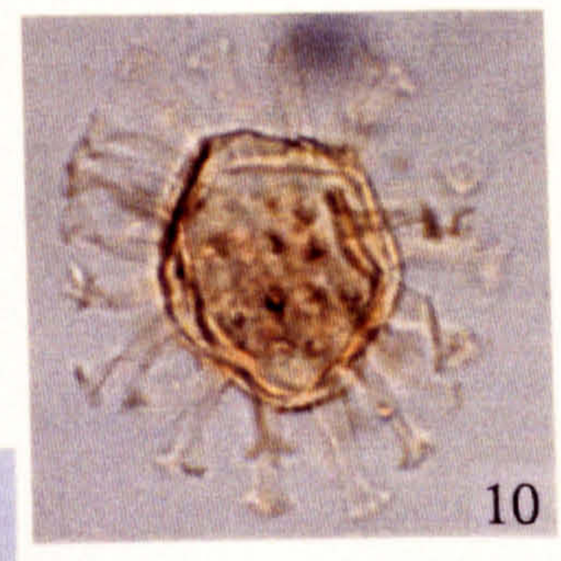


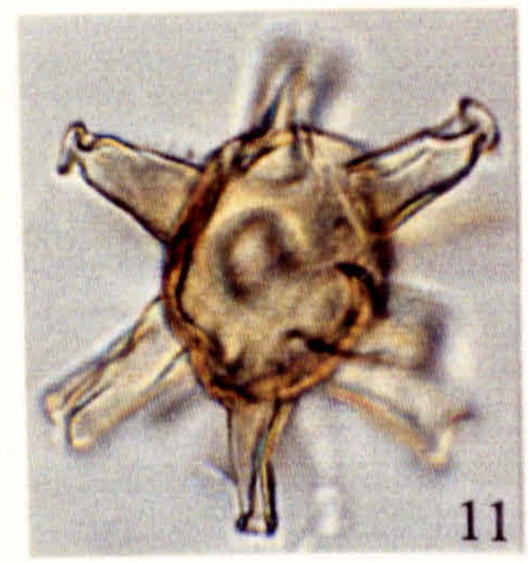


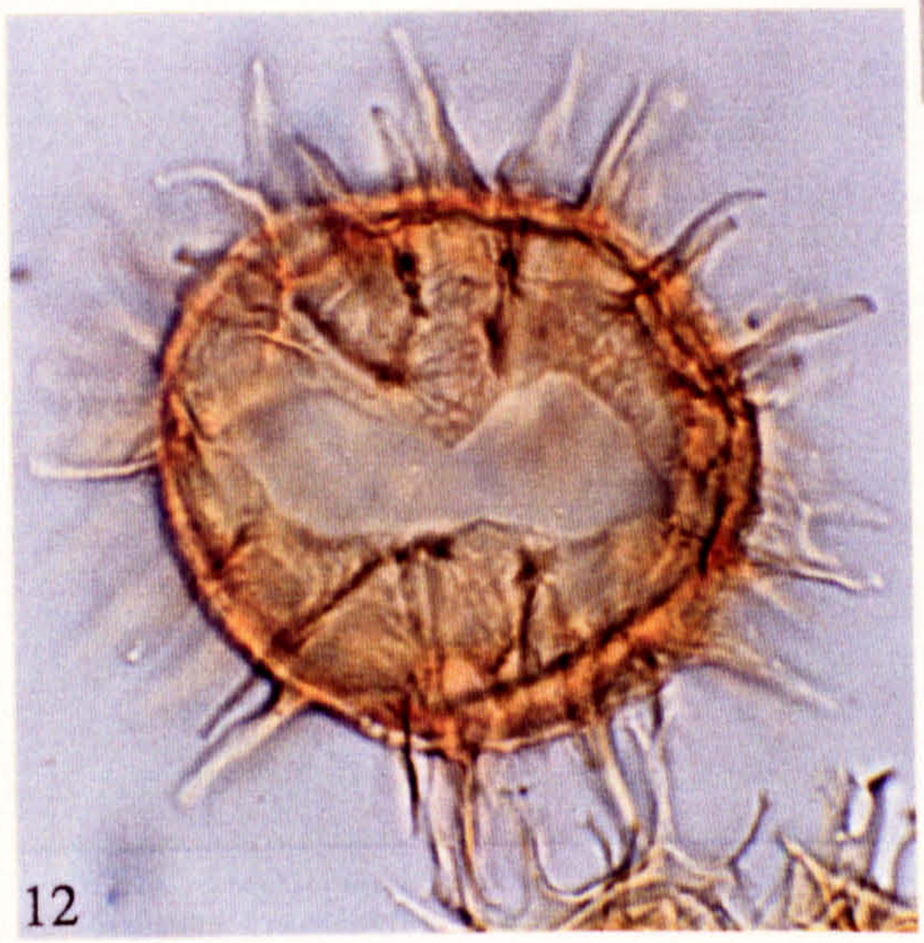












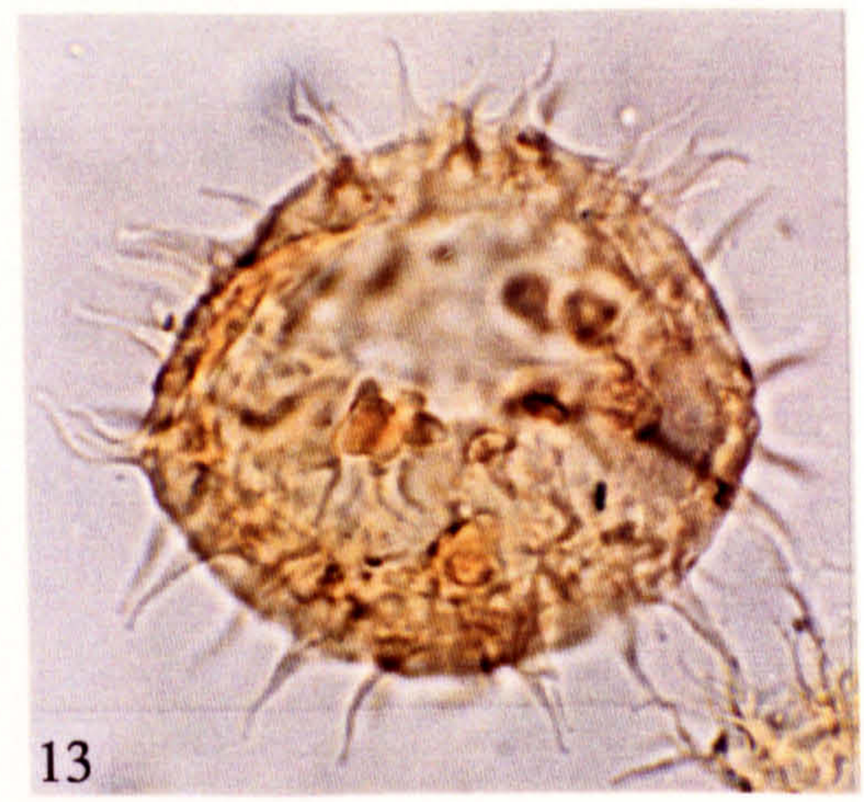


PLATE 15

1. *Heterosphaeridium difficile* (Manum & Cookson 1964) Ioannides 1986: BH 12 (C42). Apical view; high focus displaying the apical archaeopyle and the fibrous, tubular processes.

2. *Heterosphaeridium heteracanthum* (Deflandre & Cookson 1955) Eisenack & Kjellström 1971: BH1 (C32-4). Lateral view; high focus showing the apical archaeopyle and the variable nature of the processes.

3. Operculum of *Heterosphaeridium difficile* BH12 (B47). High focus.

4. *Apteodinium deflandrei* (Clarke & Verdier 1967) emend. Lucas-Clark 1987: CH 3 Ao3 (D41-4). Dorsal view; high focus showing the precingular archaeopyle, and the fibrous apical horn.

5, 8. *Exochosphaeridium* sp. *cf. arnace* Davey & Verdier 1973: BH 6 (H49-2). **5.** Oblique dorsal view; low focus displaying the precingular archaeopyle. **8.** Ventral view; high focus showing the non-tabular fine ornament which coalesces proximally.

6. *Exochosphaeridium phragmites* Davey *et al.* 1966: DOE 11 (W40-1). Oblique dorsal view; high focus displaying the precingular archaeopyle; note the discrete fibrous processes and the thick cyst wall.

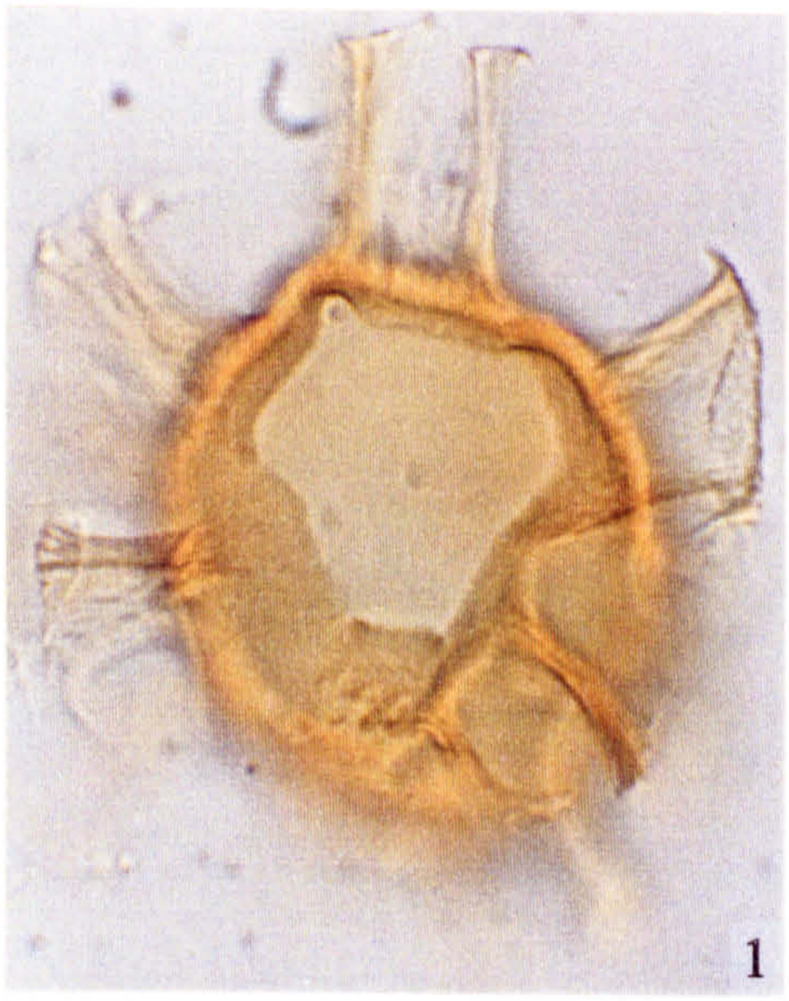
7, 10. *Ellipsodinium rugulosum* Clarke & Verdier 1967: DOE 8(i) (H47). **7.** Oblique dorsal view; low focus showing the precingular archaeopyle. **10.** Ventral view; high focus displaying the elongate nature of the reticulum from apex to antapex.

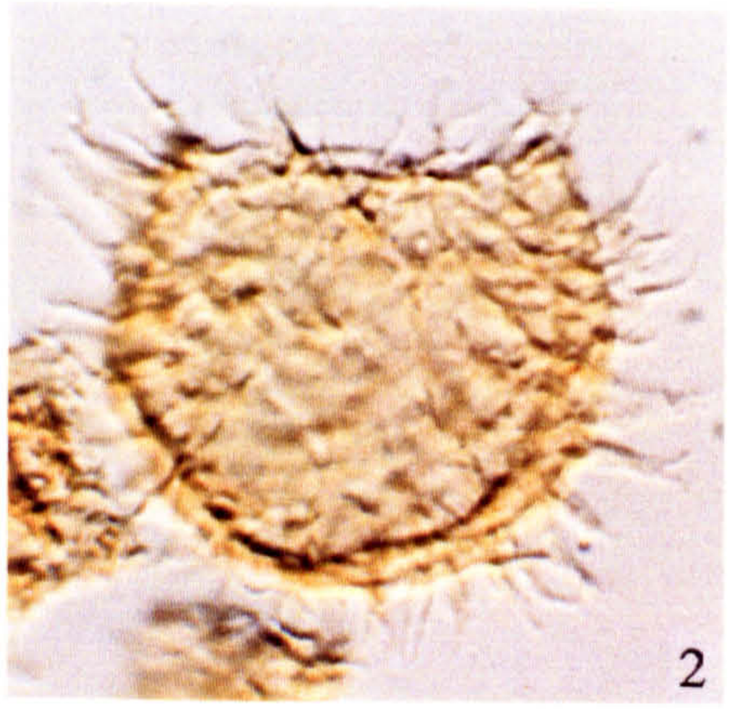
9. *Batiacasphaera euteiches* (Davey 1969) Davey 1979: DOE 1 (T37-1). Left lateral view; high focus displaying the thick, rough cyst wall with the operculum still attached. (Magnified × 338).

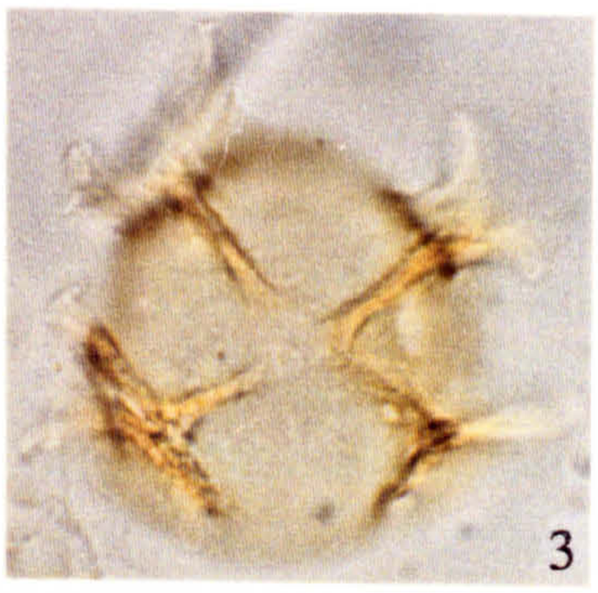
11. *Batiacasphaera euteiches* (Davey 1969) Davey 1979:LS 9 (D46). Apical view; high focus showing the apical archaeopyle with the parasulcal notch. (Magnified × 338).

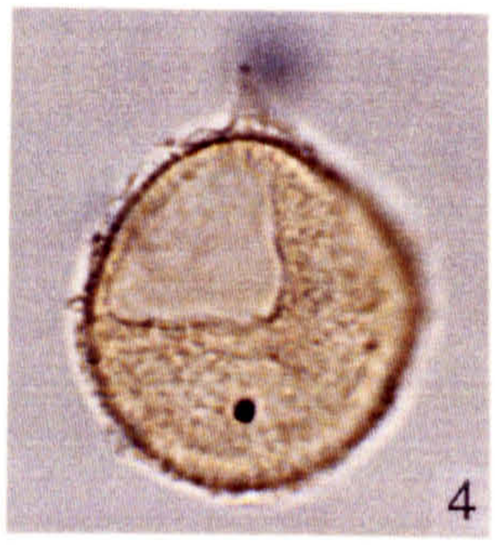
12, 13. *Trichodinium castanea* (Deflandre 1935) Clarke & Verdier 1967: BH4 Ao1 (E29). **12.** Oblique dorsal view; high focus displaying the reduced precingular archaeopyle. **13.** Ventral view; low focus showing some penitabular alignment of the ornament, defining the paracingulum and parasulcal area.

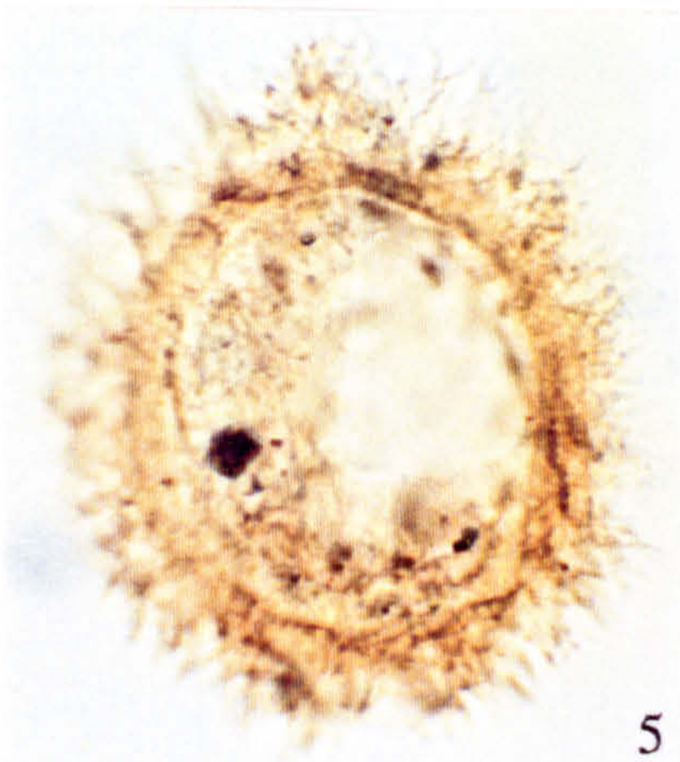
PLATE 15

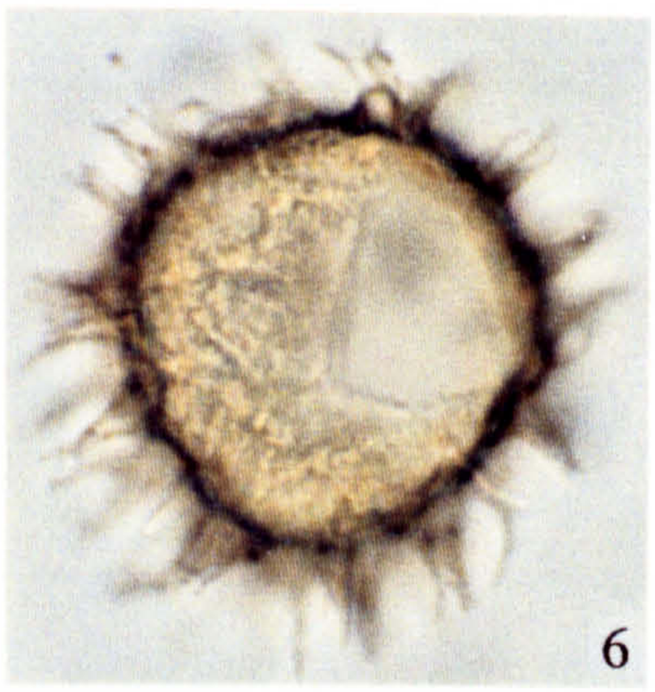


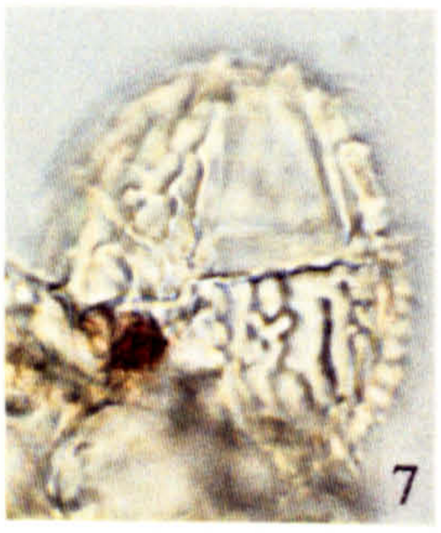


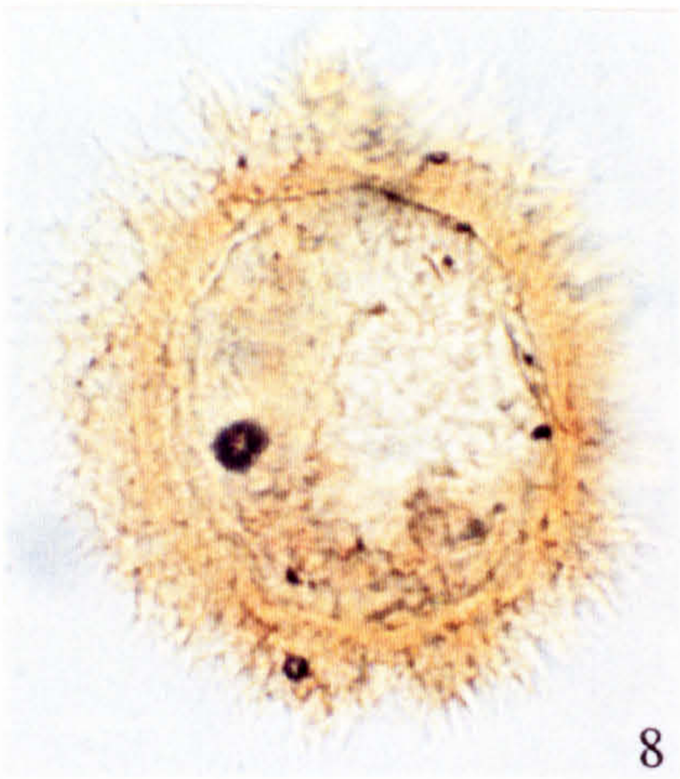


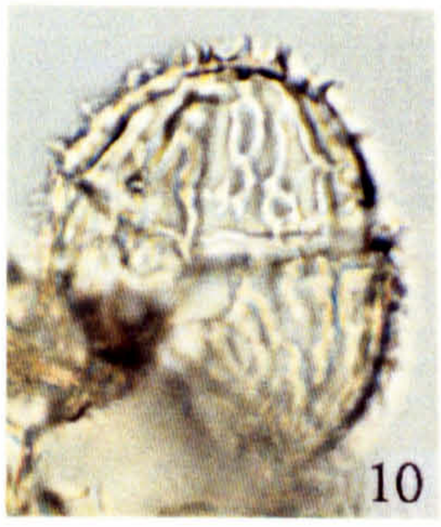


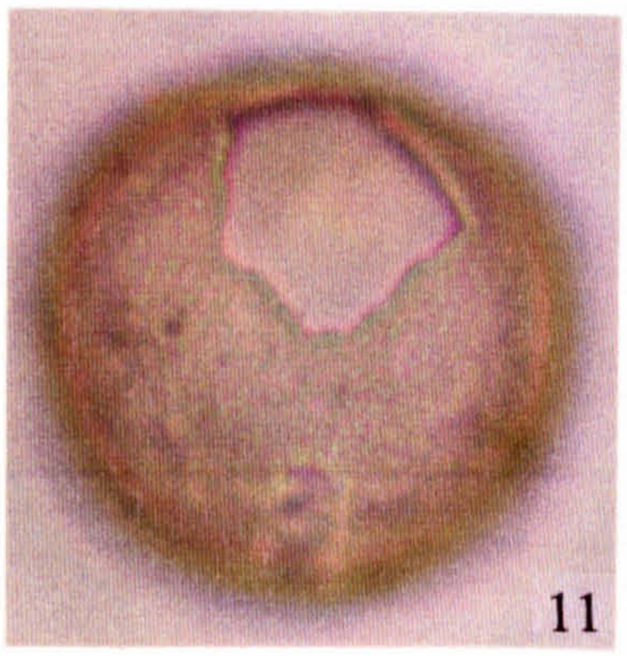


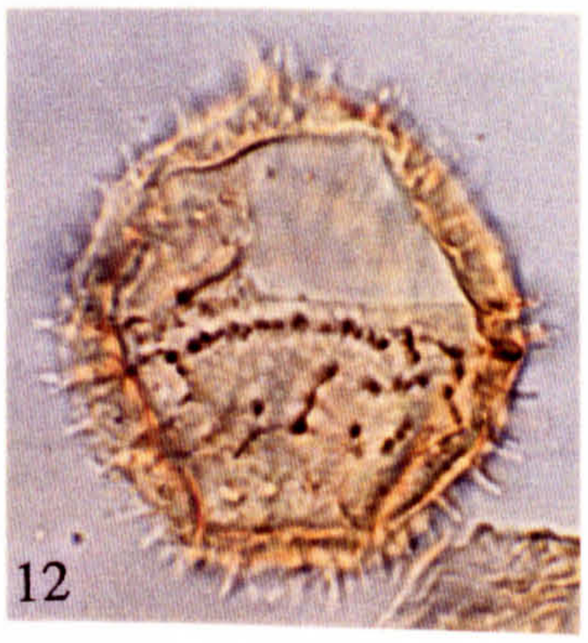












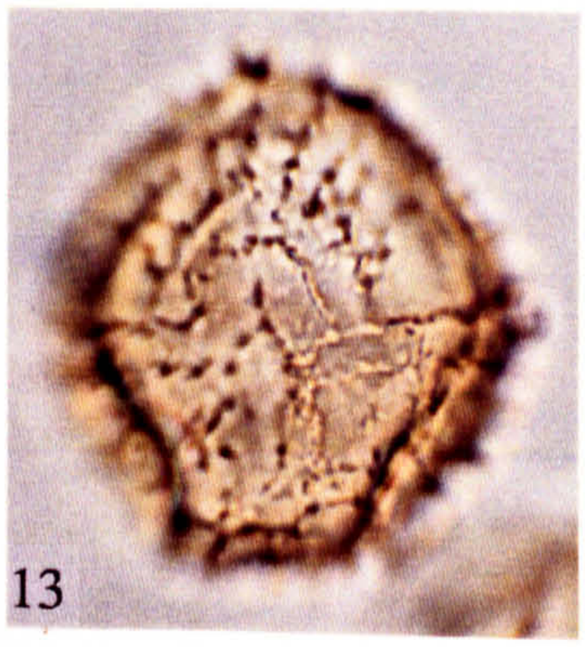


PLATE 16

1, 2. *Prolixosphaeridium conulum* Davey 1969: BH 2 (V55). **1.** Lateral view; low focus showing the apical archaeopyle and the granular surface of the cyst. **2.** High focus to show the hollow, conical processes; note the arrangement of the processes in rows around the cyst.

3. *Tanyosphaeridium variecalamus* Davey & Williams 1966b: BH 6 (C31). Lateral view; high focus displaying the cylindrical, open nature of the processes.

4, 7. *Tanyosphaeridium variecalamus* Davey & Williams 1966b: LS 11 (E50). **4.** Lateral view; high focus, to show the archaeopyle margin. **7.** Lateral view; low focus, displaying the arrangement of the processes in rows.

5. *Wallodinium anglicum* (Cookson & Hughes 1964) Lentin & Williams 1973: BH 11 (N56-1). Lateral view; low focus showing the apical archaeopyle, elongate pericyst with an ellipsoidal endocyst.

6. *Wallodinium anglicum* (Cookson & Hughes 1964) Lentin & Williams 1973: BH 6 (C31). Lateral view; high focus displaying the apical archaeopyle.

8. *Leberidocysta chlamydata* (Cookson & Eisenack 1962) Stover & Evitt 1978: 1962 SPT 4 Ao2 (A37-3). Dorsal view; high focus exhibiting the apical archaeopyle and the granular endocyst.

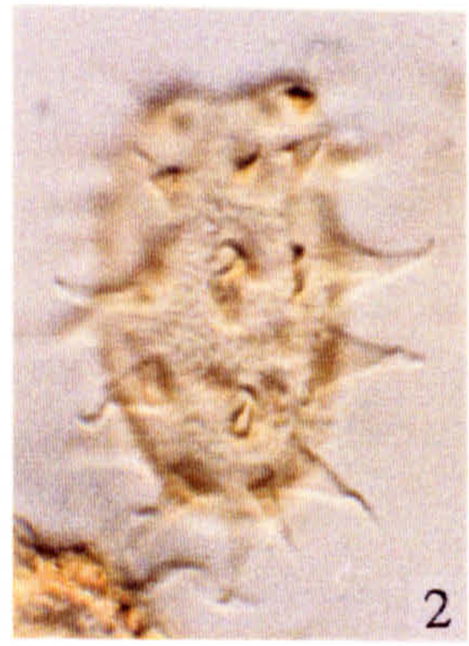
9. *Leberidocysta chlamydata* (Cookson & Eisenack 1962) Stover & Evitt 1978: BH 3 (H38). Dorsal view; low focus showing the apical archaeopyle margin and the holocavate nature of the cyst.

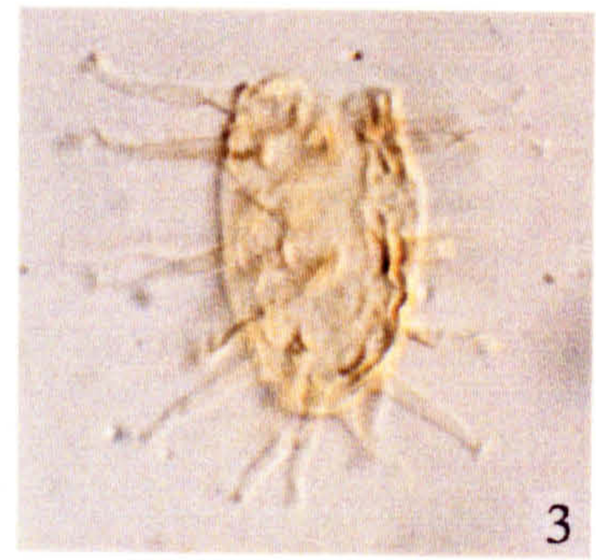
10, 13, 14. *Cassiculosphaeridia reticulata* Davey 1969:BH 6 (D60). **10.** Ventral view; high focus, showing the apical archaeopyle margin and the parasulcal notch. **13.** Dorsal view; low focus, exhibiting the reticulate nature of the cyst. **14.** Median focus, showing the height of the reticulum above the endocyst.

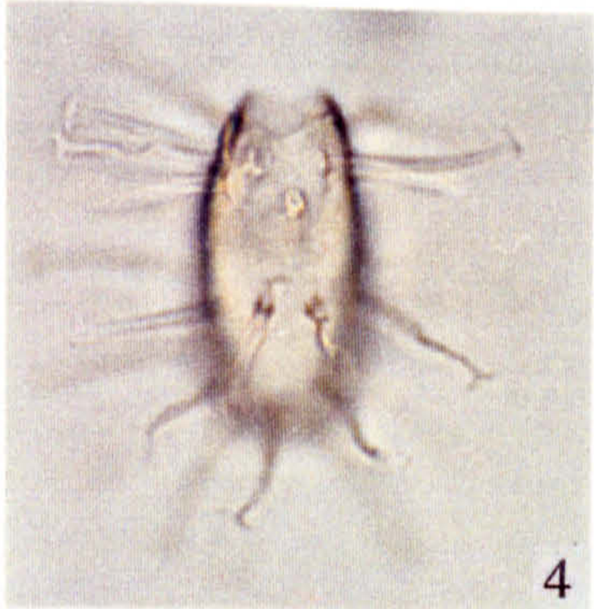
11. *Leberidocysta defloccata* (Davey & Verdier 1973) Stover & Evitt 1978: BH 1 Ao2 (R59). Apical view; high focus displaying the apical archaeopyle margin.

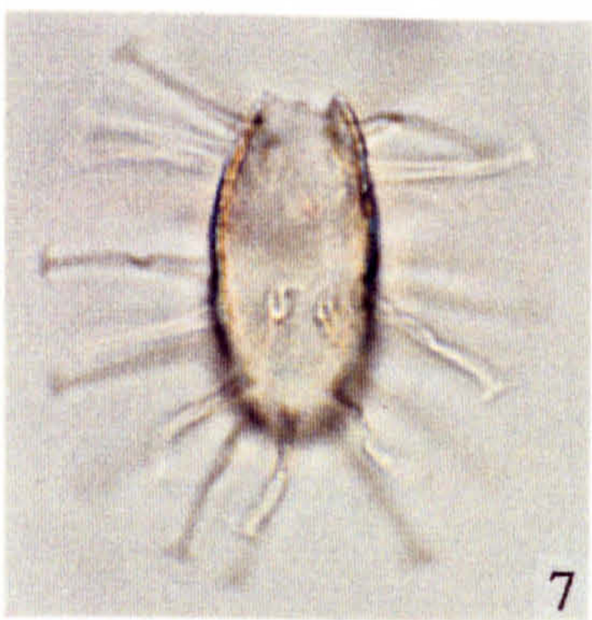
12. *Leberidocysta defloccata* (Davey & Verdier 1973) Stover & Evitt 1978: BH 2 (H60-2). Lateral view; low focus showing the smooth endocyst and the holocavate nature of the cyst.

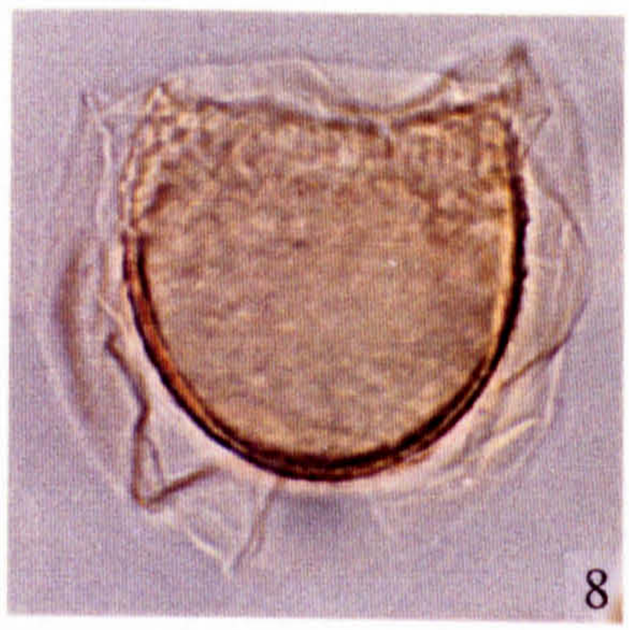
PLATE 16

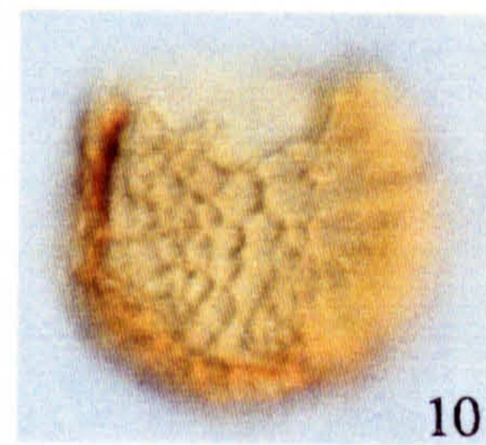


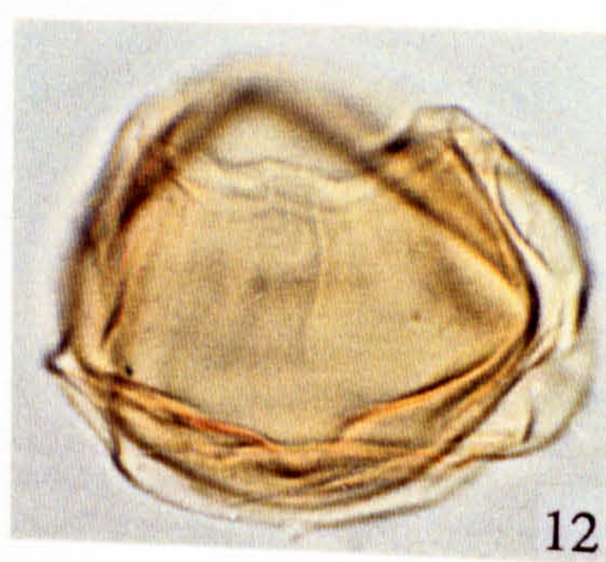


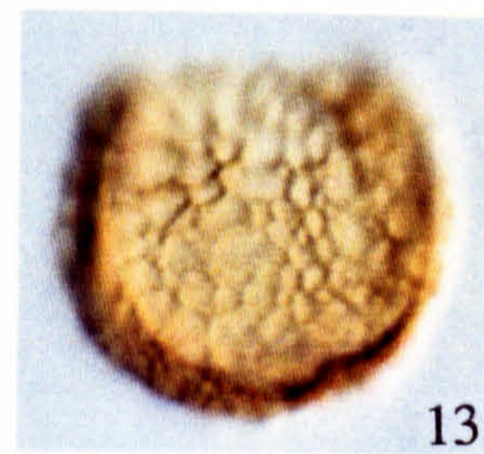












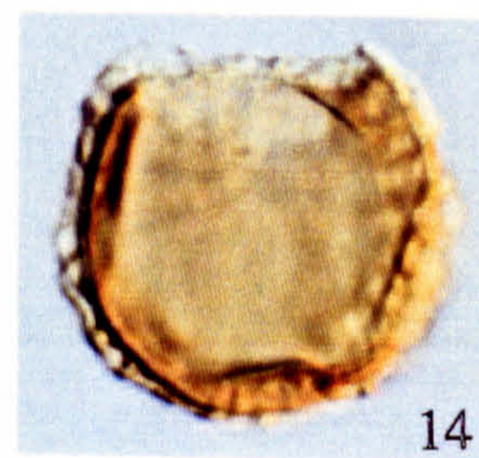
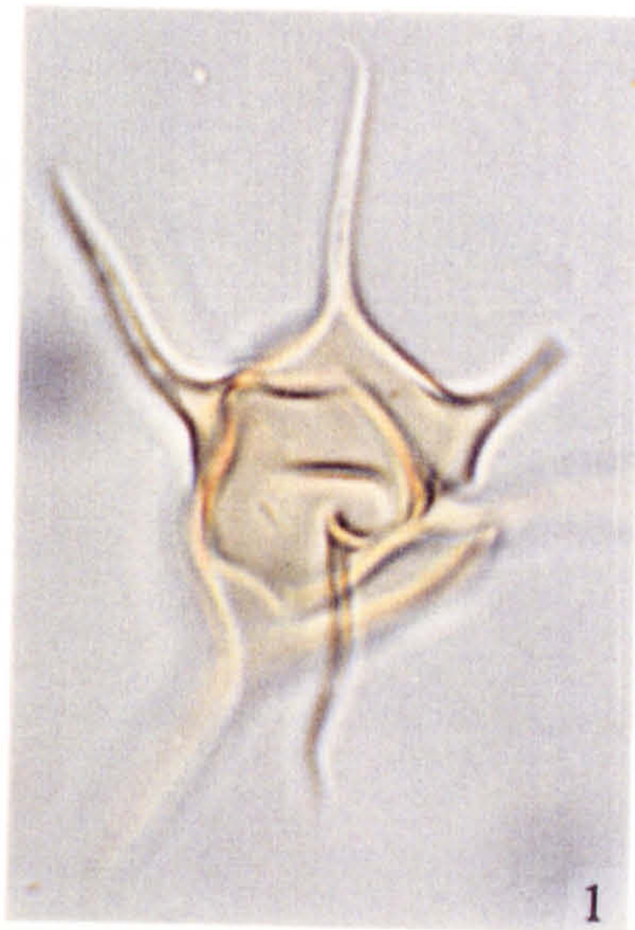


PLATE 17

1. *Veryhachium* sp. BH 12 (F61). Oblique view; high focus.
2. Foraminiferal test lining CB1 27 (K31-1). Lateral view; high focus.
3. Bisaccate pollen BH 12 (F30). High focus.
4, 6. Silicified foraminifera AS 47 (N57-1), (T34-3). High focus.
5. *Pterospermopsis* sp. HW 10 Ao1 (L34). High focus.

PLATE 17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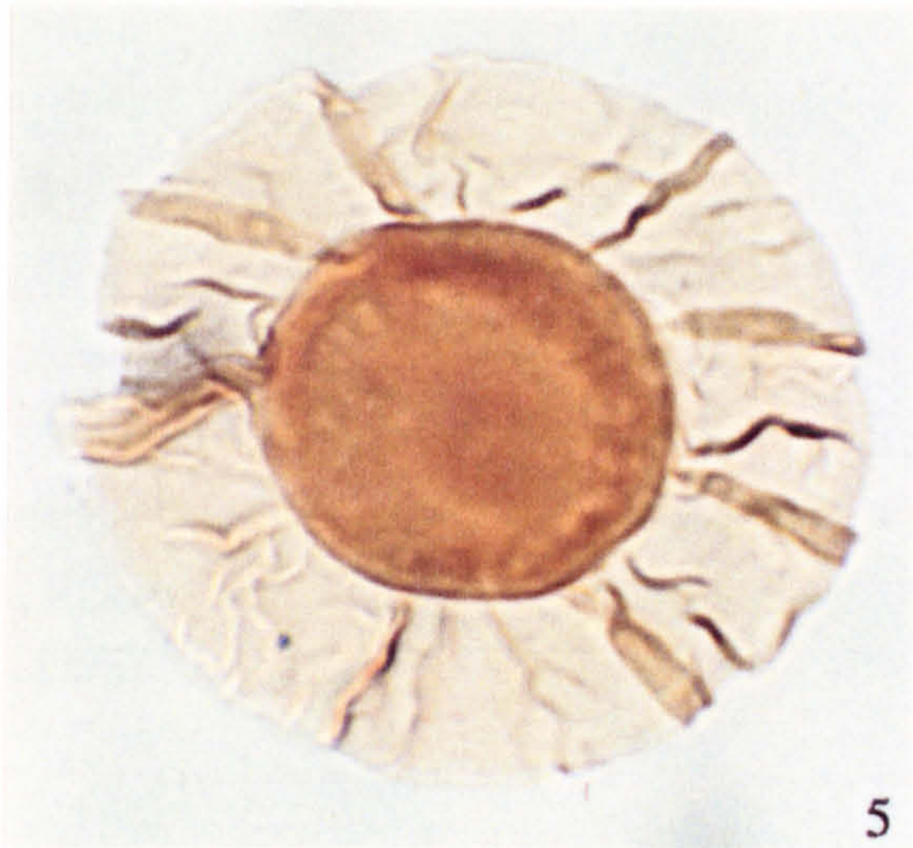
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6

APPENDIX 1 SAMPLING DETAILS

Details of sampling from the sections at Dover, Sussex and the Isle of Wight.

DOVER

Akers Steps	Lithology	Measurement
AS1	Chalk	0.55 m above the highest hardground in the basal beds of the Melbourn Rock Beds
AS2	Chalk	1.40 m above AS1
AS3	Chalk	0.80 m above AS2
AS4	Marl	0.80 m above AS3
AS5	Marl	1.35 m above AS4
AS6	Chalk	1.00 m above AS5
AS7	Chalk	1.10 m above AS6
AS8	Marl	0.65 m above AS7
AS9	Chalk	0.80 m above AS8
AS10	Chalk	0.75 m above AS9
AS11	Chalk	1.10 m above AS10
AS12	Marl	0.90 m above AS11
AS13	Chalk	1.45 m above AS12
AS14	Chalk	1.45 m above AS13
AS15	Chalk	1.20 m above AS14
AS16	Good marl	1.10 m above AS15
AS17	Marl	1.35 m above AS16
AS18	Chalk	1.65 m above AS17
AS19	Chalk	1.80 m above AS18
AS20	Chalk	2.10 m above AS19
AS21	Good marl	2.10 m above AS20
AS22	Chalk	0.55 m above AS21
AS23	Marl	1.18 m above AS22
AS24	Chalk	0.75 m above AS23
AS25	Chalk	0.45 m above AS24
AS26	Good marl	0.18 m above AS25

AS27	Chalk	0.80 m above AS26
AS28	Chalk	1.15 m above AS27
AS29	Chalk	1.00 m above AS28
AS30	Marl	1.40 m above AS29
AS31	Chalk	1.05 m above AS30
AS32	Chalk	1.00 m above AS31
AS33	Marl	1.30 m above AS32
AS34	Good marl	0.45 m above AS33
AS35	Chalk	0.55 m above AS34
AS36	Chalk	0.45 m above AS35
AS37	Chalk	1.00 m above AS36
AS38	Marl	0.20 m above AS37
AS39	Chalk	0.30 m above AS38
AS40	Marl	0.35 m above AS39
AS41	Chalk	1.00 m above AS40
AS42	Marl	1.00 m above AS41
AS43	Marl	0.55 m above AS42
AS44	Flint	1.65 m above AS43
AS45	Chalk	1.60 m above AS44
AS46	Chalk	0.80 m above AS45
AS47	Chalk	1.45 m above AS46
AS48	Chalk	1.40 m above AS47
AS49	Chalk	0.80 m above AS48
AS50	Flint	0.70 m above AS49
AS51	Marly chalk	0.90 m above AS50
AS52	Marl	1.00 m above AS51
AS53	Marl	1.30 m above AS52
AS54	Flint	0.75 m above AS53
AS55	Marl	1.15 m above AS54
AS56	Marl	1.25 m above AS55
AS57	Marl	0.70 m above AS56
AS58	Marl	1.20 m above AS57
AS59	Chalk	1.00 m above AS58
AS60	Chalk	0.86 m above AS59
AS61	Marl	0.90 m above AS60
AS62	Chalk	0.75 m above AS61
Langdon Stairs		
LS1	Good marl	Langdon Bay Marl 1
LS2	Marl	0.65 m above LS1

LS3	Marl	0.80 m above LS2
LS4	Good marl	0.75 m above LS3
LS5	Marl	1.20 m above LS4
LS6	Chalk	1.75 m above LS5
LS7	Chalk	0.50 m above LS6
LS8	Chalk	0.80 m above LS7
LS9	Flint	at the same level as LS8
LS10	Chalk	1.20 m above LS8
LS11	Flint	at the same level as LS10
LS12	Chalk	1.10 m above LS10
LS13	Good marl	0.50 m above LS12
LS14	Chalk	1.00 m above LS13
LS15	Marl	0.80 m above LS14
LS16	Chalk	0.95 m above LS15
LS17	Chalk	0.95 m above LS16
LS18	Chalk	1.00 m above LS17
LS19	Good marl	1.13 m above LS18
LS20	Chalk	0.15 m above LS19
LS21	Marl	0.90 m above LS20
LS22	Chalk	0.54 m above LS21
LS23	Chalk	0.54 m above LS22
LS24	Chalk	0.90 m above LS23
LS25	Marl	0.68 m above LS24
LS26	Chalk	1.15 m above LS25
LS27	Chalk	4.10 m above LS26
LS28	Chalk	0.65 m above LS27
LS29	Chalk	1.00 m above LS28
LS30	Good marl	0.60 m above LS29
LS31	Chalk	1.00 m above LS30
LS32	Marl	1.00 m above LS31

DOVER OVERLAP

AKS2/1	Chalk	1.20 m below Langdon Bay Marl 1
AKS2/1F	Flint	at the same level as AKS2/1F
AKS2/2	Good marl	at the level of Langdon Bay Marl 1
AKS2/3	Flaser marl	0.80 m above AKS2/2
AKS2/4	Thin flaser marl	0.60 m above AKS2/3
AKS2/5	Good marl	at the level of Langdon

		Bay Marl 2
AKS2/6	Thin marl	1.10 m above AKS2/6
DOE1	Chalk	10.0 m below Langdon Bay Marl 1
DOE2	Chalk	1.00 m above DOE1
DOE2F	Flint	at the same level as DOE2
DOE3	Thin marl	1.00 m above DOE2
DOE4	Thin marl	1.20 m above DOE3
DOE5	Chalk	0.90 m above DOE4
DOE5F	Flint	at the same level as DOE5
DOE6	Marl	0.60 m above DOE5
DOE7	Marl	0.55 m above DOE6
DOE8	Thin marl	1.30 m above DOE7
DOE9	Chalk	1.50 m above DOE8
DOE9F	Flint	at the same level as DOE9
DOE10	Chalk	0.80 m above DOE9
DOE11	Good marl	0.50 m above DOE10
DOE12	Flaser marl	0.80 m above DOE11
DOE13	Thin flaser marl	0.60 m above DOE12
DOE14	Good marl	0.80 m above DOE13
DOE15	Chalk	1.00 m above DOE14
SUSSEX		
Holywell Steps		
HW1	Marl	1.35 m above the base of the Melbourn Rock Beds
HW2	Marl	0.75 m above HW1
HW3	Marl	0.40 m above HW2
HW4	Marl	0.60 m above HW3
HW5	Marl	0.36 m above HW4
HW6	Chalk	0.55 m above HW5
HW7	Chalk	0.25 m above HW6
HW8	Marl	0.35 m above HW7
HW9	Marl	0.23 m above HW8
HW10	Chalk	0.85 m above HW9
HW11	Flaser marl	1.65 m above HW9
HW12	Nodular chalk	0.50 m above HW11
HW13	Flaser marl	0.70 m above HW12
HW14	Chalk	0.25 m above HW13
HW15	Flaser marl	0.30 m above HW14

HW16	Chalk	0.85 m above HW15
Southerham Machine Bottom		
SO1	Marl	0.65 m above the second of two strong flaser marls
SO2	Marl	1.0 m above SO1
SO3	Marl	0.90 m above SO2
SO4	Marly chalk	0.50 m above SO3
Fault		
SO5	Marl	
SO6	Marl	0.50 m above SO5
SO7	Flaser marl	0.90 m above SO6
SO8	Chalk	0.25 m above SO7
SO9	Flaser marl	0.25 m above SO8
SO10	Flaser marl	0.50 m above SO9
SO11	Flaser marl	1.50 m above SO10
SO12	Thin marl	0.25 m above SO11
SO13	Marl	0.40 m above SO12
SO14	Chalk	0.75 m above SO12
SO15	Flaser marl	0.80 m above SO14
SO16	Chalk	0.80 m above SO15
SO17	Flaser marl	0.75 m above SO16
SO18	Flaser marl	0.90 m above SO17
SO19	Chalk	0.40 m above SO18
SO20	Chalk	0.60 m above SO19
SO21	Weak marl	1.20 m above SO20
SO22	Flaser marl	0.50 m above SO21
SO23	Chalk	0.55 m above SO22
SO24	Thin marl	1.30 m above SO22
SO25	Chalk	0.80 m above SO24
SO26	Marl	0.75 m above SO25
Beachy Head		
BH1	Thick marl (20 cms)	Abundant *Inoceramus cuvieri*, and *Terebratulina lata*.
BH2	Good thin marl	0.55 m below BH1
BH3	Chalk	3.10 m below BH2
BH4	Chalk	1.50 m below BH3
BH5	Flaser marl	1.30 m below BH4
BH6	Marl	1.80 m below BH5
BH7	Marl	1.50 m below BH6

BH8	Chalk	0.70 m below BH7
BH9	Marl	0.90 m below BH8
Unexposed due to rock fall.		
BH10	Good marl	15m approximately below BH9
BH11	Flaser marl	1.70 m above BH10
BH12	Chalk	0.90 m above BH11
New Pit		
NP1	Thick marl (20 cms)	with two weak marls below.
NP2	Chalk	0.60 m above NP1
NP3	Marl	0.42 m below NP1
NP4	Chalk	1.80 m above NP1
NP5	Marl	0.70 m above NP4
NP6	Flaser marl	1.15 m above NP5
NP7	Broad flaser marl	0.65 m above NP6
NP8	Chalk	1.40 m above NP7
NP9	Thick marl	0.10 m above NP8
Unexposed for an estimated 5 metres; section grassed over.		
NP10	Good marl	New Pit Marl 1 exposed at the base of the section
NP11	Marly chalk	0.30 m above NP10
NP12	Good marl	0.30 m above NP11
NP13	Marl	0.15 m above NP12
NP14	Marl	0.46 m above NP13
NP15	Marl	0.70 m above NP14
NP16	Marl	0.48 m above NP15
NP17	Marl	0.36 m above NP16
NP18	Marl	1.80 m above NP17
NP19	Chalk	0.35 above NP18
NP20	Flaser marl	0.30 m above NP20
NP21	Flint	0.80 m above NP20
NP22	Flaser marl	1.79 m above NP21
NP23	Chalk	1.60 m above NP22
NP24	Thin marl	0.45 m above NP23
NP25	Chalk	0.70 m above NP24
NP26	Chalk	0.90 m above NP25
NP27	Good marl	0.20 m above NP26
NP28	Good marl	0.10 m above NP28
NP29	Flaser marl	0.55 m above NP28
NP30	Good marl	0.25 m above NP29

NP31	Chalk	0.30 m above NP30
NP32	Weak flaser marl	0.35 above NP31
NP33	Chalk	0.95 m above NP32
NP34	Marl	0.55 m above NP33
NP35	Chalk	0.30 m above NP34
NP36	Chalk	0.50 m above NP35
NP37	Marl	1.10 m above NP35
NP38	Chalk	2.00 m above NP37
NP39	Flint	1.65 m above NP38
NP40	Chalk	0.30 m above NP39
NP41	Flint	1.35 m above NP40
NP42	Chalk	0.45 m above NP41
NP43	Good marl	1.10 m above NP42
NP44	Flint	0.95 m above NP43
NP45	Chalk	0.56 m above NP44
NP46	Flint	1.30 m above NP45
Caburn Pit		
CA2	Chalk	1.00 m above good marl (20 cms.)
CA3	Chalk	0.50 m above CA2
CA4	Chalk	0.95 m above CA3
CA5	Chalk	0.48 m above CA5
CA6	Chalk	1.30 m above CA5
CA7	Good marl	0 .20 m above CA6
CA8	Chalk	0.50 m above CA7
CA9	Chalk	0.45 m above CA8
CA10	Chalk	0.50 m above CA9
Inaccessible part of the section for approximately 2m.		
CA11	Thin marl	2.10 m above CA10
CA12	Good marl	3.15 m above CA11
CA13	Good marl	0.60 m above CA12
CA14	Chalk	0.75 m above CA13
Southern Portal of the Tunnel		
SPT1	Flint	Prominent tabular flint
SPT2	Flint	2.00 m above SPT1
SPT3	Good marl	1.50 m above SPT2
SPT4	Flint	1.00 m above SPT3
SPT5	Marl	2.55 m above SPT4
SPT6	Chalk	1.10 m above SPT5

SPT7	Chalk	1.60 m above SPT6
Chandlers' Yard		
CH1	Chalk	2.50 m above SPT7
CH2	Chalk	0.95 m above CH1
CH3	Chalk	1.10 m above CH2
CH4	Flint	0.20 m above CH3
CH5	Marl	0.54 m above CH4
CH6	Chalk	2.30 m above CH5
CH7	Chalk	0.42 m above CH6
CH8	Chalk	1.85 m above CH7
CH9	Good marl	1.20 m above CH8
CH10	Chalk	0.50 m above CH9

ISLE OF WIGHT

Compton Bay

CB1-26	Good marl approximately 1 metre above the Melbourn	
Rock Beds		
CB1-27	Good marl	0.60 m above CB1-26
CB1-28	Chalk	1.40 m above CB1-27
CB1-29	Good marl	1.10 m above CB1-28
CB1-30	Marl	1.45 m above CB1-29
CB1-31	Chalk	1.40 m above CB1-30
CB1-32	Chalk	1.25 m above CB1-31
Poorly exposed.		
CB1-33	Chalk	1.80 m above CB1-32
Unexposed part of the section.		
CB1-34	Chalk	at the base of the section
CB1-35	Marl	2.00 m above CB1-34
CB1-36	Flaser marl	1.10 m above CB1-35
CB1-37	Chalk	1.40 m above CB1-36
CB1-38	Good marl	1.70 m above CB1-37
CB1	Marl	0.95 m below the Spurious Chalk
Rock		
CB2	Chalk	1.10 m below CB1
CB10	Thin marl	Approximately 5.00 m below
the Spurious Chalk Rock		
CB11	Flaser marl	0.55 m below CB10
CB12	Marl	1.05 m below CB11
CB13	Good marl	0.75 m below CB12

CB14	Marl	0.85 m below CB13
CB15	Good marl	0.70 m below CB14
CB16	Marl	1.65 m below CB15
CB17	Chalk	1.40 m below CB16
CB18	Good marl	0.70 m below CB17
CB19	Marl	1.40 m below CB18
CB20	Marl	1.30 m below CB19
CB21	Good marl	1.50 m below CB20
CB22	Marl	1.20 m below CB21
CB23	Marl	1.10 m below CB22
CB24	Marl	1.00 m below CB23
CB25	Marl	0.95 m below CB24
CB26	Good marl	1.10 m below CB25
CB27	Marl	1.40 m below CB26
CB28	Good marl	1.25 m below CB27
CB29	Good marl	0.65 m below CB28
CB30	Marl	1.55 m below CB29
CB31	Good marl	0.85 m below CB30
CB32	Good marl	1.25 m below CB31
CB33	Marl	0.75 m below CB32
CB34	Chalk	1.00 m below CB33
CB35	Chalk	1.00 m below CB34
CB40	Chalk	1.55 m below the Spurious Chalk
Rock (S.C.R.)		
CB41	Good marl	1.00 m below CB40
CB42	Marl	0.95 m below CB41
CB43	Chalk	0.85 m below CB42
CB44	Marl	1.10 m below CB43
CB45	Good marl	0.50 m below CB44
Military Road		
MR1	Chalk	0.50 m below the S.C.R.
MR2	Chalk	0.20 m above the S.C.R.
MR3	Chalk	1.50 m above the S.C.R.
MR4	Marl	0.25 m above MR3
MR5	Chalk	1.80 m above MR4
MR6	"Black" marl	2.70 m above MR3
MR7	Chalk	1.25 m above MR6
MR8	Flint	1.10 m above MR7
MR9	Marl	0.90 m above MR8

MR10	Chalk	1.25 m above MR9
MR11	Chalk	1.80 m above MR10
MR12	Chalk	1.00 m above MR11
MR13	Flint	at the same level as MR12
MR14	Chalk	1.20 m above MR13
MR15	Chalk	0.60 m above MR14
MR16	Marl	1.00 m above MR15
MR17	Chalk	1.30 m above MR16
MR18	Chalk	1.00 m above MR17
MR19	Chalk	1.50 m above MR18
MR20	Chalk	1.10 m above MR19
MR21	Chalk	1.55 m above MR20
MR22	Chalk	1.85 m above MR21
MR23	Chalk	0.60 m above MR22
MR24	Chalk	1.90 m above MR23
MR25	Chalk	0.60 m above MR24
MR26	Flint	at the same level as MR25
MR27	Marl	0.80 m above MR26
MR28	Marl	0.40 m above MR27
MR29	Chalk	1.25 m above MR27
MR30	Flint	0.90 m above MR29
MR31	Chalk	1.05 m above MR30
MR32	Chalk	0.60 m above MR31

APPENDIX 2 RAW DATA

Raw Data

The raw data in the form of absolute 'counts' of 300 specimens per slide are given in this appendix. If after a 'count' of 300 specimens the whole slide has not been covered the remainder of the slide is scanned to record any new species not included in the 'count'. The presence of a species on the scanned portion of the slide is denoted by an asterisk (*).

DOVER 1.
1 of 2

AKERS STEPS (AS)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Batacasphaera cutesches				1				1			9	1	37	4	6		1		2														1							1	2																						
Canningia collivien				7			1								3		7		6								8	2	*			2	3			2	1	6			1	22		20	8	3		38	18	2	2		7	4				10	4			2	5
Canningia reticulata				1							1									1		1														1																											
Cleistosphaeridium armatum				1	3						1		1	3	3		4		4	4	4			2				1		1		3			1			4			3	1		7	18	50	5	5				1		3	11	8	8	16	4	3	2	14
Chiroperidinium sp.								1					19	9	24		2	13	9				1	1					259	86	82	15	28	6	27	17	40	242	5	34	107	48	168	279	225	211	284	190	97	50	6	200	289	124	84	114	13	1		5		13
Cyclonephelium distinctum													1		2		2	4	9	3	1	1	9					2	1		4	2					3				1		9	3	1		5	5	9	2	3	12	1				11	4	2	3	6	3
Cyclonephelium membraniphorum																	22		1	2	2	5	2								3	1																														
C. compactum-membraniphorum													1									1																																							
Lapsilidinium laminaspinosum														2			1																											8									3				1				1	4
Florentinia sp.							10				14	3																		2	3	35		7	31	4			2	8	34	53					4	2					4	1			8	1			
Heterosphaeridium difficile				28	1		9												2							1							2	1				8			32						1								39	22	3				
Heterosphaeridium heteracanthum													4	2	2							1		2			3		4	2	10	1						1		1		4	6			4		1	7	1			7			5	5		4	3	2	7
Hystrichosphaeridium bowerbankii													3						1											1										1	38																					
Hystrichosphaeridium anispiniform											1																																																	
H. tubiferum var. brevispinum															6		17						3																																						
Leberidocysta deflorata				1				1			9	1	37	4	6		1		2														1		*	2	1			1	2																					
Odontochitina costata													5														5	2		3	10						2				1	3	6		2					2						2			3				1
Odontochitina operculata A																											17	3	8	15	29	4			8	1	4	13		5	24	10	20	7	8	23	7	14	3	8	4	16	11	46		2	5	9		9	22	2
O. operculata B				5	2		4	6			3		6	5	40		9	2	113	42	20	33	48	61		9	33	20	34	55	19	26	11	1	1	4	5	3	5	6	1		8		6	6	3	1	2	3	1	17	*	1		2	6		4	2	12	7
Oligosphaeridium complex																			2													1			1						4		1	1																		
O. poculum																		1	2	1		2																										1	2			1									
O. prolixispinosum											1		2				1																											1	61			6	4			9	8		2	21	77	127	17	11	36	10
Pervosphaeridium pseudhystrichodinium													•									1							1																																
Polixosphaeridium conulum													5	16	23				11	2	2	4	14	9		1		1		1	1	2	1	1	4	1	3	9		2		1		2	*	2				2	6	2	1					1	2	7		
Senoniasphaera rotundata															*		*		*	*	*	*	*	*		*				*	*	*		*	*			*			*	*	*		*	*	*	*	*	*	*		*		*	*	*	*	*	*		*	*	*
Bisaccate pollen	+	+	+			+	+		+	+	+	+	+					+		+	+					+		+					+	+	+		+	+	+	+		+					+							+							
Silicified Foraminifera																																																														

DOVER 1
2 of 2

	LANGDON STAIRS (LS)																																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Achomosphaera ramulifera	*	2	5	3				1		1						2															
A. reginensis	1	2	9																												
A. sagena	4	2	8	1						4																					
Apteodinium deflandrei				*			1				2						2				1										
Batiacasphaera euteiches									1		1				1		4									2		2	2		
Callaiosphaeridium asymmetricum		6	17					1	1		2																				
Canningia colliveri	3		1	1				1												1								5			
C. reticulata																													47	44	5
? Canningia (Species β)																												58	3		4
Cassiculosphaeridia reticulata	6	9	17	27		2	2	2	5	1		2		1	5	15	20	1	2	9	5	2				2		5	3	4	15
Cleistosphaeridium multispinosum	1	1	18	5			5	1			1	17	1	1	6	15					1	2	9	4	3	8					
C. cf. armatum	7									4	1						1	18	5						3						
Cribroperidinium sp.																									1	1		3			
Cyclonephelium distinctum	150	89	65	17		5	3		8	82	3	9	23	1	4	14	9	2	3	8	1	6	7	10	7	2	14	21	5	11	16
C. membraniphorum	5	7	3	11			4	1	3			2				2	7	1	1	3	4	6	7	5	1		3			4	2
C. complex-membraniphorum																2						4		3						26	31
Dapsilidinium laminaspinosum				*																											
Ellipsodinium rugulosum		5							1		1																				
Endoscrinium campanula	3	4	10	6		1			*		1	2						8													
Eurydinium saxoniensis	7			6			1		6		6		2			1								1	2						
Exochosphaeridium cf arnace																				2			4	4	1						
E. phragmites				23		3		1	4		*		3				7	3		2									1		1
Florentinia buspina	4	8	10	47			1	3	5		2		2			6	4			1											
F. deanei	19	4	4	14		1			*						1	2	1		1	1	3		3	10	6	1	3				
F. ferox	1			*																											
F. torulosa		1	3	5																											
Gonyaulacysta cassidata			1	2				1	11								7	7	1		1	1									
Heterosphaeridium difficile			2					1	1	1														1			1		1		
H. heteracanthum	41																														
Hystrichodinium pulchrum		3	1	4		1					2						4		1												
H. voightii																						1									
Hystrichosphaeridium bowerbankii	18	10	22	14		8	7	12	3		2	4	5	2	2	3	11		7	6	5	1	2	11	7	2	15	1	12	5	12
H. tubiferum		1		8							1												1		13						
Hystrichostrogylon membraniphorum		2	1	1																											
Kiokansium polypes	1						1																								
Kleithriasphaeridium readei	6	2	4	1					1																						
Leberidocysta chlamydata	*																														
L. deflocata		*																					1	1							
Litosphaeridium siph. siph.																							1								
Microdinium ornatum		4	1						1		1																				
M. tuberculatum																1	2						1	7	1		1	1	4		
Odontochitina costata	17					1	4						14	2	8	1	3		4	2			8	3	1	1	7	1		1	
O. operculata A						2	1																								
O. operculata B			1	4		5	7	2	1	1	1	19	5		4	9	7			3		1	5	4	6		16	3	10	3	
Oligosphaeridium complex (O. cf complex)	1	1	4	1		1	2	1	1		1	7	6	1	4	6	4	3	3	5	8	6	16	9	2	3	13	11	7	9	15
O. pocilum						1																								1	
O. prolixispinosum		3	1	1													1					4	4	5			4		2		
Palaeohystrichophora infusorioides	5	106	36	44	2	1	6	38	232		255	4	7		2		2	8	3	1	1										
Pervosphaeridium pseudhystrichodin	31	4	39	38	2	51	7	9	7	12	14	7	45	3	3	9	14	1	2	3					3		1				
P. monasteriense		3	1	1																											
Prolixosphaeridium conulum			1			1						1									1						1				
Pterodinium cingulatum cingulatum	2	6	13	3		1			5		6									1											
Rhiptocoryus veligera									*		1																				
Senoniasphaera rotundata		1	2	2		1	8	5	*				5		1	2	9	1	3	34	2	128	39	30	30	10	77	5	2	2	
Spiniferites ?dentatus		6	18	8					5		1						1														
Sp. multibrevis		15	7	5					1								2	4													
Sp. ramosus gracilis		5	1	4					2		4						1	4													
Sp. ramosus ramosus	*	9	1	6		*			2	*	12					1	*							2					1		
Sp. ramosus reticulata		2		1					1		1																				
Spiniferites sp.	1	7	3	2		1			3																						
Subtilisphaera											4																				
Tanyosphaeridium variecalamus		1															2			1									3		1
Trichodinium castanea		1				1	1		3		3																				
Wallodinium anglicum				*																											
Xenascus ceratioides	*	1		1						1	1	1	2			1	1				1						2		2	1	
Xiphophoridium alatum									2																1					1	
Bisaccate pollen			*	*		*		*	*	*			*			*	*	*													
Silicified Foraminifera					+	+	+	+									+							+		+					

DOVER 2
1 of 1

	LANGDON STAIRS (DOE)																				AKERS STAIRS (AKS)													
	1	2	2F	3	4	5	5F	6	7	8	9	9F	10	11	12	13	14	15			2/1	2/1F	2/2	2/3	2/4	2/5	2/6							
Achomosphaera ramulifera		3	1	1	1					1				3	2			1																
A. reginensis		1	1									2					2																	
A. sagena					4		1		2	1		1		1	4		3																	
Apteodinium deflandrei							1					4			1																			
Batiacasphaera extriches	15	6	3	3	2	2	1	2	4	2	3		2		1	*	11				2			2	1		15							
Callaiosphaeridium asymmetricum		*	2		2				*			2		2			2	1																
Canningia collivier	1				3			2						1		2						4	1			7	1							
C. reticulata					*			*				3																						
Canningia sp. B					*																													
Cassiculosphaeridia reticulata	2	2	1		5	1	5	4	4	1				1	3	5	17																	
Cleistosphaeridium multispinosum	14	12		8	6	5		6	4	6	19	11	4	8	5	6	5	1			6	2	6	3	1	2	30							
C. armatum			1							2													1											
Coronifera oceanica								1		1																								
Cyclonephelium distinctum	89	30	110	59	14	116	35	53	25	26	80	41	121	150	47	184	184	30			21	2	48	26	6	4	4							
C. membraniphorum	*	1	1	3		4	4	4				3											2			1	1							
Dapsilidinium laminaspinosum	1	1		1		1	1			1	1	1																						
Dinogymnium sp. cf. D. westralium									*																									
Ellipsodinium rugulosum										*	1																							
Endoscrinium campanula		4	4	1	3	1	3	3	7	2	14	12	1	5	4	2	10																	
Eunydinium saxoniensis		6					1	1	2	2	2	15	1	7	1	1		2																
Exochosphaeridium sp. cf. E. arnace			1		5		1								8	6	24	2					4			1								
E. phragmites	4	5	18	1	5		16	2	7	2	4			4																				
Florentinia buspina	3		1	2	1			4		5			3	8	5	5	13	1																
F. deanei	2	2			2	3				7	7				5	1	5	3																
F. ferox															1	4		3																
F. tonulosa		2						1	*	1				2	*												1							
Florentinia sp.		1									1																							
Heterosphaeridium difficile	11	3		5	2	1		*	1		4	1									3						6							
H. heteracanthum	14	2	1	1		1	4		6		3			6	14	3	4				6	3	18	47	6	12								
Hystrichodinium pulchrum	5	17	9		*	2	14	12	8	4	1	9	2	13		1	20	7																
Hystrichosphaeridium bowerbankii	6		1		1	2	1	2	3	1	12	3	3	3	17	19	14	5			1	1	2		2		4							
H. conispiniferum		*				1	4			2													3											
H. tubiferum	3					1			2	1		6	1	1	3	3																		
Hystrichostrogylon membraniphorum									1			1																						
Kiokansium polypes											1																							
Kleithriasphaeridium readei	2		2		2				1					1	1	1	2																	
Lebendocysta chlamydata	1	1							1	*			1	2	1		2																	
Litosphaeridium siph. siph.					*											1																		
Microdinium ornatum		*	2	1			1			*		4					1																	
Microdinium tuberculatum	4			1		1																												
Odontochitina costata					1		1			2	4						1																	
O. operculata A		1		1			3		1	2	1										1													
O. operculata B	12	3	5	4	11	7	2	7	4	11	27	3	3	4	3	2	2				9	2	2	2		2	3							
Oligosphaeridium complex	2	2				1	3		1		1		3	1	2	1	2				1				1		2							
O. cf. complex						1		2	*		1																							
O. prolixispinosum	2		1	1	2			1					1																					
Palaeohystrichophora infusorioides	79	150	87	76	98	41	45	197	196	140	22	135	6	147	70	20	103	62			1													
Pervosphaeridium pseudhystrichodinium	7	3		2	14	3		7	7	10	7	1	8	3	24	31	36	9					4	17	5	18	128							
Prolixosphaeridium conulum				1	1			*		1	1		1		*																			
Pterodinium cingulatum cingulatum	1	3	6	4	5	1	5	2	10	5	1	12		6	4		3	2																
Pt. comutum		*					1	1																										
Rhiptoxonyx veligera									1			3																						
Senoniasphaera rotundata			3			2		2	3	1	1		14	2		1					2		3	2		5	2							
Senoniasphaera sp. A								4			1																							
Spiniferites ?dentatus			3		1				2	2				3	1																			
Sp. multibrevis		5					4		4					1			1																	
Sp. ramosus gracilis			2	1			11		4			12				*	6	4																
Sp. ramosus ramosus		1	15	1			13	6	1	4	2	7		2	4	1	1	2																
Sp. ramosus reticulata			1		1		1					1	1			1																		
Spiniferites sp.	1	2	1	3	9	5	2		4	2	3	2	3	3	4	2	6	3																
Stephodinium coronatum	1		2				1			*		1																						
Subtilisphaera pontis-mariae			2																															
Tanyosphaeridium variecalamus						1	1	1			1	1					1																	
Trichodinium castanea	5		20	4	12	1	6	11	1	8					1	1																		
Xenascus ceratioides											3			2		1																		
Bisaccate pollen	*	*	*	*		*	*	*	*		*	*		*			*																	
Dinopterygium cladoides												3																						
Hystrichodinium voigtii			3				3																											
Foraminiferal Test Linings			*									*																						

SUSSEX 1 of 3

	HOLYWELL STEPS (HW)																	SOUTHERHAM (SO)																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Achomosphaera ramulifera				6																																								
A. regiunensis	1	1		1	8	11	3																																					
Apicodinium deflandrei				1																											1	1												
Batiacasphaera cuticches									1	1						4			2		7	14	8	3				2		4	6	19	14	4	20	6	7	3	11	14	3	2	7	
Cannongia collivieri			15		1	1		6	8	6	2	1			1			3								5		12	11				1	1	14	4		1	22	8	2	1	3	
Cassiculosphaeridia reticulata		2		6		6																																						
Cleistosphaeridium multispinosum		3	1	4		2	1																3						1		1	9												
C. armatum	4	1									1											1				1						2							2					
C. clavulum									1													2						1	2															
Coronifera oceanica			1			1																																						
Cyclonephelium distinctum				1		2	1		1		1				1						132	19	10	4		33	5								1		*							
C. membraniphorum	22	63		68	20	79	120	123	20	68	76	16	35	4	20	29		87	4	5	23	2	30	35	6	123	32	65	71	7	50	125	14	5	20	4	34	4	9	28	35	4	7	
C. compactum-membraniphorum		2		10		4	19	10			6								1										4	1		6	4	8		4	91	1	6	23	9	30	50	
Dapsilidinium laminaspinosum		1		3		1		4													*													*	1					1				
Ellipsodinium angulosum	1	2	22			1	1	4																																				
Endoscinium campanula						1																																						
Exochosphaeridium cf. arnase				2																																								
Florentinia busoina						3	1																																					
F. deanei				2	3																				1																			
Heterosphaeridium difficile	1	35	1	2	1	2					1							1			3	*	1			1		4				13	16	263	13	8	29	13	119	227	155	16	60	
H. heteracanthum		4		36	17	34	47	65	86	35	50	15	27		13	24		37		2	47	54	16	17	1	1	4	4	4	2	1	20	3	4	10	2	4	1	1	4	7	5	10	
Hystrichosphaeridium bowerbankii						1	1	8	1						1			1														1												
H. conispiniferum		3	1	10	1		4	7	1	1	4	1	1			1		2			1			1		2	1	1	1						1		2				1	1	2	
H. tubiferum												3	4																															
H. tubiferum brevispinum																					*	*	2			1						*											1	
Kiokansium polypes																															1													
Lebendorysira chlamydata					1				1																																			
L. deflocata				1	1			1			1											*						1				1											1	
Litosphaeridium chlidanum						2	6	1			1																																	
Litosphaeridium siph. siph.		1		1	1																											1												
Microdinium ornatum				8																						1																		
Odontochitina costata	5	19		49	18	32	66	25	25	18	53	24	8	1	1						1	18	28	7		1		2	5		1	26	4	15	1	1	15		5	6	26	5	28	
O. operculata Type A				2	2	5	5		2	3	3					2		2			3	2	7	7	2	1	1		1			2	1	3			8			1		3		
O. operculata Type B	12	29	1	8	5	38	34	39	44	22	99	50	20	1	3	2					3	10	9	7		7	6	2				5	1	4	1		12		3	3	8	4	10	
O. complex				2	6	4	4	9	1		7		11	1	2	3		22		2	96	171	91	60	6	114	43	80	48	4	24	14	4	1	5	1	7	1	5	1	3	3	8	
O. poculum											2	1										1																						
Pervosphaeridium pseudalystrichodinium	1	5		4				1																																				
P. monastrenense						1																																						
Protoperidinium sanium		1		9	1	2		8			4					1					*	9	2			1		1	1			4		1							1		4	
Pterodinium cingulatum cingulatum		3		6	1																																							
Senoniasphaera rotundata																7		2	4	11	9		4	10	2	21	5	3	5	1	5		1			1				1		2	4	
Spiniferites dentatus		1	1																																									
Spiniferites sp.		1	1																																									
Subtilisphaera		2		54	1																																							
Xenascus ceratioides																												1																
Cannongia sp. B (Species B)																					1	6	1											1	1									
Pterospermopsis sp.					2	1				1																																		
Leiofusa sp.																									1																			
Bisaccate pollen	*2	*1					*1	*3	*6		*2			*1										*1	*4	*3	*4	*3	*3	*3			*6			*2		*1	*2	*1				
Foram. test lining																																												

SUSSEX 2 of 3

BEACHY HEAD (BH)

Species	1	2	3	4	5	6	7	8	9	10	11	12
Achomosphaera ramulifera				1		1	1		1		3	1
A. reginensis	13	7	1	7	2							
A. sagena	3	3	2	1	6	*	4	2	*		*	*
Apteodinium deflandrei			2	*	1	1			*		1	1
Batiacasphaera euteiches		3	1			6	3	3	2		3	5
Callaiosphaeridium asymmetricum	2	2	6	*	1						2	2
Canningia colliveri												
C. reticulata				2		9	17	1	2			
Canningia sp. B	1	16	6			1		1	*		1	
Cassiculosphaeridia reticulata		2	3			9			2			*
Chatangiella sp.										99	2	2
Cleistosphaeridium multispinosum	2	1	5	3	7	43		2	4	1		1
C. armatum					1							
C. clavulum												
Coronifera oceanica				*			1					
Cribroperidinium sp.												
Cyclonephelium distinctum	29	18	21	7	36	22	6	2	1		4	4
C. membraniphorum	12	2	29	25	26	1	17	43	3		6	1
C. compactum-membraniphorum												
Dapsilidinium laminaspinosum				*	1	1						
Dinogymnium sp. cf westralium									1		1	
Dinopterygium cladoides	*		6	2		1						
D. medusoides		1	*									
Ellipsodinium rugulosum		2		1	*			3	*		1	*
Endoscrinium campanula	9	5	14	13	36	2	2	3	10	1	5	7
Eurydinium saxoniensis				*	1		1	10	1	5	1	
Exochosphaeridium sp. cf arnace		9	*		5	22		3	1		2	
E. phragmites	14	16	6	9	20	13	5	10	8		*	3
Florentinia buspina	13	8	7	5	4	15	3	4	2		2	1
deanei	2	1	1	2	4	13	4	2	*			4
ferox	1								1			
torulosa		2	1	2	*	2		2	*			1
Gonyaulacysta cassidata												*
Heterosphaeridium difficile		2	1		*	*					11	50
H. heteracanthum												
Hystrichodinium pulchrum	14	6	64	16	12	20	11	11			13	8
Hystrichosphaeridium bowerbankii	9	8	2	1	10	5	1	6	2			
H. conispiniferum	1	1										
H. tubiferum												
H. tubiferum-brevispinum												
Hystrichostrogylon membraniphorum		*	1	1	*				*		1	
Isabelidinium ?belfastense				*								
Kiokansium polypes		2										
Kleithriasphaeridium readei	1	19	7	2		4	1	1	1			*
Leberidocysta chlamydata			1									1
L. defloccata		2		3	1	2	2				1	1
Litosphaeridium siph. siph.	1											
Microdinium ornatum	3	3	4	2	2	2	4	7	2	82	6	2
M. tuberculatum						5			*			1
Odontochitina costata	14	2	*			1	1	1		*	*	10
O. operculata A	5	3	*	1	2	*	8	1	8		*	*
O. operculata B	6	6	4	3	1	3	14	5	10	1	*	9
O. complex	16	20	21	3	17	3	9	3	1		*	8
O. poculum												
O. polikispinosum	2	3		*		1		5				2
Palaeohystrichophora infusorioides	51	112	27	96	14	49	114	70	25	114	94	106
Pervosphaeridium pseudhystrichodinium	58	3	8	2		5	11	1	1			
P. monasteriense		1	7	8	*	1	7	3			1	4
Prolixosphaeridium conulum	1	1	1		5		2	3	1		1	1
Pterodinium cingulatum cingulatum	6	4	17	9	32		18	30	19	4	17	16
Pt. ?comitum						*						
Rhiptocorys veligera				*					*			1
Senoniasphaera rotundata	1	3	2									3
Senoniasphaera sp. A	4										*	
Spiniferites ?dentatus	2	2	1				4					
Sp. multibrevis			1		1	2	2				*	2
Sp. ramosus gracilis	17	8	9	16	10	7	18	21	11	1	17	25
Sp. ramosus ramosus	5	5	9	9	4	4	12	15	2		4	9
Sp. ramosus reticulata				1								
Stephodinium coronatum			4	*	1	6			*			
Subtilisphaera pontis-mariae										5		
Tanyosphaeridium variecalamus	*				1	3	1	1	1			2
Trichodinium castanea	*	1	19	64	40	16	1	37	2		7	15
Wallodinium anglicum											*	
Xenascus ceratioides												
Xiphophoridium alatum				*		1					*	1
Pterospermopsis sp.												
Veryhachium sp.						2			2		*	
Bisaccate pollen			*	*	*	*	*		*	*		
Foraminiferal Test Linings												

NEW PIT

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Achomosphaera ramulifera																					2		
A. reginensis																					2		
A. sagena																					1		
Apteodinium deflandrei																							
Batiacasphaera euteiches		*	4						*	3	4	6	4		7	10		5	1	*	4	*	*
Callaiosphaeridium asymmetricum																					7		
Canningia colliveri		*																					
C. reticulata				59	84	27	9	4	7	5	12				2	1		2	*			*	*
Canningia sp. B	2	16	61	6	2	1	12	19	6	27	2	2	19		13	9	21	14	25	31		5	11
Cassiculosphaeridia reticulata																							
Chatangiella sp.																							
Cleistosphaeridium multispinosum	14	5		2	1	4	4	1	4			*	9		3	3	13	2	4	23	1	3	
C. armatum									1						1						1	1	
C. clavulum	6	13	28						1														
Coronifera oceanica																							
Cribroperidinium sp.																							
Cyclonephelium distinctum	49	18	56	1	1		3	5	12	99	48	7	42		132	74	154	158	217	158	23	275	168
C. membraniphorum	43	6	4	30	14	65	16	11	97	11	1				12	2	27	5	10	2	*	8	25
C. compactum-membraniphorum					2	5			1														
Dapsilidinium laminaspinosum	7	6	9			6	4		2	12	6	2	1		1	*	1	1		3			
Dinogymnium sp. cf westralium																							
Dinopterygium cladoides																					*		
D. medusoides																							
Ellipsodinium rugulosum																							
Endoscrinium campanula		1													1						3		
Eurydinium saxoniensis																							
Exochosphaeridium sp. cf arnace																							
E. phragmites																					8		
Florentinia buspina																					4		
deanei																					*		
ferox																							
torulosa																							
Gonyaulacysta cassidata																							
Heterosphaeridium difficile	4	6	3	*			2	8		7	76	254	125		31	175	27	5	2	*	1	1	
H. heteracanthum	9	1	2	1	1	3	3	5	4	109	99	50	93		31	17	18	19	5	2			3
Hystrichodinium pulchrum																					10		
Hystrichosphaeridium bowerbankii	4	4	9	3	17	9	9	4	4	1	4		1		1	1	1	6	6	4	*	10	3
H. conispiniferum	1	2							4				1		1			3					
H. tubiferum					1														2				
H. tubiferum-brevispinum	2	1		1	1			*	5	1		1											
Hystrichostrogylon membraniphorum				2			4																
Isabelidinium ?belfastense							*																
Kiokansium polypes							*										*					3	
Kleithriasphaeridium readei																					1		
Leberidocysta chlamydata			*																				
L. defloccata	1		2								*		*								*		
Litosphaeridium siph. siph.																							
Microdinium ornatum																					1		
M. tuberculatum																					1		
Odontochitina costata	59	11	10	12	25	31	75	19	36	13	8	2	20		10	*	23	10	10	35	1	9	32
O. operculata A	21	14	24		71	44	52	34	17		1		3			1		3	*	2		8	7
O. operculata B	34	25	53	96	72	65	59	34	64	20	19	11	27		12	10	20	19	17	16	1	15	42
O. complex	86	84	40	44	44	38	52	86	43	14	8	1	7		5	4	1	9	2	3		2	7
O. poculum		*		1											1								
O. polikispinosum		*	4		1	1	4	3									1	5	7	*	*	1	
Palaeohystrichophora infusorioides																					272	1	
Pervosphaeridium pseudhystrichodinium																	3	3	1	6	1		
P. monasteriense																							
Prolixosphaeridium conulum	1	1	6	*	2		*		1	*													
Pterodinium cingulatum cingulatum																					*		
Pt. ?comitum																							
Rhiptocorys veligera																							
Senoniasphaera rotundata	45	104	3	17	18	28	62	70	14	11	2	1	7		2		5	14				*	12
Senoniasphaera sp. A												*						*	3				
Spiniferites ?dentatus																							
Sp. multibrevis																							
Sp. ramosus gracilis																					5		
Sp. ramosus ramosus																*	3				6		
Sp. ramosus reticulata																							
Stephodinium coronatum																					2		
Subtilisphaera pontis-mariae																							
Tanyosphaeridium variecalamus																							
Trichodinium castanea																					5		
Wallodinium anglicum																							
Xenascus ceratioides																							
Xiphophoridium alatum																							
Pterospermopsis sp.															1								
Veryhachium sp.																							
Bisaccate pollen								*	*		*		*		*		*				*	*	*
Foraminiferal Test Linings																					+		

Species	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Achomosphaera ramulifera																							
A. reginensis																							
A. sagena		3														2							
Apteodinium deflandrei																							
Batiacasphaera euteiches	8	4	3	4	1	1	6	2	14	9	44	75	21	5	10		55		45	4	18	31	
Callaiosphaeridium asymmetricum																							
Canningia colliveri																					32		
C. reticulata		6	1			1	*	23	28	18	23	3	3				1					9	
Canningia sp. B	12	3	11	18	26	71	5	22	44	20	15	27	61	5	1		5						
Cassiculosphaeridia reticulata																							
Chatangiella sp.																							
Cleistosphaeridium multispinosum	2	1	6	11	9	11	27		14	5	12	16	17	14	6		12		20	95	28	99	
C. armatum							1		1														
C. clavulum																							
Coronifera oceanica																							
Cribroperidinium sp.							1																
Cyclonephelium distinctum	232	86	243	253	242	192	30	19	32		24	99	40		27	3	31		13		22	19	
C. membraniphorum	11	3	1	6	20	25	19	6	26	16	10	10	22		5	1	67					2	
C. compactum-membraniphorum																							
Dapsilidinium laminaspinosum				2		1	5				5												
Dinogymnium sp. cf westralium																							
Dinopterygium cladoides																							
D. medusoides																							
Ellipsodinium rugulosum																							
Endoscrinium campanula		18																					
Eurydinium saxoniensis																							
Exochosphaeridium sp. cf arnace		4																					
E. phragmites		2	*																				
Florentinia buspina																							
deanei																							
ferox																							
torulosa																							
Gonyaulacysta cassidata																							
Heterosphaeridium difficile	2		3			*	4		1		4	1											
H. heteracanthum	3												1				1		2				
Hystrichodinium pulchrum		9																					
Hystrichosphaeridium bowerbankii	2	4	12	6	7	13	19	7	23	5	4	3	2		2								
H. conispiniferum																	1						
H. tubiferum																							
H. tubiferum-brevispinum																							
Hystrichostrogylon membraniphorum		1																					
Isabelidinium ?belfastense																							
Kiokansium polypes																							
Kleithriasphaeridium readei		2																					
Leberidocysta chlamydata																							
L. defloccata							*																
Litosphaeridium siph. siph.																							
Microdinium ornatum		3																					
M. tuberculatum		2																					
Odontochitina costata	12	3	12	2		2		22	66	116	26	7	45	1	9		3						
O. operculata A			1		*																		
O. operculata B	10	13	19	4	3	6	6	8	9	5	2	*	16		1	1	2						
O. complex	8	1	1	1	1	9	4	8	17	10	9	4	37		10	2	6		17	13		28	
O. poculum																							
O. polikispinosum																							
Palaeohystrichophora infusorioides		10				1																	
Pervosphaeridium pseudhystrichodinium	2	1					19	16	20		4		1										
P. monasteriense																							
Prolixosphaeridium conulum		1					*						1										
Pterodinium cingulatum cingulatum		10																					
Pt. ?comitum																							
Rhiptocorys veligera																							
Senoniasphaera rotundata	6	1	1	1	*		1	17	19	91	6	2	15				10		1	14		9	
Senoniasphaera sp. A			*			*	*			3													
Spiniferites ?dentatus																							
Sp. multibrevis																	1						
Sp. ramosus gracilis																	1						
Sp. ramosus ramosus																							
Sp. ramosus reticulata																	1						
Stephodinium coronatum																							
Subtilisphaera pontis-mariae																							
Tanyosphaeridium variecalamus		3																					
Trichodinium castanea																							
Wallodinium anglicum																							
Xenascus ceratioides	1					*	3																
Xiphophoridium alatum																							
Pterospermopsis sp.																							
Veryhachium sp.																							
Bisaccate pollen		*								*		*	*	*			*		*	*	*		*
Foraminiferal Test Linings		+																					

SUSSEX	CABURN PIT (CA)														SOUTHERN PORTAL OF TUNNEL (SPT)							CHANDLERS' YARD (CH)											
	2	3	4	5	6	7	8	9	10	11	12	13	14		1	2	3	4	5	6	7	1	2	3	4	5	6	7	8	9	10			
Achomosphaera sagena																															1			
Aptecodinium deflandrei																2					1	1		2	1									
Batiacasphaera entciches	11	2								11	1	3				9	11	15	18	1	14		1	2	2	11	22		8	20	6			
Cauloosphaeridium asymmetricum			1	11						2																								
Canningia collivieri																																		
C. reticulata	3	20	3	22		4	1	6		2	3	7	36			1	4	7	1		5		2	1		1	37 5		8		1			
Canningia sp. B	32	14	10	1	9	6	2	2		7	21	12				3	1									13	6		1					
Cleistosphaeridium multispinosum	13	4	1			5	3	5	1	4	1	3				13	1	3	13		2	12		2	1	2								
C. armatum																3																		
Cribroperidinium sp.								1								3		2	2		9		*	38	2	16				1				
Cyclonephelium distinctum	23	3	6	13	10	10	7	21	8	31	192	243	106		5	10	41	27	5	3	17	*	25	56	6	172	23		24	82	14			
C. membraniphorum	12	6	16	23	199	111	73		10	9	5	13	19		1	3	4	3		1	4						3			7				
Dapsilidinium					2	5		2								5	6	6			1			1										
Dinogymnium sp. cf. westralium																*																		
Ellipsodinium rugulosum			1																															
Eurydinium saxoniensis											1																							
Exochosphaerid. cf. acnacu																8																		
E. phragmites	1																								2	1	1							
Florentinia bispina	3										5																							
F. deanei																6	2		7															
Heterosphaeridium difficile	4	1	1	1		2		3			7	2	98			1										1				5				
H. heteracanthum						2																												
Hystrichodinium pulchrum																										3	3							
Hystrichosphaeridium bowerbankii	11	15	6	12	1	2	1	18	9	5	29	2			2	12	4	15	3	2	26	1	58	8		9	8		8	2	1			
H. consispiriferum				1																						1								
H. tubiferum brevispinum				1												1		1												1				
Isabelidinium ? belfastense																1																		
Leberidocysta chlamydata	2										2					4	1	6	7	2	1													
L. deflocata	7			1																														
Odontochitina costata	49	47	47	42	29	53	108	61	73	62	10	*	13		36	5	16	64	9	8	43	*	26	17	1	7	4		4	4				
O. operculata A	15	53	89	31	11	20	29	76	71	17	3		6			2	1	2		12	11		8	61	2	8	5		2	5				
O. operculata B	37	29	31	19	25	58	31	68	85	30	8	5	7		3	3	6	21	8	5	23	2	6	55	2	17	4	2	1	6				
Oligosphaeridium complex	16	85	75	67	27	26	24	24	21	114	13	8	9		12	16	41	40	14	32	34	*	29	27	14	23	10		73	157	26			
O. pecultum															1				1											1				
O. prolixispinosum	24	4		5							1	1	1			8	1	1			21		56	4			4							
Palaeohystrichophora infusorioides																										*								
Prolixosphaeridium conulum	4	3	5	3		2	1		1	2					1			1	*	1	1		5	1		1	7							
Senoniasphaera rotundata	42	21	13	38	22	20	26	3	9	10	5	4	5		37	55	121	83	231	233	74		84	20		26	101		47	10	39			
Senoniasphaera sp. A			3	17							3		6			97	43										4		7	2	5			
Xenascus ceratioides	1															3	2	11	4	2	10		1	6		4				2				
Microdinium tuberculatum																38						1	3											
Pterospermopsis sp.										*							1	3										1						
Bisaccate pollen	*						*										*													*				

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COMPTON BAY

	1 (CB1)														(CB1)																																		
	26	27	28	29	30	31	32	33	34	35	36	37	38		1	2	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	40	41	42	43	44	45
Achomosphaera ramulifera		3									1																	1			1	1						1										1	
A. reginensis		3	1								1		2			2	4						1					14				2		1						1				1			2	
A. saxena		9	1								1												1															1										
Apteodinium deflandrei	2																														2					2		1						1				
Batiacasphaera euteiches			1												1			2			1	3			2													2										
Callaiosphaeridium asymmetricum																							2		*			3												1								
Canningia colliveri		2							1		42					1	2			2		4	29		24	1	10	14	2		6				2			35	1	4				11	1	3	2	3
Cleistosphaeridium multispinosum	2	7					1				9		2		8	35	5	12		3	1	13	18	4	15	4	11	13		3	11	8		5		8		15		2				11	18	15	19	12
C. armatum											3																																						
C. clavulum		7														10	18	5				7	13		1			1			1	1						4						7	2	17	22	7
Cyclonephelium distinctum	5	15	1				4		5		7		4		7	71	30	105		5		4	80	9	118	2		5			9	3		11	15	13	6	18	11	21	4		4	52	31	14	31	5
C. membraniphorum	13	78	13			5	29	4	8	1	5		10			14	2	5				1	4		1		11	1	13	24	43	11		5	14	96		4	4	44	1			24	26	23	17	8
C. compactum-membraniphorum	1	13					4				3		8			3	1	1																															
Dapsilidinium laminaspinosum																		3		4		4	4		6		1	5								1		1		3				5	2		5	
Ellipsodinium rugulosum	1						1				10		6					1			1		2		1		1	3		2		1						1									1	
Endoscrinium campanula	1										2							2				2	4		1			4			1	1				1		1							1		2	1
Fungidinium saxoniensis											1																											1										
Exochosphaeridium cf arnace																	1						3		5										1			1		1				1			1	1
Florentinia buspina	1										1											1	1													1		*						1			1	1
F. deanei	1						1				19				1	1	2	2					4		9			4	1		1	2				1		54						2				2
F. torulosa																							1		2			1										*									1	1
Heterosphaeridium difficile											5					2							20		16	32	75	29	32	84	31	81	1	1	1	2		5		55	1			1	1	1	1	
H. hetercanthum	2	12	2					4	2		44		6			10		16				1			3			4										38		3				2			19	
Hystrichodinium pulchrum		2									1												1					1				2						1										
H. voigtii																		1																													1	
Hystrichosphaeridium bowerbankii	1	2	2				9		2				1		1	9		3				1	11							2	1	1		1	1	6	6	1		3				9	2	4	6	3
H. conispinifeum		1					1															1	1	1	1					1	2	2								4								
H. tubiferum-brevispinum		1																																														
Kiokansium polypes																2	1																															
Kleithriasphaeridium readei											13		1									1			1			5			2	1																	
Leberidocysta chlamydata	2										10					4	1	10		1			5	1	7		6	4								1		4		1			1	4			1	
L. deflocata																						5	6		4			4			2	1		2				3		1						1	2	2
Litosphaeridium siph. siph.	1																																															
Microdinium ornatum	1										4														1											1												
M. tuberculatum															2		2															1																
Odontochitina costata		26	5				3				30		1			6	2	4		1	1	11	11	1	30	5	26	49	26	78	45	28	1	3	2	8	2	31		5				34	10	11	16	1
O. operculata A	2	17					1									7	4	3			2	15	18	4	2		4	8		4	8	2				5				6				14	5	5	13	1
O. operculata B		89	9			1	10		1		13		1		4	10	11	23		4	1	12	19	8	13	2	22	28	3	15	12	9	1	5	1	4		5	1	4			2	23	7	2	9	7
Oligosphaeridium complex	3						6	2	4		1		1			1	6	5					1	5	4	4	4	11	2	6	1	4	1	8	4	21	7	1	10	54	1			4	4	1	15	
O. poculum																																																	
O. polixispinosum																1	1						6					1		1													1	3		1		
Pataeohystrichophorin infusorioides	9	14			1						22				2		1	19					10		7			20			3	4						15					55		2	12	3
Pervosphaeridium pseudhystrichodin.	8	*					1	1			4						5	3							2		1	18			4	5						14										
Polixosphaeridium conulum			3								8					1		4				3	1		*			1	1	3	*	1						7		3				1			1	
Pterodinium cingulatum cingulatum	9	6	1								1		1					6					1					9				7				1		2									5	
Rhiptocoryus veligera																1																																
Senoniasphaera abundata	9			1		2	3	8	15	1							1	4		19	12	30	24		19	6	40	13				2				1	1		2	41	1			13	4			10
Senoniasphaera sp. A															1																																	
Spiniferites ?dentatus	3																															3																
Sp. multibrevis	1																								1							2																
Sp. ramosus gracilis	7						1								1			2										2				2						4										
Sp. ramosus ramosus											1																	1			1	3								1								
Sp. ramosus reticulata	6	6	1	1		1	2						2				1				1							1				1	1					1	1									
Stephodinium comatum																																						1										
Subtilisphaera pontis-mariae											2		1				1	1														*						1									1	
Tanyosphaeridium variecalamus																		2																														
Trichodinium castanea	1						1				1																											7										
Wallodinium anglicum											1																																					
Xenascus ceratioides																									1																							
Species B (Canningia sp. B)											27					2		59		6	7	9	4		9		6	15		2	5	2						5		3				4	11	14	25	3
Bisaccate pollen	*	*				*	*		*		*		*					*																		*		*		*								
Foraminiferal test linings		+		+							+	+						+																				+		+								
Pterospermopsis sp.																1																																

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MILITARY ROAD (MR)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Achomosphaera sp.										1																						
Batiacasphaera cuteiches																		1														
Cannigia collivieri										1												2										
Cannigia sp. B			2																											1		
Cassiculosphaeridia reticulata							8																									
Cleistosphaeridium multispinosum	1						1	20	4				3					1			2							6	1			
C. armatum													2																			
C. clavulum												1	1																			
Cribroperidinium sp.																			1	1												
Cyclonephelium distractum			11	1	2			66	16	1		1			2				1	3	7				2	1	29	6	3			
C. membraniphorum			1					6	2	1	2										1				4	1	4	3				
C. compactum-membraniphorum								16																								
Dapsilidinium laminaspinosum																											1	1				
Dinogymnium sp. cf. D. westralium								1																								
Heterosphaeridium difficile								15	1		1																2	3				
Hystrichosphaeridium powerbankii								17											1								2					
H. conispiniferum																				1												
Leberidocysta																			1													
L. defloccata								1																								
Odontochitina costata								46	2						2				1													
O. operculata B								57	1										3	2	1						1		2			
Oligosphaeridium complex								11	1				1								1						9	9	2			
O. prolixispinosum								2																								
Palaeohystrichophora infusorioides								1																								
Pervosphaeridium pseudhystrichodin					5	2	5																									
Prolixisphaeridium conulum								3																								
Senoniasphaera mirandata							1	56	12			2	17	1				22	19	2	9						5	1		14	4	
Spiniferites sp.																			1													
Tanyosphaeridium variecalamus								1																								

APPENDIX 3 MORPHOLOGICAL GROUPINGS

Morphological Groupings

Each species is assigned to the appropriate morphological grouping of Evitt (1985). The figures given are absolute numbers for each group.

```
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A02 00000000000000000000000000000000
A03 00000000000000000000000000000000
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A05 00000000000000000000000000002001000
A06 00000000000000000000000000000000
A07 00000000000000200100000100401900 0
A08 00000000000000000100000000600000 1
A09 00000000000000000000000000000000
A10 00000000000000000000000000000000
A11 00000000000000000000000000401600 9
A12 00000000000000000000000000000300 1
A13 00000000000001202400000000100030 37
A14 00000000000000202500000000100030 04
A15 00000000000000105000000000360010 12
A16 00000000000000000000000000000000
A17 00000000000000203300000000110080 18
A18 00000000000000100230000000060000 00
A19 00000000000000060300000000118006 002
A20 00000000000000070080000000430040 00
A21 00000000000000050050000000200040 00
A22 00000000000000060140000000360010 01
A23 00000000000000300260000000480020 03
A24 00000000000000110100000000630000 00
A25 00000000000000000000000000000000
A26 00000000000000070010000000090010 00
A27 00000000000000220080000000360010 00
A28 00000000000000050050000000200000 00
A29 00000000000000082580000000380010 01
A30 00000000000000180870000000580020 00
A31 00000000000001190600000000290030 00
A32 00000000000000402200000000280350 00
A33 00000000000000003200000000110020 01
A34 00000000000000000700000000010070 00
A35 00000000000000120320000000020320 01
A36 00000000000000010210000000040060 02
A37 00000000000000040510000000050000 01
A38 00000000000000162570000000040120 00
A39 00000000000000000500000000050020 01
A40 00000000000000060360000000070080 02
A41 00000000000000251080000320081190 00
A42 00000000000000170490000000040540 00
A43 00000000000000431970000000630080 00
A44 00000000000000029200000000010080 00
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A46 00000000000000261350000020100500 00
A47 00000000000000133290000000030090 00
A48 00000000000000242190000000030110 00
A49 00000000000000061080000000090040 00
A50 00000000000000100540000000040000 00
A51 00000000000000020110000000010000 00
A52 00000000000000162250000000180100 00
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A54 00000000000000541250000000000070 00
A55 00000000000000020840000000000140 00
A56 00000000000000021140000000070680 00
A57 00000000000000060340000000141080 00
A58 00000000000000120090000000001540 00
A59 00000000000000000300000000080220 00
A60 00000000000000000200000000050140 00
A61 00000000000000370150000000140390 00
A62 00000000000000080210000000140280 00
L01 00000700500001713800000804908000 4
L02 00000010600400009300006303600801 0
L03 00000003600100107100007104304200 1
L04 00000604400000503100004910406202 7
L05 00000000000000000000000000000000
L06 00000000100000800600000401105400 4
L07 00000100600001201500000001000900 4
L08 00000003800000400700000201901500 2
L09 00000623200100101100001701301301 0
L10 00000000000000203200000000001300 1
L11 00000025900000200300003300801900 7
L12 00000000400001901200000001100900 3
L13 00000200700002102800000001306500 0
L14 00000000000000200100000000300400 1
L15 00000000200001200500000000700400 6
L16 00000100000102101800000101501701 5
L17 00000000200201401500000701004702 8
L18 00000000800000000400001200300500 1
L19 00000000300000400700000101102000 2
L20 00000000100000504600000101601201 0
L21 00000000200000100700000001600000 6
L22 00000000000000113900000101900500 7
L23 00000000000101305300000002600600 0
L24 00000100000704001500000203601700 1
L25 00000300000000070380000002028008 001
L26 00000000000000110020000001008006 004
L27 00000000000102509400000000420100 01
L28 00000000000000408400000301200000 7
L29 00000000000401206200000103400200 8
L30 00000000000000406100000104100000 4
L31 00000000000000003700000005800001 6
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21F 00000000000000200900000000100500 0
23  00000000000000202800000000000670 02
24  00000000500000000600000000300700 1
25  00000000000000201700000000003300 0
26  00000000000000300800000000716401 5
01  00000009900401208800001202005102 3
02  00000615000000406000000360070260 09
02F 00000008900200511300004800501902 3
03  00000009600200501700001100301800 8
04  00000009800001211900002501103202 0
05  00000004100000803900000300901101 0
05F 00000004500100603900005800802201 3
06  00000119700000703700002401001601 8
07  00000419600100003000005400603501 0
08  00000214000001508100001701002701 2
09  00000202200003512700002102204000 6
09F 00001513400700304400006401201400 8
10  00000100600000316700000601001200 4
11  00000701400000605200002801503400 2
12  00000107000000313500002503105100 7
13  00000102000000319200000703504600 6
14  00000010300100303200005203806903 1
15  00000206200000000100001901301300 0
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H07 000000000000105140000003061048001
H08 000000000000064143000000025070013
H09 000000000000091135000000003087002
H10 000000000000043074000000001035001
H11 000000000000153085000000014052005
H12 000000000000050018000000004015024
H13 000000000000028035000000016027000
H14 000000000000002004000000000000000
H15 000000000000004022000003001013000
H16 000000000000004036000000004024005
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S02 000000000000000008000000002000000
S03 000000000000000016000000002002000
S04 000000000000007165000000097050007
S05 000000000000003002700000172057023
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S07 000000000000023049000000061017003
S08 000000000000002008000000007001000
S09 000000000001009182000000117003001
S10 000000000000007042000000044004000
S11 000000000000005080000000101009000
S12 000000000000006091000000049007004
S13 000000000000000009000000008002000
S14 000000000000001035000000024003007
S15 000000000000033181000000027044025
S16 000000000000006022000000004019014
S17 000000000000022015000000003267005
S18 000000000000002070000000006024021
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S21 000000000000000006000000001014003
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S23 000000000000010060000000002134014
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S26 000000000000038064000000003070012
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B02 000000112003011039001039079034011
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B06 000000049007004033001059043042071
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B08 000010070007007047000082023019047
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B10 000102119082001000000006000001000
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B12 000002106004019008000069017058026
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C11 000000000000109061000000119004013
C12 000001000000021229000000048008003
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N08 000000000000087109000004094014000
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N44 000000000000000054000000000028018
N45 000000000000000039000000028099031
N46 000000000000000000000000000000000
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P05 000000000000021239000000023013025
P06 000000000000027237000000034000004
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131 0000000000000100070000010000000 00
132 0000000000000140360000030110020 02
133 0000000000000000120000000020050 00
134 0000000000000010290000000160020 00
135 0000000000000000020000000000000 00
136 0000010240040430840000080340650 35
137 0000000000000000000000000000000 00
138 0000000010000020220000020030080 08
001 0000000020000010080000010010080 01
002 0000000000030230880000000120590 08
010 0000000010000170360000030090300 02
011 0000000180020301730000150100390 21
012 0000000000000000000000000000000 00
013 0000000000000050320000000000070 02
014 0000000000000040190000000000010 03
015 0000000000000380480000020040260 12
016 0000000100000481410000070170480 16
017 0000000000000130090000000040360 00
018 0000000070010151710000020170480 16
019 0000000000000070090000000040360 00
020 0000000000000520670000000041880 07
021 0000000200000850480000280300700 28
022 0000000000000290190000000050330 01
023 0000000000000970300000000101870 06
024 0000000030000651870000030070460 04
025 0000000040010390390000240101940 03
026 0000000000000020000000010010010 00
027 0000000000000080170000010090060 03
028 0000000000000030310000000050010 00
029 0000000000000171100000020290110 05
030 0000000000000020070000000130000 00
031 0000010160000360620000120560780 35
032 0000000000000010180000010100000 02
033 0000000000000151130000020070650 06
034 0000000000000000060000000010010 00
035 0000000000000000000000000000000 00
040 0000000000000020040000000010000 01
041 0000000550000711270000010180270 07
042 0000000000000220730000010060230 00
043 0000000020000180540000000060330 05
044 0000000130000380770000120220670 05
045 0000000030000090290000010060200 03
M01 0000000000000000000000000000000 01
M02 0000000000000000000000000000000 00
M03 0000000000000120020000000000000 00
M04 0000000000000000010000000000000 00
M05 0000000000000000020000000000000 00
M06 0000000000000010000000000000000 00
M07 0000000000000000010000000000600 0
M08 0000000010001031280000000300360 1
M09 0000000000000030300000000010050 0
M10 0000000000000000030000000000000 0
M11 0000000000000000020000000000100 0
M12 0000000000000000010000000000100 0
M13 0000000000000000170000000010060 0
M14 0000000000000000000000000000000 0
M15 0000000000000020020000000000000
M16 0000000000000000000000000000000
M17 0000000000000000000000000000000
```

```
M18 0000000000000000220000000000001001
M19 0000000000000040200000001001000001
M20 0000000000000020050000000001000000
M21 0000000000000010170000000001001000
M22 0000000000000000020000000000000000
M23 0000000000000000000000000000000000
M24 0000000000000000000000000000000000
M25 0000000000000000060000000000000000
M26 0000000000000000020000000000000000
M27 0000000000000000380000000011001000
M28 0000000000000000100000000009010000
M29 0000000000000000030000000004000001
M30 0000000000000000000000000000000000
M31 0000000000000000140000000000000000
M32 0000000000000000040000000000000000
```

APPENDIX 4 MICROPALAEONTOLOGICAL ANALYSES

1.1 Foraminiferal Analysis

Lateral variations of benthic foraminiferal faunas were studied from three equivalent sample sets from the Dover Chalk Formation, Akers Steps Member by Dr.Joachim Schönfeld. The samples studied were split from the samples analysed for their dinoflagellate content (AKS, DOE).

The samples were processed using the Glaubersalt-freezing method at Polytechnic South West, Plymouth, where only a coarse disintegration was achieved. Further treatment with various washing liquids in ultrasonic baths was carried out for several hours at the Marine Geology Unit, Federal Bureau of Geosciences and Natural Resources, Hannover. Although a better disintegration was reached, some chalk lumps were still present in the residues. The washed residue was therefore still greater than the total sand size fraction of the sediment.

Material

Lateral variations of benthonic foraminiferal faunas were studied from three parallel sample sets from the White Chalk of Dover (Dover Chalk Formation, Akers Steps member). They were taken from the overlap section from Akers Steps and Langdon Stairs, Dover (see Chapter 6). One extra sample from Langdon Stairs (DOE 14R) was also examined.

The samples were washed on a 63μm sieve and dried at 60°C. They were split with an OTTO'1937-Splitter to an eighth or sixteenth aliquot. The 250 to 2000 μm grain size fraction was studied in detail. Relative portions of biogenic components were estimated semi-quantitatively before all benthonic and planktonic foraminifera were picked and collected in Plummer-cell slides and single cell slides respectively. Phosphatic grains, i.e. fish teeth and coprolites, were also collected in single cell slides. The benthonic foraminifera were sorted by species, and fixed with glue in different areas

of the Plummer-cell slide, where they were counted subsequently. Planktonic foraminifera were also counted, but only discerned on generic level following Jarvis *et al.* (1988) and Leary *et al.* (1989).

The dry density of the chalk was evaluated by volumetric and gravimetric methods from the chalk cubes. The Linear Sedimentation Rate was calculated with a total thickness of approximately 82.5m for the Turonian succession at Dover. The base of the Turonian was drawn at section 9.5m (Jarvis *et al.* 1988, p.16), where the top of the Turonian was placed below the lower one of the South Foreland Hardgrounds (92 section m) which probably resemble the 'Top Rock'/Navigation Hardground as indicated by B*ailey et al.*et al. (1984, Fig.1). The duration of the Turonian stage is assumed as 3 million years following Odin (1984). Accumulation rates for benthonic foraminifera, planktonic foraminifera and phosphatic grains were calculated using the formula given by Schönfeld (1990):

$$AKK = \frac{CS \times FW \times DD \times LSR}{SW \times SPW} \quad [\text{specimens/cm}^2 \times 1000 \text{ years}]$$

where CS is the number of counted specimens, FW is the weight of the sand sized fraction in grams, DD is the dry density in grams per cm^3, LSR is the Linear Sedimentation Rate in cm per 1000 years, SW is the sample weight and SPW is the split weight in grams.

Results

The species recorded from the Dover chalk are given in Table 1. Although common groups of Nodosariaceans, such as *Lenticulina* and *Dentalina* are not not described at a specific level, 35 different species are recognised. Nineteen of them however, were not previously recorded from the Dover Chalk, but three may be synonymous with those given by Jarvis *et al.*(1988:Tab.1). The diversity (number of species) of the present study is more than twice as high as that reported by Jarvis *et al.* (1988), who only found 17 different species including *Nodosariaceans.* This difference may be due to the difficulties in sample processing (Hart & Swiecicki 1988: 292). The stratigraphic ranges of several benthonic foraminifera are also extended by the new results up to the Middle Turonian, e.g. *Dorothia gradata, Eggerellina brevis, Gaudryina austinia, Gavelinella intermedia, Lingulogavelinella globosa* and *Tritaxia macfadyeni.*

Tab. 1: Benthic foraminifera recorded from the Dover Chalk at Akers Steps and Langdon Stairs. (*): Species not recorded by JARVIS et al. (1988:Tab.1). ?: Species may be synonymous to that given by JARVIS et al. (1988).

Ammobaculites rectus (BEISSEL 1891)	(*)
Arenobulimina cf. bochumensis FRIEG 1980	(*)
Arenobulimina elevata (ORBIGNY 1840)	(*)
Arenobulimina preslii (REUSS 1845)	
Ataxophragmium compactum (BROTZEN 1936)	?
Coprolithina sp.	(*)
Dentalina div. sp.	
Dorothia gradata (BERTHELIN 1880)	
Eggerellina brevis (ORBIGNY 1840)	
Frondicularia archiaciana ORBIGNY 1840	(*)
Frondicularia sp.	
Gaudryina anglica (CUSHMAN 1936)	(*)
Gaudryina austinana CUSHMAN 1936	(*)
Gavelinella intermedia (BERTHELIN 1880)	
Globorotalites turonicus KAEVER 1961	(*)
Gyroidinoides nitida (REUSS 1846)	?
Haplophragmium foedissimum (REUSS 1860)	(*)
Haplophragmium aequale (ROEMER 1841)	(*)
Lenticulina div. sp.	
Lingulogavelinella globosa (BROTZEN 1945)	
Marssonella trochus (ORBIGNY 1840)	
Neoflabellina baudouiniana (ORBIGNY 1840)	?
Plectina cf. mariae (FRANKE 1928)	
Pleurostomella subnodosa REUSS 1860	(*)
Praebulimina reussi (MORROW 1934)	(*)
Ramulina aculeata (ORBIGNY 1840)	
Ramulina arkadelphiana CUSHMAN 1938	(*)
Ramulina ornata CUSHMAN 1938	(*)
Ramulina pseudoaculeata BARNARD 1972	(*)
Ramulina wrightii BARNARD 1972	(*)
Reophax sp. 1 [small coiled form]	(*)
Reophax sp. 2 [large regular form]	(*)
Tritaxia macfadyeni (CUSHMAN)	
Tritaxia tricarinata (REUSS 1844)	
Valvulineria lenticula (REUSS 1845)	(*)

Quantitative composition of foraminiferal faunas

The percentage data for the benthonic foraminiferal faunas are given in Table 2. The faunas are characterised by high proportions of arenaceous foraminifera which characterise most Mid-Cretaceous foraminiferal assemblages. *Marssonella trochus* (mean percentage 24.7 %) and *Lenticulina* (m.p. 19.7 %, div. species) are most dominant and yield together 32 to 55.4 % of the total assemblage. *Tritaxia tricarinata* (m.p. 9.3 %), *Gavelinella intermedia* (m.p. 6.2 %), *Gaudryina austinana* (m.p. 5.7 %) and *Arenobulimina preslii* (m.p. 5.6 %) are also frequent. Foraminiferal faunas with this composition differ from typical Late Cretaceous assemblages but show close affinities with Early Cretaceous faunas. The most similar fauna is "Faunule 3" from Early to Mid Turonian limestones of Lublin Upland, SE Poland (Sawin borehole, Peryt 1988).

The species percentages of the Langdon Stairs samples were plotted against those from the related Akers Steps samples to test the similarity of the faunas (Fig. 1). The data are for low specimen numbers but show high correlation coefficients. Although a good similarity in faunal composition is recognised, selected species have considerably different proportions as is indicated by outstanding data points. Five species in all sample couplets are more frequent at Langdon Stairs than at Akers Steps and four species show the opposite (Table 3).

The generic composition of planktonic foraminiferal faunas show a high hedbergellid percentage in the lower sample couplet, but a dominance of keeled morphotypes in the upper part of the interval considered (Table 4). The numbers of specimens counted are, however, considerably low and thus differences in the assemblage composition between Langdon Stairs and Akers Steps may not be significant.

Accumulation Rates

The accumulation rates for benthonic foraminifera in the grain size fraction 250 to 2000 µm are in the range of 18.8 to 66.8, with a mean value of 39.5 specimens/cm^2 and 1000 years (Table 5). They are approximately half as high as in the Lower Maastrichtian of Lägerdorf, Lüneburg/Zeltberg and Mons Klint (Schönfeld 1988:Tab.A4-A6). The data shows, however, that the accumulation rate for benthonic foraminifera is about twice as high at Langdon Stairs than at Akers Steps. The planktonic foraminifera apparently have the same trend, but the phosphatic grains do not follow this trend.

Tab. 2: Benthic foraminiferal census data

	DOE 8R [%]	AKS 3/1 [%]	DOE 13R [%]	AKS 3/7 [%]	DOE 14AR [%]	DOE 15R [%]	AKS 3/10 [%]
Ammobaculites rectus (BEISSEL 1891)	-	-	-	-	1.3	-	1.7
Arenobulimina cf. bochumensis FRIEG 1980	0.4	-	1.4	-	1.3	0.5	0.4
Arenobulimina elevata (ORBIGNY 1840)	-	-	-	2.0	-	-	-
Arenobulimina preslii (REUSS 1845)	1.7	-	17.8	2.0	7.7	6.3	5.5
Ataxophragmium compactum (BROTZEN 1936)	10.0	-	5.5	2.0	1.9	3.7	8.0
Coprolithina sp.	-	-	-	2.0	-	-	-
Dentalina div. sp.	-	4.7	1.4	2.0	0.6	0.5	2.1
Dorothia gradata (BERTHELIN 1880)	-	-	-	2.0	1.3	-	-
Eggerellina brevis (ORBIGNY 1840)	3.5	-	1.4	2.0	2.6	1.6	1.3
Frondicularia archiaciana ORBIGNY 1840	0.9	-	1.4	-	-	-	-
Frondicularia sp.	-	1.2	-	-	1.3	1.0	0.8
Gaudryina anglica (CUSHMAN 1936)	-	-	1.4	4.0	1.3	-	-
Gaudryina austinana CUSHMAN 1936	7.4	5.9	2.7	10.0	5.8	5.2	2.9
Gavelinella intermedia (BERTHELIN 1880)	13.0	7.1	4.1	6.0	13.5	3.7	2.5
Globorotalites turonicus KAEVER 1961	1.3	1.2	-	-	0.6	4.2	2.9
Gyroidinoides nitida (REUSS 1846)	0.9	-	-	6.0	4.5	2.1	1.7
Haplophragmium foedissimum (REUSS 1860)	2.6	-	-	2.0	-	5.8	-
Haplophragmium aequale (ROEMER 1841)	0.9	-	-	2.0	-	-	-
Lenticulina div. sp.	19.1	20.0	19.2	13.0	17.4	25.1	22.2
Lingulogavelinella globosa (BROTZEN 1945)	-	-	-	2.0	2.6	1.6	2.1
Marssonella trochus (ORBIGNY 1840)	26.5	23.5	20.5	19.0	19.4	25.7	33.2
Neoflabellina baudouiniana (ORBIGNY 1840)	0.4	1.2	2.7	-	-	1.0	0.4
Plectina cf. mariae (FRANKE 1928)	-	2.4	-	-	-	-	-
Pleurostomella subnodosa REUSS 1860	-	-	-	-	0.6	-	-
Praebulimina reussi (MORROW 1934)	-	2.4	-	-	-	-	-
Ramulina aculeata (ORBIGNY 1840)	-	-	-	-	1.3	-	-
Ramulina arkadelphiana CUSHMAN 1938	0.4	-	-	-	-	-	-
Ramulina ornata CUSHMAN 1938	2.6	-	1.4	4.0	-	0.5	-
Ramulina pseudoaculeata BARNARD 1972	-	2.4	-	2.0	-	-	-
Ramulina wrightii BARNARD 1972	-	-	-	-	0.6	-	-
Reophax sp. 1 [small coiled form]	-	-	-	-	-	1.0	-
Reophax sp. 2 [large regular form]	1.7	-	-	-	-	-	0.4
Tritaxia macfadyeni (CUSHMAN)	0.4	17.6	-	8.0	12.3	-	-
Tritaxia tricarinata (REUSS 1844)	4.3	4.7	19.2	6.0	1.3	9.9	11.8
Valvulineria lenticula (REUSS 1845)	-	-	-	-	0.6	-	-
others	1.7	5.0	-	4.0	-	0.5	-
specimens counted	230	85	73	52	155	191	238

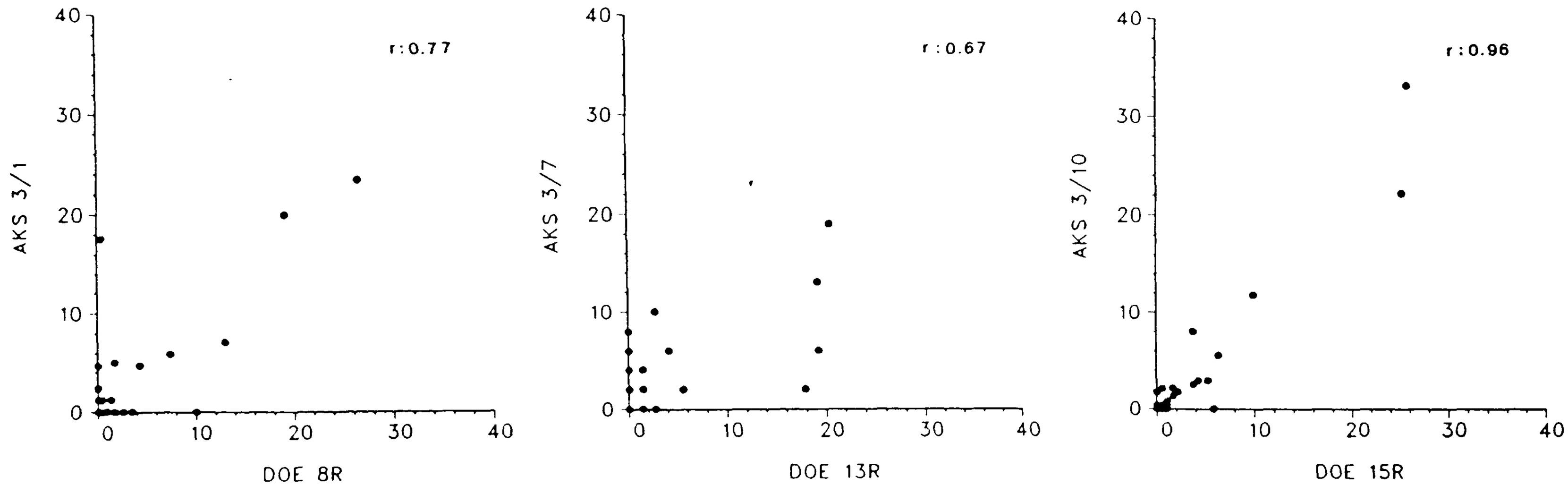

Figure 1: Species percentages from Langdon Stairs (DOE) versus Akers Steps (AKS) samples. r = correlation coefficient.

Tab. 3:

Species more frequent at Langdon Stairs than at Akers Steps	Species more frequent at Akers Steps than at Langdon Stairs
Arenobulimina cf. bochumensis	Dentalina div. sp.
Arenobulimina preslii	Lingulogavelinella globosa
Lenticulina div. sp.	Ramulina pseudoaculeata
Neoflabellina baudouiniana	Tritaxia macfadyeni
Globorotalites turonicus	

Tab. 4: Planktonic foraminiferal group census data

Planctonic foraminiferal generic groups	DOE 8R [%]	AKS 3/1 [%]	DOE 13R [%]	AKS 3/7 [%]	DOE 14AR [%]	DOE 15R [%]	AKS 3/10 [%]
Marginotruncana	14.6	-	84	64		43	68.9
Archaeoglobigerina	3.5	14	-	4	not	3	1.5
Praeglobotruncana/Dicarinella	2.6	14	12	25	counted	38	25.0
Hedbergella/Whiteinella	53.5	71	5	7		15	4.5
specimens counted	144	7	43	28	352	60	264

Tab. 5: Weights, dry densities, Linear Sedimentation Rates (LSR), counted specimens and resulting Accumulation Rates. The glass vile of sample AKS 3/10 was damaged during transport where material has been lost. It is therefore not considered herein.

Sample	Weight [g]	>63 µm [g]	Split [g]	Dry dens. [g/cm³]	LSR [cm/1000a]
DOE 8R	273.5	9.45	0.6086	1.86	2.75
AKS 3/1	246.12	6.51	0.3711	1.89	2.75
DOE 13R	255.68	9.27	0.407	1.86	2.75
AKS 3/7	217.95	5.17	0.3406	1.89	2.75
DOE 14AR	248.33	27.11	3.1516	1.86	2.75
DOE 15R	249.05	10.66	0.705	1.86	2.75

	Counted specimens			Accumulation rate [spec.>250µm/cm²*1000a]		
Sample	Benthic forams	Planct. forams	Phosphat. grains	Benthic forams	Planct. forams	Phosphat. grains
DOE 8R	230	144	13	66.8	41.8	3.8
AKS 3/1	85	7	5	31.5	2.6	1.9
DOE 13R	73	43	2	33.3	19.6	0.9
AKS 3/7	52	28	4	18.8	10.1	1.4
DOE 14AR	155	352	10	27.5	62.4	1.8
DOE 15R	191	60	10	59.3	18.6	3.1

Conclusions

Although the quantitative composition of benthonic foraminiferal faunas is rather similar at Langdon Stairs and Akers Steps, several species are more frequent in one of the sections. This distribution apparently documents differences in environmental conditions between both areas which had, however, no severe impact on the ecological conditions of benthonic habitats.

The extraordinary species composition of the assemblages allows only limited conclusions to be made. Three frequent species from Dover, i.e. *Tritaxia tricarinata*, *Arenobulimina preslii* and *Marssonella trochus*, are characteristic of Lower Maastrichtian assemblages of northwestern Germany and Denmark (Fauna G4). This fauna together with Fauna G9, are concluded to be related to near bottom water turbulence (Schönfeld 1990).

The accumulation rate of benthonic foraminifera is related to their standing stock and thus linked to the (export) productivity (Altenbach 1985, Lutze *et al.*1986). A significant change in surface productivity is, however, unlikely in a Late Cretaceous open shelf sea with a well mixed surface layer over a distance of only 5.6 km and thus could not explain the differences in accumulation rates.

If a constant lateral redeposition by bottom currents is assumed, however, it could result in favouring the accumulation of much coarser components in one area than in another. Although differences in bed thickness between the two sections are not recognised, a stronger winnowing out and thus a lowering of the sedimentation rate may have taken place in the area of Akers Steps. The non-congruence of phosphatic grain accumulation rates may also be seen as evidence for weak winnowing out.

It is concluded, that long term differences in the local hydrodynamic environment may have affected the accumulation rates of benthonic and planktonic foraminifera, but may have had no influence on the accumulation of phosphatic grains.

1.2 Nannofossil Analysis

Ten equivalent sample pairs were analysed by Dr.Jackie Burnettfrom the two sections (Figure 6.1), for their nannofossil content. The diversities range from 32 to 54 for samples from Akers Steps; and from 22 to 57 for samples

from Langdon Stairs. Mean diversities were calculated and were similar for both sections.

Mean species diversity: Akers Steps (AKS 3/1 - 3/10) = 43
Langdon Stairs (DOE 8R - 15R) = 44

The nannofossil assemblages from Akers Steps and Langdon Stairs were similar in terms of their constituent taxa, with most species occurring throughout the two sections. The species distribution throughout the succession are given below.

1.3 Ostracod Analysis

Ostracods were analysed from corresponding samples at Akers Steps and Langdon Stairs by Ian Slipper. The preliminary results are shown on Figure 2, and a faunal list (Figure 3) is also shown. These results are similar for the samples at the stratigraphic level of the Langdon Bay Marls, thus contradicting the palynological results. This would appear to confirm that the different dinoflagellate cyst assemblages from the overlap, are due to post-depositional effects such as differential weathering of the two sections.

Nannofossil Species Data

AKS 3/1: white chalk.

A. brooksii
B. bigelowii L
B. enormis
B. signata
C. biarcus?
C. bifarius
C. ehrenbergii
C. platyrhethus?
C. signum
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. praeobliquum?
H. anceps
H. valhallensis L
K. magnificus
L. carniolensis
L. maleformis
L. quadrifidus
M. pemmatoidea
P. cretacea
P. ponticula
R. achlyostaurion
R. angustiforata
R. angustus
R. crenulata
R. crenulatus
R. plebeius
R. splendens
S. laffittei?
T. gabalus
T. orionatus
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus
Z. sisyphus

AKS 3/2: soft, white chalk.

A. brooksii
A. octoradiata
B. bigelowii ML
B. ellipticum
B. enormis
B. signata
C. biarcus
C. bifarius
C. ehrenbergii
C. litterarius
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. turriseiffelii
G. obliquum & L
H. anceps
H. trabeculatus
K. magnificus & +
L. carniolensis
L. maleformis L
N. t. rectangularis
N. sp.
P. columnata
P. ponticula
Q. gartneri
R. achlyostaurion
R. angustiforata
R. angustus
R. crenulata
R. splendens
T. orionatus
W. biporta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. pseudanthophorus

AKS 3/3: as AKS 3/2 with medium 'rust' stains (?sponges).

A. brooksii
A. octoradiata
B. ellipticum
C. bifarius
C. litterarius
C. nudus
C. obscurus (R)
C. signum
D. ignotus
E. cf. E. gorkae
H. circumradiatus
H. trabeculatus
K. magnificus
L. carniolensis
L. cayeuxii (R)
L. maleformis
M. decoratus
M. pemmatoidea
O. cf. O. multiplus
P. columnata
P. cretacea
P. ponticula
P. spinosa
Q. gartneri L
R. achlyostaurion
R. angustiforata
R. angustus
R. asper
R. crenulata
R. crenulatus?
R. planus
R. plebeius
S. achylosus
T. minimus
T. orionatus
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. sisyphus

AKS 3/4: as AKS 3/3.

A. brooksii
A. octoradiata
B. bigelowii ML
B. ellipticum
B. enormis
B. signata
C. bifarius
C. ehrenbergii
C. margerelii
C. obscurus (R)
D. ignotus
E. apertior? sv
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus?
E. turriseiffelii
G. coronadventis
G. obliquum & L
H. anceps
L. carniolensis
L. septenarius
M. inconspicuus?
M. pemmatoidea
P. columnata
P. cretacea
P. ponticula
P. spinosa
Q. gartneri
R. achlyostaurion
R. angustiforata
R. crenulata
R. splendens
T. orionatus
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus

AKS 3/5: soft, pale grey, marly chalk with medium 'rust' stains.

A. brooksii
A. octoradiata
B. ellipticum
B. signata
C. ehrenbergii
C. obscurus (R)
C. signum
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum L
H. trabeculatus
H. valhallensis M
K. magnificus
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum & L
H. anceps
H. trabeculatus L
K. magnificus & +
L. carniolensis
M. pemmatoidea
N. t. rectangularis
N. regularis
N. elongatus
N. sp.
P. cretacea
P. ponticula
Q. gartneri & L
R. achlyostaurion
R. angustiforata
R. crenulata
R. crenulatus? sv
R. planus
R. plebeius
T. orionatus
W. biporta
W. barnesae
W. fossacincta
W. manivitae
W. ovata
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus
coccosphere

AKS 3/6: as AKS 3/2.

A. brooksii
B. ellipticum
B. enormis
B. signata
C. biarcus
C. bifarius
C. ehrenbergii
C. litterarius
C. obscurus (R)
C. serratus
C. signum
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus/L. septenarius
E. turriseiffelii
G. coronadventis
G. obliquum L
G. praeobliquum? S
H. trabeculatus
K. magnificus
L. carniolensis
L. maleformis
M. helicoideus
M. pemmatoidea
N. sp.
P. columnata
P. cretacea
P. ponticula
P. spinosa
Q. gartneri
R. achlyostaurion
R. angustiforata
R. angustus
R. crenulata
R. crenulatus
R. plebeius
R. splendens
T. gabalus
T. minimus
T. orionatus
W. barnesae
W. fossacincta
W. manivitae
Z. acanthus
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. noeliae
Z. pseudanthophorus?

AKS 3/8: as AKS 3/1 with pale 'rust' stains.

A. brooksii
B. ellipticum
B. signata
C. biarcus
C. ehrenbergii
C. margerelii
C. obscurus (R)
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. turriseiffelii
G. obliquum & S dk
H. circumradiatus
H. trabeculatus
K. magnificus
L. carniolensis
L. maleformis L
L. quadrifidus
M. decoratus
P. cretacea
P. ponticula
P. spinosa
R. achlyostaurion
R. angustiforata
R. crenulata
R. crenulatus
R. planus
S. laffittei?
T. orionatus
W. barnesae
W. biporta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. noeliae

AKS 3/7: as AKS 3/2.

A. brooksii
A. octoradiata
B. ellipticum
B. enormis
B. signata
C. biarcus?
C. bifarius
C. ehrenbergii
C. obscurus (R)
C. signum
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum & L
G. praeobliquum?
H. anceps
H. trabeculatus
H. valhallensis L
L. carniolensis
L. cayeuxii (R)
L. maleformis SL
M. decoratus
N. t. rectangularis
N. regularis
N. t. frequens
P. cretacea
P. ponticula
Q. gartneri
R. achlyostaurion
R. angustiforata
R. angustus
R. splendens
R. crenulata
S. fossilis
T. orionatus
W. barnesae
W. biporta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus

AKS 3/9: as AKS 3/2 with pale 'rust' stains & medium grey marl with medium 'rust' stains.

A. brooksii
B. ellipticum
B. enormis
B. signata
C. bifarius
C. coronatus
C. obscurus (R)
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum L
H. trabeculatus
K. magnificus
L. carniolensis
L. maleformis LS
M. decoratus
M. pemmatoidea
N. sp.
P. columnata
P. cretacea
P. ponticula
Q. gartneri L
R. achlyostaurion
R. angustus
R. crenulata
R. crenulatus
R. plebeius
R. splendens
T. orionatus
W. biporta
W. barnesae
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. noeliae
Z. pseudanthophorus

AKS 3/10: soft, white and pale grey, mottled, marly chalk.

A. brooksii
A. octoradiata
B. ellipticum
C. bifarius
C. ehrenbergii
C. obscurus (R)
C. rotaclypeata
C. serratus
E. cf. E. gorkae
E. eximius
E. floralis
E. turriseiffelii
G. obliquum & L
H. trabeculatus
K. magnificus
L. carniolensis
M. decoratus
N. sp.
P. cretacea
P. ponticula
R. achlyostaurion
R. angustiforata
R. planus
T. orionatus
T. saxea
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. erectus
Z. sisyphus
Z. elegans

DOE 10R: as AKS 3/3.

A. brooksii
A. octoradiata
B. ellipticum
B. enormis
B. signata
C. biarcus
C. bifarius
C. ehrenbergii
C. obscurus (R)
C. serratus
C. signum
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. turriseiffelii
G. obliquum & L
H. trabeculatus
H. valhallensis L
K. magnificus
L. carniolensis
L. maleformis SL
M. decoratus
M. pemmatoidea
P. columnata
P. cretacea
P. ponticula
P. spinosa
Q. gartneri
R. achlyostaurion
R. angustiforata
R. angustus
R. crenulata
R. splendens
S. laffittei?
T. minimus
T. orionatus
V. angusta
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. acanthus
Z. compactus
Z. embergeri
Z. noeliae
Z. elegans

DOE 11R: soft, medium grey, chalky marl.

A. brooksii
A. octoradiata
B. ellipticum
B. signata
C. bifarius
C. obscurus (R)
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum L
H. circumradiatus
H. trabeculatus
K. magnificus
L. carniolensis
L. maleformis L
M. pemmatoidea
P. cretacea
P. ponticula
Q. gartneri
R. achlyostaurion
R. crenulata
R. crenulatus
R. parvidentatum
R. planus
R. angustiforata
S. laffittei?
T. orionatus
V. quadriarculla
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. pseudanthophorus
coccosphere

DOE 8AR: as AKS 3/2.

A. brooksii
A. octoradiata
B. bigelowii L
B. ellipticum
B. enormis
B. signata
C. biarcus/coronatus?
C. bifarius
C. ehrenbergii
C. obscurus (R)
C. platyrhethus
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum & L
G. praeobliquum?
H. anceps
H. trabeculatus
K. magnificus
L. carniolensis
L. maleformis L
M. pemmatoidea
N. sp.
P. cretacea
P. ponticula
P. spinosa
Q. gartneri?
R. achlyostaurion
R. angustus
R. angustiforata
R. asper?
R. crenulata
R. planus
R. splendens
S. achylosus?

DOE 9R: as AKS 3/2.

A. brooksii
A. octoradiata
B. ellipticum
B. enormis
B. signata
C. biarcus
C. bifarius
C. ehrenbergii
C. obscurus (R)
C. platyrhethus
C. serratus
D. ignotus
E. eximius
E. floralis
E. cf. E. gorkae
E. turriseiffelii
G. coronadventis
G. obliquum & SL
K. magnificus & +
L. carniolensis
L. maleformis L
M. decoratus
M. pemmatoidea
N. sp.
P. cretacea
P. ponticula
R. angustiforata
R. crenulata
R. crenulatus
T. orionatus
W. barnesae
W. biporta
W. manivitae
Z. compactus
Z. embergeri
Z. erectus

DOE 8R: as DOE 14A.

A. brooksii
A. octoradiata
B. bigelowii L
B. ellipticum
B. enormis
B. signata
C. biarcus
C. bifarius
C. ehrenbergii
C. litterarius
C. ovalis
C. obscurus (R)
C. serratus
C. signum
Cy. sp. sv
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. turriseiffelii
E. cf. E. gorkae
G. coronadventis
G. obliquum L
H. anceps
H. trabeculatus
K. magnificus & +
L. carniolensis
L. maleformis S
M. helicoideus
M. pemmatoidea
N. elongatus
N. sp.
P. columnata
P. cretacea
P. ponticula
P. spinosa
Q. gartneri
R. achlyostaurion
R. angustiforata
R. angustus
R. crenulata
R. plebeius
R. splendens
T. gabalus
T. minimus
T. orionatus
W. barnesae
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. erectus
Z. noeliae
Z. pseudanthophorus
Z. embergeri

DOE 13R: as AKS 3/1 with medium grey marl burrowfills.

A. brooksii
A. octoradiata
B. enormis
B. signata
B. sp.2
B. ellipticum
C. bifarius
C. ehrenbergii
D. ignotus
E. cf. E. gorkae
E. eximius
E. moratus
E. turriseiffelii
G. obliquum & SLS dk?
H. trabeculatus
H. valhallensis L
L. carniolensis
L. maleformis SL
M. decoratus
M. pemmatoidea
P. ponticula
P. spinosa
Q. gartneri (5 elements)
Q. gartneri
R. achlyostaurion
R. angustiforata
R. splendens
S. bispinosa
S. laffittei?
T. gabalus
T. orionatus
W. barnesae
W. biporta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus
S. fossilis?
T. minimus
T. orionatus
W. barnesae
W. manivitae
W. biporta
Z. compactus
Z. embergeri
Z. erectus
Z. pseudanthophorus
Z. sisyphus

DOE 12R: as DOE 14A.

A. brooksii
A. octoradiata
B. ellipticum
B. signata
C. bifarius
C. coronatus
C. ehrenbergii
C. obscurus (R)
C. platyrhethus
D. ignotus
E. apertior? sv
E. cf. E. gorkae
E. cf. E. eximius
E. eximius
E. floralis
E. turriseiffelii
G. coronadventis
G. obliquum L
G. praeobliquum? S dk
H. anceps
H. trabeculatus
K. magnificus
L. carniolensis
L. cayeuxii (R)
L. maleformis SL
M. pemmatoidea
N. sp.
P. columnata
P. cretacea
P. ponticula
Q. gartneri L
R. achlyostaurion
R. angustus
R. angustiforata
R. crenulata
S. laffittei?
T. minimus
T. orionatus
V. angusta
W. barnesae
W. biporta
W. fossacincta
W. manivitae
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. pseudanthophorus?
Z. sisyphus

DOE 14A: as AKS 3/3 with medium grey marl burrowfills.

A. brooksii
A. octoradiata
B. ellipticum
B. enormis
B. signata
B. sp.1
C. bifarius
C. ehrenbergii
C. nudus
C. obscurus (R)
D. ignotus
E. cf. E. gorkae
E. eximius
E. floralis
E. moratus
E. turriseiffelii
G. obliquum
G. praeobliquum S dk
H. trabeculatus
H. valhallensis S
K. magnificus
L. carniolensis
L. maleformis SL
M. decoratus
N. sp.
P. cretacea
P. ponticula
P. spinosa
R. achlyostaurion
R. angustiforata
R. angustus
R. asper
R. crenulata
R. crenulatus
R. splendens
T. minimus
T. orionatus
W. barnesae
W. biporta
W. manivitae
Z. compactus
Z. embergeri
Z. erectus
Z. noeliae

DOE 14R: as DOE 11R.

A. brooksii
B. ellipticum
C. bifarius
E. cf. E. gorkae
E. eximius
E. moratus
E. turriseiffelii
G. obliquum L
H. trabeculatus
P. cretacea
P. ponticula
R. angustiforata
R. achlyostaurion
R. angustiforata
R. crenulata
R. planus?
T. orionatus
W. barnesae
W. manivitae
Z. compactus
Z. elegans
Z. embergeri

DOE 15R: as AKS 3/8.

A. brooksii
B. ellipticum
B. signata
B. bigelowii L
C. bifarius
C. ehrenbergii
C. obscurus (F)
C. serratus
C. litterarius
Cy. sp. sv
D. ignotus
E. apertior? sv
E. eximius
E. floralis
E. cf. E. gorkae
E. moratus
E. turriseiffelii
G. coronadventis
G. obliquum
H. anceps
H. trabeculatus
H. valhallensis S
K. magnificus
L. carniolensis
L. cayeuxii (R)
L. maleformis L
L. quadrifidus
M. decoratus
M. helicoideus
M. pemmatoidea
N. t. frequens
N. sp.
P. cretacea
P. ponticula
P. spinosa
Q. gartneri
R. achlyostaurion
R. angustiforata
R. crenulata
R. plebeius
R. splendens
S. bispinosa (11 elements, end view)
S. laffittei?
T. gabalus
T. minimus
T. orionatus
T. saxea
W. barnesae
W. fossacincta
W. manivitae
W. ovata
Z. compactus
Z. elegans
Z. embergeri
Z. erectus
Z. noeliae
Z. pseudanthophorus

NANNOFOSSIL SPECIES INDEX

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C. nudus Bukry, 1969
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L. maleformis Reinhardt, 1966
L. quadrifidus Forchheimer, 1972
Manivitella pemmatoidea (Deflandre *in* Manivit, 1965) Thierstein, 1971
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P. spinosa (Bramlette and Martini, 1964) Gartner, 1968
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Rhagodiscus achlyostaurion (Hill, 1976)
R. angustus (Stradner, 1963) Reinhardt, 1971
R. asper (Stradner, 1963) Reinhardt, 1967
R. plebeius Perch-Nielsen, 1968
R. splendens (Deflandre, 1953) Verbeek, 1977
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Tranolithus gabalus Stover, 1966
T. minimus (Bukry, 1969) Perch-Nielsen, 1984
T. orionatus (Reinhardt, 1966) Reinhardt, 1966 (= T. phacelosus Stover, 1966)
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W. fossacincta (Black, 1971) Bown in Bown and Cooper, 1989
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Zeugrhabdotus acanthus Reinhardt, 1965
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Z. elegans (Gartner, 1968) Mutterlose, 1988 (invalid)
Z. embergeri (Noel, 1958) Perch-Nielsen, 1984
Z. erectus (Deflandre, 1954) Reinhardt, 1965
Z. noeliae Rood, Hay and Barnard, 1971
Z. pseudanthophorus (Bramlette and Martini, 1964) Perch-Nielsen, 1984
Z. sisyphus (Gartner, 1968) Crux, 1989 (= R. sisyphus (Gartner, 1968) Varol and Jakubowski, 1989)

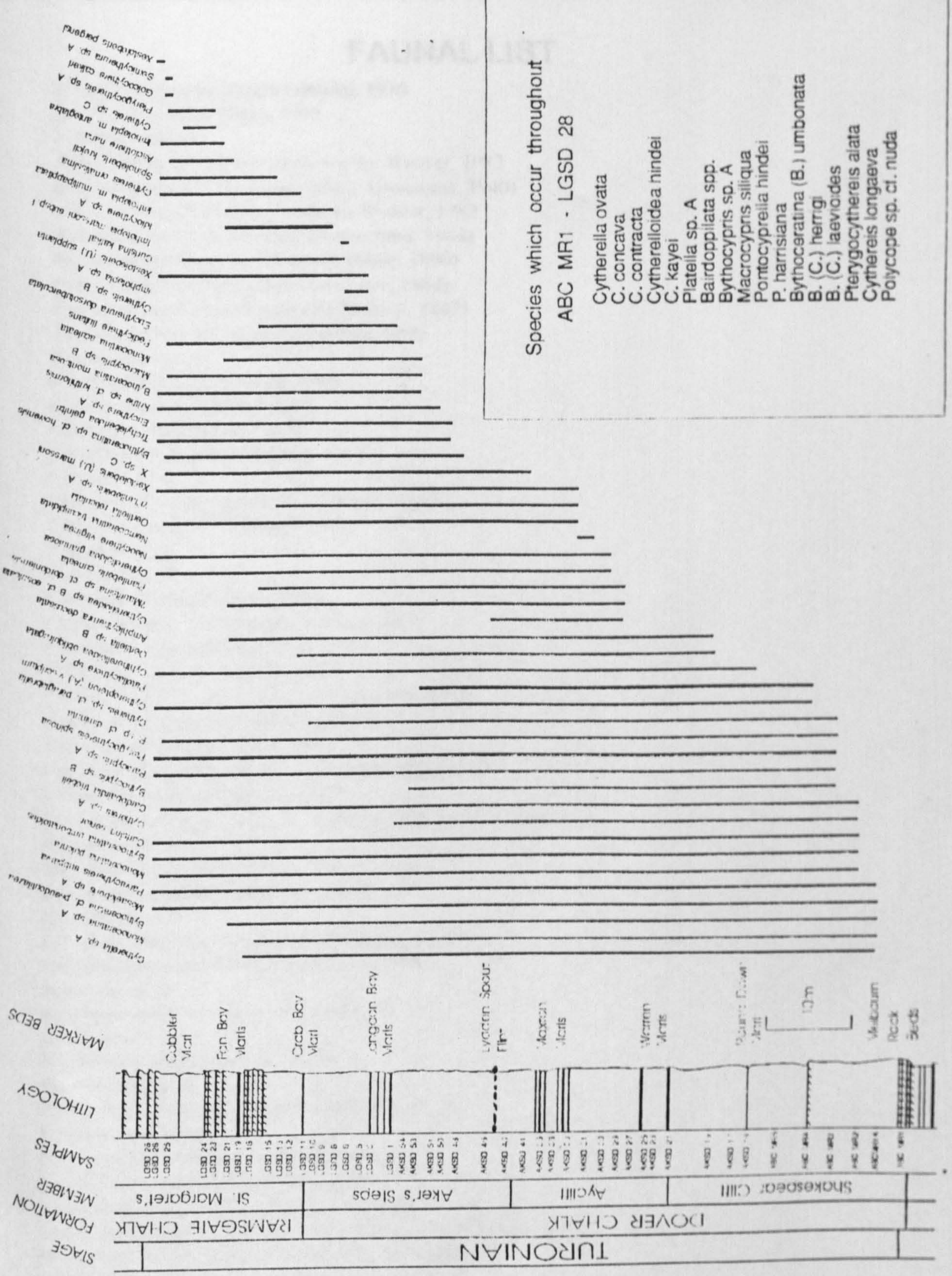


Figure 2 Distribution chart of Ostracod species from Dover

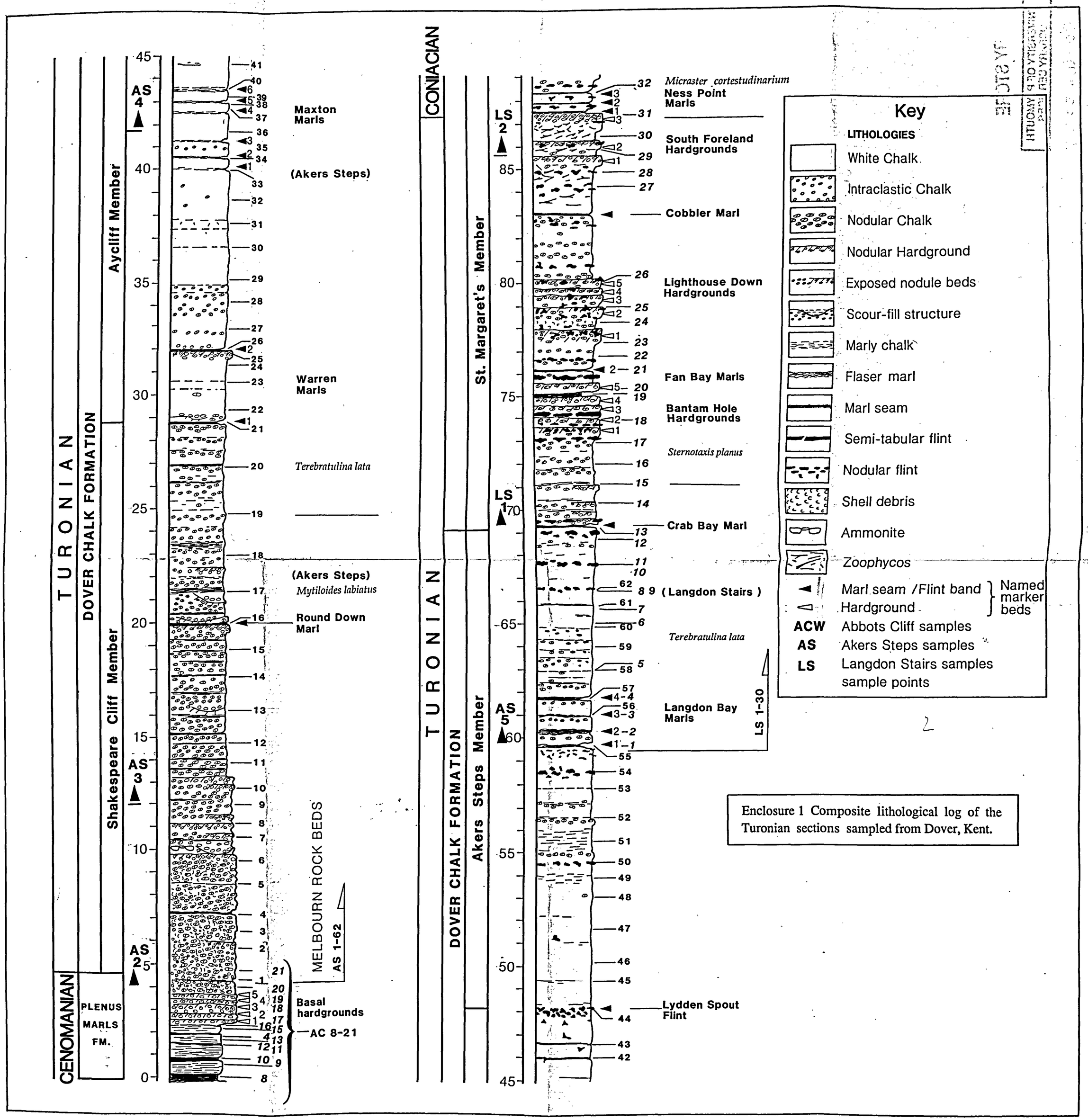
FAUNAL LIST

Amphicytherura decussata Gründel, 1970
Asciocythere nana Nuyts, 1990
Bairdoppilata spp.
Bythoceratina (Cuneoceratina) herrigi Weaver, 1982
Bythoceratina (C.) cf. *M. laevioides* (Bonnema, 1940)
Bythoceratina cf. *B. pseudoutilazea* Weaver, 1982
Bythoceratina cf. *B. howensis* (Szczechura, 1964)
Bythoceratina montuosa (Jones & Hinde, 1890)
Bythoceratina (B.) umbonatoides (Kaye, 1964)
Bythoceratina (B.) umbonata (Williamson, 1847)
Bythocypris brownei Jones and Hinde, 1890
Bythocypris sp. B
Cardobairdia triebeli Nuyts, 1990
Curfsina senior Pokorný, 1967
Curfsina kafkai Pokorný, 1967
Cythereis ornatissima Pokorný, 1963
Cythereis sp. C
Cythereis cf. *C. paraglabrella* Pokorný, 1965
Cythereis longaeva Pokorný, 1963
Cythereis sp. A
Cythereis sp. B
Cytherella ovata (Roemer, 1840)
Cytherella cf. *C. chatamensis* Weaver, 1982
Cytherella contracta Van Veen, 1932
Cytherella concava Weaver, 1982
Cytherelloidea sp. aff. *C. foveata* Van Veen, 1932
Cytherelloidea granulosa (Jones, 1849)
Cytherelloidea hindei Kaye, 1964
Cytherelloidea obliquirugata (Jones and Hinde, 1890)
Cytherelloidea kayei Weaver, 1982
Cytheropteron (Aversovalva) v-serpitum (Van Veen, 1936)
Eucythere sp. A
Eucytherura dorsotuberculata Van Veen, 1938
Golcocythere calkeri (Bonnema, 1941)
Idiocythere sp. A
Imhotepia marssoni multipappilata Pokorný, 1964
Imhotepia marssoni anteglabra Pokorný, 1964
Imhotepia sp. A
Imhotepia marssoni subsp. 1 Pokorný, 1964
Krithe sp. A
Macrocypris siliqua (Jones, 1849)
Macrocypris sp. B
Mauritsina? cf. *M. dordoniensis* (Damotte, 1971)
Monoceratina sp. A
Monoceratina aculeata Van Veen, 1936
Monoceratina pulchra Van Veen, 1936
Mosaeleberis sp. A (sensu Jarvis *et al.*, 1988)
Nemoceratina (Paniceratina) tricuspidata (Jones & Hinde, 1890)
Neocythere (Physocythere) virginea (Jones, 1849)
Oertliella sp. B
Oertliella reticulata (Kalka, 1886)
Paracypris cf. *P. wrothamensis* Kaye, 1965
Parvacythereis subparva (Pokorný, 1967)
Patellacythere sp. A
Pedicythere fluitans (Bonnema, 1941)
Planileberis cuneata (Kalka, 1886)
Planileberis? sp. A
Platella sp. A

Figure 3

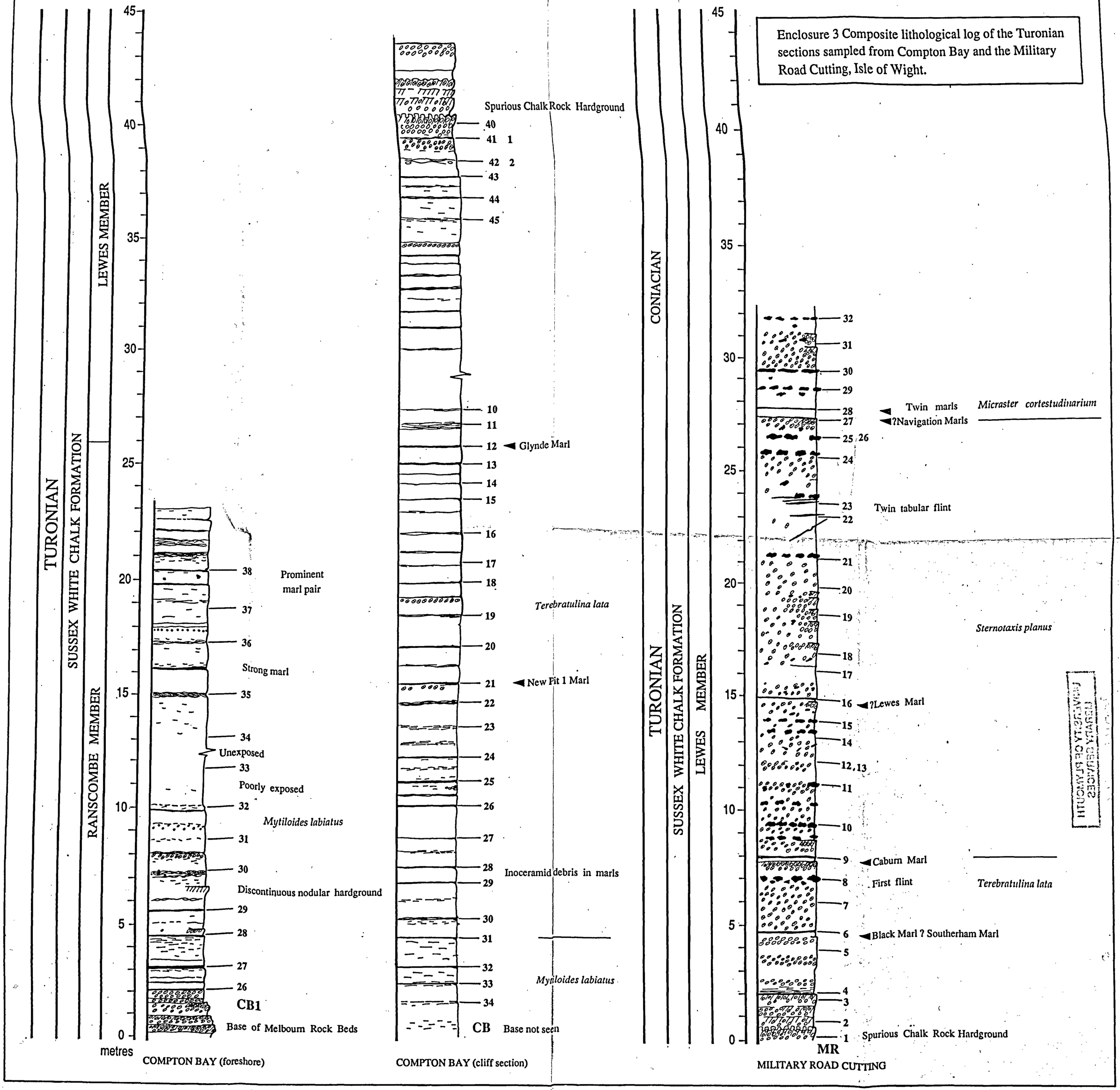
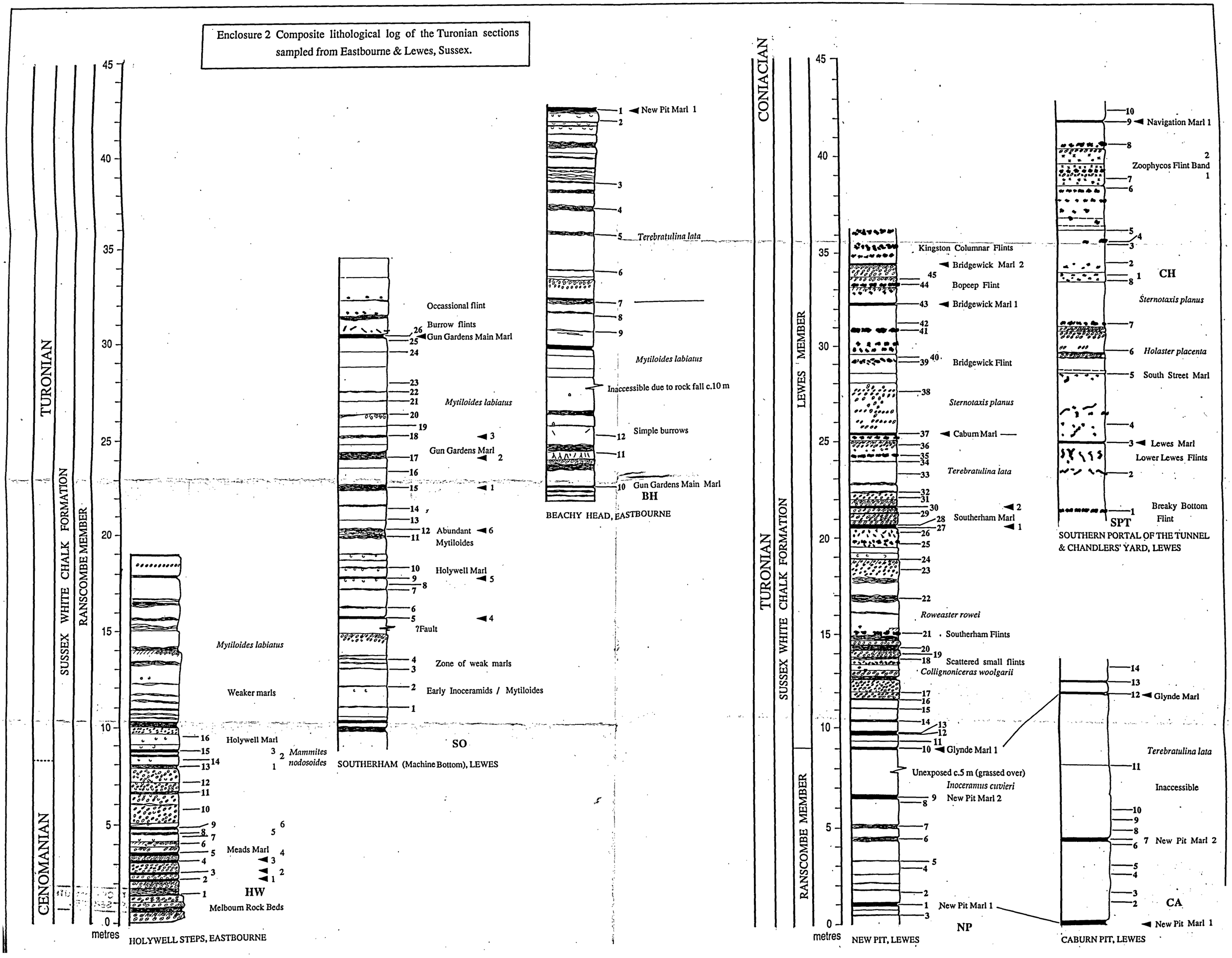
Polycope nuda Kaye, 1965
Pontocyprella harrisiana (Jones, 1849)
Pontocyprella hindei Weaver, 1982
Pterygocythereis cf. *Brachycythere sphenoides* (Reuss, 1854)
Pterygocythereis cf. *P. diminuta* Weaver, 1982
Pterygocythereis alata
Pterygocythereis spinosa (Reuss, 1846)
Semicytherura sp. A
Spinoleberis krejcii Pokorný, 1968
Trachyleberidea geinitzi (Reuss, 1874)
Xestoleberis pergensi Van Veen, 1936
Xestoleberis (Uroleberis) marssoni Bonnema, 1941
Xestoleberis (U.) supplanta Van Veen, 1936
Xestoleberis sp. C

Figure 3



Enclosure 1 Composite lithological log of the Turonian sections sampled from Dover, Kent.

Enclosure 3 Composite lithological log of the Turonian sections sampled from Compton Bay and the Military Road Cutting, Isle of Wight.



Enclosure 2 Composite lithological log of the Turonian sections sampled from Eastbourne & Lewes, Sussex.